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ABSTRACT

Water qualities of two natural streams (Buffalo and Kings Rivers), one new cold-tailwater (Beaver), and two old cold-tailwaters (Norfork and Bull Shoals) in northwestern Arkansas were studied from July 1965 through October 1968.

The essential difference between the old cold-tailwaters and natural streams is a change in water quality which allows the development of a new productive ecological environment. Features which typify the old tailwaters are as follows: (1) relatively homioithermal temperatures; (2) stream beds scoured by strong hydoelectric power generation currents; (3) abundant phytoplankton and benthic macroinvertebrates; and (4) absence of warm water game fishes.

Environmental factors characterizing natural streams are as follows: (1) high summer temperatures; (2) seasonal and individual current fluctuations at the various stations; (3) a greater variety of benthic macroinvertebrates and ichthyofauna; (4) abundant zooplankters; and (5) a tendency toward an equal distribution of the phyla Chrysophyta, Cyanophyta, and Chlorophyta.

By October 1968, the new Beaver cold-tailwater had lost all of its warm-water characteristics but had not developed the biotic features of the old tailwaters.
KEYWORDS/*cold-tailwater/*temperature/*current/*trout/phytoplankton/zooplankton/benthic macroinvertebrates/Chironomidae/Oligochaeta/Isopoda/Amphipoda/Trichoptera/Ephemeroptera/Chrysophyta/Cyanophyta/Chlopophyta/*Fish/.

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FOREWORD

This Bulletin is published in accordance with the Water Resources Research Act of 1964. This report is the fifth in a series of publications summarizing research information on water resources in the state of Arkansas.

This research was designed to determine abiotic and biotic changes in Arkansas streams affected by the construction of a series of impoundments on the White River. These impoundments offered a unique opportunity to compare not only old and new tailwaters on this stream and its tributary (North Fork River) but also to compare these with two natural streams, the Buffalo and Kings Rivers.

The Buffalo River country, because of its sparse population and scenic environment, appears to resemble a natural unpolluted Arkansas stream. For further information concerning the Buffalo and Kings Rivers the reader is referred to Smith (1967) and Anonymous (1969).

Six graduate students (listed on page 4) have received training as scientists in the field of aquatic biology and the factors which affect water. In addition, three other graduate students and nine graduate classes have benefited from equipment made available through the Water Research Act of 1964.

For the convenience of the reader, graphs in this Bulletin are expressed to the nearest whole number throughout the text. Exact numerals of the data are presented in the Appendix.

INTRODUCTION

Part of the White River drainage system in northern Arkansas has been transformed by three hydroelectric dams into a series of large, sprawling reservoirs and cold-tailwaters. These tailwaters still resemble natural free-flowing streams, but certain changes are obvious. Water used for generating electricity is drawn from the depths of these reservoirs, and as a result water temperatures in the tailwaters remain quite low throughout the year. Seasonal variations in flow have been replaced by daily fluctuations caused by power generation.

Each of these cold-tailwaters offers an unique opportunity to study the changes in a stream brought about by the construction of dams. The tailwater below Beaver Dam, which was completed in 1963, provides a chance to follow such changes. Tailwaters below Norfork and Bull Shoals dams, completed in 1944 and 1951 respectively, provide study areas that probably have become biologically stabilized. The Beaver Dam tailwater also differs from the other two in that it empties into a reservoir a few miles below the dam. The Norfork Dam tailwater covers 4.5 miles before entering the Bull Shoals tailwater; the latter might be considered to end at the first lock at Batesville, some 120 miles below Bull Shoals Dam (Figure 1).

Prior to this study, limited information concerning physico-chemical conditions of cold-tailwaters was available; however, Pfitzer (1962) conducted a similar physico-chemical study of several tailwaters in the TVA system. In other physico-chemical studies, Summers (1954) conducted a study in the Illinois River below Tenkiller Reservoir; Moffett (1942) conducted an investigation in the Colorado River below Boulder Dam. Related plankton studies include the following: Kofoid's (1903, 1908) extensive studies of the plankton of the Illinois River; Pennak's (1943) study of Boulder Creek, Colorado; Chandler's (1937) study of the fate of lake plankton introduced into running waters; Reinhard's (1931) investigation of the plankton in the upper Mississippi River; Williams' (1966) study of the rotifers of the major waterways in the United States; and Williams' and Scott's (1962) investigation of the principal diatoms of major waterways of the United States.

Similar tailwaters in the United States have been investigated extensively concerning the ichthyofauna; however, most of these studies have been concerned with sport fishes and fishing. Baker (1959) reviewed the history of the trout fishery below Norfork and Bull Shoals dams. Fry (1962) discussed fishing and fishing success in Missouri tailwaters. Fishery programs below TVA impoundments in Tennessee have been similarly examined (Cahn, 1937; Parsons, 1955). Other investigations have involved the effects of cold water on the tailwater fishes (Eschmeyer and Smith, 1943; Eschmeyer, 1944; Pfitzer, 1962) and the possibilities of establishing trout fisheries in cold tailwaters (Finnel, 1953; Summers, 1954). Fogle and Shields (1961) assimilated all available data on tailwaters.

The general objectives of this investigation are to compare relative values of dammed versus natural streams, to follow the development of a cold-tailwater created by Beaver Reservoir which has recently been impounded, and to compare these values with those obtained from the established tailwaters of Norfork and Bull Shoals reservoirs.

During this investigation the following factors were analyzed as possible indices for water quality: physico-chemical, plankton, benthic macroinvertebrates, and ichthyofauna.

The objectives of the physico-chemical studies were threefold: (1) to obtain general patterns of changes of physico-chemical conditions at various stages during the aging of the tailwater of the newly created Beaver Reservoir; (2) to determine physico-chemical conditions in the established tailwaters of Bull Shoals and Norfork reservoirs; and (3) to compare these results with physico-chemical data obtained from two natural warm-water streams, the Buffalo and Kings Rivers.

The objectives of the plankton studies were fourfold: (1) to follow the development of plankton communities that have resulted from the formation of a cold-tailwater below Beaver Reservoir; (2) to determine plankton communities present in established cold-tailwaters below Bull Shoals and Norfork reservoirs; (3) to follow the fate of lake plankton after they are introduced into the cold-tailwater below Beaver Reservoir; and (4) to compare the plankton collected in the tailwaters described above with those found in two natural warm-water streams, the Buffalo and Kings Rivers.

The objectives of the bottom fauna studies are as follows: (1) to study changes in benthic communities that have resulted from the creation of a cold-tailwater below Beaver Dam; (2) to study established benthic communities in the old cold-tailwaters of Bull Shoals and Norfork dams; (3) to study seasonal benthic population fluctuations and patterns in the cold-tailwater below Beaver Dam; and (4) to compare presumed polythermic benthic species in the Buffalo River and Kings River with those found in cold-tailwaters.

The primary purpose of the ichthyofauna studies was to investigate fish populations below Beaver, Norfork, and Bull Shoals dams. Specific objectives were: (1) to determine the species of fishes present immediately below the dams and in the vicinity of the confluence of the White and Buffalo Rivers some 25 miles below Bull Shoals Dam; (2) to compile data on the seasonal abundance and distribution of fishes in these stream sections; (3) to follow the development of a cold-water fish fauna in the new cold-tailwater below Beaver Dam; and (4) to determine the effect of a warm-water stream, Buffalo River, flowing into a cold-tailwater, White River below Bull Shoals Dam, on the seasonal abundance and distribution of fishes.

Additional data, regarded as not feasible to present in this report, are on file as Master's theses in the University of Arkansas Library. Theses covering this investigation from 1965 to 1970 are as follows: Brown (1967), Cashner (1967), Dennie (1967), Liston (1967), Blanz (1970), and Gray (1970).

DESCRIPTION OF STUDY AREAS

The White River originates in the Ozark Mountains in western Arkansas and flows in a northeasterly direction. It enters Missouri in Carroll County and re-enters Arkansas in Boone County. The stream flows southeasterly from Missouri and unites with the Arkansas River near its confluence with the Mississippi River. It is 690 miles long and drains an area of 28,000 square miles.

The Buffalo River rises in the western part of Newton County, Arkansas and empties into the White River a few miles below Buffalo City in Marion County, Arkansas. It is about 148 miles long and drains an area of 1,338 square miles.

The North Fork, a tributary of the White River, begins in southern Missouri and courses south to its confluence with the White River in Baxter County, Arkansas. It is about 70 miles long.

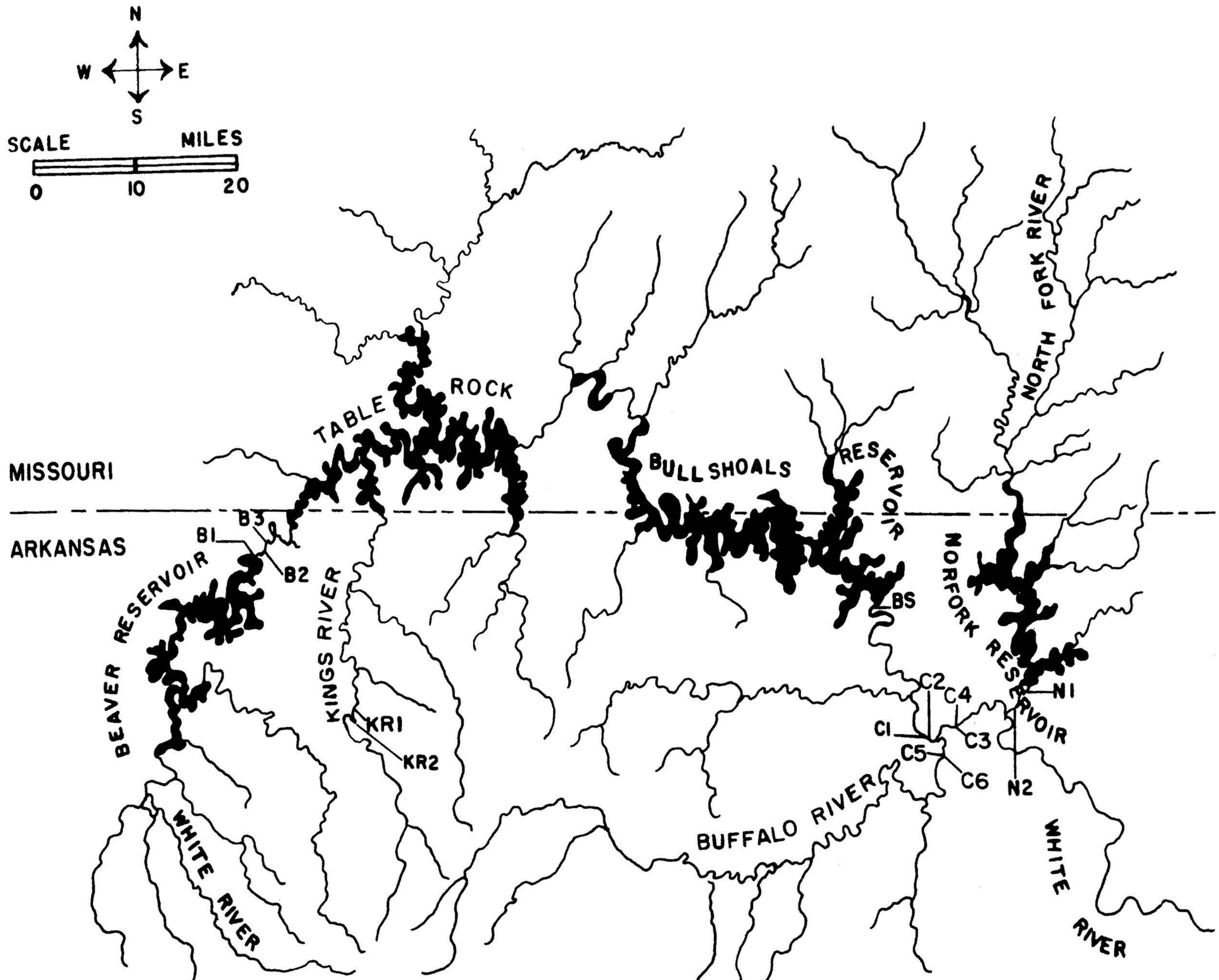
The stream sections studied lie in the Ozark Plateau. The most abundant rocks in this region are limestone, dolomite, sandstone, and shale, with the first two predominating (Branner, 1927). River basins are narrow and steep-sided, and entrenched meanders are numerous. Many stream bends have limestone bluffs on the outside with gradual slopes on the inside. Stream beds consist primarily of bedrock, rubble, gravel, and sand, with silt occurring in areas of slight current. Ozark streams are typically spring-fed, clear, broken by numerous rapids and riffles, and, if undammed, subject to extreme seasonal variation in temperature and flow.

Higher forms of aquatic vegetation are generally scarce along the stream sections studied. Water cress (*Nasturtium officinale* Linnaeus), water weed (*Anacharis* sp.), and arrowhead (*Sagittaria* sp.) occur in scattered areas. Lower aquatic plants such as filamentous green and blue-green algae are rather abundant in some sections.

Major uses of land bordering the stream sections studied are for beef cattle grazing and timber production. Forests consist of mixed hardwoods and scattered pockets of evergreens. Willows (*Salix* sp.) are common along stream banks.

Figure 1 indicates the locations of the collecting stations. B1, B2, and B3 were approximately 0.25, 1.9, and 3.5 miles, respectively, below Beaver Dam. Bull Shoals tailwater stations were designated BS, C1, and C2. Station BS was approximately 0.75 of a mile below Bull Shoals Dam; C1 and C2, located on opposite sides of the stream, were approximately 20 miles below the dam. Stations C3 and C4 were approximately 3 miles below stations C1 and C2. Stations C3 and C4 were also located on opposite sides of the stream. Norfork tailwater stations, N1 and N2, were located approximately 0.25 and 3.5 miles, respectively, below the dam. Stations B1, BS, and N1 were chosen to compare quantitative differences among the stations nearest the dams. Stations C1, C2, C3, and C4 were selected to show quantitative effects the Buffalo River might have upon the ichthyofauna present in the White River tailwater below Bull Shoals Dam. The Buffalo River was studied using stations C5 and C6; both were nearly 0.75 of a mile upstream from its confluence with the White River and on opposite sides of the stream from each other. Kings River stations were KR1 and KR2. KR1 was approximately 0.25 of a mile upstream from the Highway 68 bridge or 0.50 of a mile east of Marble, Arkansas. Station KR2 was located beneath the same bridge.

FIGURE 1. MAP OF THE STUDY AREA AND VARIOUS COLLECTING SITES.


N
W
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SCALE
MILES
0
10
20
MISSOURI
ARKANSAS
TABLE ROCK
BULL SHOALS RESERVOIR
NORTH FORK RIVER
NORFORK RESERVOIR
BEAVER RESERVOIR
KINGS RIVER
WHITE RIVER
BUFFALO RIVER
WHITE RIVER
B1
B2
B3
KR1
KR2
BS
C1
C2
C3
C4
C5
C6
N1
N2

Beaver Dam Tailwater

Beaver Dam, the uppermost dam on the White River, is located in Carroll County, Arkansas. The effluent flow enters Table Rock Reservoir 4.5 miles below Beaver Dam. Beaver Dam has two hydroelectric units and is 228 feet high. Minimum and maximum discharges are 60 cfs and 5,000 cfs, respectively. Tailrace elevation is 916.6 feet during periods of minimum discharge; rises of 10 feet occur during periods of maximum discharge (Table I).

The riffle at station B1 is characterized by small gravel that shifts about during high water periods. Originally it was located on the southeast side of the river bed but, after continued high water stages in the winter and spring of 1968, it shifted to the northwest side of the bed. This shallow riffle had little vegetation growing on the finely divided gravel, and thus very few places were available for the benthic organisms to attach and grow undisturbed.

Station B2 was somewhat deeper and therefore, had a slower current than B1. This station had larger stones exposed on the shallow east side of the bed. The deeper west side was not sampled. Undoubtedly, the larger stones and less turbid water provided a more suitable habitat for benthic organisms at station B2 than at B1.

Station B3 was located just below the confluence of a small creek, Spider Creek, and the cold-tailwater. This station, like B1, also changed during the course of the study. At the onset B3 was a very

TABLE I. PHYSICAL DESCRIPTION OF BEAVER, BULL SHOALS, AND NORFORK RESERVOIRS, DAMS, AND TAILWATERS (DENNIE, 1967)

PHYSICAL FEATURES	BEAVER	BULL SHOALS	NORFORK
Drainage area, mi.	1,186	6,036	1,806
Height of dam, ft	228	258	226
Outlets, power number	2	8	2
Outlet depth, ft	140	110	100
Avg. ann. discharge, cfs	1,550	6,130	1,900
Storage begun	1964	1951	1943
Maximum depth, ft	216	201	177
Maximum discharge, cfs	5,000	7,500	2,900
Minimum discharge, cfs	60	50	20
Tailrace elevation, ft	916.6	449.7	372.6
Max. rise of tailwater, ft (max. discharge)	10	9	7
Width of tailwater, ft (below dam)	200	600	50-100
Max. tailwater depth, ft (min. discharge)	5-6	7	8

fast riffle. It was located just around a bend in the river downstream from a large quiet pool. However, after the high water period it changed from a riffle to a large pool. At times the water from Table Rock Reservoir backed up and covered this area. During periods of generation this riffle, along with B1 and B2, was as much as ten feet in depth. The substrate of area B3 was similar to B1 after high water periods in the winter and spring of 1968.

Norfork Dam Tailwater

Norfork Dam is located on the North Fork of the White River 4.5 miles above its confluence with the White River in Baxter County, Arkansas. The 226-foot high Norfork Dam contains two hydroelectric units. During periods of no generation, discharge amounts to 20 cfs and tailrace elevation stands at 372.6 feet. During periods of maximum generation, discharge approaches 2,900 cfs and tailrace elevation rises about seven feet.

Waste water from the Norfork Trout Hatchery, located near Norfork Dam, flows into the tailwater just below the dam. There are no direct indications of pollution in the area, and the main effect of this water may be to enrich the Norfork Dam tailwaters. The width of the tail-water varies from 50 to 100 feet, and maximum depths do not exceed seven feet during periods of minimum discharge (Table I).

Bull Shoals Dam Tailwater

Bull Shoals Dam, located in Baxter County, Arkansas, is the lower-most dam on the White River. The dam is 258 feet high and contains eight hydroelectric units. Minimum and maximum discharges are 50 cfs and 7,500 cfs, respectively. Tailrace elevation is 449.7 feet during periods of minimum discharge, and maximum generation results in depth increases of up to nine feet. Stream width just below the dam approaches 600 feet. Maximum depths in this area do not exceed nine feet during periods of minimum discharge (Table I).

Confluence of the White and Buffalo Rivers

The Buffalo River empties into the White River about 25 miles below Bull Shoals Dam. The Buffalo River is still a natural free-flowing stream and is, therefore, more characteristic of Ozarkian streams in the days prior to large impoundments. Stream width varies from 75 to 250 feet. Pool depths approach 15 feet.

The White River is large and rapid near its confluence with the Buffalo River. Buffalo Shoals, one of the largest on the White River, is located about 1.5 miles upstream from the mouth of the Buffalo River. Here the river elevation drops 10.5 feet in 1.7 miles (Gladson, 1911). Stream width approaches 375 feet. Some pools below Buffalo Shoals are as much as 15 feet deep.

Water temperatures taken in the White River downstream from the mouth of the Buffalo River indicate that water discharged from the Buffalo River flows downstream on its side of entry while original White River water flows on the opposite side. This condition exists for several miles downstream depending upon physical and thermal conditions and respective flows (Brown, Liston, and Dennie, 1967).

Kings River

The Kings River originates in Madison County, Arkansas and flows into Table Rock Reservoir. The two Kings River stations were different from each other in speed of water flow. Station KR1 had the stronger current and was located just below a large quiet pool. It contained rather large stones which provided excellent habitats for benthic organisms. The substrate was rather rigid and little evidence was available to indicate any large shifting of materials. Station KR2 had a slower riffle and numerous attachment sites for organisms. During this study these two riffles did not shift in location. High water marks along the stream indicated maximum depths of four or five feet. The two stations were chosen for their differences in habitat and riffle speeds.

METHODS AND MATERIALS

Sampling Techniques

Sampling stations were established during July and August 1965 in the tailwaters below Beaver, Bull Shoals, and Norfork reservoirs, and near the mouth of the Buffalo River. These stations are shown in Figure 1.

In order to assure random sampling, each station below Beaver Dam was sub-divided into areas and assigned a number. The specific area of a station sampled on each collecting trip was determined by drawing a number from a hat.

This investigation involved different approaches and the stations mentioned can be located by referring to Figure 1.

Beginning July 1965 through December 1966 collecting trips were made weekly to the tailwater below Beaver Reservoir, and monthly to both the tailwaters below Bull Shoals and Norfork reservoirs and to the Buffalo River. In the 1967-1968 study, collecting trips were made bimonthly to the Beaver tailwater and to the Kings River.

To differentiate between the three Beaver stations during the 1965-1966 and 1967-1968 investigation periods, the earlier samplings are referred to as B1L, B2L, and B3L; the latter are referred to as B1, B2, and B3.

On each collecting trip air and water temperatures were taken with mercury thermometers. The thermometer used for taking water temperatures was calibrated to one-tenth degree Celsius, and the one used to take air temperatures was calibrated to one degree Celsius. Time of day, weather conditions, general water conditions, depth, length and width measurements, and riffle speeds were recorded at each site on each collecting trip. Riffle speed was calculated by using a float traveling a specified distance. In general, turbidity was low in all study areas and was, therefore, not routinely analyzed since it was not considered to be a limiting factor.

Free carbon dioxide, dissolved oxygen, and hydrogen ion concentration determinations were performed in the field from July 1965 through December 1966. Analyses for free carbon dioxide followed the method described in APHA, AWWA, and FSIWA (1960). A Hach field version of the Winkler method was used for the analyses of dissolved oxygen (model AL-36-P). Hydrogen ion concentrations were determined by use of a Hellige pocket hydrogen ion comparator (model 605AHT) utilizing Hellige certified indicator solutions.

Beginning in January 1966 new procedures for determining the major chemical constituents in the water were initiated with the exception of methyl orange alkalinity which was performed from July 1965. These procedures were as follows: ortho- and meta-phosphate using the StannaVer method; nitrite-nitrogen using the sulfanilic acid-1, naphthylamine method; nitrate-nitrogen using the chromatropic acid method; silica using the silicomolybdate method; and methyl orange alkalinity using the procedures described in APHA, AWWA, and FSIWA (1960). Chemical determinations were performed in the laboratory from water samples taken from the various collecting sites. Water samples were transported from the field to the laboratory in glass quart jars. With the exception of silica and methyl orange alkalinity the above determinations were performed using a Bausch and Lomb "spectronic-20" colorimeter-spectrophotometer. Determinations for silica concentrations were performed with a Hach chemical kit, model S1-2. Chloroform (2-3 drops) was added to the samples in the field to inhibit decomposition. As an added precaution against bacterial activity, water samples were placed in a refrigerator (4 C) until the various determinations could be performed.

A Surber Square Foot Sampler, as described by Lagler (1956), was used for bottom fauna collections. This sampler consists of a collapsible metal frame and a tapered nylon net. In use, the metal frame is placed on the substrate, and organisms are dislodged from within the square foot area by washing the bottom material with the hand. The current carries the organisms and detritus into the tapered net, and the material is concentrated by rigorously swishing the net back and forth through the water. The organisms and detritus were placed in quart jars containing 5% formalin. These samples were transported back to the laboratory, separated from the detritus, sorted according to taxonomic category, counted, and weighed to the nearest milligram on an analytical balance. Organisms were separated in a white porcelain pan illuminated by a fluorescent light equipped with a built-in magnifying glass. Wet weight was determined after placing the organisms on filter paper and allowing the formalin to drain off. The organisms were then placed into a 70% ethanol solution and stored for later study.

Identification mainly consisted of separating the organisms into classes, orders, and families. Some of the dominant forms have been identified at the generic level.

Quantitative net plankton samples were collected in the riffles at each site with a standard cone-shaped number 25 silk bolting cloth plankton net. The net had a removable bottom bucket also equipped with number 25 silk bolting cloth. These samples were collected by pouring 20 liters of water through the plankton net and concentrating it to 100 milliliters in the field. The concentrated samples were then introduced into four-ounce, wide-mouth, screw-cap bottles and preserved in 3% formalin. In the laboratory, the samples were further concentrated to 20 milliliters and deposited in French, square, screw-cap bottles. Two direct counts, each of 1 milliliter volume, were made from each sample with a Sedgwick-Rafter counting cell. Whenever a single genus exceeded 2,000 cells per milliliter the random counting technique of Serfling (1949) was used. An average was then determined and the results expressed as the number of organisms or cells per liter, each milliliter being the equivalent of one liter.

On various collecting trips qualitative plankton samples were taken. These were examined for rare organisms. References used for the identification and grouping of the organisms were Kudo (1966), Pennak (1953), Prescott (1964), Ward and Whipple (1959), and Smith (1950).

During the 1965-1966 period of investigation 249 plankton samples were collected and preserved. They are deposited in the Zoology Department of the University of Arkansas for future reference.

Fishes were collected by two methods. Pools were seined with a 6 x 20-foot straight seine with one-eighth square inch mesh. A variation of the electro-seining 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.

RESULTS AND DISCUSSION

Physico-chemical Data

Investigation Period from July 1965 through December 1966[1]

Records for comparisons of ranges and averages of physical factors for this period of study are presented in Figure 2a and Table II.

In general, the tailwater immediately below Beaver Reservoir was colder than the tailwaters below Norfork and Bull Shoals reservoirs. The outlets are deeper at Beaver Reservoir than they are at the other reservoirs, and this fact may account for the lower temperatures observed in the Beaver tailwater. However, the range of temperature below Norfork Reservoir (N1) was greater than that of the other two tailwaters at comparable stations. The least variation in water temperature occurred below Beaver Reservoir.

In a pre-impoundment study of the physico-chemical factors of the upper White River below the present Beaver Reservoir dam site, Baker (1960) concluded that the sole limiting factor was temperature. He found that the water temperature ranged from 1.1 C in January 1956 to 30.0 C in July and August 1956. In an investigation of the water below Bull Shoals Reservoir from July 1951 through January 1952 (before the dam was "operational"), Baker (1959) found the average water temperature

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[1] Information compiled from thesis of Dennie (1967).

Table II

AVERAGES AND RANGES OF PHYSICAL DATA FOR ALL THE STATIONS IN BOTH THE 1965-1966 AND THE 1967-1968 STUDIES BASED UPON DATA FROM DENNIE (1967), AND BLANZ (1970).

STATION		CURRENT (Ft./Sec.)	WATER TEMP (°C)	DEPTH (In.)	WIDTH (Ft.)
B1L	A	2.7	8.2	5	34
	R	4.2 - 1.4	10.0 - 6.2		
B2L	A	1.9	9.8	8	64
	R	3.0 - 1.1	16.2 - 5.1		
B3L	A	3.8	11.2	11	26
	R	5.0 - 2.4	23.0 - 4.2		
B1	A	2.6	9.4	6	45
	R	5.6 - 0.5	10.5 - 6.0		
B2	A	1.6	10.7	8	64
	R	2.5 - 1.1	15.0 - 5.0		
B3	A	1.2	11.9	14	18
	R	4.0 - 0.3	17.9 - 6.5		
BS	A	2.6	10.6	7	45
	R	3.2 - 1.8	15.4 - 7.1		
C1	A	2.8	12.5	8	300
	R	3.6 - 1.4	17.3 - 5.7		
N1	A	2.6	11.1		
	R	3.3 - 1.8	15.4 - 6.1	9	30
N2	A	2.9	13.0		
	R	4.0 - 1.6	16.5 - 8.0	8	35
C5	A	2.6	18.5	8	35
	R	3.7 - 1.0	32.0 - 1.0		
C6	A	2.7	18.2	6	35
	R	4.3 - 1.5	32.9 - 1.0		
KR1	A	4.1	16.1	11	31
	R	6.6 - 1.5	26.0 - 4.0		
KR2	A	2.8	16.2	12	24
	R	5.0 - 1.2	26.3 - 6.0		

was 20.0 C. This is in contrast to the average water temperature of 10.6 C found in this study below Bull Shoals Reservoir after it had operated for several years.

Depending upon the prevailing atmospheric temperature, the tailwaters were either colder or warmer as they proceeded downstream below the dams. In accordance with mean yearly temperature, the temperatures of the various tailwaters increased as the water traveled downstream.

The data in Figure 2a graphically illustrate the ranges of the temperatures at three stations along the tailwater below Beaver Reservoir. The greatest variation between these stations occurred in the summer of 1965 and in the fall of 1966. There was very little discharge during the summer of 1965. Consequently, the water was warmed by the higher atmospheric temperatures as it advanced downstream. In the spring of 1966 Table Rock Reservoir backed up, covering the riffle designated as station B3 with several feet of still water. This somewhat stagnant water was then warmed by the rising ambient temperatures. In the summer of 1966 high environmental temperatures again warmed the water as it traveled downstream. However, less variation was observed between the stations during this period than in the previous summer because water was frequently being discharged from the dam. During periods of discharge, there was very little difference in water temperature between the three stations regardless of the ambient temperature. During the late fall of 1965 and early winter of 1966 the water, as it traveled downstream from the dam, became cooler because of the low atmospheric temperatures. The water being discharged from the outlets in the dam reflects the temperature of the reservoir at the level of intake.

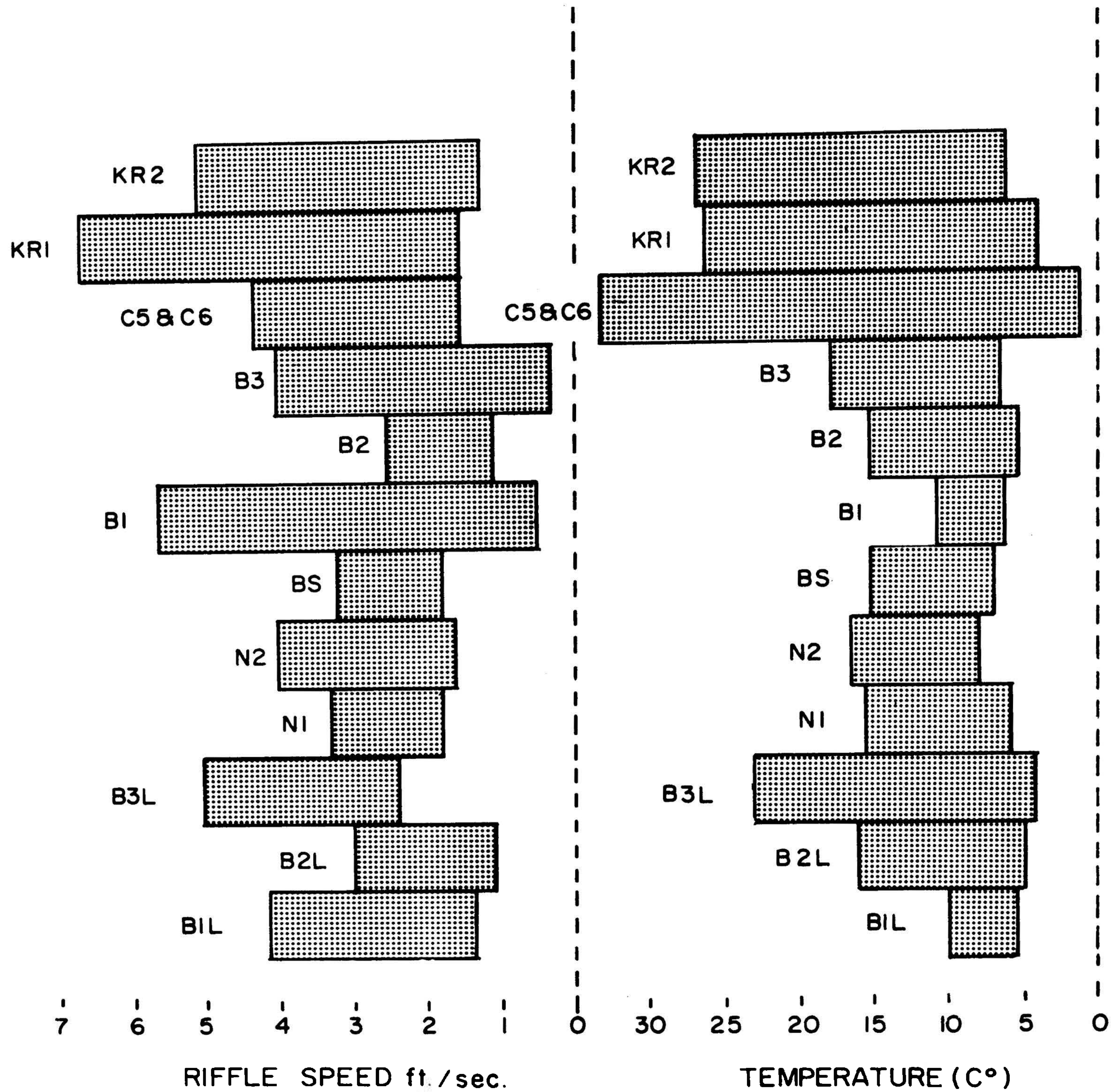

FIGURE 2a. MINIMUM AND MAXIMUM TEMPERATURES AND RIFFLE SPEEDS AT ALL COLLECTING SITES

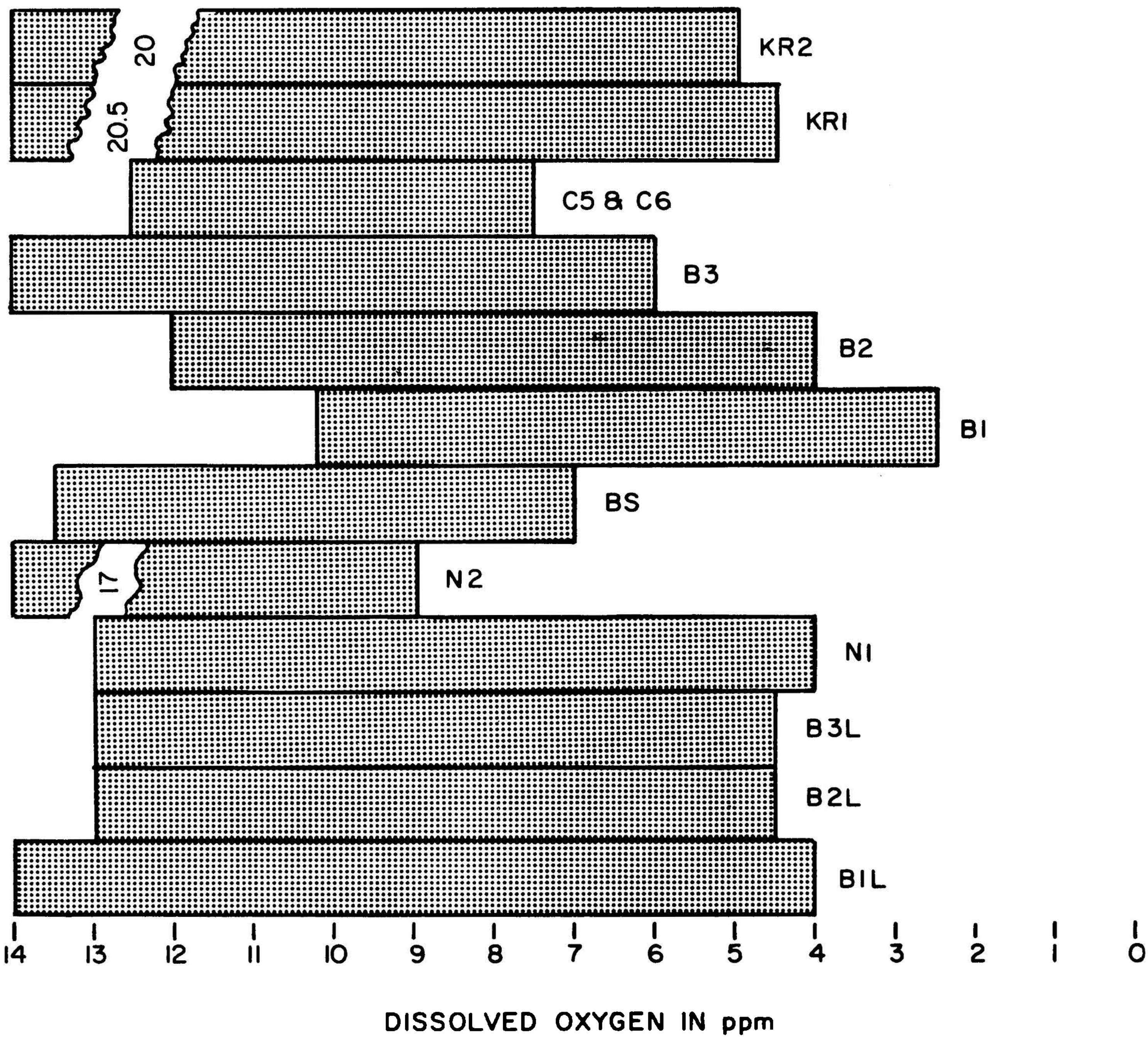

FIGURE 2b. MINIMUM AND MAXIMUM QUANTITIES OF DISSOLVED OXYGEN IN PPM

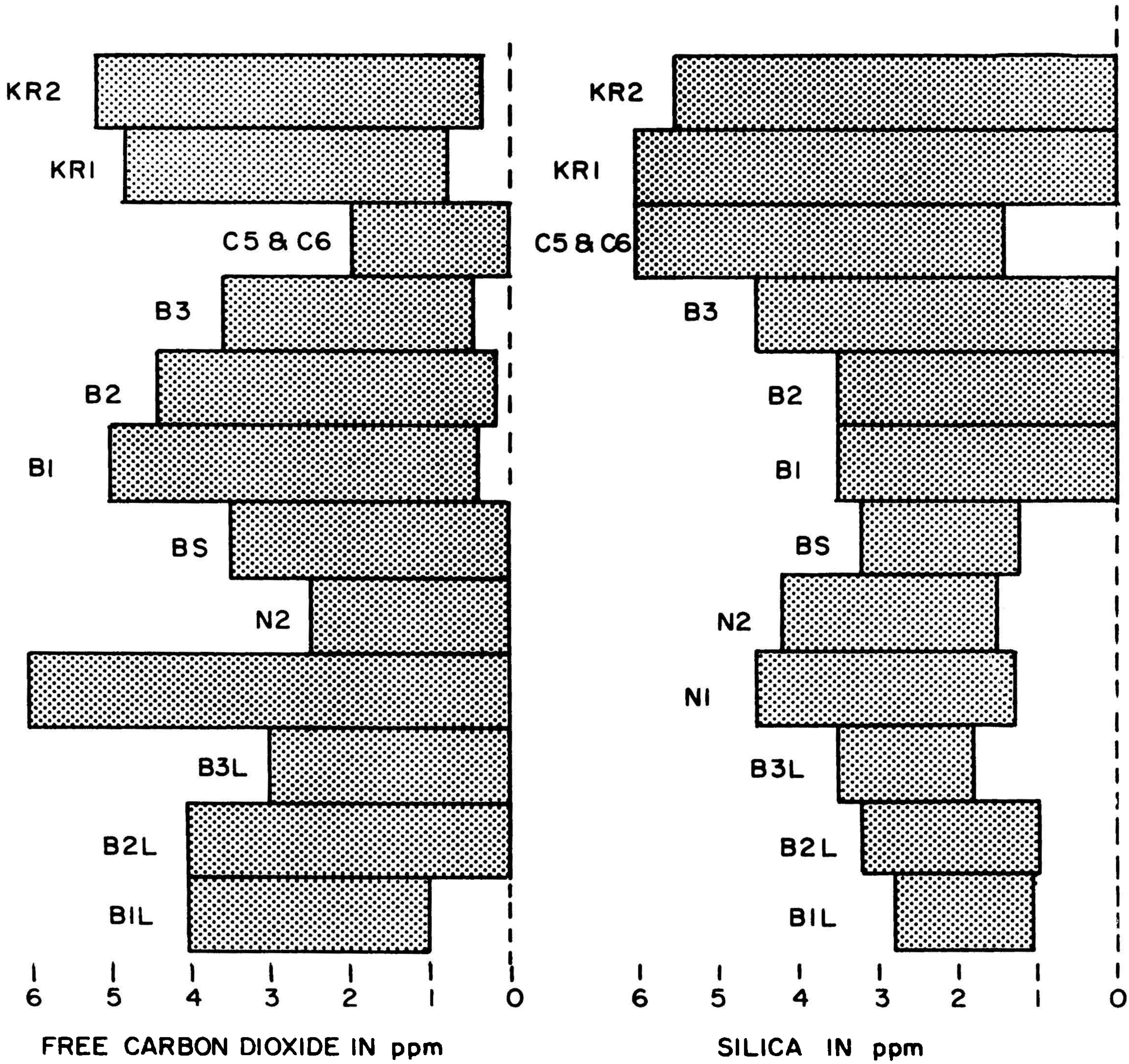

FIGURE 2c. MINIMUM AND MAXIMUM FREE CARBON DIOXIDE AND SILICA IN PPM

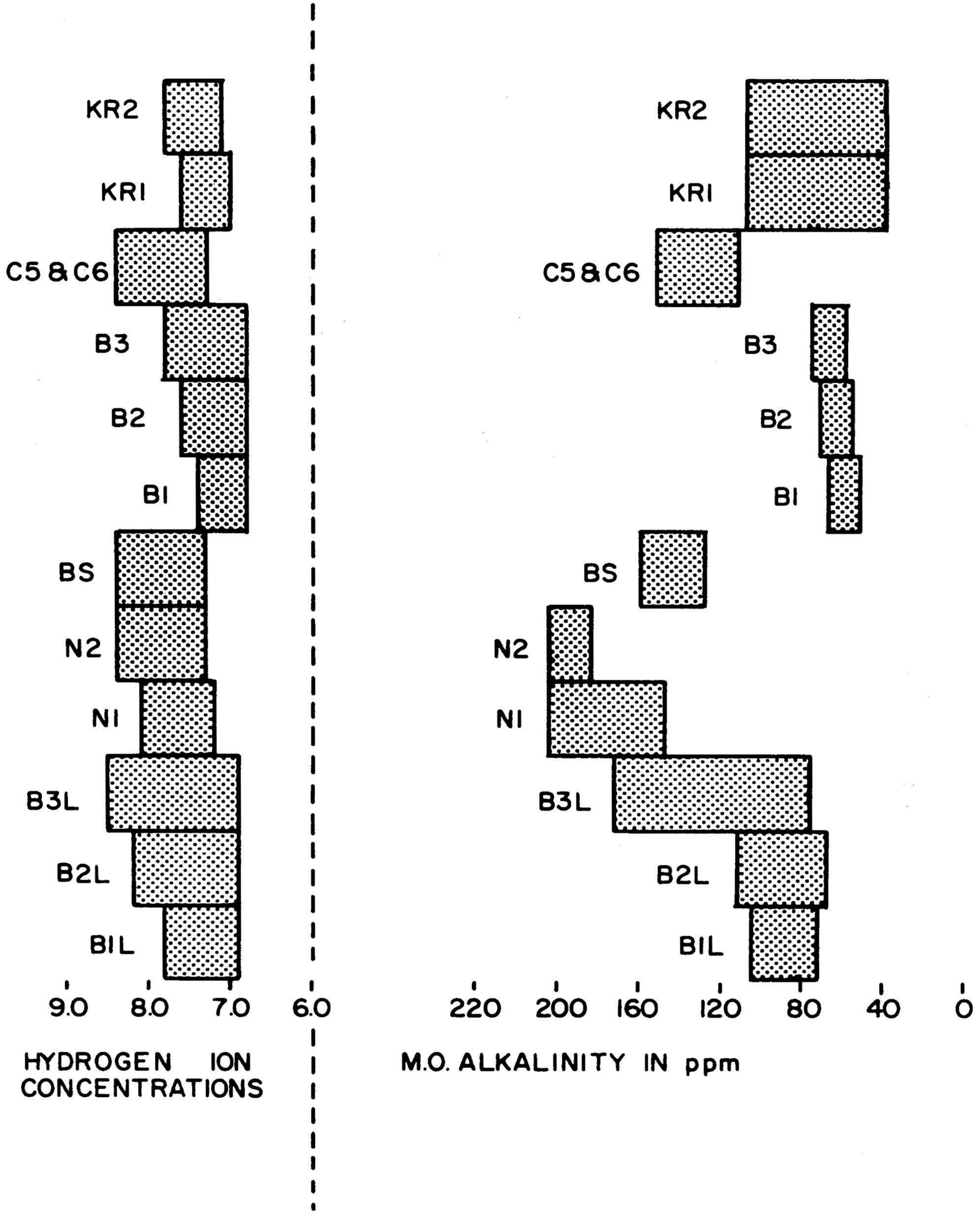

FIGURE 2d. MINIMUM AND MAXIMUM HYDROGEN ION CONCENTRATIONS AND METHYL ORANGE ALKALINITY IN PPM

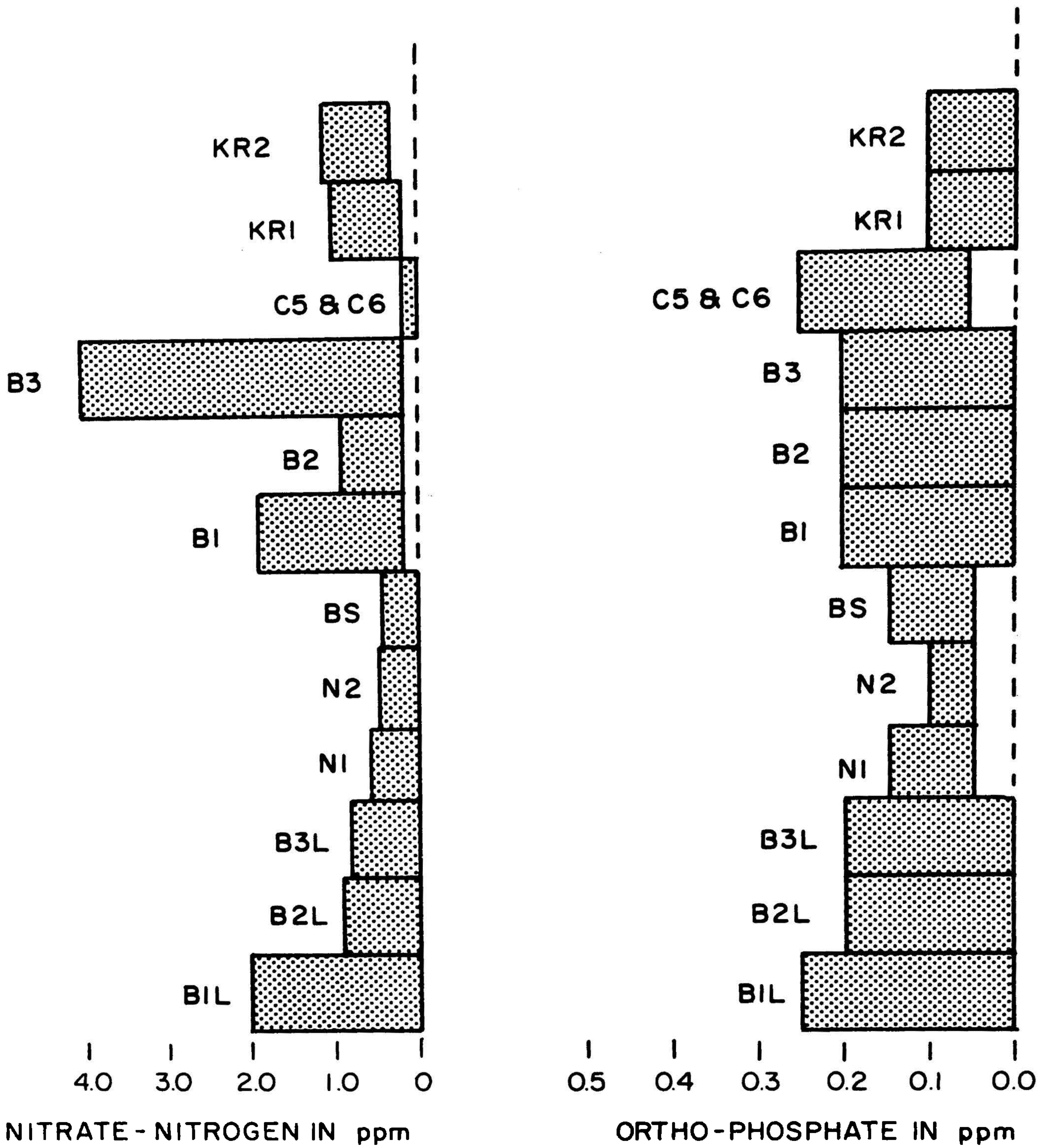

FIGURE 2e. MINIMUM AND MAXIMUM NITRATE-NITROGEN AND ORTHO-PHOSPHATE IN PPM

The tailwaters below Bull Shoals and Norfork reservoirs reached their lowest water temperatures in March 1966, whereas the tailwater immediately below Beaver Reservoir reached its lowest water temperature in February of 1966. The tailwater of Bull Shoals Reservoir (BS) reached its maximum temperature in November of 1966, as did the water at station Beaver 1 (B1L), while the tailwater below Norfork Reservoir (N1) arrived at its maximum temperature in October of 1966. The Buffalo River (C5 and C6), being a natural free-flowing stream and subject to drastic fluctuations in water temperatures in accordance with atmospheric temperature, exhibited the widest range of water temperatures (Figure 2a) throughout the year and also the highest average temperature of all the study areas (Table II). During parts of the winter, however, the Buffalo River is, in fact, colder than the cold-tailwaters.

Average riffle speed was rather constant at the first stations below all three dams and in the Buffalo River except during periods of high water. Values which varied appeared to differ in a random fashion. Many fresh-water algae, including species belonging to the genera Batrachospermum, Cladophora, Oedogonium, and Spirogyra are current-inhabiting organisms (Smith, 1950). For distribution of Spirogyra and Cladophora, see Appendix H. Whitford (1960) suggested that a current produces a steep diffusion gradient which increases exchange of materials between an attached, current-inhabiting species and the water. It appears that when a current velocity is greater than one-half foot per second, a steep diffusion gradient is produced around the attached organism; and, as a result, the up-take of vital substances is substantially increased (Whitford and Schumacher, 1961). Previous work indicates that this so-called current demand is due to a significantly higher respiratory rate in lotic species (Fox, Simmons and Washburn, 1935). All riffle velocities recorded in the 1965-1966 investigation were well above the one-half foot per second suggested by Whitford and Schumacher (1961).

Records for the range and average comparisons of chemical factors in the 1965-1966 investigation are presented in Table III. Ranges for the more significant chemical values are illustrated in Figures 2b through 2e.

Of all of the tailwaters, the average amount of dissolved oxygen was found to be highest at station number one below Bull Shoals Dam and lowest below Norfork Dam. Average dissolved oxygen values of the Beaver tailwater remained fairly constant throughout the course of the stream. However, an increase was noted in the average amount of dissolved oxygen as the tailwater proceeded downstream from the Norfork dam. Summers (1954), in a survey of the Illinois River below Tenkiller Reservoir, concluded that low dissolved oxygen values and high temperatures during summer months would render the stocking of trout impossible. Moffett (1942) in a study of the Colorado River below Boulder Dam, found that the temperature did not vary significantly; and that the amount of dissolved oxygen was abundant at all times. Burdick, Lipschuetz, Dean, and Harris (1954) demonstrated lethal oxygen concentrations of 1.34 ppm for rainbow trout after a period of 48 hours at 60 F. In the course of the 1965-1966 investigation, temperatures and values of dissolved oxygen were generally adequate for the survival of trout with regard to the parameters set forth by Burdick, Lipschuetz, Dean, and Harris (1954).

The average amount of free carbon dioxide was lowest below Bull Shoals Dam and highest below Norfork Dam, whereas, the average pH value

TABLE III. AVERAGES AND RANGES OF CHEMICAL FACTORS FOR THE 1965-1966 STUDY (DENNIE, 1967)

SITE		CO_2, ppm			D.O., ppm			pH			M.O. Alk., ppm		
		Avg.	Max.	Min.	Avg.	Max.	Min.	Avg.	Max.	Min.	Avg.	Max.	Min.
Beaver	B_1L	2.2	4.0	1.0	9.0	14.0	4.0	7.2	7.8	6.9	84.1	103.0	73.2
	B_2L	2.0	4.0	0.0	9.0	13.0	4.5	7.3	8.2	6.9	87.3	109.2	68.9
	B_3L	1.7	3.0	0.0	9.5	13.0	4.5	7.4	8.5	6.9	99.0	171.6	76.8
Norfork	N_1	2.4	6.0	0.0	8.3	13.0	4.0	7.4	8.1	7.2	178.6	205.0	147.5
	N_2	1.0	2.5	0.0	12.0	17.0	9.0	8.0	8.4	7.3	193.7	204.0	182.4
Bull Shoals		1.4	3.5	0.0	9.9	13.5	7.0	7.6	8.4	7.3	149.6	160.8	127.2
Buffalo River		0.5	2.0	0.0	10.1	12.5	7.5	7.9	8.4	7.3	134.3	152.0	112.8

SITE		Silica, ppm			Nitrate-N, in ppm			Ortho-phos., ppm			Meta-phos., ppm		
		Avg.	Max.	Min.	Avg.	Max.	Min.	Avg.	Max.	Min.	Avg.	Max.	Min.
Beaver	B_1L	2.2	2.8	1.1	0.24	2.00	0.00	0.08	0.25	0.00	0.25	0.50	0.05
	B_2L	2.2	3.2	1.0	0.17	0.90	0.00	0.08	0.20	0.00	0.28	0.65	0.05
	B_3L	2.4	3.5	1.8	0.18	0.80	0.00	0.08	0.20	0.00	0.26	0.45	0.05
Norfork	N_1	3.0	4.5	1.3	0.20	0.60	0.00	0.08	0.15	0.05	0.29	0.45	0.10
	N_2	3.1	4.2	1.5	0.21	0.50	0.00	0.07	0.10	0.05	0.35	0.50	0.20
Bull Shoals		2.2	3.2	1.2	0.14	0.45	0.00	0.06	0.15	0.05	0.23	0.45	0.15
Buffalo River		3.8	6.0	1.4	0.08	0.20	0.00	0.10	0.25	0.05	0.34	0.80	0.15

was highest below Bull Shoals Dam and lowest below Beaver Dam. The Buffalo River exhibited the least amount of average free carbon dioxide of all study areas and also had a high average pH value. The tailwater immediately below Norfork Reservoir displayed the widest range of carbon dioxide (Figure 2c). Current tends to keep the carbon dioxide from accumulating (Welch, 1952). Consequently, the average amount of free carbon dioxide decreased as the water moved downstream from the dams, while the pH value, in general, tended to increase slightly.

The values of the methyl orange alkalinity determinations varied widely in the tailwaters directly below the dams (Table III and Figure 2d). The water below Norfork Reservoir exhibited the highest average alkalinity value and the water below Beaver Reservoir the lowest average value. Station 1 (N1) below Norfork Reservoir showed the greatest variation in methyl orange alkalinity, while the first station below Beaver Reservoir exhibited the least variation. Methyl orange alkalinity is closely associated with productivity. Tarzwell (1937) stated that streams which have a high methyl orange alkalinity invariably have a high food production. Ruttner (1953) attributed this phenomenon to the buffer effect of the carbonates and bicarbonates in the water. Pfitzer (1962), in a survey of several tailwaters in the TVA system, found that all pre-impoundment methyl orange alkalinity values were considerably higher than in the post-impoundment tailwater area. The post-impoundment methyl orange alkalinity values in the tailwater area below Beaver Reservoir were lower than the values reported by Horn and Garner (1965) in their pre-impoundment study in the Beaver Reservoir area. The data represented in Figure 2d graphically illustrate ranges in methyl orange alkalinity values in the tailwater of Beaver Reservoir. The average methyl orange alkalinity values increased as the water proceeded downstream (Table III). The peak at station B3, occurring in the spring of 1966, appeared at the same time that Table Rock Reservoir backed up, covering this collecting area with several feet of water, as was mentioned before in the temperature discussion.

Average silica values were relatively constant below all three dams. However, silica concentrations were slightly higher below Norfork Reservoir (Table III). The Buffalo River exhibited the highest average value of silica of all areas and also showed the greatest variation, while the tailwater below Beaver Reservoir displayed the least variation. Silica values remained fairly constant as the water proceeded downstream in the tailwaters, but a very slight increase in downstream stations was observed (Figure 2c or Table III).

The average nitrate-nitrogen values were lowest in the Buffalo River and highest below Beaver Dam (Table III). The tailwater below Beaver Reservoir also exhibited the greatest variation during the 1965-1966 investigation (Figure 2e). This variation is assumed to be due to the fact that Beaver Reservoir contained an abundance of organic matter which decomposed during the period in which it was filling (Applegate and Mullan, 1967).

The determinations for nitrite-nitrogen were always found to produce negative results. Because of this and the instablity of the compound, this test was discontinued.

The average ortho-and meta-phosphate values did not differ significantly in the stations below the dams (Table III). However, these values were slightly higher in the Buffalo River.

Investigation Period from September 1967 through October 1968[1]

A summary of ranges and averages of physical factors for this period of investigation are presented in Table II. Figure 2a graphically shows the ranges of water temperatures and riffle speeds (current) for this period.

Stream plankton (potamoplankton) observed in this study are under the influence of several environmental factors which they do not encounter in other aquatic habitats. The most important of these factors is current. Current induced problems are as follows: maintenance of position, lack of stratification, a large variety of substrates, and an alteration of chemical characteristics (Reid, 1961). Whitford and Schumacher (1961) found that a current velocity of 0.5 feet per second greatly increases nutrient uptake thus satisfying the need for a rapid exchange of material with the water that lotic organisms need. Average riffle speeds for all stations monitored in this investigation, with the exception of one, were above the suggested 0.5 feet per second velocity (Table II); station Beaver 3 (B3) had a minimum range of 0.3 feet per second for a short period of time.

Figure 3 graphically represents seasonal fluctuations in riffle speeds at the three stations along the tailwater below Beaver Reservoir and at the two stations along the Kings River. During the

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[1] Information compiled from thesis of Gray (1970).

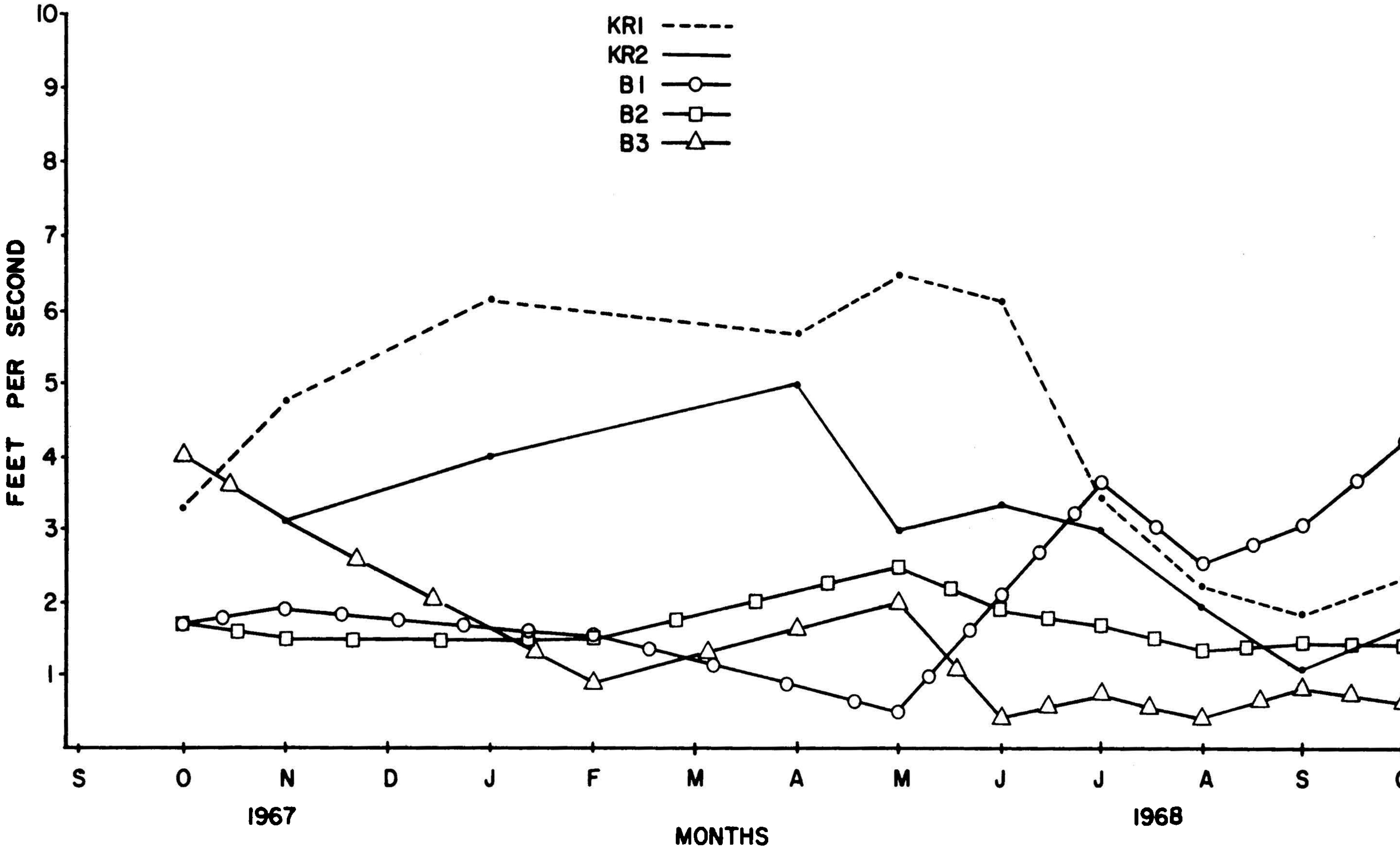

FIGURE 3. RIFFLE SPEED AT THREE STATIONS ALONG THE TAILWATER BELOW BEAVER RESERVOIR AND AT THE STATIONS ON THE KINGS RIVER. (MODIFIED FROM GRAY, 1970)

months of maximum generation, March to May of 1968 (Figure 4), riffle speeds at station B1 were at their lowest. As generation times decreased, June to October of 1968, riffle speeds at B1 increased. At station B2, riffle speeds did not appear to be as directly correlated to monthly discharges as at station B1. At station B2, riffle speeds remained relatively constant, showing a range of only 1.4 feet per second. Considering riffle speeds, it appears that station B3 changed from a fast riffle to a quiet pool after the maximum discharge months of March to May of 1968. Average riffle speeds, after the period June to October 1968, were 0.6 feet per second compared to 2.5 feet per second for the period of October 1967 to May 1968.

Station KR1 exhibited a consistently higher riffle speed than station KR2. The period of July through September of 1968 had a marked decrease in riffle speed at both stations. The average riffle speed during this three month period was 2.6 to 2.0 feet per second for stations KR1 and KR2, respectively, while average riffle speed for the three months previous to this period was 3.1 and 3.8 feet per second for the same stations.

Seasonal temperature fluctuations are shown in Figure 5. Station B1 exhibited the smallest variation (4.5C) in temperature of the three tailwater stations studied. With the exception of December 1967 through February 1968, monthly temperature averages were within 1.0 C of the over-all investigational average of 9.4 C.

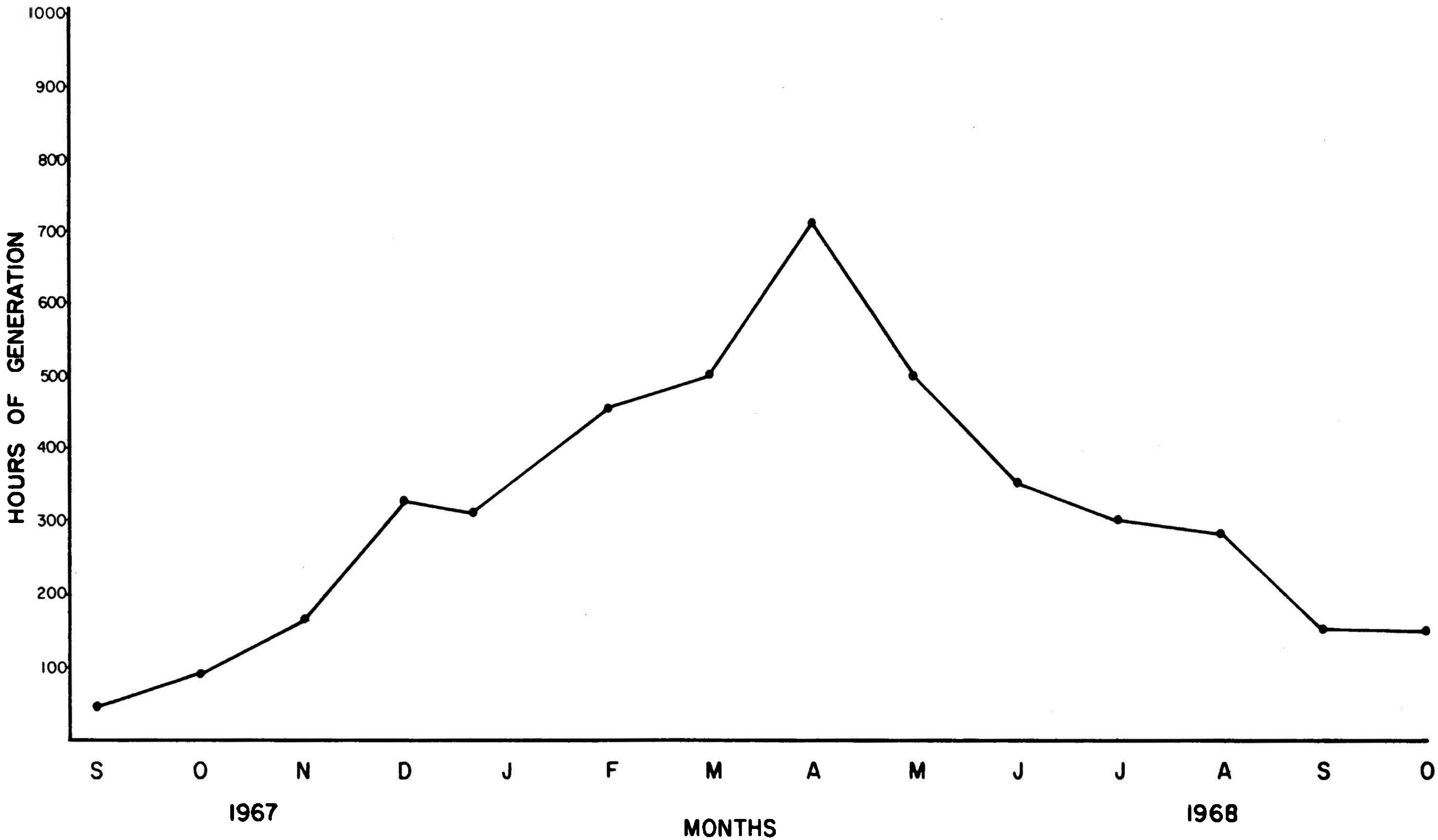

FIGURE 4 SEASONAL VARIATIONS OF GENERATION TIME AT BEAVER RESERVOIR

(AFTER GRAY, 1970)

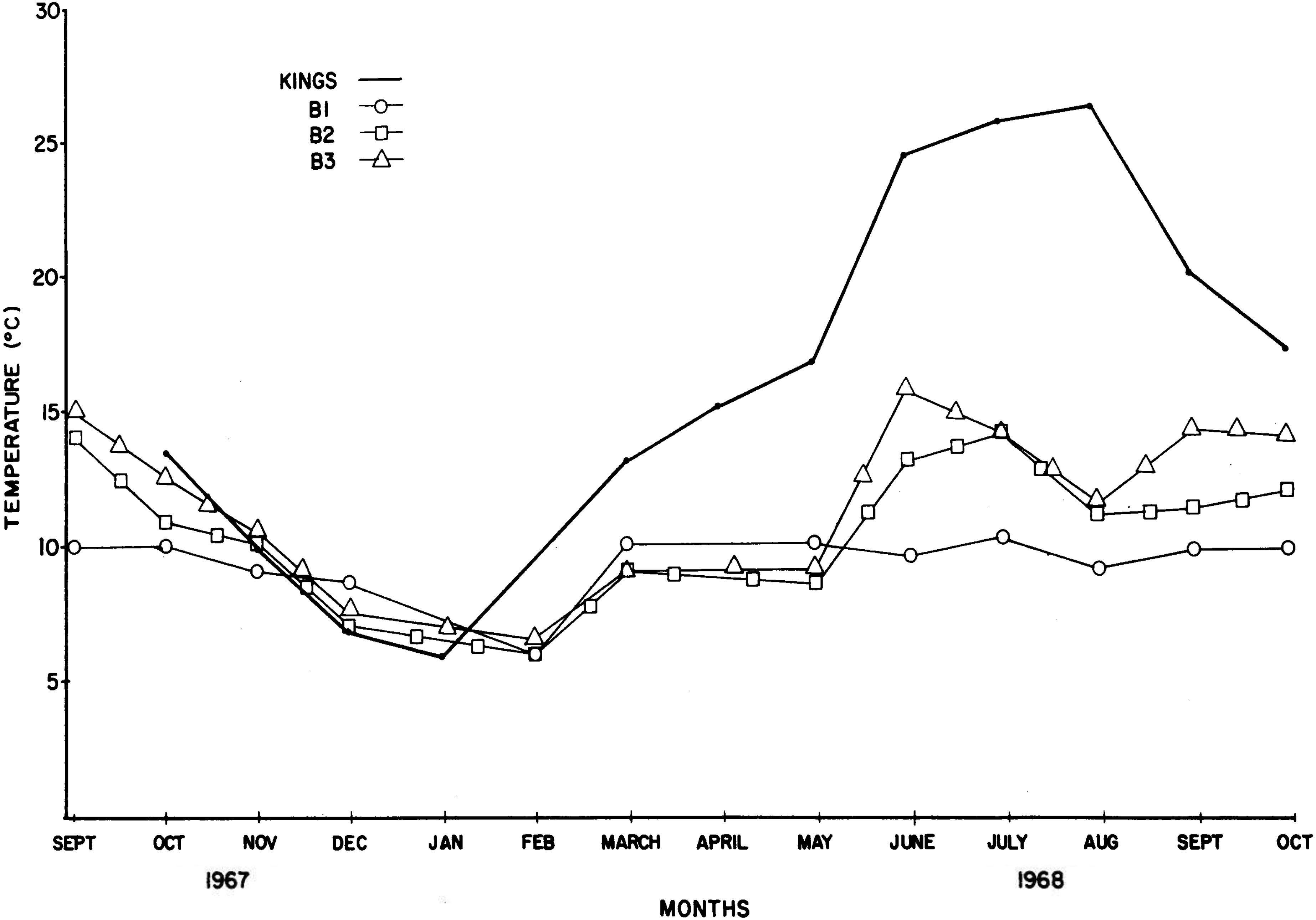

FIGURE 5 SEASONAL TEMPERATURE FLUCTUATIONS AT THREE STATIONS ALONG THE TAILWATER BELOW BEAVER RESERVOIR AND KINGS RIVER (MODIFIED FROM GRAY, 1970)

At this station, water temperatures did not appear to be correlated with either seasonal atmospheric variations or generation discharge times. A greater variation of temperature (10.0 C) was recorded at station B2 than at B1 (4.5 C). Temperatures at station B2 also showed more of a seasonal fluctuation, exhibiting a monthly average low of 6.0 C in February of 1968 and a monthly average high of 14.0 C in July of 1968. Station B3 had the greatest range of temperature, 11.4 C. The lowest monthly average temperature at this station was recorded in February of 1968; the highest occurred in June of 1968. Seasonal fluctuations were greatest at station B3. The temperature readings at the Beaver tailwater stations suggest that, as the water proceeds downstream from its relatively homoiothermal source, environmental temperatures play an increasingly important role. Blum (1956) states that an impoundment tends to act as a thermal stabilizer.

From December 1967 to May 1968, with the exception of February 1968, water was cooled by low atmospheric temperatures as it coursed downstream. The warmer temperature at station B1 during this period evidently reflects the temperature of the impoundment at the level of intake. During the remaining months of this investigation the water was warmed by higher atmospheric temperatures as it moved downstream. The average temperatures of the tailwater stations were lower than those for the Kings River during parts of the winter. At times the Kings River was colder than the cold-tailwater.

Temperature variations for KR1 and KR2 were plotted as one line because of the small differences in monthly temperatures between stations (Figure 5). The average temperatures at both stations (Table II) were within 0.1 C of each other. The Kings River, a natural free-flowing stream, was greatly affected by seasonal variations in atmospheric temperatures. During the course of this investigation, temperatures ranged from 4.0 C at station KR1 in January 1968 to 26.3 C at station KR2 in August 1968.

The Report of the Committee on Water Quality Criteria (FWPCA, 1968) states that free carbon dioxide concentrations should not exceed 25 ppm. The average amount of free carbon dioxide at all stations was well below this specified maximum (Table IV). In the Beaver cold-tailwaters, the highest average concentration of free carbon dioxide was found at station B1 and the lowest at station B3. This difference may be explained by the fact that, in limestone regions, the presence of large amounts of soluble carbonates, which readily combine with carbon dioxide, tend to lower the concentration of free carbon dioxide (Reid, 1961). Welch (1952) stated that current tends to keep carbon dioxide from accumulating.

In most productive fresh-water streams, the hydrogen ion concentration ranges from 6.5 to 8.5 (FWPCA, 1968). The minimum and maximum pH values for all stations studied in this investigation fell within this specification (Figure 2d and Table IV). Average pH values increased slightly from station B1 to B2. Limestone substrates which add large quantities of carbonate ions tend to shift the pH value to the basic range of the scale (Reid, 1961).

Dissolved oxygen concentrations are represented graphically in Figure 2b and Table IV. In the Beaver cold-tailwater, dissolved oxygen concentrations increased downstream from the dam (Table IV). The lower dissolved oxygen concentration at station B1 might be due to anaerobic conditions in the hypolimnion of Beaver Reservoir. The per cent of oxygen saturation in relation to average temperature also

TABLE IV. **AVERAGES AND RANGES OF PHYSICO-CHEMICAL DATA (GRAY, 1970).**

	B1	B2	B3
Riffle Speed, Ft./Sec.	A2.6 R0.5-5.6	1.6 1.1-2.5	1.2 0.3-4.0
Depth, in	A5.6 R3.0-10.0	8.4 4.0-14.0	13.9 6.0-25.0
Temperature, C	A9.4 R6.0-10.5	10.7 5.0-15.0	11.9 6.5-17.9
pH	A7.0 R6.8-7.4	7.1 6.8-7.6	7.1 6.8-7.8
CO_2, ppm	A2.1 R0.4-5.0	1.9 0.2-4.4	1.7 0.4-3.6
D. O., ppm	A7.5 R2.5-10.2	8.2 4.0-12.0	8.4 6.0-14.0
M. O. Alkalinity, ppm	A62.8 R53.0-66.0	64.7 55.0-70.0	67.3 60.0-75.0
Ammonia-Nitrogen, ppm	A0.1 R0.0-0.2	0.1 0.0-0.2	0.1 0.0-0.2
Nitrate-Nitrogen, ppm	A0.8 R0.2-1.9	0.6 0.2-0.9	1.2 0.2-4.0
Ortho-phos., ppm	A0.1 R0.0-0.2	0.1 0.0-0.2	0.1 0.0-0.2
Silica, ppm	A1.7 R0.0-3.5	1.4 0.0-3.5	1.5 0.0-4.5
Riffle Width, ft	45.0	64.0	18.0

A = average
R = range

TABLE IV. (CONTINUED)

	KR1	KR2
Riffle Speed, Ft./Sec.	A4.1 R1.5-6.6	2.8 1.2-5.0
Depth, in	A10.7 R3.0-22.0	12.0 3.0-32.0
Temperature, C	A16.1 R4.0-26.0	16.2 6.0-26.3
pH	A7.3 R7.0-7.6	7.3 7.1-7.8
CO_2, ppm	A2.1 R0.8-4.8	2.1 0.4-5.2
D. O., ppm	A8.5 R4.5-20.5	8.7 5.0-20.0
M. O. Alkalinity, ppm	A59.5 R38.0-108	59.3 40.0-106
Ammonia-Nitrogen, ppm	A0.3 R0.0-2.0	0.5 0.0-3.6
Nitrate-Nitrogen, ppm	A0.6 R0.2-1.0	0.6 0.3-1.1
Ortho-phos., ppm	A0.07 R0.0-0.1	0.06 0.0-0.1
Silica, ppm	A3.5 R0.0-6.0	3.2 0.0-5.5
Riffle Width, ft	31.1	24.5

increased downstream. These calculations were based on the data presented by Welch (1952). The saturations of dissolved oxygen, related to average temperatures, were 66, 72, and 73 per cent at stations B1, B2, and B3, respectively (Gray, 1970). All average dissolved oxygen values for the Beaver cold-tailwater were lower than those of Kings River.

Station KR1 showed a lower average dissolved oxygen concentration (8.5 ppm) and per cent saturation (81 per cent) than station KR2 (8.7 ppm O_2 and 83 per cent saturation). Dissolved oxygen concentrations at the Kings River showed an inverse relationship to temperature (Gray, 1970).

Dissolved oxygen levels, for good growth of cold-water biota, should not be below 6.0 mg/l at any time (FWPCA, 1968). Provided other water conditions are favorable DO may range between 5 and 6 mg/l for short periods. However, in this study, minimum dissolved oxygen values at stations B1 and B2 (Figure 2b) fell below this concentration, nevertheless, the average dissolved oxygen value was above the Water Quality Criteria minimum of 6.0 mg/l. The range of dissolved oxygen concentration during the 1967-1968 study at station B3 was at the specified minimum concentration.

Methyl orange alkalinity, or alkalinity as parts per million calcium bicarbonate, is an important factor in productivity. Carbon dioxide and bicarbonate, formed by the disassociation of bound carbonates, help to supply the essential carbon needed in the construction of all carbohydrates and protein molecules. A limited supply of carbon affects the rate of photosynthesis, which, in turn, affects other metabolic processes indirectly (McCombie, 1953). Prescott (1956) stated that calaphilic habitats have a more profuse algal growth due to high reserves of carbon dioxide used in plant metabolism.

Below Beaver Reservoir, methyl orange alkalinity increased from stations B1 to B3. This increase, with the comparable pH increase mentioned earlier, indicates an addition of carbonate ions as the water flows downstream. Methyl orange alkalinity estimates at both the Kings River stations were similar. Although the cold-tailwater stations had higher average methyl orange alkalinity readings, those at the Kings River stations exhibited a wider range, possibly attributable to seasonal fluctuations.

Average ammonia-nitrogen concentrations for all cold-tailwater samples were the same, 0.1 ppm; station KR1 had a lower amount of ammonia-nitrogen than station KR2. Water Quality Criteria (FWPCA, 1968), states that, generally, ammonia-nitrogen concentrations at pH levels of 8.0 and above should not exceed 1.5 ppm. Beaver Reservoir samples did not exceed this recommended limit. Maximum concentrations for the Kings River samples were above the specified amount (Table IV). However, average ammonia-nitrogen values for both Kings River stations were below the Water Quality Criteria limit.

The average nitrate-nitrogen concentrations decreased downstream from stations B1 to B2 below Beaver Dam. The high values at B1 may be related to high nitrate-nitrogen concentrations in the Beaver Lake hypolimnion (Applegate and Mullan, 1967). Maximum nitrate-nitrogen amounts were only slightly higher at station KR 2 (1.1 ppm) than KR1 (1.0 ppm). Average ortho-phosphate values remained constant at the Beaver Reservoir stations (0.1 ppm). The two Kings River stations were essentially the same.

Ranges of silica concentrations are graphically shown in Figure 2c. Silica is of special importance to diatoms because they incorporate large amounts of it in their shells (McCombe, 1953). According to Pearsall (1923) seasonal changes in silica may be correlated with diatom production. Reid (1961) states that growth of diatoms such as Asterionella, Melosira, and Tabellaria may be inhibited by concentrations of silicon dioxide below 0.5 to 0.8 ppm.

Monthly average silica concentrations at Beaver Reservoir stations fluctuated randomly (Gray, 1970). Average silica amounts decreased slightly downstream from stations B1 to B2 below Beaver Dam (Table IV). Average silica values at Kings River were approximately twice that of the Beaver Reservoir cold-tailwater. Monthly silica concentrations at Kings River appear to be inversely related to temperature. None of the stations monitored in this investigation showed a direct relationship between seasonal silica changes and diatom production. Average silica values, well above the minimum (0.5 - 0.8 ppm) suggested by Reid (1961), may be responsible for this phenomenon.

Phytoplankton

Investigation Period from July 1965 through October 1968[1]

INTRODUCTION

During this investigation period the phytoplankton of two natural streams, the Buffalo and Kings Rivers, and the cold-tailwaters below three reservoirs were studied (Figures 6 through 9).

Standing crop (biomass) is defined by Reid (1961) as the instantaneous quantity of organisms. Water Quality Criteria (FWPCA, 1968), defines standing crop as biota present in an environment on a selected date. The average standing crop of net phytoplankton enumerated at each collecting station during this investigation is shown diagramatically in Figure 6a through 6e. The standing crop is broken down into its percentage composition of major algal phyla. These data are also presented numerically in Appendix E. Minor phyla of phytoplankton (Euglenophyta, Pyrrhophyta, and Rhodophyta) were grouped together because of their infrequent occurrences and their small percentage composition of the total standing crop. Due to their apparent minor importance these phyla will not be discussed in relation to standing crops.

During the 1965-1966 study period, 100 genera of net phytoplankton were identified from all areas investigated. The tailwater of Beaver Reservoir exhibited the largest number of genera (82), and the tailwater below Bull Shoals Reservoir showed the least number of genera of phytoplankton (68). In the tailwater of Norfork Reservoir, 75 genera were observed, while the Buffalo River displayed 79 genera of phytoplankton. The genera of phytoplankton present in the samples

[1]Information compiled from field data and thesis of Dennie (1967) and thesis of Gray (1970).

of the various study areas are listed in Appendix A. Amphicampa, Aphanochaete, Coelastrum, Euglena, and Westella were observed in the tailwater of Beaver Reservoir. Anabaenopsis, Chaetoceros, Chroococcus, Glootrichia, Hydrodictyon, Microthamnion, Selenastrum, Sorastrum, and Treubaria were observed only in the Buffalo River. The phytoplankters occurring only in the tailwater of Norfork Reservoir were Gonatozygon and Terpsinoë.

Eighty-four genera of phytoplankton were identified during the 1967-1968 investigation period (Appendix C). Of the three major phyla represented in this study the Cyanophyta exhibited 12, the Chrysophyta 26, and the Chlorophyta (the largest number) 39 . The minor phyla in this study (Euglenophyta, Pyrrophyta, and Rhodophyta) contributed seven genera. The largest number of individual cells representing genera of the three phyla of phytoplankton were as follows: Fragilaria (Chrysophyta), Oscillatoria[1] (Cyanophyta), and Spirogyra, Pediastrum, Stigeoclonium, and Ulothrix (Chlorophyta). In the Kings River, during the 1967-1968 period, the important genera were the following: Melosira, Fragilaria, (Chrysophyta), Oscillatoria[1] (Cyanophyta), and Cladophora, Ulothrix, and Pediastrum (Chlorophyta) (Figures 7 through 9).

During the 1965-1966 period the Bacillariophyceae, or diatoms, constituted the overwhelming majority of the Chrysophyta in all the study areas. Collectively, the diatoms are an extremely important group of organisms in the food chain because of their ability to multiply rapidly and to grow in all waters at all ordinary temperatures (Needham and Lloyd, 1928). Diatoms are some of the most prolific photosynthetic producers in the fast regions of upland streams (Reid, 1961). A larger

[1] In the 1967-1968 investigation Phormidium and Lyngbya were included with Oscillatoria (Drouet, 1968). In the 1965-1966 study each was considered a separate genus.

percentage of the fresh-water diatoms are coldwater organisms and are, therefore, especially common in spring and autumn (Smith, 1950). Williams and Scott (1962) found that the diatoms constituted the largest group of plankton in the major waterways of the United States, both in number of individuals and number of species, except in some impoundments during warm seasons at which time the blue-green algae predominated. Kofoid (1908) found the predominating group of phytoplankton in the Illinois River to be the Chlorophyceae (Chlorophyta) with the diatoms ranking second. A possible explanation for the preponderance of diatoms in lotic environments, according to Reinhard (1931), is that rivers, in general, contain more silt than lakes and, consequently, present a greater amount of available silica for diatom utilization. In a year-round study of Boulder Creek, Colorado, Pennak (1943) found that the net phytoplankton was limited to Ulothrix and diatoms.

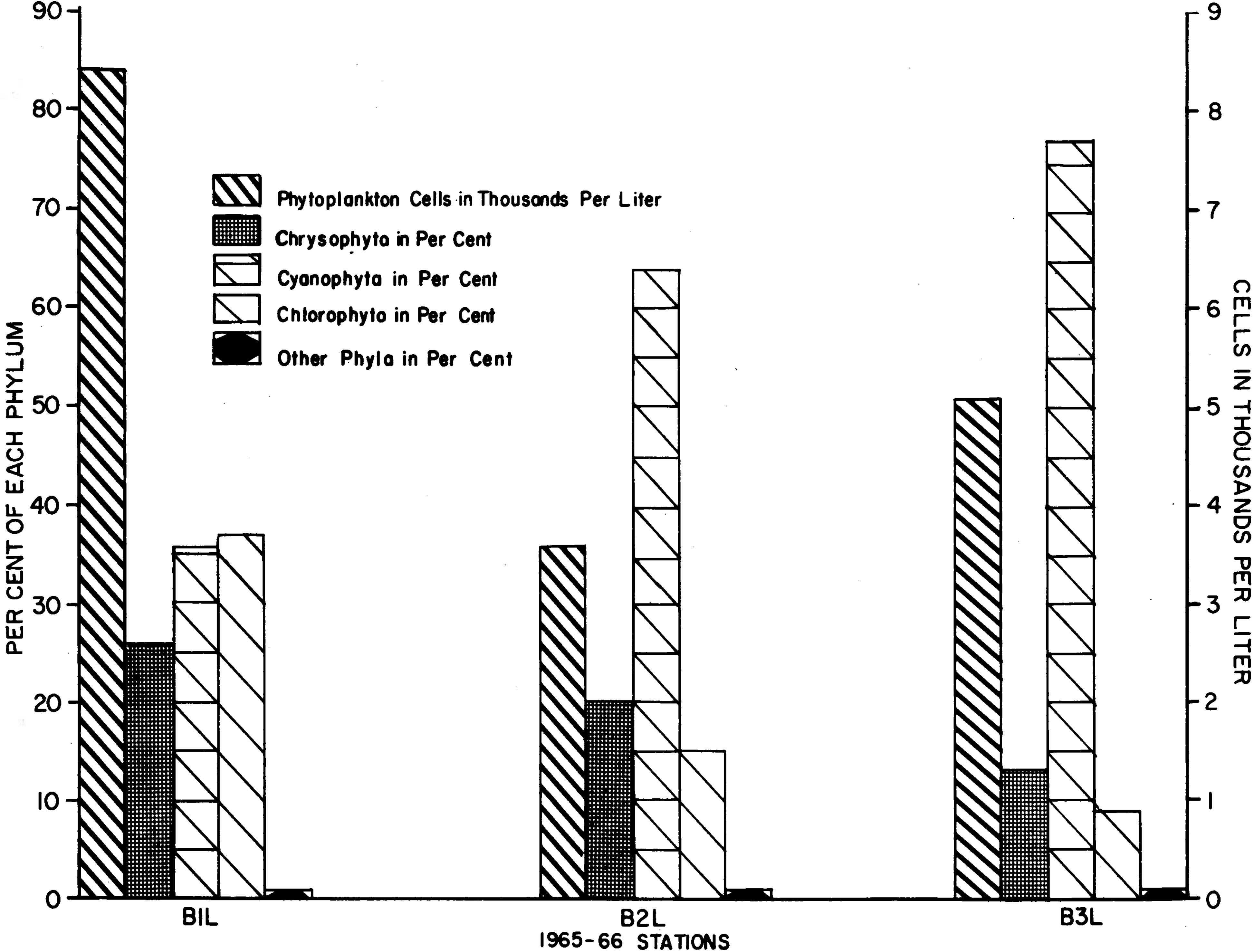

FIGURE 6a. DOMINANT PHYTOPLANKTON AS PER CENT OF AVERAGE CELLS PER LITER. STATIONS ON THE BEAVER TAILWATER.

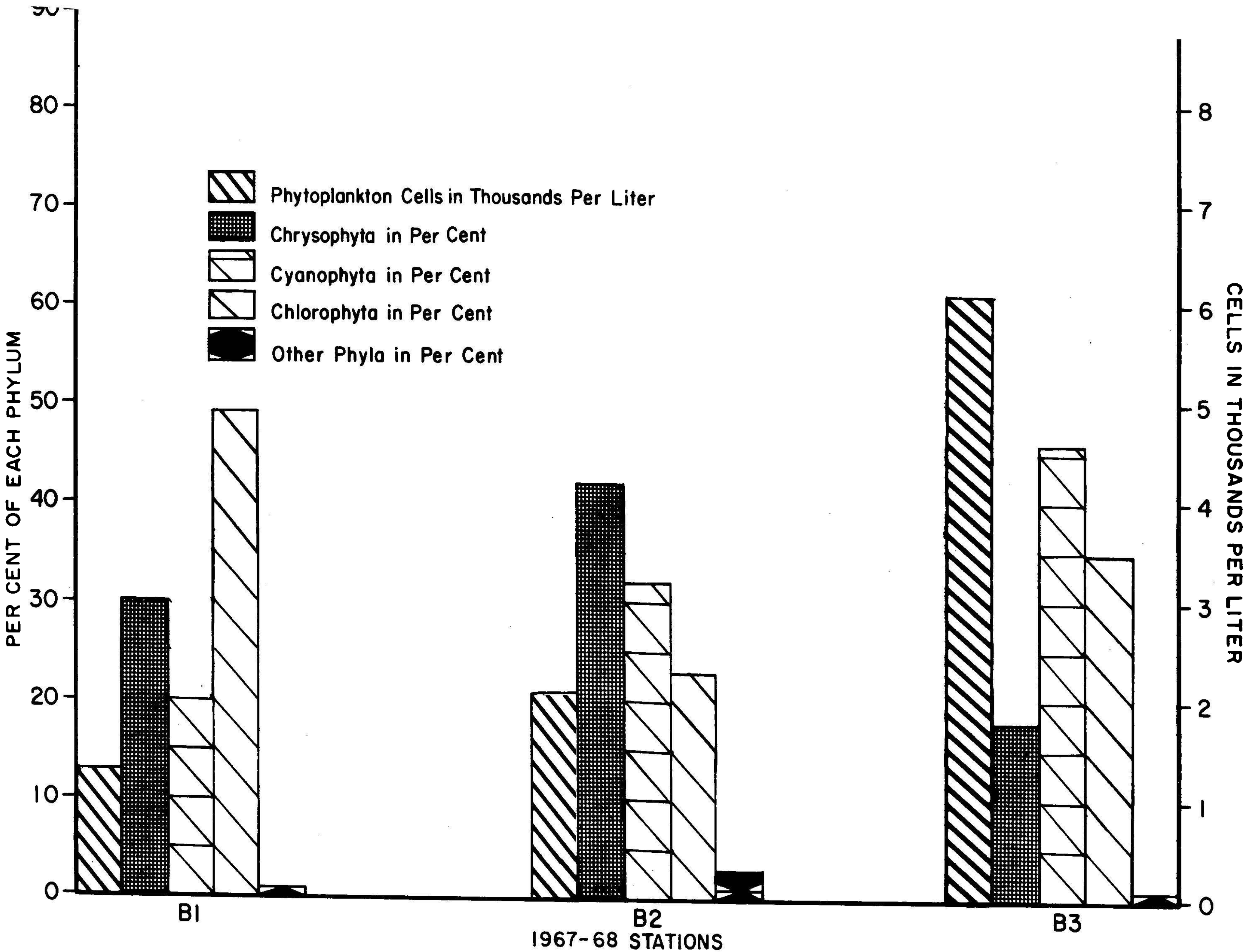

FIGURE 6b. STANDING CROPS OF DOMINANT PHYTOPLANKTON EXPRESSED AS PER CENT OF AVERAGE CELLS PER LITER. STATIONS ON THE BEAVER TAILWATER.

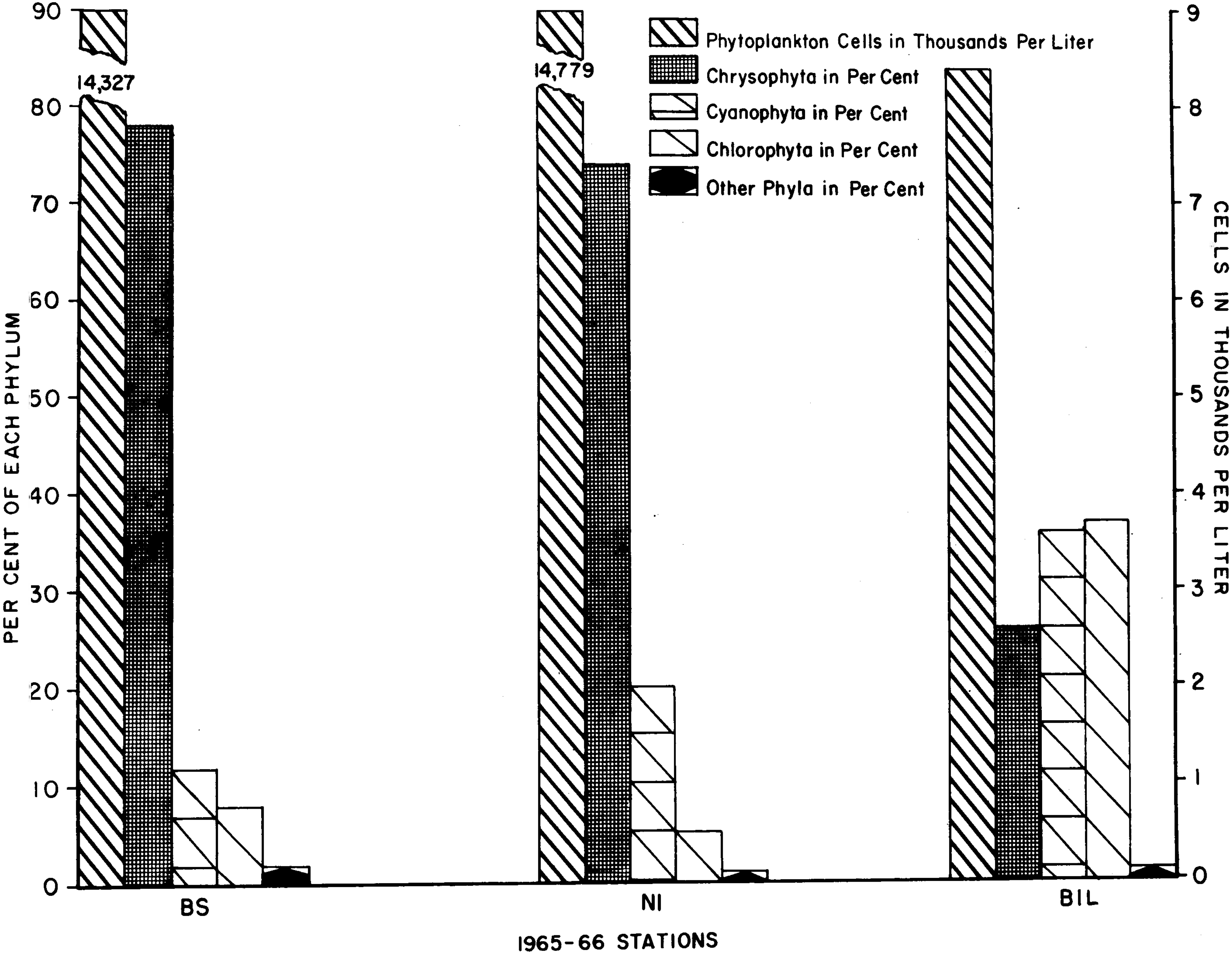

FIGURE 6c. STANDING CROPS OF DOMINANT PHYTOPLANKTON EXPRESSED AS PER CENT OF AVERAGE CELLS PER LITER. STATIONS NUMBER 1, JUST BELOW THE DAM, ON BULL SHOALS, NORFORK, AND BEAVER TAILWATERS

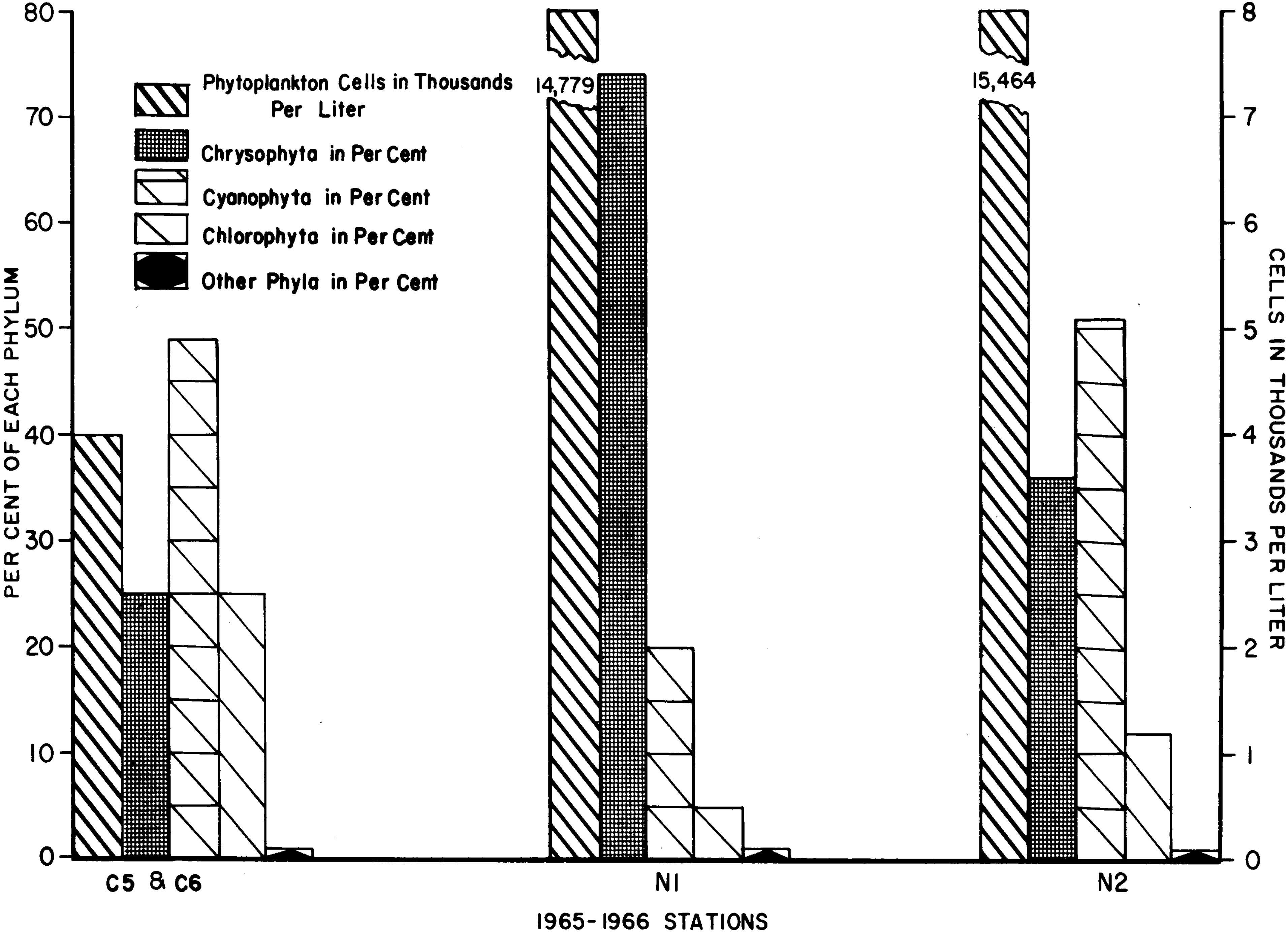

FIGURE 6d. STANDING CROPS OF DOMINANT PHYTOPLANKTON EXPRESSED AS PER CENT OF AVERAGE CELLS PER LITER. STATIONS ON THE BUFFALO RIVER AND THE NORFORK TAILWATER.

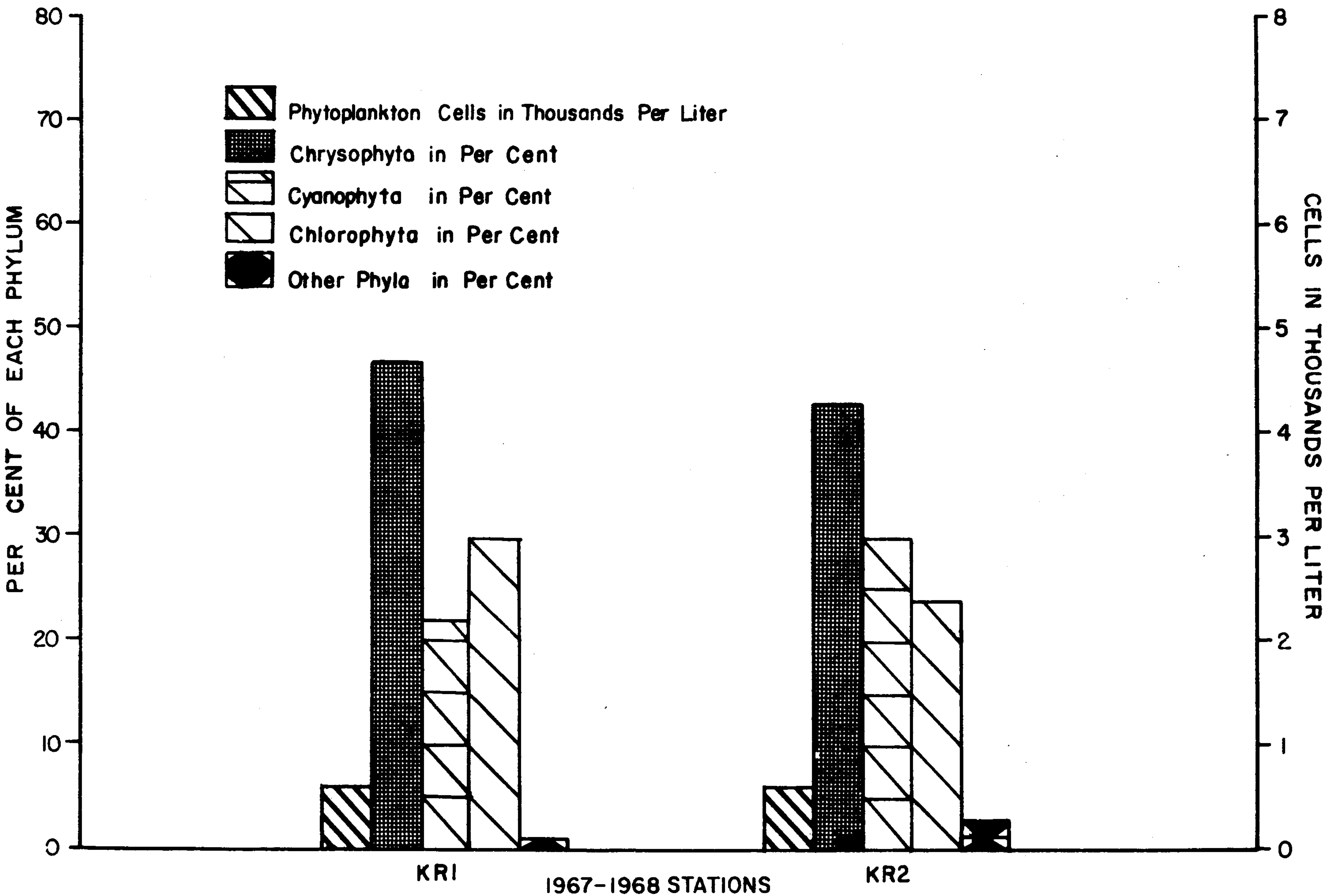

FIGURE 6e. STANDING CROPS OF DOMINANT PHYTOPLANKTON EXPRESSED AS PER CENT OF AVERAGE CELLS PER LITER. STATIONS ON THE KINGS RIVER.

NATURAL STREAMS

Buffalo and Kings Rivers

The Buffalo River, because the area is sparsely populated and most of the watershed is in wilderness, comes as close as any river in Arkansas to resembling a natural unpolluted stream. Some examples of pollutants in Arkansas streams are: poultry farms, vegetable farms, cattle grazing fields, canning factories, oil wells, paper mills, coal mines, bauxite mines, and municipal sewage disposal plants. When all collecting sites studied from 1965-1968 are considered, the Buffalo River ranks seventh in productivity as expressed in phytoplankton cells per liter, while the two Kings River stations have the lowest phytoplankton productivity. Figures 6d and 6e graphically represent the average standing crops in cells per liter for both the 1965-1966 and 1967-1968 investigations. The number of cells in thousands per liter is approximately six times greater in the Buffalo River (C5 & C6) than in the Kings River stations (KR1 and KR2). Although there appears to be a tendency towards an equal distribution among the three phyla, the Cyanophyta occur in larger numbers in the Buffalo River and the Chrysophyta in larger numbers in the two Kings River stations.

In the Kings River stations the average standing crop of net phytoplankton was less at station KR1 than at KR2 (Figure 6e and Appendix E). The major algal phylum at KR1 was the Chrysophyta (47%). Chlorophyta comprised 30% and Cyanophyta 22% of the standing crop of net phytoplankton at this station. At station KR2 the Chrysophyta also comprised the major part (43%) of the standing crop of net phytoplankton. The per cent composition of other algal phyla was Chlorophyta 24% and Cyanophyta 30%.

According to investigational data, the Chrysophyta show a habitat selection toward the more rapid riffle (station KR1). McIntire (1966), in laboratory work with artificial streams, found a higher per cent composition of diatoms (Chrysophyta) in fast moving waters than in slow moving waters.

The average standing crops of each major phylum of phytoplankton were broken down into per cent composition of major genera (Figures 7 through 9). Corresponding numerical values for per cent compositions are given in Appendixes F, G, and H.

The Kings River stations exhibited a different Chlorophyta genera composition during the 1967-1968 investigation than the Beaver cold-tailwater stations (Figures 9b, 9c and Appendix H). At station KR1 Cladophora comprised 47% of the standing crop of Chlorophyta. Other abundant genera at KR1 were Ulothrix (21%), Pediastrum (12%) and Chaetophora (6%). At station KR2, Cladophora was the most prevalent green algal form (26%); other important genera were Pediastrum (22%), Chaetophora (17%) and Ulothrix (14%).

Smith (1950) states that Cladophora is a current inhabiting alga. Its preference is demonstrated at the Kings River stations. The Chlorophyta of station KR1, the station with a higher average riffle speed, was comprised of a greater percentage of Cladophora than station KR2, which had a lower average riffle speed (Table II).

At Kings River the genera composition of Chrysophyta was more evenly distributed (Figure 7d and Appendix F). Major genera of Chrysophyta at station KR1 were Melosira (42%), Dinobryon (19%), Fragilaria (8%) and Tribonema (7%). At station KR2 Melosira comprised

33% of the Chrysophyta. Other abundant yellow-greens at KR2 were Fragilaria (17%), Tribonema (12%) and Dinobryon (10%).

The composition of blue-green algae at the Kings River stations is presented in Figure 8d or Appendix G. The most abundant genus was Oscillatoria (KR1 87%, KR2 85%). Anacystis was the second most abundant (KR1 10%, KR2 5%).

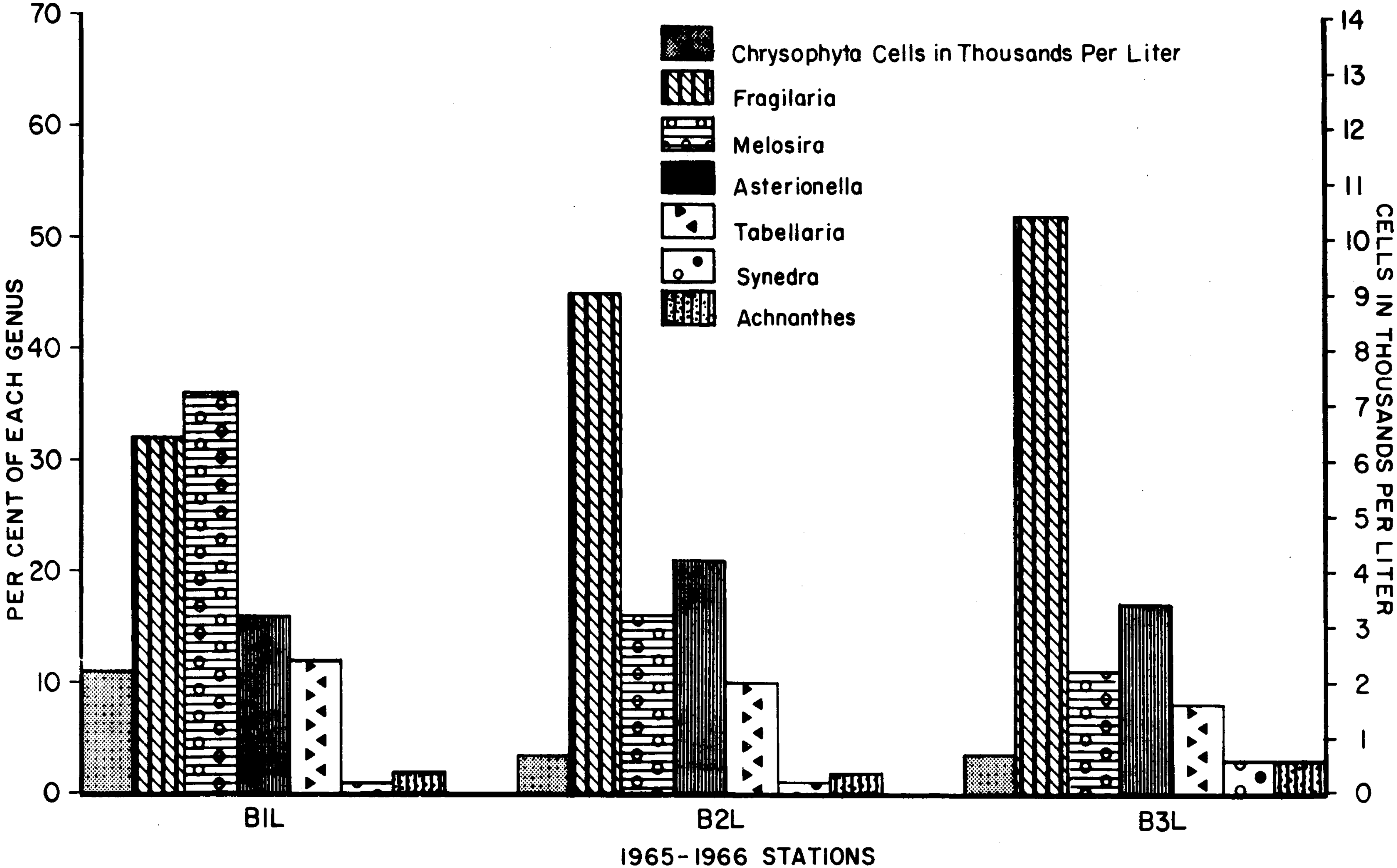

FIGURE 7a. AVERAGE STANDING CROPS OF CELLS PER LITER OF CHRYSOPHYTA AND OF EACH MAJOR GENUS REPRESENTED AND ITS RESPECTIVE PERCENTAGES. STATIONS ON THE BEAVER TAILWATER.

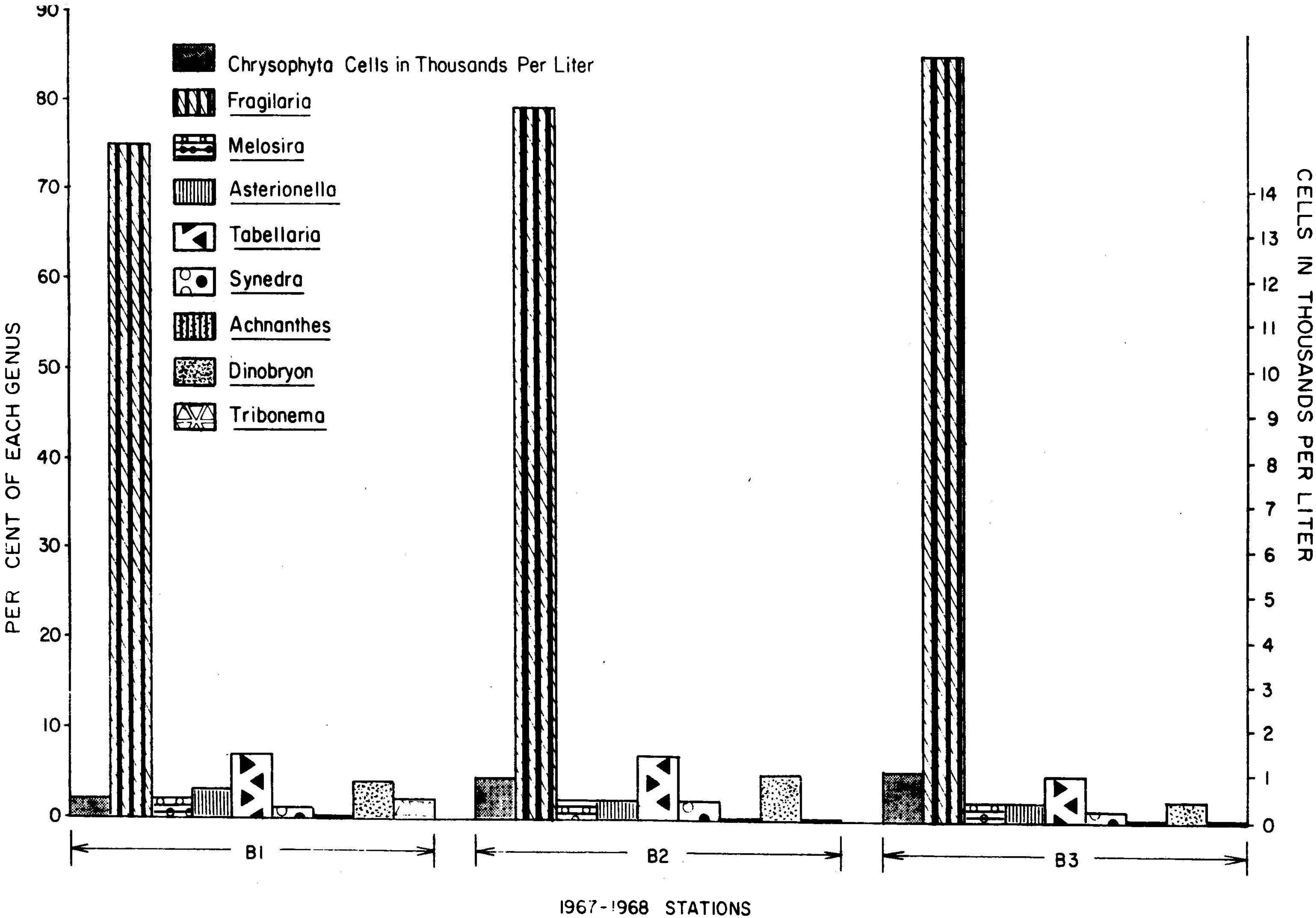

FIGURE 7b. AVERAGE STANDING CROPS OF CELLS PER LITER OF CHRYSOPHYTA AND OF EACH MAJOR GENUS REPRESENTED AND ITS RESPECTIVE PERCENTAGES. STATIONS ON THE BEAVER TAILWATER.

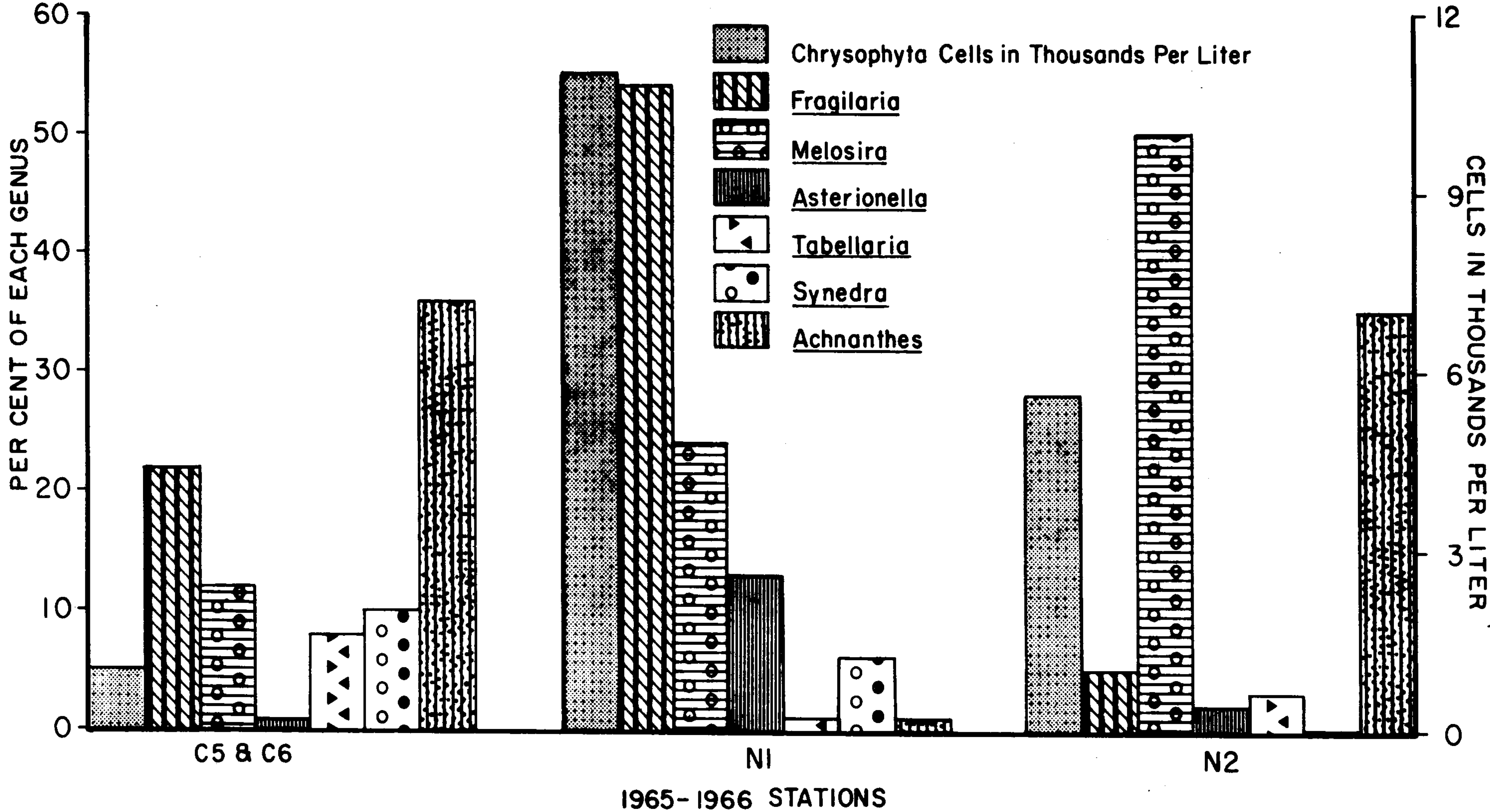

FIGURE 7c. AVERAGE STANDING CROPS OF CELLS PER LITER OF CHRYSOPHYTA AND OF EACH MAJOR GENUS REPRESENTED AND ITS RESPECTIVE PERCENTAGES. STATIONS ON THE BUFFALO RIVER AND THE NORFORK TAILWATER.

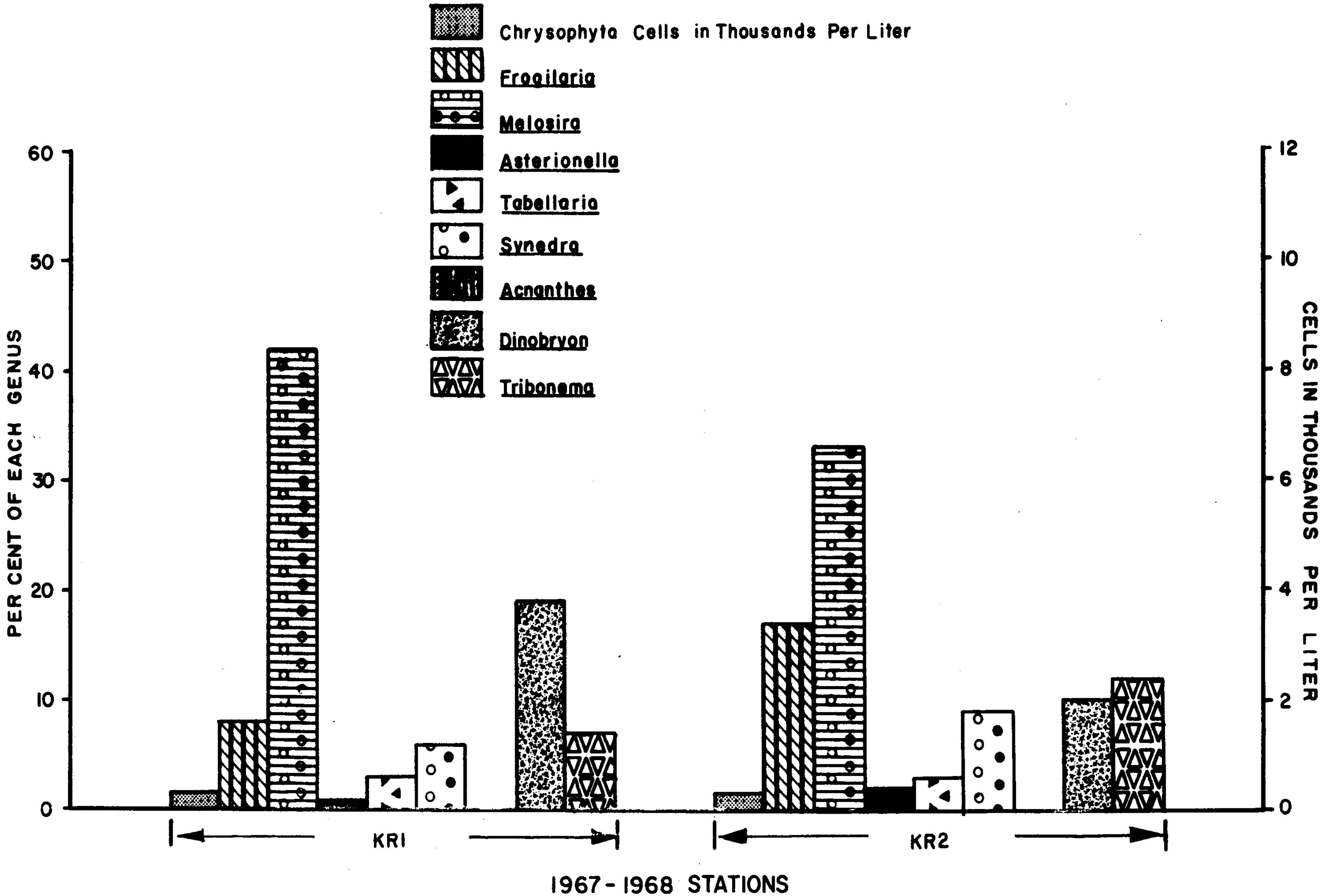

FIGURE 7d. AVERAGE STANDING CROPS OF CELLS PER LITER OF CHRYSOPHYTA AND OF EACH MAJOR GENUS REPRESENTED AND ITS RESPECTIVE PERCENTAGES. STATIONS ON THE KINGS RIVER.

NEW TAILWATER

Beaver Tailwater

Data represented in Figure 6a graphically illustrates the average standing crops of phytoplankton for the 1965-1966 period at three stations along the tailwater below Beaver Reservoir. The phytoplankton of this tailwater comprised 99.8% of the total net plankton. Chandler (1937) stated that the total plankton population of a river is augmented by lake plankton just below the outlet of a lake, but that this lake plankton soon decreases under river conditions. During the course of this period of investigation, the total net phytoplankton of the Beaver tailwater exhibited a decrease in the average number of cells per liter from station B1L to station B2L and increased from station B2L to station B3L.

The Chrysophyta constituted about one-fourth of the total net phytoplankton collected at station B1L in the tailwater of Beaver Reservoir. At stations B2L and B3L, the Chrysophyta comprised about one-fifth and one-eighth of the total phytoplankton, respectively. Diatoms made up 99.5% of the Chrysophyta at stations B1L and B2L and 98.8% at station B3L. The dominant genera of diatoms observed in the samples from the Beaver Reservoir tailwater were Fragilaria, Melosira, Asterionella and Tabellaria. Fragilaria was the dominant form at stations B2L and B3L. At station B1L, Fragilaria contributed 32%, Melosira 36%, and Asterionella and Tabellaria 15% and 12%, respectively (Figure 7a or Appendix F).

Total phytoplankton cells collected from the first two Beaver tailwater stations in the 1965-1966 study exceeded those taken during the 1967-1968 investigation. The phytoplankton cells at station B1L in the earlier study were six and one-half times greater than those of the later study; at station Beaver 2 (B2L) standing crops were about one and one-half times greater; and the number of cells at Beaver station 3 (B3L) were of a 6:5 ratio, with B3 the larger. There appeared to be a tendency towards a more even distribution of the three phyla at the Beaver 2 station during the 1967-1968 study period (Figures 6a and 6b).

The Cyanophyta, or blue-green algae, were the dominant plankters in the two downstream stations of the Beaver tailwater (B2L and B3L). They represented slightly more than one-third of the total net phytoplankton collected at station B1L in the Beaver tailwater. At station B1L, the blue-green algae were abundant only in the midsummer of 1965. The maximum Cyanophyta density reached during this time was over 120,000 cells per liter. At this time Beaver Reservoir was filling, and the organic matter was quite abundant (Applegate and Mullan, 1967).

The average number of cells per liter of blue-green algae decreased about one-fourth from station B1L to station B2L; nevertheless, they comprised 64% of the total net phytoplankton at this station. There was a 23% increase in the average number of blue-green cells per liter from station B1L to station B3L; this phylum formed 77% of the total phytoplankton at station B3L (Figure 6a).

In general, blue-green algae in lakes occur in abundance in the warm months of the year when the organic matter is high (Welch, 1952). However, certain species may become abundant during the winter months (Smith, 1920 as cited in Smith, 1950). There is evidence that some of the blue-greens are utilized at certain times by fish for food (Ward and Whipple, 1918).

The dominant genus in all three Beaver stations was Oscillatoria, comprising 87%, 74%, and 57% at stations B1L, B2L, and B3L, respectively. Phormidium was also a major organism at the two downstream stations of the Beaver tailwater, contributing 15% to the Cyanophyta at B2L and 24% to B3L. Lyngbya formed 17% of the total blue-green algae at station B3L (Footnote Appendix G).

The Chlorophyta, or green algae, represented slightly more than one-third of the total net phytoplankton collected at station B1L. As a taxon, the green algae at stations B2L and B3L were the smallest group of the three major phyla of phytoplankton present. The dominant genera of Chlorophyta were: Draparnaldia at station B1L, Spirogyra and Pediastrum at B2L, and Spirogyra, Pediastrum and Stigeoclonium at B3L (Figure 9a and Appendix H). With the exception of Pediastrum and Spirogyra, the above plankters were abundant throughout the year and were present in an apparently random fashion. They did not present any well defined seasonal cycles in the data from this investigation. Pediastrum pulsed in October 1966, exhibiting a maximum density of over 9,000 cells per liter. Several pulses of Spirogyra were detected. Some of these apparently occurred independently of the other stations of the tailwater. For example, there was a pulse of Spirogyra at station B2L in May 1966; during the same period, the other two stations did not experience a similar pulse.

In the Beaver cold-tailwater, the average standing crops of net phytoplankton increased downstream during the 1967-1968 period (Figure 6b). At station B1 the green algae (Chlorophyta) comprised the major portion (49%) of net phytoplankton. The yellow-green algae (Chrysophyta) composed 30% and the blue-green algae (Cyanophyta) 20% of the average standing crop at B1. Downstream, at station B2, the Chlorophyta decreased to 23% of the average standing crop. Both the Chrysophyta and Cyanophyta increased to 42 and 32%, respectively. At station B3 the Chlorophyta increased to 35%, the Chrysophyta decreased to 18%, while the Cyanophyta increased to 46% of the average standing crop.

An over-all consideration of the Beaver Reservoir cold-tailwater stations shows a net per cent decrease of Chlorophyta in relation to standing crops of net phytoplankton from B1 to B2 downstream from the dam. Station B2 exhibited the lowest per cent composition of Chlorophyta. The Chrysophyta per cent composition of net phytoplankton was similar (i.e., decreasing downstream from the dam, except for station B2 which showed the greatest per cent composition of yellow-green algae). The Cyanophyta continued to increase at each downstream station.

At station B1 the three major genera of Chlorophyta were *Chaetophora* (26%), *Cladophora* (24%), and *Ulothrix* (15%) (Figure 9b and Appendix H). Downstream, at station B2, *Chaetophora* comprised 53% of the Chlorophyta. Other abundant genera at B2 were *Pediastrum* (15%) and *Ulothrix* (8%). The major genera of Chlorophyta at station B3 consisted of *Chaetophora* (65%), *Stigeoclonium* (20%), and *Ulothrix* (6%). *Cladophora* and *Ulothrix* decreased in per cent composition downstream from the dam, while *Chaetophora* increased.

The per cent composition of major genera of Chrysophyta for the Beaver cold-tailwater and Kings River is shown in Figures 7b and 7d and the numerical data in Appendix F. The majority of Chrysophyta at the Beaver tailwater stations consisted of two genera, *Fragilaria* and *Tabellaria*.

Fragilaria, the most abundant yellow-green alga, comprised 75, 79, and 85% of the standing crop at stations B1, B2, and B3, respectively. Per cent composition of *Tabellaria* were as follows: B1, 7%; B2, 7%; and B3, 5%.

The standing crop and per cent composition of major genera of Cyanophyta for the Beaver cold-tailwater and Kings River are given in Figures 8b and 8d and Appendix G. Algae of this division during the 1967-1968 investigation were classified in accordance with the reclassification of the Oscillatoriaceae (Drouet, 1968).

Oscillatoria was the major genus found at all Beaver Reservoir stations, and in per cent composition, it increased downstream from the dam (B1, 77%; B2, 89%; and B3, 95%). The second most abundant blue-green alga was *Anacystis*, which decreased in per cent composition downstream from the dam (B1, 8%; B2, 3%; and B3, 1%). *Gomphosphaeria* was relatively abundant at station B1 (9%) but not at the other Beaver Reservoir stations (B2, 1%; B3, 1%).

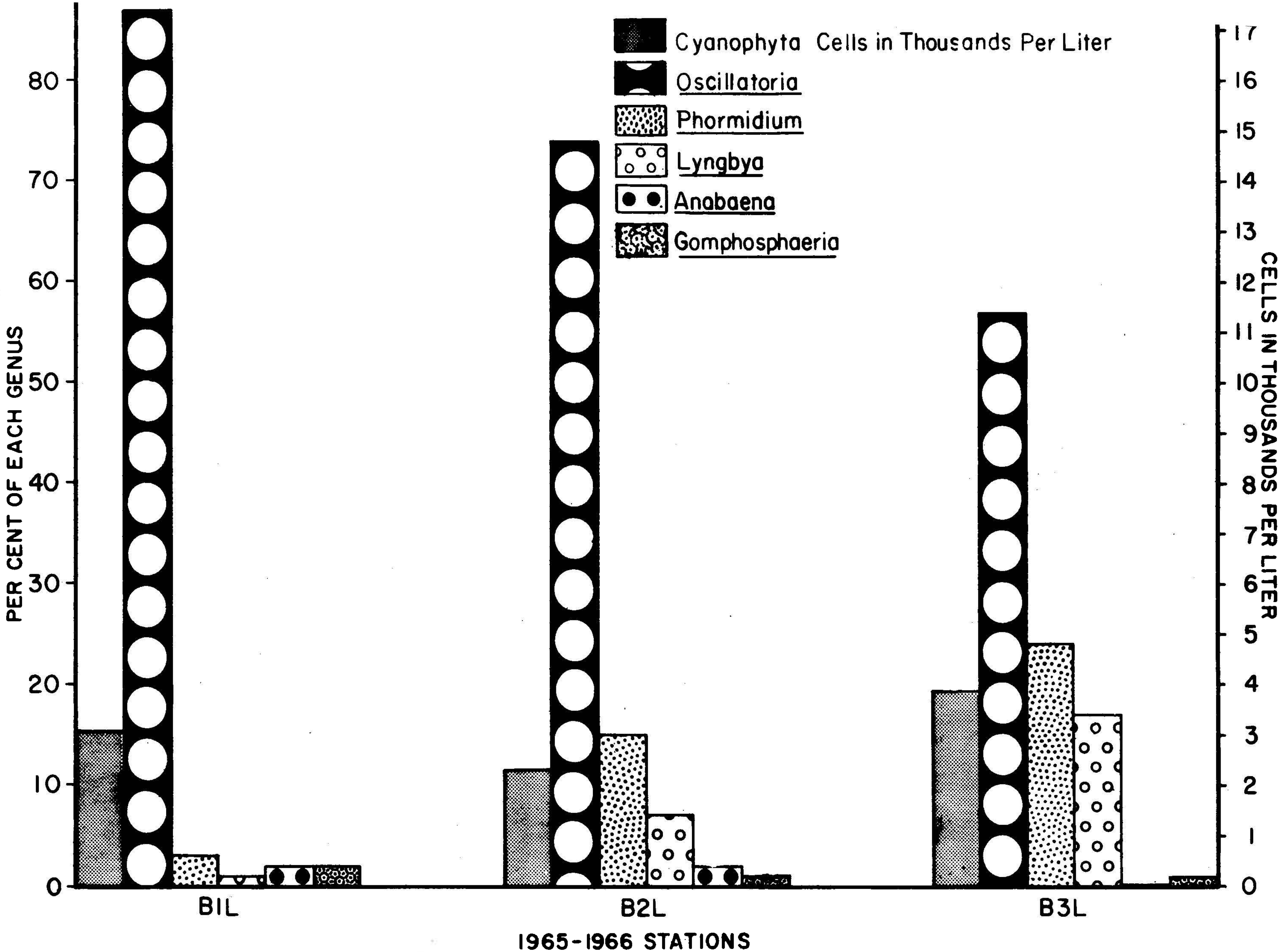

FIGURE 8a. AVERAGE STANDING CROPS OF CELLS PER LITER OF CYANOPHYTA AND OF EACH MAJOR GENUS REPRESENTED AND ITS RESPECTIVE PERCENTAGES. STATIONS ON THE BEAVER TAILWATER.

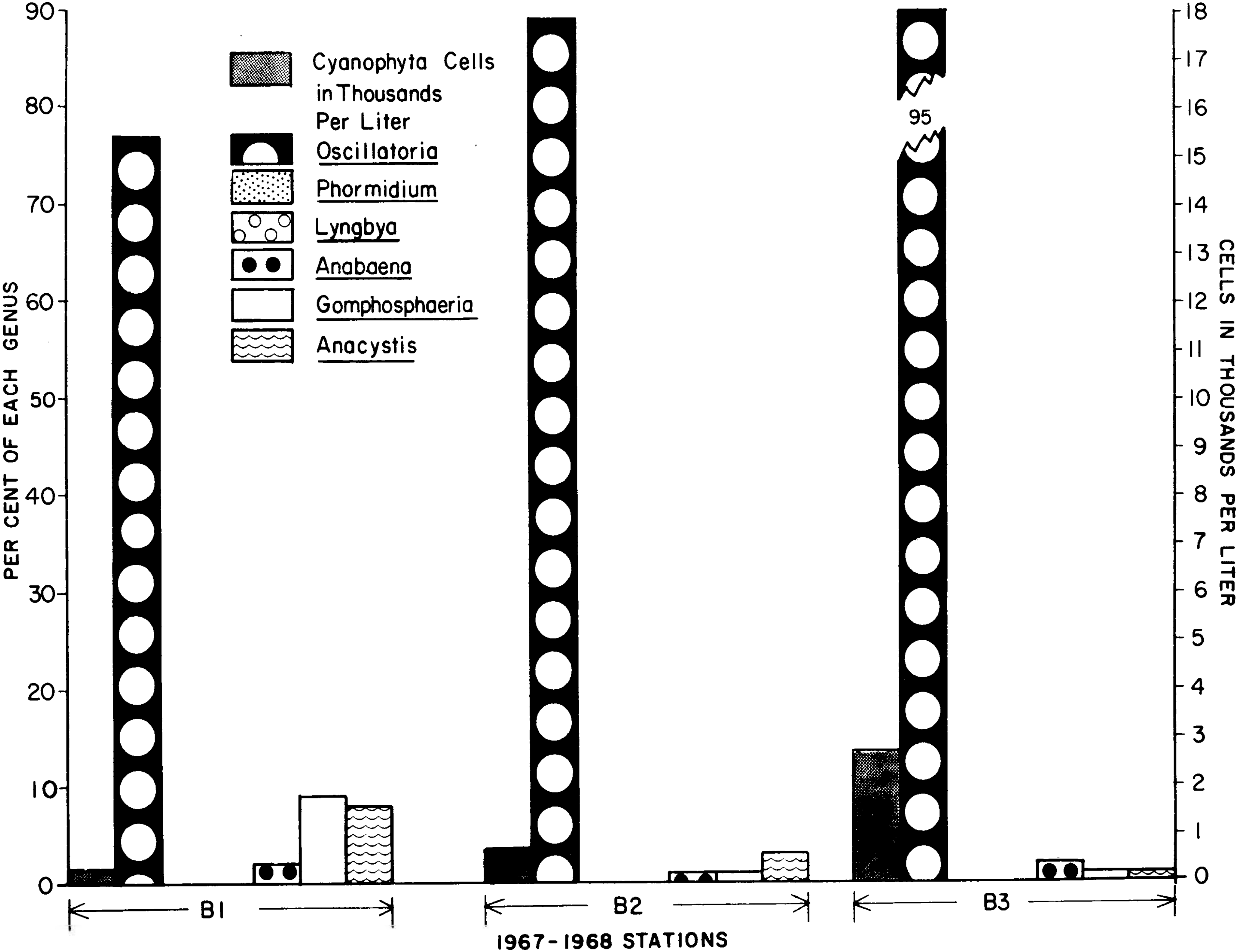

FIGURE 8b. AVERAGE STANDING CROPS OF CELLS PER LITER OF CYANOPHYTA AND OF EACH MAJOR GENUS REPRESENTED AND ITS RESPECTIVE PERCENTAGES.

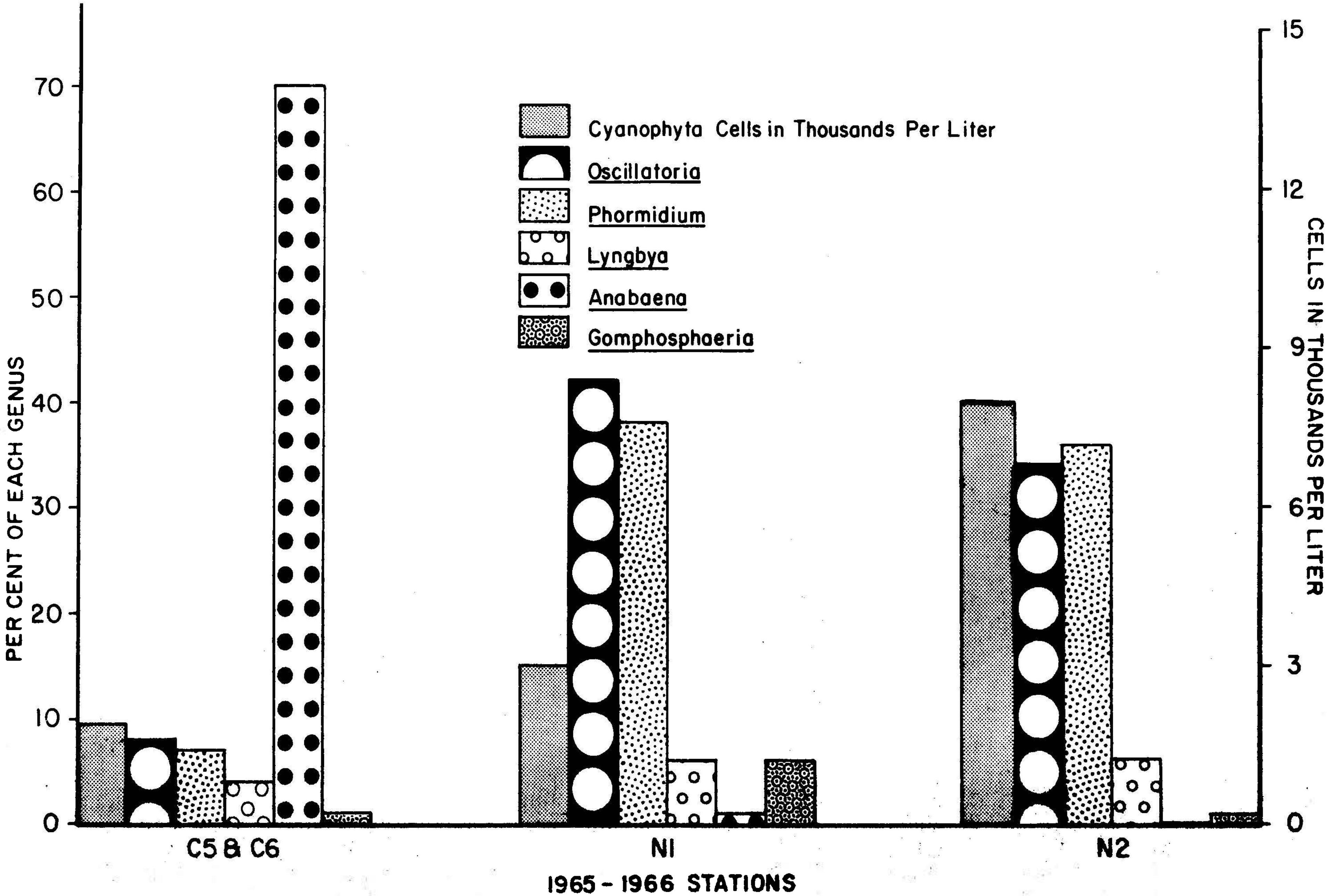

FIGURE 8c. AVERAGE STANDING CROPS OF CELLS PER LITER OF CYANOPHYTA AND OF EACH MAJOR GENUS REPRESENTED AND ITS RESPECTIVE PERCENTAGES. STATIONS ON THE BUFFALO RIVER AND NORFORK TAILWATER.

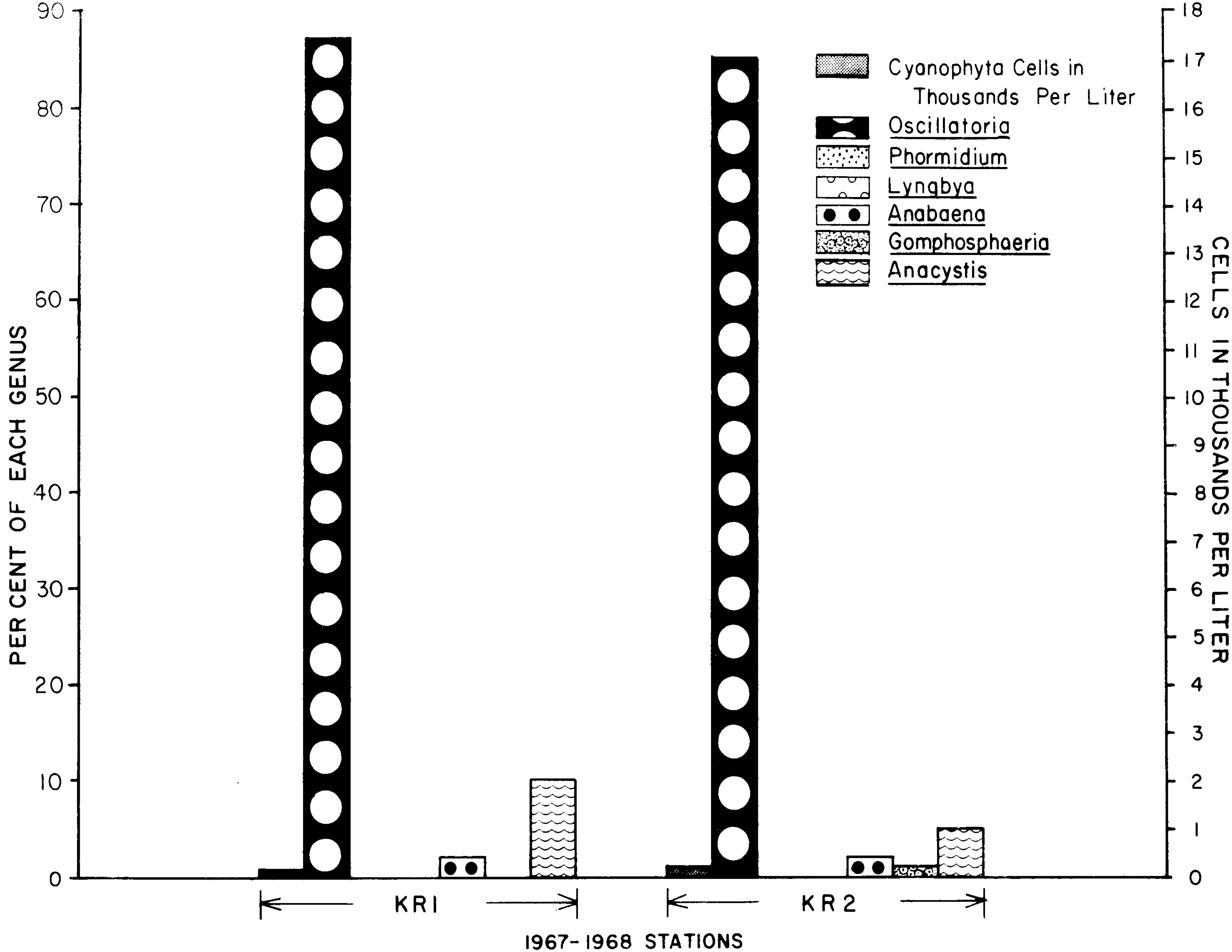

FIGURE 8d. AVERAGE STANDING CROPS OF CELLS PER LITER OF CYANOPHYTA AND OF EACH MAJOR GENUS REPRESENTED AND ITS RESPECTIVE PERCENTAGES

OLD TAILWATERS

Norfork and Bull Shoals Tailwaters

As a taxon, the Chrysophyta represented by far the most abundant group of phytoplankton in the tailwater samples of Bull Shoals (BS) and Norfork stations 1 (N1), with the former having a slightly larger percentage. The Chrysophyta comprised 78% of the phytoplankton at Bull Shoals tailwater, 74% in Norfork 1 (N1), but only 36% in Norfork station 2 (N2) (Figures 6c and 6d and Appendix E). Diatoms constituted 99.6% of the Chrysophyta in the Norfork tailwater (N1) and 98.95% in the tailwater of Bull Shoals Reservoir. The slight increase in the percentage of Chrysophyta in the Bull Shoals tailwater was due to a pulse of Dinobryon (1,622 cells per liter) in mid-spring of 1966. The dominant genera at station one in the tailwater samples of both Bull Shoals (BS) and Norfork (N1) were Fragilaria and Melosira. Asterionella comprised 13% of the total Chrysophyta in the Norfork (N1) tailwater, while Achnanthes formed 11% in the tailwater at Bull Shoals (BS). Norfork station 2 (N2) had an abundance of Melosira (50%) and Achnanthes (35%) (Figure 7c and Appendix F).

The Cyanophyta represented approximately one-eighth and one-fifth of the total net phytoplankton collected in the tailwater stations directly below the Bull Shoals and Norfork dams, respectively; the blue-greens comprised approximately one-half of the total phytoplankton at Norfork station 2. Range of densities of blue-green algae was greater for the Buffalo River (140 to 17,328 cells per liter) than for the tailwater of the Norfork (263 to 8,733 cells per liter) and Bull Shoals (159 to 4,358 cells per liter) reservoirs. The dominant genera in the older tailwaters, Bull Shoals and Norfork, were Oscillatoria and Phormidium; Anabaena was also a major form in the Bull Shoals tailwater, forming 16% of the total Cyanophyta (Footnote, Appendix G).

The phylum Chlorophyta was the least abundant group of the three major phyla of phytoplankton in the old tailwaters. In Norfork 2 (N2) it constituted the largest percentage, 12%; in Bull Shoals it composed 8%; and in Norfork station 1 (N1) it contributed only 5% of the total phytoplankton (Figures 6c and 6d and Appendix E). The abundant genera and their percentages for the three old tailwater stations were as follows: Norfork station 1 Pediastrum (35%), Microspora (18%), and Chaetophora (13%); Norfork station 2 Microspora (32%), Ulothrix (27%), and Chaetophora (13%); Bull Shoals station 1 Stigeoclonium (27%), Chaetophora (22%), Pediastrum (15%), and Ulothrix (11%) (Figure 9c and Appendix H).

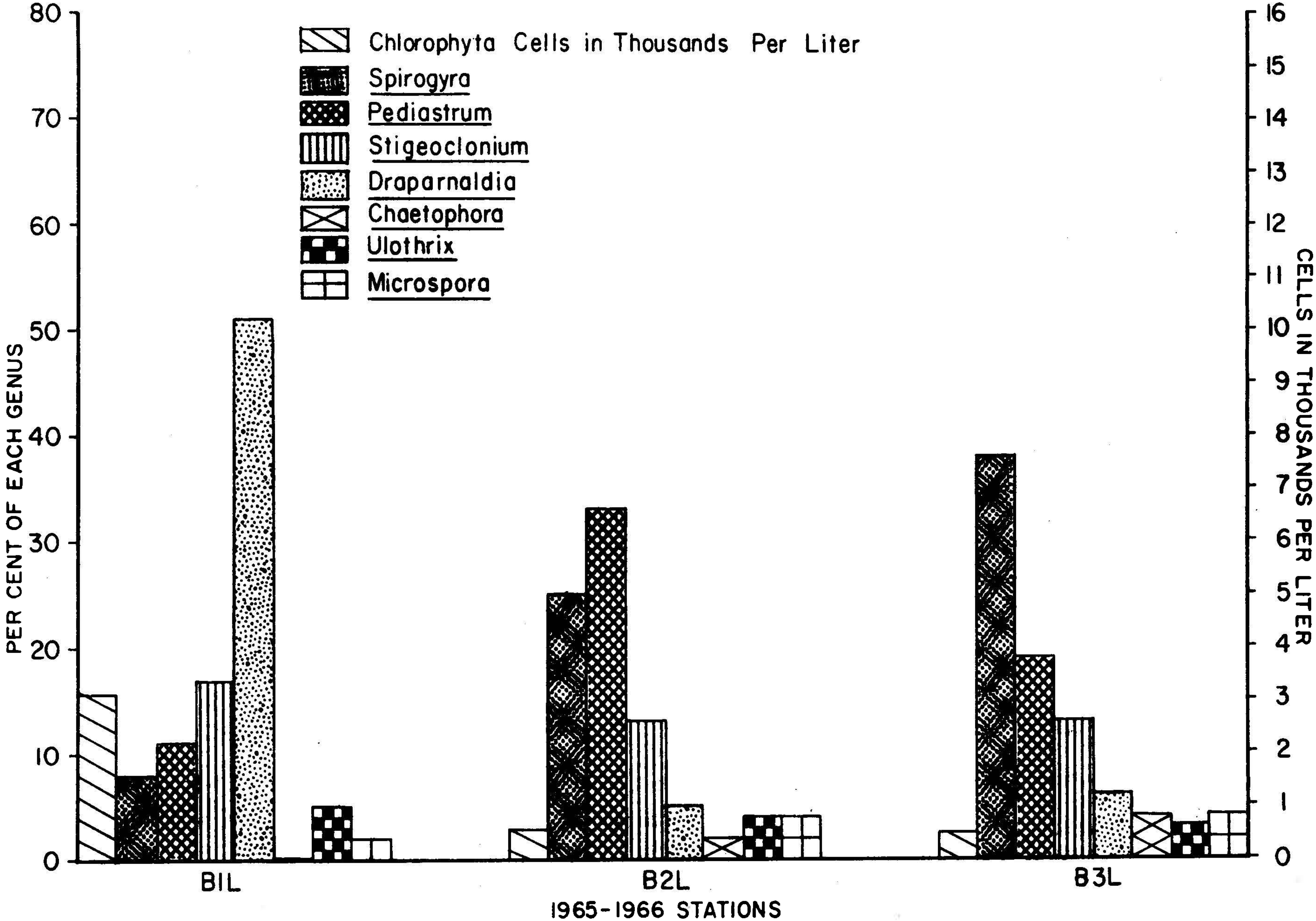

FIGURE 9a. AVERAGE STANDING CROPS OF CELLS PER LITER OF CHLOROPHYTA AND OF EACH MAJOR GENUS REPRESENTED AND ITS RESPECTIVE PERCENTAGES. STATIONS ON THE BEAVER TAILWATER.

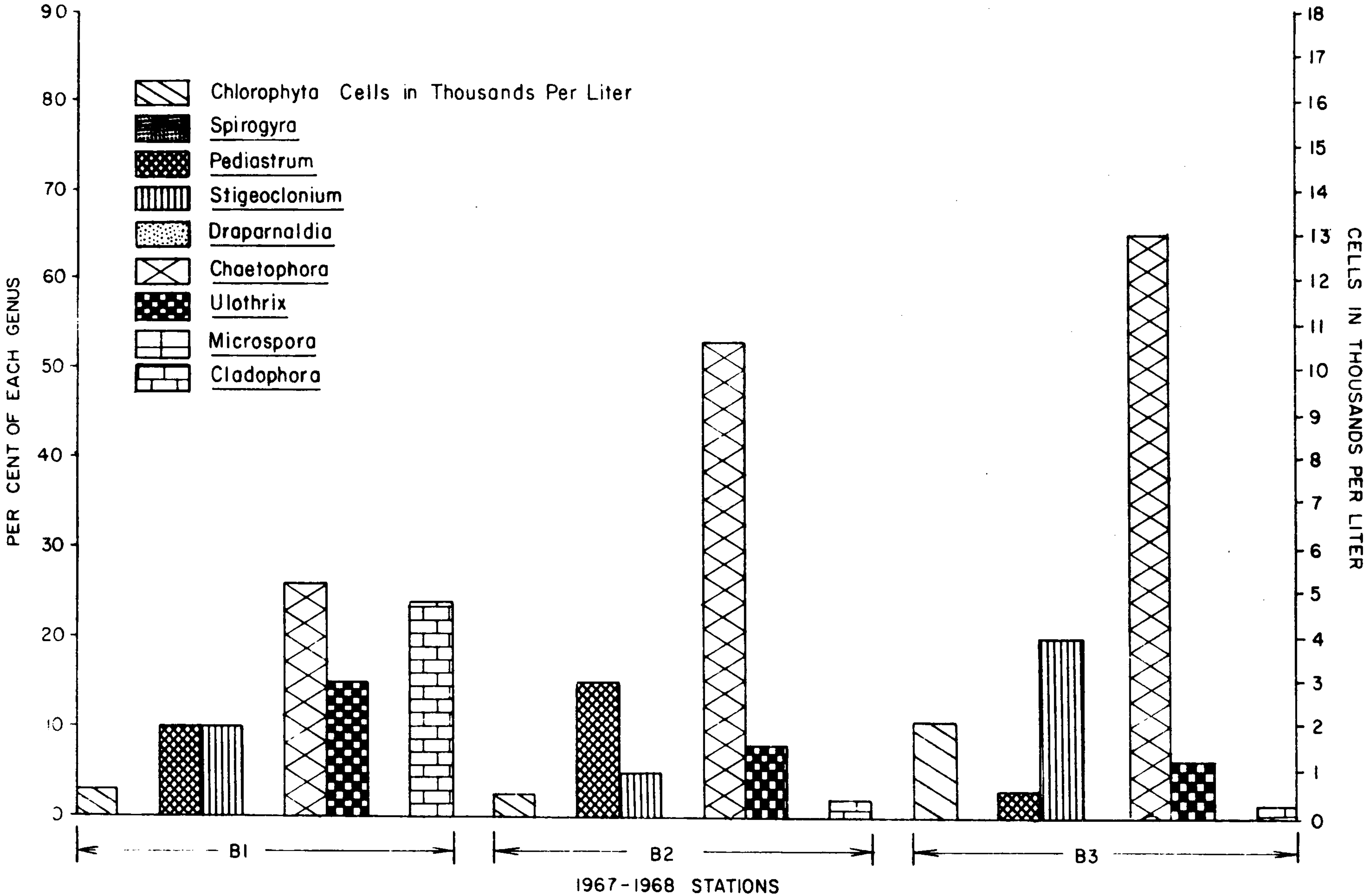

FIGURE 9b. AVERAGE STANDING CROPS OF CELLS PER LITER OF CHLOROPHYTA AND OF EACH MAJOR GENUS REPRESENTED AND ITS RESPECTIVE PERCENTAGES. STATIONS ON THE BEAVER TAILWATER.

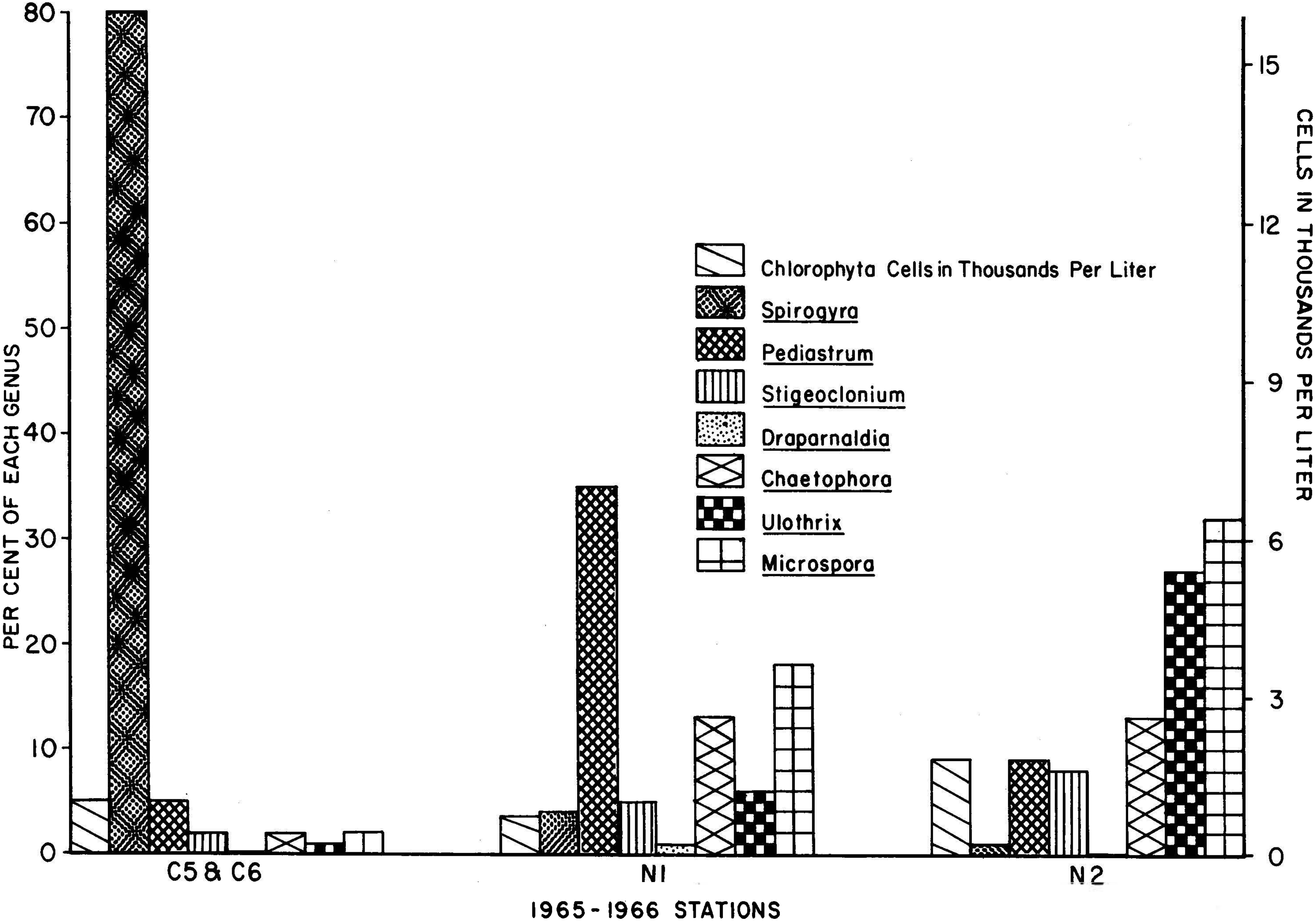

FIGURE 9c. AVERAGE STANDING CROPS OF CELLS PER LITER OF CHLOROPHYTA AND OF EACH MAJOR GENUS REPRESENTED AND ITS RESPECTIVE PERCENTAGES. STATIONS ON THE BUFFALO RIVER AND NORFORK TAILWATER.

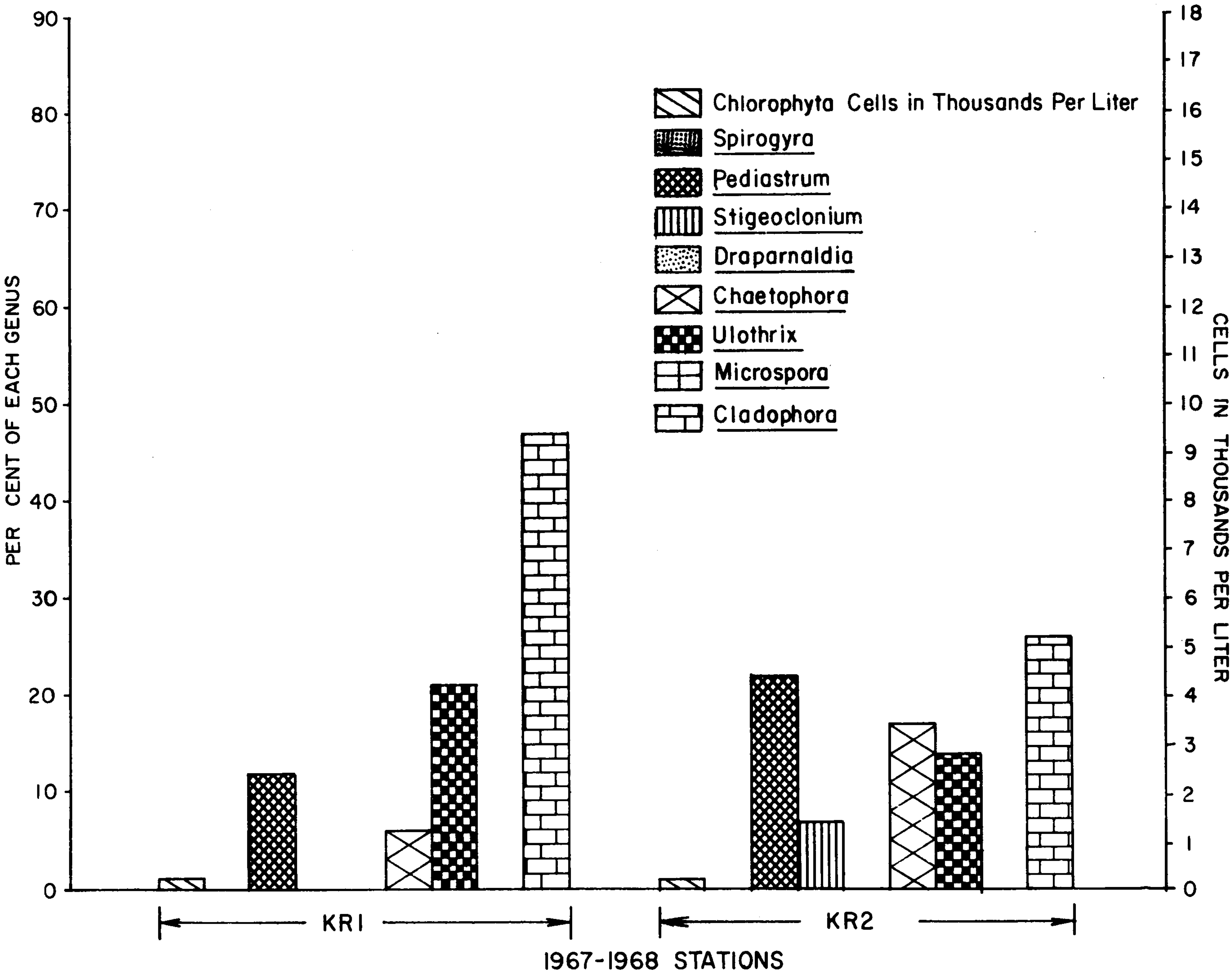

FIGURE 9d. AVERAGE STANDING CROPS OF CELLS PER LITER OF CHLOROPHYTA AND OF EACH MAJOR GENUS REPRESENTED AND ITS RESPECTIVE PERCENTAGES. STATIONS ON THE KINGS RIVER.

Zooplankton

Investigation Period from July 1965 through October 1968[1]

INTRODUCTION

A total of 40 genera of net zooplankton was identified during the 1965-1966 investigation period from all areas; in addition, nauplii, rotifers of the class Digononta (Pennak, 1953), and one ostracod were observed. The tailwater of Beaver Reservoir and the Buffalo River showed the largest number of genera (36) and Bull Shoals tailwater exhibited the lowest number (25). The Norfork tailwater displayed 27 genera of zooplankton. Also, creeping rotifers (Digononta) and nauplii were observed in all areas studied. One ostracod occurred in a sample from the Buffalo River. Actinosphaerium, Scaridium, and Bosminopsis were identified only in samples from the Buffalo River. A list of the taxa of zooplankton present in samples from the various collecting areas is presented in Appendix B.

During the 1967-1968 study period a total of 35 genera was found in the Beaver tailwater and the Kings River. The Rotifera had the largest number of genera (18), and the Copepoda had the least (two each). The taxon Cladocera was represented by six genera. Thirty-two genera were identified from the Kings River and 26 from the Beaver tailwater stations (Appendix D).

[1]Information compiled from thesis and field data of Dennie (1967) and thesis of Gray (1970).

NATURAL STREAMS

Buffalo and Kings Rivers

The data in Figure 10d graphically illustrate the average standing crops of organisms per liter of the total net zooplankton and of each taxon represented and its respective percentage in the Buffalo River. Because of the wilderness of the country surrounding it, the Buffalo River gives the impression that it resembles the conditions of rivers and/or natural streams before they were polluted by man. The Buffalo River, with the exception of Norfork station 2 (N2), was the most productive area in terms of average number of zooplankton organisms per liter of all the streams investigated from 1965 through 1968 (Figures 10a, 10b, 10c, 10d, and 10e or Appendix I). It displayed an average standing crop of more organisms per liter than the number one stations on the Norfork and Bull Shoals cold-tailwaters. It also had a larger standing crop of zooplankton per liter than the two Kings River stations (KR1 and KR2). The Kings River, a natural stream, was sampled during the 1967-1968 period.

In the study of the major waterways of the United States, Williams (1966) found that rotifers were by far the most numerous metazoans present in plankton samples, and he concluded that planktonic rotifers of lotic environments are not qualitatively distinct from those of lentic environments. He found the most widely distributed and dominant genus of rotifers to be *Keratella*.

The rotifers comprised the largest group of zooplankton in the Buffalo River. In terms of average standing crops in numbers of organisms per liter, Norfork station number two was the most productive,

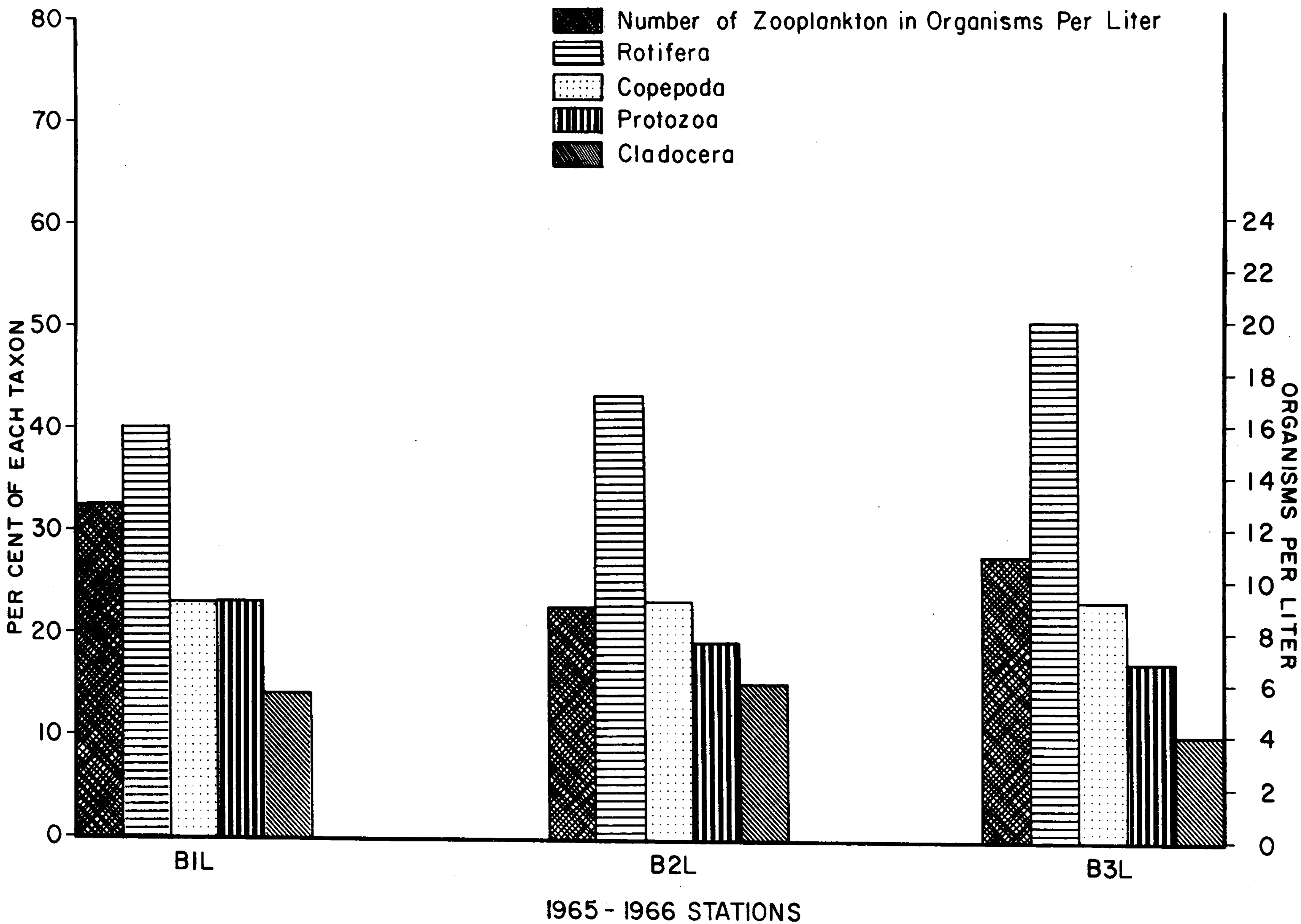

FIGURE 10a. AVERAGE STANDING CROPS OF DOMINANT ZOOPLANKTON EXPRESSED AS AVERAGE ORGANISMS PER LITER. STATIONS ON BEAVER TAILWATER.

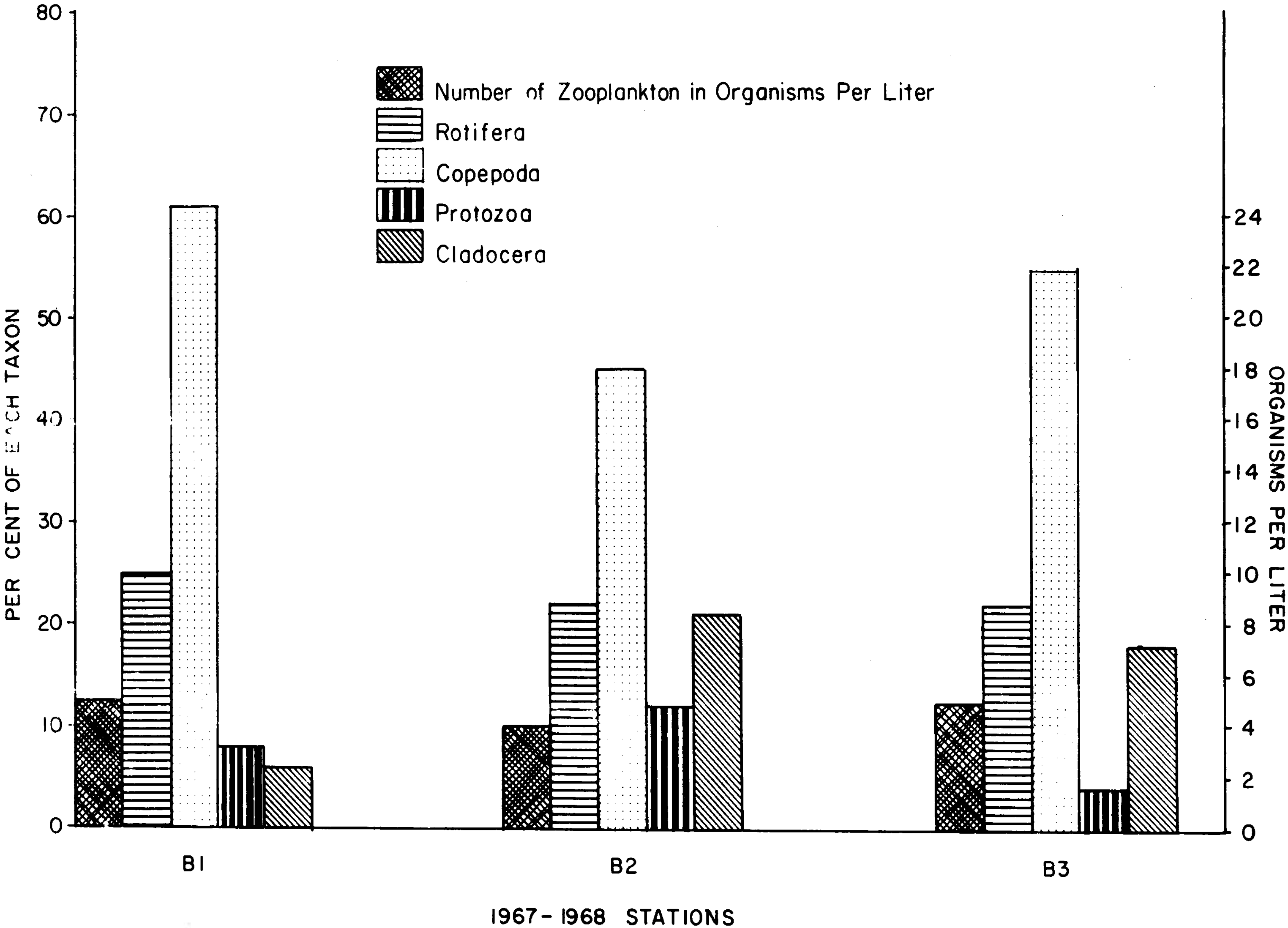

FIGURE 10b. AVERAGE STANDING CROPS OF DOMINANT ZOOPLANKTON EXPRESSED AS AVERAGE ORGANISMS PER LITER. STATIONS ON BEAVER TAILWATER.

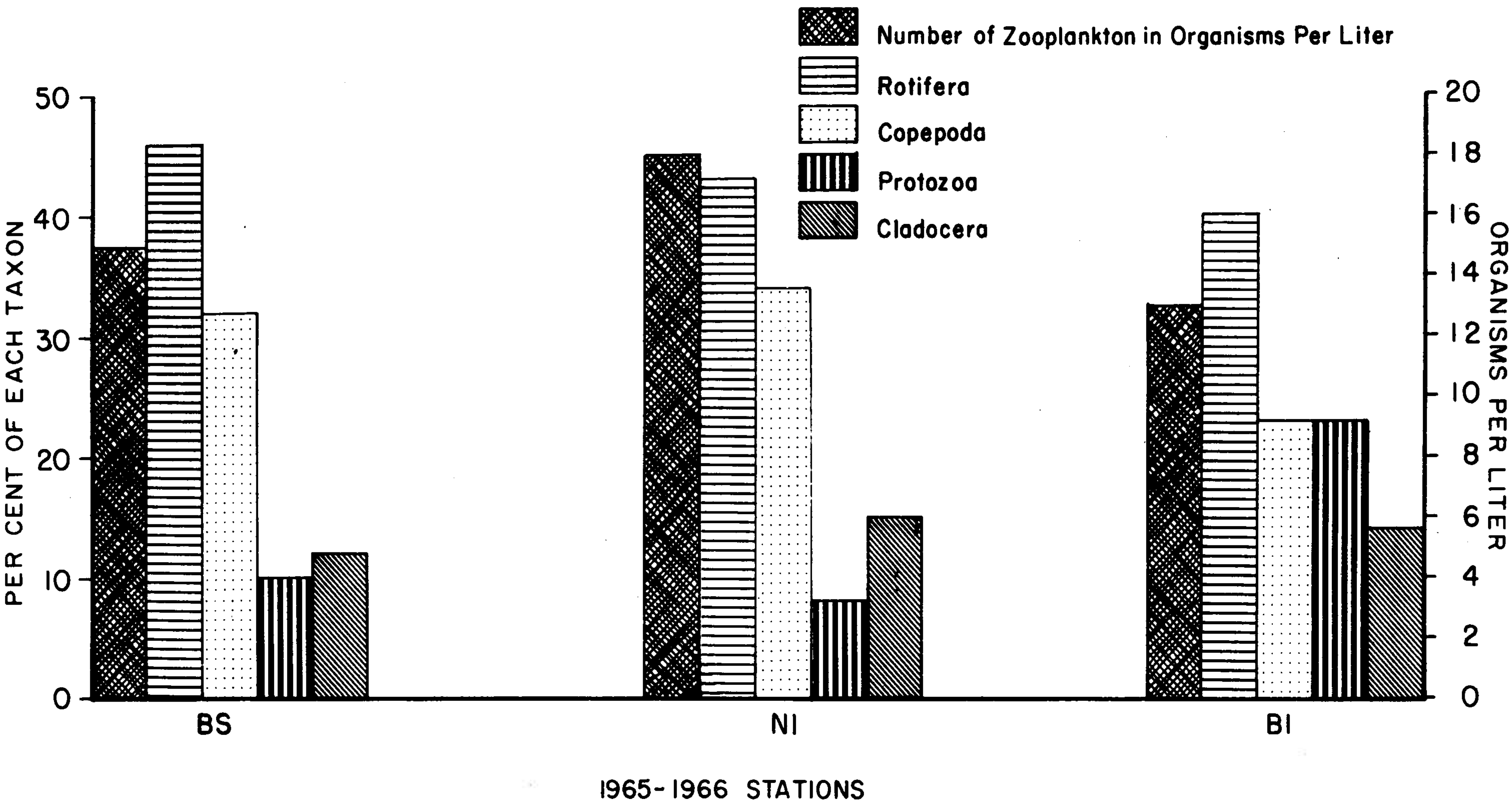

FIGURE 10c. STANDING CROPS OF DOMINANT ZOOPLANKTON EXPRESSED AS AVERAGE ORGANISMS PER LITER. STATIONS NUMBER 1, JUST BELOW THE DAMS ON BULL SHOALS, NORFORK, AND BEAVER TAILWATERS.

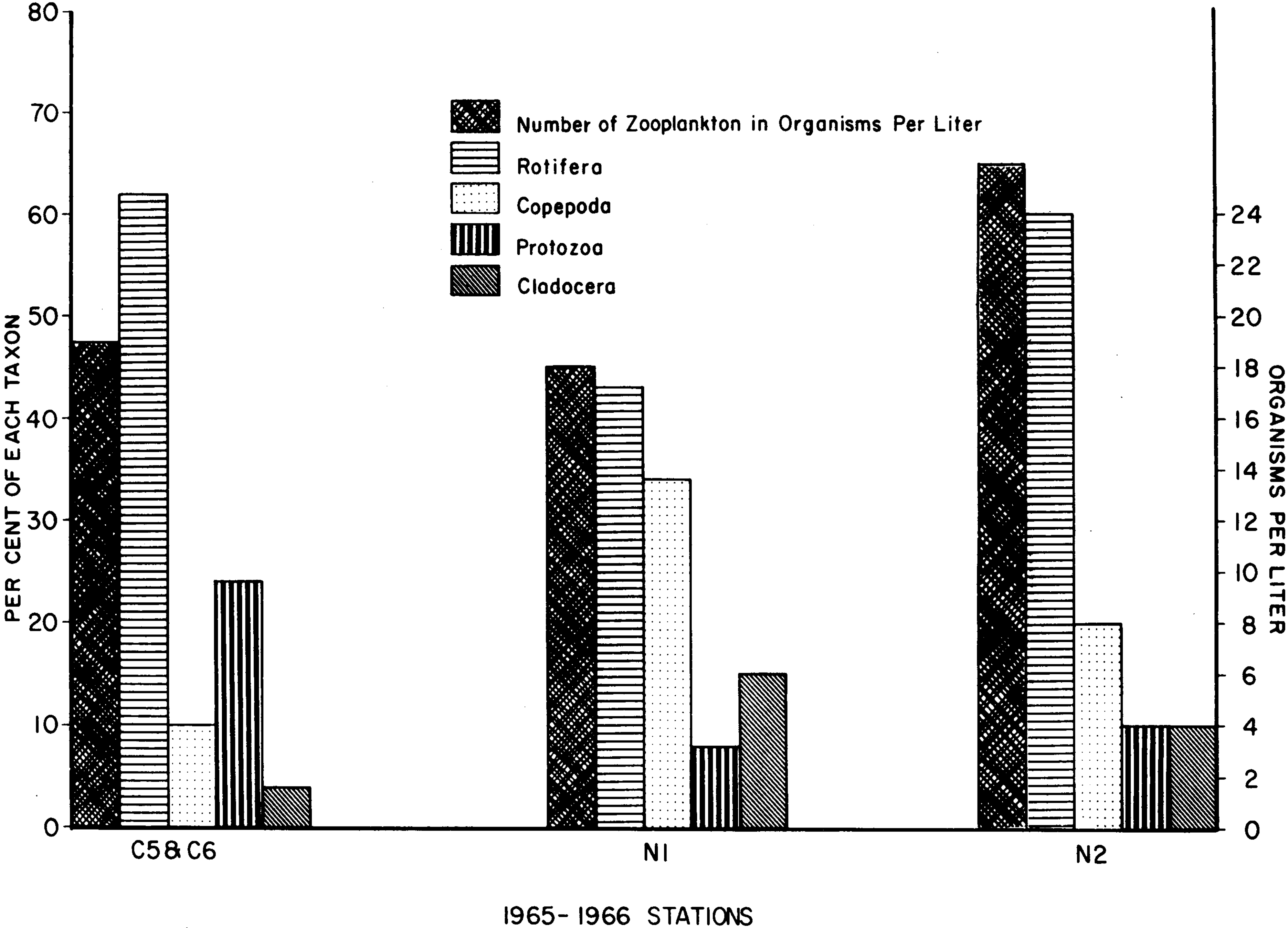

FIGURE 10d. AVERAGE STANDING CROPS OF DOMINANT ZOOPLANKTON EXPRESSED AS AVERAGE ORGANISMS PER LITER. STATIONS ON THE BUFFALO RIVER AND NORFORK TAILWATER.

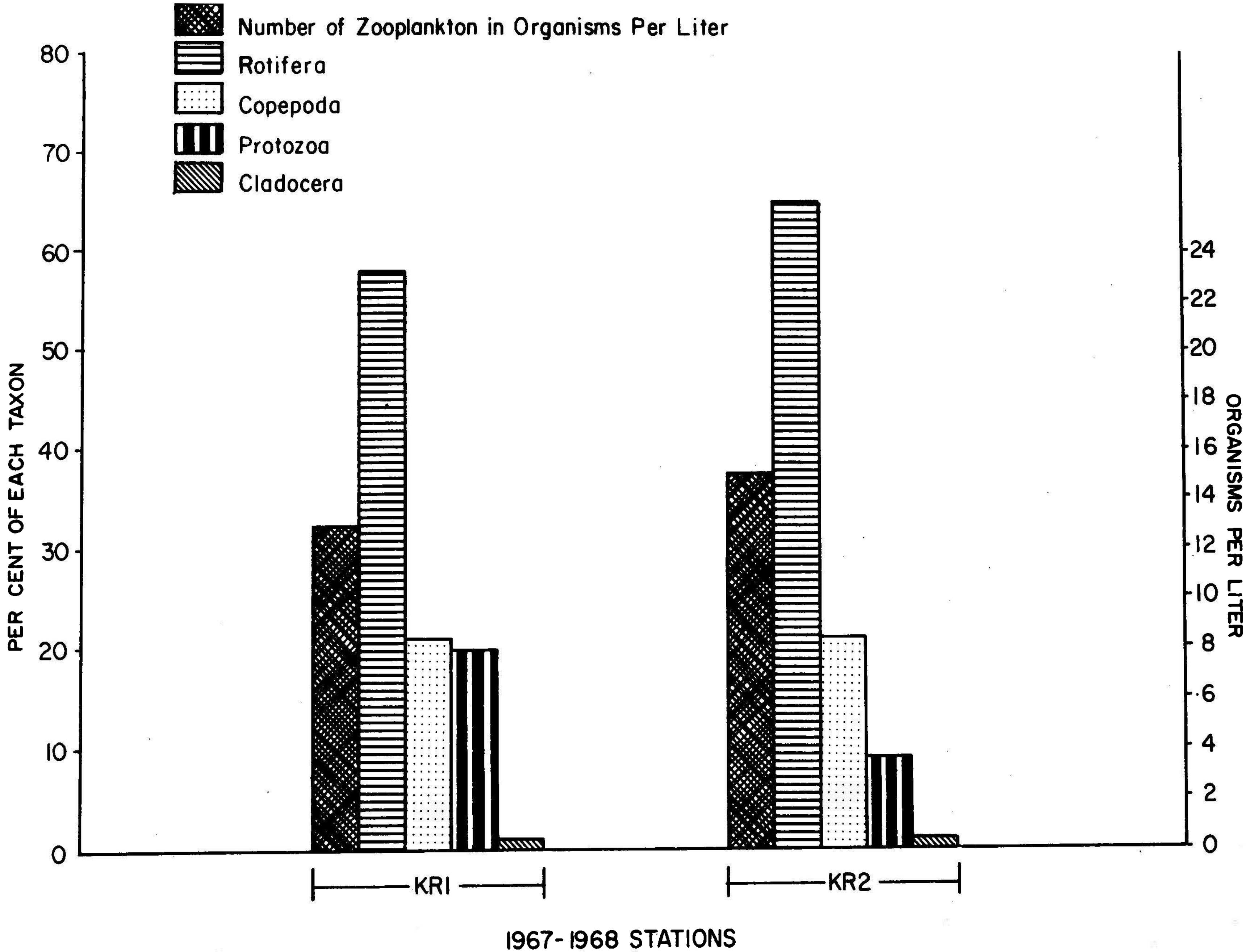

FIGURE 10e. AVERAGE STANDING CROPS OF DOMINANT ZOOPLANKTON EXPRESSED AS AVERAGE ORGANISMS PER LITER. STATIONS ON THE KINGS RIVER.

with the Buffalo River (C5 and C6) being second (Figure 10d or Appendix I). The Buffalo River exhibited maximum rotifer densities in the mid-spring of 1968. The dominant genera in this stream were Keratella and Filinia (Figure 11b). Keratella pulsed in early spring of 1966, exhibiting 82 organisms per liter, while Filinia pulsed during this same period displaying 30 organisms per liter.

After the rotifers, protozoans were the next most abundant group of zooplankton in the Buffalo River (Figure 10d). Samples from the Buffalo River contained protozoans more consistently than did those from the other areas. Difflugia and Codonella constituted 44% and 25% respectively, of the protozoans in the Buffalo River.

The cladocerans formed the smallest group of zooplankton in the Buffalo River, their occurrence being relatively rare. In this stream the dominant genera, although few in number, were Bosmina and Daphnia; each presented maximum densities in early spring of 1966.

The Copepoda ranked third in abundance compared to major groups of zooplankton in the Buffalo River. Of all the areas investigated during the 1965-1966 period, the Norfork and Bull Shoals tailwaters were most abundant in copepods, with those in the Buffalo River being the least abundant; the maximum density occurred in early spring 1966. In general, nauplii comprised the largest number (nearly 75%) of Copepoda in all areas. The Buffalo River displayed nauplii densities in early spring of 1966, with a maximum of only three organisms per liter.

In the 1967-1968 study period the standing crops of net zooplankton were greater in number in the Kings River than in the three Beaver cold-tailwater stations (Figures 10b and 10e); in KR1 and KR2 organisms of the phylum Rotifera were well represented (Appendix I). At station KR1, 57.8% and at KR2, 65.3% of the standing crops of zooplankton were composed of rotifers. These data correlate with the findings of Williams (1966). Copepods were the most abundant organisms in the three Beaver tailwater stations during the 1967-1968 study.

The most prevalent rotifer was Keratella. Williams (1966) found Keratella and Polyarthra to be the most numerous rotifers in the streams he examined. In the Kings River the Copepoda comprised 21.5% and 20.9% of the zooplankton at stations KR1 and KR2, respectively (Appendix I). Nauplii were the most frequently recorded copepods. Protozoa were more abundant at station KR1 (19.7%) than at station KR2 (9.2%). Arcella was the most commonly observed protozoan. Cladocerans constituted 1.0% (KR1) and 1.3% (KR2) of the zooplankton. The most common cladoceran was Bosmina. The one ostracod was found at station KR2.

NEW TAILWATER

Beaver Tailwater

The data for the 1965-1966 study period are represented in Figure 10a and graphically illustrate the average standing crops of net zooplankton at three stations along the tailwater below Beaver Reservoir. The maximum zooplankton densities at station B1L and B3L occurred in late winter of 1966, and at station B2L in the late fall of 1966. In late fall of 1965, minimum zooplankton densities appeared at station B1L, and during midsummer of 1965 at stations B2L and B3L. Seasonally, the maximum average standing crops of cells per liter at all three stations occurred in the winter of 1966, and minimum mean standing crops of zooplankton appeared in the summer of 1965 at all three stations. In general, the zooplankton became more abundant when power was being generated. The summer of 1965, when the zooplankton populations were least abundant, was also a period of minimal discharge (Dennie, 1967). There was a decrease in the average number of zooplankton per liter of about 30% from station B1L to station B2L, and a decrease of 15% from station B1L to station B3L (Figure 10a and Appendix I).

Many of the delicate protozoans are destroyed by formalin. Usually the ones observed in preserved samples are test-encased. Kofoid (1908) reported the Protozoa to be the most diversified group among the zooplankton in the Illinois River.

In the tailwater of Beaver Reservoir the protozoans presented an average decrease in the number of organisms per liter of about one-third from station B1L to station B2L and a decrease of one-twentieth from station B2L to station B3L (Appendix I). In late summer and early fall of 1966, the protozoans presented maximum densities at all three stations. These pulses were due almost entirely to Difflugia, except for a pulse in early fall of 1966, at station B3L for which Epistylis was primarily responsible. Difflugia was the most abundant genus in the Beaver tailwater in which it comprised over 70% of the protozoans.

Rotifers were the most abundant group of zooplankton at all stations in the 1965-1966 study of the tailwater of Beaver Reservoir (Figure 10a). The maximum densities of rotifers appeared in mid- and late winter 1966, at all stations in the Beaver tailwater (Dennie, 1967). From station B1L to station B2L there was a 25% decrease in the average number of rotifers per liter, 30% increase from station B2L to station B3L, and a 5% increase from station B1L to station B3L. During early fall of 1965, there was a progressive increase in the average number of rotifers per liter of 20% from station B1L to station B2L and a 17% increase from station B2L to station B3L. The dominant genera in the Beaver tailwater samples were Filinia, Kellicottia, Keratella, and Synchaeta (Figure 11a). Keratella decreased rapidly as it traveled downstream. Synchaeta, Keratella, and Filinia were abundant at all three stations. Kellicottia was most abundant at station B2L, but was relatively numerous at the other stations. Notholca was recorded about eight times more frequently at station B3L than at the other two stations (Dennie, 1967).

The copepods were the second most abundant type of zooplankton in the samples from B2L and B3L in the Beaver tailwater (Figure 10a). Maximum densities occurred at all stations in late fall 1966. The percentage relationship of this taxa remained the same at all three stations. Nauplii were by far the most abundant organisms of this

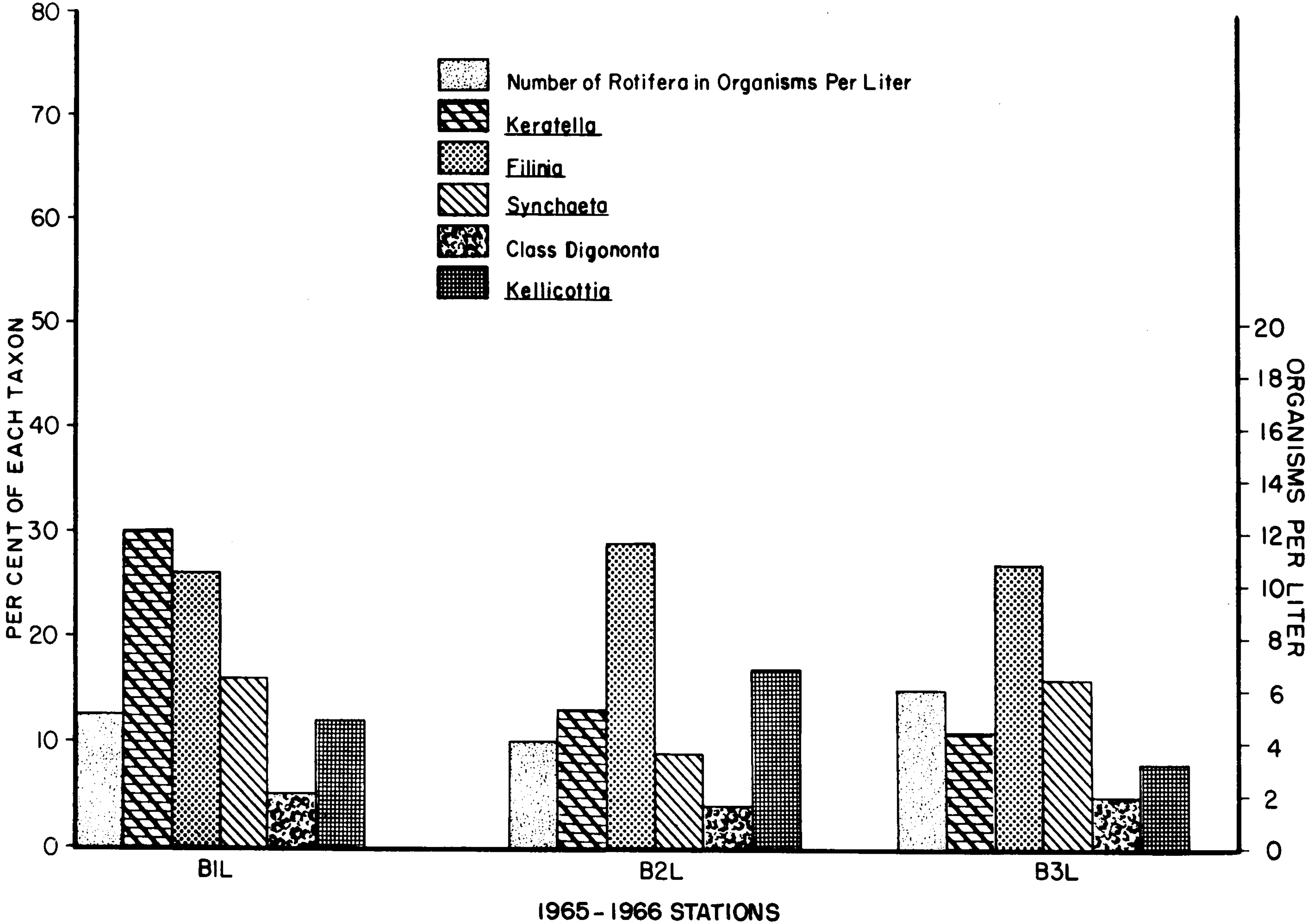

FIGURE 11a. AVERAGE STANDING CROPS OF ROTIFERA EXPRESSED AS ORGANISMS PER LITER AND OF EACH MAJOR GENUS AND ITS RESPECTIVE PERCENTAGES. STATIONS ON THE BEAVER TAILWATER.

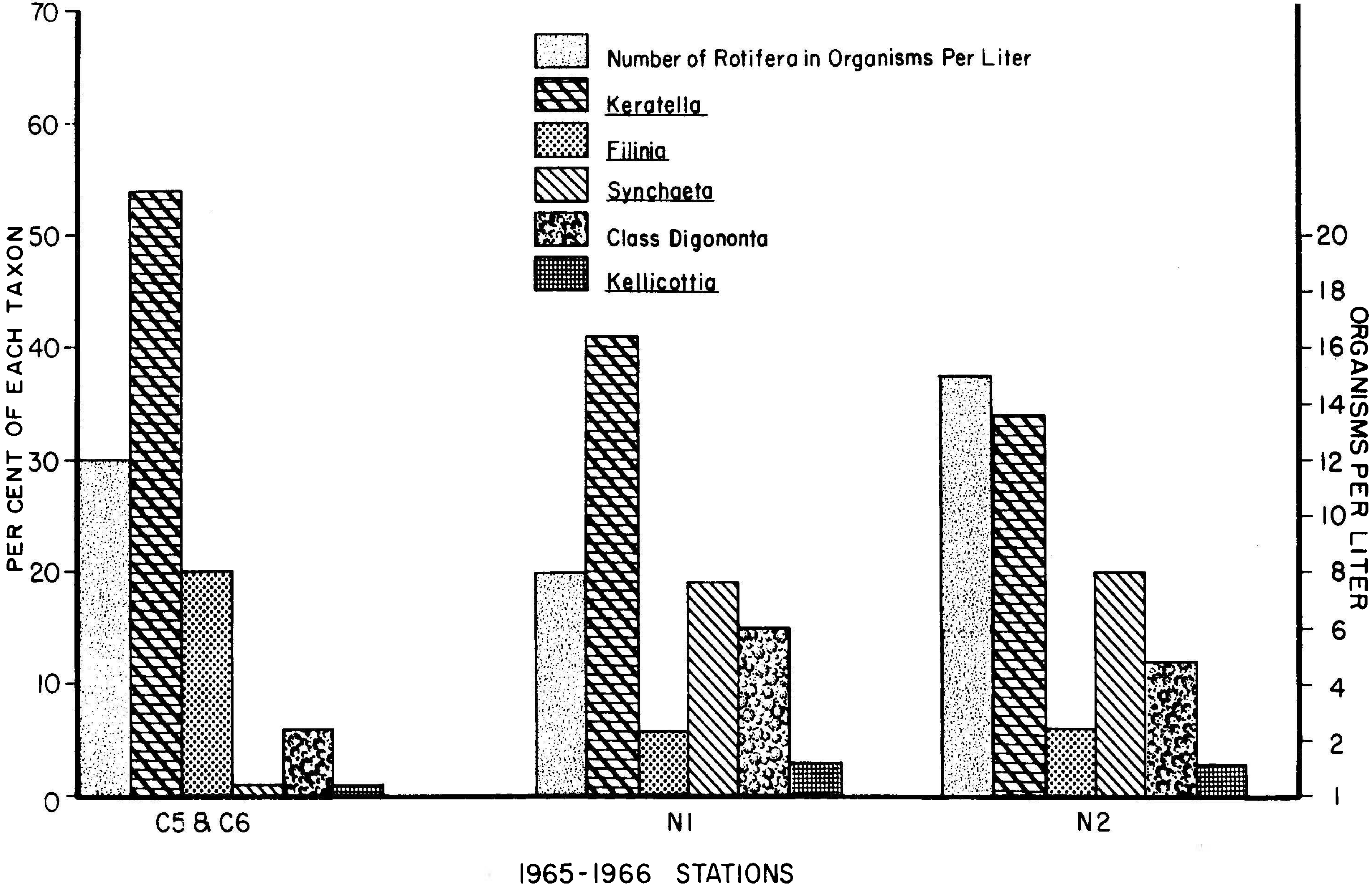

FIGURE 11b. AVERAGE STANDING CROPS OF ROTIFERA EXPRESSED AS ORGANISMS PER LITER OF EACH MAJOR GENUS REPRESENTED AND ITS RESPECTIVE PERCENTAGES. STATIONS ON THE BUFFALO RIVER AND NORFORK TAILWATER.

group, exhibiting a maximum density of 16 organisms per liter in late fall, 1966. Cyclops and Diaptomus each comprised about 40% of the Copepoda and presented maximum densities of 12 and 15 organisms per liter, respectively, in late fall, 1966.

The cladocerans formed the smallest major group among the zooplankton at all three stations in the 1965-1966 investigation of the tailwater of Beaver Reservoir (Figure 10a). Maximum densities of cladocerans occurred in early spring, 1966, at station B1L and in late spring, 1966, at stations B2L and B3L (Dennie, 1967). The average number of cladocerans per liter decreased 28% from station B1L to station B2L and decreased approximately one-sixth from station B2L to B3L. An overall decrease of 39% occurred from station B1L to station B3L (Appendix I). Daphnia was the most common genus at all stations. Maximum densities of Daphnia appeared at all stations in late spring of 1966, exhibiting 30, 19, and 27 organisms per liter at stations B1L, B2L, and B3L, respectively (Dennie, 1967).

The average standing crops of net zooplankton during the 1967-1968 study period and the per cent composition of their constituent phyla are presented in Figure 10b and Appendix I. Because of small quantities of organisms of each phylum present, the percentages of genera are not presented.

The standing crops of net zooplankton at all Beaver tailwater stations were quite low in relation to net phytoplankton vlaues. Copepods were the most frequently recorded zooplankton at station B1; they comprised 61.2% of the net zooplankton (Appendix I). The second most abundant phylum, the Rotifera, comprised 24.5% of the B1 standing crop.

The per cent compositions of other zooplankton at this station were Protozoa, 8.2% and Cladocera, 6.1%. At station B2, the copepods comprised 45.2% and rotifers, 21.4% of the standing crop. The Cladocera and Protozoa comprised 21.4 and 11.9% of the net zooplankton. Station B3 had a net zooplankton composition of the following: Copepoda, 55.5%; Rotifera, 22.2%; Cladocera, 18.2%; and Protozoa, 4.1%.

During the 1967-1968 study, copepods were the most frequently recorded zooplankton at all Beaver tailwater stations. The dominance of this taxon was due to large numbers of immature copepods (nauplii). There was a slight over-all decrease in copepod composition of net zooplankton downstream from Beaver Dam station B1 to B2. Ordinarily, representatives of the phylum Rotifera are the most abundant net zooplankters (Williams, 1966). However, in this study the rotifers were the second most numerous zooplankters in the Beaver cold-tailwaters. There was a slight decrease in composition of Rotifera in relation to standing crop downstream from the impoundment (Appendix I). Beach (1960), in his work with planktonic rotifers in the Ocqueoc River system, found a decrease in rotifers downstream from the outlets of lakes and impoundments. The most common rotifer in the later investigation period was Keratella. Protozoa were most abundant at station B2 and least abundant at station B3. The low protozoan composition may be explained in that many delicate ones lose their identity when they die or are preserved (Williams, 1966). Therefore, it is appropriate to note that the most abundant protozoan was the test-encased Difflugia. Cladocerans became a greater part of the zooplankton as the cold-tailwater moved downstream from Beaver Dam. The most frequently recorded cladocerans at all stations were Daphnia.

OLD TAILWATERS

Norfork and Bull Shoals Tailwaters

The data in Figures 10c and 10d graphically illustrate the average standing crops of total net zooplankton in the tailwaters of Norfork, Bull Shoals, and the Buffalo River. This graph shows the average standing crops at each station along with each taxon represented and its respective percentages. Maximum densities of zooplankton appeared in the tailwater of Norfork Reservoir in late winter, 1966. Seasonally, maximum mean standing crops of cells per liter appeared in the tailwater of Norfork Reservoir in the winter and spring of 1966, whereas the Buffalo River incurred a maximum mean standing crop in the spring of 1966 (Dennie, 1967).

After the rotifers, the protozoans were the next most abundant group of zooplankton in the Buffalo River but were the least abundant group at station one in the tailwaters of both Bull Shoals and Norfork reservoirs. Maximum protozoan densities appeared in the tailwaters of Bull Shoals and Norfork reservoirs in late winter, 1966, and in early fall, 1966, in the Buffalo River. The samples from the Buffalo River more consistently contained protozoans than did the other areas. *Difflugia*, *Codonella*, and *Epistylis* were the dominant genera in the Norfork tailwater, comprising 48%, 24%, and 19%, respectively, of the protozoans. *Difflugia* and *Epistylis* each constituted 38% in the tailwater of Bull Shoals Reservoir and 44% and 25% of the Protozoa in the Buffalo River.

Maximum rotifer densities were observed in the Norfork and Bull Shoals tailwaters in early spring, 1966, while the Buffalo River exhibited maximum rotifer densities in the mid-spring of 1966. The following taxa were dominant in the tailwaters of Bull Shoals and Norfork reservoirs: Digononta, *Keratella*, and *Synchaeta* (Figure 11b). Of the above, *Keratella* was the most abundant. It exhibited a maximum density in both tailwaters in late winter of 1966 of 11 organisms per liter (Norfork) and 14 organisms per liter (Bull Shoals). The dominant genera in the Buffalo River samples were *Keratella* and *Filinia*. *Keratella* pulsed in early spring of 1966, exhibiting 82 organisms per liter, while *Filinia* pulsed during this same period displaying 30 organisms per liter.

The copepods were the second most abundant group of zooplankton at stations number one in the tailwaters of Bull Shoals and Norfork reservoirs; but next to the Protozoa, they were the second least abundant major group of zooplankton in the Buffalo River (Appendix I). Of all the areas investigated during 1965-1966, the Norfork and Bull Shoals tailwaters were the most abundant in copepods with those in the Buffalo River being the least abundant. Maximum copepod densities were displayed in the tailwater of Bull Shoals Reservoir in late spring of 1966, and in the Norfork tailwater in late winter of 1966, while the Buffalo River presented its maximum density in early spring, 1966. In all of the above study areas, nauplii comprised about 75% of the Copepoda. Maximum densities of 17 organisms per liter occurred in late winter of 1966 in the tailwater of Norfork Reservoir, while the Bull Shoals tailwater exhibited 13 organisms per liter in late spring, 1966 (Dennie, 1967).

The cladocerans formed about one-seventh and one-eighth of the zooplankton at stations number 1 in the Norfork and Bull Shoals tailwaters.

They contributed one-tenth of the total net zooplankton at Norfork 2 (N2). They were the smallest of the major groups of zooplankton in the Buffalo River, their occurrence being relatively rare (Appendix I). The tailwater of Bull Shoals Reservoir exhibited maximum cladoceran densities in late winter and late spring, 1966, and the Norfork tail-water presented maximum densities in late winter, 1966. Maximum densities occurred in the Buffalo River in the spring of 1966. Dominant genera of cladocerans in the Norfork tailwater were *Bosmina*, *Daphnia*, and *Diaphanosoma*. *Bosmina*, the most abundant, presented a maximum density in late winter, 1966, of 9 organisms per liter. *Bosmina* and *Daphnia* were the dominant genera in the tailwater of Bull Shoals Reservoir, with the former being the most abundant and displaying maximum densities of 4 organisms per liter in late winter and late spring, 1966. In the Buffalo River, the dominant genera were *Bosmina* and *Daphnia*; each presented maximum densities of 2 organisms per liter in early spring, 1966 (Dennie, 1967).

Benthic Macroinvertebrates

Investigation Period from July 1965 through October 1968[1]

INTRODUCTION

The relative abundances of the dominant taxa in the Beaver, Bull Shoals, and Norfork tailwaters and the Kings and Buffalo Rivers are presented in Figure 12 and Appendix J. The percentages of dominant taxa in the Kings and Buffalo Rivers are given to show the conditions in natural streams in Arkansas. The figure and table show that, with the exception of Bull Shoals station 2 (C1 and C2), the older tailwaters, in general, yielded more organisms per square foot than the new tailwater and the natural streams. The data also show that the dominant organisms in the old tailwaters and those in the natural streams differ from each other.

The most striking physical difference between the natural streams and the tailwaters was temperature (Table II). The Buffalo and Kings Rivers exhibited a higher average and a wider range of temperatures than did the cold-tailwaters. In general, the tailwaters reflect the current condition of the water at the level of intake. As the water moves downstream, it is influenced to some extent by local conditions.

[1]Information compiled from thesis and field data of Liston (1967) and field data of Blanz (1970).

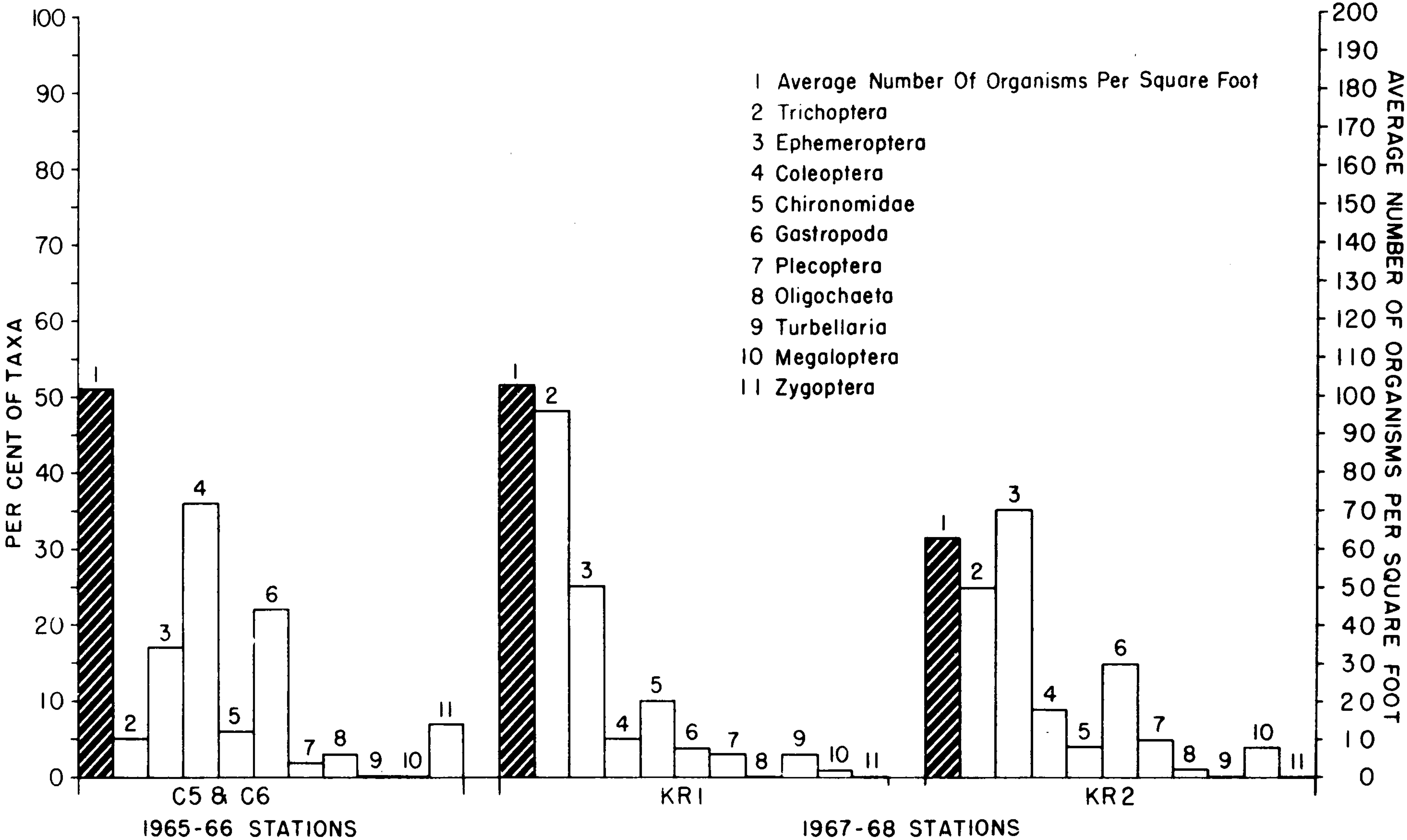

FIGURE 12a. DOMINANT TAXA OF BENTHIC MACROINVERTEBRATES EXPRESSED AS PER CENT OF AVERAGE CROPS OF ORGANISMS PER SQUARE FOOT. STATIONS ON THE BUFFALO RIVER (C 5 & C 6), AND TWO STATIONS ON THE KINGS RIVER (KR1 and KR2).

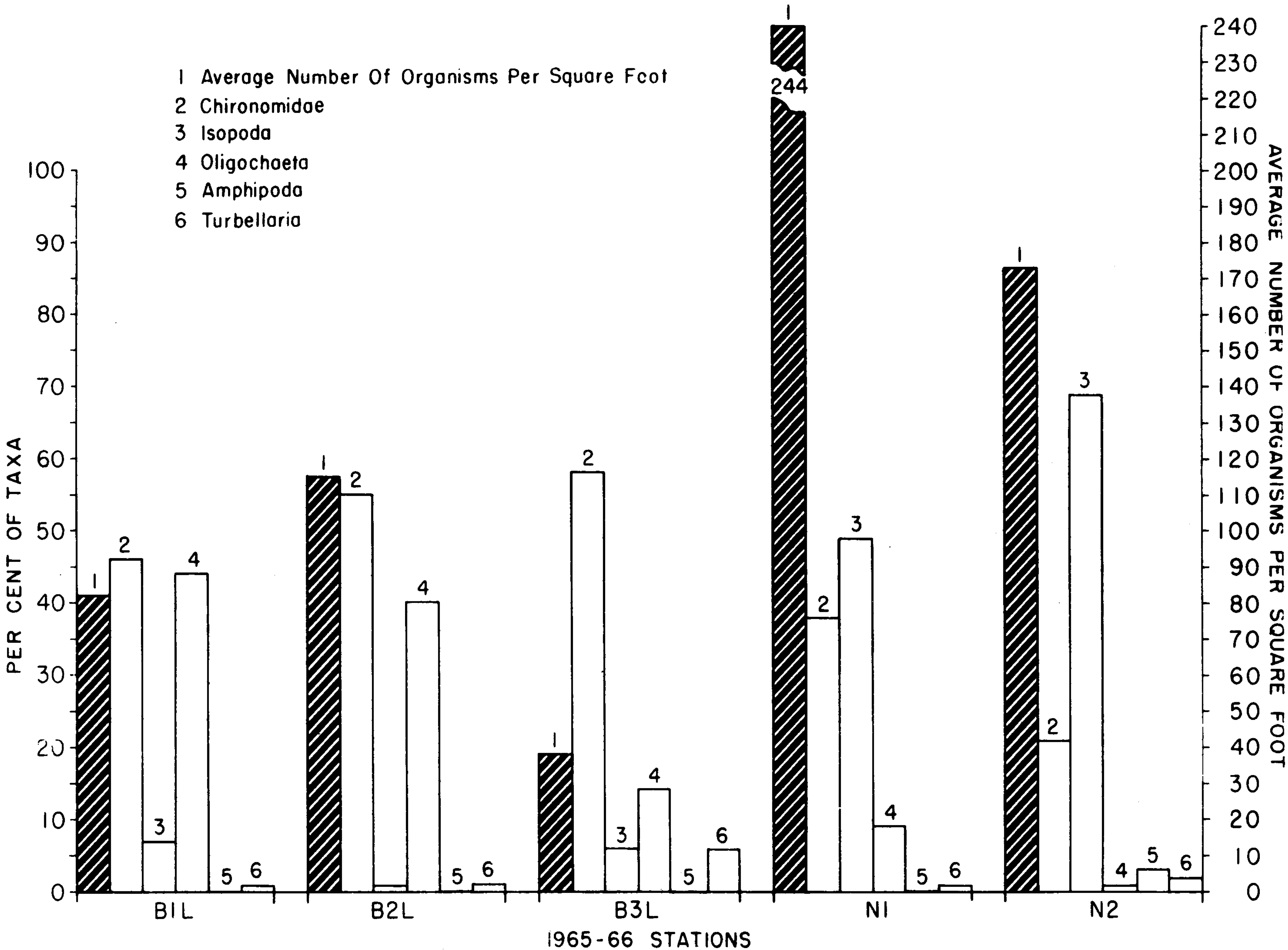

FIGURE 12b. DOMINANT TAXA OF BENTHIC MACROINVERTEBRATES EXPRESSED AS PER CENT OF AVERAGE CROPS OF ORGANISMS PER SQUARE FOOT. SECTIONS ON THE BEAVER TAILWATER (B1L, B2L and B3L) AND ON THE NORFORK TAILWATER (N1 and N2).

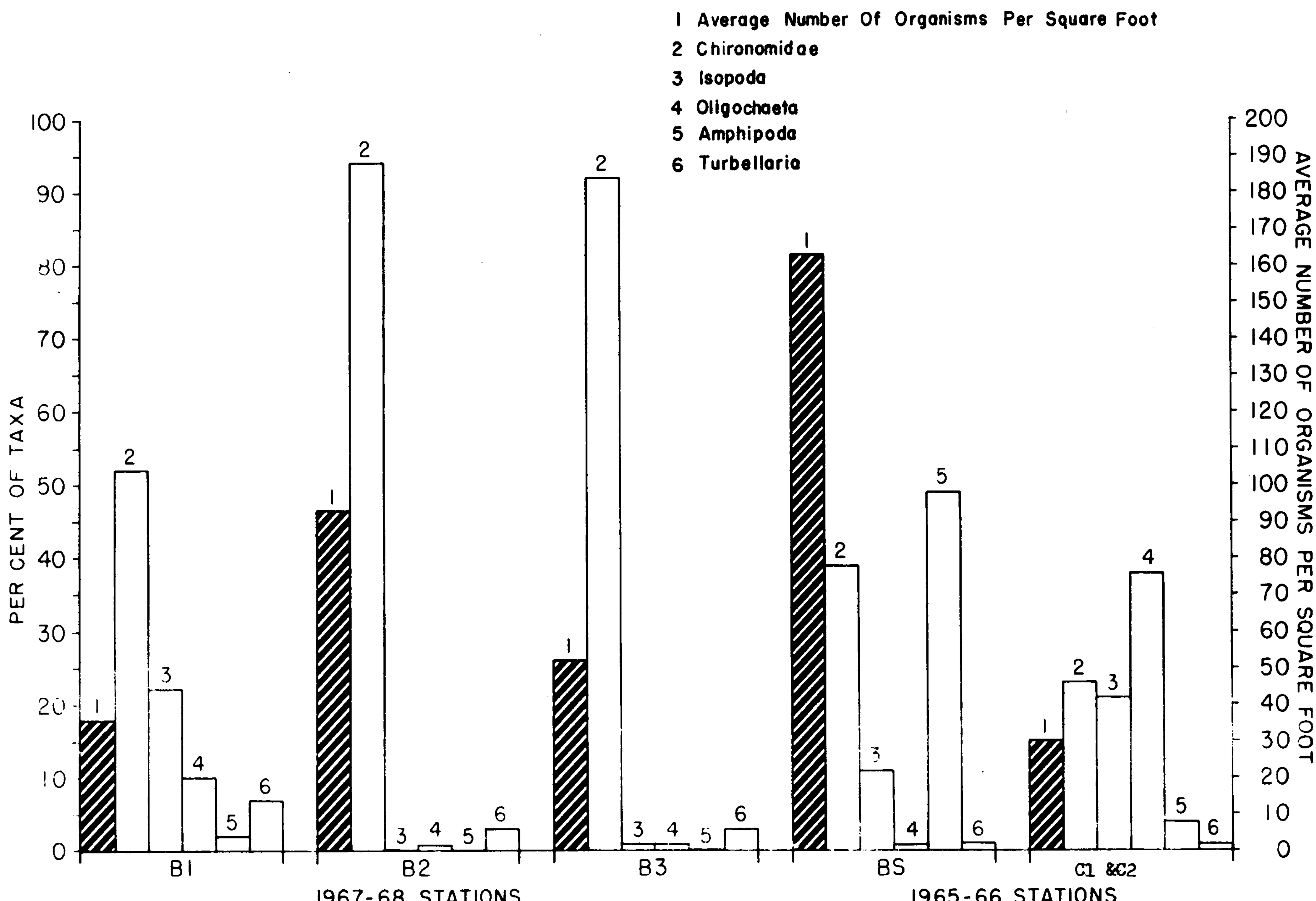

FIGURE 12c. DOMINANT TAXA OF BENTHIC MACROINVERTEBRATES EXPRESSED AS PER CENT OF AVERAGE CROPS OF ORGANISMS PER SQUARE FOOT. STATIONS ON THE BEAVER TAILWATER (B1, B2 and B3), AND BULL SHOALS (BS) AND BULL SHOALS 2 (C 1 & C 2).

NATURAL STREAMS

Buffalo and Kings Rivers

During the period from 1965-1968, bottom organisms from two natural streams, the Buffalo and Kings Rivers, environments unaltered by man-made activities, were studied for biotic productivity and composition to compare with cold-tailwaters. The Buffalo River station (C5 and C6) averaged 102 organisms per square foot; station number 1 on the Kings River (KR1) had 103 organisms per square foot. Station number two on the Kings River (KR2), had a slower riffle speed (Table II) and yielded a lower average, 63 organisms per square foot.

The dominant organisms in the Buffalo River were Coleoptera (36%), Gastropoda (22%), and Ephemeroptera (17%). In the Kings River, the dominant organisms at station KR1 were Trichoptera (48%), Ephemeroptera (25%), and Coleoptera (5%). At station KR2 in the Kings River, organisms were Ephemeroptera (35%), Trichoptera (25%), Gastropoda (15%), and Coleoptera (9%). Figure 12 and Appendix J show that the natural streams supported a greater variety of organisms and a minimal number of Chironomidae.

OLD TAILWATERS

Norfork and Bull Shoals Tailwaters

Forty-one square foot bottom samples were taken and analyzed from Bull Shoals and Norfork tailwaters. These samples, taken from old tailwaters, yielded a total of 6,120 organisms, weighing 24.8 grams.

Amphipoda (49%), Chironomidae (38%), and Isopoda (11%) were dominant taxa at station number 1(BS) of the Bull Shoals tailwater (Figure 12). Oligochaeta (38%), Chironomidae (23%), and Isopoda (21%) were the dominant taxa at the second station (C1 & C2) of the Bull Shoals tailwater. The average number of organisms at station 1 (BS) was 163 per square foot while the second station (C1 & C2) averaged only 30 per square foot. Consistently higher numbers of organisms per sample were collected directly below Bull Shoals Dam than at stations (C1 & C2) located approximately twenty miles downstream from the dam.

Three dominant groups of bottom organisms were taken from station 1 (N1) from the Norfork tailwater. These were as follows: Isopoda (49%), Chironomidae (38%), and Oligochaeta (9%). The second station (N2) had two dominant taxa: Isopoda (69%), and Chironomidae (21%). This tailwater appeared to be somewhat similar at both stations with two exceptions, such as, the abundance of total organisms and the per cent of Oligochaeta (Figure 12). The Norfork tailwater also exhibited greater benthic productivity than other cold-tailwaters studied. Samples taken from the stations directly below Bull Shoals and Norfork dams yielded consistently higher numbers of organisms and wet weights per sample than did the samples from comparable distances below Beaver Reservoir.

NEW TAILWATER

Beaver Tailwater

In this investigation, July 1965-1966 and 1967-1968, an attempt was made to determine the development of the benthos of the Beaver tailwater. Stations were identical in location in both studies of this tailwater; however, the stations of the earlier study have been referred to as B1L, B2L, and B3L for clarity. Using the studies of the established tailwaters of Bull Shoals and Norfork reservoirs as a base, the data obtained in 1967-1968 may be compared to the data of the older tailwaters (Figure 12). Station BS, below Bull Shoals Reservoir, is comparable to B1; B3 is comparable to N2 below Norfork Dam and, to a very limited degree, to C1 and C2 in the White River below Bull Shoals Dam.

In the 1965-1966 study 13,303 organisms in 168 samples were taken from the three Beaver tailwater stations for an average of 79.2 organisms per square foot. From the same stations, the 1967-1968 study yielded 3,694 organisms in 63 samples for an average of 58.6 per square foot. The 1967-1968 study had fewer organisms per square foot at B1 and B2 than did the 1965-1966 investigation (Appendix J).

The relative abundances of dominant taxa in the Beaver, Bull Shoals, and Norfork tailwaters, along with the Kings and Buffalo Rivers, are presented in Figure 12. The percentages of dominant taxa in the tailwaters and the Kings and Buffalo Rivers are given to show the conditions in the older tailwaters and natural streams in Arkansas.

Representatives of the dipteran family Chironomidae have become more abundant at stations B2 and B3 (Figure 12c). In the 1965-1966 study this family comprised 55% at station B2L and 58% at B3L, compared with 94% and 92%, respectively, at the same stations in the 1967-1968 study. In the older tailwaters and natural streams the percentages of Chironomidae were as follows: 38% at N1, 21% at N2, 38% at BS, 23% at C1 and C2, 6% in the Buffalo River (C5 and C6), and 10% at KR1 and 4% at KR2 (Figure 12, Appendix J). Aggus and Warren (1965) found that in streams Diptera (mostly Chironomidae) decreased in number with warmer temperatures. In comparing stations B1L and B1, Isopoda increased at station B1 in the Beaver tailwater while Oligochaeta decreased at all three Beaver stations (Figures 12b and 12c).

According to Neel (1963), evidently a more stabilized substrate in natural streams permits attachment sites for a larger variety of organisms. Aquatic insects, especially those requiring long mating and egg-laying flights, appear to cope with controlled fluctuating power generations, but sedentary forms of organisms, such as clams and oligochaetes, find survival difficult under such conditions.

Seasonal occurrences of organisms are obscured by the relative constant temperatures of tailwaters. In addition, sporadic power generations may give false impressions as to seasonal cycles. Nevertheless, it appears that the late summer is the most productive season for natural streams and tailwater communities. However, low water conditions brought about by minimal power demands may be coincidental with these productivity increases in tailwaters.

The same genera of Chironomidae present in the 1965-1966 study also appeared in the latter samples. Specimens of Cardiocladius (Kieffer) were found abundant in the 1967-68 study.

The Beaver tailwater benthic community evidently is adversely affected in its development because of the turbulent substrate caused by excessive power generations. Figure 12b and 12c presents the average number of organisms per square foot for the first station below each dam. Station B1, below Beaver Dam, contains fewer organisms than found below the older dams (BS and N1) and B1L (Appendix J). During January, February, and April of 1968, high water in the Kings River and large water discharges in the Beaver tailwater made sampling impossible; however, these missing samples do not seem to alter the overall picture. Monthly totals ranged from 35 to 450 organisms more in the older, established tailwaters than in B1.

The second station below each dam generally produced fewer organisms than the first station in the older tailwaters. B2 had fewer organisms than the older stations except for a large pulse of Chironomidae in the fall of 1968, although it was the most productive Beaver station. A more stabilized substrate, undoubtedly caused by controlled generation coupled with an expected spring pulse, might account for an increase in the older tailwater stations.

Kruskall-Wallis One Way Analysis of Variance provides some insight into the relationship of the sample stations with respect to the number of organisms per square foot. Stations assigned B1 and B1L, and B2 and B2L were significantly different between the two study periods at the 0.05 level. However, the difference between B3 and B3L was not significant for these same periods (Blanz, 1970)

The Beaver tailwater benthic fauna, compared with the older tailwaters of Bull Shoals and Norfork, is not fully developed. However, it appears that more controlled water releases, allowing a more stabilizing substrate to form, will eventually provide the Beaver tailwater with a rich benthic fauna. The presence of some of the taxa found in the older tailwaters, along with the quick recovery potential displayed in the Beaver tailwater in the late summer of 1968, leads to this conclusion.

Ichthyofauna

Beaver, Norfork, and Bull Shoals Tailwater Ichthyofauna[1]

NEW TAILWATER

Beaver Tailwater

Fish collections were made from October 1965 to December 1966 (Brown, 1967) and also during spring, summer and fall of 1968 (Bacon et al., 1968; Noble, 1968) in the Beaver Dam tailwater at stations B1, B2, and B3 (Figure 1). These stations were located at 0.25, 1.9 and 3.5 miles, respectively, below the dam.

The fish fauna in this tailwater was mainly represented by three families: Cyprinidae, Percidae and Centrarchidae in that order of abundance among the 1965-1966 and 1968 collections (Figure 13). It was also evident that the fishes of the sunfish family increased in 1968; the salmonids that were stocked appeared during 1968 collections (Bacon et al., 1968).

Among the cyprinids, the stoneroller (Campostoma anomalum) was the most abundant species in both study periods and the darters the most abundant of the family Percidae. The young-of-the-year large-mouth bass were the dominant centrarchids in the 1965-1966 collections; whereas, the green sunfish was dominant in the 1968 collections.

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[1]Information compiled from thesis of Brown, 1967; Bacon et al., 1968; and, (Personal Communication) field data of Noble, 1968.

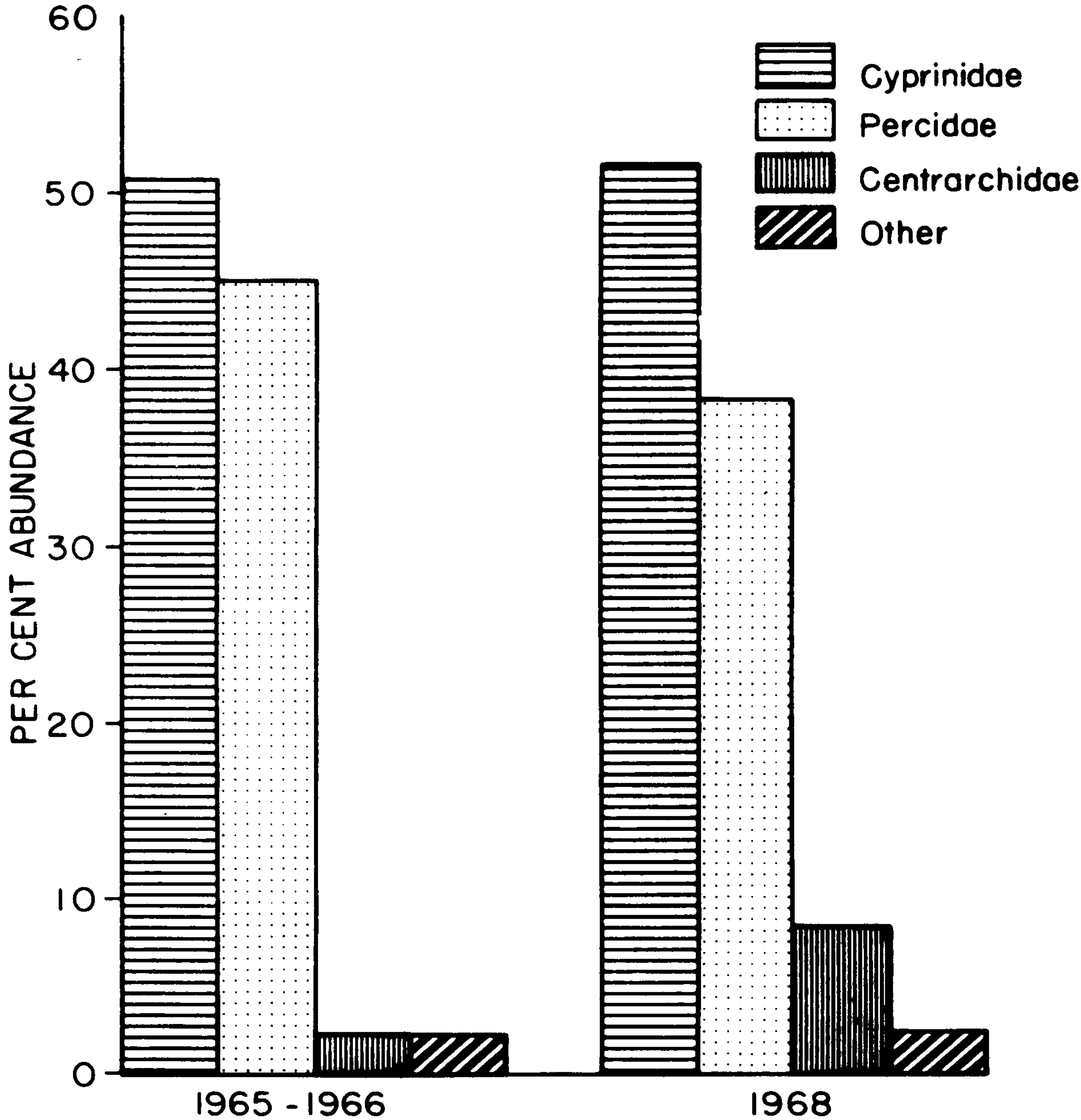

Figure 13: Percentages of dominant fish families in Beaver Dam Tailwaters during 1965-1966 and 1968.

Keith (1964) reported 72 species and five hybrid combinations in a preimpoundment survey of Beaver Reservoir; whereas in the Beaver tailwater following impoundment only 29 species of fishes were collected. Subsequent to impoundment, the ichthyofauna in the Beaver tailwater was greatly altered. It appears from the 1965-1966, and 1968 surveys, that the qualitative and quantitative fluctuations of fish fauna in the Beaver Dam tailwater had not reached a stable condition at that time.

OLD TAILWATERS

Norfork Tailwater

Stations N1 and N2 located 0.25 and 3.5 miles, respectively, below Norfork Dam were sampled from October 1965 to November 1966 (Brown, 1967), (Figure 1). Collections were not made in January, March, May, and June due to high water resulting from maximum generation.

A total of 18 species, 11 genera and 4 families was represented in the collections from N1 and N2. Of these, 65.8% of the fishes belonged to the family Cottidae, 34.1% to Cyprinidae, and the rest comprised 0.1%. The bulk of the fish populations was composed of Campostoma anomalum, Notropis pilsbryi and Cottus bairdi. Darters were rare in this tailwater. The logperch, Percina caprodes, which was abundant in the Beaver tailwater, was scarce in the Norfork Dam tailwater. Etheostoma caeruleum and Cottus bairdi were in spawning condition when collected in April, 1966.

Baker (1959) reported the occurrence of redhorse suckers, Moxostoma spp; hog suckers, Hypentilium nigricans; green sunfish, Lepomis cyanellus;

bluegill sunfish, *L. macrochirus*; and longear sunfish, *L. megalotis* in the Norfork Dam tailwater in the fall of 1950. The absence of these fishes from the collections of this investigation indicates that these species of fishes probably have disappeared from the Norfork Dam tailwater.

Bull Shoals Tailwater

Fishes were collected from a single station, BS, below Bull Shoals Dam from October 1965 to November 1966 (Brown, 1967), (Figure 1). Several collections were missed in winter and spring due to high water from almost continuous power generation. A total of 188 fishes representing six species, four genera and three families was collected (Table V). Fishes belonging to the families Cottidae, Cyprinidae, and Percidae comprise 82.5%, 17%, and 0.5%, respectively.

The Bull Shoals Dam tailwater fish fauna resembles the Norfork Dam tailwater in that *Cottus bairdi* was the most abundant species present.

Since only one station was sampled, and collections were not made in January, March, May, and June, the data for the Bull Shoals Dam tailwater were not as complete as those from the other tailwaters.

Comparison of the Ichthyofauna of Beaver, Norfork, and Bull Shoals Tailwaters

The number of families, genera and species occurring in the three tailwaters is given in Table V. It is evident that the ichthyofauna

Table V

SUMMARY OF NUMBER OF FAMILIES, GENERA AND SPECIES OF FISHES COLLECTED (EXCLUDING SALMONIDS) IN THE TAILWATERS

OCCURRENCE CATEGORY	BEAVER 1965-1966+1968	NORFORK 1965-1966	BULL SHOALS 1965-1966
FAMILIES	9	4	3
GENERA	15	11	4
SPECIES	29	18	6

in the Beaver tailwater was more diverse than in the tailwaters of Norfork and Bull Shoals reservoirs. The majority of fishes (listed in order of abundance) collected in the Beaver tailwater belonged to the families Cyprinidae, Percidae and Centrarchidae; whereas, in the Norfork and Bull Shoals tailwaters fishes of the families Cottidae and Cyprinidae were predominant (Figure 14).

A valid comparison of the ichthyofauna from the three tailwaters is difficult to make as the areas sampled were different. In the Beaver and Norfork tailwaters, fishes were collected up to 3.5 miles away from the dam, while in the Bull Shoals tailwater the only station sampled was located 0.7 miles below the dam. However, it is evident that the fish fauna of the Beaver Dam tailwater is more diverse than in the other two tailwaters (Table V). The reason for this may be that the Beaver Dam tailwater flows into Table Rock Reservoir, and fish, during the colder seasons of the year, may move between the Beaver Dam tailwater and the headwaters of the Table Rock Reservoir. Although Beaver Dam tailwater ichthyofauna is represented by more families, genera, and species than the other tailwaters, it cannot be said this situation is a stable one. An answer to this may be found by looking at the changes brought about in the fish fauna of Norfork Dam tailwater. Baker (1959) reported the presence of the redhorse suckers, hog sucker, bluegill sunfish, longear sunfish, green sunfish, miscellaneous minnows, and rainbow trout in the Norfork tailwater. In the 1965-1966 collections from the Norfork tailwater, the sunfishes were absent indicating the nonsuitability of the tailwater for these species; the fauna is currently composed mostly of

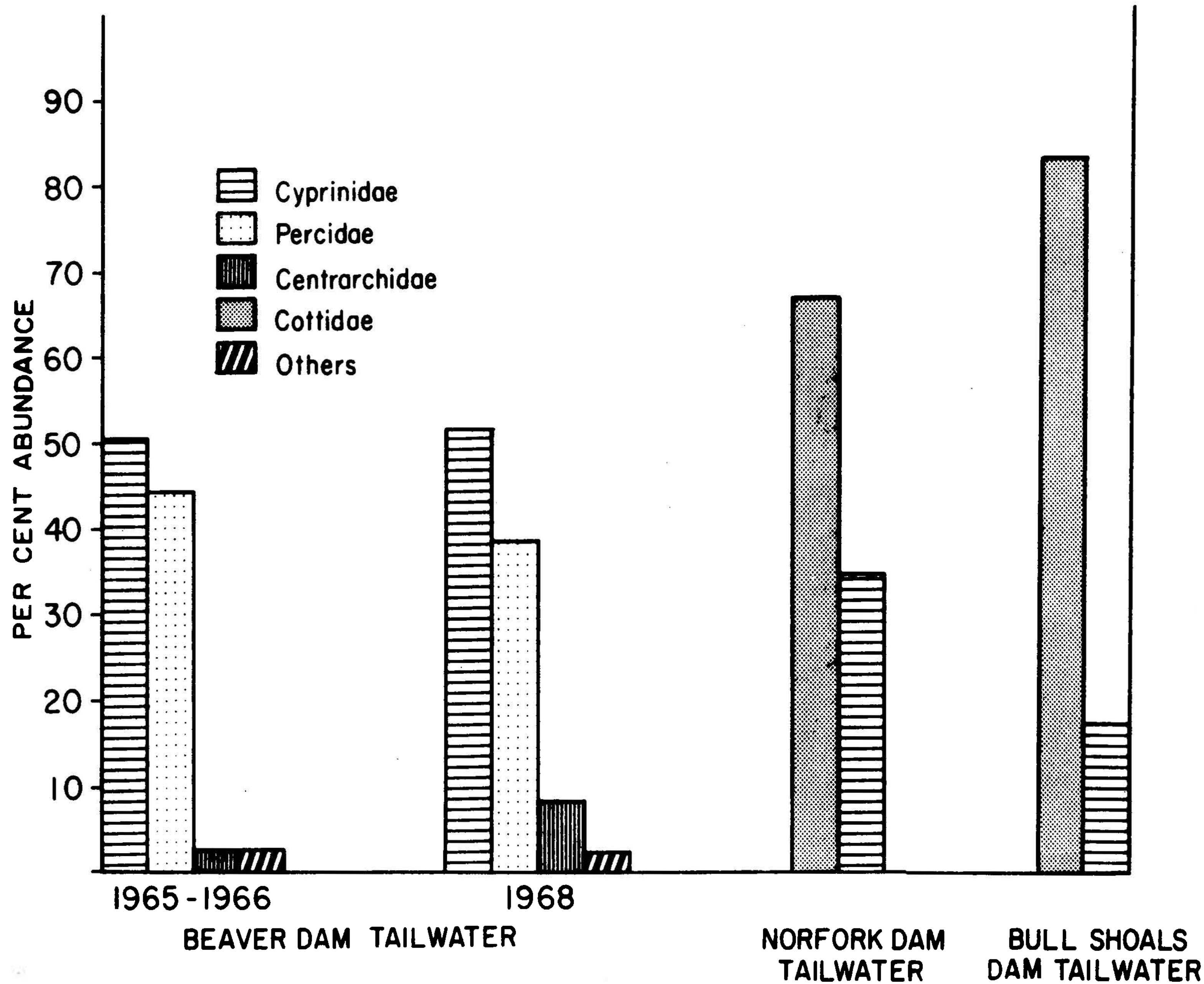

Figure 14: Percentages of dominant fish families in Beaver, Norfork and Bull Shoals Dam tailwaters.

sculpins. At the present time the Beaver tailwater shows a more diverse fish fauna, but the situation might change in the future as was the condition in the Norfork tailwater. Therefore, it will be necessary to follow the changes in the ichthyofauna in the Beaver tailwater in the near future. There is a definite need to continue the ichthyofauna survey, along with an investigation of the food and feeding habits of the tailwater fishes in relation to the abundance and fluctuations in the available food organisms. Such a study would give an insight as to whether the changes in fish fauna in the tailwaters are due to physico-chemical factors, food organisms, food preference, or interrelationships between them.

It is significant to note the virtual absence of warm-water game fishes in the tailwaters, and that the few game fishes found were not in breeding conditions. An interpretation of this observation should be sought from the physico-chemical characteristics of the tailwaters.

Water quality criteria (FWCPA, 2968) for warm water biota, in regard to dissolved oxygen for game fishes, should be 5 mg/l, and it may range between 5 and 4 mg/l for short periods during any 24-hour period; for the cold water biota, especially in spawning areas, 7 mg/l, is recommended and may go as low as 5 to 6 mg/l for short periods. It is also recommended that the "free" carbon dioxide concentrations should not exceed 25 mg/l and pH ranges should be between 6.0 and 9.0 (FWCPA, 1968). Maximum temperatures recommended for the well being of cold water and warm water fishes are given in Table VI.

TABLE VI *

Provisional maximum temperatures recommended as compatible with the well-being of various species of fish and their associated biota

93 F:	Growth of catfish, gar, white or yellow bass, spotted bass, buffalo, carpsucker, threadfin shad, and gizzard shad.
90 F:	Growth of largemouth bass, drum, bluegill, and crappie.
84 F:	Growth of pike, perch, walleye, smallmouth bass, and sauger.
80 F:	Spawning and egg development of catfish, buffalo, threadfin shad, and gizzard shad.
75 F:	Spawning and egg development of largemouth bass, white and yellow bass, and spotted bass.
68 F:	Growth or migration routes of salmonids and for egg development of perch and smallmouth bass.
55 F:	Spawning and egg development of salmon and trout (other than lake trout).
48 F:	Spawning and egg development of lake trout, walleye, northern pike, sauger, and Atlantic salmon.

Note.--Recommended temperatures for other species, not listed above, may be established if and when necessary information becomes available.

*Reprinted from the Report of the Committee on Water Quality Criteria (Table III, FWPCA, 1968).

Physico-chemical characteristics of the three tailwaters studied are given in Tables II, III, and IV. Hydrogen-ion concentrations and free carbon dioxide readings are well within the standards of the water quality criteria. Dissolved oxygen could be stated to be within the required limits, although readings of 4 mg/l are reported as the lowest observed in the tailwater. Average temperature readings during this investigation ranged from 4.2 - 23.0 C (39.6 F - 73.4 F). Based on the water quality criteria standard, it appears that the tailwaters are unsuitable for spawning and growth of the warm water game fishes. Although the game fishes were destroyed in the tailwaters due to cold water discharges below the dams, these waters appear to be suitable for the development of a trout fishery.

Fishes in the Confluence of the White and Buffalo Rivers[1]

Six stations C1, C2, C3, C4, C5, and C6 in the vicinity of the confluence of the White and Buffalo Rivers were sampled from October 1965 to October 1966 (Figure 1). Stations C1 and C2 were located in the White River upstream from the confluence with the Buffalo River, extending from 0.5 to 1.5 miles from the confluence. A riffle and a pool collection were made at this station on each side of the White River. A riffle and two pool collections were made at station C3 located on the same side of the mouth of the Buffalo River, extending from 0.3 to 1.0 miles below the confluence. A riffle and two pool collections were made at station C4 located across from station C3. Stations C5 and C6 were in the Buffalo River 0.75 of a mile upstream from the confluence; a riffle and a pool collection were made on each side of the river.

Average seasonal temperatures and ranges for each station are presented in Table VII. These illustrate some of the changes that are produced in a river when a dam with a low-level outlet is built upon it. The variation between summer and winter temperatures is less in the White River than in the undammed Buffalo River. During summer months, when water temperatures in the free-flowing Buffalo River are quite high (29.5C), the White River (C1 and C2) water remains cold (16.0C). In

[1]Information compiled from Thesis of Brown, 1967.

Table VII

AVERAGE TEMPERATURES AND RANGES AT STATIONS IN THE VICINITY OF THE CONFLUENCE OF THE WHITE AND BUFFALO RIVERS

Season	Station			
	C1 & C2	C5 & C6	C3	C4
Fall				
Average	13.5	15.0	15.0	13.5
Range	11.0-16.0	7.0-20.0	9.0-20.0	11.5-16.0
Winter				
Average	7.5	5.0	6.5	7.5
Range	5.5-9.0	1.0-7.5	3.0-8.0	6.0-9.0
Spring				
Average	13.0	21.0	20.0	12.5
Range	9.5-16.0	14.5-27.5	15.5-24.5	10.0-15.0
Summer				
Average	16.0	29.5	20.5	16.0
Range	13.5-19.0	25.0-33.0	18.5-23.0	15.5-18.0

winter months, White River water remains somewhat warmer than Buffalo River water. Perhaps the most significant feature of this section of the White River is that its water temperature remains low enough throughout the year to maintain rainbow trout.

A comparison of water temperatures recorded at stations C3 and C4 shows an interesting pattern. Temperatures recorded at station C3 were similar to those in the Buffalo River (C5 and C6) while temperatures taken at station C4 followed closely those taken upstream in the White River (C1 and C2). This indicates that water discharged from the Buffalo River does not immediately mix with White River water. It remains on its side of entry while original White River water flows down the opposite side of the White River bed. This condition exists for varying distances downstream depending upon the difference in temperature between the two rivers and the volume of water discharged from the Buffalo River.

Dissolved oxygen and free carbon dioxide were relatively stable at all stations throughout the 13 month period, and few differences between stations were recorded. Ranges for dissolved oxygen and free carbon dioxide were 7.5 to 13.0 ppm and 0.5 to 3.0 ppm, respectively. Waters remained slightly alkaline throughout the study. The range (7.3 to 8.4) was large, but there were few differences between stations.

Fishes representing 40 species, 20 genera, and 11 families were collected from the stations in the vicinity of the confluence of the White and Buffalo Rivers. Details of the percentages of species obtained in the riffle and pool collections illustrating the overall distribution and relative abundance are given in Table VIII .

Table VIII

PERCENTAGES OF SPECIES COLLECTED IN RIFFLES AND POOLS IN THE VICINITY OF THE CONFLUENCE OF THE WHITE AND BUFFALO RIVERS

	Station							
	C1 & C2		C5 & C6		C3		C4	
Species	Riffle	Pool	Riffle	Pool	Riffle	Pool	Riffle	Pool
Petromyzontidae (ammocoete)	0.1				0.2		0.2	
Salmo gairdneri		T						
Hypentelium nigricans	0.1		0.1	0.1		0.1		
Notemigonus crysoleucas						T		
Chrosomus erythrogaster		0.1		T				
Hybopsis biguttata				0.5				0.2
Hybopsis amblops		0.4	0.1	T		T	0.1	
Hybopsis dissimilis		T	5.4	0.2	0.7	T		0.2

TABLE VIII CONTINUED

Species	C1 & C2 Riffle	C1 & C2 Pool	C5 & C6 Riffle	C5 & C6 Pool	C3 Riffle	C3 Pool	C4 Riffle	C4 Pool
Notropis rubellus		24.2	8.6	2.3		6.5	1.2	5.7
Notropis chrysocephalus		0.2		0.6		0.8		
Notropis pilsbryi	3.2	28.0	20.5	19.2	5.5	53.0	11.5	65.6
Notropis boops		9.1	0.3	32.3		9.5	0.1	1.9
Notropis ariommus		0.5		0.4		0.1		0.3
Notropis galacturus		6.4	2.1	6.4		5.1		3.2
Notropis greenei	0.2	1.1	3.5	0.6	0.2	2.9	0.2	1.2
Notropis ozarcanus			0.1	0.4		1.1		0.2
Notropis species		0.5		5.3		0.1		0.8

TABLE VIII CONTINUED

Species	Station: C1 & C2		C5 & C6		C3		C4	
	Riffle	Pool	Riffle	Pool	Riffle	Pool	Riffle	Pool
Dionda nubila		5.8	0.4	3.8		3.1	0.1	2.9
Pimephales notatus		2.5		5.5		0.9		0.3
Campostoma anomalum	1.0	11.7	12.5	3.3	13.1	8.7	0.4	5.9
Pylodictis olivaris	0.1							
Noturus exilis			0.2					
Noturus species			1.8	T			0.4	
Noturus species			1.1	T			0.2	
Fundulus catenatus		0.6	0.2	5.1		4.3		0.3
Fundulus olivaceous				2.5		0.1		

TABLE VIII CONTINUED

	Station							
	C1 & C2		C5 & C6		C3		C4	
Species	Riffle	Pool	Riffle	Pool	Riffle	Pool	Riffle	Pool
Labidesthes sicculus		0.3	0.1	2.3		0.3		
Micropterus dolomieui			0.2	0.4		0.2		
Lepomis cyanellus				T			0.1	
Lepomis megalotis		0.4	0.4	5.9	0.5	0.4	0.1	
Ambloplites rupestris				0.2				
Percina sciera					0.2			
Percina evides			0.3					
Percina uranidea			0.1					
Etheostoma euzonum			2.3	0.1	0.5	0.2		0.2

TABLE VIII CONTINUED

Species	C1 & C2 Riffle	C1 & C2 Pool	C5 & C6 Riffle	C5 & C6 Pool	C3 Riffle	C3 Pool	C4 Riffle	C4 Pool
Etheostoma zonale	0.1		5.3	0.7	1.7	1.1	1.3	2.2
Etheostoma blennioides	0.4	T	1.0	1.0	0.7	0.7	0.6	0.3
Etheostoma juliae	0.1		17.7	T	18.6			
Etheostoma caeruleum	7.6	0.8	15.2	0.9	8.4	0.4	1.5	4.8
Cottus bairdi	86.8	7.1	0.3		49.6	0.2	82.0	3.4
Cottus carolinae	0.2	0.1	0.4			T	0.3	0.3

T-less than 0.1 percent.

The fishes, rosy face shiner, Notropis rubellus; the bleeding shiner, N. pilsbryi; the bigeye shiner, N. boops; the stoneroller, Campostoma anomalum; and the rainbow darter, Etheostoma caeruleum were abundant in all stations. Species obtained only from the White River were Lamprey ammocoete, rainbow trout, Salmo gairdneri; golden shiner, Notemigonus crysoleucas; flat head catfish, Polydictis olivaris; and the dusky darter, Percina sciera; while slender madtom, Noturus exilis; rock bass Ambloplites rupestris; gilt darter, Percina evides; and the stargazing darter, Percina uranidea were captured only in the Buffalo River. These data should not be construed as a measure of absolute distribution since only a few specimens of each of these species were collected.

Cottus bairdi was the most abundant fish in White River riffles but was rarely encountered in the Buffalo River. Several species including the Ozark and checkered madtoms; brook silversides, Labidesthes sicculus; and the longear sunfish, Lepomis meagalotis occurred frequently in Buffalo River but seldom in White River. Several species more characteristic of the Buffalo River fish fauna than that of the White River occurred commonly in both pool and riffle collections at station C3. Species showing this pattern of distribution were the northern studfish, Fundulus catenatus; the blackspotted topminnow, Fundulus olivaceous; the smallmouth bass, Micropterus dolomieui; the Arkansas saddled darter, Etheostoma euzonum; and the yolk darter, Etheostoma juliae. The resemblance of the ichthyofauna between stations C5 and C6, and C3 was due to the flow of the Buffalo River water on this side of the White River for some distance below the region of confluence of the White and Buffalo Rivers.

The number of species and individuals collected seasonally in riffles and pools at each of the four locations are listed in Tables IX and X. The Buffalo River (C5 & C6) seems to support a more diverse fish fauna than the White River (C1 & C2) even though many species were common to both streams. Below the confluence, more species of fishes were collected in the riffle at station C4 than at station C3. The riffle at C4 was deep and rapid while the riffle at C3 was shallow with a moderate current. Therefore, the presence of more species at station C4 might be the result of habitat preference. A greater number of species was always present in the pool collections at station C3 than at station C4. Since the water temperatures at station C3 were similar to those in the Buffalo River (C5 & C6), it would be reasonable to expect a greater number of species at station C3 than at C4 as was the case with regard to stations C5 and C6, and C1 and C2.

As for seasonal abundance, the number of species and individuals collected at each station were generally lower in winter than in any other season (Tables IX and X). This was especially true for the Buffalo River (C5 & C6) and station C3. Several cyprinids that were frequently encountered at these stations during spring, summer, and fall were absent in winter. The riffle at station C3 was void of fishes during winter and a gradual increase in the number of fishes at this station was noticed during spring and summer months. This trend is indicative of the movement of fishes from riffles to shallow pools in winter thereby making their capture unlikely with the methods used.

Table IX

NUMBERS OF SPECIES AND INDIVIDUALS COLLECTED IN RIFFLES AT STATIONS IN THE VICINITY OF THE CONFLUENCE OF THE WHITE AND BUFFALO RIVERS

	Station							
	C1 & C2		C5 & C6		C3		C4	
Season	Species	No.	Species	No.	Species	No.	Species	No.
Fall	5	178	15	299	9	160	7	333
Winter	5	193	9	60	5	13	4	75
Spring	8	214	22	681	5	28	8	91
Summer	8	299	18	409	8	167	12	410
Totals	12	844	27	1449	13	368	17	909

Table X

NUMBERS OF SPECIES AND INDIVIDUALS COLLECTED IN POOLS AT STATIONS IN THE VICINITY OF THE CONFLUENCE OF THE WHITE AND BUFFALO RIVERS

	Station							
	C1 & C2		C5 & C6		C3		C4	
Season	Species	No.	Species	No.	Species	No.	Species	No.
Fall	16	310	26	695	15	287	11	164
Winter	15	511	10	208	13	99	11	36
Spring	16	880	20	1075	22	583	9	34
Summer	15	884	16	230	18	1459	9	346
Totals	21	2585	30	2208	26	2422	19	580

It was evident from the riffle and pool collections in the study area that fish abundance was related to the type of habitat. In general, deep, rapid riffles with rubble bottoms appeared to be the most densely populated. Deeper pools that were somewhat protected from strong river currents usually yielded larger and more varied collections.

In general, temperature is probably a major factor in determining the abundance and distribution of fishes in the study areas. The greatest observable difference between the White and Buffalo River sampling sites is temperature. Lower temperatures in the cold waters of the White River may have a limiting effect on the reproduction of some species. The studies of Eschmeyer and Smith (1943) and Pfitzer (1962) on the cold tail-waters in the TVA system revealed that the spawning of warm water fishes was inhibited. Since many species of minnows were numerous in the White River study area, some successful spawning evidently occurs. Baker (1959) reported occurrences of trout spawning at Cotter in the White River, but that fluctuating water levels and rolling gravel repeatedly destroyed the beds. The same fate seems likely for the spawning efforts of other species. Although, some fishes in ripe condition were taken in both the White and Buffalo Rivers, they were all forage fishes. Pfitzer (1962) reported that in the cold tailwaters in the TVA system, only some forage fishes appeared to spawn with some success, but populations of centrachids and minnows declined or disappeared. Pfitzer's findings seem to concur with these results reported for the White River below the Bull Shoals Reservoir.

Comparison of Ichthyofauna of White River, Kings, River, Buffalo River, Black River and Norfork River[1]

During the summer of 1965 and 1966, fuanal composition, distribution and relative abundance of fishes in White River below Bull Shoals Dam, and in Norfork River below Norfork Dam were determined. These data were then compared with those for the Kings, Buffalo and Black rivers obtained during the same period. Collecting stations were established on the five rivers (Figure 15). The White River was intensively sampled with a total of 15 stations from below Beaver Dam to the confluence of the White and Black rivers. The Buffalo River was sampled at nine stations from the headwaters to the mouth; three stations on the Black River were sampled from the mouth of the river to a point 10 miles upstream; the Kings River was sampled at 2 stations, and the Norfork River was sampled at one station.

The bulk of the North American freshwater ichthyofauna is concentrated in the Mississippi drainage system. The White River, a tributary of the Mississippi, has one of the richest inland ichthyofaunas of the southeastern United States. A total of 108 species comprising 48 genera and 21 families was collected in the White River drainage in this survey. Cyprinids, centrachids, and percids were the dominant groups, with cyprinids alone accounting for 30 species and two-thirds of the total specimens collected.

In general, the number of species in the White River increases from its origin to the confluence with the Arkansas River, with this phenomenon being associated with stream size, gradient, turbidity, and temperature. The importance of these factors was emphasized by Starrett (1950) in a study

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[1] Information compiled from Thesis of Cashner, 1967.

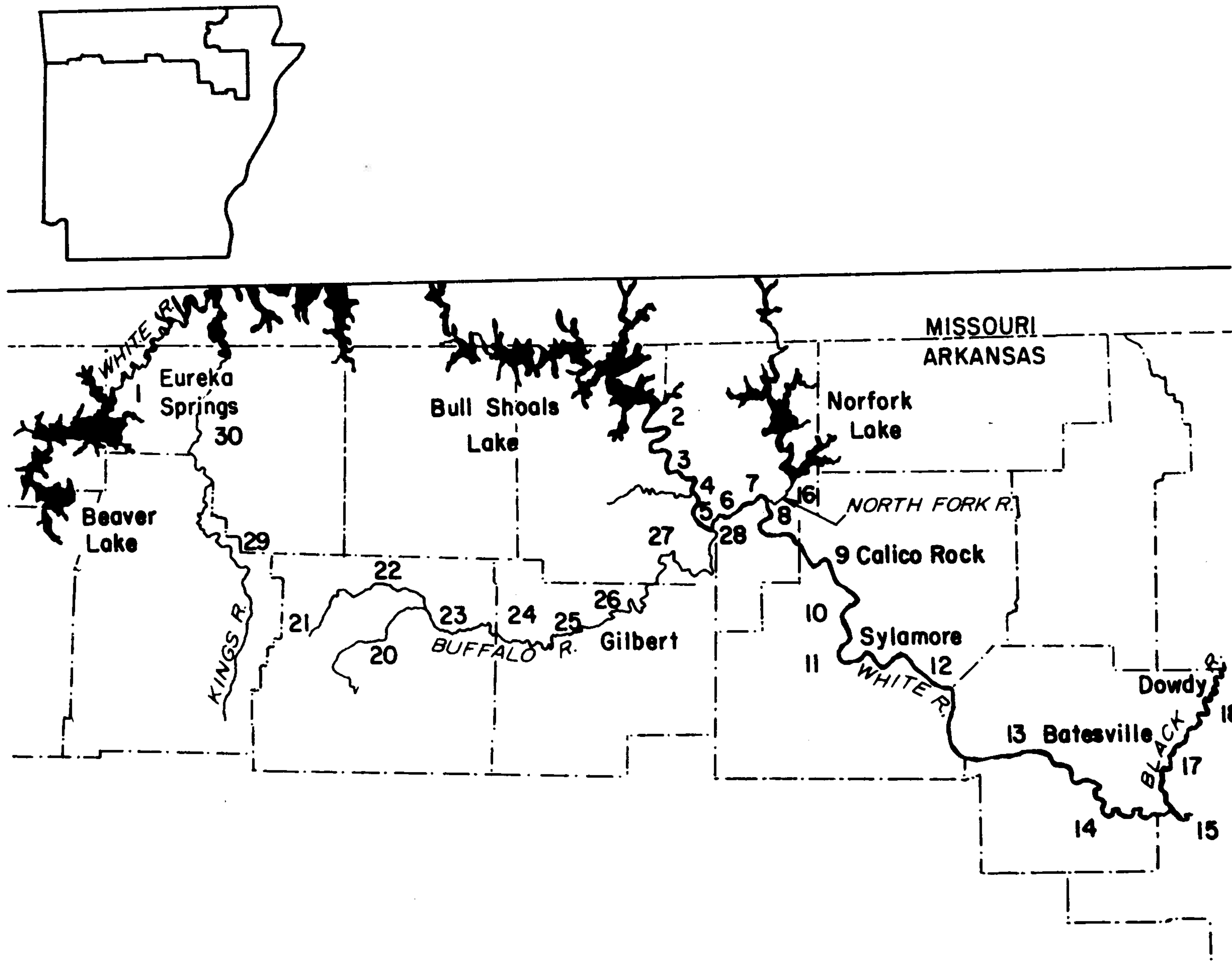

FIGURE 15. LOCATIONS OF COLLECTING SITES FROM THE WHITE RIVER DRAINAGE IN NORTHERN ARKANSAS

of Mountain Lake, Virginia.

Inter-stream Difference - Important breaks in normal species distribution occur in cold tailwater areas such as below Bull Shoals Dam where only seven species were collected. Although no pre-impoundment data for this tailwater are available, the number of species has been reduced by approximately 60% since the construction of the dam. This percentage is based upon a comparison with a stream section of comparable size largely unaffected by impoundment. Severe reduction in number of cyprinids and centrarchids is the most apparent result of the effect of cold tailwaters (also observed by Pfitzer, 1962). From Bull Shoals Dam to Cotter, Arkansas, the river becomes progressively wider, the temperature increases from 8 to 11 C, and as the result of these and other factors the species list increases to 33.

The Buffalo drains into the White River approximately 10 miles south of Cotter, Arkansas. In this area several species that are widely distributed in the Buffalo River are encountered for the first time in the White River proper. These species include: *Notropis ariommus*, *Notropis ozarcanus*, *Notropis boops*, *Etheostoma euzonum*, *Etheostoma zonale* and *Etheostoma juliae*. Fifty species were recorded from the mouth of the Buffalo River to Sylamore, whereas only 33 species were collected from Bull Shoals Dam to Cotter. The increase in the faunal list is the result of more complex ecological conditions such as a sharp temperature differential between the Buffalo River side and White River side at the point of confluence. The temperature of the Buffalo River side of the White ranges between 19 and 23 C, whereas the White River side ranges between 12 and 16 C in the absence of large discharges from Bull Shoals Dam. This condition persists some 25 miles downstream to Calico Rock, Arkansas. About 30 miles south of Calico Rock in the vicinity of Guion, the river begins to resemble a lowland stream; temperatures range from 17 to

19 C, turbidity increases, and the stream bed becomes wider. No lowland species were taken in this region, but there appeared to be a decrease in abundance of upland species.

Striking faunal differences occur between the upper and lower parts of the White River. The river passes through two major physio-graphical divisions, the Ozark Plateau and the Gulf Coastal Plain, with the separation occuring near the low-water bridge at Batesville. Replacement of species occurs as a result of competition, adverse physical or chemical conditions, or a combination of the three. The faunal difference above and below this point can be seen by the following groups of indicator fishes:

Upper White	Lower White
Carpiodes velifer	Dorosoma cepedianum
Moxostoma duquesnei	Ictiobus cyprinellus
Moxostoma erythrurum	Ictiobus niger
Hypentelium nigricans	Carpiodes cyprinus
Hybopsis dissimilis	Carpiodes carpio
Notropis rubellus	Moxostoma breviceps
Notropis pilsbryi	Hybopsis x-punctata
Notropis boops	Notropis atherinoides
Notropis greenei	Notropis venustus
Dionda nubila	Notropis volucellus
Pimephales notatus	Notropis sabinae
Salmo gairdneri	Hybognathus nuchalis
Micropterus dolomieui	Pimephales vigilax
Lepomis megalotis	Micropterus salmoides

<u>Ambloplites rupestris</u>	<u>Lepomis macrochirus</u>
	<u>Chaenobryttus gulosus</u>
	<u>Lepisosteus osseus</u>

Burton and Odum (1945) reported distinct longitudinal succession in mountain streams in Virginia and regarded temperature as the most important physical factor limiting the distribution of fishes in a stream. Many features of the White River change as it moves downstream, such as increases in turbidity and average temperature. The lower White River temperature ranges from 8 -10 C and is warmer than the upper White, even when cold water is discharged from Bull Shoals Dam.

Succession in the White River is evident. The lower phase of the river has a distinct ichthyofauna from that of the upper phase. Ninety-four species were taken in the White River proper, 44 of these were encountered for the first time below the low-water dam at Batesville. Dominant upland species were collected in the lower phase but were usually outnumbered by lowland forms in a given habitat.

The Black River, a tributary of the lower White, has a distinct fauna from most of the other tributaries; most species of the Black River occur in the White River only in the vicinity of their confluence. Some common species in the Black River are: <u>Amia calva</u>, <u>Lepisosteus platostomus</u>, <u>Dorosoma cepedianum</u>, <u>Esox niger</u>, <u>Ictiobus cyprinellus</u>, <u>Notropis whipplei</u>, <u>Notropis venustus</u>, <u>Notropis sabinae</u>, <u>Aphredoderus sayanus</u>, <u>Chaenobryttus gulosus</u>, <u>Pomoxis annularis</u>, <u>Ammocrypta vivax</u>, and <u>Etheostoma histrio</u>.

SUMMARY AND CONCLUSIONS

Generalizations Concerning This Investigation

In many areas of the United States, natural free-flowing streams have been impounded for purposes of flood control, hydroelectric power generation, public water supplies, recreation, and retirement areas and homes for the aged. The impoundment of a stream with a deep water outflow dam drastically alters the ecological conditions. A large portion of the White River, 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 show that native warm-water fisheries are 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. By 1957, only six years after Bull Shoals was impounded, the cold-tailwaters supported 47,792 man days of fishing, amounting to $684,732 worth of business to fishing-service operators alone (Baker, 1959). Since the White River has only a few areas available for the natural spawning of trout, a hatchery located near Norfork Dam was constructed for the purpose of providing trout for the Norfork and White River cold-tailwaters. Trout have been stocked below Beaver Dam, but at the present time it is too early to determine the success of the trout fishery in this stream.

Data taken and analyzed during this investigation indicate that the cold-water is not of poorer quality but rather produces a new environment which allows replacement of the original warm-water biota with cold-water organisms.

The Buffalo River, because it flows through sparsely populated country, appears to resemble the natural unpolluted streams of the past. The publication by the Committee on Water Quality Criteria (FWPCA, 1968) gives excellent values for evaluation of environmental factors for the streams studied in this investigation.

Data in this investigation show that homoiothermal temperatures and hydroelectric generation currents are the important causes of abiotic variations when compared to natural streams. Expressed in terms of productivity, the older cold-tailwaters contain more abundant links of the biotic food chain than the newer cold-tailwaters and natural streams. Physico-chemical and plankton factors at the stations near the dams are definitely under the influence of ecological conditions in the lake. At the downstream stations, environmental factors are affected by the area through which the stream flows. The analyzed data also show that the newer Beaver cold-tailwater has not reached the stage of development found in the older tailwaters.

Physico-chemical

The most striking differences between the cold-tailwaters and the natural streams are temperature and the scouring action of the stream beds due to periods of power generation on the cold-tailwaters. Seasonal temperature fluctuations in the cold-tailwaters increased as the water proceeded downstream from its homoiothermal source. The greatest range of temperature occurred in the natural streams. Riffle speeds in the natural streams exhibited seasonal and individual fluctuations, as did the speeds in the cold-tailwaters, although the latter currents were also influenced by power generation times.

The report of the Committee on Water Quality Criteria (FWPCA, 1968) states that free carbon dioxide concentrations should not exceed 25 mg/l, and that the pH should not be below 6.0 or above 9.0. The averages and ranges of carbon dioxide were well within this specification, and the pH values were within these limits. The carbon dioxide content decreased as the water coursed downstream, and hydrogen ion concentration increased.

For a diversified warm-water biota, dissolved oxygen concentrations may drop to a value between 5 and 4 mg/l for short periods of time. Provided other water conditions are favorable for a cold-water biota, the dissolved oxygen concentrations may range between 6 and 5 mg/l for short periods (FWPCA, 1968). The lowest dissolved oxygen concentrations were at the stations nearest the dam. During the 1967-1968 study, the dissolved oxygen dropped at station Beaver 1 to 2.5 ppm for a short period of time; nevertheless, average dissolved oxygen values were well above the specified range. Minimum dissolved oxygen values in the Kings River dropped to the specified lower ranges of between 5 and 4 mg/l for a short period of time without any apparent biota "kills." The average dissolved oxygen values were well within those specified for good water quality. The Buffalo River, a natural stream with little or no pollution, had an average dissolved oxygen reading of 10.1 ppm (the high value was 12.5, and the low was 7.5 ppm).

The cold-tailwaters below Bull Shoals, Norfork, and also the Buffalo River (a tributary of the White River in this area) had the highest methyl orange alkalinity values. Beaver cold-tailwater station 3, during the 1965-1966 investigation period, had a high methyl orange alkalinity concentration (171.6 ppm) for a short period of time but had a much lower average than the old tailwaters and the Buffalo River. In the Beaver cold-tailwater, methyl orange alkalinity increased as the water moved downstream.

Reid (1961) states that growth of diatoms such as Asterionella, Melosira, and Tabellaria may be inhibited by concentrations of silica below 0.5 to 0.8 ppm. Average silica values were well above those suggested by Reid; however, the Kings River stations and the three Beaver cold-tailwater stations were free of silica for short periods during the 1967-1968 study. Buffalo River, a clean natural stream, had the highest average silica values of all stations monitored.

The Buffalo River exhibited the lowest average nitrate-nitrogen values, whereas the 1967-1968 samplings of the Beaver cold-tailwater and Kings River displayed the highest. The 1967-1968 series of samples from the Beaver cold-tailwater and the Buffalo River had the highest average values of ortho-phosphate. Norfork cold-tailwater and the Buffalo River stations showed the highest averages of meta-phosphate. The highest range of nitrate-nitrogen was 4.0 ppm at station Beaver 3 during the 1967-1968 series. Other high maxima were found at the Beaver cold-tailwater station 1 with 2.0 ppm (1965-1966) and 1.9 at station 1 (1967-1968).

Ortho-phosphate averages ranged from 0.06 ppm to 0.1 ppm. Meta-phosphate ranged from an average of 0.23 ppm at Bull Shoals to 0.35 ppm at Norfork station number 2.

Plankton

Plankton samples were taken at nine stations, three in the old cold-tailwaters, three in the new Beaver cold-tailwater, and three in natural streams. The Beaver cold-tailwater was sampled during the 1965-1966 and 1967-1968 investigations. For productivity rankings, each sampling series was considered separately on the Beaver cold-tailwater, giving a total of 12 samplings.

Phytoplankton

Phytoplankton, measured as cells per liter to express productivity in the streams, varied as follows: (1) Norfork, the oldest tailwater at stations 1 and 2 (the latter a distance of 3.5 miles below the dam) had the largest number of cells per liter (14,779 and 15,465, respectively), values almost four times greater than the Buffalo River; (2) the Buffalo River ranked seventh in number of cells per liter (3,965); (3) stations 1 and 2 on the Kings River showed the smallest number of cells per liter (581 and 646, respectively).

In the older Norfork cold-tailwater and the 1967-1968 samplings of the newer Beaver cold-tailwater, there was an increase in number of cells downstream from the dam to the last station, a distance of 3.5 miles. In the 1965-1966 study period, there was an increase in number of cells per liter from station Beaver 2 to 3; however, station 1 had the largest number of cells of the three stations.

At stations 1 and 2 on the Norfork, 0.25 and 3.5 miles below the dam, respectively, the organisms of the phyla Chrysophyta and Cyanophyta formed the greatest percentages. At Norfork station 1 the Chrysophyta were the most abundant, while at station 2 members of the Cyanophyta were most numerous.

In the natural streams, Buffalo and Kings Rivers, there was a tendency towards an equal distribution between the three major phyla. However, the Chrysophyta were more numerous in the Kings River, and the Cyanophyta more abundant in the Buffalo River.

In the 1965-1966 Beaver cold-tailwater study the three major phyla at station 1 appeared to be somewhat equally distributed. Members of the phylum Cyanophyta comprised the largest percentages at stations 2 and 3. During the 1967-1968 Beaver cold-tailwater investigation, the number of cells was greatly reduced at station number 1 when compared to the 1965-1966 study. At stations 2 and 3, members of the Cyanophyta increased in percentages, while the Chlorophyta continued to be abundant.

Zooplankton

In the cold-tailwaters, the largest numbers of zooplankton were found at Norfork stations 1 and 2 (18.0 and 25.0 organisms per liter, respectively). The Buffalo River, a natural stream, ranked second in productivity with 19.1 organisms per liter. The Kings River, the other natural stream, was more productive than the Beaver cold-tailwater during both investigations. The 1967-1968 investigation of the Beaver cold-tailwater showed fewer zooplankton than the earlier study period. This result was possibly due to excessive generation.

In the Norfork cold-tailwater, the number of organisms increased from the first station below the dam to the second, approximately 3.5 miles downstream. However, during both periods of the Beaver cold-tailwater study, a decrease of organisms was evident from the first to the second station downstream. In both investigations, a slight increase was again evident at the third station.

Except in the 1967-1968 Beaver cold-tailwater the most numerous organisms in the streams were members of the taxon Rotifera, while the Copepoda were usually second. The protozoans ranked second in the Buffalo River. The Rotifera increased 53% from Norfork station 1 to 2, a distance of 3.5 miles below the dam. Rotifers accounted for the largest number of organisms in the fresh water streams.

Benthic Macroinvertebrates

Benthic macroinvertebrates were taken at ten stations, four in the old cold-tailwaters, three in the new cold-tailwater, and three in natural streams. However, since the new Beaver cold-tailwater was sampled twice, once during 1965-1966 and again during the 1967-1968 investigation, productivity ranks are based on 13 samplings.

Productivities, expressed in terms of number of organisms per square foot, were as follows: (1) the largest number of organisms was found in the old cold-tailwaters within three and one half miles downstream from the dam--for instance, Norfork station 1 had an average of 244 organisms per square foot, Norfork station 2 had 173, and Bull Shoals station 1 had 163; (2) the Buffalo River station ranked sixth with an average of 102 organisms per square foot; (3) station number 1 on the Kings River ranked fifth with 103 organisms, and station 2 on this stream ranked ninth with 63; (4) the lowest number of organisms per square foot was found at the second station on the White River (C1 and C2), twenty miles below the dam, where only 30 organisms per square foot were recorded.

The biomass, measured in average wet weight, showed an entirely different productivity pattern compared to the number of organisms per square foot. Some of these differences were as follows: (1) the two Kings River stations ranked first and second, and the two Norfork stations third and fourth in biomass productivity; (2) the least productive were the Beaver cold-tailwater stations during the 1967-1968 study; (3) the Buffalo River ranked sixth.

The four major taxa in the cold-tailwaters were the Chironomidae, Oligochaeta, Isopoda and Amphipoda. The Isopoda were common in the Norfork cold-tailwater, while larger numbers of Amphipoda were found in the Bull Shoals cold-tailwater. Chironomidae were the most abundant in all of the Beaver cold-tailwater samplings, with the Oligochaeta also prominent in the 1965-1966 series. Isopoda ranked second in number per square foot at Beaver station 1 in the 1967-1968 study.

The five major taxa found in the natural streams were Trichoptera, Ephemeroptera, Coleoptera, and Gastropoda. Common taxa in the Buffalo River were the Coleoptera, Gastropoda and Ephemeroptera. Those in the Kings River were the Trichoptera, Ephemeroptera, and Gastropoda.

Ichthyofauna

Beaver, Norfork, and Bull Shoals Tailwater Ichthyofauna

Fish collections in Beaver tailwater were made from October 1965 to December 1966, and during Spring, Summer and Fall of 1968. Norfork and Bull Shoals tailwaters were sampled from October 1965 to November 1966. A comparison of Beaver, Norfork, and Bull Shoals tailwater ichthyofauna showed a more diverse fauna in Beaver tailwater compared to the other two tailwaters. The Beaver tailwater fish fauna was represented by the families Cyprinidae, Percidae and Centrarchidae in that order of abundance. In the Norfork and Bull Shoals tailwaters fishes of the families Cottidae and Cyprinidae were predominant. The sunfishes that were reported from Norfork tailwater (Baker, 1959) were absent there in the 1965-1966 collections indicating the nonsuitability of this tailwater for the sunfishes. Although Beaver tailwater currently shows a more diverse ichthyofauna than the other tailwaters, the situation may change in future as was the case in Norfork tailwater. It is recommended that the Beaver tailwater ichthyofauna survey be continued along with an investigation of the food and feeding habits of the tailwater fishes in relation to the abundance and fluctuations in the available food organisms. Such an investigation would allow an understanding as to whether the changes in the tailwater ichthyofauna are due to physico-chemical conditions, food organisms or an overall interaction between all of these factors.

This study showed a virtual absence of warm water game fishes in the tailwaters, and that the few game fishes found were not in breeding condition. The physico-chemical characteristics of the three tailwaters were compared with water quality criteria established by the Federal Water Pollution Control Administration (1968). Based on the water quality standards, it appears that the tailwaters are unsuitable for spawning and growth of the warm water game fishes as the tailwater temperature readings during this investigation ranged from 4.2 to 23.0 C (39.6 F to 73.4 F). Although the tailwaters do not provide suitable habitat for warm water game fishes due to cold water discharges below the dams, these waters appear to be suitable for the cold water fishes and fishery.

Fishes in the Confluence of the White and Buffalo Rivers

Six stations C1, C2, C3, C4, C5 and C6 in the vicinity of the confluence of White and Buffalo Rivers were sampled from October 1965 to October 1966. Stations C1 and C2 were located in the White River upstream from the confluence with the Buffalo River. Station C3 was located on the same side as the Buffalo River below the confluence, and C4 was situated across from station C3. Stations C5 and C6 were in the Buffalo River one mile upstream from the confluence.

Along with the fish collections, water quality parameters on temperature, dissolved oxygen, free carbon dioxide and pH were also obtained. The winter and summer temperature differences at C1 and C2, C3, C4, and C5 and C6 were 8.5, 14.0, 8.5, and 24.5, respectively.

During summer months, when average water temperature in the Buffalo River was high (29.5 C), the White River (C1 and C2) water remained cold (16.0 C). In winter months, White River water remained somewhat warmer (7.5 C) than Buffalo River water (5.0 C). The water temperatures at stations C3 and C4 corresponded with temperatures in the Buffalo River and White River, respectively, indicating that water discharged from the Buffalo River does not immediately mix with White River water. Ranges for dissolved oxygen and free carbon dioxide were 7.5 to 13.0 ppm, and 0.5 to 3.0 ppm, respectively, at all the stations. The pH range was from 7.3 to 8.4.

Species of fishes common to both the White and Buffalo Rivers, and specific to each of these rivers were given in detail under results. There was similarity of ichthyofauna between the Buffalo River (C5 and C6) and station C3, and this similarity was interpreted as due to the flow of Buffalo River water on the side of station C3 of the White River for some distance below the confluence of White and Buffalo Rivers.

The number of species and individuals of fishes collected seasonally in riffles and pools showed that the Buffalo River (C5 and C6) support a more diverse fish fauna than the White River. The riffle collections at C4 had more species of fishes than at C3 and this was attributed to habitat differences as the riffle at station C4 was deep and rapid while the riffle at C3 was shallow with moderate current. However, pool collections at C3 had more species of fishes than station C4. Since the water temperature at station C3 was similar to that of

Buffalo River (C5 and C6), it would be reasonable to expect more species at station C3 than at C4 as was the case with regard to stations C5 and C6 (Buffalo River), and C1 and C2 (White River).

This ichthyofauna study in the confluence of the White and Buffalo Rivers points out that temperature is probably the major factor in determining the abundance and distribution of fishes in the study areas. The recorded values of the physico-chemical factors showed that the greatest observable difference between the White River and the Buffalo River sampling stations was the water temperature. Lower temperatures in the cold waters of the White River may have an inhibiting effect on the reproduction of some species. Eschmeyer and Smith (1943) and Pfitzer (1962) reported on the inhibition of the spawning activity of warm water fishes in the cold tailwaters of the TVA system. The occurrence and abundance of minnows in the White River study areas suggest some successful spawning of these fishes. However, fluctuating water levels and rolling gravel may destroy the spawning beds. Baker (1959) reported the destruction of trout spawning beds by fluctuating water levels and rolling gravelin the White River at Cotter. Pfitzer (1962) stated that in the cold tailwaters of the TVA system, only some forage fishes appeared to spawn with some success, but populations of centrarchids and minnows declined or disappeared. His findings seem to concur with our observations for the White River fishes below the Bull Shoals Reservoir.

Ichthyofauna of White River, Kings River, Buffalo River, Black River and Norfork River

During the summers of 1965 and 1966 fishes were collected from White River below the Bull Shoals Dam, Norfork River below Norfork Dam, Kings River, Buffalo River and Black River to determine the faunal composition, distribution and abundance of fishes.

In the White River the number of species increases from its origin to the confluence with the Arkansas River. Important breaks in normal species distribution occur in cold tailwater areas below the Bull Shoals Dam. From Bull Shoals Dam to Cotter, Arkansas, the river becomes progressively wider and the temperature increases resulting in an increase in the number of species. There was a succession in fish species in the White River, with the lower end of the river having a distinct ichthyofauna from that of the upper end. Burton and Odum (1945) reported distinct longitudinal succession in mountain streams in Virginia and regarded temperature as the most important factor limiting the distribution of fishes in a stream. The ichthyofaunal differences in the White River are attributable to temperature variations in various parts of the river.

The Buffalo River drains into the White River about 10 miles south of Cotter. In this region several species that were widely distributed in the Buffalo River were found for the first time in the White River proper. While only 33 species were collected in the White River between Bull Shoals Dam and Cotter, 50 species were recorded from the confluence area with the Buffalo River to Sylamore. This increase in species below the confluence was due to sharp temperature differential between the Buffalo River side and White River side at the point of confluence.

A comparison of the five rivers showed that the White River had the richest ichthyofauna, and among the tributaries the Black River appeared to be the richest. There were some intra-stream differences with regard to ichthyofauna. Within a stream three types of habitats, riffles, pools, and main channels were present. The riffle habitats were characteristically inhabited by percids, cottids, small catastomids and some cyprinids; in the pool habitats centrarchids, most of the cyprinids and occasional percids were found; large catastomids, lepisosteids, clupeids and salmonids were collected from the main channels.

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APPENDIX

APPENDIX A. GENERIC LIST OF PHYTOPLANKTON IN THE BUFFALO RIVER AND THE THREE TAILWATERS (DENNIE, 1967)

TAXA	BEAVER	NORFORK	BULL SHOALS	BUFFALO RIVER
Chlorophyta				
Actinastrum	x	x	x	
Ankistrodesmus	x			x
Aphanochaete	x			
Basicladia	x	x	x	x
Bulbochaete	x	x	x	x
Chaetophora	x	x	x	x
Cladophora	x	x	x	x
Closteriopsis	x	x	x	
Closterium	x	x	x	x
Coelastrum	x			
Coleochaete		x	x	
Desmidium	x	x		x
Draparnaldia	x	x	x	
Draparnaldiopsis	x	x	x	
Eudorina	x	x	x	x
Genicularia		x	x	x
Gonatozygon		x		
Gymnozyga		x		x
Hyalotheca	x	x	x	x
Hydrodictyon				x
Micrasterias			x	x
Micractinium	x	x		
Microspora	x	x	x	x
Microthamnion				x
Mougeotia	x	x	x	x
Oedogonium	x	x	x	x
Pandorina	x	x		x
Pediastrum	x	x	x	x
Pleodorina	x	x	x	x
Pleurotaenium	x	x	x	x
Rhizoclonium	x	x	x	x
Schizogonium	x		x	x
Selenastrum				x
Sorastrum				x
Spirogyra	x	x	x	x
Spirotaenia	x			x
Staurastrum	x	x	x	x
Stigeoclonium	x	x	x	x
Tetraspora	x			x
Treubaria				x
Ulothrix	x	x	x	x

APPENDIX A (continued).

TAXA	BEAVER	NORFORK	BULL SHOALS	BUFFALO RIVER
Volvox	x			x
Westella	x			
Zygnema	x	x	x	x
Euglenophyta				
Euglena	x			
Trachelomonas	x	x	x	x
Chrysophyta				
Achnanthes	x	x	x	x
Amphicampa	x			
Amphora	x	x	x	x
Anomoeoneis	x	x	x	
Asterionella	x	x	x	x
Chaetoceros				x
Cymbella	x	x	x	x
Diatoma	x	x	x	
Dinobryon	x	x	x	x
Epithemia	x		x	x
Eunotia	x	x	x	x
Fragilaria	x	x	x	x
Frustulia	x	x	x	
Gomphonema	x	x	x	x
Gyrosigma	x		x	x
Mallomonas		x		
Melosira	x	x	x	x
Meridion	x	x	x	x
Navicula	x	x	x	x
Nitzschia	x	x	x	x
Peroniella	x	x		
Pinnularia	x	x	x	x
Rhopalodia	x	x	x	x
Stauroneis	x	x	x	x
Stephanodiscus	x	x	x	x
Surirella	x	x	x	x
Synedra	x	x	x	x
Tabellaria	x	x	x	x
Terpsinoë		x		
Tribonema	x	x	x	x
Pyrrophyta				
Ceratium	x	x	x	x
Peridinium	x	x	x	

APPENDIX A (continued).

TAXA	BEAVER	NORFORK	BULL SHOALS	BUFFALO RIVER
Cyanophyta				
Agmenellum	x			x
Anabaena	x	x	x	x
Anabaenopsis				x
Anacystis	x	x	x	x
Aphanizomenon	x	x		
Aphanocapsa	x	x		
Chroococcus				x
Coelosphaerium	x	x	x	x
Dichothrix	x	x		x
Gloeotrichia				x
Gomphosphaeria	x	x	x	x
Lyngbya	x	x	x	x
Microcoleus	x			x
Nostoc			x	x
Oscillatoria	x	x	x	x
Phormidium	x	x	x	x
Plectonema		x		x
Rivularia	x	x	x	x
Spirulina	x	x	x	x
Symploca	x	x	x	
Rhodophyta				
Audouinella	x	x	x	x
Batrachospermum	x	x	x	x

APPENDIX B. GENERIC LIST OF ZOOPLANKTON IN THE BUFFALO RIVER AND THE THREE TAILWATERS (DENNIE, 1967)

TAXA	BEAVER	NORFORK	BULL SHOALS	BUFFALO RIVER
Protozoa				
Actinosphaerium				x
Arcella	x	x		x
Centropyxis	x	x	x	x
Codonella	x	x	x	x
Difflugia	x	x	x	x
Epistylis	x	x	x	x
Paracinta	x			x
Sphaerophrya	x			x
Vorticella	x	x		x
Rotifera				
Asplanchna	x			x
Brachionus	x	x	x	x
Cephalodella	x	x	x	x
Collotheca	x	x		x
Conochiloides	x	x		
Conochilus	x	x	x	
Digononta	x	x	x	x
Euchlanis	x	x	x	x
Filinia	x	x	x	x
Gastropus	x		x	x
Kellicottia	x	x		x
Keratella	x	x	x	x
Lecane	x	x		x
Macrochaetus	x			x
Monostyla	x	x		x
Notholca	x			x
Platyias			x	x
Polyarthra	x	x	x	x
Scaridium				x
Synchaeta	x	x	x	x
Testudinella	x	x	x	x
Trichocerca	x	x	x	x
Trichotria	x		x	x
Cladocera				
Alona	x		x	x
Bosmina	x	x	x	x

APPENDIX B (continued).

TAXA	BEAVER	NORFORK	BULL SHOALS	BUFFALO RIVER
Bosminopsis				x
Ceriodaphnia	x	x	x	
Chydorus	x		x	x
Daphnia	x	x	x	x
Diaphanosoma	x	x	x	
Copepoda				
Cyclops	x	x	x	x
Diaptomus	x	x	x	x
Nauplii	x	x	x	x
Ostracoda				x

APPENDIX C. GENERIC LIST OF PHYTOPLANKTON IN THE KINGS RIVER AND THE BEAVER TAILWATER (GRAY, 1970)

TAXA	BEAVER TAILWATER	KINGS RIVER
Chlorophyta		
Ankistrodesmus	x	x
Bulbochaete	x	x
Chaetophora	x	x
Cladophora	x	x
Closteriopsis	x	
Closterium	x	x
Coleochaete	x	
Cosmarium	x	x
Dictyosphaerium	x	
Dimorphococcus		x
Draparnaldia	x	
Eudorina	x	
Geminella	x	x
Gloeocystis	x	x
Gonatozygon	x	
Hormidium	x	
Hyalotheca	x	
Kirchneriella	x	
Microspora	x	x
Mougeotia	x	x
Oedogonium	x	x
Oöcystis	x	x
Pediastrum	x	x
Pithophora	x	
Pleurodiscus	x	
Pleurotaenium	x	x
Scenedesmus	x	x
Sphaerocystis	x	x
Sphaeroplea	x	
Spirogyra	x	x
Spondylosium	x	x
Staurastrum		x
Stigeoclonium	x	x
Tetraëdron	x	x
Tetraspora	x	
Trochiscia	x	
Ulothrix	x	x
Volvox	x	
Zygnema	x	

APPENDIX C (continued).

TAXA	BEAVER TAILWATER	KINGS RIVER
Chrysophyta		
Achnanthes	x	x
Amphora	x	x
Asterionella	x	x
Characiopsis		x
Cyclotella	x	x
Cymbella	x	x
Diatoma	x	x
Dinobryon	x	x
Eunotia	x	x
Fragilaria	x	x
Frustulia	x	x
Gomphonema	x	x
Gyrosigma	x	x
Hydrurus		x
Mallomonas	x	x
Melosira	x	x
Meridion	x	x
Navicula	x	x
Nitzschia	x	x
Pinnularia	x	x
Stauroneis	x	x
Stephanodiscus	x	x
Surirella	x	x
Synedra	x	x
Tabellaria	x	x
Tribonema	x	x
Cyanophyta		
Agmenellum	x	
Anabaena	x	x
Anacystis	x	x
Aphanizomenon	x	
Gomphosphaeria	x	x
Nodularia	x	
Nostoc		x
Oscillatoria	x	x
Plectonema		x
Rivularia	x	x
Spirulina	x	x
Stichosiphon	x	

APPENDIX C (continued).

TAXA	BEAVER TAILWATER	KINGS RIVER
Euglenophyta		
Euglena	x	x
Phacus	x	x
Trachelomonas	x	x
Pyrrophyta		
Ceratium	x	x
Peridinium	x	x
Rhodophyta		
Audouinella	x	x
Batrachospermum	x	x

APPENDIX D. GENERIC LIST OF ZOOPLANKTON IN THE KINGS RIVER AND THE BEAVER TAILWATER (GRAY, 1970)

TAXA	BEAVER TAILWATER	KINGS RIVER
Protozoa		
<u>Actinosphaerium</u>	x	x
<u>Arcella</u>	x	x
<u>Centropyxis</u>	x	x
<u>Codonella</u>		x
<u>Colpoda</u>	x	x
<u>Difflugia</u>	x	x
<u>Epistylis</u>	x	x
<u>Euplotes</u>		x
<u>Vorticella</u>	x	x
Rotifer		
<u>Asplanchna</u>	x	x
<u>Brachionus</u>	x	x
<u>Cephalodella</u>		x
<u>Conochilus</u>	x	x
<u>Euchlanis</u>		x
<u>Filinia</u>		x
<u>Gastropus</u>	x	x
<u>Hexarthra</u>		x
<u>Kellicottia</u>	x	x
<u>Keratella</u>	x	x
<u>Lecane</u>	x	
<u>Monostyla</u>	x	x
<u>Philodina</u>	x	x
<u>Platyias</u>	x	x
<u>Polyarthra</u>	x	x
<u>Synchaeta</u>	x	x
<u>Testudinella</u>		x
<u>Trichotria</u>	x	x
Cladocera		
<u>Alona</u>		x
<u>Bosmina</u>	x	x
<u>Ceriodaphnia</u>	x	
<u>Chydorus</u>		x
<u>Daphnia</u>	x	x
<u>Simocephalus</u>	x	

APPENDIX D (continued).

TAXA	BEAVER TAILWATER	KINGS RIVER
Copepoda		
Cyclops	x	x
Diaptomus	x	x
Nauplii	x	x
Ostracoda	x	x

APPENDIX E. DOMINANT PHYLA OF PHYTOPLANKTON EXPRESSED AS PER CENT OF AVERAGE CELLS PER LITER

STATION	Buffalo River		Kings River 1		Kings River 2		Beaver 1		Beaver 1		Beaver 2	
YEAR	1966		1968		1968		1966		1968		1966	
SYMBOL	C5 & C6		KR1		KR2		B1L		B1		B2L	
	Avg. Cells Per Liter	%	Avg. Cells Per Liter	%	Avg. Cells Per Liter	%	Avg. Cells Per Liter	%	Avg. Cells Per Liter	%	Avg. Cells Per Liter	%
Chrysophyta	991	25	273	47	278	43	2,193	26	388	30	713	20
Cyanophyta	1,943	49	128	22	194	30	3,037	36	259	20	2,280	64
Chlorophyta	991	25	174	30	155	24	3,121	37	635	49	534	15
Others	40	1	6	1	19	3	84	1	13	1	36	1
Total	3,965	100	581	100	646	100	8,435	100	1,295	100	3,563	100

	Beaver 2		Beaver 3		Beaver 3		Norfork 1		Norfork 2		Bull Shoals 1	
	1968		1966		1968		1966		1966		1966	
	B2		B3L		B3		N1		N2		BS	
	Avg. Cells Per Liter	%	Avg. Cells Per Liter	%	Avg. Cells Per Liter	%	Avg. Cells Per Liter	%	Avg. Cells Per Liter	%	Avg. Cells Per Liter	%
Chrysophyta	900	42	663	13	1,093	18	10,936	74	5,567	36	11,175	78
Cyanophyta	686	32	3,928	77	2,794	46	2,956	20	7,887	51	1,719	12
Chlorophyta	493	23	459	9	2,126	35	739	5	1,856	12	1,146	8
Others	64	3	51	1	61	1	148	1	155	1	286	2
Total	2,143	100	5,101	100	6,074	100	14,779	100	15,465	100	14,326	100

APPENDIX F. DOMINANT GENERA OF CHRYSOPHYTA EXPRESSED IN PER CENT OF CELLS PER LITER

STATION	SYMBOL	AVG. NO. OF CELLS PER LITER	FRAGILARIA	MELOSIRA	ASTERIONELLA	TABELLARIA	SYNEDRA	ACHNANTHES	DINOBRYON	TRIBONEMA	OTHERS	TOTAL
Buffalo River (1966)	C5 & C6	991	22	12	1	8	10	36	0	0	11	100
Kings River 1 (1968)	KR1	273	8	42	1	3	6	0	19	7	14	100
Kings River 2 (1968)	KR2	278	17	33	2	3	9	0	10	12	14	100
Beaver 1 (1966)	B1L	2,193	32	36	16	12	1	2	0	0	1	100
Beaver 1 (1968)	B1	388	75	2	3	7	1	0	4	2	6	100
Beaver 2 (1966)	B2L	713	45	16	21	10	1	2	0	0	5	100
Beaver 2 (1968)	B2	900	79	2	2	7	2	0	5	0	3	100
Beaver 3 (1966)	B3L	663	52	11	17	8	3	3	0	0	6	100
Beaver 3 (1968)	B3	1,093	85	2	2	5	1	0	2	0	3	100
Norfork 1 (1966)	N1	10,936	54	24	13	1	6	1	0	0	1	100
Norfork 2 (1966)	N2	5,567	5	50	2	4	0	35	0	0	4	100
Bull Shoals 1 (1966)	BS	11,175	57	24	3	2	1	11	0	0	2	100

APPENDIX G. DOMINANT GENERA OF CYANOPHYTA EXPRESSED IN PER CENT OF CELLS PER LITER[1]

STATION	SYMBOL	AVG. NO. OF CELLS PER LITER	OSCILLATORIA	PHORMIDIUM	LYNGBYA	ANABAENA	GOMPHOSPHAERIA	ANACYSTIS	OTHERS	TOTAL
Buffalo River (1966)	C5 & C6	1,943	(19) 8	7	4	70	1	0	10	100
Kings River 1 (1968)	KR1	128	87	0	0	2	0	10	1	100
Kings River 2 (1968)	KR2	194	85	0	0	2	1	5	7	100
Beaver 1 (1966)	B1L	3,037	(91) 87	3	1	2	2	0	5	100
Beaver 1 (1968)	B1	259	77	0	0	2	9	8	4	100
Beaver 2 (1966)	B2L	2,280	(96) 74	15	7	2	1	0	1	100
Beaver 2 (1968)	B2	686	89	0	0	1	1	3	6	100
Beaver 3 (1966)	B3L	3,928	(98) 57	24	17	0	1	0	1	100
Beaver 3 (1968)	B3	2,794	95	0	0	2	1	1	1	100
Norfork 1 (1966)	N1	2,956	(86) 42	38	6	1	6	0	7	100
Norfork 2 (1966)	N2	7,887	(76) 34	36	6	0	1	0	23	100
Bull Shoals (1966)	BS	1,719	(80) 51	21	8	16	2	0	2	100

[1] In the earlier study (Stations C5 and C6, B1L, B2L, B3L, N1, N2, and BS) the oscillatoriaceae were considered as separate genera, Oscillatoria, Phormidium, and Lyngbya; for clarification the sum of these three genera is given in parenthesis.

APPENDIX H. DOMINANT GENERA OF CHLOROPHYTA EXPRESSED AS PER CENT OF CELLS PER LITER

STATION	SYMBOL	AVG. NO. OF CELLS PER LITER	SPIROGYRA	PEDIASTRUM	STIGEOCLONIUM	DRAPARNALDIA	CHAETOPHORA	ULOTHRIX	MICROSPORA	CLADOPHORA	OTHERS	TOTAL
Buffalo River (1966)	C5 & C6	991	80	5	2	0	2	1	2	1	7	100
Kings River 1 (1968)	KR1	174	0	12	0	0	6	21	0	47	14	100
Kings River 2 (1968)	KR2	155	0	22	7	0	17	14	0	26	14	100
Beaver 1 (1966)	B1L	3,121	8	11	17	51	0	5	2	2	4	100
Beaver 1 (1968)	B1	635	0	10	10	0	26	15	0	24	15	100
Beaver 2 (1966)	B2L	534	25	33	13	7	2	4	4	7	5	100
Beaver 2 (1968)	B2	493	0	15	5	0	53	8	0	2	17	100
Beaver 3 (1966)	B3L	459	38	19	13	3	4	3	4	3	13	100
Beaver 3 (1968)	B3	2,126	0	3	20	0	65	6	0	1	5	100
Norfork 1 (1966)	N1	739	4	35	5	1	13	6	18	4	14	100
Norfork 2 (1966)	N2	1,856	1	8	7	0	13	27	32	5	7	100
Bull Shoals 1 (1966)	BS	1,146	2	15	27	1	22	11	8	4	10	100

APPENDIX I. DOMINANT TAXA OF ZOOPLANKTON EXPRESSED AS PER CENT OF AVERAGE ORGANISMS PER LITER

STATION	Buffalo River		Kings River 1		Kings River 2		Beaver 1		Beaver 1		Beaver 2	
YEAR	1966		1968		1968		1966		1968		1966	
SYMBOL	C5 & C6		KR1		KR2		B1L		B1		B2L	
	Avg. Org. Per Liter	%	Avg. Org. Per Liter	%	Avg. Org. Per Liter	%	Avg. Org. Per Liter	%	Avg. Org. Per Liter	%	Avg. Org. Per Liter	%
Rotifera	11.8	62.0	7.8	57.8	10.0	65.3	5.2	40.0	1.2	24.5	4.0	43.0
Copepoda	1.9	10.0	2.9	21.5	3.2	20.9	3.0	23.0	3.0	61.2	2.1	23.0
Protozoa	4.6	24.0	2.7	19.7	1.4	9.2	3.0	23.0	0.4	8.2	1.7	19.0
Cladocera	0.76	4.0	0.1	1.0	0.2	1.3	1.8	14.0	0.3	6.1	1.4	15.0
Others		0.0	0.0	0.0	0.5	3.3	0.0	0.0	0.0	0.0	0.0	0.0
Total	19.1	100.0	13.5	100.0	15.3	100.0	13.0	100.0	4.9	100.0	9.2	100.0

STATION	Beaver 2		Beaver 3		Beaver 3		Norfork 1		Norfork 2		Bull Shoals 1	
YEAR	1968		1966		1968		1966		1966		1966	
SYMBOL	B2		B3L		B3		N1		N2		BS	
	Avg. Org. Per Liter	%	Avg. Org. Per Liter	%	Avg. Org. Per Liter	%	Avg. Org. Per Liter	%	Avg. Org. Per Liter	%	Avg. Org. Per Liter	%
Rotifera	0.9	21.4	5.5	50.0	1.1	22.2	7.8	43.0	15.0	60.0	6.9	46.0
Copepoda	1.9	45.2	2.5	23.0	2.7	55.5	6.1	34.0	5.0	20.0	4.8	32.0
Protozoa	0.5	11.9	1.9	17.0	0.2	4.1	1.4	8.0	2.5	10.0	1.5	10.0
Cladocera	0.9	21.4	1.1	10.0	0.9	18.2	2.7	15.0	2.5	10.0	1.8	12.0
Others	P.	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	4.2	100.0	11.0	100.0	4.9	100.0	18.0	100.0	25.0	100.0	15.0	100.0

P. = present

APPENDIX J. DOMINANT TAXA EXPRESSED AS PER CENT OF TOTAL ORGANISMS

STATION	SYMBOL	AVG. NO. PER SQ. FT.	AVG. WT. PER SQ. FT.	TRICHOPTERA	EPHEMEROPTERA	COLEOPTERA	CHIRONOMIDAE	GASTROPODA	PLECOPTERA	OLIGOCHAETA	TURBELLARIA	MEGALOPTERA	ZYGOPTERA	OTHERS	NO. OF SAMPLES
Buffalo River (1966)	C5 & C6	102	0.37	5%	17%	36%	6%	22%	2%	3%	P	P	7%	2%	19
Kings River 1 (1968)	KR1	103	2.34	48	25	5	10	4	3	P	3	1	0	1	20
Kings River 2 (1968)	KR2	63	2.74	25	35	9	4	15	5	1	P	4	P	1	20

APPENDIX J. (CONTINUED)

STATION	SYMBOL	AVG. NO. PER SQ. FT.	AVG. WT. PER SQ. FT.	CHIRONOMIDAE	ISOPODA	OLIGOCHAETA	AMPHIPODA	TURBELLARIA	OTHERS	NO. OF SAMPLES
Beaver 1 (1966)	B1L	82	0.10 gms.	46%	7%	44%	0	1%	2%	61
Beaver 1 (1968)	B1	36	0.07	52	22	10	2	7	7	20
Beaver 2 (1966)	B2L	115	0.16	55	1	40	0	1	3	55
Beaver 2 (1968)	B2	93	0.10	94	0	1	0	3	2	18
Beaver 3 (1966)	B3L	38	0.15	58	6	14	0	6	16	52
Beaver 3 (1968)	B3	52	0.05	92	1	1	0	3	3	25
Bull Shoals 1 (1966)	BS*	163	0.54	38	11	1	49	1	0	11
Bull Shoals 2 (1966)	C1 & C2*	30	0.23	23	21	38	4	1	13	11
Norfork 1 (1966)	N1	244	1.03	38	49	9	0	1	3	10
Norfork 2 (1966)	N2	173	0.67	21	69	1	3	2	4	9

*Referred to as BS1 and BS2 in Brown, Liston, and Dennie (1967)