Changes in zooplankton species composition in newly filled Bighorn Lake, Montana and Wyoming
by Abraham Andrew Horpestad

A thesis submitted in partial fulfillment of the requirements for the degree of DOCTOR OF PHILOSOPHY in Botany
Montana State University

Abstract:
The zooplankton community of newly filled Bighorn Lake was studied during 1968 and 1970. Samples were collected from six sampling stations throughout the reservoir on 37 different dates. Birth rates, death rates and rates of population change were calculated for Daphnia pulex and Daphnia galeata mendota. Assimilation rates for these two species were also calculated.

Genera contributing more than 5% of the total standing crop included two cladocerans, Daphnia pulex and Daphnia galeata mendota, and two copepods, Diaptomus ashlandi and Cyclops bicuspidatus thomasi.

Daphnia pulex and Diaptomus ashlandi became less abundant while Daphnia galeata mendota, Cyclops bicuspidatus thomasi and rotifers became more abundant over the three year period. Increases in total standing crops of zooplankton and phytoplankton were similar. However, the percentage of the primary productivity assimilated by Daphnia species declined. The average length of Daphnia pulex was. 20% greater than Daphnia galeata mendota. These two species were most abundant at different stations, depths and times. There were no significant changes in the mean lengths of the two Daphnia species over the three year period.

The observed changes support the hypothesis that declines in sport fish "production" of newly filled reservoirs results from predation by planktiverous fish on large zooplankters.

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Approved:

John C. Wright
Chairperson, Graduate Committee

James M. Pickett
Head, Major Department

Henry L Parsons
Graduate Dean

MONTANA STATE UNIVERSITY
Bozeman, Montana

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ABSTRACT

The zooplankton community of newly filled Bighorn Lake was studied during 1968 and 1970. Samples were collected from six sampling stations throughout the reservoir on 37 different dates. Birth rates, death rates and rates of population change were calculated for *Daphnia pulex* and *Daphnia galeata mendota*. Assimilation rates for these two species were also calculated.

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The observed changes support the hypothesis that declines in sport fish "production" of newly filled reservoirs results from predation by planktiverous fish on large zooplankters.

INTRODUCTION

In this study, factors which could cause declines in fishing success in newly filled reservoirs and other factors enabling cogeneric species to exist in the same habitat are investigated.

Newly impounded reservoirs usually have a large population of desirable sized sport fishes which soon declines (Bennett, 1971; Carlander, et al., 1963; Neel, 1963). This initial high "productivity" has been attributed to an initially high level of nutrients resulting from decomposition of newly flooded organic matter. However, Bennett established in 1947 (Bennett, 1971) that the high productivity of sport fishes was also related to the numbers and kinds of fish introduced into ponds lacking fish. The mechanisms causing the declines in productivity have not been established.

A comprehensive 3-year limnological investigation of Bighorn Lake which started in 1968, one year after initial filling of the reservoir, afforded an opportunity to determine what could cause a decline in sport fish production. Usable data was not gathered in 1969 due to mechanical failures.

In 1967, the Montana Fish and Game Department started to document the kinds of fish present and their population sizes. The documentation was not done in sufficient detail to be of value to this study. However, Galbraith (1967) demonstrated that rainbow trout, the dominant fish in Bighorn Lake, filter feeds on zooplankton at least until they are 15 inches long.

Preliminary sampling showed that two similar sized *Daphnia* species were present in the reservoir. Ecological theory indicates that two such similar species should not continue to coexist unless there are factors which ecologically separate them. This study included a search for such factors.

Soltero (1971) gives physical, chemical and phytological data for this reservoir for the same three year period. My report does not include raw data; complete copies of all raw data are on file with the biology department of Montana State University.

DESCRIPTION OF THE STUDY AREA

The Bighorn River is impounded by Yellowtail Dam approximately 80.5 kilometers (50 miles) southeast of Billings, Montana. Bighorn Lake, the resulting reservoir, normally extends from the dam at Fort Smith, Montana, latitude 45°18'27", longitude 107°57'26", south into Wyoming for a distance of 98.4 kilometers (61 miles). The water is used for power production, flood control, irrigation and recreation.

The Bureau of Reclamation began construction of Yellowtail Dam in 1961 and completed construction in 1967. Storage began 4 November 1965. The reservoir has a usable capacity of 169 x 10^7 m^3 (1,375,000 acre-ft) below elevation 1,114.6 m (3,657 ft). Normal operating capacity is 144 x 10^7 m^3 (1,097,000 acre-ft) at elevation 1,109.5 m (3,640 ft) and minimum operating level is 60 x 10^7 m^3 (483,400 acre-ft) at elevation 1,081.1 m (3,547 ft). Dead storage amounts to 234 x 10^5 m^3 (18,970 acre-ft) below elevation 1,005.8 m (3,296 ft). Other morphometric data for the reservoir are given in Table I.

Water can be discharged from the reservoir through three outlets; (1) the spillway--elevation 1,095.1 m (3,593 ft); (2) the power penstocks--elevation 1,051.6 m (3,450 ft); and (3) the river outlet invert--elevation 1,005.8 m (3,296 ft). All water is normally discharged through the power penstocks.

Six permanent sampling stations were established on the reservoir

Table I. Morphometric data for Bighorn Lake at maximum capacity (elevation 1,115.5 m). Table adapted from Soltero (1971).

Maximum Length	98.4 km (61 mi)
Maximum Width	3.2 km (2.0 mi)
Mean Width	739 m (2,425 ft)
Maximum Depth	140 m (459 ft)
Mean Depth	24 m (80 ft)

(Fig. 1). Kilometer 0 (Station 0) was located at the dam site with the remaining stations at approximately 16.1 kilometer (10 mile) intervals up the reservoir for 80.5 kilometers to station 50.

The major tributaries to the reservoir are the Bighorn and Shoshone Rivers (Fig. 1).

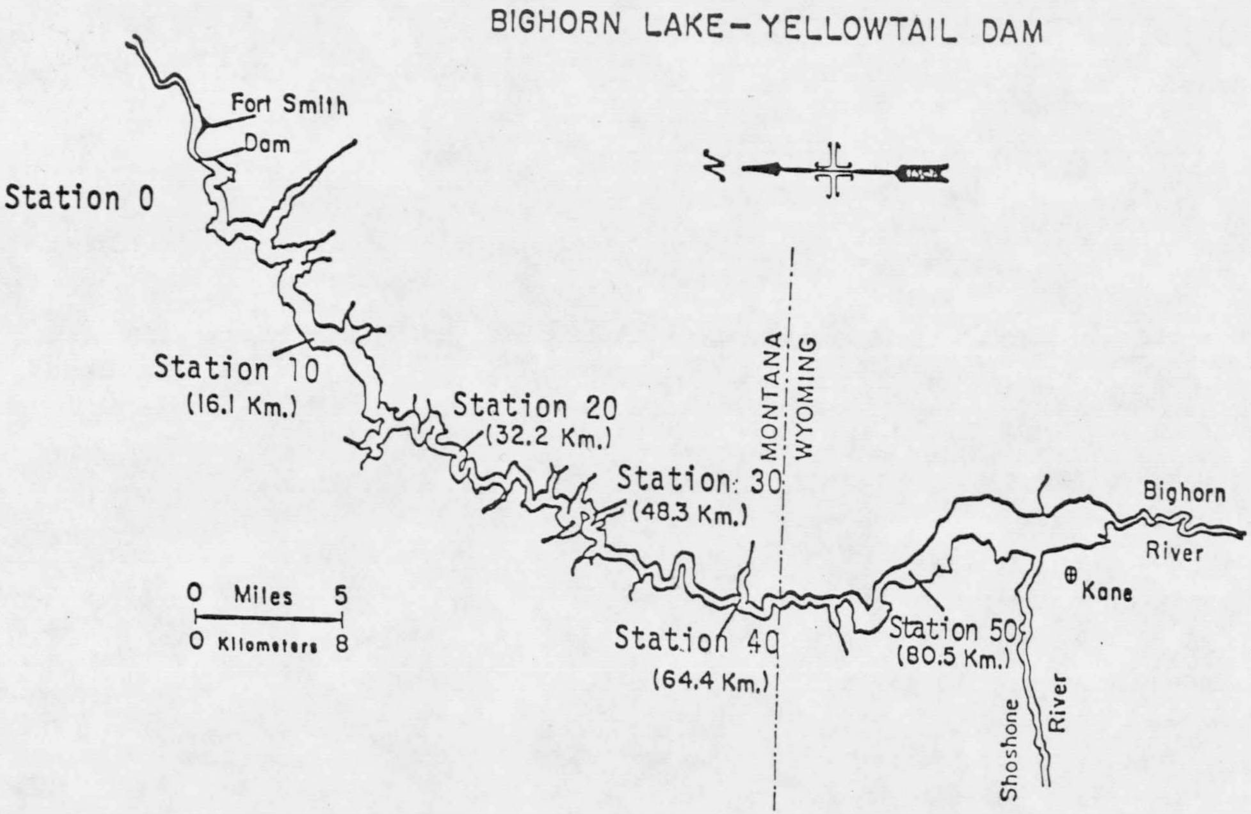

Figure 1. Map of Bighorn Lake (adapted from Soltero, 1971) showing location of the six permanent sampling stations.

METHODS

A Clarke-Bumpus plankton sampler with a no. 20 net (0.080 mm aperture size) was used to collect zooplankton samples at each of the permanent stations during daylight hours. Oblique tows from 25 meters depth or the bottom (whichever was less) to the surface were made. Deeper tows were also made on selected dates in 1968 and 1970. Samples were preserved in the field with 95% ethanol. In 1968, collections were made on 24 occasions between May 5th and November 2nd. In 1970, collections were made on 14 occasions between June 10th and September 9th.

Zooplankton were counted using a Sedgwick-Rafter cell and a binocular microscope equipped with a Whipple micrometer. Magnifications ranged from 30X to 90X. Although dilutions were sometimes necessary, at least one 1 ml aliquot was counted. All organisms were counted until approximately 100 of the most abundant cladoceran were counted. The distance from the top of the head to the base of the spine was determined for each _Daphnia_ counted. All of the identifiable cladoceran eggs and embryos in each aliquot were counted. Identification followed Edmondson (1959). Unattached eggs and embryos were assigned to species according to species densities. The entire sample was examined for the presence of large organisms.

Birth rates, death rates and rates of population change were calculated for both _Daphnia pulex_ and _Daphnia galeata mendota_. If the populations are sampled at suitable intervals, the average instantaneous rate of population change (r) can be calculated from successive pairs of population density values. If the density of the initial population is N_o and the density after time t is N_t then:

$$N_t = N_o e^{rt} .$$

The finite birth rate (B), the number of newborn per individual per day, can be calculated using the methods of Edmondson (1960), if the number of eggs in a population (E), the population density (N), and the developmental time of the embryonic stage (D) are known, as follows:

$$B = \frac{E}{DN_o} .$$

Developmental times under laboratory conditions have been determined by Edmondson (1960) and Hall (1964). Hall's laboratory data were applied to the field data using the temperatures at 12.5 m or the surface. Temperatures used are from Soltero (1971). Developmental times so derived are similar to those Wright (1965) obtained for a comparable field situation.

Instantaneous birth rates (b) were estimated using the Leslie method as suggested by Caswell (1972):

$$b = \frac{rB}{(e^r-1)} .$$

If estimates of b and r have been generated by the equations above then instantaneous death rates (d) can be calculated since:

$$r = b - d .$$

These equations assume constant continuous per capita birth rate (b), constant continuous rate of increase (r) and thus a constant continuous death rate (d). They also assume that migration (out or in) does not occur.

Total standing crops (in mg/l) were calculated using the size to weight relationships and the average weights developed by LeSeur (1959) and Hall et al. (1970). For species not listed in these sources, interpolation and size comparisons were used to establish mean dry weights.

Zooplankton population biomass was also computed in areal units (g/m^2).

RESULTS

Abundance of Zooplankton

Twenty-six taxa were identified during this investigation; 10 taxa were in the Cladocera, 3 were in the Copepoda, and 13 were in the Rotifera (Tables 2 and 3).

The total standing crop was much higher at station 0 in 1968 than at any other station and it decreased "upstream". In contrast, in 1970 the total standing crop was lowest at station 0 and increased upstream.

The cladoceran, *Daphnia galeata mendota* was the most abundant and contributed more to the total standing crop than any other taxon. *Daphnia pulex* was most abundant at station 0 in both years and contributed more to the total standing crop at this station than any other taxon in both years.

The dominant copepods were *Diaptomus ashlandi* and *Cyclops bicuspidatus thomasi*. In both 1968 and 1970 *Diaptomus ashlandi* adults were most abundant at station 0 while nauplii were most abundant at station 40; copepodites were most abundant at stations 0 and 50 in 1968 and 1970, respectively.

Adult *Cyclops bicuspidatus thomasi* were also most abundant at station 0 in 1968 while nauplii and copepodites were most abundant at station 50; all life stages were most abundant at station 50 in 1970.

Rotifers were generally most abundant at stations 40 and 50 in 1968 and 1970, respectively.

Table 2: Mean number/liter of each taxon at each station in 1968, mean percent contribution to total standing crop (in parenthesis) and mean total standing crop at each station.

taxa	Stations 0	10	20	30	40	50
Cladocera						
Daphnia galeata mendota Birge 1881	6.33 (6.2)	12.05 (29.1)	11.81 (42.7)	8.91 (24.6)	16.30 (31.3)	.01 (5.2)
D. pulex Leydig 1860 emend. Richard 1896	18.92 (43.9)	3.70 (17.9)	1.51 (7.6)	1.79 (11.7)	1.10 (4.2)	.02 (10.5)
Diaphanosoma leuchtenbergianun, Fisher 1850		.03 (<0.1)	.12 (0.3)			
Ceriodaphnia reticulata (Jurine) 1820		1.34 (2.4)	2.72 (4.0)	2.71 (6.1)	4.21 (6.3)	.03 (1.7)
Moina spp. Baird 1850	.04 (<0.1)	.15 (0.3)	.49 (0.7)	.21 (0.5)	2.01 (3.0)	.01 (0.5)
Bosmina longirostris (O.F. Muller) 1785		2.58 (2.8)	5.37 (3.4)	6.19 (6.1)	2.24 (1.4)	.05 (1.2)
Macrothrix rosea (Jurine) 1820				.01 (<0.1)	.03 (<0.1)	.06 (1.6)
Kurzia latissima (Kurz) 1874					.10 (<0.1)	.03 (<0.1)
Leydigia quadrangularis (Leydig) 1960	.05 (<0.1)	.01 (<0.1)	.002 (<0.1)	.01 (<0.1)	.04 (<0.1)	.05 (<0.1)