BIOLOGY AND PREDATOR USE OF CISCO (*Coregonus artedi*) IN FORT PECK RESERVOIR, MONTANA

by

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APPROVAL

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VITA

Mark Scott Mullins was born March 1, 1964 in Akron, Ohio to Thomas A. and Paula R. Mullins. After graduating from high school he attended Kent State University in Kent, Ohio. He then transferred to Montana State University were he received a Bachelor of Science degree in Biology in June of 1988. In July of 1988, he began a Master of Science Degree program with the Montana Cooperative Fishery Research Unit at Montana State University. He is married to Amy Jo Mullins and has two daughters, Paige Elizabeth and Baily Christan.

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ABSTRACT

Selected biological parameter of the cisco (*Coregonus artedi*) and its use by predators in Fort Peck Reservoir were examined during 1989 and 1990. The average length of cisco was approximately 144, 210, and 273 mm at ages 1, 2, and 3, respectively. The average size of spawners was approximately 240 mm and mean condition factors for size groups ranged from 0.75 to 0.91. Comparisons indicated that average size, growth, and condition factors have declined from previous years. Fecundity ranged from 1,119 to 13,956 for spawners with most gonadal development occurring during the fall months for both males and females. Qualitative analysis of stomach contents showed that the cisco utilized primarily *Daphnia* spp. and copepods and appeared to select the larger zooplankton types. Densities of reservoir zooplankton have not changed from pre-cisco (1984) introduction densities, but the zooplankton community composition has shifted towards smaller species. Examination of fish predator stomach contents showed that cisco were the most frequent prey species.

INTRODUCTION

Cisco (*Coregonus artedi*) is a salmonid endemic to North America (Lee et al. 1980), with a historical range in the northern Midwest and eastern United States, the Great Lakes region, and over most of Canada (Scott and Crossman 1977; Hubbs and Lagler 1964). *Coregonus artedi* has the widest distribution of all cisco species (Scott and Crossman 1977) and within its range, has evolved into 22 subspecies (Hubbs and Lagler 1964).

Cisco is both a commercial and a forage species. In the past it was an important commercial fish in the Great Lakes with huge quantities being sold annually; now harvests are clearly smaller (Becker 1983; Eddy and Underhill 1974). Its importance as a prey item for many predaceous fish is well known (Becker 1983). The ciscos importance as a sport fish is limited. Cisco may provide some recreational fishing in the spring as well as through the ice in the winter (Scott and Crossman 1973), but Becker (1983) reported that cisco have little value as a sport fish in Wisconsin.

Cisco were introduced into Fort Peck Reservoir in the spring of 1984 by the Montana Department of Fish, Wildlife, and Parks (MDFWP) (Wiedenheft 1984). Subsequent stockings were made in 1985 and 1986 (W.D. Wiedenheft, MDFWP, unpublished data). Source of cisco and the number of fish planted are listed in the Appendix, Table 16.

Cisco were introduced to enhance the prey base for walleye (*Stitzostedion vitreum*), sauger (*Stitzostedion canadense*), lake trout (*Salvelinus namaycush*), and northern pike (*Esox lucius*) (Wiedenheft 1983). They were to supplement a 1982 introduction of spottail shiners (*Notropis hudsonius*) in providing forage (W.D.Wiedenheft, MDFWP, personal communication). At this time it is the only population of cisco in the state of Montana.

Recently fisherman and sportsman groups have asked the MDFWP to stock cisco into additional reservoirs in central Montana to improve the prey base for sport fish. Before additional stockings the MDFWP determined that an assessment of the status and utilization of the existing cisco population was needed. This study was undertaken to aid in making decisions relative to further introductions in the state. Its major objectives were to determine:

1. the well being of the cisco as indicated by:
   a. age and growth
   b. fecundity, gonadosomatic index (GSI), and egg development
   c. condition factors
2. food habits of cisco

3. depth and/or temperature preference of cisco
4. utilization of cisco by predator sport fish

In addition, information was gathered on gill raker morphology to determine its relationship to the size of zooplankton eaten, and the condition factors of the fish. Field work was initiated in August 1989 and terminated in December 1990.

STUDY SITE DESCRIPTION

Fort Peck Reservoir is located in northeast Montana, approximately 29 km southeast of the city of Glasgow (Figure 1). The reservoir lies within the Charles M. Russell National Wildlife Refuge. Fort Peck was created by damming the Missouri River in 1939, and was filled by 1947 (Phenicie 1950). The reservoir is long and narrow in shape and has two distinct sections. The largest section, the Missouri Arm, extends 215.6 km up the Missouri River. The other major section, the Big Dry Arm, extends 64.4 km south of the dam. The Missouri and the Musselshell Rivers are the main sources of water feeding the reservoir. The U.S. Corps of Engineers operate Fort Peck Reservoir to provide water storage for navigation and flood control on the lower Missouri River, with hydroelectric power being a secondary benefit (Phenicie 1950).

The normal operating elevation of the reservoir is 684.6 m above mean sea level (MSL) with an average annual fluctuation since 1966 of 2.7 m (Liebelt 1981). At normal level the reservoir has a storage capacity of 506,928 m^3, and a surface area of 97,128 ha (Liebelt 1981). Its maximum depth is 67 m, with an average depth of 24 m. Its average width is 4.8 km and has a shoreline of 2,445.7 km

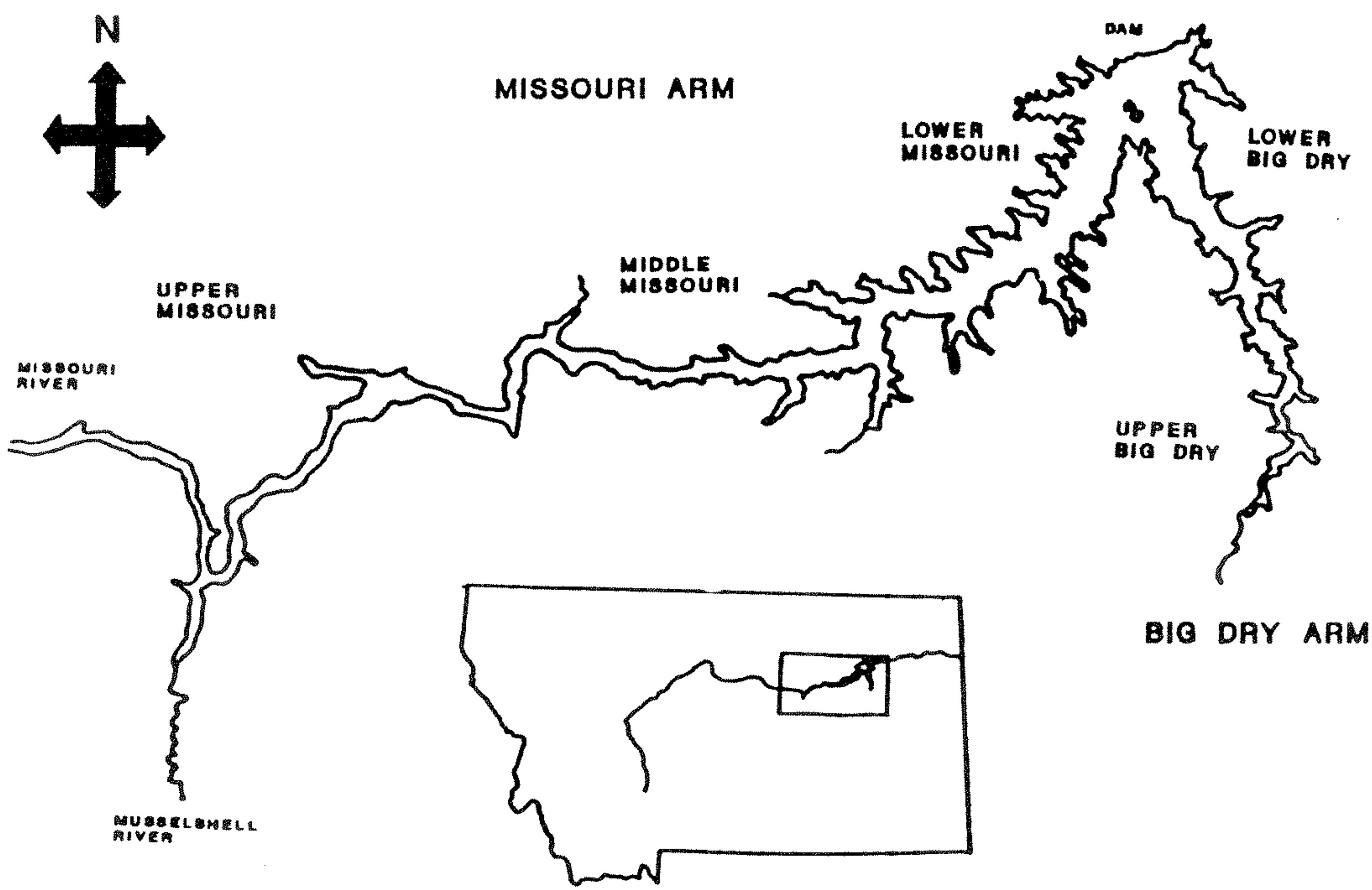

Figure 1. Map of Fort Peck Reservoir and its location in Montana.

(Alvord 1979). Because of several years of drought, during this study water levels varied between 677.2 m and 673.3 m above MSL (U.S. Corps of Engineers, Fort Peck, Montana, unpublished data).

Nutrient measurements in the reservoir show that it is ultra-oligotrophic in inorganic nitrogen and meso-eutrophic in phosphorus concentrations (Hadley 1982). During this study the pH fluctuated between 7.9 and 8.9 (U.S. Corps of Engineers, unpublished data). The reservoir is dimictic and its stratification is typical of northern temperate waters (Hadley 1982). The theoretical water exchange rate of the reservoir is 635 days (d) (Hadley 1982).

There were 46 known species of fish in Fort Peck Reservoir at the time of this study (Appendix Table 17), with only six predator species of recreational significance. These game species are indicated in the table. Commercial fishing for goldeye (*Hiodon alsoides*) has occurred in the past.

METHODS

Cisco

Specimen Collection

Cisco were collected mainly from the lower end of the reservoir, with various types and sizes of gill nets (Appendix Table 18) in the summer and fall of 1989, and in the spring, summer, and fall of 1990. Schools of suspected cisco were located with a Lowrance X-15B fish finder and nets placed at those locations. Nets were generally set during the morning and retrieved the following morning, conditions permitting.

Length and Weight

Total length (TL) of cisco was measured to the nearest 1.0 millimeter (mm) and weight was measured to the nearest 1.0 gram (g) using an Ohaus Lume-O-Gram digital balance.

Age and Growth

Scales for age determination were collected in both 1989 and 1990. Cellulose acetate impressions were made of scales or scales were mounted between two microscope slides. These were examined using a microfiche reader at 42X magnification. Scale radius and distance to annuli were measured following the method of Jearld (1983).

Age was estimated from the scales by the method of Tesch (1968). Growth was estimated from back calculation, assuming the body length to scale radius relationship was isometric (R^2=0.79, N=148 for 1989; R^2=0.76, N=101 for 1990). The back calculation formula was:

$$l_n = (S_n/S)\ (l)$$

where l_n is the length of the fish when annulus n was formed, l is the length of the fish at the time the scale sample was obtained, S_n is the radius of annulus n, and S is the total scale radius (Tesch 1968).

Condition Factors

Condition factors were calculated with the formula from Anderson and Gutreuter (1983):

$$K = (10^5)\ (W)/l^3$$

where K is the condition factor, W is the total weight (g), and l is the total length (mm).

Gonad Development

The ovaries and testes of selected cisco were removed and placed in vials containing four percent (%) formalin with 40 g/liter (L) sucrose (Haney and Hall 1973). Gonads were collected during all periods of sampling. Females collected during spawning were classified as being either ripe or spent. Spent females had broken egg sacs and loose eggs in the body cavities and were not included in the gonad analysis. Spawning males were classified as ripe or not ripe, with only ripe males used in analysis. After preservation, ovaries and testes were blotted dry and weighed on a Mettler Analytical Balance to the nearest 0.01 g. Ovarian tissue was removed as completely as practical prior to weighing.

<u>Gonadosomatic Index</u>. The gonadosomatic index (GSI), was calculated for both female and male cisco. The GSI is the weight of the gonads expressed as a percentage of the body weight (Snyder 1983). The GSI calculated in this study was based on the fishes total weight prior to gonad removal. It was used to show gonadal development in cisco throughout the year.

<u>Fecundity</u>. Total egg number in ripe females was estimated by counting the eggs in a subsample from each ovary. Subsample size was 15 % (± 1 %) of the total ovary weight for each individual. This size was chosen after comparing different percentages and their accuracy in determining total egg numbers (Table 1). The number of eggs/g for each subsample was determined and applied by proportion to the total ovary weight to estimate the total number of eggs. Eggs used for subsample counts were taken from random locations on the ovary of each fish (DuBios et al. 1989).

Table 1. Comparison of the estimated number of eggs from partial counts to the actual number of eggs from total counts for four cisco.

Ovary weight (gm)	Subsample weight (gm)	Percent of total weight	Estimated total count	Actual total count	Percent error
6.87	1.04	15.1	1885	1796	+ 4.9
	1.66	24.2	1880	1796	+ 4.7
	3.43	49.9	1896	1796	+ 5.7
7.99	1.19	14.9	2296	2305	- 0.3
	2.02	25.3	2361	2305	+ 2.4
	4.00	50.1	2357	2305	+ 2.3
10.53	1.58	15.0	2359	2281	+ 3.4
	2.63	24.9	2370	2281	+ 3.9
	5.24	49.7	2312	2281	+ 1.4
20.11	3.02	15.0	4928	4862	+ 1.4
	5.06	25.2	4475	4862	- 8.0
	10.12	50.3	4724	4862	- 2.8

Fecundity was regressed on fish total length to determine the relationship between cisco size and the number of eggs produced. Egg numbers in cisco from this study were compared to those in other populations of cisco.

Egg Diameters. Egg diameters in cisco were determined during all periods of sampling. Diameters were measured using a binocular dissecting microscope (30X) fitted with an ocular micrometer, calibrated with a stage micrometer. Non-spherical eggs were measured through their smallest diameter (Fuiman and Trojnar 1980). Twenty maturing eggs from each fish were measured.

Maturing egg diameters were regressed on fish total length to determine the relationship between the two parameters. Egg diameters were also compared between size classes and between fish of the same size from 1989 and 1990. They were also used to evaluate trends in gonadal development throughout the year.

Food Habits

Cisco stomachs were removed and placed in 4 % formalin with 40 g/L sucrose. Zooplankton and other invertebrates present in the stomachs were placed in easily recognizable groups based on size and morphology using a binocular dissecting microscope under varying magnification. The type of item that appeared to be the most abundant in each individual was noted. Stomach contents were compared to reservoir zooplankton samples to compare the most utilized zooplankton with availability.

Gill Raker Morphology

The first branchial arch of selected cisco was removed from the left side and stored in 4 % formalin with 40 g/L sucrose. Gill rakers were mounted on microscope slides (MacNeill and Brandt 1990) and viewed using a binocular dissecting microscope under 15 - 30X magnification. Gill raker number, length, and spacing were obtained for up to five fish in 25 mm size groups over the study period. Gill raker filtering area was determined by the method described by MacNeill and Brandt (1990). The method involved summing the trapezoidal areas formed between each pair of adjacent gill rakers over the entire arch.

Gill raker number, mean gill raker length and spacing, and filtering area were regressed on cisco length. The latter two parameters also were regressed on condition factors. Gill raker spacing was compared to zooplankton lengths to determine what zooplankton types might be too small to be filtered effectively by various sized cisco.

Depth Distribution

Vertical gill nets were marked in 1 meter (m) increments to determine the depth of cisco capture. A cisco was considered caught at a depth that corresponded to the depth mark directly above its location of capture. The depths at which cisco were captured were analyzed to determine if the cisco exhibited any depth or corresponding temperature preference.

Fish Predators on Cisco

Predator Stomach Contents

The stomachs of predators, primarily walleye and sauger, were examined during three fishing tournaments held in the summer of 1990. The location, dates, and the areas of the reservoir fished during these tournaments are shown in Figure 2. Stomachs of additional predators were

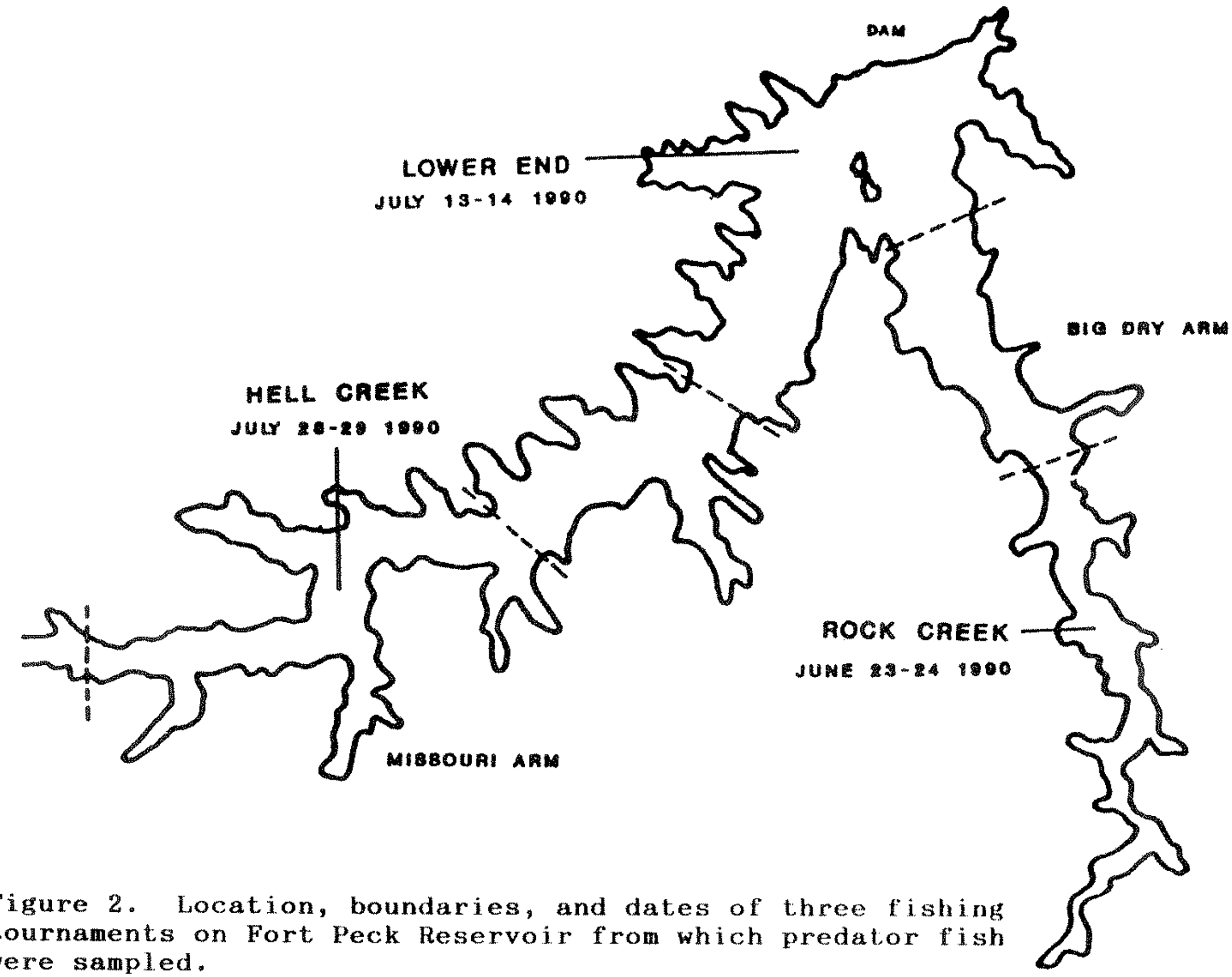

Figure 2. Location, boundaries, and dates of three fishing tournaments on Fort Peck Reservoir from which predator fish were sampled.

collected by the personnel of the MDFWP during a creel census conducted from May through September of 1990.

The stomachs of sampled predators were cut open and examined. If they contained fish, the contents were preserved in 5 % formalin. Relatively intact forage fish found in the stomachs were identified in the field or lab using characteristics described by Gould (1988) or Pflieger (1975). Partially digested forage fish could often be identified by remaining bony parts. Cisco were identified by the last three vertebrate being upturned and fused which is a characteristic of salmonid fishes (Nelson 1984). Intact heads and caudal fins also were useful in identifying cisco. Cisco were the only salmonid prey species available in the reservoir (W.D. Wiedenheft, MDFWP, personal communication). Fish in stomachs that could not be identified as a cisco or cyprinid were classified as unidentified species. Food habit information was used to estimate the level of use of prey species by predators and by location in the reservoir.

Mouth Gapes of Predators

Mouth gapes were measured on predator fish to estimate the maximum size of prey they could swallow. Both vertical and horizontal mouth gapes were measured to the nearest 1 mm with a micrometer. Maximum vertical gape was measured by opening the fishes' mouth until resistance was felt and measuring the distance inside the tips of the jaws. Horizontal gape was measured as the maximum distance between the premaxillae on the inside of the mouth.

Size Determination of Prey

Total length and body depth of cisco found in predator stomachs was determined by direct measurement of the whole fish or estimated from body parts by regression equations determined from cisco captured during cisco sampling. One hundred and thirty two cisco ranging from 105 to 367 mm were collected from gill nets for use in the body part regressions. Measurements used in length estimations were the length of the vertebral column, length of the vertebral column and caudal fin, and head length. These were typical body parts remaining in predator stomachs. Cisco body depth was then estimated using body depth to length relationships from gill netted fish.

The body depth of a cisco eaten by a predator was compared to the maximum estimated size of fish that could be eaten as indicated by its mouth gape. The body depth:total length relationship was also used to estimate the size at which a cisco would become too large for a predator to swallow based on mouth measurements.

Reservoir Zooplankton

Zooplankton were collected during each sampling period throughout the study as conditions permitted. Two vertical tows were made at gill netting sites, sampling from the bottom to the surface in approximately 30 m of water. The plankton net used had an opening diameter of 30.48 centimeters (cm) and a mesh size of 160 microns. Zooplankton samples were preserved in 4 % formalin with 40 g/L sucrose.

Zooplankton were identified using characteristics by Pennak (1978) and a binocular dissecting microscope and/or a compound microscope. ~~A list of species of zooplankton found is shown in the Appendix, Table X.~~ Zooplankton species were placed in groups for analysis by the same criteria as described for cisco food habit analysis.

Density (no./L) of the zooplankton types and total zooplankton density was estimated from subsamples using the formula from Wetzel and Likens (1979):

$$n = (N)(V_s) / V_f$$

where n is the density of organisms (no./L), N is the average number of organisms per subsample (no./milliliter (ml)), V_s is the volume of sample (ml), and V_f is the volume of water sampled (L). Three subsamples of 1 ml each were taken from each well mixed zooplankton sample using a

Hensen-Stempel Pipette. Each subsample was counted using a Ward counting wheel. The density for each sample was estimated using the previously described formula and the average of the two vertical tow samples were then averaged to give the estimated zooplankton density for that location.

Zooplankton length was determined by measuring 100 individuals from each zooplankton group that constituted more than 5 % of the total density during all periods of the study by the method described by Horpestad (1977). Individuals used for measurement were taken randomly from the samples using a Hensen-Stempel Pipette. Individuals were measured using a binocular dissecting microscope fitted with an ocular micrometer under 30X magnification.

Reservoir Limnology

Temperature measurements of the reservoir were taken at each of the netting sites throughout the study when conditions permitted. Water temperatures were measured at 1 m intervals from the bottom to the surface using a Yellow Springs Instrument Company (YSI) model 54A Temperature and Dissolved Oxygen Meter. Additional temperature information along with dissolved oxygen and pH measurements were obtained from the U.S. Corps of Engineers, Fort Peck.

Statistical Analysis

Statistical computations were made using the computer programs MSUSTAT (Lund 1987), and programs developed by S. Lohr (Biology Department, Montana State University). Differences were considered statistically significant at the 0.05 level.

RESULTS

Cisco

Length and Weight Relationship

Separate length to weight relationship equations were calculated for cisco sampled in 1989 and 1990. The relationships were best described using a logarithmic transformation of the data. The log or linear equations for the 2 years were not significantly different from each other, therefore data were combined (Figure 3).

Age and Growth

The back calculated mean total lengths at annuli for cisco sampled during 1989 (Table 2) showed the sizes at age of the three year classes were not significantly different from each other. This also was true in 1990.

A comparison of the estimated lengths at annuli of age classes 1 and 2, between years showed no significant differences. However, the estimated mean length at the third annulus for the age 3 fish from 1989 was significantly greater.

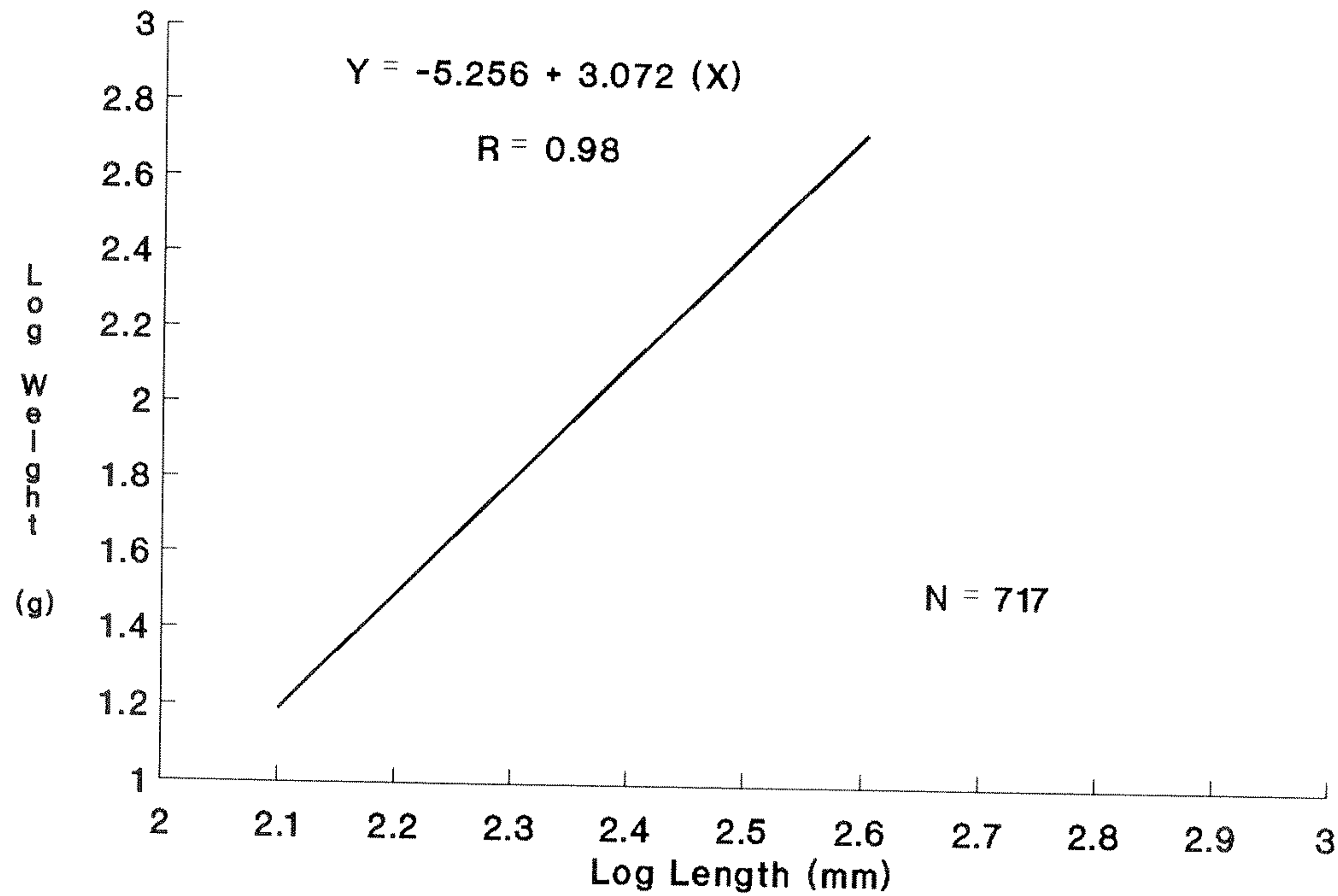

Figure 3. Regression line of the log weight on the log of total length of cisco from Fort Peck Reservoir during 1989 and 1990.

Table 2. Back calculated mean lengths (standard deviations) at annuli by age class for cisco sampled in 1989 and 1990 from Fort Peck Reservoir.

		Mean length (mm) at annuli			
Age	N	1	2	3	4
			1989		
1+	62	145.4(19.2)			
2+	57	141.6(11.6)	207.6(31.7)		
3+	9	143.0(12.3)	240.3(46.3)	295.6(58.2)	
4+	1	168.2	221.3	268.5	342
Grand mean		144.7(15.9)	212.2(35.6)	292.9(56.1)	342
			1990		
1+	33	146.2(22.0)			
2+	43	141.4(10.0)	208.1(23.6)		
3+	12	141.7(6.8)	209.7(15.5)	247.0(14.3)	
4+	1	146.6	269.9	339.6	373.6
Grand mean		143.3(15.5)	209.6(23.4)	254.1(28.2)	373.6

Condition Factors

Mean condition factor of cisco < 275 mm was < 0.9 (Table 3). Multiple comparison tests between size groups for both years (Appendix, Table 19) showed no consistent differences in condition factors. A similar comparison of like size groups between the years (Appendix, Table 20) also produced no apparent difference. Mean condition factors for the various size groups between the different sampling periods of both 1989 and 1990 also were not different.

Table 3. Average condition factors (standard deviations) of cisco taken from Fort Peck Reservoir in 1989 and 1990.

	Size groups (mm)							
Parameter	100-124	125-149	150-174	175-199	200-224	225-249	250-274	275 +
				1989				
N	14	56	5	59	66	99	29	16
Mean	0.839	0.801	0.748	0.758	0.808	0.844	0.884	0.810
	(0.054)	(0.049)	(0.030)	(0.061)	(0.112)	(0.107)	(0.104)	(0.126)
				1990				
N	18			36	97	113	30	11
Mean	0.884	-	-	0.768	0.774	0.810	0.898	0.908
	(0.121)			(0.048)	(0.088)	(0.098)	(0.079)	(0.095)

Condition factors of individual cisco were placed in categories (Figure 4) developed by the Minnesota Department of Natural Resources (MDNR) for cisco (Carlander 1969). This ranking showed that nearly 75 % of the cisco sampled from Fort Peck in 1989 and 1990 were in either poor or fair condition, with only one cisco classified as in above average condition.

Gonad Development

Gonadosomatic Index. Gonad development analysis showed that male GSI increased throughout the sampling period for both years, with maximum GSI occurring during spawning (Table 4). In comparing the mean GSI for spawning males of the same size groups between years, the only

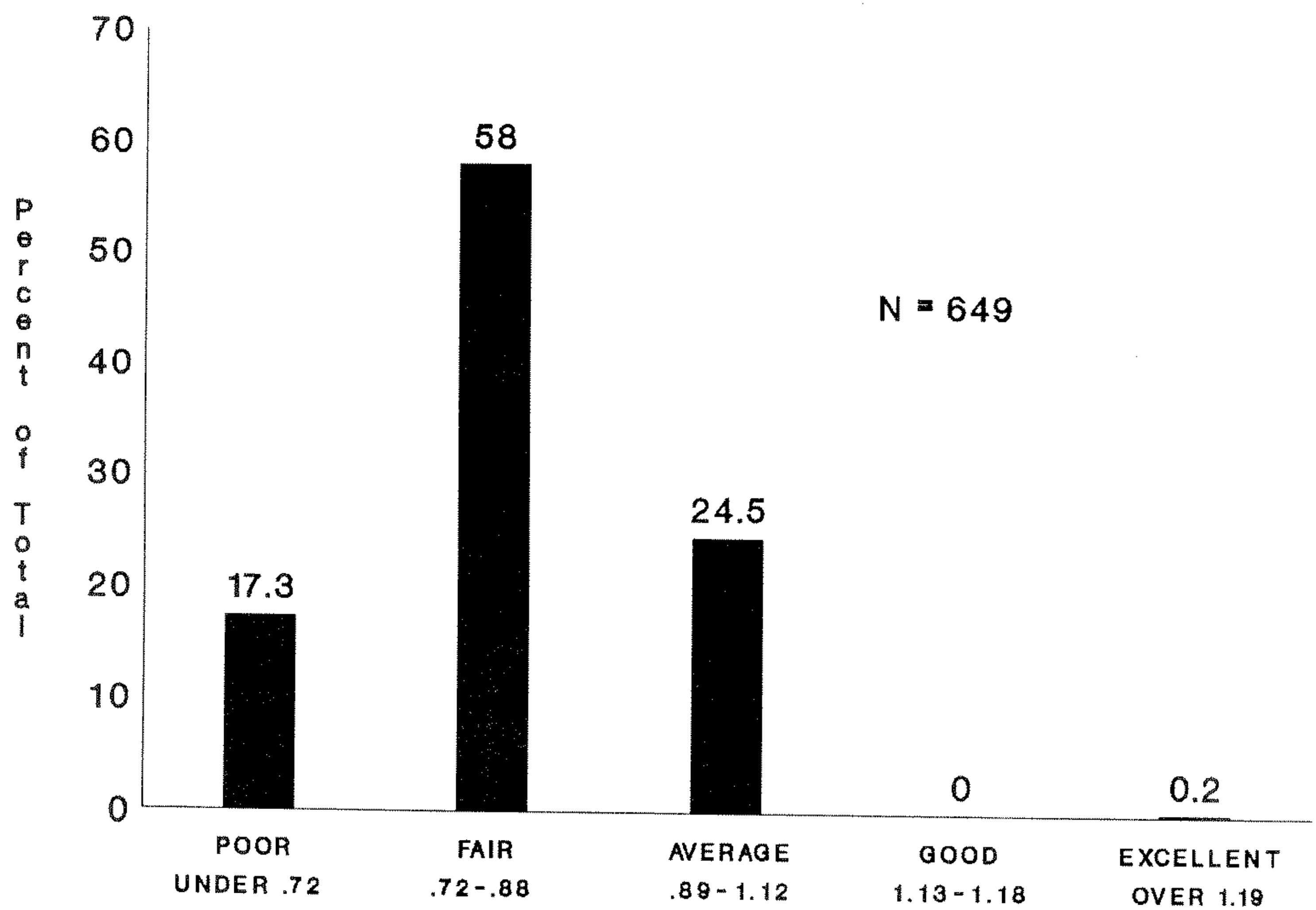

Figure 4. Condition factors of Fort Peck cisco as rated by criteria of Minnesota Department of Natural Resources.

significant difference was the 250 mm size group which was greater in 1990 than in 1989 (Appendix, Table 21).

Table 4. Mean gonadosomatic index (GSI) for male cisco taken from Fort Peck Reservoir.

Time	N	Length (mm)	Mean GSI	SD
1989				
August	5	175-199	0.0032	0.0056
	8	200-224	0.0019	0.0009
	8	225-249	0.0040	0.0043
	1	250-274	0.0053	-
	1	275 +	0.0021	-
September	2	125-149	0.0051	0.0001
	4	175-199	0.0058	0.0063
	6	200-224	0.011	0.0076
	2	225-249	0.013	0.0006
	1	275 +	0.00085	-
November[a]	2	175-199	0.0094	0.0018
	4	200-224	0.011	0.0012
	15	225-249	0.013	0.0022
	7	250-274	0.013	0.0015
	5	275 +	0.014	0.0041
1990				
May-June	3	200-224	0.0015	0.0003
	9	225-249	0.0017	0.0012
July-August	1	100-124	0.0018	-
	3	175-199	0.0026	0.0013
	17	200-224	0.0018	0.0010
	15	225-249	0.0025	0.0015
	1	275 +	0.023	-
November[a]	12	200-224	0.011	0.0019
	17	225-249	0.013	0.0032
	14	250-274	0.016	0.0034
	6	275 +	0.015	0.0033

[a] Spawning fish.

Female gonad development was similar in pattern to that of the males throughout the sampling period (Table 5). However, the maximum GSI values for females was significantly greater than for males.

There was a significant difference between years in mean GSI in the size groups of spawning females (where N > 1) (Appendix, Table 22). The mean GSIs were greater for the 200 mm and 225 mm groups in 1989 and the 250 mm group was greater in 1990.

Egg Diameters. The average diameters of maturing eggs in cisco sampled in 1989 and 1990 (Table 6) increased throughout the sampling periods in both years. This pattern of increase was consistent with the increase in the GSI development through time. The results of a comparison test of mean egg diameters (where N > 1) between spawning cisco in 1989 and 1990 showed the only significant differences were in the 225 and 250 mm size groups (Appendix, Table 23).

Fecundity. The mean number of eggs in spawning cisco collected during 1989 and 1990 ranged from 1,119 to 13,956 (Table 7). A total length to number of eggs regression equation calculated for 1989 data (Figure 5) showed a weak correlation (R = 0.59, N = 66). A logarithmic transformation of the data only improved the correlation to r = 0.65. The regression equation calculated for 1990

(Figure 6) showed a higher correlation (r = 0.85, N = 30) than the 1989 sampling.

Table 5. Mean gonadosomatic index (GSI) for female cisco taken from Fort Peck Reservoir.

Time	N	Length (mm)	Mean GSI	SD
1989				
August	3	150-174	0.0017	0.0014
	4	175-199	0.0023	0.0010
	8	200-224	0.0073	0.0045
	8	225-249	0.0091	0.0043
	4	275 +	0.0029	0.0012
September	5	175-199	0.0094	0.0096
	3	225-249	0.017	0.018
	1	250-274	0.039	-
	3	275 +	0.0039	0.0009
November[a]	1	125-149	0.16	-
	7	175-199	0.13	0.015
	17	200-224	0.18	0.022
	39	225-249	0.14	0.032
	8	250-274	0.13	0.033
	1	275 +	0.064	-
1990				
May-June	5	200-224	0.0022	0.0007
	3	225-249	0.0033	0.0005
	1	275 +	0.011	-
July-August	1	100-124	0.0059	-
	1	150-174	0.0025	-
	4	175-199	0.0086	0.0066
	16	200-224	0.0087	0.0054
	18	225-249	0.0087	0.0039
	1	250-274	0.0066	-
	1	275 +	0.023	-
November[a]	1	175-199	0.10	-
	11	200-224	0.12	0.019
	11	225-249	0.11	0.025
	6	250-274	0.14	0.020
	1	275 +	0.16	-

[a] Spawning fish.

Table 6. Average egg diameters (standard deviation) maturing in cisco from Fort Peck Reservoir.

Time	N	Length (mm)	Diameter (mm)	SD
1989				
August	3	150 - 174	0.32	0.11
	4	175 - 199	0.33	0.011
	7	200 - 224	0.59	0.17
	8	225 - 249	0.59	0.12
	4	275 +	0.47	0.18
September	5	175 - 199	0.54	0.31
	2	250 - 274	0.71	0.50
	2	275 +	0.36	0.001
November[a]	6	175 - 199	1.78	0.064
	10	200 - 224	1.82	0.076
	23	225 - 249	1.87	0.085
	8	250 - 274	1.90	0.085
1990				
May-June	5	200 - 224	0.38	0.077
	3	225 - 249	0.42	0.031
July-August	2	175 - 199	0.58	0.12
	6	200 - 224	0.69	0.21
	5	225 - 249	0.69	0.065
November-December[a]	8	200 - 224	1.95	0.40
	7	225 - 249	1.89	0.075
	5	250 - 274	1.83	0.051

[a] Spawning fish.

A comparison test of the mean number of eggs among size groups (where N > 1) showed significant differences between each size group in both years. Egg numbers increased with size group in both 1989 and 1990, with the exception of the 275+ mm size group in 1989 (Table 7). A comparison of similar size groups (where N > 1) between years showed no significant differences in egg numbers.

Table 7. Average number of maturing eggs in spawning cisco from Fort Peck Reservoir.

Size group (mm)	N	Mean number of eggs	SD
		1989	
125-149	1	1119	-
175-199	6	2092	231
200-224	16	2873	663
225-249	35	4020	1280
250-274	7	5542	1594
275 +	1	4878	-
		1990	
175-199	1	1653	-
200-224	11	2468	715
225-249	11	3811	1742
250-274	6	5703	1453
275 +	1	13956	-

Spawner Characteristics

Spawning cisco were age 1+ through 4+ in both 1989 and 1990, however the most common age groups sampled were 1+ and 2+ in both years. The age 1+ group made up 47.4 % (N = 57) of the sample in 1989 and 19.6 % (N = 56) in 1990. Age 2+ made up 47.4 % in 1989 and 58.9 % in 1990. Age 3+ cisco made up a larger percentage in 1990 (21.4 %) than in 1989 (5.3 %). The age 4+ group was rare with only one identified individual from that age group sampled in both 1989 and 1990.

Average size of spawning cisco (Figure 7) for 1989 (N = 330) was 249 mm for males and 262 mm for females. The average size (N = 100) of males in 1990 was 237 mm and 245 mm for females.

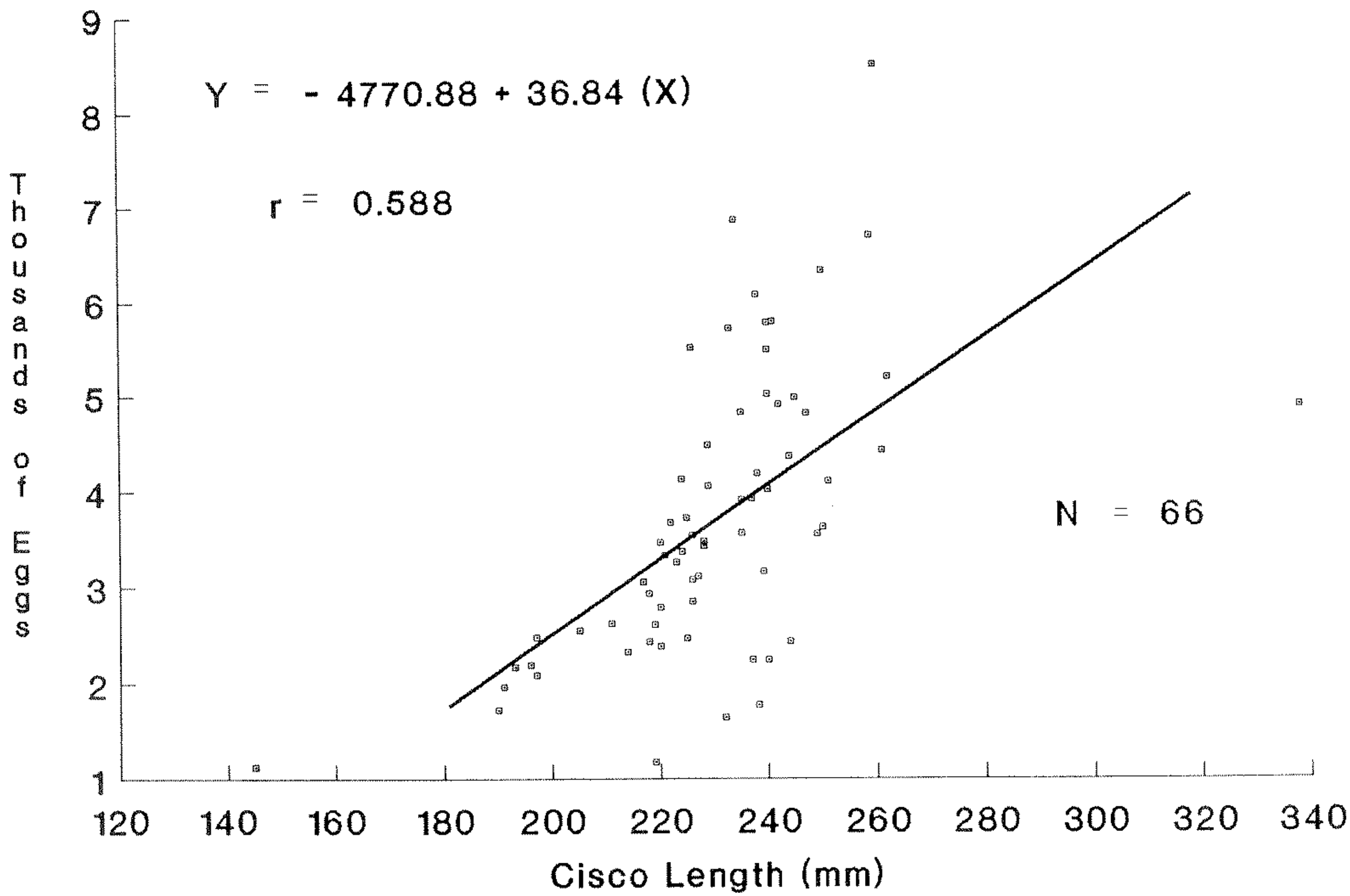

Figure 5. Regression of the number of mature eggs present against total length of cisco sampled from Fort Peck Reservoir in 1989.

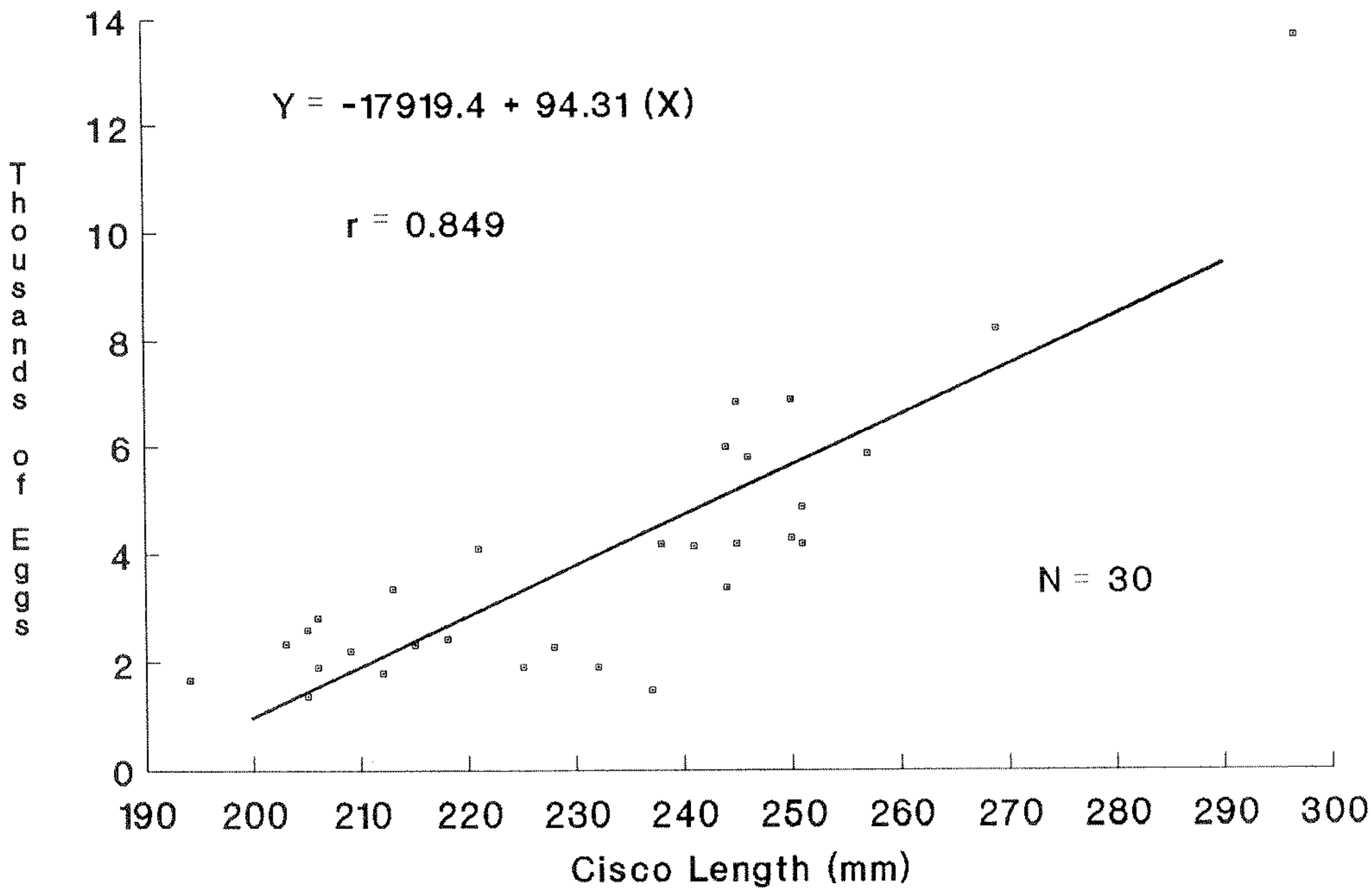

Figure 6. Regression of the number of mature eggs present against total length of cisco sampled from Fort Peck Reservoir in 1990.

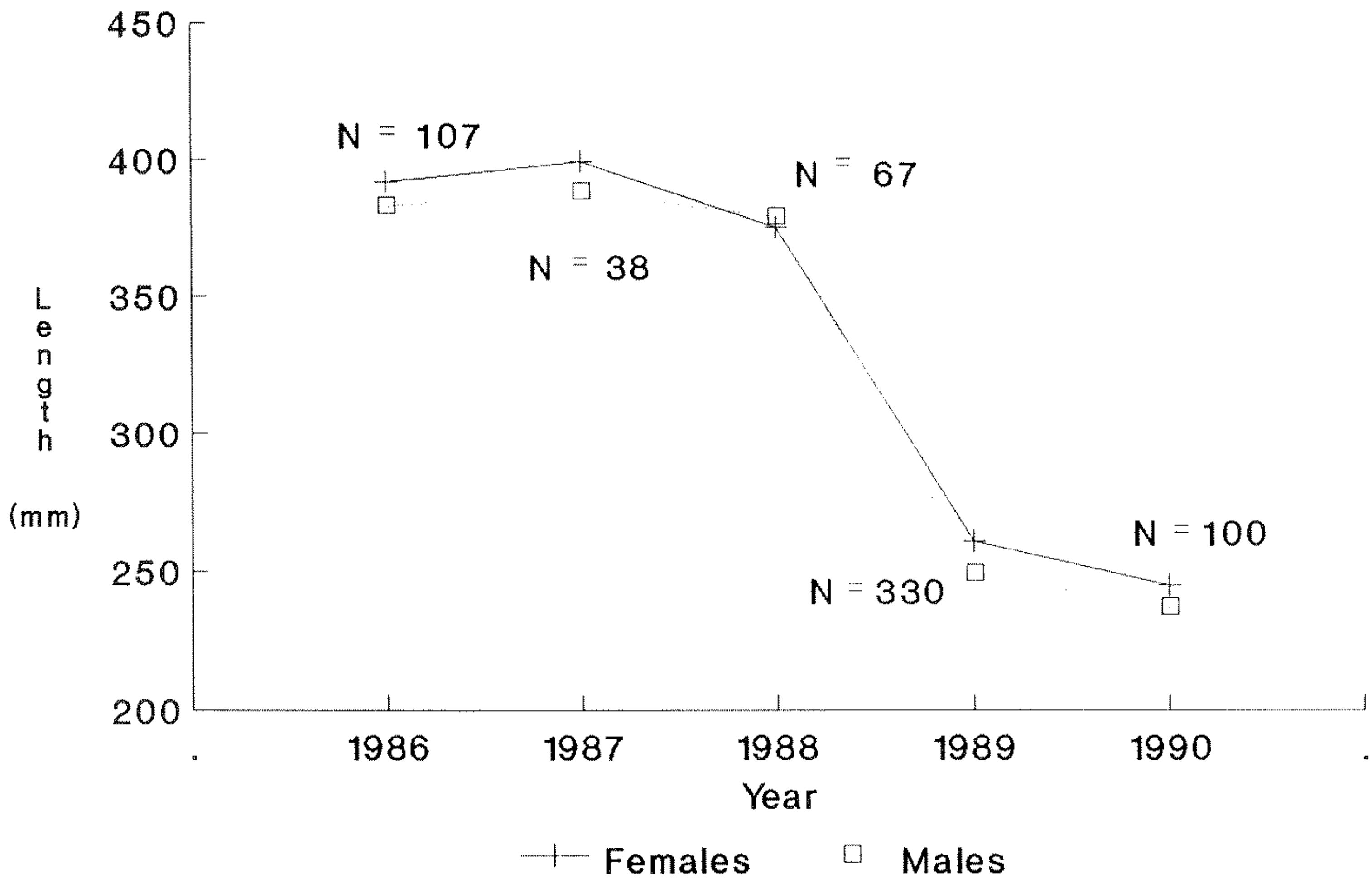

Figure 7. Average length of spawning cisco in Fort Peck Reservoir from 1986 to 1990. Data from 1986 - 1989 provided by Montana Department of Fish, Wildlife, and Parks.

The male to female sex ratio for spawning cisco was 2.4 : 1.0 (N = 131) in 1989. In 1990 it was 8.1 : 1.0 (N = 668).

Food Habits

About 50.0 % of the cisco stomachs examined were empty, with percentages greater in 1990 (66.8 %) than in 1989 (37.5 %) (Table 8). Food items found in the stomach samples consisted of the four types of zooplankton sampled in vertical tows from the reservoir (Table 9) and terrestrial invertebrates.

Copepods (*Cyclops* sp. and *Diaptomus* sp.) were the most frequently encountered food item in cisco stomachs throughout all sampling periods (Figure 8). *Daphnia* were the second most frequent food item, and were common except in the May-June sampling of 1990. Terrestrial insects were primarily found in stomachs during summer samples of both years.

A qualitative analysis to determine the most numerous food type in individual cisco stomachs showed that copepods were the most abundant item in most of the cisco sampled (Figure 9). *Daphnia* appeared to be used heavily only during the summer months.

Table 8. Number of cisco stomachs examined for food items and number (percentage) containing food items.

Time	N	No. empty	No. with food items
1989			
August	53	27 (50.9)	26 (49.1)
September	30	12 (40.0)	18 (60.0)
November	53	12 (22.6)	41 (77.4)
1990			
May-June	18	11 (61.1)	7 (38.9)
July-August	91	62 (68.1)	29 (31.9)
November	81	54 (66.7)	27 (33.3)

Table 9. Taxa identified in Fort Peck Reservoir zooplankton samples during 1989 and 1990.

Order	Genus species
Cladocera	
	Daphnia retrocurva
	Daphnia galeata mendote
	Bosmina longirostris
	Diaphnasoma leuchtenbergianum
	Leptodora kindti
Calanoida	
	Diaptomus sp.
Cyclopoida	
	Cyclops sp.

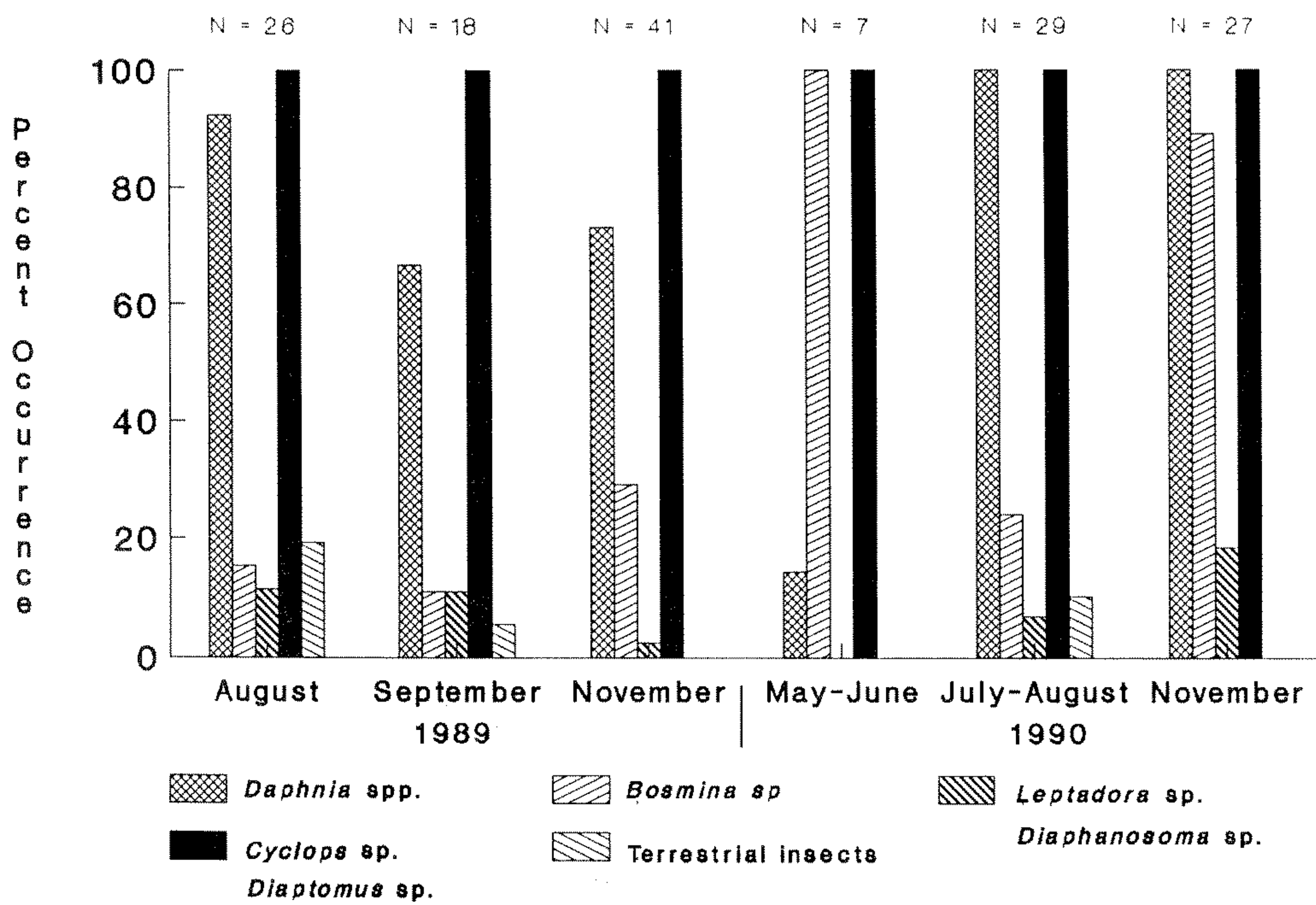

Figure 8. The frequency of occurrence of zooplankton types in stomachs of cisco sampled from Fort Peck Reservoir during 1989 and 1990.

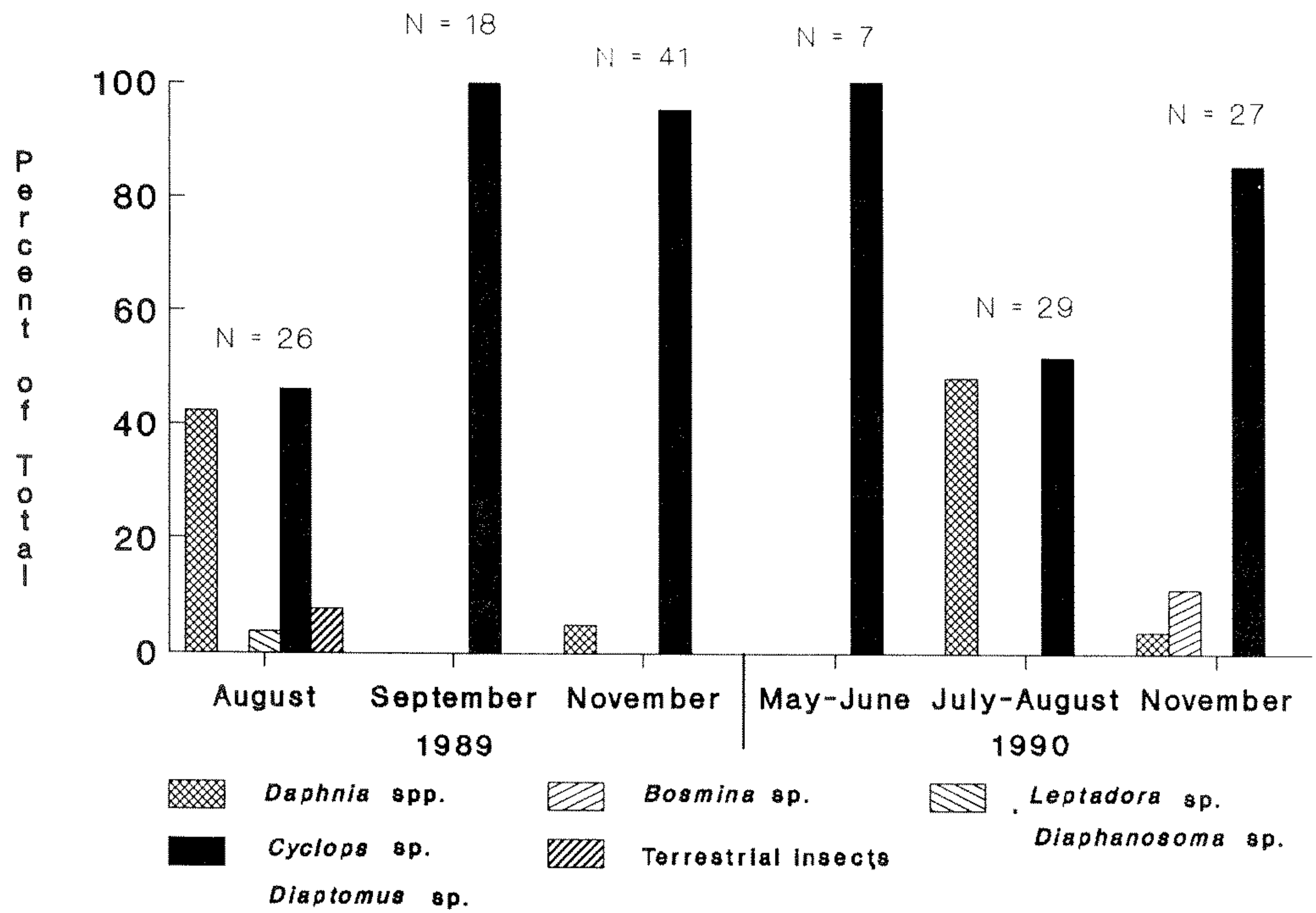

Figure 9. The estimated most abundant zooplankton types in individual cisco stomachs from Fort Peck Reservoir during 1989 and 1990.

Gill Raker Characteristics

Sizes of the filter feeding structures in cisco varied between size groups (Table 10). Mean gill raker length increased with cisco length for all groups with the exception of the 200 mm and 225 mm groups. No significant differences in gill raker length occurred between the size groups except in the 275+ group which had significantly longer gill rakers than all others (Appendix, Table 24). Gill raker length and cisco total length were highly correlated ($R = 0.98$, $N = 17$) (Figure 10.).

Table 10. Mean gill raker length, spacing, filtering area (standard deviation), and gill raker numbers for various size groups of cisco sampled in Fort Peck Reservoir during 1989 and 1990.

Size groups (mm)	N	Mean length (mm)	Mean spacing (mm)	Mean filtering area(mm^2)	Gill raker numbers
100-125	1	2.05	0.20	18.28	44
125-149	2	2.28(0.47)	0.28(0.006)	20.94(5.21)	39-41
175-199	2	3.52(0.28)	0.35(0.017)	54.76(7.69)	41-42
200-224	3	4.14(0.11)	0.37(0.026)	71.15(1.45)	43-46
225-249	2	4.19(0.22)	0.39(0.021)	88.21(4.57)	48-51
250-274	2	4.86(0.18)	0.37(0.027)	90.80(0.42)	48-50
275 +	5	6.48(0.75)	0.46(0.020)	149.32(18.87)	45-53

Mean gill raker spacing increased with cisco length except with the 250 mm group (Table 10). The correlation between gill raker spacing and cisco total length ($R = 0.90$, $N = 17$) was lower than the correlation between gill raker length and cisco total length (Figure 11).

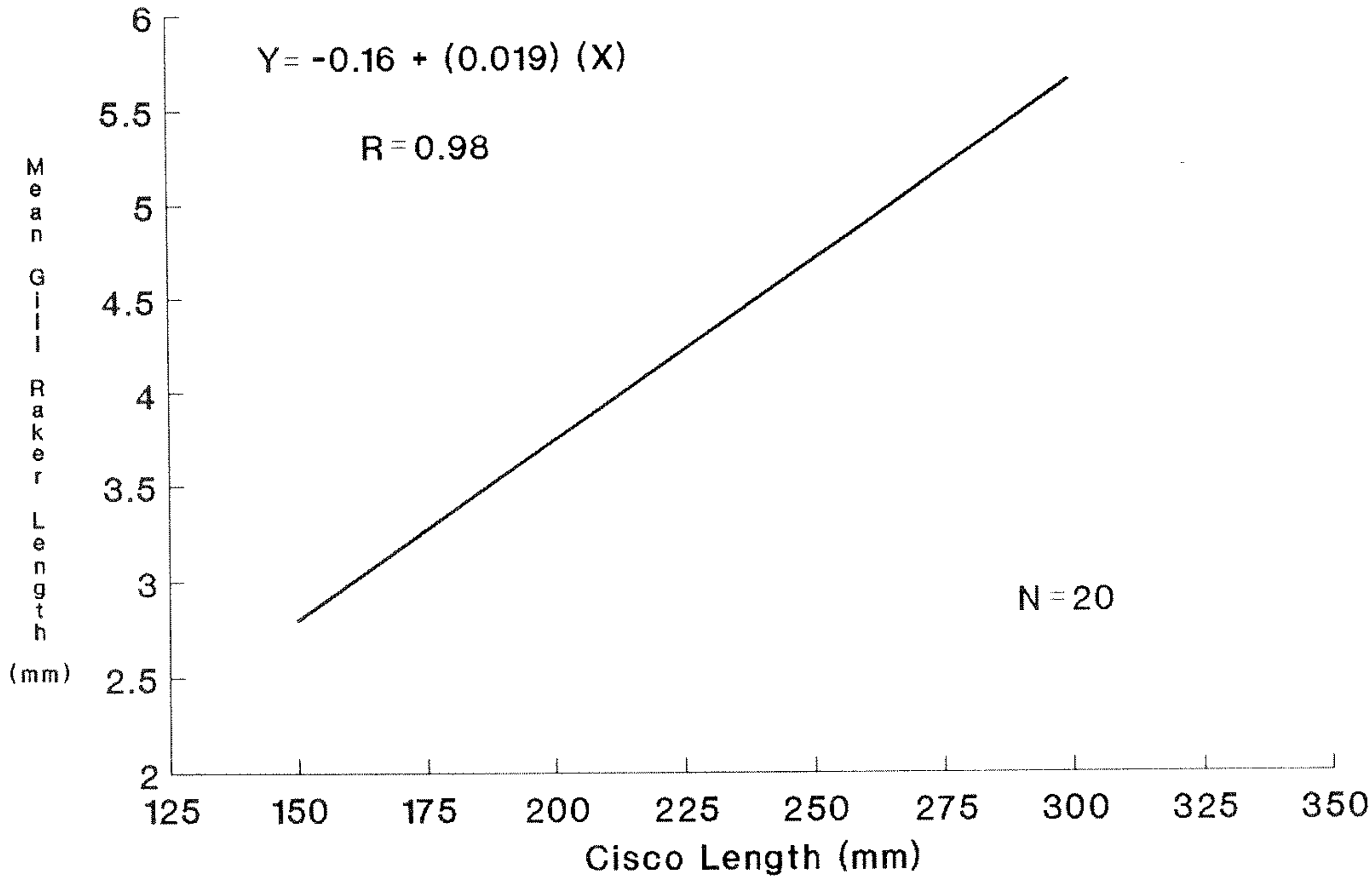

Figure 10. Regression of mean gill raker length (mm) with total length (mm) for cisco sampled from Fort Peck Reservoir during 1989 and 1990.

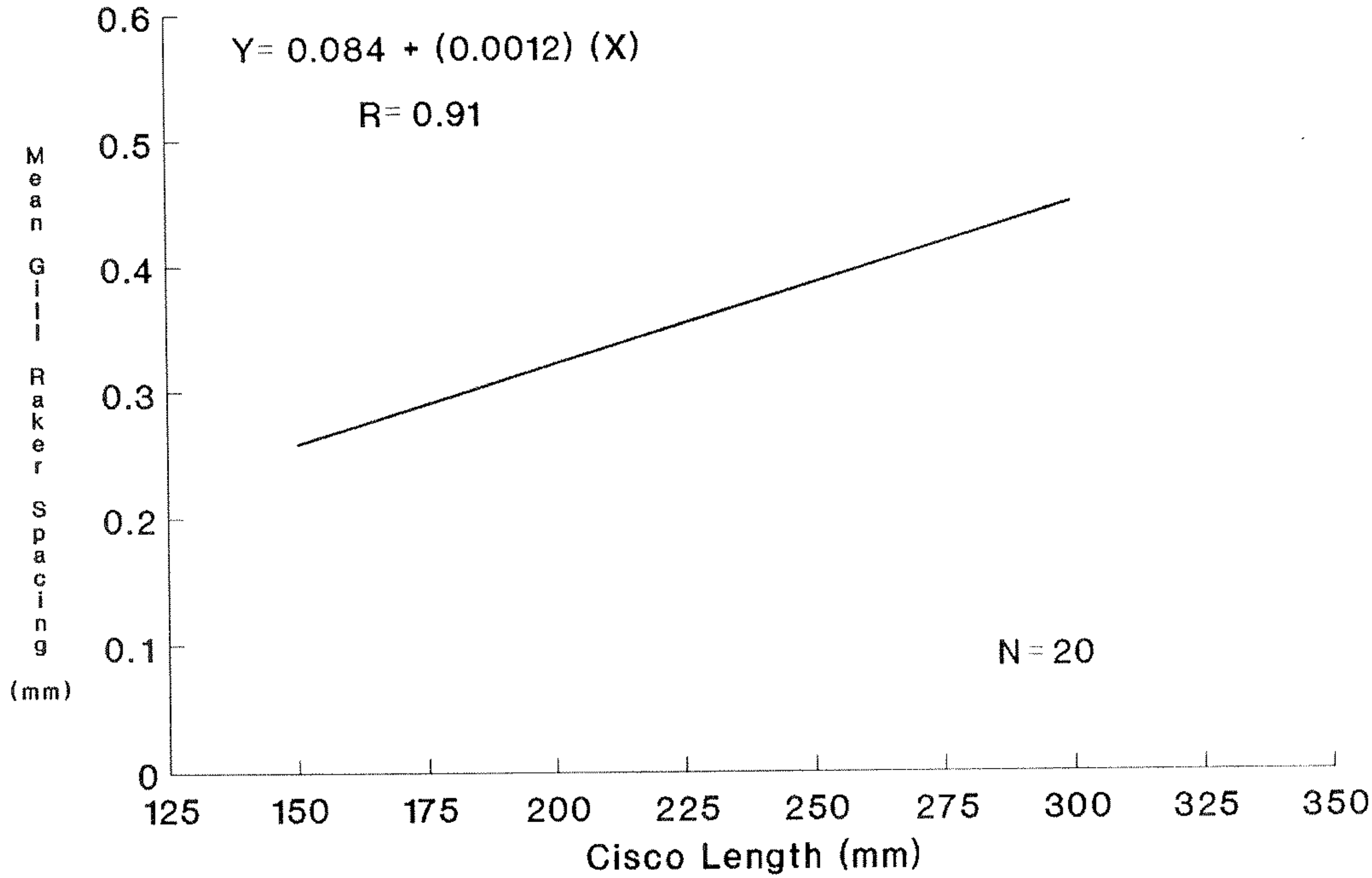

Figure 11. Regression of mean gill raker spacing (mm) with total length (mm) for cisco sampled from Fort Peck Reservoir during 1989 and 1990.

Mean gill raker filtering area generally increased with cisco length, largely due to the increase in gill raker length and gill raker spacing. The correlation between gill raker filtering area and cisco length was better (R = 0.99, N = 17) than for both gill raker length and spacing (Figure 12).

Vertical Distribution

Vertical gill nets (30 m in length) used to determine adult cisco distribution in the water column yielded an average of less than one fish per net set in over 120 sets. Because of small sample sizes the vertical distribution and temperature preference of cisco could not be determined with certainty. During the August sampling of 1989 and 1990, when the reservoir was stratified, cisco were captured at depths ranging from 3 to 30 m and in temperatures from 21.2 to 10.0 C.

Reservoir Zooplankton

Zooplankton Density

The maximum estimated zooplankton density was about 37/L (Table 11). Copepods were the most abundant zooplankters, comprising 50 % or more of all samples. Copepods reached their maximum percentage in the May and July 1990 samples. *Daphnia* and *Bosmina* were the two most common cladocerans sampled. Their individual and combined

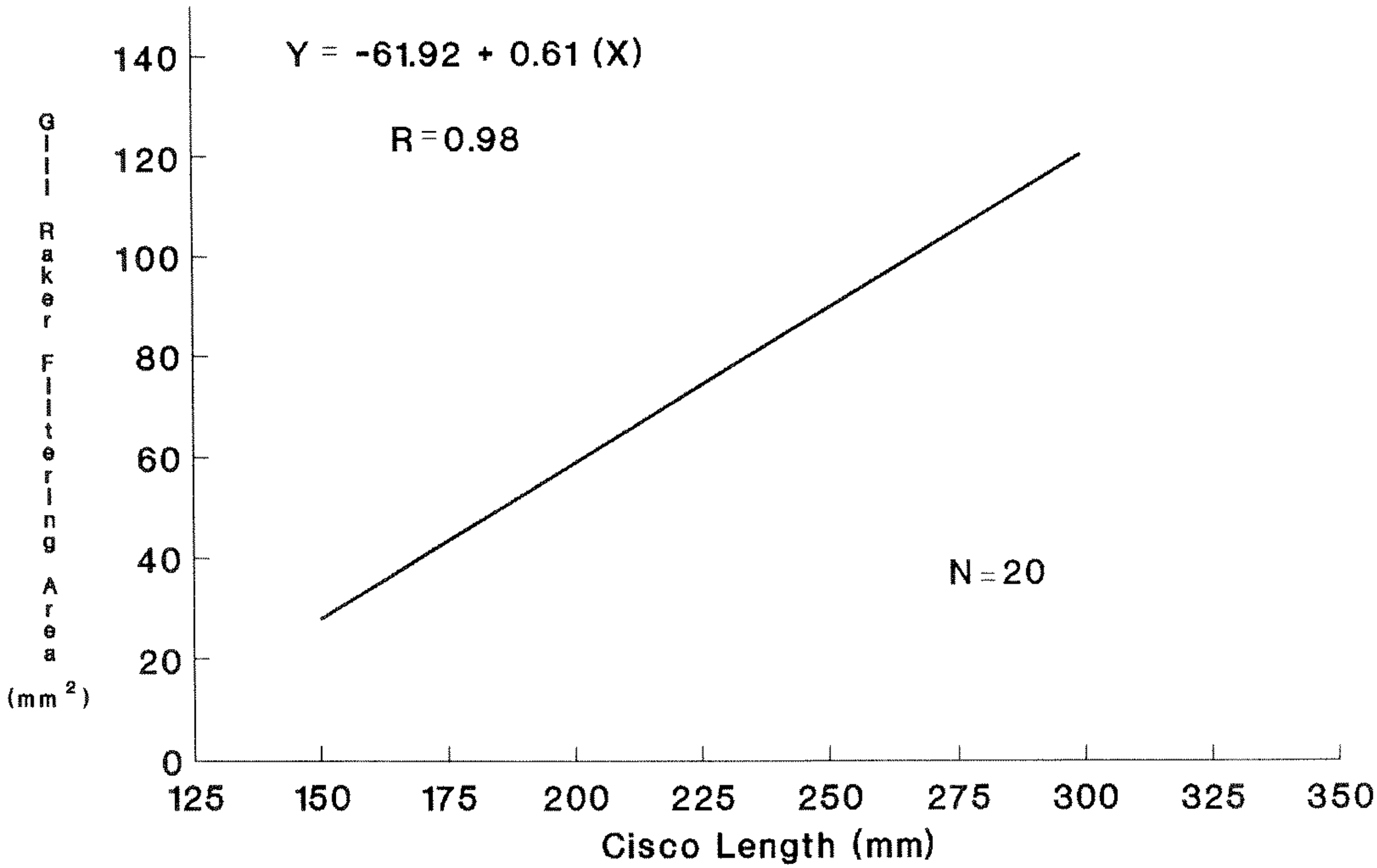

Figure 12. Regression of mean gill raker filtering area (mm^2) with total length (mm) for cisco sampled from Fort Peck Reservoir during 1989 and 1990.

contribution to the total densities varied greatly and without a notable pattern. *Daphnia* were most abundant in August and September of 1989 and August of 1990 (> 23.0 % of total) while *Bosmina* were most abundant in the June sample of 1990 (> 42.0 % of total). Cladocerans, *Leptedora* and *Diaphanosoma*, were present in small numbers and were only collected periodically. Their combined density never contributed more than 1.5 % to total zooplankton density.

Table 11. Estimated zooplankton densities (percent of total density) in samples from Fort Peck Reservoir, 1989 - 1990.

	Density (no./L)				
Date	*Daphnia spp.*	*Bosmina sp.*	*Leptedora sp.* *Diaphanosoma sp.*	*Cyclops sp.* *Diaptomus sp.*	Total
1989					
29 August	7.7 (23.2)	0.2 (0.6)	0.5 (1.5)	24.8 (74.7)	33.2
21 September	5.9 (28.0)	0.9 (4.3)	0.0 (0)	14.3 (67.7)	21.1
26 September	4.8 (22.1)	1.1 (5.1)	0.1 (0.5)	15.7 (72.3)	21.7
29 November	0.9 (15.5)	1.2 (20.7)	0.0 (0)	3.7 (63.8)	5.8
1990					
5 May	0.2 (0.9)	1.1 (5.2)	0.0 (0)	19.9 (93.9)	21.2
26 May	0.2 (0.7)	2.0 (6.9)	0.0 (0)	26.9 (92.4)	29.1
22 June	0.2 (0.5)	15.5 (42.2)	0.0 (0)	21.0 (57.3)	36.7
14 July	1.2 (6.2)	3.6 (18.5)	0.0 (0)	14.7 (75.3)	19.5
29 July	4.6 (13.5)	0.5 (1.5)	0.0 (0)	28.9 (85.0)	34.0
21 August	7.5 (29.6)	0.1 (0.4)	0.1 (0.4)	17.6 (69.6)	25.3
30 November	1.6 (10.8)	5.7 (38.5)	0.1 (0.7)	7.4 (50.0)	14.8

Zooplankton Size

Mean lengths for zooplankters were about 1.35, 0.35, and 0.80 mm for *Daphnia*, *Bosmina*, and copepods, respectively (Table 12). Comparisons showed that *Daphnia* lengths were significantly greater than those of the other types and copepods were significantly longer than *Bosmina*. At least 75 % of the *Daphnia*, copepods, and *Bosmina* were 0.8 - 1.5 mm, 0.5 - 1.1 mm, and 0.3 - 0.4 mm, respectively.

Table 12. Mean length (standard deviation) of 100 zooplankton per type for types comprising more than 5 % of the total density per sample from Fort Peck Reservoir.

	Mean length (mm)		
Date	*Daphnia*	*Bosmina*	*Cyclops* *Diaptomus* sp.
1989			
29 August	1.27(0.30)	-	0.71(0.24)
26 September	1.39(0.25)	-	0.83(0.27)
29 November	1.31(0.37)	0.36(0.06)	0.82(0.26)
1990			
5 May	-	0.35(0.06)	0.85(0.29)
22 June	-	0.35(0.05)	0.69(0.21)
14 July	1.37(0.38)	0.36(0.06)	0.74(0.21)
21 August	1.46(0.33)	-	0.89(0.29)
30 November	1.30(0.37)	0.35(0.06)	0.88(0.30)

The mean *Daphnia* and copepod lengths differed significantly between some samples, but no pattern was observed between seasons or years. *Bosmina* mean lengths did not differ significantly between samples.

Mean lengths of zooplankters were compared to the mean gill raker spacing of different size cisco. This showed all size groups of cisco could capture 100 % of the *Daphnia* based on gill raker spacings, and at least 84 % of the copepods in the zooplankton samples. By contrast, cisco greater than 200 mm in total length could only capture up to 51 % of the *Bosmina* .

Cisco Utilization

Frequency of Use

Prey were found in only about 25 % of the predators stomachs examined from the three regions of the reservoir (Figure 2). Cisco was the major prey item found in predator stomachs (Table 13). They were identified in approximately 69, 64, 100, and 67 % of the walleye, sauger, northern pike, and smallmouth bass stomachs containing prey, respectively. The number of cisco found in a stomach was never more than two and usually only one.

Table 13. Number (percent of total) of predator stomachs examined, with prey and type of prey in samples during 1990.

		Prey fish		
Predator	N	Cisco	Spottail shiner	Unidentified
Walleye	402	69(17.2)	6(1.5)	25(6.2)
Sauger	64	9(14.1)	0	5(7.8)
Northern pike	16	7(43.8)	0	0
Smallmouth bass	7	2(28.6)	0	1(14.3)

Spottail shiners were utilized less frequently than cisco. They were found in only 6 % of the walleye stomachs that had food items. Walleye stomachs contained from 1 - 10 spottails.

The frequency of cisco in predator stomachs varied by regions of the reservoir (Table 14). The highest occurrence was in the lower end of the reservoir for walleye and in the Hell Creek region for sauger (Figure 2). The lowest occurrence of cisco in both walleye and sauger was in the Rock Creek region.

Table 14. Number of stomachs examined (percent of total) and type of prey in walleye and sauger stomachs from three regions of Fort Peck Reservoir during 1990.

		Prey fish		
Location[a]	N	Cisco	Spottail shiner	Unidentified
		Walleye		
Rock Creek	94	5(5.3)	4(4.3)	3(3.2)
Lower end	162	34(21.0)	1(0.6)	6(3.7)
Hell Creek	146	30(20.5)	1(0.7)	14(9.6)
		Sauger		
Rock Creek	10	1(10.0)	0	0
Lower end	27	3(11.1)	0	2(7.4)
Hell Creek	27	5(18.5)	0	3(11.1)

[a] See Figure 2.

Size of Prey

Selected body measurements of cisco were highly correlated with total length (Table 15). Body length (total length minus head length) had the highest correlation with total length and body depth had the lowest, although all correlations had values of $R > 0.9$.

Table 15. Regression equations for total length on body part measurements for cisco in Fort Peck Reservoir during 1989 and 1990. Total lengths were 105 - 367 mm and N = 132.

Body part	Regression equation[a]	R
Head	$Y = 13.402 + 5.114\ (X)$	0.97
Vertebral column	$Y = -4.933 + 1.563\ (X)$	0.99
Vertebral column and head	$Y = -4.350 + 1.219\ (X)$	0.99
Body length	$Y = -0.445 + 1.226\ (X)$	1.00
Body depth	$Y = 68.506 + 3.759\ (X)$	0.92

[a] Where X is the length of the body part (mm) and Y is the total length of the cisco (mm).

The estimated length of cisco eaten by walleye and sauger (Figure 13) had a low correlation with predator total length. The estimated length of cisco eaten by lake trout (lake trout stomach contents provided by MDFWP) showed virtually no correlation with lake trout length. The sample sizes of cisco lengths estimated from body parts were less than three in both northern pike and smallmouth bass, so no regression equations were calculated.

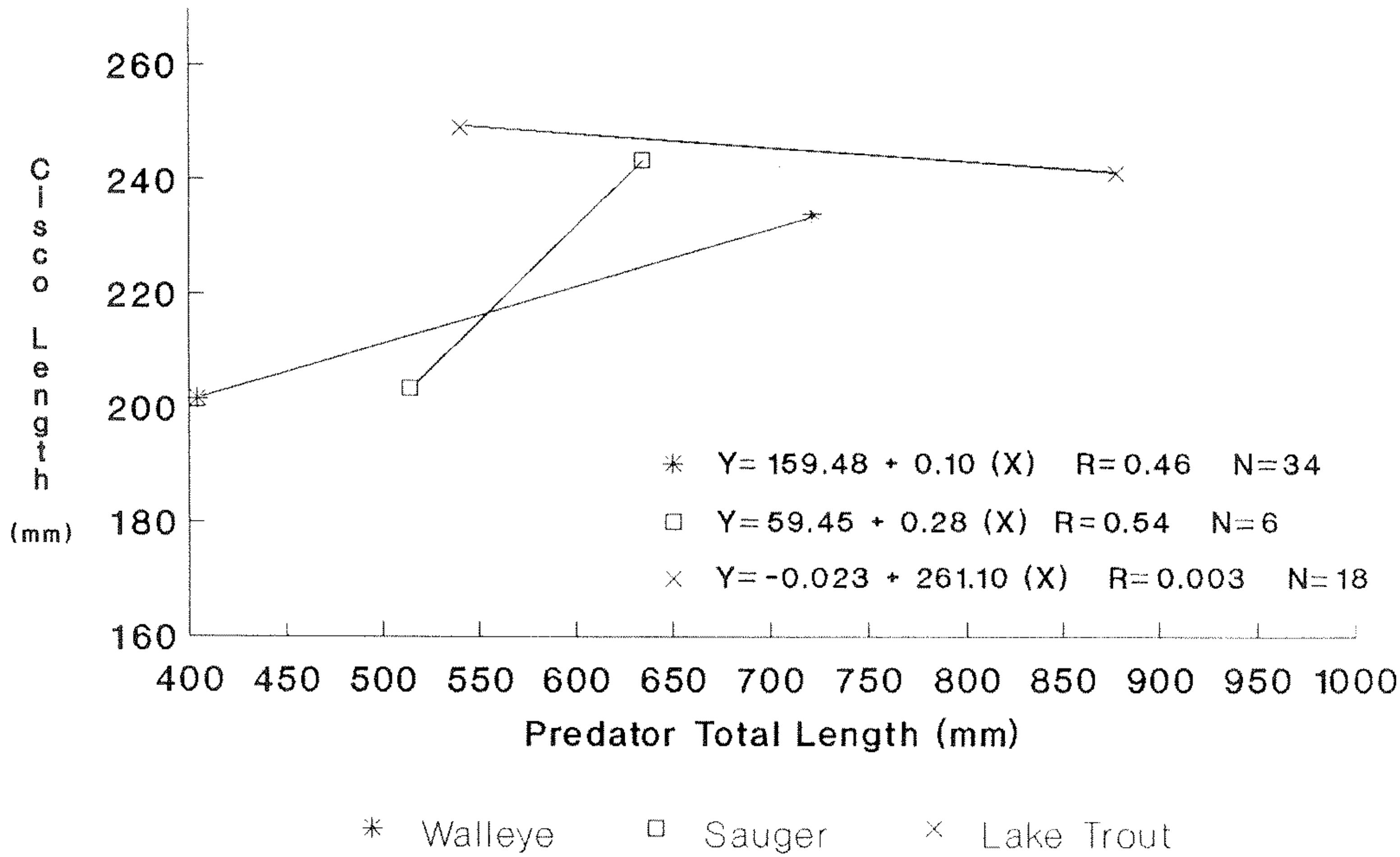

Figure 13. Regression of estimated cisco total length (mm) from stomach samples with predator total length (mm) for fish sampled from Fort Peck Reservoir during 1990.

The estimated sizes of cisco found were 176 - 261 mm in walleye stomachs and 193 - 262 mm in sauger. For northern pike and lake trout the estimated sizes of cisco eaten were 125 - 242 mm and 214 - 350 mm, respectively.

Cisco Availability

The average horizontal mouth gape was found to be larger than the vertical gape for all species of fish predators examined. Since this best represented a predators ability to take prey (Keast and Webb 1966), it was regressed on body length. The resulting regression correlation coefficients were highest for walleye and lowest for sauger (Figure 14).

The estimated body depth of ciscos found in a predator stomach was compared to that predator's horizontal gape. In all comparisons, estimated cisco body depths were equal to or less than predator horizontal mouth gapes.

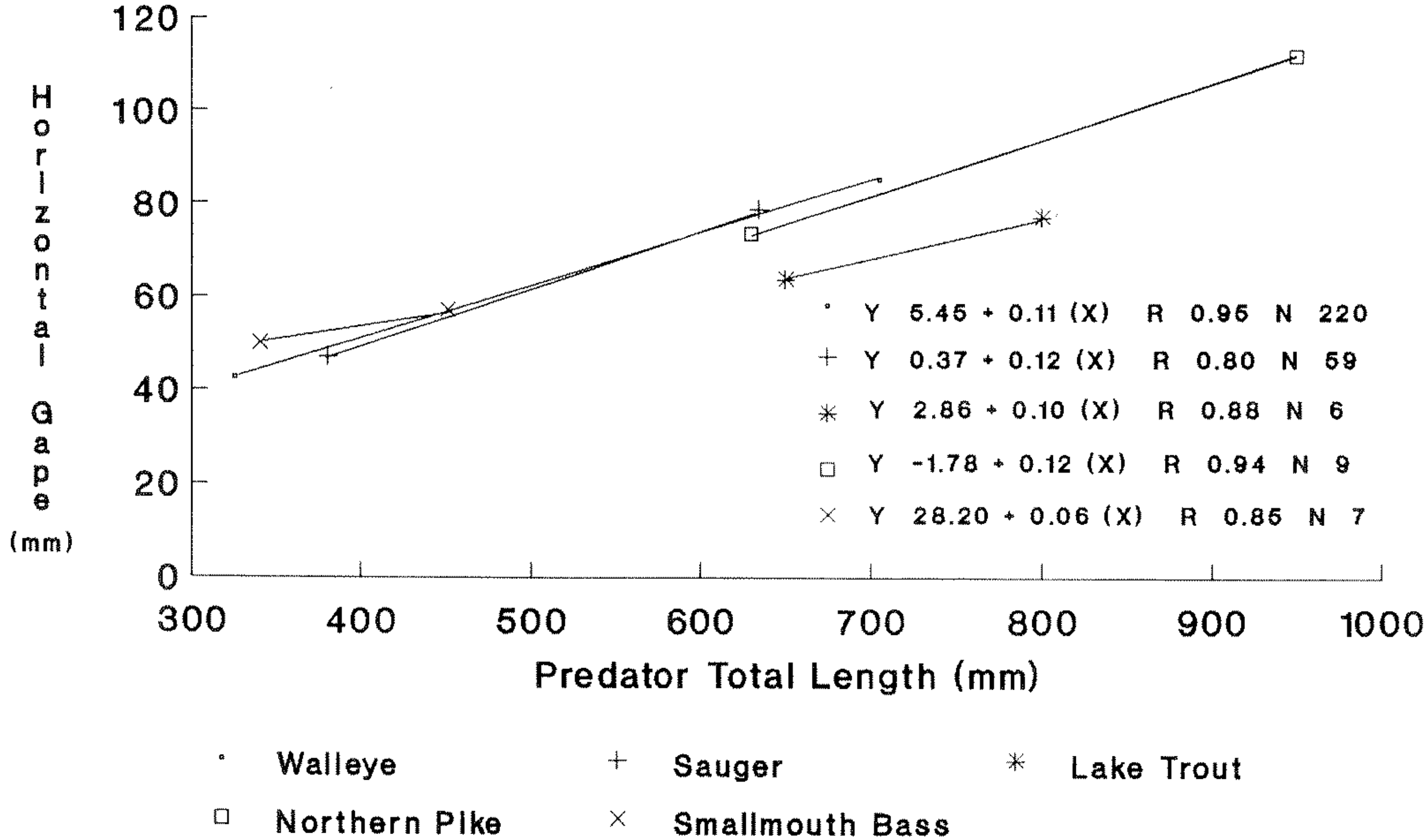

Figure 14. Regression of the horizontal mouth gape (mm) with predator total length (mm) for fish sampled from Fort Peck Reservoir during 1990.

DISCUSSION

Growth and condition of the cisco in Fort Peck Reservoir have declined in the 7 years following their introduction. The average size of spawning cisco has decreased dramatically, from about 390 mm in 1986 to 240 mm in 1990. Wiedenheft (1989) reported that from 1986 to 1989 the average size of age 1 fish declined from 307 mm to 201 mm and size of age 2 cisco decreased from 399 mm to 271 mm (Appendix, Table 28). A similar decline in cisco growth was noted by Matuszek et al. (1990) in an introduced cisco population in Lake Opeongo, Ontario. Growth rates may have stabilized now since I found that growth was similar between 1989 and 1990 which may indicate that growth has stabilized. However, even after declining to the present levels, the mean lengths at annuli found in 1989 and 1990 are greater than or about equal to those reported by Carlander (1969) for other cisco populations.

The condition of the cisco declined concurrently with growth rates. Wiedenheft (1989) found that the average condition factor was about 1.3 in 1985. In 1990, I found that the condition factors were 0.77 to 0.98.

Egg numbers per unit of length may have declined. In 1985 the average number of mature eggs for cisco in Fort

Peck averaging 332 mm in total length was about 20,000 (W.D. Wiedenheft, MDFWP, unpublished data). Using my regression equation relating fecundity to cisco total length, a 332 mm cisco would be predicted to have only about 7,500 mature eggs. This number is on the low end of the range of eggs (6,500 - 30,000) reported for similar sized cisco from other studies (Stone 1937; Brown and Moffett 1942; Carlander 1969).

The egg diameters of the cisco apparently did not respond as fecundity did. The average egg diameters measured in 1989 and 1990 were 1.82 - 1.95 mm which were similar to the 1.8 - 2.1 mm diameters reported in other studies (Scott and Crossman 1977).

Reduced growth, condition, and fecundity of the Fort Peck cisco may be food related. Although total zooplankton density apparently has not decreased since 1983 (prior to the cisco introduction), zooplankton community composition has changed. The average zooplankton densities for various sampling stations around the reservoir were 11.9 - 38.2/L in 1983 (Wiedenheft 1983) and 5.8 - 36.7/L in this study, although I used a somewhat different sampling technique.

Wiedenheft (1984) reported that *Daphnia pulex* and *D. schodleri* were the most abundant cladocerans sampled during the first year of the cisco introduction and made up about 37.0 % of the zooplankton density. These two zooplankers were not found in samples during 1989 and 1990. The disappearance is probably the result of the cisco introduction. Filter feeding fish, such as the cisco, can eliminate or reduce the number of larger sized zooplankton in a body of water (Brooks and Dodson 1965; Wells 1969; Northcote 1988). These relatively large zooplankters (Vanni 1986; Mills et al. 1987; Gilbert 1988; Pennak 1989) are of sizes (> 2.0 mm), exceeding those of cladocerans sampled in this study. The elimination of the larger cladocerans also may account for the appearance of the smaller *Bosmina* in this study. Vanni (1986) reported that *D. pulex* reduced the density of *Bosmina* in nutrient enriched and unenriched environments. The removal of *D. pulex* resulted in higher densities of *Bosmina*. *Bosmina* were not reported from the reservoir during the first year of the cisco introduction (Wiedenheft 1984).

Growth rates of fish are correlated with food size (Paloheimo and Dickie 1966; Mills et al. 1989a; Miller et al. 1990). Therefore the apparent elimination of larger cladocerans in Fort Peck may have caused the decreased growth and lower condition of cisco observed in this study.

Stomach analyses indicate that the cisco in Fort Peck are selecting for the largest zooplankton available. When *Daphnia* constituted only about 25 % of the total zooplankton density they still appeared to be the most abundant zooplankton type in up to 48 % of the cisco stomachs. In contrast, during periods when *Bosmina* made up greater than 38 % of the total density less than 10 % of the cisco stomachs sampled showed them to be the most utilized.

In addition, the change in the zooplankton types may account for the reduced fecundity. Scott (1962) and Bagenal (1968) found that the number of eggs produced in rainbow trout (*Oncorhynchus mykiss*) and brown trout (*Salmo trutta*), respectively, were positively related to the amount of food available and consumed. The reduction in larger zooplankton types may result in less energy being available for the development of eggs.

The differing sex ratios observed for spawning cisco in 1989 and 1990 may not be as dramatic as the results would suggest. Sampling for spawners in 1990 was performed at water temperatures approximately 4° C warmer than in 1989. Male ciscos typically move on to the spawning areas before females (Scott and Crossman 1977), so it would appear the timing of the sampling in both years directly affected the results of the sex ratio analysis.

Results of the predator stomach content analysis showed that cisco were the most utilized prey species in Fort Peck and were the only prey found in northern pike, sauger, and smallmouth bass. This is similar to results found in other work on Fort Peck predators (Wiedenheft 1990).

The 20.0 % utilization rate of cisco by predators in this study is probably an underestimate. Based on my personal observation and fisherman reports of regurgitated cisco in the live wells of fishing boats prior to the examination of the predator stomachs, the actual percentage of predators containing cisco was probably much higher.

The relation of the estimated length of cisco found in predator stomachs to predator length indicated little size selection for larger cisco by the larger walleye and sauger. Parsons (1971) reported that the size of prey taken by walleye does increase with walleye size. However, since there was only a narrow range of cisco sizes available (> 80 % were 180 to 270 mm in length), the opportunity for size selection by walleye and sauger was small.

The introduction of the cisco as forage in Fort Peck Reservoir appears to have resulted in increased growth rates of predators. Wiedenheft (1989; 1990) reported that since the introduction of the cisco the condition and average weights of the majority of the predators has improved.

The shift in the zooplankton community to smaller types and the accompanying reduction in growth and condition of cisco may be in part the reason for the improved growth rate in the predators in Fort Peck Reservoir. The smaller size and shallower body depth may make them more available as prey to a greater size range of predators over a longer time period than they were soon after their introduction. Based on the horizontal mouth gapes, virtually all predators sampled could take > 90 % of the cisco collected in this study.

While the introduction of cisco into Fort Peck Reservoir seems to have provided benefits for adult predators, its effects on other parts of the fish community are unknown. Cisco may be competing with existing planktivores (paddlefish, *Polydon spathula*, and goldeye) and by the elimination of larger zooplankton types may cause reduced growth rates and survival of age 0 predators. Slower growth rates in these fish would increase the period in which they would be vulnerable to predation (Mills et al. 1989b) and may affect their over winter survival rate due to decreased fat reserves (Shuter et al. 1980).

Additionally, a lower survival rate of juvenile predatory fish may be detrimental to the sport fishing in Fort Peck Reservoir despite the apparent benefits of increased growth rates of adult predators. A similar introduction of a forage fish (threadfin shad, *Dorosoma petenense*) in California waters improved the growth rate of gamefish initially, but it was later shown that the shad were competing for food with young largemouth bass (*Micropterus salmoides*). Ultimately the fishing success for largemouth bass declined (Wydoski and Bennett 1981). The risks involved in the introduction of an efficient planktivore, such as the cisco, should be carefully considered before that action is taken.

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APPENDIX

Table 16. Dates cisco planted in Fort Peck Reservoir (W.D. Wiedenheft, MDFWP, personal communication).

Stocking date	Egg source	Fish size	Number stocked
3 March 1984	Minnesota	25.4 mm fry	1,000,000
25 April 1984	Saskatchewan	25.4 mm fry	7,000,000
4 June 1984	Saskatchewan	50.8 to 76.2 mm fingerlings	10,000
19 April 1985	Saskatchewan	25.4 mm fry	10,000,000
6 June 1985	Saskatchewan	50.8 to 76.2 mm fingerlings	50,000
6 April 1986	Saskatchewan	25.4 mm fry	14,000,000

Table 17. List of fish species in Fort Peck Reservoir (Wiedenheft 1983).

1.	Pallid sturgeon	*Scaphirhnchus albus*
2.	Shovelnose sturgeon	*Scaphirhynchus platorynchus*
3.	Paddlefish	*Polydon spathula*
4.	Mountain whitefish	*Prosopium williamsoni*
5.	Cisco[a]	*Coregonus artedi*
6.	Chinook salmon[a b]	*Oncorhynchus tshawytscha*
7.	Rainbow trout[a]	*Oncorhynchus mykiss*
8.	Brown trout[a]	*Salmo trutta*
9.	Lake trout[a b]	*Salvelinus namaycush*
10.	Northern pike[a b]	*Esox lucius*
11.	Goldeye	*Hiodon alosoides*
12.	Sauger[b]	*Stizostedion canadense*
13.	Walleye[a b]	*Stizostedion vitreum*
14.	Yellow perch[a]	*Perca flavescens*
15.	Iowa darter	*Etheostoma exile*
16.	White Crappie	*Pomoxis annularis*
17.	Black crappie[a]	*Pomoxis nigromaculatus*
18.	Smallmouth bass[a b]	*Micropterus dolomieui*
19.	Black bullhead	*Ictalurus melas*
20.	Channel catfish	*Ictalurus punctatus*
21.	Stonecat	*Notorus flavus*
22.	Burbot	*Lota lota*
23.	Carp[a]	*Cyprinus carpio*
24.	Northern redbelly dace	*Phoxinus eos*
25.	Longnose dace	*Rhinichthys cataractae*
26.	Emerald shiner	*Notropis atherinoides*
27.	Sand shiner	*Notropis stramineus*
28.	Spottail shiner[a]	*Notropis hudsonius*
29.	Fathead minnow	*Pimephales promelas*
30.	Plains minnow	*Hybognathus placitus*
31.	Western silvery minnow	*Hybognathus argyritis*
32.	Brassy minnow	*Hybognathus hankinsoni*
33.	Lake chub	*Couesius plumbeus*
34.	Creek chub	*Semotilus artromaculatys*
35.	Flathead chub	*Hybopsis gracilis*
36.	River carpsucker	*Carpiodes carpio*
37.	Blue sucker	*Cycleptus elongatus*
38.	Smallmouth buffalo	*Ictiobus bubalus*
39.	Bigmouth buffalo	*Ictiobus cyprinellus*
40.	Shorthead redhorse	*Moxostoma macrolepidotum*
41.	Longnose sucker	*Catostomus catostomus*
42.	White sucker	*Catostomus commersoni*
43.	Freshwater drum	*Aplodinotus grunniens*
44.	Plains killifish[a]	*Fundulus zebrinus*

[a] Introduced species.
[b] Important game species.

Table 18. Material, size, mesh size, and deployment of nets used to collect cisco.

Material	Length(m)	Width(m)	Mesh (mm)	Deployment
monofilament	15.24	1.83	12.7	vertical
nylon	15.24	1.83	25.4	vertical
nylon	15.24	1.83	31.75	vertical
monofilament	15.24	3.05	34.9	vertical
nylon	30.48	1.83	25.4	vertical
nylon	30.48	1.83	31.75	vertical
monofilament	30.48	3.05	34.9	vertical
nylon	27.4	3.66	25.4	horizontal suspended
nylon[a]	38.1	1.83	19.65, 25.4, 31.75, 38.1, 58.8	horizontal perpendicular to shore

[a] Five panels 7.62 m in length with different mesh size.

Table 19. Comparisons of condition factors among cisco size groups, 1989 and 1990.

	Size groups (mm)							
Size groups (mm)	100-124	125-149	150-174	175-199	200-224	225-249	250-274	275 +
				1989				
100-124	-							
125-149	S[a]	-						
150-174	S	S	-					
175-199	S	S	NS	-				
200-224	NS	NS	S	S	-			
225-249	NS	S	S	S	S	-		
250-274	NS	S	S	S	S	NS	-	
275 +	NS	NS	NS	NS	NS	NS	NS	-
				1990				
100-124	-							
125-149	-	-						
150-174	-	-	-					
175-199	S	-	-	-				
200-224	S	-	-	NS	-			
225-249	S	-	-	S	S	-		
250-274	NS	-	-	S	S	S	-	
275 +	NS	-	-	S	S	S	NS	-

[a] S=significant difference, NS=no significant difference.

Table 20. Comparison of mean condition factors for cisco of the same size groups between 1989 and 1990.

Size groups (mm)	Size groups (mm)							
	100-124	125-149	150-174	175-199	200-224	225-249	250-274	275 +
1990				1989				
100-124	NS[a]							
125-149		-						
150-174			-					
175-199				NS				
200-224					S			
225-249						S		
250-274							NS	
275 +								S

[a] S=significant difference, NS=no significant difference.

Table 21. Comparisons of gonadosomatic index (GSI) between size groups for spawning male cisco during 1989 and 1990.

Size group(mm)	Size group(mm)			
	175-199	200-224	225-249	250-274
			1989	
200-224	NS[a]			
225-249	NS	S		
250-274	NS	S	NS	
275 +	NS	NS	NS	NS
			1990	
200-224	-			
225-249	-	S		
250-274	-	S	S	
275 +	-	NS	NS	NS

[A] S=significant difference, NS=no significant difference.

Table 22. Comparisons of gonadosomatic index (GSI) between size groups for spawning female cisco during and 1989 and 1990.

Size groups	Size groups (mm) 175-199	200-224	225-249
		1989	
200-224	S[a]		
225-249	NS	S	
250-274	NS	S	NS
		1990	
200-224	-		
225-249	-	NS	
250-274	-	NS	S

[a] S=significant difference, NS=no significant difference.

Table 23. Comparison of mature egg diameters for spawning cisco of different size groups for 1989 and 1990.

Size groups(mm)	Size groups(mm) 175-199	200-224	225-249
		1989	
175-199			
200-224	NS[a]		
225-249	S	NS	
250-274	S	NS	NS
		1990	
200-224	-		
225-249	-	NS	
250-274	-	NS	NS

[a] S=significant difference, NS=no significant difference.

Table 24. Comparisons of mean gill raker length, spacing, and filtering area (where N > 1) among cisco size groups from Fort Peck Reservoir.

Size groups (mm)	125-149	175-199	200-224	225-249	250-274
			Gill raker length (mm)		
125-149	-				
175-199	NS[a]				
200-224	NS	NS			
225-249	NS	NS	NS		
250-274	NS	NS	NS	NS	
275 +	S	S	S	S	S
			Gill raker spacing (mm)		
125-149	-				
175-199	NS				
200-224	S	NS			
225-249	NS	NS	NS		
250-274	NS	NS	NS	NS	
275 +	NS	S	S	NS	S
			Gill raker filtering area (mm^2)		
125-149	-				
175-199	NS				
200-224	S	NS			
225-249	S	NS	NS		
250-274	S	NS	S	NS	
275 +	S	S	S	S	S

[a] S=significant difference, NS=no significant difference

Table 25. Length frequency distribution for 100 *Daphnia* in 0.1 mm length groups in samples from Fort Peck Reservoir.

	Size group (mm)														
Date	0.5	0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9+
1989															
29 August	2	4	2	3	1	17	12	6	14	12	13	8	4	2	0
26 September	0	0	0	2	3	7	13	10	19	8	16	12	3	6	1
29 November	1	8	0	8	2	13	6	7	9	7	10	15	3	9	2
1990															
14 July	0	0	1	10	9	11	8	4	9	8	6	10	8	4	12
21 August	0	0	0	4	0	11	5	11	8	9	12	13	11	7	9
30 November	3	6	2	4	2	14	10	7	8	11	8	11	5	5	4

Table 26. Length frequency distribution for 100 copepods (*Cyclops* sp., *Diaptomus* sp.) in 0.1 mm length groups in samples from Fort Peck Reservoir.

	Size group (mm)														
Date	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.3	1.4	1.5	1.6+
1989															
29 August	1	7	12	12	15	16	9	9	12	7	0	0	0	0	0
26 September	1	3	3	13	13	14	11	9	17	6	7	1	0	0	2
29 November	0	1	8	14	16	7	16	7	15	4	6	4	2	0	0
1990															
5 May	6	2	3	8	8	11	13	12	18	10	3	5	1	0	0
22 June	3	1	8	31	22	12	8	1	8	3	2	1	0	0	0
14 July	1	1	4	16	24	17	18	7	7	2	1	1	0	1	0
21 August	1	2	2	9	14	14	18	3	12	8	6	6	3	0	2
30 November	2	2	4	10	9	14	17	8	10	10	3	6	1	2	2

Table 27. Length frequency distribution for 100 *Bosmina* in 0.05 mm length groups in samples from Fort Peck Reservoir.

	Size group (mm)						
Date	0.20	0.25	0.30	0.35	0.40	0.45	0.50
1989							
29 November	0	9	48	10	22	5	6
1990							
5 May	3	10	42	20	19	2	4
22 June	3	8	45	23	14	4	3
14 July	0	4	45	22	21	6	2
30 November	4	9	39	26	15	3	4

Table 28. Comparison of average lengths (mm) and ranges of lengths for various age classes of cisco from Fort Peck Reservoir, 1985-1989 (Wiedenheft 1990).

Year	Age 1	Age 2	Age 3	Age 4
1985				
Mean	307.3			
Range	254.0-350.5			
N	58			
1986				
Mean	279.4	398.8		
Range	261.6-307.3	330.2-403.9		
N	14	13		
1987				
Mean		401.3		
Range		368.3-403.9		
N		30		
1988				
Mean	238.8	365.8	381.0	
Range	221.0-266.7	238.8-403.9	-	
N	61	46	1	
1989				
Mean	200.6	271.9	299.7	381.0
Range	175.3-236.2	223.5-375.9	248.9-383.5	274.3-396.2
N	27	38	20	11