Variations in the Horizontal Abundance of Certain Plankton Species in Flaming Gorge Reservoir

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ABSTRACT

Flaming Gorge is a large reservoir with complicated topographic and hydrographic features. Heterogeneity in spatial relationships and abundance of 14 dominant and codominant species of limnoplankton inhabiting Flaming Gorge Reservoir were examined and contrasted within the reservoir's mainstem and four major arms over a 24-month period. Distinctive tributaries supplied each location, however it was thought that the discharge from the dam had a larger influence than the tributary at any one location.

Results showed that independent limnoplankton populations generally existed in each of the areas studied. Results on individual plankters, delimiting zones of high or low productivity, were nearly as variable as the number of species treated. One diatom, one green alga and one rotifer were distributed randomly over the reservoir. Two myxophycean species demonstrated a marked preference for the midsection of the reservoir. Copepod and cladoceran populations were, for the most part, depressed by conditions near the dam and the influence of the two major tributaries. These same tributaries favored the production of two species of rotifers and three species of diatoms.

Results demonstrated that sampling within one area would not give quantitative and probably not the qualitative information needed to describe the limnoplankton to the entire reservoir.

INTRODUCTION

The pelagic plankton of reservoirs has long been recognized to represent a significant portion of the food pyramid and thereby contribute heavily to the diet of various fish species.

Hutchinson (1967) stated, "In very large lakes, particularly of complicated form, in which there is a possibility of existence of largely independent water masses, the zooplankton populations would not be expected to be uniform horizontally." Welch (1952) pointed out that one of the well-established facts concerning horizontal distribution of plankton was its irregularity in a fair-sized area. Ruttner (1963) noted, "Lasting differences in plankton composition and numbers can occur in shallow waters, irregular basins or isolated portions of lakes." If major and lasting differences occur in the limnoplankton in Flaming Gorge Reservoir, such differences could exert a profound effect on abundance, biology and distribution of fishes.

During the years 1963 through 1966, the nature of the limnoplankton in a newly created mainstem reservoir was investigated as a segment of extensive reservoir fishery investigations concerned principally with rainbow trout (*Salmo gairdneri*). This paper represents a phase of the plankton investigations which attempted to define spatial relationships and abundance of fourteen limnetic plankton species during 1965 and 1966.

The objective was to determine whether there was homogeneity in the abundance of species inhabiting the mainstem reservoir and the four major arms. Each arm receives distinctive tributary waters. Analysis of variance was used to determine significant differences. Relatively few studies have employed parametric tests to accurately pinpoint homgeneity or significant and lasting differences.

DESCRIPTION OF THE AREA

Flaming Gorge Reservoir has been in existence since November 1962. When filled it is approximately 145 km (90 mi) long covers an area of almost 17,000 ha (42,000 surface acres). During this study the reservoir varied between 125 and 135 km long (78 to 84 mi) and ranged between 10,117 and 11,048 ha (25,000 and 27,300 surface acres).

Four tributary and four mainstem reservoir stations were chosen for comparison (Fig. 1). The four tributaries differed limnologically and ranged from soft water with few minerals to hard water that was highly mineralized. Physical and chemical features of the tributaries and their corresponding mid-reservoir stations detail the variations between locations (Table 1).

The four reservoir stations were located in separate and arbitrary divisions of the reservoir based upon topographical, physical and chemcial differences (Eiserman et al. 1967). These areas were the canyon area, open hills area and the inflow area (Fig. 1). The inflow area of the reservoir reflects the influence of two major tributaries — the Green River and Black's Fork River.

The tributary stations were selected on the basis of, and defined as, a location in close enough proximity to the confluence to be heavily influenced by the tributary. They ranged from 10 to 20 m in depth. Mid-reservoir stations were in close proximity to the tributary stations but were judged to be far enough from the tributary waters to be free of their immediate effects. These stations were located in water ranging from 20 to 100 m in depth. Each tributary station and its corresponding reservoir station are termed a location complex (Fig. 1).

METHODS

Sampling at each site was done monthly over a 24-month period. Collections were made through the ice during January and February and from a boat the remaining months.

Plankton sampling was limited to those species retained by #20 silk bolting cloth and commonly designated as "net" plankton. Field sampling was accomplished using vertical hauls of a Wisconsin-type closing net from 3.048 m (10 ft) to the surface. The volume of water filtered by this method was calculated at 33.3 1. The distance from surface to 3.048 m was shown in simultaneous sampling to contain approximately 53 percent of the total number of net plankters in a column of water from the surface to 45.72 m (150 ft) or the bottom, whichever was reached first (Varley 1967).

Plankton was counted using a binocular microscope at 100X magnification. The method used is described in detail by the American Public Health Association (1960). Necessary microscope calibrations and conversion factors followed the method outlined by Jackson and Williams (1962).

In this study, a computer programmed, two-way analysis of variance (fixed model) was used to test population homogeneity and variation in the selected reservoir environments. Multiple range tests were included in the program to indicate where differences may exist between row, column and treatment means. A Log transformation, LN (X + 1.0), was necessary to transform the multiplicative plankton populations (X) to additive populations. Variations

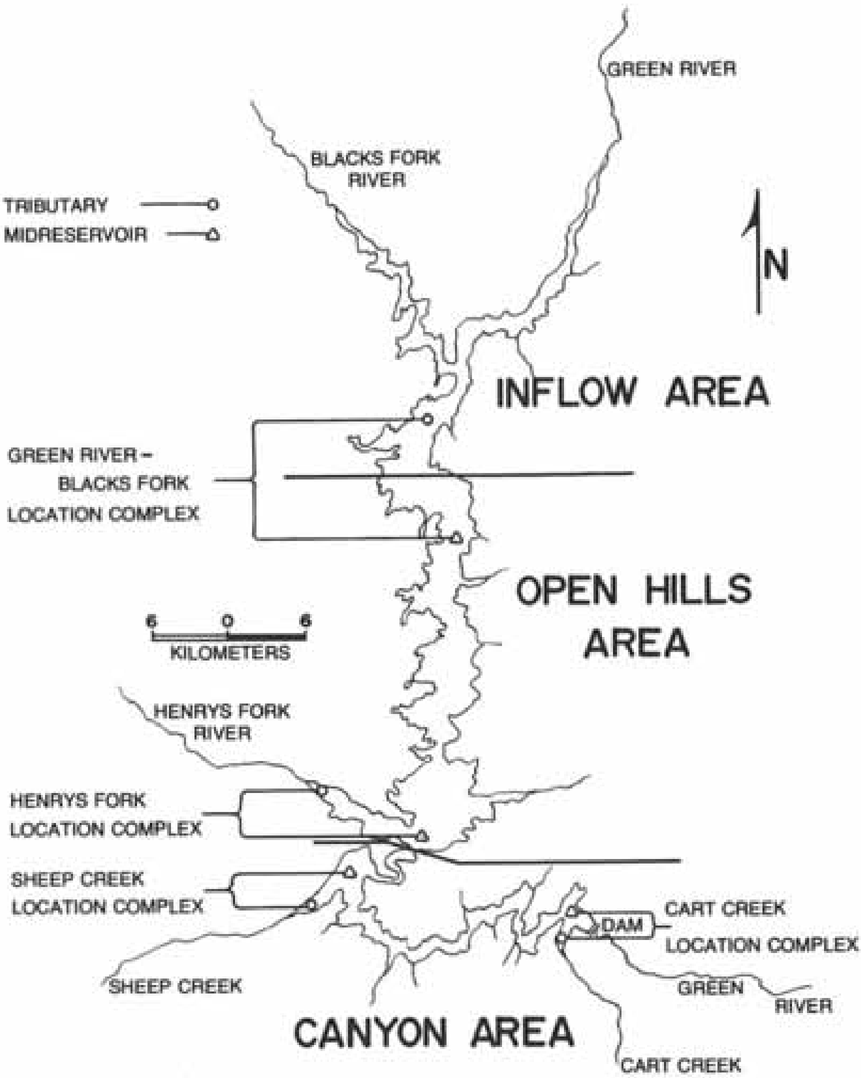

Figure 1

Flaming Gorge Reservoir showing reservoir divisions, tributary and mid-reservoir stations, and location complexes.

Table 1

Range of hydrographic, chemical and physical characteristics of tributaries and the waters of their corresponding mid-reservoir stations, Flaming Gorge Reservoir 1965-1966.

	CART CREEK			MID-RESERVOIR STATION		
Visibility (feet-Secchi)		—		3.5	—	30.0
Turbidity (ppm)	0.0		40.	0.0	—	410.
Temperature (°F)	32.	—	70.	32.	—	69.
pH	7.4	—	8.3	7.9	—	8.8
Dissolved oxygen (ppm)	6.7	—	14+	4.6	—	12.0
Carbon Dioxide (ppm)	0.0	—	2.8	0.0	—	6.0
Phenothalein alkalinity (ppm)	0.0	—	Trace	0.0	—	18.0
Methyl orange alkalinity (ppm)	30.	—	70.	120.	—	155.
Sulphates (ppm)	4.0	—	20.	160.	—	220.
Calcium hardness (ppm)	25.	—	65.		—	
Magnesium hardness (ppm)	5.	—	50.		—	
Total hardness (ppm)	30.	—	80.	220.	—	310.
Nitrate (ppm)	0.0	—	1.4	0.0	—	2.4
Total phosphate (ppm)	0.0	—	0.1	0.14	—	2.76
18 month ave. flow (cfs)		75*			—	

	SHEEP CREEK			MID-RESERVOIR STATION		
Visibility (feet-Secchi)		—		3.5	—	30.
Turbidity (ppm)	0.0	—	800.	0.	—	120.
Temperature (°F)	32.	—	65.	32.	—	70.
pH	7.6	—	8.4	7.9	—	8.4
Dissolved oxygen (ppm)	7.3	—	12.0	5.1	—	12.5
Carbon Dioxide (ppm)	0.6	—	2.3	0.0	—	2.5
Phenothalein alkalinity (ppm)	0.0	—	15.	0.	—	15.
Methyl orange alkalinity (ppm)	60.	—	155.	100.	—	150.
Sulphates (ppm)	50.	—	320.	120.	—	270.
Calcium hardness (ppm)	50.	—	420.		—	
Magnesium hardness (ppm)	30.	—	340.		—	
Total hardness (ppm)	80.	—	650.	200.	—	290.
Nitrate (ppm)	0.0	—	0.8	0.35	—	2.70
Total phosphate (ppm)	0.0	—	0.2	0.26	—	2.87
18 month ave. flow (cfs)		75*			—	

	HENRY'S FORK	MID-RESERVOIR STATION
Visibility (feet-Secchi)	—	7. — 26.
Turbidity (ppm)	15. — 940.	—
Temperature (°F)	32. — 70.	32. — 69.
pH	7.9 — 8.4	7.9 — 8.7
Dissolved oxygen (ppm)	7.0 — 14+	5.3 — 12.6
Carbon Dioxide (ppm)	0.0 — 4.0	0. — 3.7
Phenothalein alkalinity (ppm)	0. — 15.	0. — 12.
Methyl orange alkalinity (ppm)	140. — 240.	130. — 180.
Sulphates (ppm)	190. — 450.	100. — 330.
Calcium hardness (ppm)	190. — 330.	—
Magnesium hardness (ppm)	50. — 280.	—
Total hardness (ppm)	240. — 580.	190. — 330.
Nitrate (ppm)	—	0.15 — 3.90
Total phosphate (ppm)	—	0.27 — 1.62
18 month ave. flow (cfs)	156	—

	GREEN RIVER	BLACK'S FORK	MID-RESERVOIR STATION
Visibility (feet-Secchi)	—	—	1. — 23.
Turbidity (ppm)	0. — 425.	10. — 3050.	—
Temperature (°F)	32. — 68.	32. — 75.	32. — 68.
pH	8.0 — 8.8	8.2 — 8.8	8.1 — 8.5
Dissolved oxygen (ppm)	6.5 — 14+	6.0 — 14+	5.5 — 11.5
Carbon Dioxide (ppm)	0. — 2.2	0. — 2.5	0. — 12.0
Phenothalein alkalinity (ppm)	0. — 15.	0. — 20.	0. — 20.
Methyl orange alkalinity (ppm)	90. — 210.	110. — 240.	115. — 160.
Sulphates (ppm)	90. — 480.	120. — 550.	75. — 310.
Calcium hardness (ppm)	90. — 220.	80. — 280.	—
Magnesium hardness (ppm)	30. — 155.	40. — 190.	—
Total hardness (ppm)	150. — 355.	120. — 440.	180. — 310.
Nitrate (ppm)	—	—	0.05 — 3.10
Total phosphate (ppm)	0.0 — 0.2	—	0.32 — 2.56
18 month ave. flow (cfs)	1973	473	—

*Estimated from limited data

were considered valid if the differences existed at the 0.95 probability level or higher.

Initially, the mean numerical value of each species for all tributary stations was compared with a like value for all mid-reservoir stations. Secondly, the mean value of each location complex was compared with the other location complexes. Finally, within the structure of the treatment means multiple range test, each station was compared with all other station means.

Seven zooplankton and seven phytoplankton dominant or codominant species were chosen from the 56 species of phytoplankton and zooplankton that were identified and recorded from the reservoir during 1965-1966. These 14 were the most common and most abundant forms encountered during the study period and were representative of the major groups of limnoplankton. The organisms included seven phytoplankters: *Aphanizomenon flos-aquae, Anabaena flos-aquae, Asterionella formosa, Tabellaria fenestrata, Fragilaria crotonensis, Fragilaria capucina,* and *Pandorina morum;* and seven zooplankters, *Daphnia pulex, Diaptomus clavipes, Cyclops bicuspidatus thomasi,* combined *Copepoda* nauplii, *Asplanchna* sp., *Polyarthra* sp. and *Keratella cochlearis.*

RESULTS

Of the seven phytoplankton species tested, none showed significant differences between the population mean for all tributary and the mean for all mid-reservoir stations. Five of seven species showed valid population differences when means of each location complex were compared to means of the other three location complexes. None were significantly different in the treatment means multiple range test which compared each station mean to all other station means (Table 2).

Of the seven zooplankton forms tested three of the seven species revealed a valid difference between the population mean for all tributary and the mean for all mid-reservoir stations. Five of seven showed differences in abundance between the location complexes, and four of seven demonstrated population differences when each station mean was compared to all other station means (Table 2).

Two phytoplankton forms, the diatom *Tabellaria fenestrata* (Fig. 2) and the Chlorophycean species, *Pandorina morum* (Fig. 3), and one rotifer, *Asplanchna* sp. (Fig. 4), did not show valid population differences in any of the comparisons. The three species could be assumed to have been hemogeneously abundant throughout the reservoir.

Asterionella formosa was the most common plankton species encountered in the reservoir and was seldom completely absent from any collection. Analyses of *Asterionella* populations (Fig. 5) indicated that tributary and mid-reservoir abundance was similar. Significant differences occurred between the Green River — Black's Fork location complex, where production was highest, and each of the remaining location complexes. Production was similar within the mainstem, excluding the two Green River stations.

Fragilaris crotonensis (Fig. 6) was most common during the summer months although it was found in limited numbers during all seasons. There was no valid difference between the tributary and mid-reservoir means. Similar to *Asterionella,* the species indicated significant population differences between the Green River — Black's Fork complex than at the lowest production areas. Mainstem reservoir production, excluding the Green River — Black's Fork inflow area, was homogeneous throughout.

Fragilaria capucina (Fig. 7) was found more abundant in the Green River — Black's Fork inflow area, but was encountered in lesser numbers throughout the reservoir. There were no significant population differences between tributary and mid-reservoir stations. Similar to *Asterionella* and *F. crotonensis,* produc-

Table 2

Synopsis of the significance levels of plankton species tested in a two-way analysis of variance (fixed model) that included multiple range analyses.*

	COMPARISON TEST					
	Column Means		Row Means		Treatment Means	
Species	Tributary vs. Mid-reservoir %Sig.	%N.S.	Location Complex vs. Location Complex %Sig.	%N.S.	Each Station vs. All Other Stations %Sig.	%N.S.
Asterionella formosa	—	49.2	100	—	—	28.6
Tabellaria fenestrata	—	19.2	—	45.3	—	12.2
Fragilaria crotonensis	—	9.5	100	—	—	9.5
Fragilaria capucina	—	42.2	99.7	—	—	84.8
Aphanizomenon flos-aquae	—	33.9	99.2	—	—	29.3
Anabaena flos-aquae	—	20.6	99.8	—	—	39.7
Pandorina morum	—	34.2	—	21.9	—	17.7
Cyclops bicuspidatus thomasi	—	48.8	—	79.1	95.9	—
Daphnia pulex	98.7	—	100	—	99.8	—
Diaptomus clavipes	99.6	—	100	—	100	—
Polyarthra sp.	95.8	—	99.9	—	96.6	—
Copepod nauplii	—	69.9	99.3	—	—	45.4
Keratella cochlearis	—	46.6	94.7	—	—	18.2
Asplanchna sp.	—	69.0	—	64.4	—	17.1

*Significance accepted at 0.95 or greater

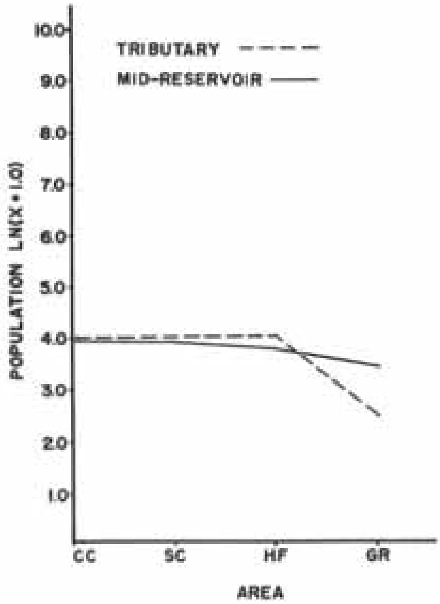

Figure 2

Reservoir distribution of *Tabellaria fenestrata* abundance.

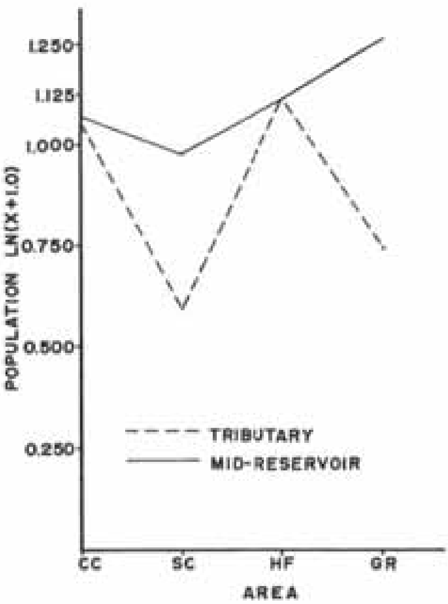

Figure 3

Reservoir distribution of *Pandorina morum* abundance.

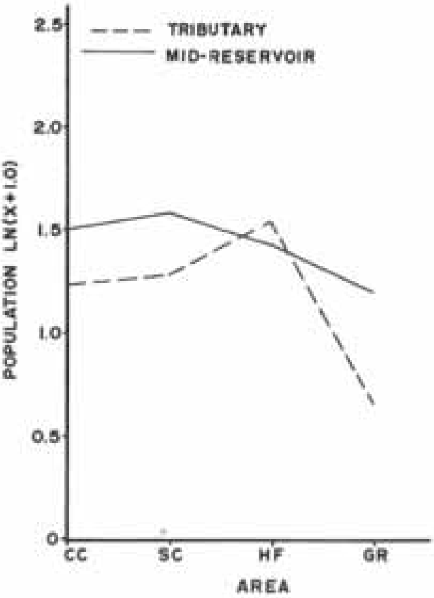

Figure 4

Reservoir distribution of *Asplanchna* sp. abundance.

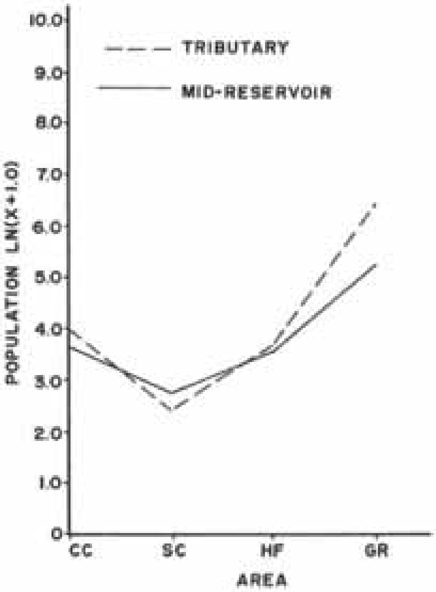

Figure 5

Reservoir distribution of *Asterionella formosa* abundance.

tion was highest at the Green River — Black's Fork location complex and was dissimilar to the remaining locations. No significant variation occurred within the mainstem reservoir populations excluding the Green River — Black's Fork inflow.

Aphanizomenon flos-aquae (Fig. 8) bloomed in the summer and fall of 1965 but was conspicuously absent in 1966. The abundance of the species showed no significant difference between tributary and mid-reservoir locations. The Sheep Creek and Henry's Fork location complexes showed significantly higher production levels than those at the Green River-Black's Fork complex. Populations at the Cart Creek complex were most similar to those at the Green River-Black's Fork location.

Anabaena flos-aquae (Fig. 9) was a codominant bloom species in the reservoir and was generally associated with the flowering of other species, notably *Aphanizomenon*. This myxophycean form did not show valid differences between tributary and mid-reservoir. The very strong production of the Henry's Fork location complex was similar to the Sheep Creek complex but was significantly dissimilar to the lower production levels at the Green River-Black's Fork and Cart Creek complexes.

The small copepod, *Cyclops bicuspidatus thomasi* (Fig. 10), showed no significant differences in abundance between tributary and mid-reservoir stations nor any of the location complexes. It was demonstrated, however, that a highly significant interaction existed between the tributary and mid-reservoir stations in both the Sheep Creek and Henry's Fork areas. As Fig. 9 illustrates, a statistically significant cross-over occurs at these locations and species production appears to be favorably influenced by the tributary over that of the mid-reservoir environment.

Daphnia pulex (Fig. 11) and *Diaptomus clavipes* were the most common zooplankters encountered in the reservoir. Analysis indicated that tributary production of *D. pulex* was different than mid-reservoir production. The significance was probably due to the extremely low populations found in the Green River-Black's Fork tributary station. The abundance of this plankter in the samples from Green River-Black's Fork tributary station was significantly lower than at all other stations tested. The Green River-Black's Fork and Cart Creek location complexes were similar but each produced less than the Sheep Creek and Henry's Fork locations.

Diaptomus clavipes (Fig. 12), together with *D. pulex*, were the most common and largest zooplankters in the reservoir during most seasons. Tests did not reveal valid differences in the abundance of *D. clavipes* between combined tributary and mid-reservoir populations but indicated a lower production level at the Green River-Black's Fork location complex than at any of the other complexes. Similarly, the tributary and mid-reservoir Green River-Black's Fork stations demonstrated lower populations than that found at all other reservoir stations. Population densities in the mid-and lower sections of the reservoir were homogenous (Fig. 12).

Analysis of the population levels of *Polyarthra* sp. (Fig. 13) showed no difference between the tributary and mid-reservoir means. Abundance at the Cart Creek location complex was significantly lower than that at the Henry's Fork and Sheep Creek locations. The Sheep Creek complex had lower production than Henry's Fork and the Green River-Black's Fork complexes. Populations of the species generally increased with increased distance from the dam (Fig. 13). The highest populations were found at the mid-reservoir Green River-Black's Fork station.

Keratella cochlearis (Fig. 14), a rotifer, occured sporadically in the spring and summer months. The only valid difference in abundance, found in the analysis, was between the Cart Creek location complex and the Green River-Black's Fork

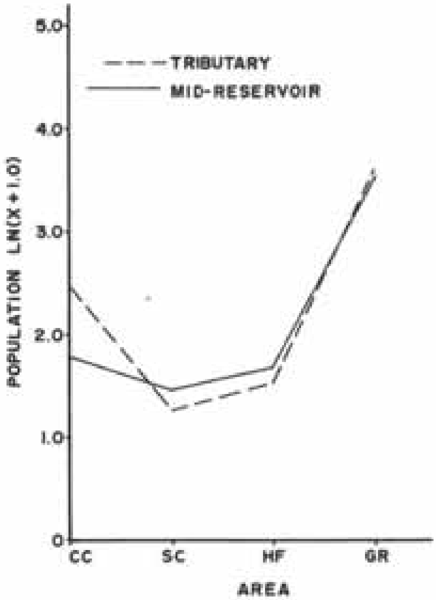

Figure 6

Reservoir distribution of *Fragilaria crotonensis* abundance.

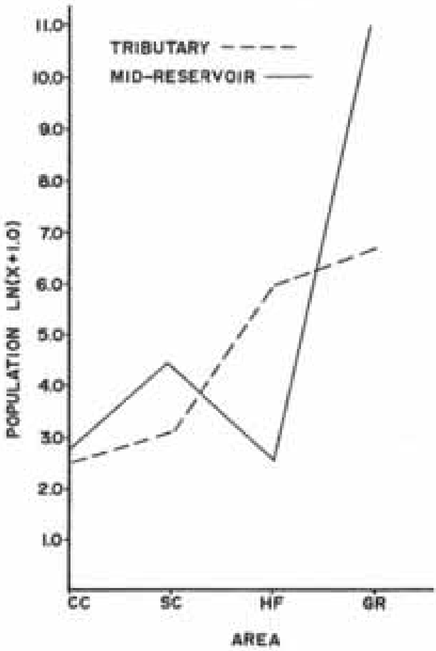

Figure 7

Reservoir distribution of *Fragilaria capucina* abundance.

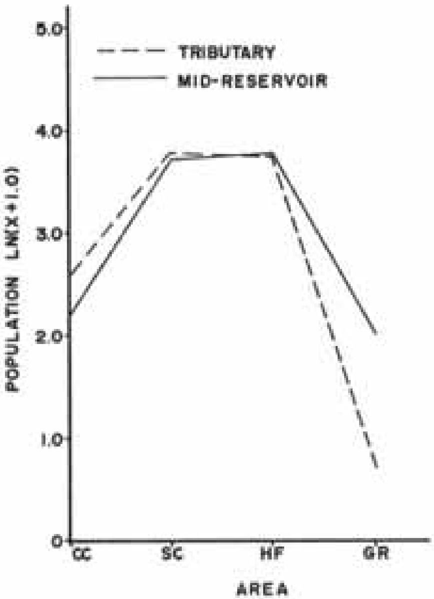

Figure 8

Reservoir distribution of *Aphanizomenon flos-aquae* abundance.

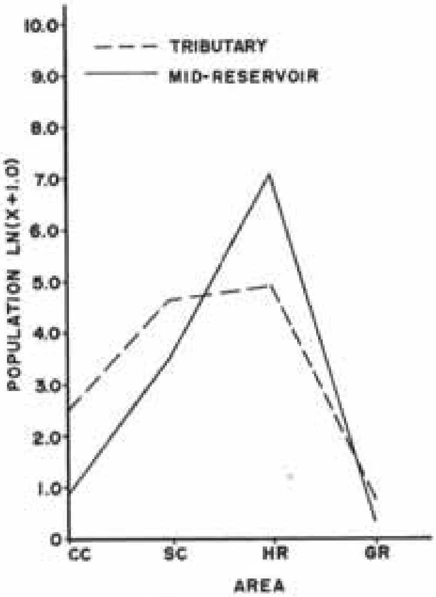

Figure 9

Reservoir distribution of *Anabaena flos-aquae* abundance.

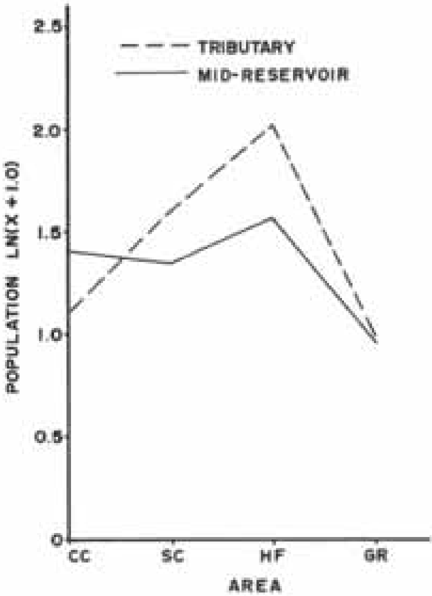

Figure 10

Reservoir distribution of *Cyclops bicuspidatus thomasi* abundance.

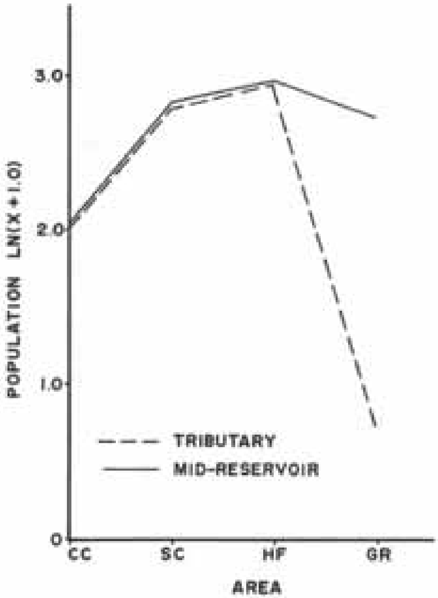

Figure 11

Reservoir distribution of *Daphnia pulex* abundance.

location complex. Abundance was directly proportional to increased distance from the dam (Fig. 14).

No attempt was made to identify copepod nauplii and copepodids to the generic or species level. The combined *Copepoda* nauplii (Fig. 15) followed a similar abundance pattern to those of the parent *Diaptomus* and *Cyclops* populations. There were no differences between tributary and mid-reservoir population means. The populations at Green River-Black's Fork complex were different than the populations at Henry's Fork. The lower production level at the Green River-Black's Fork complex closely followed the lower production shown by the parent species (Fig. 10 and 12) at the same location.

DISCUSSION AND CONCLUSIONS

Overall production of zooplankton species from a standpoint of availability to the trout fishery appeared to be superior in, but not necessarily limited to, the midsection of the reservoir between the Sheep Creek and Henry's Fork areas. The largest hindrance for most favored zooplankton species was the inflowing waters from the Black's Fork and Green Rivers, and secondly, one or more factors in the Cart Creek area, where the major factor appears to be the discharge of water from the dam. Hutchinson (1967) noted that there are cases where plankton organisms appear to avoid the outlets of natural lakes. A similar situation may occur near dams.

Zooplankton species, perhaps due to far less variation in the mean numbers, differed significantly in more of the comparisons than the phytoplankton species. The populations of five organisms, *Daphnia, Diaptomus, Cyclops, Asplanchna* and copepod nauplii were notably depressed by factors inherent in the inflowing waters of the Green River and Black's Fork. *Daphnia* and copepod nauplii demonstrated a similar lack of preference for the area nearest the dam. Conversely, the abundance of *Keratella* and *Polyarthra* was directly proportional to the increased distance from the dam indicating a preference for conditions in the Green River-Black's Fork area. It is interesting to note that there were indications of an inverse relationship with regard to abundance along the length of the reservoir between *Asplanchna* and the two other species of rotifers, *Keratella* and *Polyarthra* (Fig. 4, 13, and 14).

Cyclops demonstrated an apparent environmental preference for the tributary influence at Sheep Creek and Henry's Fork and a decided lack of preference for the tributaries at Cart Creek and the Green River-Black's Fork.

Some phytoplankton species could also be placed into broad categories of ecological preference. The myxophycean species, *Aphanizomenon* and *Anabaena*, demonstrated a decided preference for the midsection of the reservoir (Fig. 8 and 9), lower production was manifest at the Green River-Black's Fork inflow area and Cart Creek area. Conversely, the diatoms *Asterionella* and *F. crotonensis* showed a marked preference for the Green River-Black's Fork inflow and the Cart Creek location. *F. capucina* production was directly proportional to increased distance from the dam with the highest populations found in the inflow area. The preference for the Green River-Black's Fork area by the diatoms may be influenced by the almost constant introduction of some species (*Asterionella* and *Fragilaria*) from the Green River proper (Varley 1967). Conversely, the inflowing waters from Sheep Creek may have surpressed *Asterionella, F. crotonensis,* and *Pandorina* (Fig. 5, 6 and 3).

Of the plankters tested in only one instance, involving *Daphina*, did abundance differ in the overall tributary — mid-reservoir comparison. The instance was questioned and thought to be a statistical artifact due to the weighting effect of the extremely low population of the species at the tributary Green River-Black's Fork station (Fig. 11).

When individual stations were compared to each other, only three species,

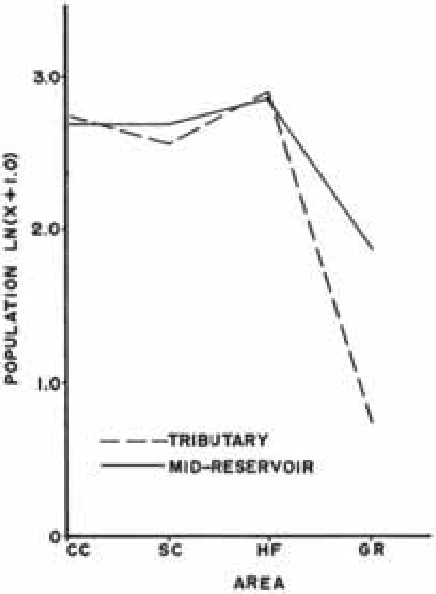

Figure 12

Reservoir distribution of *Diaptomus clavipes* abundance.

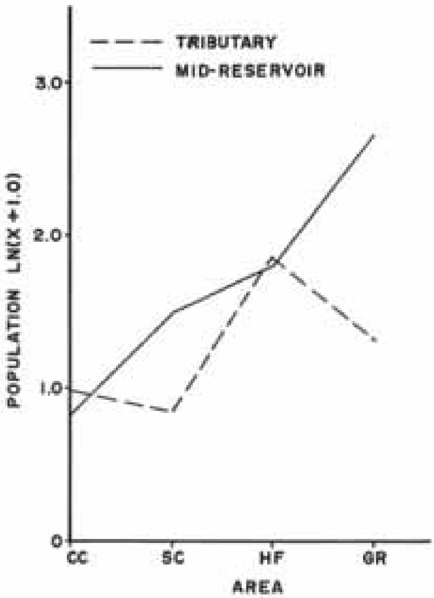

Figure 13

Reservoir distribution of *Polyarthra* sp. abundance.

Daphnia, *Diaptomus* and *Polyarthra*, showed differences between a tributary station and its corresponding mid-reservoir station. All three instances occurred at the Green River-Black's Fork tributary and mid-reservoir stations. For all location complexes other than the Green River-Black's Fork, there were generally no significant differences in abundance between any of the tributary stations selected and their corresponding mid-reservoir stations.

Frequently, a location complex differed with other location complexes. These differences demonstrated that the reservoir arms, and perhaps tributaries, however large or small, created heterogeneous plankton populations. The differences noted at the Cart Creek location complex may have reflected the influence of the discharge at the dam more than the influence of the comparatively small Cart Creek tributary (Fig. 1).

Individual station means commonly showed differences which reflected the distinctions shown in the location complexes.

The lack of spatial homogeneity is not unique to Flaming Gorge Reservoir. Gaufin and McDonald (1965) stated that horizontal distribution of plankton in Deer Creek Reservoir, Utah, was irregular within the same areas of the reservoir but despite the irregularity the kinds and populations of plankters were similar in the mainstem of the reservoir. Hudson and Cowell (1966) and Cowell (1967) found wide variation in the abundance of phytoplankton and zooplankton between sampling stations on Lewis and Clark Lake. Variability was reduced when stations means were compared. They also stated there were greater differences (using mean densities) when specific taxonomic groups or individual species were compared, although statistically significant differences were observed only with one species of *Cladocera*.

Variation in plankton abundance within two Ozark reservoirs was noted by Applegate and Mullan (1967). In Bull Shoals Reservoir greater abundance was measured near the midpoint of the reservoir than either the upper or lower ends. In Beaver Reservoir the mean numbers of *Entomostraca* increased progressively from the area near the dam to the upper reservoir. Funk (1966) reported that uniform distribution in abundance was lacking among sampling stations on a well-circulated, 1,150 surface acre reservoir in Wyoming. Summers (1961), however, in studies on Tenkiller Reservoir, Oklahoma, stated there was no evidence that distinct plankton communities developed in isolated areas of the reservoir.

Previous studies on Flaming Gorge Reservoir have shown that the reservoir is essentially three reservoirs in one. Conclusions drawn from studies on limnology, topography, trout growth and food habits, benthos, and abundance of fishes have consistantly suggested the three-in-one concept (Eiserman et al. 1967, Varley et al. 1971). As the limnoplankton comprise the bulk of the diet of fishes in Flaming Gorge Reservoir (Varley 1978, Wiley 1975), a sound knowledge of the distribution and dynamics of fish requires some definition of plankton distribution. These data reveal that an arbitrary division of the reservoir made on the basis of limnoplankton would be largely impossible. A method of dividing the reservoir into special interest production zones could possibly be devised and be reliable if species or small combinations of species were used.

The variations in abundance of each species at the various locations subjected to analysis suggests that complicated and intricate factors control the presence and production of plankton organisms in Flaming Gorge Reservoir.

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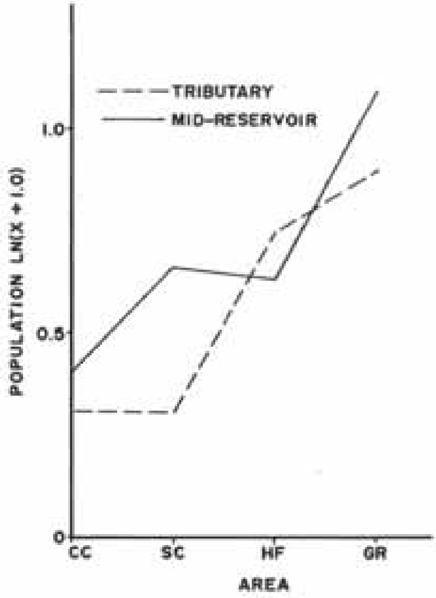

Figure 14

Reservoir distribution of *Keratella cochlearis* abundance.

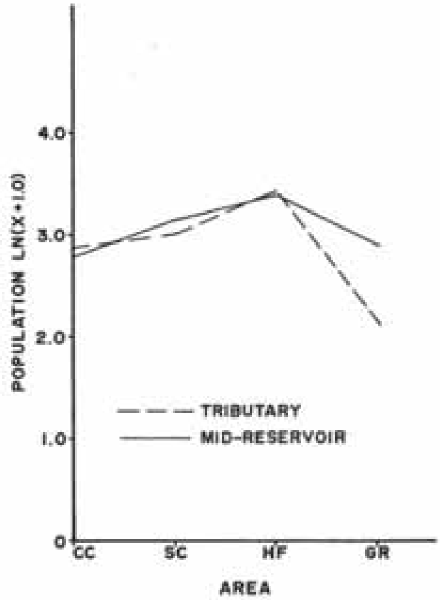

Figure 15

Reservoir distribution of combined *Copepoda* nauplii abundance.

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