Limnology of Clark Canyon Reservoir, Montana
by Rodney Kent Berg

A thesis submitted to the Graduate Faculty in partial fulfillment of the requirements for the degree of MASTER OF SCIENCE in Fish and Wildlife Management
Montana State University

Abstract:
A limnological study was conducted on Clark Canyon Reservoir during 1971 and 1972 with particular efforts being made to determine the relationships between primary and secondary productivity and selected chemical and physical factors.

Runoff at 159% of normal reduced the average retention time. Turbidity never exceeded 10 JTU. Euphotic zone depth varied from 5 to 15 1/2 meters. Storage of advected and solar heat during summer in the reservoir was attributed to deep water withdrawal. Conductivity ranged from 420 to 650 micromhos. Pronounced vertical conductivity gradients were not observed. Levels of DO in the deep zone decreased with time following each of the three observed overturn periods. pH ranged from 7.80 to 8.63 with highs and lows occurring during overturn and severest stagnation periods, respectively. Ranges of total alkalinity and total hardness, respectively, were 177 to 222 ppm and 157 to 230 ppm. Reductions in the levels of euphotic zone plant nutrients following vernal and autumnal overturn were attributed to uptake by phytoplankton and transfer to the deep water zone by sinking.

Thirty-one algal genera were observed in the euphotie zone during the study period. The five genera with the largest mean annual standing crops were, in descending order of abundance, Asterionella Aphanizomenon, Cvyptomonas, Rhodomonas and Synedra. Mean total phytoplankton standing crops during winter, spring, summer and fall, respectively, were 2.67, 3.34, 4.05 and -4.10 mm 3/1 Water temperature was the most significant variable measured influencing phytoplankton standing crop. Mean euphotic zone chlorophyll a concentrations during winter, spring, summer and fall, respectively, were 3.36, 9.86, 5.57 and 8.03 ug/1. The small correlation coefficient, 0.34, between chlorophyll a concentration and phytoplankton standing crop was attributed to seasonal variation in the taxonomic composition of the phytoplankton community.

Daphnia schodleri and Cyclops bicuspidatus thomasii were the dominant zooplankters during all seasons and averaged 11.86 and 6.18 organisms/1, respectively,' on an annual basis. Regression analyses revealed that Asterionella Cvyptomonas and Rhodomonds may have been used as food by herbivorous zooplankton. Instantaneous birth and mortality rates of D. schodleri averaged near 0.06 annually. Water temperature and chlorophyll a. concentration were the only measured variables significantly affecting D. schodleri population dynamics.

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March, 1974

ACKNOWLEDGMENT

The author wishes to extend his appreciation to those who assisted him during the course of the investigation: Dr. Richard J. Graham directed the study and assisted in the preparation of the manuscript; Drs. John C. Wright, and Don C. Quimby critically read the manuscript; Dr. Martin Hamilton assisted with the statistical analyses; Kenneth M. Smith aided in the field work; the Montana Fish and Game Department loaned equipment and vehicles; the Bureau of Reclamation, Upper Missouri Region, Billings, Montana, and the U. S. Geological Survey, Helena, Montana provided hydrologic data. The project was financed by the Montana State University Endowment and Research Foundation and the Montana Cooperative Fishery Unit.

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ABSTRACT

A limnological study was conducted on Clark Canyon Reservoir during 1971 and 1972 with particular efforts being made to determine the relationships between primary and secondary productivity and selected chemical and physical factors.

Runoff at 159% of normal reduced the average retention time. Turbidity never exceeded 10 JTU. Euphotic zone depth varied from 5 to 15½ meters. Storage of advected and solar heat during summer in the reservoir was attributed to deep water withdrawal. Conductivity ranged from 420 to 650 micromhos. Pronounced vertical conductivity gradients were not observed. Levels of DO in the deep zone decreased with time following each of the three observed overturn periods. pH ranged from 7.80 to 8.63 with highs and lows occurring during overturn and severest stagnation periods, respectively. Ranges of total alkalinity and total hardness, respectively, were 177 to 222 ppm and 157 to 230 ppm. Reductions in the levels of euphotic zone plant nutrients following vernal and autumnal overturn were attributed to uptake by phytoplankton and transfer to the deep water zone by sinking.

Thirty-one algal genera were observed in the euphotic zone during the study period. The five genera with the largest mean annual standing crops were, in descending order of abundance, *Asterionella, Aphanizomenon, Cryptomonas, Rhodomonas* and *Synedra*. Mean total phytoplankton standing crops during winter, spring, summer and fall, respectively, were 2.67, 3.34, 4.05 and 4.10 mm^3/l. Water temperature was the most significant variable measured influencing phytoplankton standing crop. Mean euphotic zone chlorophyll a concentrations during winter, spring, summer and fall, respectively, were 3.36, 9.86, 5.57 and 8.03 ug/l. The small correlation coefficient, 0.34, between chlorophyll a concentration and phytoplankton standing crop was attributed to seasonal variation in the taxonomic composition of the phytoplankton community.

Daphnia schodleri and *Cyclops bicuspidatus thomasii* were the dominant zooplankters during all seasons and averaged 11.86 and 6.18 organisms/l, respectively, on an annual basis. Regression analyses revealed that *Asterionella, Cryptomonas* and *Rhodomonas* may have been used as food by herbivorous zooplankton. Instantaneous birth and mortality rates of *D. schodleri* averaged near 0.06 annually. Water temperature and chlorophyll a concentration were the only measured variables significantly affecting *D. schodleri* population dynamics.

INTRODUCTION

Clark Canyon Dam was constructed on the Beaverhead River, southwestern Montana, during the period from 1961 to 1964 as a part of the East Bench Unit of the Pick-Sloan Missouri Basin Program. The principal features of the unit include Clark Canyon Dam and Reservoir, Barretts Diversion Dam, East Bench Canal, and a system of irrigation laterals and drains. The primary functions of the reservoir are flood control and irrigation.

Personnel of the Montana Fish and Game Department initiated studies in 1969 to evaluate the fish population of the reservoir and to determine the effect of the reservoir and altered stream flow patterns on the fish population of the Beaverhead River. I conducted a supporting study on the limnology of the reservoir with emphasis on primary and secondary productivity in relation to certain controlling chemical and physical environmental factors. Field research was carried out from June 23, 1971, through November 4, 1972. A concurrent study was conducted on the limnology of the inlet streams and outlet river (Smith, 1973).

DESCRIPTION OF THE STUDY AREA

Clark Canyon Reservoir (Figure 1) is an artificial impoundment of the Beaverhead River located approximately 32.2 kilometers (20 miles) upstream from Dillon, Montana. The reservoir is formed behind a 40.08 meter (131.5 ft) high zoned earthfill dam with concrete control works and spillway. The impoundment covers the lower portions of Red Rock River and Horse Prairie Creek which previously had joined to form the Beaverhead River 396 meters upstream from the present damsite.

Water storage began on August 28, 1964. The reservoir has a useable storage capacity of 405.721 X 10^6 m^3 between the inverted outlet works and the maximum water surface (Table 1). Dead storage capacity below the inverted outlet works amounts to 0.075 X 10^6 m^3. Morphometric characteristics of the reservoir at the average operating level of 1688.6 m (5540 ft) are given in Table 2.

Water can be discharged from the reservoir through two outlets; (1) the spillway (uncontrolled)-- elevation 1694.8 m and (2) the inverted outlet works-- elevation 1662.7 m. Normally, all water is discharged through the inverted outlet works which is located 2.6 m above the old streambed. Discharge consequently comes from the deepest water of the reservoir; 25.9 m at the average operating level.

The major inlet streams to the reservoir are Red Rock River and Horse Prairie Creek which drain largely from the Centennial and Tendoy Mountains. According to Alt and Hyndman (1972) the Centennial

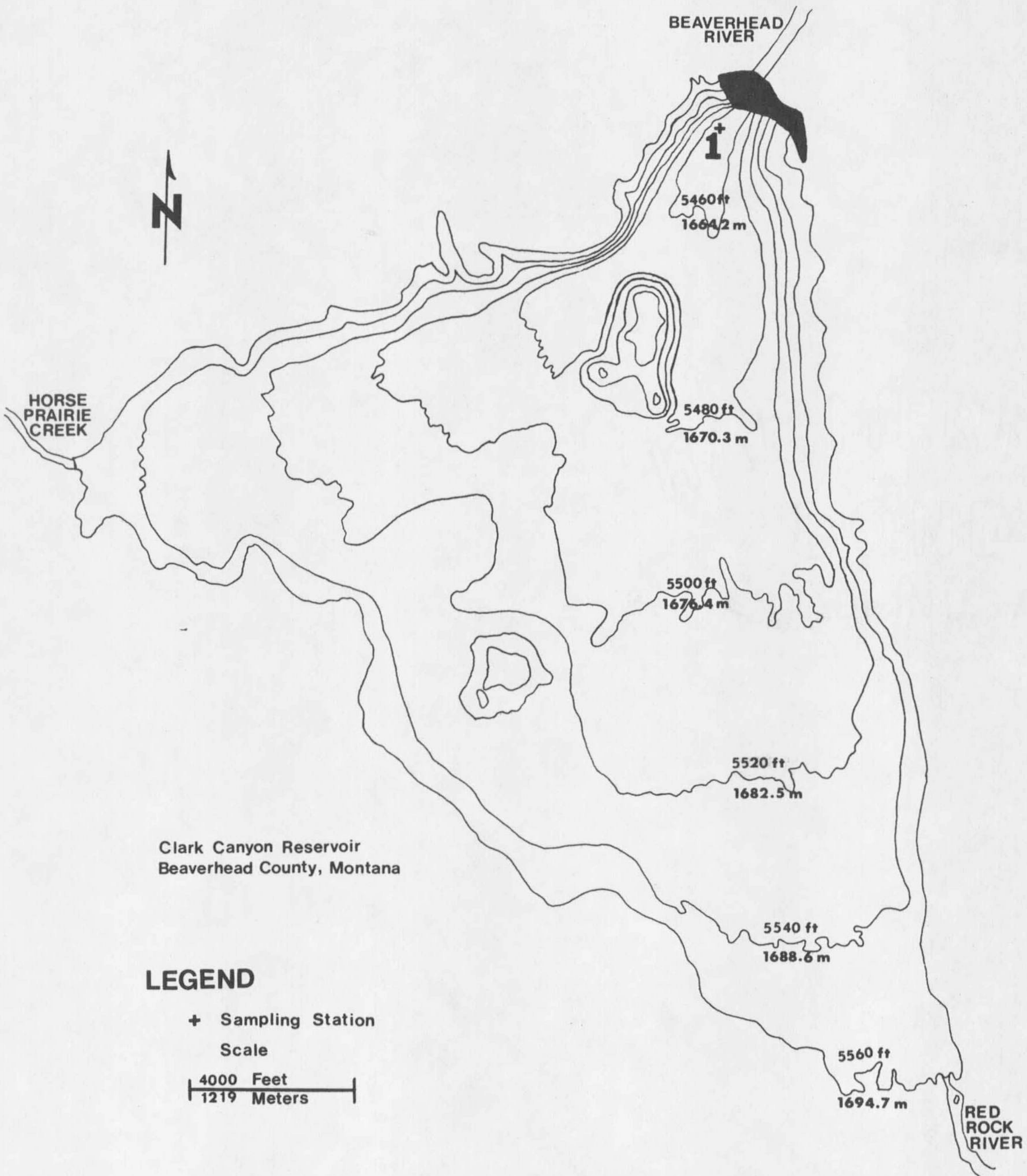

Figure 1. Contour map of Clark Canyon Reservoir showing the location of the sampling station.

Table 1. Surface area and capacity of Clark Canyon Reservoir at various defined operating levels. (Bureau of Reclamation data)

	Elevation - meters (feet)	Surface Area - $m^2 \times 10^6$ (acres $\times 10^3$)	Capacity - $m^3 \times 10^6$ (acre-ft $\times 10^3$)
Top of Dam	1700.2 (5578.0)	------	------
Maximum Water Surface	1698.3 (5571.9)	26.710 (6.600)	405.796 (328.979)
Top of Flood Control Storage (Uncontrolled Spillway Crest)	1694.8 (5560.4)	23.889 (5.903)	317.197 (257.152)
Top of Joint Use Storage	1689.2 (5542.1)	19.971 (4.935)	194.724 (157.863)
Top of Active Conservation Storage	1687.3 (5535.7)	18.195 (4.496)	157.427 (127.626)
Top of Inactive Storage	1667.4 (5470.6)	0.846 (0.209)	1.861 (1.509)
Top of Dead Storage (Inverted Outlet Works)	1662.7 (5455.0)	0.093 (0.023)	0.075 (0.061)
Old Streambed	1660.1 (5446.5)	------	------

Table 2. Morphometric data for Clark Canyon Reservoir at the average operating level--elevation 1688.6 m (5540 ft).

Maximum Depth	28.5 m (93.5 ft)
Mean Depth	9.35 m (30.68 ft)
Maximum Length	6.47 km (4.02 mi)
Maximum Breadth	5.01 km (3.11 mi)
Mean Breadth	3.06 km (1.90 mi)
Area	19.789×10^6 m^2 (4.890×10^3 acres)
Volume	185×10^6 m^3 (150×10^3 acre-ft)
Length of Shoreline	26.01 km (16.16 mi)
Shoreline Development	1.65

Mountains are composed of complexly folded Paleozoic and Mesozoic sedimentary rocks covered by much younger light colored volcanic rocks, while the Tendoy Mountains contain Precambrian igneous and metamorphic basement rocks overlain by Paleozoic sedimentary rocks. The drainage area of Red Rock River is approximately 4092 km^2 while Horse Prairie Creek drains approximately 1765 km^2. Minor basins which drain into the reservoir account for an additional drainage area of 154 km^2. Thus the entire drainage area of Clark Canyon Reservoir is approximately 6011 km^2.

METHODS

Monthly reservoir elevation and volume data were obtained from the Bureau of Reclamation, Upper Missouri Region, Billings, Montana. Discharge data were obtained from the United States Geological Survey in Helena, Montana. The data were recorded at the Grant gaging station which is located on the Beaverhead River 0.64 km downstream from Clark Canyon Dam.

A sampling station was established near the dam site where, at the average operating level of the reservoir, the depth was 25.0 m. Water samples and field measurements were taken at near biweekly intervals during the summer (mid June-mid September) and at near monthly intervals during the remainder of the year except when hazardous ice conditions prevailed in the spring and fall.

Water samples were taken during early morning from the surface and at 5 meter intervals to the bottom of the reservoir. These samples were used for chemical and physical determinations. A composite euphotic zone sample, consisting of equal amounts of water taken at one meter intervals from the surface of the reservoir to a depth of eight meters was collected. This sample was used for chlorophyll analysis and phytoplankton counts. A 3.0 liter Van Doren water bottle was used to obtain the samples.

Measurements of temperature, conductivity and turbidity were made at one, five and five meter intervals, respectively, from the surface of the reservoir to the bottom using an ARA Model FT3 All-Weather Hydrographic Thermometer, a Solu-Bridge Model RB3-338-Y147 Conductivity Meter, and a Hach DR Colorimeter contained in a Hach Field Kit.

Secchi disc depth was determined using a standard Secchi disc in accordance with the procedure outlined in Welch (1948). It has been estimated that the Secchi disc disappears at approximately the zone of 10% transmission of total surface radiation (Wright, personal communication). The compensation point for most phytoplankton organisms is reached at light intensities of about 1% of total surface radiation (Verduin, 1964). Thus, the depth of the euphotic zone was defined as that region where there was 1% light transmission. Euphotic zone depth was approximated using the following formula derived by Wright (personal communication):

Depth of Euphotic Zone = 2.7 X Secchi Disc Depth.

The method used for dissolved oxygen analysis was the Alsterberg modification of the Winkler technique using phenylarsene oxide (PAO) instead of sodium thiosulfate as the titrant solution. The pH was measured with an Orion Ionalyzer (Model 407) using a Sargent combination pH electrode. Analyses for total alkalinity, total hardness and ammonia followed procedures outlined in Standard Methods for the Examination of Water and Wastewater (APHA, 1965). Orthophosphate, nitrate and nitrite determinations were made according to methods outlined by Hach (1969). A Bausch & Lomb Spectronic 20 Spectrophotometer was used whenever colorimetric procedures were required.

Dissolved oxygen, pH, and total alkalinity determinations were made within 2-6 hours after field collection, and the remainder of the chemical determinations were made within 48 hours of collection.

The chemical analyses described above were made throughout the course of the study. A more extensive chemical analysis was done on a water sample collected from the euphotic zone of the primary station on September 23, 1972. Colorimetric or titrimetric procedures as outlined in Standard Methods for the Examination of Water and Wastewater (APHA, 1965) were used for all determinations except sodium and potassium were analyzed using a Beckman Atomic Absorption Flame Spectrophotometer, and carbonaceous components were measured using a Beckman Carbonaceous Analyzer.

For phytoplankton analyses 125 ml was taken from the composite euphotic zone water sample. This water was placed in a French square bottle and preserved with 1 ml of Lugol's solution. Phytoplankton were identified, counted, and measured in a Sedgewick-Rafter cell, and standing crop (mm^3/l) was calculated for each taxon.

Chlorophyll a concentrations were determined by filtering (0.45 micron Millipore* filters) a known volume of the euphotic zone

*Registered Trademark, Millipore Filter Corporation, Bedford, Massachusetts.

composite water sample. The filter was then dissolved in 5 ml of 90% acetone and allowed to stand in the dark for 24 hours. The solution was then centrifuged, and the optical density of the supernatant was measured at 665 millimicrons using a Bausch & Lomb Spectronic 20 Spectrophotometer. The micrograms of chlorophyll a per liter were calculated according to the method of Odum *et al.* (1958).

Zooplankton samples were collected by making an oblique tow from the bottom of the reservoir to the surface with a Clark-Bumpus plankton sampler. A #20 plankton net was used, and the collection was preserved in the field using 95% ethanol.

In the laboratory the total volume of the zooplankton sample was measured, and upon uniformly suspending the organisms in the sample by shaking, 1 to 5 ml aliquots were removed and placed in a modified circular counting cell of the type described by Ward (1955). Successive aliquots were examined with a 30X binocular microscope until at least 150 individuals of the most common taxon had been counted. From the data collected population density (number/liter) was calculated for each taxon in the zooplankton community. Population dynamics of *Daphnia schodleri* were estimated following the methods described by Edmonson (1960), Hall (1964) and Wright (1965) except instantaneous birth rates were calculated using Casewell's (1972) correction.

RESULTS

Hydrology

Due to excessive runoff Clark Canyon Reservoir and Dam handled an abnormal volume of water throughout 1971 and 1972 (Figure 2). In 1971 the January-March inflow was high at 68.743 X 10^6 m^3, 123% of normal based on a 1963-1970 average (Table 3). On April 1, the April-July runoff was forecast to be well above normal, and consequently the discharge rate was gradually increased to 28.317 m^3/sec (1000 ft^3/sec) on May 12 and maintained at this level through July 26. This is the maximum rate desired to meet established flood control objectives in the Beaverhead River below Clark Canyon Dam. In spite of maximum release rates, the reservoir was in the flood pool (above elevation 1690.5 m) between June 12 and July 26 reaching a record high storage of 228.198 X 10^6 m^3 (185.000 X 10^3 acre-ft) at elevation 1690. 86 m on July 2 (Figure 3). The realized April-July inflow was 280.511 X 10^6 m^3, 190% of normal. Fifty-one percent of the total net inflow for 1971 occurred during this 4 month period. Inflows during the intervening fall and winter period remained unusually high at 196.052 X 10^6 m^3, 159% of normal during August-December, 1971, and 97.323 X 10^6 m^3, 178% of normal during January-March, 1972. During this period, reservoir releases were necessarily higher than normal to maintain the reservoir at no higher than the maximum winter operating level. The accumulation of snow in the reservoir's watershed was at near