

Life-history Aspects of *Moxostoma cervinum* (Blacktip Jumprock) in the Roanoke River, Virginia

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ABSTRACT

Life-history aspects of *Moxostoma cervinum* (Blacktip Jumprock) were identified using specimens from recent collections and the Roanoke College Ichthyological Collection. The largest specimen examined was a female 161.27 mm SL and 66 months of age. Spawning appears to occur in May, with a mean of 2477.6 oocytes (SD = 2825.3) up to 1.54 mm diameter in gravid females. Sexual maturity appears to occur by 1-2 years of age in males and 2-3 years of age in females. Male to female ratio was not significantly different from 1:1. Chironomidae composed the bulk of the diet; while detritus, Trichoptera, Ephemeroptera, and Acari were important food items in multiple months. Weight of gut contents and proportion of Chironomidae as food items increased with size of specimens examined.

INTRODUCTION

Moxostoma cervinum (Cope) (Blacktip Jumprock) inhabits upland streams in the James, New, Roanoke, Tar, and Neuse river systems of Virginia and North Carolina (Jenkins and Burkhead 1994). Jenkins (1970), Buth (1978), and Smith (1992) all placed the species in the genus *Scartomyzon* with other small suckers inhabiting faster, shallower waters. However, most recent analyses embed the species within the genus *Moxostoma* (Harris et al. 2002, Doosey et al. 2010, Chen and Mayden 2012) with larger suckers often found in very different habitats. This phylogenetic placement means that understanding the biology and life-history of *M. cervinum* is important in identifying derived and ancestral character states, thus helping to interpret the substantial variation in the biology and life-history of the *Moxostoma*. Despite this importance, our understanding of this species' life history is restricted to three paragraphs in the species account in *Freshwater Fishes of Virginia*, which gives limited details on aspects of diet, size and age at maturity, and timing of spawning (Jenkins and Burkhead 1994). The objective of this study is to document more detailed life-history aspects of *M. cervinum* from specimens collected throughout the year employing methods utilized in similar studies.

MATERIALS AND METHODS

Moxostoma cervinum were collected from the Roanoke River near Salem, VA (Roanoke County) between September 2010 and August 2011 by sampling daylight

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hours near the end of each month using a Smith-Root LR-24 electrofisher and a 3.3-m x 1.3-m seine with 9.5-mm mesh. We supplemented our collections with specimens from the Roanoke College Ichthyological Collection (RC) for months when we collected few specimens ($n < 15$). Specimens were collected following Nickum et al. (2004) protocols, fixed in 10% formalin, rinsed with water and then stored in 45% isopropyl alcohol. A total of 154 specimens were examined in this study. Details on specimens examined (collection sites, collection dates, numbers of specimens taken, collector field numbers) are available from the authors upon request. Standard length (SL) of preserved specimens was measured to the nearest 0.01 mm using digital calipers. Total weight (TW) and eviscerated weight (EW) were measured by blotting the specimens dry and weighing to the nearest 0.001g on a digital analytical scale. Regressions by least sum of squares were performed for EW and SL to examine the relationship between length and weight. A two sample t-test was used to test for difference between male and female standard length. A chi-square test was used to detect a sex ratio different from 1:1. All statistical analyses were performed using Minitab 17 Statistical Software (Minitab, Inc., State College, PA) with alpha equal to 0.05.

Specimens were aged using two methods. For all specimens, three scales were removed from the right dorsolateral portion of the body, mounted on a slide and examined under 40x magnification for annuli (see Bond 1996). If the three scales removed did not have the same number of annuli (e.g. regenerated scales that lack a focus), more scales were removed until a clear consensus number of annuli was identified. For specimens with a standard length >119 mm, a single opercle was removed, prepared and analyzed following Beckman and Hutson (2012). Each opercle was removed from the left portion of the body, set in boiling water for 10 minutes, then set in bleach for another 10 minutes to facilitate the removal of excess tissue and then allowed to air dry until annuli were clearly visible. Annuli were read by locating the presence of an opaque region near the edge of the opercle, and counting each opaque region as a single annulus; the number of annuli present was determined by two observers. This method, in comparison to scale annuli data, revealed that the number of annuli on the scales underestimated the age of specimens three years of age or greater and agreed with the scale data for specimens less than three years of age. Therefore, the number of annuli on the opercle was solely used to estimate the age of specimens three years of age or greater.

Specimens less than 12 months of age were counted as 0+, specimens 12-23 months were counted as age 1+, specimens 24-35 months were counted as age 2+, specimens 36-47 months were counted as age 3+, specimens 48-59 months were counted as age 4+, and specimens greater than 60 months were counted as age 5+. The proportion of all specimens examined represented by each age class was calculated to approximate the age-class distribution of the population. A t-test of age in months was used to test for differences in lifespan among sexes.

Gonads were examined to determine sex, removed from each specimen, and weighed to the nearest 0.001 g. Gonadosomatic Index (GSI) was calculated for all specimens by dividing gonad weight by EW. One-way analysis of variance was performed to test for differences in GSI among specimens of the same sex collected from different months. In gravid females, fully yolked, mature oocytes were counted, and five representative oocytes were measured to provide an approximation of ova size

and number (Heins and Baker 1988). Regression of SL as a predictor of number of mature oocytes was performed to test the influence of specimen size on fecundity. Due to GSI values peaking in May, declining in June, and reaching a minimum level in July, we used May as the month of spawning for estimating age of specimens.

The anterior third of the gastrointestinal tract was opened and its contents were removed and weighed using a digital analytical balance and recorded to the nearest 0.001 g. Weight of gut contents for specimens with empty guts was recorded as 0. Food items were counted and identified to the lowest taxonomic category possible following Thorp and Covich (1991) and Merritt and Cummins (1996). Detritus was noted as being present or absent in an individual specimen. The number of identifiably different food items in each specimen was recorded as variety of food items. One-way analysis of variance was performed on weight of gut contents, variety of food items, and percent Chironomidae to test for differences in feeding throughout the year. Regressions by least sum of squares were performed for SL and weight of gut contents, SL and variety of gut contents, and SL and percent Chironomidae to test the influence of size on feeding.

RESULTS

Eviscerated weight increased with standard length ($r^2 = 88.78\%$, $P < 0.0001$) and is described by the model $EW = (SL) \times 0.4952 - 29.05$. Females were larger than males ($P < 0.0001$) with the mean size of females 105.57 mm SL (SD = 33.26) and males 85.02 mm SL (SD = 25.46). The smallest specimen examined (37.94 mm SL) was collected in January, had zero annuli and appeared to be eight months of age. The largest specimen examined (161.27 mm SL) was a female collected in November, had five annuli, and appeared to be one of the oldest specimens examined at 66 months of age (Figure 1). All specimens examined for annuli had zero to five which corresponded to annuli forming near the end of winter or early spring in specimens up to 66 months of age. Mean lifespan was greater ($P = 0.003$) for females (24.76 months, SD = 16.11) than males (18.08 months, SD = 11.31). There was also a slightly skewed sex ratio of 1:1.69 in favor of females; however, the difference in the number of males and females was not significant ($P = 0.938$). Standard length increased with age in months ($r^2 = 83.99$, $P < 0.0001$) and is described by the model $LOGSL = (LOG \text{ age in months}) \times 0.4906 + 1.3465$. Of the 154 collected specimens, 25.97% were age 0+, 35.06% were age 1+, 23.38% were age 2+, 6.49% were age 3+, 7.41% were age 4+, and 1.95% were age 5+ (Figure 2).

Monthly GSI was not uniform for females (females $P = 0.005$), but did not differ significantly for males ($P = 0.116$). Individual GSI was highest in May for females (0.135) (Figure 3) and males (0.052) (Figure 4). Maximum GSI values declined in June to 0.002 for males, and for females reaching a minimum value of 0.00453 in July. Mean GSI values were lowest during June and July for both females (June = 0.01, SD = 0.013; July = 0.008, SD = 0.004) and males (June = 0.003, SD = 0.0005; July = 0.004, SD = 0.004). Mean GSI values were highest for both sexes during November (females = 0.05, SD = 0.04; males = 0.03, SD = 0.008). Elevated GSI values generally persisted from fall months through spring for both sexes (Figures 3 and 4). Mature oocytes were 0.6-1.54 (mean = 0.96, SD = 0.19) mm in diameter and numbered from 560 to 15,441 (mean = 2477.6, SD = 2825.3). The smallest female with mature oocytes was 24 months of age and had a SL of 93.3 mm. All females collected during spring

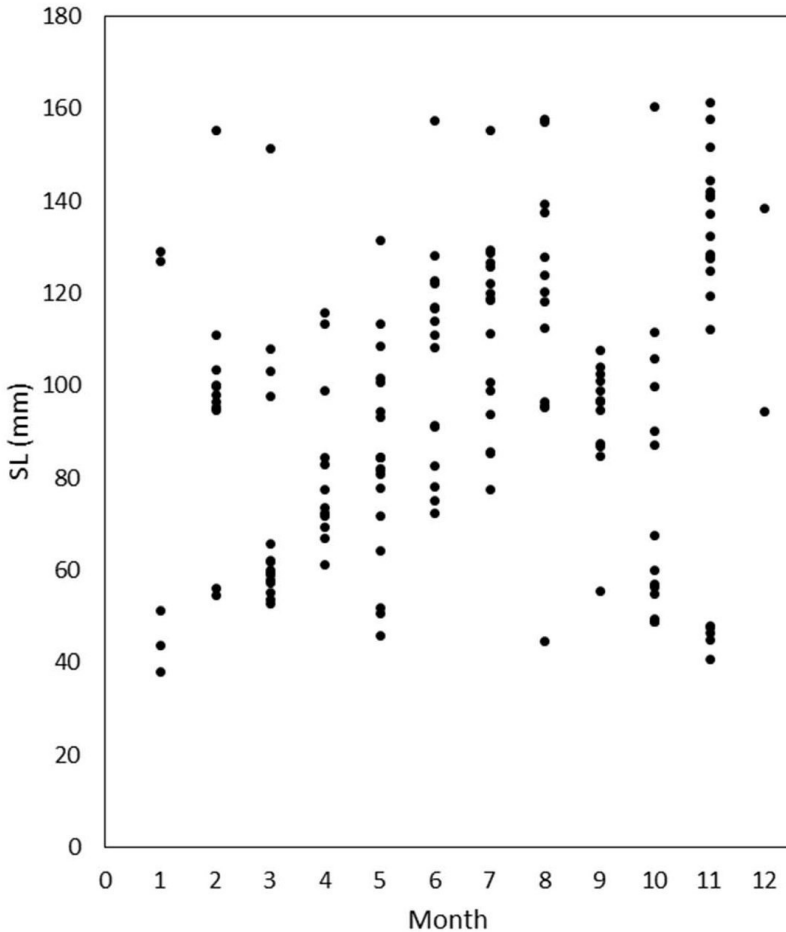


FIGURE 1. Standard length in mm by month of collection for *Moxostoma cervinum*. (1=January, 2 = February, etc.). N = 154

months approximately three years of age had mature oocytes, while 57% of females 24+ months of age had mature oocytes. Number of mature oocytes and SL were significantly correlated ($P = 0.002$) with a modest r^2 of 29.76%. The smallest sexually mature male (GSI = 0.028) was 65.93 mm SL and 10 months of age. All males approximately two years of age or greater were sexually mature, and 7% of males approximately one year of age were sexually mature.

Due to mastication by pharyngeal teeth, most food items were not identifiable below the order or family level (Table 1). Weight of gut contents was not uniform across all months ($P > .0001$). The highest mean weight of gut contents (0.077 g) was

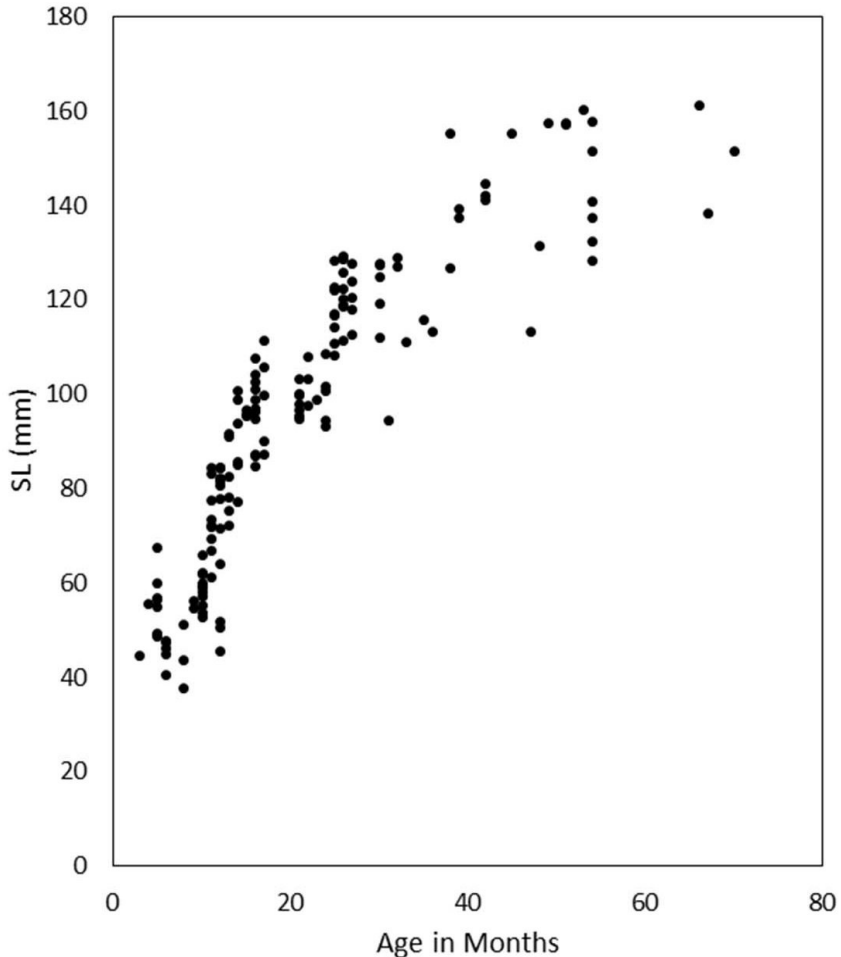


FIGURE 2. Standard length in mm versus hypothesized age in months for *Moxostoma cervinum*. N = 154

in August and was lowest in January (0.000 g). The relationship between SL and weight of gut contents was significant ($P < 0.0001$) and had a modest r^2 value of 24.1%. Chironomidae and detritus were found in 70% and 82% of specimens examined, respectively, and 14% contained no gut contents. Variety of gut contents was not uniform across all months ($P < 0.0001$) and peaked in August ($n = 13$). The relationship between SL and variety of gut contents was significant ($P < 0.0001$) and had a modest r^2 value of 17.8%. The proportion of gut contents that were Chironomidae

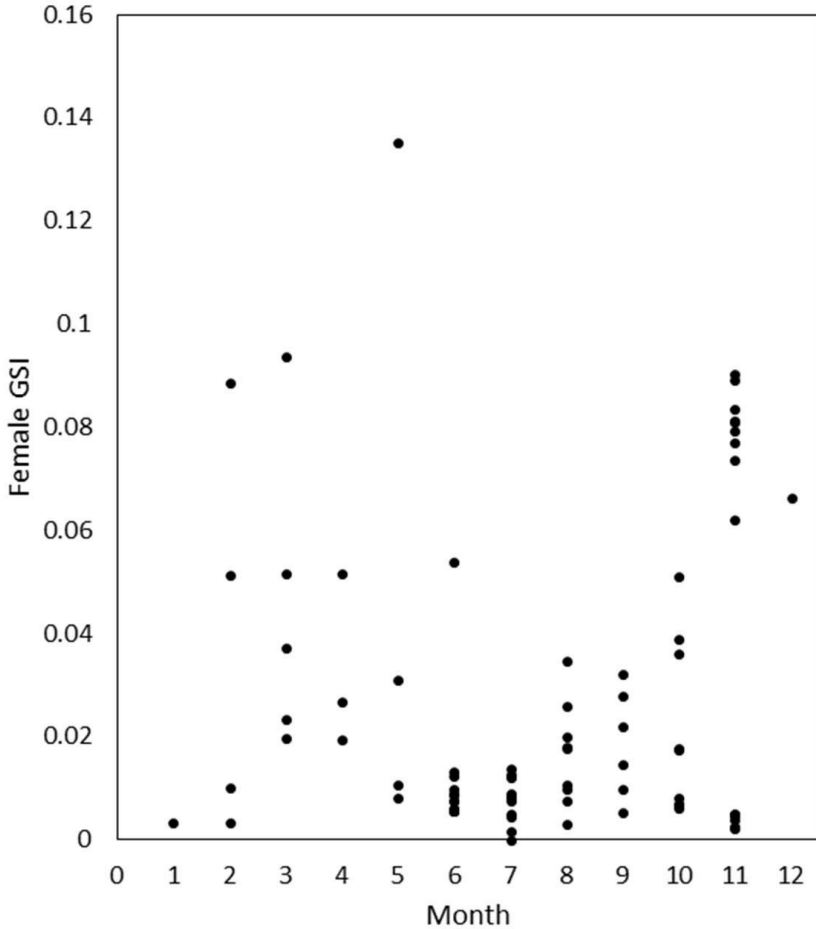


FIGURE 3. Gonadosomatic index by month of collection for female *Moxostoma cervinum*. (1=January, 2 = February, etc.). N = 76

was not uniform across all months ($P < 0.0001$) and was greatest during April and lowest during July. A significant positive relationship ($P = 0.013$) between SL and proportion of gut contents as Chironomidae had a low r^2 value of 3.99%.

DISCUSSION

Moxostoma cervinum appear to grow up to approximately 84 mm SL in their first year, up to 129 mm SL by the end of their second year, up to 156 mm SL by the end of their third year, up to 158 by the end of their fourth year, and up to 161 by the end of their fifth year. The largest specimen examined (161.27 mm SL) for this study is similar in size to the maximum size reported by Jenkins and Burkhead (1994) of 164

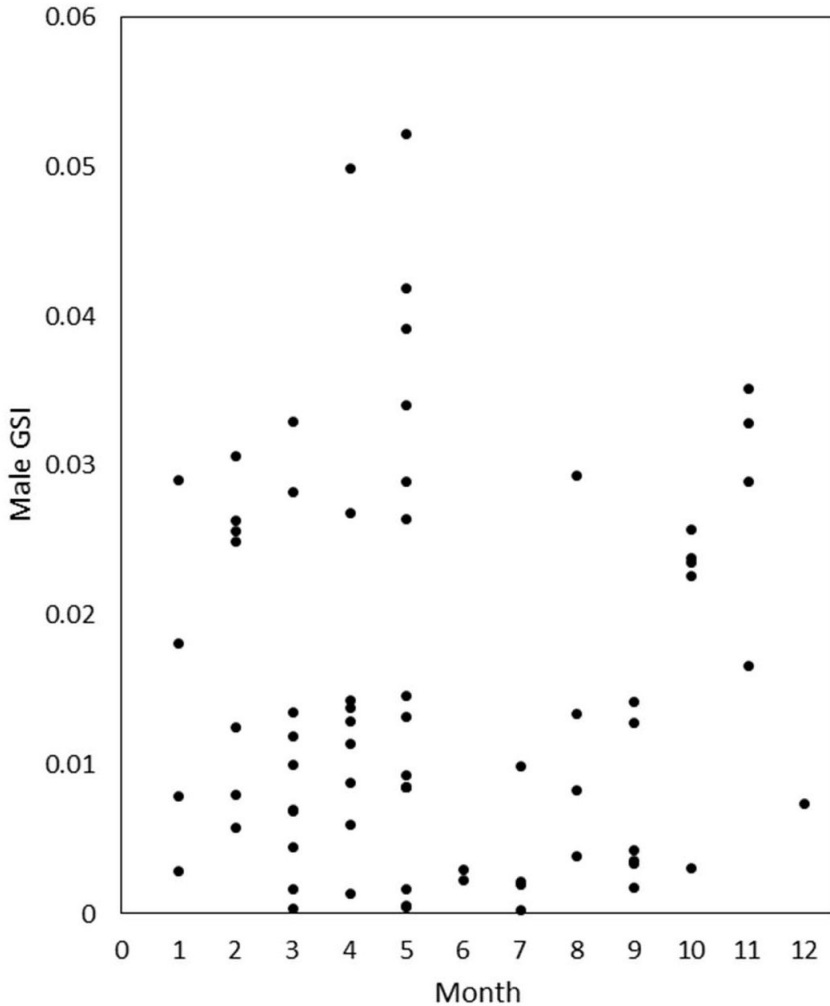


FIGURE 4. Gonadosomatic index by month of collection for male *Moxostoma cervinum*. (1=January, 2 = February, etc.). N = 63

mm SL suggesting that maximum age for the species is five years. The relatively low proportion of specimens less than one year old is likely explained in part by the difficulty capturing small specimens in a seine with 9.5 mm mesh as many are likely to pass through without being captured. The difference in habitat between juvenile and adult specimens noted by Jenkins and Burkhead (1994) may also partly explain the low number of juveniles, as most collections for this study were conducted in flowing habitats over larger substrate preferred by adults. The relatively high proportion (39%)

TABLE 1. Number of individuals of each taxon identified from gut contents of *Moxostoma cervinum* collected in the Roanoke River from corresponding months and total number. Total number of food items from each month is the second row from the bottom, and number of taxa represented each month is the bottom row.

Taxon	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Acari	0	0	0	0	18	3	1	11	3	0	0	0	36
Brachiopoda	0	0	0	0	0	0	0	3	0	0	0	0	3
Chironomidae	0	108	26	350	723	515	99	500	196	28	604	0	3149
Coleoptera larvae	0	0	0	0	0	0	0	2	0	0	0	0	2
Coleoptera adults	0	0	0	0	0	0	0	2	0	0	0	0	2
Diptera adults	0	0	0	9	0	0	0	3	0	0	8	0	20
Ephemeroptera	0	0	0	8	5	0	4	7	4	0	0	0	28
Oligochaeta	0	0	5	0	0	0	0	0	0	0	0	0	5
Prosobranchia	0	0	1	0	0	0	0	0	0	0	0	0	1
Simuliidae	0	0	0	0	6	0	0	0	2	0	0	0	8
Trichoptera	0	1	0	1	1	29	16	6	4	54	7	0	119
Unidentified eggs	0	0	0	0	0	0	294	0	0	0	0	0	294
Total	0	109	32	368	753	547	414	534	209	82	619	0	3667
Taxa each month	0	2	3	4	5	3	5	8	5	2	0	0	0

of specimens two years of age or greater suggests a high survivorship of adult specimens as would be expected due to few large piscivorous predators in the relatively shallow, flowing habitat preferred by *M. cervinum*. The difference in mean size among sexes is likely due to the difference in lifespan as females appear to outlive males.

A relatively small proportion of males appear to be sexually mature at approximately one year of age, and all appear to be mature by two years of age. Females appear to take longer to mature than males as a majority are mature by two years of age and all are mature by three years of age. Spawning appears to begin in April and continue through May as indicated by GSI values and condition of oocytes (Figures 3 and 4). Jenkins and Burkhead (1994) reported water temperatures during likely spring spawning of *M. cervinum* as 14-23° C, and water temperature during our collections from April and May for this study were within that range. The low GSI values for both sexes in summer months, followed by an increase in fall indicate an early physiological preparation for spring spawning. While this appears to be unusual, other recent studies have documented similar increases in GSI during fall for small Catostomidae species (O'Kelley and Powers 2007, Tarasidis and Powers 2014).

Feeding appears least intense during colder months of winter as indicated by lower values for weight of gut contents and variety of food items from December to March (Table 1). The abundance of Chironomidae and detritus in the gut of specimens indicates a similar diet to that of other small catostomids (Timmons et al. 1983, O'Kelley and Powers 2007, Tarasidis and Powers 2014). The high number of Chironomidae may indicate selective feeding by *M. cervinum*, or may be the result of high densities of chironomids (>20,000 individuals/m²) in the substrate of streams (Benke et al. 1984). While the proportion of the diet made up by Chironomidae is not uniform across all months, the variation does not appear to be strongly seasonal as the two months with the lowest proportion of food items as Chironomidae are adjacent to months with >90% Chironomidae in the diet. The abundance of Trichoptera, Acari, and unidentified eggs from some months, and complete absence from others suggest that *M. cervinum* may simply be opportunistic benthic feeders. While variety of gut contents does appear to increase with SL, the modest relationship between these variables suggests that there is not a strong shift in feeding throughout the life of *M. cervinum*. Larger specimens may simply be able to ingest a greater variety of food items also suggesting that *M. cervinum* are not particularly selective, but rather opportunistic benthic feeders taking advantage of almost any currently abundant food source. While significant, the low r^2 value suggests size of specimens has little influence on the proportion of food items as Chironomidae also suggesting that changes in diet are slight throughout the life of *M. cervinum*.

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Specimen collection was done primarily by J.S. Bentley and S.L. Powers. Data analyses were done by D.A. Thompson and S.L. Powers.

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