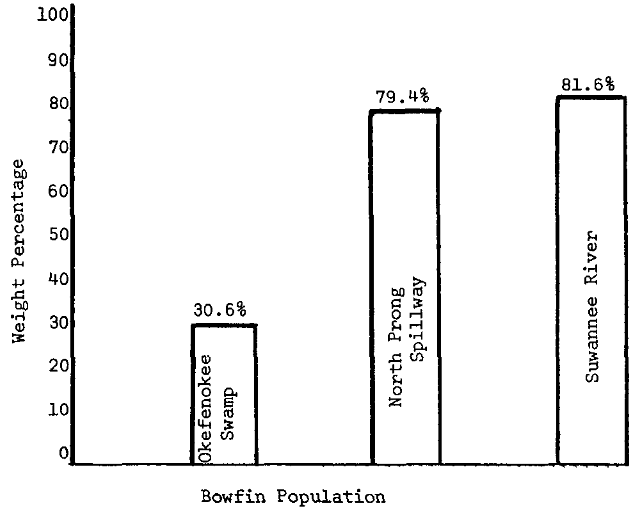

Figure 10 Comparison of Bowfin Weight Percentages of Fish Population in the Okefenokee Swamp, Over the East Prong Spillway, and in the Suwannee River

SEASONAL CYCLES OF NET PLANKTON IN A COLD-TAILWATER AND A NATURAL STREAM IN THE STATE OF ARKANSAS

by

John S. Gray
Department of Zoology, University of Arkansas
Fayetteville, Arkansas

ABSTRACT

The information presented here is a phase of an overall investigation entitled "Environmental Changes Produced by Cold-water Outlets from Three Arkansas Reservoirs", supported by funds provided by the Office of Water Resources Research, and published in a bulletin by Hoffman and Kilambi (1970). The data herein presented compare the seasonal cycles of net plankton of a natural stream (Kings River) with a new tailwater (Beaver Reservoir, impounded in 1965). Quantitative net plankton abundance and physico-chemical conditions at each area were monitored bimonthly from September 1967, through October 1968.

Mid-winter blooms of Chrysophyta at the Beaver Dam stations were preceded by an increase in average monthly temperatures and followed by a decrease in silica concentrations. Downstream from Beaver Dam, late summer blooms of Cyanophyta were recorded. Most of these increases occurred in conjunction with high average dissolved oxygen concentrations and temperatures. At the Kings River, winter blooms of Chlorophyta coincided with maximum dissolved oxygen concentrations. Summer blooms appeared to show a positive correlation with increases in temperature and dissolved oxygen concentrations.

Zooplankters were most abundant during the winter months at the Beaver Dam stations. Consequent net zooplankton decreases appeared to be inversely proportional to the average seasonal temperature. From July to October 1968, the Kings River stations showed a positive correlation of zooplankton number with seasonal increases in temperatures and decreases in average riffle speeds.

INTRODUCTION

A large part of the White River in northwestern Arkansas has been transformed into a series of large reservoirs by the construction of hydroelectric dams. This has resulted in many physico-chemical and biological changes within the impoundment and in downstream cold-tailwaters. The cold-tailwater below Beaver Dam on the White River offers an excellent opportunity to study such a change. A cold-tailwater, as defined by Pfitzer (1962), is the river below the dam, from the dam downstream to the mouth or to the next impoundment.

The general objective of this investigation was to compare the seasonal cycles of net plankton of the cold-tailwater below Beaver Dam with the Kings River, a natural free-flowing warm-water stream. Productivities of phytoplankton and zooplankton were compared to relevant physico-chemical factors and hydroelectric generation times.

A similar study was conducted by Dennie (1967) on the cold-tailwaters of three reservoirs in northern Arkansas. Related physico-chemical studies were conducted by Fish (1959) on the effects of impoundment on downstream water quality, Pfitzer (1962) on the physico-chemical characteristics of several tailwaters in the TVA system, and Churchill (1956) on the effects of storage impoundments on water quality. Other relevant studies are by McCombie (1953) on factors influencing the growth of phytoplankton and the recent federal report on Water Quality Criteria (1968). Correlated plankton studies include the following: Hartman and Himes (1961) on phytoplankton from Pymatuning Reservoir in downstream areas; Cushing (1964) on plankton and water chemistry in lakes and streams in Canada; and Williams (1966) a study of the common rotifers of major United States water ways.

DESCRIPTION OF STUDY AREAS

The White and Kings Rivers are located in the Ozark Plateau; the highest and most southern part of this plateau is comprised of the Boston Mountains. These rivers as well as many of their tributaries originate from the north slope of these mountains. The mountains are narrow and form deep, irregular canyon-like drainage basins. The northern part is a more open plateau. Stream beds consist mainly of bedrock, rubble, gravel, and sand with silt occurring in the areas with a slight current. The most common surface rocks are dolomites and limestones (Branner, 1927).

The White River originates in the Boston Mountains near the western border of Arkansas. It flows in a northeasterly direction and enters Missouri from Carroll County, Arkansas. It re-enters Arkansas in Boone County and flows southeasterly, uniting with the Arkansas River near its confluence with the Mississippi River. The stream drains an area of 28,000 square miles and is approximately 690 miles in length (Figure 1).

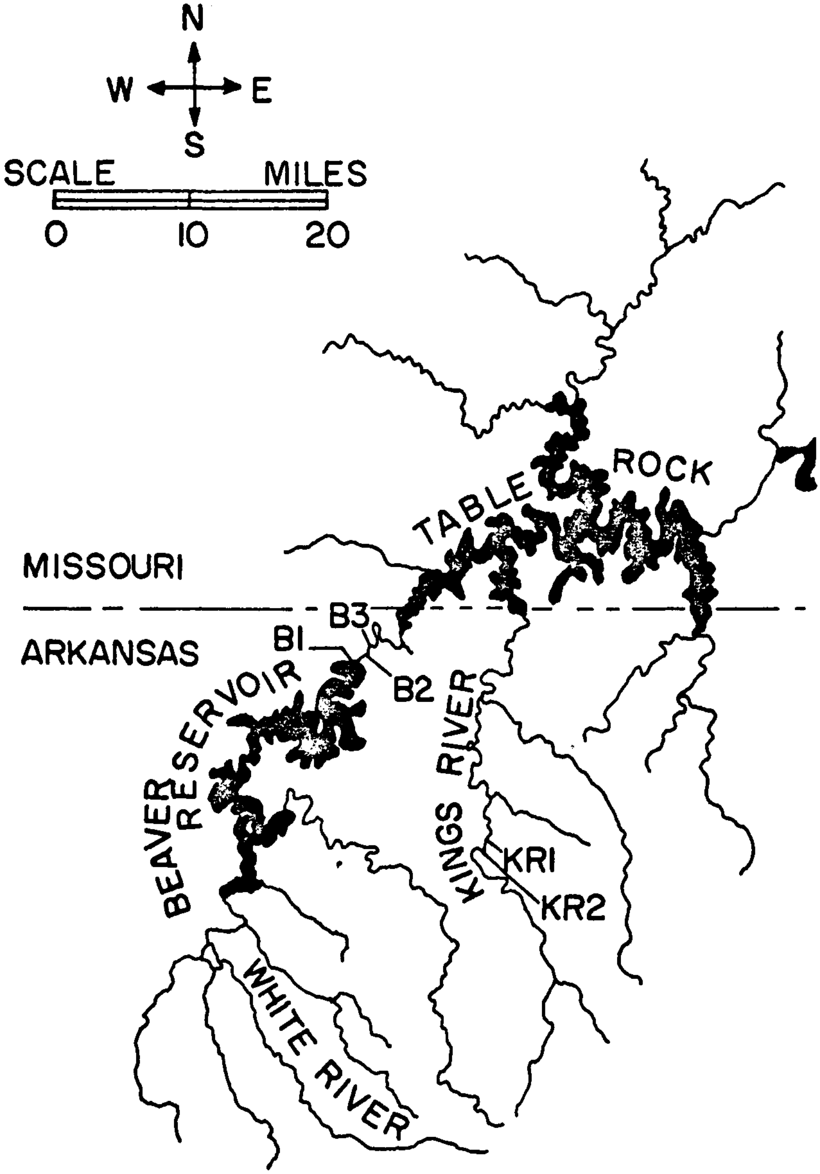

Figure 1. Map of the General Study Area and Various Collecting Sites.

The uppermost part of the White River, in Carroll County, was impounded by Beaver Dam. Construction of this dam was initiated in November 1960, and was completed in June of 1966. The effluent from Beaver Dam enters Table Rock Reservoir 4.5 miles downstream from the dam. Electric power generation was begun on May 14, 1965, and has continued generally on a daily basis subject to power demands. Beaver Dam is 228 feet high, and minimum and maximum discharges are 60 cfs and 5,000 cfs. The average annual discharge is 1,550 cfs.

Sample areas on the White River were B1, B2, and B3 located 0.25, 1.9, and 3.5 miles, respectively, below Beaver Dam (Figure 1). Sample areas were selected because of their accessibility and/or distances from one another. All stations were subject to fluctuations in depth during periods of power generation. Depths of 10 feet were not uncommon.

The Kings River originates in the southeastern corner of Madison County, Arkansas, and flows northerly into Table Rock Reservoir in Carroll County. The stream is approximately 47 miles in length (Figure 1). The topography of the drainage area consists mainly of limestone cliffs. At present the Kings River is a natural free-flowing warm-water stream, subject to extreme physical variations.

Stations along the Kings River were designated as KR1 and KR2. KR1 was approximately 0.25 of a mile upstream from the Highway 68 bridge which is located 0.50 of a mile east of Marble, Arkansas. Station KR2 was located beneath this bridge (Figure 1). These sample areas were selected because of their differences in habitat and riffle speed.

MATERIALS AND METHODS

Sampling stations were established in July 1965, in the Beaver cold-tailwater and in the Kings River in September of 1967. Collecting trips in the 1967-68 study were made bimonthly from September 1967, through October 1968.

Quantitative net plankton (mesoplankton) samples were collected at each station with a standard Wisconsin cone-shaped number 25 silk bolting cloth plankton net. Samples were obtained by concentrating 20 liters of water to 20 milliliters. A direct count of 1 milliliter volume was made from each sample with a Sedgwick-Rafter counting cell, each milliliter being the equivalent of one liter. Results were tallied and recorded as cells or organisms per liter.

On each collecting trip, time of day, weather and general water conditions were recorded. Riffle width measurements were taken with a calibrated steel tape. Depth measurements were taken with a stick rule calibrated in inches. Riffle speed was determined using a float traveling a specified distance. Water and air temperatures were taken with mercury thermometers calibrated to one-tenth and one degree Celsius, respectively. Chemical qualities of the water at each station were analyzed and are presented in detail by Gray (1970).

RESULTS AND DISCUSSION

Seasonal Cycles-Phytoplankton

The seasonal abundance of total net phytoplankton at the three stations along the tailwater below Beaver Reservoir and at the Kings River is presented in Figure 2.

The bloom of net phytoplankton recorded at station B3 in September 1967, was due to a marked increase in the diatom *Fragilaria* (6,954 cells per liter), Two months later, station B2 exhibited a bloom of plytoplankton due to a pulse of *Fragilaria* (6,523 cells per liter). In March 1968, all three Beaver Reservoir stations exhibited a marked increase in net phytoplankton numbers due to pulses of *Fragilaria*. Station B2 exhibited the most prolific pulse (4,360 cells per liter). Station B3 displayed a density of 4,317 cells per liter and station Bl 3,064 cells per liter.

The March bloom of Chryosphyta might be correlated with the increased generation discharge time (Figure 3) during this period. The sudden rise in average monthly temperatures at all three stations (Figure 4) may also have been an important stimulus. Silica concentrations were not extremely high during this bloom, but do exhibit a considerable decrease in the following two months (Figure 5). Low silica concentrations may have been due to the increased utilization of silica in the formation of diatom valves.

At station B2 in June 1968, there was a small pulse of *Chaetophora* (320 cells per liter), a green alga, and slightly larger pulse of *Audouinella* (594 cells per liter), a red alga (Rhodophyta). July and August was a period of high net phytoplankton density at station B3. In July 1968, there was a prodigious bloom of the blue-green alga *Oscillatoria* (11,255 cells per liter) and of *Chaetophora* (6,615 cells per liter). By August 1968, members of the genus *Oscillatoria* had decreased to 3,718 cells per liter and *Chaetophora* to 5,047 cells per liter. Other increases in net phytoplankton during this two month period were at station Bl (July 1968), where a bloom of *Stigeoclonium,* a green alga occurred, (533 cells per liter); and at station B2 (August 1968), where a bloom of *Oscillatoria* occurred (1,610 cells per liter). In October 1968, station B3 experienced another bloom of *Oscillatoria* (4,569 cells per liter).

At all Beaver Reservoir tailwater stations, high average dissolved oxygen concentrations (Figure 6) preceded the late summer net phytoplankton blooms. The high average temperature in June of 1968 (Figure 4), along with increased dissolved oxygen concentrations (Figure 6), may have stimulated the July bloom of *Oscillatoria* and *Chaetophora* at station B3. Similar physicochemical conditions coincided with the July bloom of *Stigeoclonium* at station B2. As the total net phytoplankton increased during this period, the dissolved oxygen concentrations decreased (Figures 2 and 6). Low dissolved oxygen concentrations in correlation with an average temperature drop may have been some of the factors causing the early autumnal decrease in total net phytoplankton at the Beaver tailwater stations. The August bloom of *Oscillatoria* at station B2 and the October bloom of *Oscillatoria* at station B3 did not appear to be directly correlated with any of the monitored physicochemical factors.

The seasonal distribution of net phytoplankton at the Kings River stations showed more of a bimodal distribution than the beaver tailwater stations (Figure 2).

During December 1967, there was an increase in net phytoplankton at both Kings River stations. An increase of *Cladophora*, a green alga,' was responsible. At station KR1 *Cladophora* densities reached 1,725 cells per liter and at station KR2, 820 cells per liter. In April of 1968, station KR2 experienced a small pluse of *Oscillatoria* (340 cells per liter) and the green alga *Spondylosium* (196 cells per liter). The following month at station KR1 a bloom of *Ulothrix,* a green alga, was recorded (263 cells per liter). During June of 1968 there was a small bloom of *Tribonema,* a yellow-green alga (128 cells per liter) at station KR2. The following month, this station exhibited a slight pulse of both *Chaetophora* and *Oscillatoria* (268 and 170 cells per liter, respectively). At station KR1 *Dinobryon,* a yellow-green alga, pulsed in August 1968, (466 cells per liter). This pulse was followed by a September bloom of the diatom *Melosira* (922 cells per liter).

At both Kings River stations, the December bloom of *Cladophora* (Figure 2) coincided with maximum dissolved oxygen concentrations (Figure 6). A seasonal temperature increase (Figure 4) in March 1968, preceded the April bloom of *Oscillatoria* at station KR2. The following month, increased riffle speeds (Figure 7) and high oxygen concentrations (Figure 6) correlated with the KR1 bloom of *Ulothrix.* At station KR2, the June bloom of *Tribonema* and the July bloom of *Chaetophora* and *Oscillatoria* may have been influenced by increased seasonal temperatures (Figure 4). There appears to be no positive correlation between physico-chemical fluctuations and the August bloom of *Dinobryon* at station KR1. However, the September bloom of *Melosira* at KR1 was preceded by a marked increase in silica concentrations (Figure 5) and a similar but less dramatic increase in dissolved oxygen concentration (Figure 6).

Seasonal Cycles-Zooplankton

The seasonal abundance of total net zooplankton at the three stations along the tailwater below Beaver Reservoir and at the Kings River is presented in Figure 8.

Stations B2 and B3 showed an increase in net zooplankton in December 1967. The augmentation of net zooplankton was due to the presence of the Cladocerans, *Bosmina* (12 organisms per liter, B3) and *Daphnia* (6 organisms per liter, B2). The abundance of net zooplankton coincided with a marked increase in generation time at Beaver Reservoir (Figure 3) and extremely high dissolved oxygen concentration at both stations (Figure 6). It is interesting to note that net phytoplankton abundance decreased (Figure 2) at both stations during this month. This may possibly be due to the grazing of the increased numbers of *Bosmina* and *Daphnia.*

In February 1968, copepod nauplii (14 organisms per liter) accounted for the increase in net zooplankton at station B1. Again, this gain in net zooplankton number appears to be correlated with an increased oxygen concentration (Figure 6). Nauplii concentrations remained relatively high at all stations the following month (Figure 8.)

Net zooplankton number slowly decreased at all stations as the summer progressed. The Beaver Reservoir decrease of net zooplankton appears to be inversely proportional to the average seasonal temperature (Figure 4). Additional evidence of this relationship is found in August 1968, when a sudden drop in temperature coincided with a small but distinct increase in zooplankton at stations B1 and B3. This increase was due in part to copepod nauplii (3 organisms per liter, B1; and 2 organisms per liter, B3). During this period, there appeared to be no correlation between dissolved oxygen concentration and zooplankton abundance. Thus during periods of more than optimal temperature, dissolved oxygen concentration no longer seems to be an important stimulus to net zooplankton abundance.

Net zooplankton abundance at the Kings River stations (Figure 8) exhibited more of a seasonal distribution than the Beaver Reservoir stations.

At both the Kings River stations, the rotifer *Gastropus* was responsible for a small increase in net zooplankton in October 1967 (KR1, 4.5 organisms per liter; KR2, 3 organisms per liter). No appreciable increase in net zooplankton number was observed until May of 1968 at station KR2. The rotifer, *Brachionus,* was the most abundant zooplankton at this time (6 organisms per liter). Low average riffle speeds (Figure 7) in conjunction with steadily increasing temperatures (Figure 4) may have been important factors in providing the optimal conditions for the increase in *Brachionus* number.

July of 1968 marked the increase in net zooplankton at both Kings River stations. During this month a protozoan, *Difflugia* (2 organisms per liter) was most abundant at KR1, and the rotifer *Gastropus* (3 organisms per liter) was most abundant at KR2. By August of 1968 the number of net zooplankton had peaked at both stations. The rotifer *Keratella* was responsible for the increase. Both stations exhibited a density of 24 organisms per liter. At station KR2 another rotifer, *Polyarthra* (11 organisms per liter) was found in maximum densities at this time. By September both stations showed a decrease in zooplankton number. Once again, the most abundant zooplankter was *Keratella* (KR1, 12 organisms per liter; KR2, 20 organisms per liter). In October, station KR1 showed an increase in zooplankton number, due in part to the presence of copepod nauplii (15 organisms per liter). At station KR1 zooplankton number decreased. The most abundant zooplankter forms were copepod nauplii (12 organisms per liter).

From July to October 1968, both Kings River stations seem to show a positive correlation of zooplankton number with seasonal increases in temperature (Figure 4) and decreases in average riffle speeds (Figure 7). These factors appear to be more important than dissolved oxygen concentration which during December, the period of maximum concentration (Figure 6), did not appear to stimulate net zooplankton abundance.

ACKNOWLEDGEMENT

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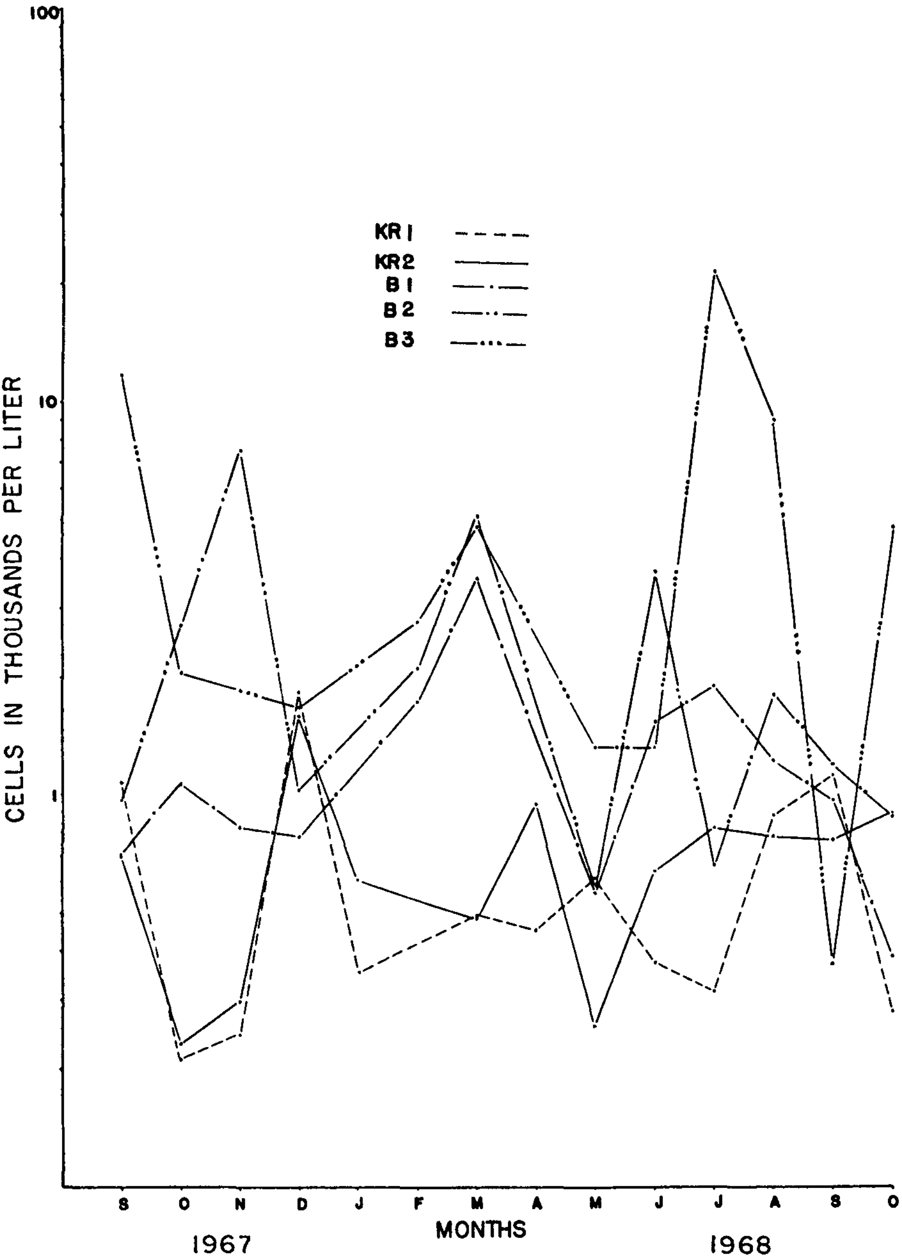

Figure 2. Seasonal Abundance of the Total Net Phytoplankton at Three Stations Along the Tailwater Below Beaver Reservoir and at Two Stations on the Kings River (Plotted on Three Cycle Semi-Logarithmic Graph Paper).

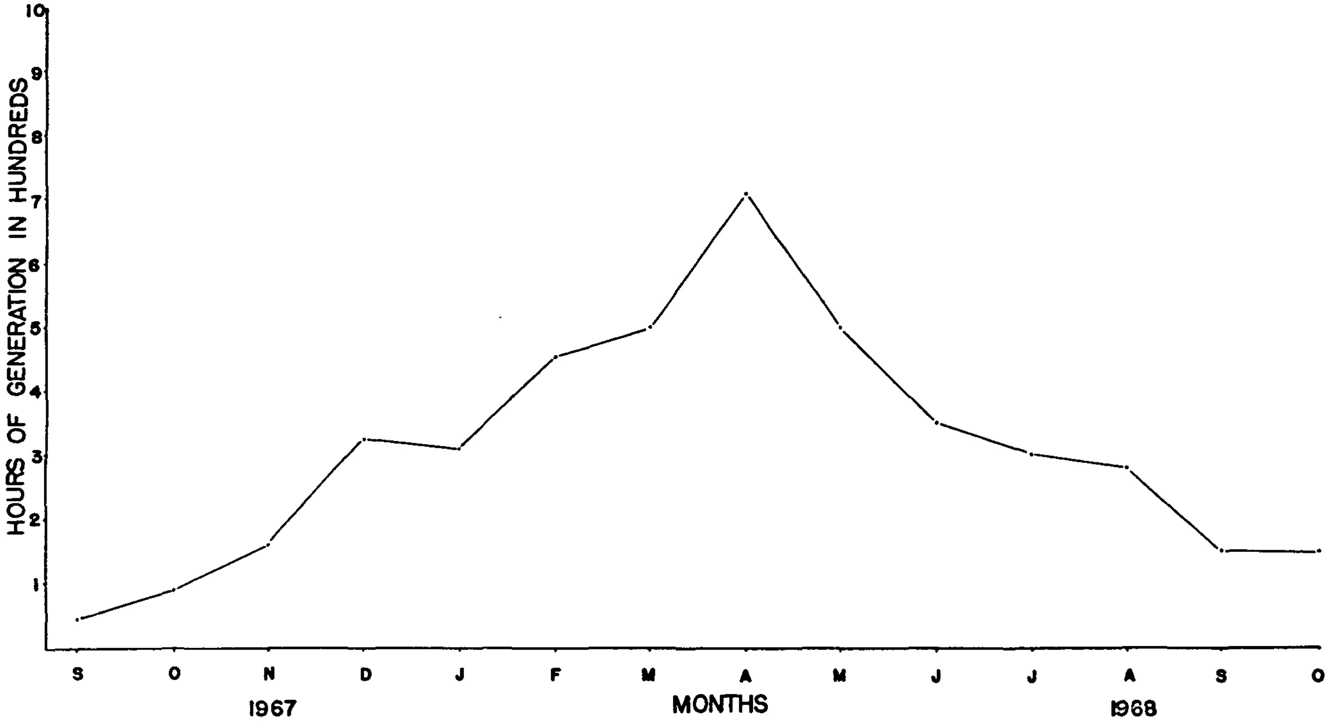

Figure 3. Seasonal Variation of Generation Time at Beaver Reservoir.

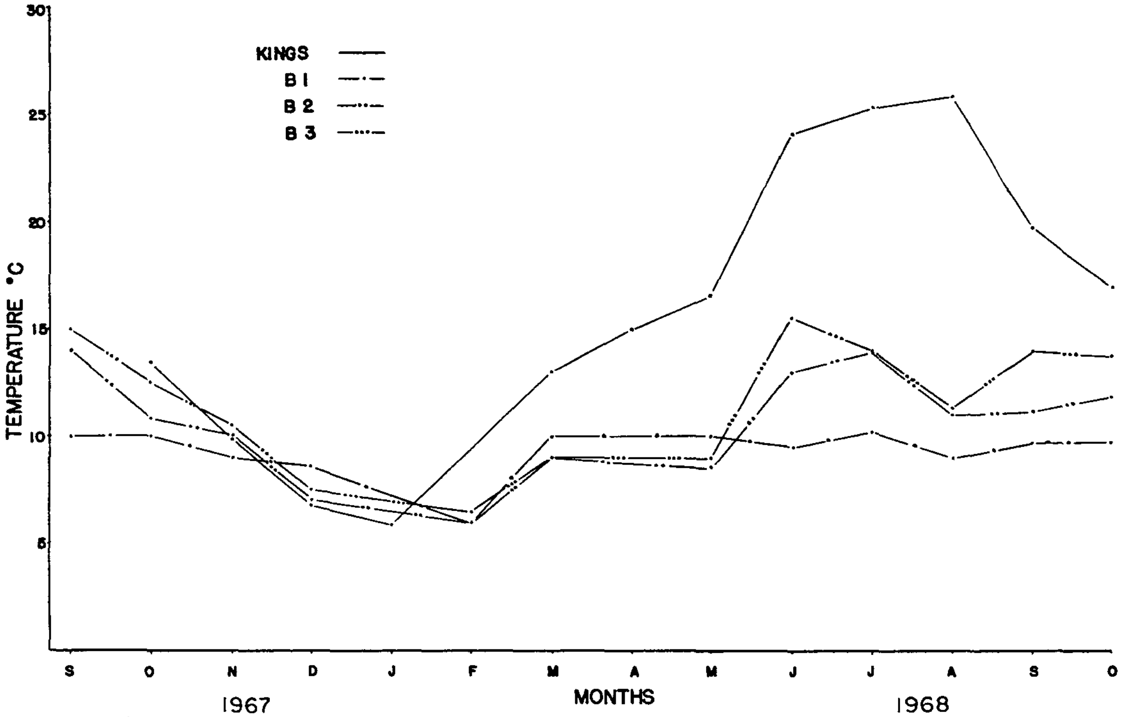

Figure 4. Seasonal Temperature Fluctuation at Three Stations Along the Tailwater Below Beaver Reservoir and at the Kings River.

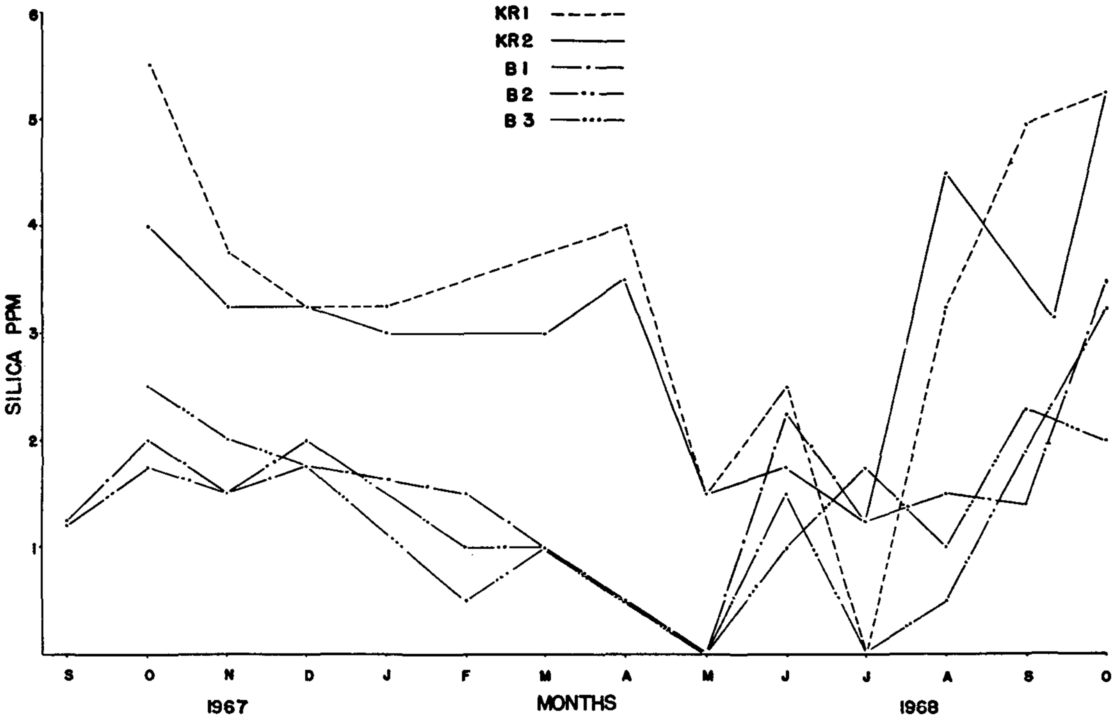

Figure 5. Seasonal Variation in Silica Concentration at Three Stations Along the Tailwater Below Beaver Reservoir and at Two Stations on the Kings River.

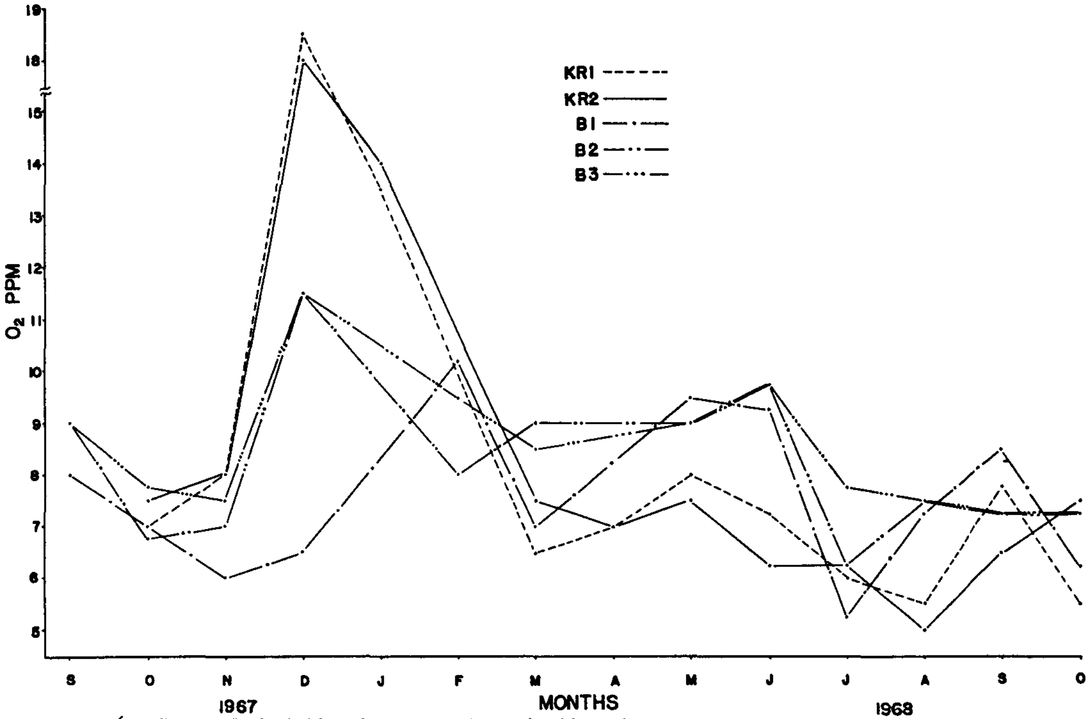

Figure 6. Seasonal Variation in Oxygen Concentration at Three Stations Along the Tailwater Below Beaver Reservoir and at Two Stations on the Kings River.

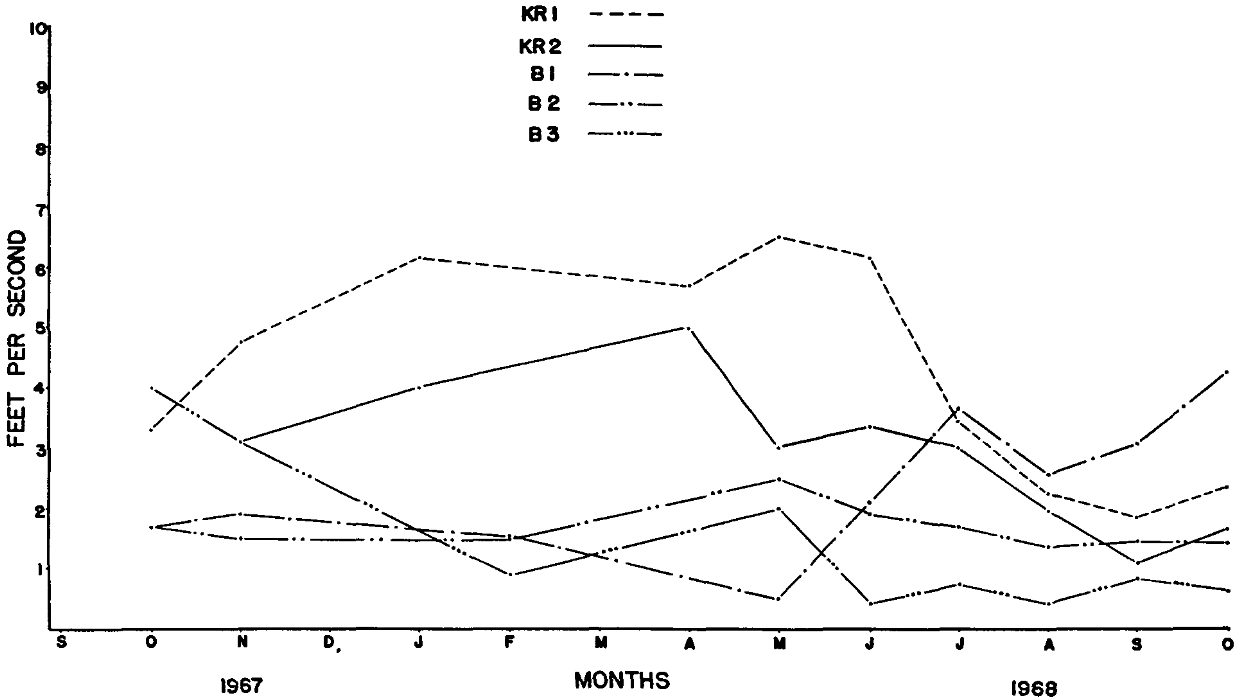

Figure 7. Riffle Speed at Three Stations Along the Tailwater Below Beaver Reservoir and at Two Stations on the Kings River.

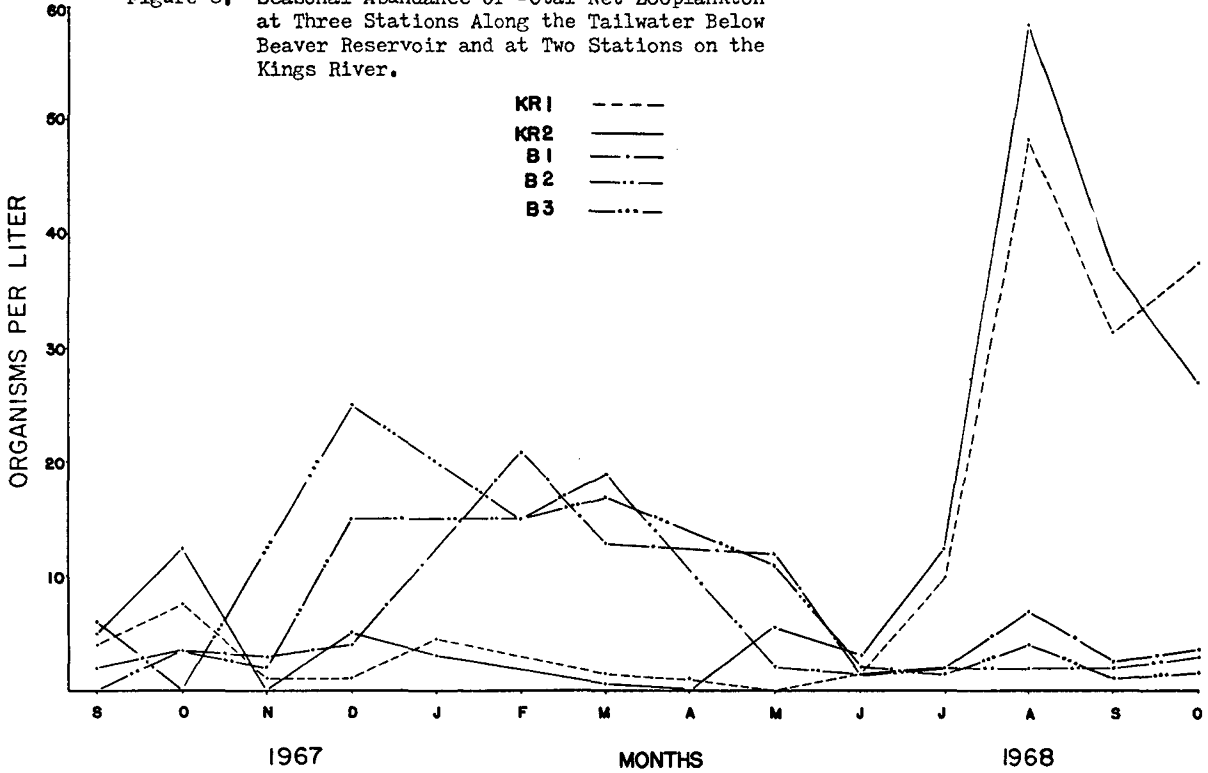

Figure 8. Seasonal Abundance of Total Net Zooplankton at Three Stations Along the Tailwater Below Beaver Reservoir and at Two Stations on the Kings River.