1984

Comparitive life histories of some species of redhorse,subgenus moxostoma,genus Moxostoma

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VITA

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COMPARATIVE LIFE HISTORIES OF SOME SPECIES OF REDHORSE, SUBGENUS *MOXOSTOMA*, GENUS *MOXOSTOMA*

A Dissertation

Presented to

The School of Graduate Studies

Indiana State University

Terre Haute, Indiana

In Partial Fulfillment

of the Requirements for the Degree

Doctor of Philosophy

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by

Barbara A. Brown

August 1984

APPROVAL SHEET

The dissertation of Barbara A. Brown, Contribution to the School of Graduate Studies, Indiana State University, Series III, Number 315, under the title Comparative Life Histories of Some Species of the Subgenus *Moxostoma*, Genus *Moxostoma* is approved as partial fulfillment of the requirements for the Doctor of Philosophy Degree.

11 May 1984
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9 July 1984
Date

For the School of Graduate Studies

ABSTRACT

Three species of Moxostoma (M. anisurum, the silver redhorse; M. erythrurum, the golden redhorse; M. duquesnei, the black redhorse) were examined in order to characterize them as they occur in Otter and Brouillettes Creeks in Vigo County, Indiana and to quantify differences between them in habitat, food habits, and morphology. Low numbers of captures of Moxostoma made habitat evaluation difficult. The three species co-occurred in both creeks. Temporal differences in occurrence of redhorses in the creeks were observed. Redhorses were captured with low frequency before August of both years. Golden redhorses were captured in higher numbers than the other species. Moxostoma duquesnei was the least common.

The species exhibited similar food habits. Insect larvae, especially chironomids, were found in the highest volume and frequency in all three species. Copepods were the second most important items of both M. anisurum and M. erythrurum, while the item second in abundance in M. duquesnei was insect pupae. Age 0 fish varied significantly in % volume insect larvae consumed between M. erythrurum (63.9% vol) and M. duquesnei (79.4% vol) and M. erythrurum and M. anisurum (76.2% vol). Similar results occurred in % volume of copepods eaten (M. erythrurum = 21.3% vol; M. duquesnei = 4.6% vol; M. anisurum = 15.8% vol).

Detailed morphological data were collected from each species. No differences were seen between the sexes. Age classes were compared by ANOVA and Discriminant Function Analysis. Individuals of silver

and black redhorses could be identified to age class 100% of the time. Golden redhorses could be correctly aged only 90% of the time due to difficulty in separating older fish.

The shape of the lower lips was the best character for discriminating among the three species. Moxostoma anisurum was characterized by a very acute angle formed by the meeting of the halves of the lower lips, Moxostoma erythrurum by an obtuse angle of approximately 140 degrees, and M. duquesnei by an angle of 180 degrees. Only a single specimen of M. erythrurum was difficult to identify using this character. Other characters used exhibited much overlap among the species.

ACKNOWLEDGEMENTS

I am indebted to the members of my dissertation committee (Dr. John O. Whitaker, Jr., Dr. Max A. Proffitt, Dr. Marion T. Jackson, Dr. William B. Hopp and Dr. Robert Howe) for their comments and suggestions. I would like to thank Wynn W. Cudmore, Rita A. Veal, William Santee, William Kern and Steven J. Ropski for their help in collecting specimens. Special thanks go to John O. Whitaker, Jr. for his support and guidance throughout my years at Indiana State University.

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INTRODUCTION

Species of the genus *Moxostoma* are the redhorse suckers. They are moderate to large sized bottom dwelling fishes with mouths adapted for suctorial feeding. The genus is relatively large and composed of three subgenera (Robins and Raney, 1956). The best represented in this area is the subgenus *Moxostoma*. Whitaker and Wallace (1973) reported five species of this subgenus in Vigo County, listed in order of decreasing abundance: *Moxostoma erythrurum*, the golden redhorse (Rafinesque), *M. anisurum*, the silver redhorse (Rafinesque); *M. duquesnei*, the black redhorse (Le Sueur); *M. carinatum*, the river redhorse (Cope); and *M. macrolepidotum*, the northern redhorse (Le Sueur). They also reported the occurrence of *M. valenciennesi*, the greater redhorse (Jordan), a member of the subgenus *Megapharynx*.

Although the systematics of the genus *Moxostoma* has been studied (Jordan, 1878; Hubbs, 1930; Robins and Raney, 1956; Minkley and Cross, 1960; Eastman, 1971; Jenkins, 1971; Phillips, 1972), the redhorses are still difficult to identify and little is known of their habits. Bowman (1970) and Kott, Jenkins and Humphreys (1979) studied aspects of the life history of *M. duquesnei*, Tatum and Hackney (1960) that of *M. carinatum* and Mayer (1962) *M. erythrurum*, *M. anisurum* and *M. macrolepidotum*. Data on food habits are available but general in nature (Meyer, 1962; Bowman, 1970). The habitat requirements of these species have been described (Trautman, 1957; Meyer, 1962; Kott et al., 1979) and much overlap occurs. These species are frequently collected at the same sites.

The purposes of this study were (1) to further describe the habitat requirements of these species, (2) to study in depth their food habits, (3) to describe in detail the species as they occur in Vigo County, (4) to determine a reliable method for identifying them.

MATERIALS AND METHODS

Fish included in this study were collected in seines from Brouillettes and Otter Creeks, Vigo County, Indiana (Figure 1), between 1980 and 1983 or were part of the Indiana State University Fish Collection and had been collected since 1962. All animals were preserved in 10% formalin and brought into the lab for further study.

In order to determine habitat preferences of the various species, 50-foot-long plots were located and randomly sampled in both Otter and Brouillettes Creeks in the spring and summer of 1982. This method proved ineffective and a stratified random sampling was employed. Three strata were identified based on bottom type (gravel, rock, and sand/silt). Sampling success was again low, so sampling was then confined to areas where Moxostoma had been previously taken. Sampling was concentrated in one general area in each creek. In Otter Creek, the area extended from Markle's Dam down stream below a riffle area approximately 1/4 mile. This area contained 30 plots, each 50 feet long. The area in Brouillettes Creek was located above and below the bridge at Sheppardsville, Indiana. This area included 40 plots. Each plot was seined twice per sampling.

Data on environmental parameters were collected at all study sites. Characters studied were stream depth (m), current speed (m/s), and temperature (F). Sites were categorized as sand, gravel and rock bottoms. Both dissolved oxygen and pH were determined using a Hach kit. All species of fish found in association with Moxostoma were identified and numbers tabulated.

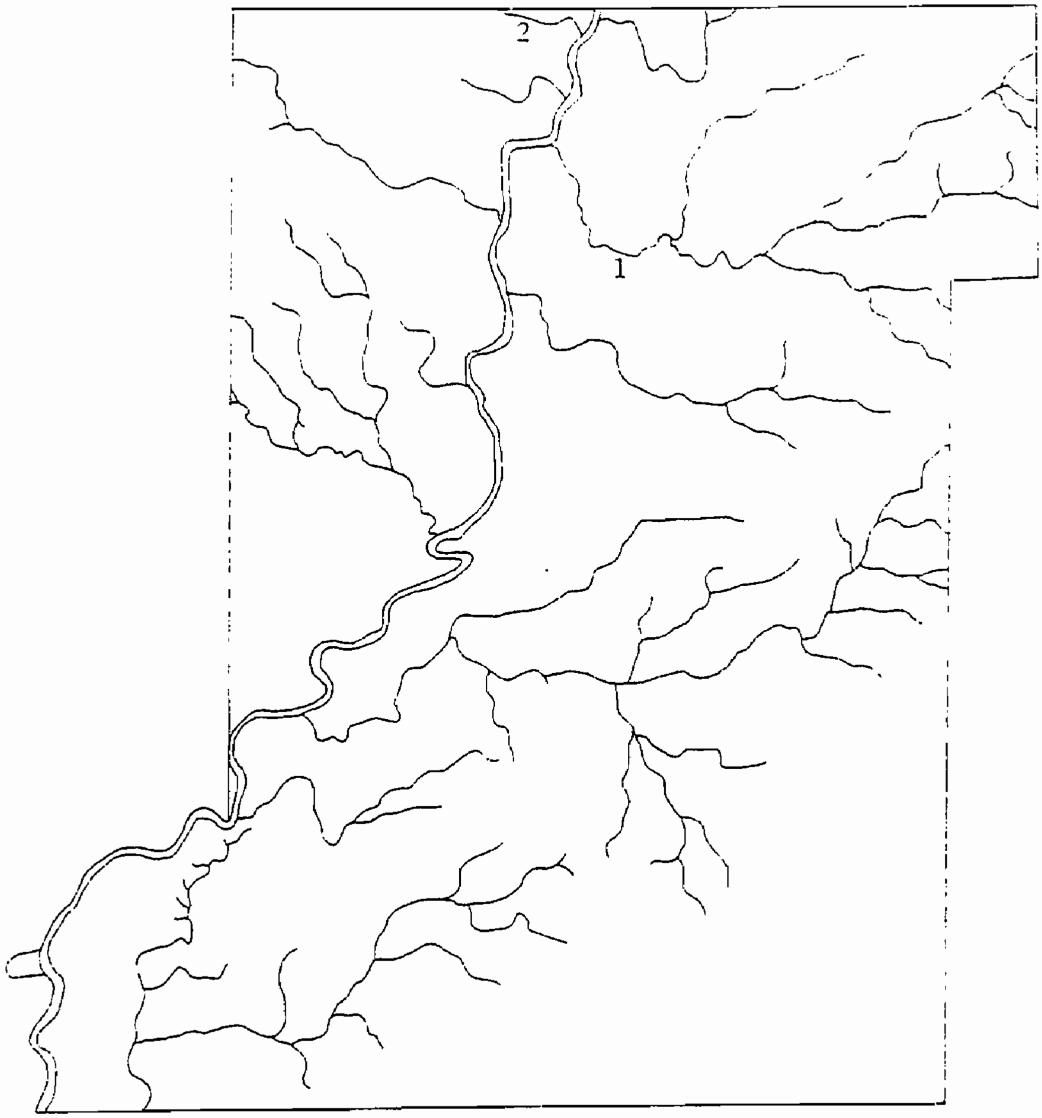

Figure 1. Map of Vigo County, Indiana indicating the location of Otter and Brouillettes Creeks. (Location 1 = Otter Creek; Location 2 = Brouillettes Creek)

The species of redhorses common in these creeks are difficult to identify using available keys (Hubbs, 1930; Hubbs and Lagler, 1949; Gerking, 1955; Jenkins, 1971); therefore, detailed systematic work was conducted in order to segregate these animals and to describe the populations as they occur in Vigo County, Indiana. Standard measurements and counts were made in accordance with Hubbs and Lagler (1949) as follows: total length, standard length, body depth, depth of caudal peduncle, predorsal length, height of dorsal, length of dorsal base, length of flattened dorsal, length of longest dorsal ray, pectoral length (r+1), pelvic length (r+1), length of anal base, length of longest pectoral ray (r+1), length of longest pelvic ray (r+1), length of longest anal ray, height of anal, length of flattened anal, head length, head width, snout length, postorbital length, cheek height, interorbital width, orbital length, distance between pectoral fins, distance between pelvic fins, length of upper fork of caudal fin, length of lower fork of caudal fin, number of dorsal rays, number of pectoral rays (r+1), number of pelvic rays (r+1), number of anal rays, scales before dorsal, scales around caudal peduncle, scales in lateral line and scales between dorsal and midventral line. All measurements were taken with calipers to 0.1 mm.

Data were analyzed to determine significant differences between species using ANOVA and Discriminant Function Analyses. In order to compare the species for differences not due to age, lengths were converted to % standard length (distance from the tip of the snout to the end of the vertebral column) and analyzed.

Variation within species was assessed using oneway ANOVA with Duncan's Multiple Range Tests. Comparisons were made between sexes and locations using % standard length data and between the different age classes on non-transformed data. Discriminant Function Analysis was also used to analyze the age class data.

The shape and texture of the lips (Figure 2) of the members of the genus Moxostoma are quite useful in separating species. The lips of each fish were categorized based on the angle formed by the joining of the halves of the lower lip (acute, obtuse, straight).

In order to age individuals, scales were collected from all animals from an area anterior to the dorsal fin and dorsal to the lateral line. Scales were mounted on slides in Hoyer's solution and sealed with Euparal. At least five scales were mounted per individual. Meyer (1962) and Bowman (1970) used this technique with redhorses from Iowa and Missouri. Tatum and Hackney (1960) aged M. carinatum by scales.

Stomachs were removed and contents analyzed under dissecting and compound microscopes. Percent volume and percent frequency were estimated for all food items. Foods were identified to genus and species whenever possible in order to assess differences in the food habits between species. A oneway analysis of variance with Duncan's Multiple Range Test was used to analyze for significant differences among food groupings. The ANOVA was conducted on transformed data (equal to the arcsine of the square root of the percentage estimate) and non-transformed data.

Fish were weighed in grams and sex was determined by examining the gonads of each individual under a dissecting microscope. Testes appeared as white, opaque thread-like organs and ovaries were orange-pink in color and translucent. Eggs could be seen even in immature individuals.

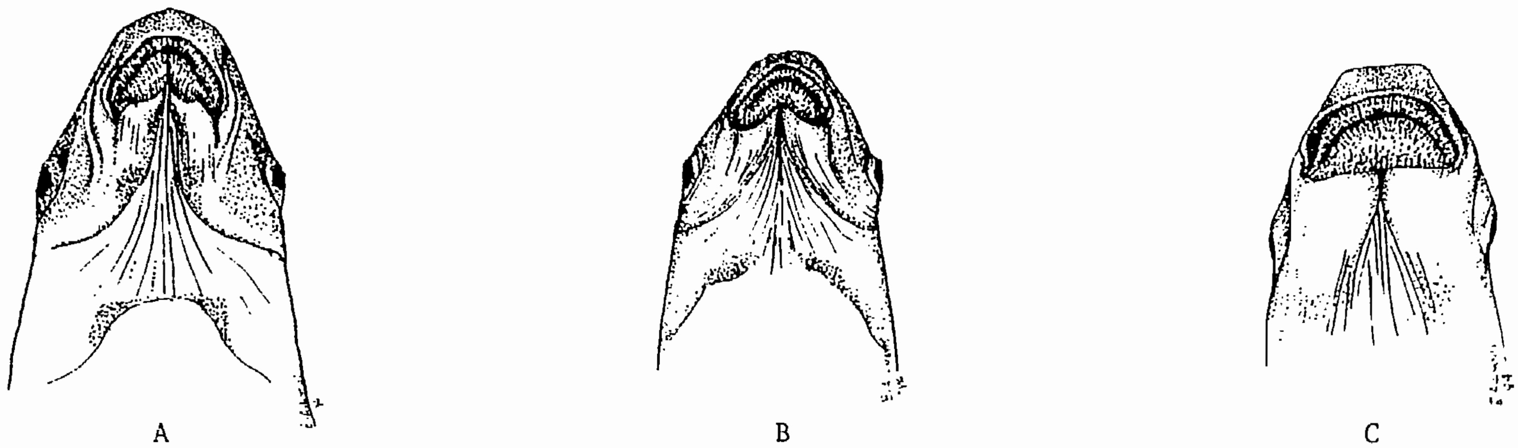

Figure 2. Diagrams of the heads of the three species of _Moxostoma_ showing the shapes of the lower lips.

A = _M. anisurum_; B = _M. erythrurum_; C = _M. duquesnei_

RESULTS AND DISCUSSION

Description of Study Area

The creeks sampled in this study were located in west, central Indiana on the Illinois border, in Vigo County (Figure 1). Otter (location 1) and Brouillettes (location 2) Creeks were chosen as study areas based on previous success in collection of Moxostoma (Whitaker and Wallace, 1973). It was expected that Moxostoma could be collected frequently, though in low numbers, in both creeks. However, success in capturing these species was poor. Random and stratified random sampling proved ineffective. Sampling was then conducted only in areas where the suckers had been previously collected.

In these areas, seventy-seven 50-foot plots were sampled, seining twice per sample. Twenty-seven yielded Moxostoma. Environmental data were collected (see Methods) from 34 sites. Comparisons were made between sites where specimens were collected and sites sampled without Moxostoma (Table 1). Statistically significant differences were found between sites in two parameters. Redhorses were taken at sites characterized by greater depth ($\overline{x}$ = 0.61 m vs 0.31 m, t = 4.25) and slower current ($\overline{x}$ = 0.06 m/s vs 0.49 m/s, t = 5.73. All other differences between characteristics were not significant including pH, DO_2, and temperature. Bottom types were variable in both sites where fish were and were not collected.

Both creeks were sampled in spring and summer of 1982 and 1983. Few Moxostoma were collected before August (2%, N = 4), and most were collected in September and October of both years. This temporal pattern

Table 1. Summary of environmental data collected at sampling sites.

	Sites with Redhorses				Sites without Redhorses					
Parameter	N	$\bar{x}$	SD	SE	N	$\bar{x}$	SD	SE	t	df
Depth (m)	16	0.61	20.81	5.20	18	0.31	20.72	4.88	4.25	32
Current Speed (m/s)	16	.06	0.15	0.04	18	0.49	0.26	0.06	5.73	32
Temperature (°F)	16	70.56	8.15	2.04	17	67.35	6.74	1.63	0.77	31
pH	16	8	0.0	0.0	18	8.05	0.16	0.04	0.82	32
Dissolved oxygen (ppm)	14	8	1.11	0.30	18	8.05	0.72	0.17	0.13	30

of capture or occurrence in the creeks seems to indicate some factor other than habitat preference affecting distribution of the fish. At these times fish of all species, sexes and ages were captured together, indicating perhaps schooling or migratory behavior. More work is needed in this area to further understand this behavior.

Description of Species

Moxostoma anisurum, the silver redhorse. A total of 57 silver redhorses were examined in order to characterize the species as it occurs in Vigo County, Indiana. Age, sex and various morphological data were recorded for each specimen when possible. Information on variation within this species is summarized in Table 2. Fin ray and scale counts are given as actual data. Total length to length of lower fork of caudal fin are given as % standard length. This was done to try to eliminate age-related size differences from the general description of the species and comparisons between species.

The silver redhorses collected during this study ranged from 64.1 mm to 191.0 mm total length, but members of the species attain much greater size. The habitat of the larger individuals has been described as rivers, particularly in areas of slow moving deep water (Meyer, 1962). The younger animals are frequently collected from smaller, shallower streams. This may be a partial explanation of the lack of larger animals collected from Otter and Brouillettes Creeks.

Moxostoma anisurum is a relatively deep-bodied fish ($\bar{x}$ = 26.25% standard length) with a thick caudal peduncle ($\bar{x}$ = 11.27). The head is long ($\bar{x}$ = 28.66) and deep ($\bar{x}$ = 19.92). The upper fork of the caudal fin is usually longer than the lower (Table 2). The eye is large and the

Table 2. Mean, Range, SD, SE for 23 characters of *M. anisurum* (total length to length lower fork caudal fin given as % standard length).

Character	N	Mean($\bar{x}$)	SD	SE	Range
Total length	55	131.36	10.20	1.37	67.80-140.31
Body depth	57	26.25	2.48	0.33	11.40-30.80
Depth caudal peduncle	57	11.27	1.03	0.14	5.20-12.73
Length caudal peduncle	57	14.71	1.97	0.26	7.50-19.39
Predorsal length	56	48.83	3.65	0.49	24.70-53.52
Head length	57	28.66	2.30	0.30	14.50-32.20
Head depth	56	19.92	1.76	0.23	17.58-28.27
Head width	56	16.56	1.52	0.20	7.50-18.52
Snout length	56	10.56	1.30	0.17	4.90-12.88
Postorbital length	57	10.74	1.10	0.15	5.40-12.50
Cheek height	57	12.06	1.20	0.16	6.00-13.98
Interorbital width	57	8.73	1.33	0.18	4.00-13.04
Orbital length	57	8.75	1.07	0.14	4.50-11.04
Length upper fork caudal fin	52	82.40	3.36	0.47	14.90-40.40
Length lower fork caudal fin	53	29.69	3.21	0.44	13.40-38.15

Table 2 - continued

	N	Mean ($\bar{x}$)	SD	SE	Range
Dorsal ray count	57	15.67	0.76	0.10	14.00-17.00
Pectoral ray count R	57	16.05	0.81	0.10	13.00-17.00
Pectoral ray count L	56	16.05	0.70	0.09	14.00-17.00
Pelvic ray count R	57	8.98	0.30	0.04	8.00-10.00
Pelvic ray count L	57	9.05	0.29	0.04	8.00-10.00
Anal ray count	57	8.03	0.26	0.03	7.00-9.00
Scales before dorsal fin	51	13.06	1.19	0.17	10.00-15.00
Caudal peduncle scales	56	12.46	0.67	0.09	12.00-15.00
Scales in lateral line	50	40.94	1.39	0.20	38.00-44.00

snout long. Dorsal ray counts ranged from 14 to 17 ($\bar{x}$ = 15.67), pectoral rays averaged 16.05 for both right and left fins. Pelvic ray counts were recorded between 8 and 10 ($\bar{x}$ = 8.98R, 9.05L). The number of scales in the lateral line averaged 40.94 and those around the caudal peduncle 12.46. These measurements and counts fall in the range of those previously recorded in the literature (Jenkins 1971). No significant differences were found between the sexes, so they were pooled in the above description.

The lips of M. anisurum have been described as distinctly plicate, with some papillae, deeply notched or "V-shaped", forming a very acute angle between the halves of the lower lip (Hubbs, 1932; Gerking, 1953; Jenkins, 1971; Phillips, 1972). All silver redhorses examined in this study fit the above description and could be readily identified by the shape of their lips (Figure 2A).

Animals were aged based on the number of annuli (year rings) present on their scales. Three age classes (0, I, II) were represented in M. anisurum. Data were summarized in Table 3 in order to quantify the characteristics of the different age classes represented in the samples. No significant differences were seen between the age classes in either scale row or fin ray counts. Therefore, these data were excluded from Table 3.

Data were analyzed by oneway ANOVA followed by Duncan's Multiple Range Rests. Significant F values were obtained by ANOVA on all 17 measurements examined. Some of these characters, F values and Duncan's subsets, are given in Figure 3. The means of Age 0 fish for all measurements varied significantly from both other age classes (Figure 3). Means for Age I and Age II fish were separated by Duncan's Multiple Range

Table 3. Mean, SD, SE for 17 characters of *Moxostoma anisurum* by age class.

	Age 0				Age I				Age II			
Character	$\bar{x}$	SD	SE	N	$\bar{x}$	SD	SE	N	$\bar{x}$	SD	SE	N
Weight	12.86	11.42	2.12	29	37.60	14.63	4.09	13	64.40	0	0	1
Total length	82.62	21.92	3.60	37	143.42	22.60	5.65	16	167.50	27.58	19.50	2
Standard length	63.02	16.93	2.74	38	107.85	16.33	4.08	16	124.45	19.16	13.55	2
Body depth	16.54	5.41	0.86	39	29.44	4.74	1.18	16	32.75	4.88	3.45	2
Depth of caudal peduncle	7.08	2.18	0.35	39	12.61	1.89	0.47	16	14.35	1.63	1.15	2
Length of caudal peduncle	9.55	2.34	0.375	39	14.70	3.15	0.79	16	18.70	1.27	0.90	2
Predorsal length	30.88	8.91	1.44	38	53.39	7.92	1.87	16	61.35	8.70	6.15	2
Head length	18.13	4.21	0.83	39	31.325	4.16	1.04	16	35.85	5.87	4.15	2
Head depth	12.43	3.72	0.60	38	22.27	5.07	1.27	16	24.00	3.82	2.70	2
Head width	10.45	3.11	0.50	39	18.25	2.32	0.60	15	21.70	1.84	1.30	2
Snout length	6.50	2.26	0.37	38	12.53	1.875	0.47	16	14.40	2.26	1.60	2
Postorbital length	6.73	2.25	0.36	39	12.14	1.60	0.40	16	13.35	1.77	1.25	2
Cheek height	7.64	2.32	0.37	39	13.49	2.33	0.58	16	13.10	5.66	4.00	2

Table 3 - continued

	Age 0				Age I				Age II			
Character	$\bar{x}$	SD	SE	N	x	SD	SE	N	x	SD	SE	N
Interorbital width	5.33	1.92	0.31	39	10.34	1.81	0.34	16	13.40	0	0	2
Orbital length	5.65	1.35	0.22	39	9.02	1.24	0.31	16	9.05	1.48	1.05	2
Length upper fork caudal fin	19.96	5.70	0.96	35	36.60	6.33	1.63	15	42.35	13.22	9.35	2
Length lower fork caudal fin	18.42	5.56	0.93	36	34.33	6.17	1.59	15	39.40	9.76	6.90	2

Figure 3. Some characters varying significantly by ANOVA among age classes in *Moxostoma anisurum*, indicating F value and subsets formed by Duncan's Multiple Range Tests.

Character	F value	Duncan's Multiple Range Subsets
Total length	50.36	0 ($\bar{x}$=82.62) / I ($\bar{x}$=143.42) II ($\bar{x}$=167.50)
Body depth	40.16	0 ($\bar{x}$=16.54) / I ($\bar{x}$=29.44) II ($\bar{x}$=32.75)
Depth of caudal peduncle	46.63	0 ($\bar{x}$=7.08) / I ($\bar{x}$=12.61) II ($\bar{x}$=14.35)
Length of caudal peduncle	31.19	0 ($\bar{x}$=9.55) / I ($\bar{x}$=14.70) / II ($\bar{x}$=18.70)
Interorbital width	52.595	0 ($\bar{x}$=5.33) / I ($\bar{x}$=10.34) / II ($\bar{x}$=13.40)

Tests for length of caudal peduncle ($\overline{x}$ = 14.70 vs $\overline{x}$ = 18.70) and interorbital width ($\overline{x}$ = 10.34 vs $\overline{x}$ = 13.40). Overlap occurred between all age classes in all measurements. No single measurement could be used to definitely identify a specimen's age. However, general size differences were fairly reliable. The young of the year (Age 0) silver redhorses appeared as slightly smaller versions of the larger fish and could be identified to species on general shape as well as lip characteristics.

Moxostoma erythrurum, the golden redhorse. One hundred and nine golden redhorses were examined. Data summarized in Table 4 are given as % standard length. This is the most frequently occurring redhorse in this area. Whitaker and Wallace (1973) collected more M. erythrurum than any other redhorse between 1962 and 1965 [%F = 12.1 vs 0.7 (M. duquesnei) and 3.5 (M. anisurum)]. Golden redhorses represented 59.4% of the total Moxostoma collected in 1982 and 1983 in this study. Individuals of M. erythrurum are long and slender. They are characterized by the obtuse angle formed by the meeting of the halves of the lower lips (Figure 2B). Their lips are plicate and with few marginal papillae. The number of scales in the lateral line is moderate, ranging from 35 to 47 ($\overline{x}$ = 41.33), pelvic fin rays averaged 9.17R, 9.20L, pectoral rays: $\overline{x}$ = 15.92L, 15.87R for both fins. Scales around the caudal peduncle ranged from 12 to 15 ($\overline{x}$ = 12.27). The body and caudal peduncle depths are moderate. The caudal peduncle length is short ($\overline{x}$ = 13.29% std. length). The distance between the orbits is narrow ($\overline{x}$ = 8.48). The length of the upper fork of the caudal fin is slightly greater than that of the lower fork ($\overline{x}$ = 30.91 vs 29.23). No

Table 4. Mean, SD, SE, Range for 24 characters of *Moxostoma erythrurum* (total length to length lower fork caudal fin given as % standard length).

Character	N	Mean ($\bar{x}$)	SD	SE	Range
Total length	102	131.08	3.46	0.34	122.92-143.40
Body depth	109	23.60	2.22	0.21	20.97-41.85
Depth caudal peduncle	108	9.67	0.78	0.70	7.81-11.18
Length caudal peduncle	108	13.29	1.58	0.15	10.36-19.24
Predorsal length	109	48.61	1.89	0.18	42.28-58.40
Head length	109	24.84	2.92	0.28	16.83-29.68
Head depth	109	17.42	1.32	0.13	14.28-26.00
Head width	107	15.15	0.97	0.09	11.97-18.16
Snout length	109	9.33	1.10	0.11	7.61-12.54
Postorbital length	109	10.10	0.77	0.07	7.96-12.10
Cheek height	109	11.32	0.64	0.06	9.54-13.13
Interorbital width	109	8.48	0.93	0.09	6.43-10.86
Orbital length	109	6.63	1.09	0.10	4.81-8.99
Length upper fork caudal fin	95	30.91	2.38	0.24	24.25-36.04
Length lower fork caudal fin	106	29.23	3.43	0.33	13.67-43.68

Table 4 - continued

	N	Mean ($\bar{x}$)	SD	SE	Range
Dorsal ray count	109	14.01	0.74	0.07	12.00-16.00
Pectoral ray count R	109	15.87	0.58	0.05	14.00-17.00
Pectoral ray count L	109	15.92	0.71	0.07	14.00-17.00
Pelvic ray count R	109	9.17	0.52	0.05	7.00-10.00
Pelvic ray count L	109	9.20	0.51	0.05	8.00-11.00
Anal ray count	108	8.00	0.19	0.02	7.00-9.00
Scales before dorsal	106	14.63	1.83	0.18	11.00-19.00
Caudal peduncle scales	109	12.27	0.57	0.05	12.00-15.00
Scales in lateral line	97	41.33	2.75	0.28	35.00-47.00

differences were seen between the sexes in this species.

Six age classes (0 to 5 years) were identified from age rings on scales. Many more young-of-the-year fish (Age 0) were collected (N = 57) than for any other age class. Fewer two-year fish were collected (N = 6) than any other group, but overall numbers in classes I to V were similar when compared to Age 0. Obviously mortality is high for young redhorses.

Actual data rather than % standard length are summarized in Table 5. The general trend was an increase in size and weight from one age group to the next (Table 5), but overlap occurred between all age classes. Statistical analyses of the differences between age classes indicated that Age 0 fish varied significantly from all other age classes in all measurements taken except weight (Figure 4). There was no significant difference in weight ($\bar{x}$ = 5.48 vs $\bar{x}$ = 40.79) between Age 0 and Age I. Group I fish differed significantly from all other higher classes in all characters but weight ($\bar{x}_{I}$ = 40.79 vs $\bar{x}_{II}$ = 77.68) and postorbital length ($\bar{x}_{I}$ = 12.05 vs $\bar{x}_{II}$ = 13.83). There was no difference between means of groups IV and V in depth of caudal peduncle ($\bar{x}$ = 22.51, $\bar{x}$ = 26.63) or caudal peduncle length ($\bar{x}$ = 34.11, $\bar{x}$ = 33.79). Age IV fish did not vary significantly in orbital length from either Age III or Age V fish. The means of Age III and Age V fish were significantly different when tested by Duncan's Multiple Range Test ($\bar{x}$ = 12.66 vs $\bar{x}$ = 14.04). The means for all other measurements varied significantly between all age classes. These results are difficult to interpret. However, they seem to indicate that differences in weight between age classes become greater with age, but that differences in size (length, depth) are greater between younger aged fish.

Table 5. Mean, SD, SE for 17 characters of *M. erythrurum* by age class.

	Age 0				Age I				Age II			
Character	$\bar{x}$	SD	SE	N	$\bar{x}$	SD	SE	N	$\bar{x}$	SD	SE	N
Weight	5.48	1.86	0.27	48	40.79	10.07	3.39	9	77.68	13.05	5.84	5
Total length	81.39	11.21	1.53	54	150.22	10.96	3.16	12	196.17	11.65	4.76	6
Standard length	61.47	8.41	1.11	67	113.26	8.46	2.44	12	149.92	10.24	4.18	6
Body depth	14.57	3.39	0.45	57	28.375	2.78	0.80	12	36.43	1.26	0.51	6
Depth of caudal peduncle	6.12	1.01	0.13	67	11.75	1.11	0.32	12	14.43	0.99	0.40	6
Length of caudal peduncle	8.07	1.72	0.23	56	15.35	2.24	0.65	12	22.63	3.68	1.50	6
Predorsal length	29.76	4.72	0.62	57	56.65	5.79	1.67	12	73.82	4.98	2.03	6
Head length	15.54	3.29	0.44	57	29.99	2.14	0.62	12	36.53	2.22	0.91	6
Head depth	10.45	1.82	0.24	57	21.17	3.41	0.98	12	26.35	1.39	0.57	6
Head width	9.42	1.76	0.24	67	17.96	1.30	0.39	11	22.62	1.39	0.62	5
Snout length	5.29	1.11	0.15	57	11.19	0.86	0.24	12	15.80	0.50	0.20	6
Postorbital length	6.39	1.03	0.15	57	12.05	1.38	0.40	12	13.83	0.71	0.29	6
Cheek height	6.96	1.09	0.14	57	13.29	1.08	0.31	12	16.37	1.03	0.42	6

Table 5 - continued

Character	Age 0				Age I				Age II			
	$\bar{x}$	SD	SE	N	$\bar{x}$	SD	SE	N	$\bar{x}$	SD	SE	N
Interorbital width	4.80	0.93	0.12	57	10.22	0.79	0.23	12	13.33	0.84	0.34	6
Orbital length	4.49	0.87	0.11	57	8.01	0.54	0.15	12	9.12	0.40	0.20	6
Length upper fork caudal fin	19.65	2.64	0.37	52	35.79	2.46	0.71	12	43.78	3.11	1.39	5
Length lower fork caudal fin	18.90	3.33	0.44	56	33.86	2.61	0.75	12	39.42	3.62	1.47	6
	Age III				Age IV				Age V			
Weight	225.74	121.43	42.93	8	350.19	95.47	24.65	15	450.94	63.28	19.08	11
Total length	258.93	47.22	17.85	7	320.50	32.45	8.67	14	351.11	18.90	6.30	9
Standard length	212.26	43.98	15.55	8	252.07	27.23	7.03	15	273.45	14.44	4.35	11
Body depth	49.40	8.47	2.99	8	57.65	6.18	1.59	15	62.89	3.72	1.12	11
Depth caudal peduncle	19.33	3.30	1.25	7	20.51	2.24	0.58	15	23.63	1.92	0.58	11
Length of caudal peduncle	29.16	5.52	1.95	8	34.11	4.62	1.19	15	33.79	2.84	0.86	11

Table 5 - continued

Character	Age III				Age IV				Age V			
	$\bar{x}$	SD	SE	N	$\bar{x}$	SD	SE	N	$\bar{x}$	SD	SE	N
Predorsal length	103.66	21.88	7.74	8	122.87	14.17	3.66	15	131.15	10.75	3.24	11
Head length	52.325	11.13	3.93	8	59.21	6.89	1.78	15	63.00	2.86	0.86	11
Head depth	38.65	8.27	2.92	8	44.33	4.90	1.26	15	48.25	3.16	0.95	11
Head width	32.875	6.95	2.46	8	36.83	3.58	0.93	15	39.23	1.99	0.60	11
Snout length	21.61	4.80	1.70	8	24.71	4.00	1.03	15	28.20	2.08	0.63	11
Postorbital length	21.224	4.84	1.71	8	23.79	2.79	0.72	15	25.90	2.01	0.61	11
Cheek height	24.51	5.58	1.97	8	28.23	2.61	0.68	15	30.24	1.65	0.50	11
Interorbital width	20.575	4.54	1.60	8	23.21	2.74	0.71	15	25.64	1.77	0.53	11
Orbital length	12.66	2.09	0.74	8	13.32	1.18	0.30	15	14.04	0.67	0.20	11
Length upper fork caudal fin	60.80	10.14	4.14	6	71.31	7.08	1.96	13	79.38	4.03	1.52	7
Length lower fork caudal fin	58.48	10.99	4.15	7	67.77	7.34	1.96	14	73.78	6.06	1.83	11

Figure 4. Some characters varying significantly by ANOVA among age classes of _Moxostoma erythrurum_ indicating F value and subsets formed by Duncan's Multiple Range Tests.

Character	F value	Duncan's Subsets					
Weight	182.28	0	I				
		($\bar{x}$ = 5.48)	($\bar{x}$ = 40.79)				
			I	II			
				($\bar{x}$ = 77.68)			
					III		
					($\bar{x}$=225.74)		
						IV	
						($\bar{x}$=350.19)	
							V
							($\bar{x}$ = 450.94)
Total length	546.23	0					
		($\bar{x}$ = 81.39)	I				
			($\bar{x}$ = 150.22)	II			
				($\bar{x}$ = 196.17)	III		
					($\bar{x}$ = 258.93)	IV	
						($\bar{x}$ = 320.50)	V
							($\bar{x}$ = 351.11)

Figure 4 - continued

		0	I	II	III	IV	V
Depth of caudal peduncle	454.29	($\bar{x}$ = 6.12)	($\bar{x}$ = 11.75)	($\bar{x}$ = 14.43)	($\bar{x}$ = 19.33)	($\bar{x}$ = 22.51)	($\bar{x}$ = 23.63)
Postorbital length	343.77	($\bar{x}$ = 6.39)	($\bar{x}$ = 12.05)	($\bar{x}$ = 13.83)	($\bar{x}$ = 21.22)	($\bar{x}$ = 23.79)	($\bar{x}$ = 25.90)

The results of the comparisons of scale and fin ray counts between age classes are variable. There were no significant differences between the means of numbers of dorsal or pectoral rays. Significant differences were seen between age groups in number of pelvic and anal rays (Figure 5). Means varied significantly between group 0 and groups II+V for pelvic rays right (F = 3.54) and group I and V+II; 0 and V+II; IV and II for pelvic rays left (F = 7.07). This is an interesting result, because this character (number of pelvic rays) is frequently used to help distinguish M. erythrurum from M. duquesnei (Hubbs and Lagler, 1949; Jenkins, 1971). Results here indicate that it is too variable to be used for that purpose.

The number of scales in the lateral line was also extremely variable between age classes. The Duncan's Multiple Range Test created three subsets (Figure 5). The younger age fish (0, I) varied significantly from older fish (IV, V), and both groups overlapped with middle aged fish (F = 12.08). The number of lateral line scales is also used as a distinguishing character between black and golden redhorses but appears to be highly variable in this species. Its use taxonomically is probably limited. The number of scales before the dorsal and the number found in the lateral line indicate scales increase in number with age of the fish. However, scales around the caudal peduncle do not show this trend. These results are interesting and somewhat unexpected. Variation within species in ray and scale counts is fairly common, but significant differences between age classes were not expected and the reasons are unclear. Perhaps they reflect differing environmental conditions during early developmental periods of the fishes' lives.

Figure 5. Subsets created by Duncan's Multiple Range Test for significant differences among means of age classes of <u>Moxostoma erythrurum</u>. Placement within a subset indicates no significant differences in means among any members of that subset.

Character	F Value						
Pelvic rays right	3.54	0	I	IV	III		
		($\bar{x}$ = 9.02)	($\bar{x}$ = 9.08)	($\bar{x}$ = 9.53)	($\bar{x}$ = 9.375)		
			I	IV	III	II	
						($\bar{x}$ = 9.50)	
				IV	II	II	V
							($\bar{x}$ = 9.545)
Pelvic rays left	7.07	I	0	IV	III		
		($\bar{x}$ = 9.00)	($\bar{x}$ = 9.03)	($\bar{x}$ = 9.33)	($\bar{x}$ = 9.375)		
				IV	III	V	
						($\bar{x}$ = 9.64)	
						V	II
							($\bar{x}$ = 9.83)
Anal rays	2.27	II	0	I	IV		
		($\bar{x}$ = 7.83)	($\bar{x}$ = 7.98)	($\bar{x}$ = 8.00)			
			0	I	IV	V	III
						($\bar{x}$ = 8.09)	($\bar{x}$ = 8.125)
Scales before dorsal fin	15.01	0	III	I	II		
		($\bar{x}$ = 13.85)	($\bar{x}$ = 14.00)	($\bar{x}$ = 14.08)	($\bar{x}$ = 12.375)		
						IV	V
						($\bar{x}$ = 16.60)	($\bar{x}$ = 16.82)

Figure 5 - continued

Caudal peduncle scales	3.83	II	0	IV	III		
		($\bar{x}$ = 12.09)	($\bar{x}$ = 12.12)	($\bar{x}$ = 12.33)	($\bar{x}$ = 12.375)		
						I	II
						($\bar{x}$ = 12.67)	($\bar{x}$ = 12.83)
Scales in lateral line	12.08	0	I	III			
		($\bar{x}$ = 39.93)	($\bar{x}$ = 40.25)	($\bar{x}$ = 41.25)			
				III	II		
					($\bar{x}$ = 43.17)		
						IV	V
						($\bar{x}$ = 43.53)	($\bar{x}$ = 44.27)

Moxostoma duquesnei, the black redhorse. Twenty black redhorses were examined. This is the least common species of the three in this area. M. duquesnei represented only 61.% of the redhorses taken between 1982 and 1983. Morphological data are summarized in Table 6. It is a slender fish with a long ($\bar{x}$ = 15.31 % std. length), narrow ($\bar{x}$ = 9.19) caudal peduncle. The snout ($\bar{x}$ = 10.60) and head ($\bar{x}$ = 23.70) are long and the body depth is small ($\bar{x}$ = 23.11). The eye is relatively small ($\bar{x}$ = 5.84) and the width between the orbits is moderate ($\bar{x}$ = 8.65). The number of scales in the lateral line ($\bar{x}$ = 45.17) and before the dorsal fin ($\bar{x}$ = 16.10) are high, which corresponds to the general long shape of members of the species. Fin ray counts are variable. Pectoral rays range from 14 to 18 ($\bar{x}$ = 15.55R, $\bar{x}$ = 15.70L). Pelvic rays are high in number but these were also variable ($\bar{x}$ = 9.60R, $\bar{x}$ = 9.40L, range = 8-11). The most distinctive feature of the species is the lower lip (Figure 2C), the halves of which meet in a straight line (approx. 180 degrees). The lips are plicate with few papillae.

Five age classes were represented in the samples of black redhorses. Data are summarized as actual measurements in Table 7. The numbers in all age classes were low. Age class I fish were missing. Age class 0 were the most common (N = 8).

The specimens were homogeneous in fin ray counts. No statistically significant differences were found between them by ANOVA. Scale row counts were more variable between age classes but no clear pattern was indicated (Figure 6). Group II fish averaged higher on all scale row counts than any other group.

Differences were seen among the age classes in all other morphological measurements. Age class 0 fish were significantly

Table 6. Mean, SD, SE, Range for 24 characters of *Moxostoma duquesnei* (total length to length lower fork caudal fin given as % standard length).

Character	N	Mean ($\bar{x}$)	SD	SE	Range
Total length	19	128.97	2.36	0.54	124.46-133.27
Body depth	20	23.11	1.20	0.27	20.31-25.00
Depth caudal peduncle	20	9.19	0.94	0.21	7.99-11.55
Length caudal peduncle	20	15.31	1.98	0.44	10.94-18.17
Predorsal length	20	49.53	1.53	0.34	47.06-52.31
Head length	20	23.70	0.96	0.21	22.29-25.90
Head depth	20	1.729	0.88	0.20	15.47-18.79
Head width	20	14.51	0.68	0.15	12.81-15.41
Snout length	20	10.60	1.74	0.39	7.51-13.96
Postorbital length	20	9.19	0.70	0.16	8.05-10.47
Cheek height	20	10.78	1.02	0.22	8.61-12.30
Interorbital width	20	8.65	0.75	0.17	6.875-9.60
Orbital length	20	5.84	1.04	0.23	4.71-8.38
Length upper fork caudal fin	17	28.07	2.14	0.52	23.88-31.25
Length lower fork caudal fin	18	25.96	2.45	0.57	22.45-30.00

Table 6 - continued

	N	Mean($\bar{x}$)	SD	SE	Range
Dorsal ray count	20	13.85	0.87	0.19	12.00-15.00
Pectoral ray count R	20	15.55	0.89	0.20	14.00-18.00
Pectoral ray count L	20	15.70	0.80	0.18	14.00-17.00
Pelvic ray count R	20	9.60	0.50	0.11	9.00-10.00
Pelvic ray count L	20	9.40	0.68	0.15	8.00-11.00
Anal ray count	20	8.00	0.32	0.725	7.00-9.00
Scales before dorsal fin	19	16.10	1.33	0.30	14.00-18.00
Caudal peduncle scales	19	12.16	0.37	0.08	12.00-13.00
Scales in lateral line	18	45.17	1.58	0.37	42.00-48.00

Table 7. Mean, SD, SE for 17 characters of *Moxostoma duquesnei* by age class.

	Age 0				Age II				Age III			
Character	$\bar{x}$	SD	SE	N	$\bar{x}$	SD	SE	N	$\bar{x}$	SD	SE	N
Weight	9.66	6.40	2.86	5	135.10	0	0	1	214.80	25.71	14.85	3
Total length	83.15	14.79	5.23	8	220.50	21.92	15.50	2	276.80	16.21	9.36	3
Standard length	64.26	12.01	4.25	8	169.20	18.10	12.80	2	214.10	8.30	4.79	3
Body depth	14.86	2.63	0.93	8	38.40	6.36	4.50	2	49.27	2.51	1.45	3
Depth of caudal peduncle	6.34	1.11	0.39	8	15.70	2.97	2.10	2	18.50	1.87	1.08	3
Length of caudal peduncle	10.01	1.54	0.54	8	27.55	2.05	1.34	2	31.57	2.73	1.58	3
Predorsal length	31.325	6.21	2.19	8	84.40	15.27	10.80	2	106.10	5.63	3.25	3
Head length	15.65	3.47	1.23	8	39.35	4.87	4.15	2	49.17	3.01	1.74	3
Head depth	10.86	2.06	0.73	8	29.25	3.75	2.65	2	37.23	2.39	1.38	3
Head width	9.25	2.11	0.74	8	25.65	3.32	2.35	2	30.77	1.46	0.84	3
Snout length	6.05	1.82	0.64	8	18.85	5.73	4.05	2	22.47	2.73	1.58	3
Postorbital length	5.64	1.24	0.44	8	15.80	3.11	2.20	2	20.87	1.115	0.64	3
Cheek height	6.375	1.74	0.61	8	18.85	2.05	1.34	2	24.40	1.51	0.87	3

Table 7 - continued

	Age 0				Age II				Age III			
Character	$\bar{x}$	SD	SE	N	$\bar{x}$	SD	SE	N	$\bar{x}$	SD	SE	N
Interorbital width	5.16	0.97	0.34	8	15.05	1.91	1.35	2	19.03	1.27	0.74	3
Orbital length	4.41	0.73	0.26	8	9.60	0.71	0.50	2	11.17	0.58	0.33	3
Length upper fork caudal fin	18.80	3.61	1.28	8	46.95	2.76	1.95	2	59.93	2.27	1.31	3
Length lower fork caudal fin	17.09	4.30	1.52	8	43.85	3.18	2.25	2	55.30	1.73	1.00	3

	Age IV				Age V			
Character	$\bar{x}$	SD	SE	N	$\bar{x}$	SD	SE	N
Weight	349.10	102.41	51.20	4	460.35	58.90	41.65	2
Total length	332.55	26.65	14.33	4	357.00	16.97	12.00	2
Standard length	255.40	27.11	12.12	5	278.50	16.26	11.50	2
Body depth	60.28	7.42	3.32	5	61.85	2.76	1.95	2
Depth of caudal peduncle	22.26	2.13	0.95	5	23.05	1.20	0.85	2
Length of caudal peduncle	38.18	7.77	3.47	5	39.60	1.70	1.20	2
Predorsal length	128.86	11.94	5.34	4	139.80	5.66	4.00	2

Table 7 - continued

	Age IV				Age V			
Character	$\bar{x}$	SD	SE	N	$\bar{x}$	SD	SE	N
Head length	59.54	6.36	2.84	5	66.95	5.73	4.05	2
Head depth	44.82	4.56	2.04	5	50.10	6.22	4.40	2
Head width	36.84	4.26	1.91	5	41.70	3.11	2.20	2
Snout length	30.90	6.43	2.87	5	33.50	5.66	4.00	2
Postorbital length	23.78	2.87	1.28	5	27.25	2.47	1.75	2
Cheek height	29.30	3.85	1.72	5	32.45	2.76	1.95	2
Interorbital width	23.26	2.92	1.31	5	25.90	1.70	1.20	2
Orbital length	12.52	1.28	0.57	5	13.85	0.495	0.35	2
Length upper fork caudal fin	67.43	0.93	0.54	3	79.70	0	0	1
Length lower fork caudal fin	63.625	1.78	0.89	4	74.80	0	0	1

Figure 6. Subsets created by Duncan's Multiple Range Tests for significant differences among age classes of *Moxostoma duquesnei*. Placement within a subset indicates no significant differences among means of any members of that subset.

Character	F value					
Scales before dorsal	5.14	0	III	V		
		($\bar{x}$ = 15.125)	($\bar{x}$ = 16.00)	($\bar{x}$ = 16.00)		
			III	V	IV	II
					($\bar{x}$ = 17.00)	($\bar{x}$ = 18.00)
Caudal peduncle scales	9.76	IV	V	0	III	
		($\bar{x}$ = 12.00)	($\bar{x}$ = 12.00)	($\bar{x}$ = 12.00)	($\bar{x}$ = 12.33)	
						II
						($\bar{x}$ = 13.00)
Lateral line scales	2.58	III	V	0	IV	
		($\bar{x}$ = 44.00)	($\bar{x}$ = 44.00)	($\bar{x}$ = 45.00)	($\bar{x}$ = 45.60)	
						II
						($\bar{x}$ = 47.50)

smaller than all other age groups in all measurements (Figure 7). Perhaps if Age I fish had been included in this study this would not have been so. Age IV and V fish were the most similar. No significant differences were found between them in any measurement except the lengths of the upper and lower forks of the caudal fin, in which comparison Age V fish were not included because only one fish was represented. Overlap in morphological characters was seen between Age II and III fish. No significant differences were found between them in five measurements including depth of caudal peduncle ($\bar{x}$ = 15.70, $\bar{x}$ = 18.50), length of caudal peduncle ($\bar{x}$ = 27.55, $\bar{x}$ = 31.57), head width ($\bar{x}$ = 25.65, $\bar{x}$ = 30.77), snout length ($\bar{x}$ = 18.85, $\bar{x}$ = 22.47), and orbital length ($\bar{x}$ = 9.60, $\bar{x}$ = 11.17). Groups III and IV did not vary significantly in three measurements (length of caudal peduncle, $\bar{x}$ = 31.57 vs $\bar{x}$ = 38.18; postorbital length, $\bar{x}$ = 20.87 vs $\bar{x}$ = 23.78; orbital length, $\bar{x}$ = 11.17 vs $\bar{x}$ = 12.52). Length of caudal peduncle and orbital length were the least variable measurements taken for this species.

Comparison of Age Classes. Step-wise Discriminant Function Analyses were performed on morphological variables of all three species in order to isolate those characters which separated the age classes most distinctly and to verify if possible the scale method of aging which was not included in the analysis.

Results from the discriminant analysis of *M. duquesnei* indicate that no specimens were misclassified as to age. Four discriminant functions were computed, but only the first made a significant ($P < .05$) contribution to group separation. Variables contributing most to the

Figure 7. Some characters varying significantly by ANOVA among age classes in *Moxostoma duquesnei*, indicating F value and subsets formed by Duncan's Multiple Range Tests.

Character	F Value					
Total length	162.56	0				
		($\bar{x}$ = 83.15)	II			
			($\bar{x}$ = 220.50)	III		
				($\bar{x}$ = 276.80)	IV	V
					($\bar{x}$ = 332.55)	($\bar{x}$ = 357.00)
Depth of caudal peduncle	87.87	0				
		($\bar{x}$ = 6.34)	II	III		
			($\bar{x}$ = 15.70)	($\bar{x}$ = 18.50)	IV	V
					($\bar{x}$ = 22.26)	($\bar{x}$ = 23.05)
Length of caudal peduncle	43.315	0				
		($\bar{x}$ = 10.01)	II	III		
			($\bar{x}$ = 27.55)	($\bar{x}$ = 31.57)		
				III	IV	V
					($\bar{x}$ = 38.18)	($\bar{x}$ = 39.60)
Snout length	35.01	0				
		($\bar{x}$ = 6.05)	II	II		
			($\bar{x}$ = 18.85)	($\bar{x}$ = 22.47)	IV	V
					($\bar{x}$ = 30.90)	($\bar{x}$ = 33.50)

Figure 7 - continued

Orbital length	93.37	0				
		($\bar{x}$ = 4.41)	II	III		
			($\bar{x}$ = 9.60)	III	IV	
				($\bar{x}$ = 11.17)	IV	V
					($\bar{x}$ = 12.52)	($\bar{x}$ = 13.50)

discrimination are head width, dorsal rays, pectoral rays, body depth, postorbital length, standard length and head length. For standardized canonical discriminant function coefficients see Table 8.

Two discriminant functions were computed from _M. anisurum_. Both contributed significantly to the discrimination between the three age classes ($P < .05$). The best discriminating variables in these functions were head length, body depth, cheek height, interorbital width and length of caudal peduncle. Their standardized coefficients are given in Table 8. This analysis indicated that group membership could be predicted correctly 100% of the time for Age I and II fish and 97.4% for Age 0. The analysis predicted that 98.25% of the fish had been correctly identified to age.

Results of the discriminant function analysis from the golden redhorses were more variable. Fish could be placed into age groups 0, I and II ($P < .05$). However, some older fish were more difficult to correctly place. Age III and IV fish group membership could be correctly predicted in 87.5% and 80.0% of the cases and group V fish in 90.0% of the cases. Overall, the discriminant function analysis indicated that only 93.58% of the golden redhorses were grouped correctly by age. These results were not unexpected. As the fish got larger differences between them in size were reduced and age became more difficult to predict based on basic morphology.

Four discriminant functions were computed for _Moxostoma erythrurum_, three of which contributed significantly to the discrimination. Important variables for separating the age classes included: standard length, predorsal length, cheek height, postorbital length and orbital length (Table 8).

Table 8. Standardized Canonical Discriminant Function Coefficients for all species. (The absolute value of the coefficient is an index to the importance of each variable in the function.)

Moxostoma anisurum

Variable	Function 1	Function 2
Head length	12.351	7.944
Body depth	-10.821	-3.892
Cheek height	-6.450	-0.266
Interorbital width	3.276	0.894
Caudal peduncle L.	0.438	2.091

Moxostoma erythrurum

	Function 1	Function 2	Function 3
Standard length	2.030	-1.648	-1.289
Predorsal length	-1.164	0.771	1.318
Cheek height	0.286	-0.431	1.969
Postorbital length	-0.658	0.381	-1.170
Orbital length	0.007	1.184	-0.418

Moxostoma duquesnei

	Function 1
Head width	18.573
Dorsal rays	-8.089
Pectoral rays - R	-6.698
Body depth	-6.49
Postorbital length	5.390
Standard length	-3.560
Head length	3.213

Comparison between Species

Fish of the genus Moxostoma are morphologically similar and many species are difficult to distinguish. Species were compared in order to determine differences among them. Data are summarized by species in Tables 2 (*M. anisurum*), 4 (*M. erythrurum*), and 6 (*M. duquesnei*). Data were analyzed by oneway ANOVA followed by Duncan's Multiple Range Tests. Results indicated many significant differences among the species but also considerable overlap. In this section Species 1 refers to *M. anisurum*, Species 2 to *M. erythrurum* and Species 3 to *M. duquesnei*.

No significant differences were found among any of the three species in total length, predorsal length, interorbital width, number of pectoral rays in the right fin, anal rays or caudal peduncle scales. The number of scales around the caudal peduncle is used to separate the genus *Moxostoma* into subgenera (Hubbs and Lagler, 1949; Robins and Raney, 1956; Jenkins, 1971) and therefore was not expected to vary among these species, which are all members of the subgenus *Moxostoma*.

All species varied significantly from each other in eight of the 24 characters considered here (Figure 8). The golden redhorses were intermediate between the other two species in most measurements (20/24). They differed significantly from both the black and silver redhorses in 14 of 24 characters and similarly from the silver redhorses (Figure 8). *Moxostoma duquesnei* averaged smaller in more measurements (14/24) than the other two species, significantly so in seven. But they averaged significantly higher on the right pelvic ray count, lateral line scale count and scales before the dorsal fin. The silver redhorse, *M. anisurum*, averaged larger than the other species on 14 characters, significantly so on nine including: depth of caudal peduncle, head

Figure 8. Some characters varying significantly by ANOVA among species indicating F value and subsets formed by Duncan's Multiple Range Tests. (Sp1 = *M. anisurum*, Sp2 = *M. erythrurum*, Sp3 = *M. duquesnei*).

Character	F value	Duncan's Subsets
Depth of caudal peduncle	73.835	Sp3 ($\bar{x}$= 9.19); Sp2 ($\bar{x}$= 9.67); Sp1 ($\bar{x}$=11.27)
Length of caudal peduncle	19.19	Sp2 ($\bar{x}$=13.29) Sp1 ($\bar{x}$=14.71); Sp3 ($\bar{x}$=15.31)
Head length	48.51	Sp3 ($\bar{x}$=23.70) Sp2 ($\bar{x}$=24.84); Sp1 ($\bar{x}$=28.66)
Head depth	60.04	Sp3 ($\bar{x}$=17.29) Sp2 ($\bar{x}$=17.42); Sp1 ($\bar{x}$=19.92)
Head width	36.695	Sp3 ($\bar{x}$=14.51); Sp2 ($\bar{x}$=15.15); Sp1 ($\bar{x}$=16.56)
Snout length	22.23	Sp2 ($\bar{x}$= 9.33) Sp1 ($\bar{x}$=10.56); Sp3 ($\bar{x}$=10.60)
Postorbital length	24.62	Sp3 ($\bar{x}$= 9.19); Sp2 ($\bar{x}$=10.10); Sp1 ($\bar{x}$=10.74)

Figure 8 - continued

Cheek height	20.36	Sp3 ($\bar{x}$=10.78)	Sp2 ($\bar{x}$=11.32)	Sp1 ($\bar{x}$=12.06)
Orbital length	90.55	Sp3 ($\bar{x}$= 5.84)	Sp2 ($\bar{x}$= 6.63)	Sp1 ($\bar{x}$= 8.75)
Length of upper fork caudal fin	16.555	Sp3 ($\bar{x}$=28.07)	Sp2 ($\bar{x}$=30.91)	Sp1 ($\bar{x}$=32.40)
Length of lower fork caudal fin	9.15	Sp3 ($\bar{x}$=25.96)	Sp2 ($\bar{x}$=29.23)	Sp1 ($\bar{x}$=29.69)
Dorsal ray count	96.74	Sp3 ($\bar{x}$=13.85)	Sp2 ($\bar{x}$=14.01)	Sp1 ($\bar{x}$=15.67)
Pectoral ray count right	4.01	Sp3 ($\bar{x}$=15.55)	Sp2 ($\bar{x}$=15.87)	Sp1 ($\bar{x}$=16.05)
Pelvic ray count right	13.19	Sp1 ($\bar{x}$= 8.98)	Sp2 ($\bar{x}$= 9.17)	Sp3 ($\bar{x}$= 9.40)
Pelvic ray count left	4.32	Sp1 ($\bar{x}$= 9.05)	Sp2 ($\bar{x}$= 9.20)	Sp3 ($\bar{x}$= 9.40)
Scales before dorsal fin	29.00	Sp1 ($\bar{x}$=13.06)	Sp2 ($\bar{x}$=14.63)	Sp3 ($\bar{x}$=16.10)

Figure 8 - continued

Lateral line scales	24.14	Sp1	Sp2	
		($\bar{x}$=40.94)	($\bar{x}$=41.35)	Sp3
				($\bar{x}$=45.17)

length, orbital length and dorsal ray count.

Variation in the shape of the lower lips was also examined. This was found to be the most distinctive character among the species. All silver and black redhorses could be distinguished by the angle formed by the meeting of halves of the lower lips. Moxostoma anisurum, the silver redhorse, is distinguished by the formation of a very acute angle (Figure 2A). Papillae are also present, but it was found to be unnecessary to look for them in order to distinguish this species. The lips of the black redhorse form an angle of 180 degrees. The lips are plicate with a few papillae (Figure 2B). Only a single golden redhorse was difficult to identify using this characteristic. Generally the lips form a moderately obtuse angle (140 degrees) which is readily distinguishable from the 180 degree angle formed by the lips of M. duquesnei (Figure 2C). The lips of this one fish were nearly straight across and therefore difficult to categorize.

Members of the species Moxostoma anisurum can also be identified by their deep bodies, high number of dorsal rays, deep caudal peduncles and large eye. Other characters have been suggested (Hubbs and Lagler, 1949; Gerking, 1955; Jenkins, 1971) as useful in distinguishing between the golden and black redhorses. They include lateral line scale count, pelvic fin ray count, caudal peduncle depth and caudal peduncle length. Moxostoma duquesnei is reported to have 44-46 lateral line scales, usually 10 pelvic rays in at least one fin and a longer, narrower caudal peduncle. Moxostoma erythrurum conversely should exhibit 40-42 lateral line scales, 9 pelvic fin rays and a shorter, broader caudal peduncle. Results in this study tend to concur with these descriptions. However, tremendous overlap occurs, rendering these characters nearly useless in consistently separating the two species.

Discriminant Function Analysis was performed in order to identify those variables which distinguished among the species most successfully. Two functions were computed, but only one contributed significantly ($P < .05$) to group separation. Variables contributing most to the discrimination were lip shape (coefficient = 1.05), standard length (0.456), orbital length (0.405), and lateral line scales (0.277). This analysis indicated that species membership could be predicted correctly 99.5% of the time. Black and silver redhorses could be correctly identified using these variables 100.0% of the time. Golden redhorses could be identified using these variables 99.1% of the time.

Comparisons were also made between the different age classes of the different species. All three species were represented only in two age classes (0, II). Age 0, I, II silver redhorses, age 0, II, II, IV, V black redhorses and 0, I, II, III, IV, V golden redhorses were included. Different age classes were compared between species in an attempt to isolate differences between the species, in the various age classes, that might be different from those seen when the species in general were compared.

Age 0 fish were more variable among species than any other age group (Figure 9). However, the Age 0 fish were not significantly different in more characters (11/26) than the species as a whole (6/24). Only two variables were found to vary significantly among all three species in this age group: scales before the dorsal ($\overline{x}_1$= 12.97, $\overline{x}_2$ 13.85, $\overline{x}_3$ = 15.12, F = 10.58) and lateral line scales ($\overline{x}_2$ = 39.93, $\overline{x}_1$ = 41.23, $\overline{x}_3$ = 45.00, F = 25.28). Black and golden redhorses were

Figure 9. Some characters varying significantly by ANOVA among species in age class 0 indicating F value and subsets formed by Duncan's Multiple Range Tests (Sp1 = *M. anisurum*, Sp2 = *M. erythrurum*, Sp3 = *M. duquesnei*).

Character	F value			
Caudal peduncle length	8.17	Sp2 ($\bar{x}$=6.12)	Sp3 ($\bar{x}$=6.34)	Sp1 ($\bar{x}$=7.08)
Orbital length	14.57	Sp3 ($\bar{x}$=4.41)	Sp2 ($\bar{x}$=4.49)	Sp1 ($\bar{x}$=5.65)
Dorsal fin ray count	61.39	Sp3 ($\bar{x}$=13.62)	Sp2 ($\bar{x}$=14.07)	Sp1 ($\bar{x}$=15.74)
Pectoral fin ray count right	7.88	Sp3 ($\bar{x}$=15.12)	Sp2 ($\bar{x}$=15.82)	Sp1 ($\bar{x}$=16.08)
Pectoral fin ray count left	3.41	Sp3 ($\bar{x}$=15.37)	Sp2 ($\bar{x}$=15.89)	Sp1 ($\bar{x}$=16.05)
Pelvic fin ray count right	3.64	Sp1 ($\bar{x}$=8.95)	Sp2 ($\bar{x}$=9.02)	Sp3 ($\bar{x}$=9.37)
Scales before dorsal fin	10.58	Sp1 ($\bar{x}$=12.97)	Sp2 ($\bar{x}$=13.85)	Sp3 ($\bar{x}$=15.12)
Caudal peduncle scales	5.57	Sp3 ($\bar{x}$=12.00)	Sp2 ($\bar{x}$=12.12)	Sp1 ($\bar{x}$=12.42)
Lateral line scales	25.28	Sp2 ($\bar{x}$=39.93)	Sp1 ($\bar{x}$=41.23)	Sp3 ($\bar{x}$=45.00)

more similar to each other than to the silver redhorses, varying significantly in six characters. Silver and black redhorses varied significantly in nine. Silver and golden redhorses were the most different, varying significantly in 11 of 26 variables. Age 0 silver redhorses could be distinguished from the other two species by caudal peduncle scales ($\bar{x}_3$ = 13.62, $\bar{x}_2$ = 12.12, $\bar{x}_1$ = 12.42, F = 5.57), scales before the dorsal (F = 10.58), and lateral line scales (F = 25.28), in which they averaged smaller and dorsal rays ($\bar{x}_3$ = 13.62, $\bar{x}_2$ = 14.07, $\bar{x}_1$ = 15.74, F= 61.39) and orbital length ($\bar{x}_3$ = 4.41, $\bar{X}_2$ = 4.49, $\bar{x}_1$ = 5.65, F = 14.57) in which they averaged larger. Age 0 black redhorses were significantly different from either silver or golden redhorses in pectoral ray counts ($\bar{x}_3$ = 15.12R, 15.37L, $\bar{x}_2$ = 15.82R, 15.89L, $\bar{x}_1$ = 16.08R, 16.05L, F = 7.88 R, 3.41 L), scales before the dorsal, lateral line scales, and right pelvic fin ray count ($\bar{x}_1$ = 8.95, $\bar{x}_2$ = 9.02, $\bar{x}_3$ = 9.37, F = 3.64). Golden redhorses had significantly shorter caudal peduncles than either of the other two species ($\bar{x}_2$ = 6.12, $\bar{x}_3$ = 6.34, $\bar{x}_1$ = 7.08, F = 8.17). Only the differences found among all Age 0 fish in scales before the dorsal and lateral line scales and silver redhorses from both other species in dorsal rays are consistent with results from the general species comparisons.

Age class II also consisted of fish from all species. Variation among the species was greatly reduced from that seen with Age 0 fish. No single character was found to vary significantly among all three species (Figure 10). Silver redhorses were still significantly different in dorsal ray count ($\bar{x}_2$ = 13.83, $\bar{x}_3$ = 14.00, $\bar{x}_1$ = 16.00, F = 30.52) but also in standard length ($\bar{x}_1$ = 124.45, $\bar{x}_2$ = 149.92, $\bar{x}_3$ = 169.20, F = 5.815) from both golden and black redhorses. Black

Figure 10. Some characters varying significantly by ANOVA among species in Age Classes I, II, IV, and V indicating F value and subsets formed by Duncan's Multiple Range Tests (Sp1 = *M anisurum*, Sp2 = *M. erythrurum*, Sp3 = *M. duquesnei*).

Character	F value	Duncan's Subsets
	Age I	
Snout length	5.251	Sp2 ($\bar{x}$=11.19) Sp1 ($\bar{x}$=12.53)
Orbital length	6.95	Sp2 ($\bar{x}$=8.01) Sp1 ($\bar{x}$=9.02)
Dorsal fin ray count	60.33	Sp2 ($\bar{x}$=13.83) Sp1 ($\bar{x}$=15.44)
	Age II	
Standard length	5.815	Sp1 ($\bar{x}$=124.45) Sp2 ($\bar{x}$=149.92), Sp3 ($\bar{x}$=169.20)
Dorsal fin ray count	30.52	Sp2 ($\bar{x}$=13.83), Sp3 ($\bar{x}$=14.00) Sp1 ($\bar{x}$=16.00)
Scales before dorsal fin	5.48	Sp1 ($\bar{x}$=12.50), Sp2 ($\bar{x}$=14.67) Sp3 ($\bar{x}$=18.00)
Lateral line scale count	5.65	Sp1 ($\bar{x}$=40.00), Sp2 ($\bar{x}$=43.17) Sp2 ($\bar{x}$=43.17), Sp3 ($\bar{x}$=47.50)
	Age IV	
Snout length	4.68	Sp2 ($\bar{x}$=25.71) Sp3 ($\bar{x}$=30.90)

Figure 10 - continued

	Age V		
Length of caudal peduncle	7.51	Sp2 ($\bar{x}$=33.79)	Sp3 ($\bar{x}$=39.60)
Snout length	6.96	Sp2 ($\bar{x}$=28.20)	Sp3 ($\bar{x}$=33.50)

redhorses varied significantly from the others in scales before the dorsal ($\bar{x}_1$ = 12.50, $\bar{x}_2$ = 14.67, $\bar{x}_3$ = 18.00, F = 5.48). Golden redhorses were not significantly different from the other species in any measurement.

Age 0 and II year fish exhibited more significant variation among the species than the other age classes. This may be due to the lack of representatives of all three species in the other age groups. However, Age 0 fish occur in the highest numbers in all three species. Differences among them may reflect environmental or competitive pressures. Significant differences in % volume insect larvae consumed were also determined for this age class.

Age I fish included only M. anisurum and M. erythrurum individuals (Figure 10). Dorsal ray count and orbital length varied significantly between them ($\bar{x}_2$ = 13.83, $\bar{x}_1$ = 15.44, F = 60.33 and $\bar{x}_2$ = 8.01, $\bar{x}_1$ = 9.02, F = 6.95). This is consistent with results seen in the other age classes and the general species comparison. Snout length ($\bar{x}_2$ = 11.19, $\bar{x}_1$ = 12.53, F = 5.25) was also found to be significant by ANOVA as found between Age 0 silver and golden redhorses (F = 6.07). Snout length did not vary significantly between silver and golden redhorses but the golden and black redhorses, in the general species comparison.

Age classes III, IV and V are represented by only golden and black redhorses (Figure 10). These were the least variable age groups in the characters examined. No significant differences were found between the species in Age class III and only snout length in Age class IV ($\bar{x}_2$ = 25.71, $\bar{x}_3$ = 30.90, F = 2.68). Age group V Moxostoma duquesnei and *M. erythrurum* varied significantly in snout length ($\bar{x}_2$ = 28.20, $\bar{x}_3$ = 33.50, F = 6.96) and length of caudal peduncle ($\bar{x}_2$ = 33.79, $\bar{x}_3$ = 39.60, F = 7.50).

Differences in lip shapes could not be tested by ANOVA because it is a qualitative rather than quantitative measurement. However, such analysis was not necessary. Variation among species in lip shape was the most consistently different characteristic. Species could be easily separated by this character therefore specimens in this study were primarily identified using lip shape. Young black and golden redhorses were frequently more easily distinguished by this character than were adults.

The redhorses varied more between species in younger age classes. *Moxostoma anisurum* consistently varied significantly from either *M. duquesnei* or *M. erythrurum* in dorsal ray count. *Moxostoma erythrurum* and *M. duquesnei* exhibited less morphological differences as larger, older fish. Reasons for this trend are unknown. Competition between young animals may be a factor. More work in this area is needed.

Food Habits

The redhorse suckers are bottom feeders, moving over the substrate sucking in material and expelling wastes. Not all wastes are removed, and most stomachs contained fine grains of sand.

Meyer (1962) reported generally on the foods of the golden, silver, and northern redhorses from Iowa. Chironomid, Ephemeropteran and Trichopteran larvae were the principal foods of all three species, in order of frequency of occurrence. No data were given on % volumes or comparisons between species. Bowman (1970) gave % frequencies of the major foods of the black redhorse from Missouri. Major foods included Diptera, Ephemeroptera, copepods and cladocerans. Young black redhorses fed more frequently on copepods, cladocerans and nemathelminthes, while adults ate more aquatic insects. Again % volumes were not given and statistical comparisons not made.

The stomachs of a total of 184 redhorses (32 of M. anisurum, 75 of M. erythrurum and 12 of M. duquesnei) were examined for contents. Sixty-five (35%) were empty. Comparisons were made among species, sexes and age groups within and between species and between localities.

Data for all three species are summarized in Table 9. Major groupings of foods were compared within and among species by ANOVA followed by Duncan's Multiple Range Tests on actual and transformed data. Results were similar among these sets of data though the transformed data indicated fewer statistically significant differences than did the actual data. No significant differences were indicated between the sexes in any of the species. Sexes were therefore combined for all analyses.

Moxostoma anisurum, the silver redhorse. The contents of 32 stomachs were analyzed for % volume and % frequency (Table 9). The most frequently eaten foods were larval Chironomidae, totalling 68.45% volume. Most important of the chironomids were Calopsectra (37.6% volume, 75.0% frequency) and Cryptochironomus (11.3% vol, 34.4% f) larvae; followed by Eucyclops (9.7% vol, 81.25% f) and unidentified Psocoptera larvae (3.1% vol, 3.1% f).

Table 9. Food of three species of redhorse suckers from Vigo County, Indiana.

Food item	*Moxostoma anisurum* N=32 % Vol	% Freq	*Moxostoma erythrurum* N=75 % Vol	% Freq	*Moxostoma duquesnei* N=12 % Vol	% Freq
LARVAE - Insecta						
Diptera						
Chironomidae						
Calopsectra	37.6	75.0	19.9	58.6	30.8	75.0
Harnishia	2.85	12.5	19.2	50.7	23.1	41.7
Cryptochironomus	11.3	34.4	8.5	34.7		
Spaniotoma	6.1	21.9	1.3	8.0	17.7	58.3
Unidentified and misc.*	10.6	43.75	15.0	46.7	9.6	66.7
Ceratopogonidae						
Culicoides	1.95	9.4	0.5	2.7		
Alluaudomyia	0.1	3.1				
Unidentified	0.24	3.1	0.3	5.3		
Tipulidae						
Antocha			0.5	2.7		
Unidentified			0.1	1.3		
Stratiomyiidae						
Unidentified			0.1	1.3	0.4	8.3
Unident. Diptera	0.8	9.4	0.3	1.3		
Trichoptera						
Unidentified	2.0	12.5	1.2	14.7	2.7	25.0
Hydroptilidae						
Unidentified					0.5	8.3
Rhycophila					0.4	8.3
Coleoptera						
Elmidae, unid.			1.3	14.7	0.8	8.3
Ephemeroptera						
Unidentified			0.1	1.3		
Baetidae, unid.			0.1	1.3		
Psocoptera						
Unidentified	3.1	3.1				
Plecoptera, unid.			0.1	2.7		
Thysanoptera, unid.	0.25	3.1				
Insecta, unid.	0.2	3.1				

Table 9 - continued

	M. anisurum		M. erythrurum		M. duquesnei	
	% Vol	% Freq	% Vol	% Freq	% Vol	% Freq
PUPAE - Insecta						
Diptera						
Unidentified	1.8	31.25	0.8	12.0	2.4	25.0
Chironomidae						
Orthocladinae	1.0	9.4	0.9	10.7	0.2	8.3
Chironominae			0.2	4.0	0.2	8.3
Unidentified	0.2	6.25	0.6	9.3	0.6	25.0
Brachycera	0.6	12.5	0.1	1.3	3.0	25.0
Ceratopogonidae, unidentified			0.7	2.6		
ADULTS - Insecta						
Unidentified	0.4	6.25	0.2	1.3		
Coleoptera, unid.			0.3	4.0		
Thysanoptera						
Merothripidae	0.2	3.1				
Homoptera						
Aphididae	0.2	3.1				
COPEPODA						
Cyclopoidea						
Cyclopidae						
Eucyclops	9.7	81.25	10.8	62.7	2.6	33.3
Macrocyclops	1.1	40.6	1.0	13.3	0.3	25.0
Ectocyclops	0.1	6.25				
Unidentified	1.4	31.25	0.9	10.7	0.2	8.3
Unidentified	0.4	12.5	0.3	4.0		
Unidentified Copepoda	0.01	6.25				
Nauplius larvae	0.4	6.25				
CLADOCERA						
Macrothricidae						
Unidentified	0.04	3.1	0.4	5.4		
Macrothrix	0.04	3.1	2.4	13.3		
Pleuroxus	0.1	3.1				
Camptocerus	0.2	3.1				
Chydoridae						
Unidentified	0.5	18.75	0.6	6.7	0.1	16.7
Calyptomera	0.1	3.1				
Unidentified	0.7	15.6	0.3	6.7	0.4	8.3
OSTRACODA						
Unidentified	1.9	28.1	1.5	24.0		
Cypridae						
Cypris	0.8	9.4	0.03	1.3		

Table 9 - continued

	M. anisurum		M. erythrurum		M. duquesnei	
	% Vol	% Freq	% Vol	% Freq	% Vol	% Freq
HYDRACARINA						
Arrenuridae						
Arrenurus			0.5	9.3		
ACARINA						
Unidentified mites	0.2	6.25	0.1	2.7		
CHLOROPHYTA						
Spirogyra	0.5	12.5	2.0	21.3		
Unidentified items	0.2	3.1	6.9	9.3	4.2	8.3
TOTALS	99.9		100.0		100.0	

*Misc. includes other specimens identified to genus (not exceeding 3.0% vol in any species) as well as specimens identified only to family or subfamily.

Transformed data were compared for differences in major groupings of foods consumed between localities and age classes. Actual % volumes are given in Table 10. There were significant differences (F = 14.19) in the amounts of insect pupae eaten between silver redhorses captured in Otter Creek (% vol = 2.2) and those taken in Brouillettes Creek (% vol = 10.0). This difference is likely due to differences in availability of the food between these two streams.

Only three age classes (0, I, II) were represented in the samples of silver redhorses. The one-year class ate more ostracods than did the other two groups (% vol_{I} = 6.7, % vol_{0} = 0.4, % vol_{II} = 0). The oneway ANOVA indicated a significant difference (F = 6.945) in the proportions of ostracods eaten between these groups. However, the Duncan's Multiple Range Test did not separate the age classes into different subsets.

Moxostoma erythrurum, the golden redhorse. Seventy-five stomachs were examined for contents. Foods were identified and % volume and % frequency estimated (Table 9). Golden redhorses fed most often on chironomid larvae (63.3% volume) including the genera *Calopsectra* (19.9% vol, 58.6% f), *Harnishia* (19.2% vol, 50.7% f); unidentified (15.0% vol, 46.7% f) followed by copepods of the genus *Eucyclops* (10.8% vol, 62.7% f). No other item occurred in greater than 1.3% volume (Table 9). The major groups of foods were again compared to determine variation in food habits within the species. Seventy stomachs were included in this analysis. Significant differences in the amount of copepods (% vol location 1 = 4.8, location 2 = 23.3, F = 43.97), cladocerans (F = 15.32) and algae (F = 6.93) consumed were shown

Table 10. Percent volume of major foods of the Silver Redhorse (*Moxostoma anisurum*) from Vigo County, Indiana (Location 1 = Otter Creek, Location 2 = Brouillettes Creek).

	LOCATION		AGE		
	1	2	0	I	II
Food Items	N=25	N = 7	N=18	N=12	N = 2
LARVAE	76.2	80.0	76.2	77.7	80.0
PUPAE	2.2	10.0	4.1	3.7	2.5
ADULTS	0.3	0.7	1.1	0.4	0.0
COPEPODA	15.1	6.0	15.8	8.8	15.0
CLADOCERA	1.5	1.8	2.4	0.6	0.0
OSTRACODA	3.3	0.7	0.4	6.7	0.0
ALGAE	2.2	0.0	0.0	0.8	2.5

between the Otter Creek (location 1) and Brouillettes Creek (location 2) populations (Table 11). These were also the three groups of foods varying significantly among age groups by ANOVA (F = 12.52, 2.38, 4.65). Mean values of the proportions of copepods consumed differed significantly between age classes 0 (% vol = 21.3) and all other age classes as indicated by Duncan's Multiple Range Tests (Figure 11). The 0 age class consumed significantly greater volumes of copepods than the other age classes. Percent volumes varied significantly between classes 0 and IV (% vol = 0.0 vs 9.4) and III and IV (% vol = 0.0 vs 9.4) in amount algae consumed (Table 11). The oneway analysis of variance indicated a significant difference (F = 2.38) between age classes in the amount of ostracods eaten, but age classes were not separated by Duncan's into different subsets. However, age class III fish ate proportionately greater amounts of ostracods (% vol = 4.6) followed by age class I (% vol = 1.9) and age class 0 (% vol = 1.7).

Moxostoma duquesnei, the black redhorse. The stomachs of 12 black redhorses were examined and results were summarized by % volume and % frequency (Table 9). The most common items in these stomachs again were chironomid larvae (*Calopsectra* 30.8% vol, 75.0% f; *Harnishia* 23.1% vol, 41.7% f; *Spaniotoma* 17.7% vol, 58.3% f; unidentified and miscellaneous chironomid larvae 9.6% vol, 66.7% f). These larvae represented 81.2% of the foods eaten by volume. Other items were identified but none exceeded 3.0% of the total volume.

Statistical analysis of % volumes of the major groups of foods for this species revealed no significant differences between fish captured at Brouillettes and Otter Creeks (Table 12). Since so few

Table 11. Percent volume of major foods of the Golden Redhorse (M. erythrurum) from Vigo County, Indiana.

	LOCATION		AGE					
	1	2	0	I	II	III	IV	V
Food Items	N=41	N=34	N=41	N=10	N = 3	N = 6	N = 8	N = 7
LARVAE	70.7	62.8	63.9	81.9	83.1	78.3	46.9	71.3
PUPAE	3.2	4.2	4.3	3.3	8.3	0.8	2.8	1.5
ADULTS	0.8	0.0	0.0	1.2	0.0	0.0	2.5	0.4
COPEPODA	4.8	23.3	21.3	7.7	4.2	1.05	0.3	2.6
CLADOCERA	0.4	7.2	6.2	0.4	0.0	0.2	0.0	0.0
OSTRACODA	1.3	2.0	1.7	1.2	1.9	4.6	0.3	1.0
ALGAE	3.7	0.0	0.0	3.0	1.7	0.0	9.4	5.7

Figure 11. Subsets created by Duncan's Multiple Range Tests for significant differences between % volumes of major food groups for different age classes of *Moxostoma erythrurum*.

Food Group	F Value	Duncan's Subsets					
Copepods	12.52	Age IV (% vol = 0.31)	Age III (% vol = (1.05)	Age V (% vol = (2.66)	Age II (% vol = (4.17)	Age I (% vol = (7.67)	
							Age 0 (% vol = 21.28)
Algae	4.63	Age 0 (% vol = 0.0)	Age III (% vol = 0.0)	Age II (% vol = 1.67)	Age I (% vol = 3.0)	Age V (% vol = 5.71)	
				Age II	Age I	Age V	Age IV (% vol = 9.37)

Table 12. Percent volume of major foods of *Moxostoma duquesnei* (the Black Redhorse) from Vigo County, Indiana.

	LOCATION		AGE		
	1	2	0	IV	V
Food Items	N = 8	N = 4	N = 8	N = 3	N = 1
LARVAE	82.8	92.0	79.4	98.3	100.0
PUPAE	7.5	4.25	9.0	1.7	0.0
ADULTS	0.0	0.0	0.0	0.0	0.0
COPEPODA	2.7	3.75	4.6	0.0	0.0
CLADOCERA	0.8	0.0	0.8	0.0	0.0
OSTRACODA	0.0	0.0	0.0	0.0	0.0
ALGAE	0.0	0.0	0.0	0.0	0.0

black redhorses were captured, only three age classes (0, IV, V) were represented. Only one major group of food (Larvae, F = 4.543) was found to differ significantly among different age classes (Table 12). Percent volumes for age classes 0 (% vol = 79.4) and IV (% vol = 98.3) were found to differ significantly by Duncan's Multiple Range Test. Age class V (% vol = 100.0) was excluded from this test because only one stomach was involved.

Comparison between species. Food habits were compared among species in an attempt to explain how three such closely related species could co-exist. Differences in food habits seemed the most likely way of partitioning the resources to allow co-existence. However, the foods of each of the species were similar. Each fed predominantly on insect larvae, particularly chironomids (*M. anisurum*, 77.0% vol; *M. erythrurum*, 67.1% vol; *M. duquesnei*, 85.8% vol), with insect larvae occurring in nearly all stomachs examined (Table 13). Copepods were the next important food items of the silver (13.1% vol) and golden redhorses (13.2% vol), while insect pupae were that of the black redhorses (6.4% vol). The most obvious differences in the food habits of these species was the absence of adult insects, ostracods and algae from the black redhorse stomachs and their presence in the other two species (Tables 9 and 13).

Comparisons of stomach contents by ANOVA and Duncan's Multiple Range Tests indicated significant differences among the species in % volume of insect larvae (F = 4.87) and copepods (F = 4.94) consumed. The golden redhorses ate significantly less insect larvae (67.1% vol) than did the silver redhorses (77.0% vol) or the black redhorse (85.8%

Table 13. Major food groups of three species of *Moxostoma* (% volume, % frequency).

Food Item	*M. anisurum* (N=32) % Vol	*M. anisurum* (N=32) % Freq	*M. erythrurum* (N=70) % Vol	*M. erythrurum* (N=70) % Freq	*M. duquesnei* (N=12) % Vol	*M. duquesnei* (N=12) % Freq
Insect larvae	77.0	100.0	67.1	93.3	85.8	100.0
Insect pupae	3.9	46.9	3.6	37.3	6.4	50.0
Insect adults	0.8	9.4	0.5	5.3		
Copepoda	13.1	87.5	13.2	72.0	3.2	41.7
Cladocera	1.6	37.5	3.5	21.3	0.5	25.0
Ostracoda	2.8	37.5	1.6	25.3		
Algae	0.5	12.5	2.0	21.3		

vol), and the differences between the others were not significant. However, M. duquesnei consumed significantly less copepods (3.2% vol) than did either M. erythrurum (13.2% vol) or M. anisurum (13.1% vol). The difference in % volume between the golden and silver redhorses was not significant statistically.

The differences in % volume of copepods and insect larvae between age classes of the different species were compared. Significant differences were found in % volume insect larvae consumed by age class 0 fish between Moxostoma erythrurum and M. anisurum (F = 5.20, % vol = 63.9 and 76.2) and M. erythrurum and M. duquesnei (F = 4.08, % vol = 63.9 and 79.4). Lack of fish in the various age classes (Tables 10 and 12) in M. anisurum and M. duquesnei prevented comparison of foods of all age groups. However, no other age classes represented were found to differ significantly in amount of insect larvae eaten.

Similar results were obtained by comparisons of age classes in % volume copepods consumed. Moxostoma duquesnei differed significantly in % volume copepods (4.6) from M. erythrurum (21.3) and M. anisurum (15.8) when tested by ANOVA (F = 12.65, F = 8.93). The 0 age class (young of the year) fish was the only group to differ significantly among the species in % volume copepods taken.

Results seem to indicate resource partitioning is not occurring among these three species. The minor differences found, though significant statistically, do not necessarily indicate partitioning. However, specimens are needed in the missing age classes of M. anisurum and M. duquesnei to further verify these results.

Associated Species

Forty-six species from nine families were caught in association with Moxostoma. Most samples contained more than one species of redhorse, so all species were considered together. Data are summarized in Table 14. Total number per species, % frequency and mean number per sample with Moxostoma are given for each species. Similar data are given in Table 15 for species either occurring in greater than 40% of, or with mean values greater than one per sample in, samples in which Moxostoma were captured, for their captures in samples not including redhorses.

The most frequently collected species in association with redhorses were Notropis spilopterus, the spot fin shiner (82.4%), Lepomis macrochirus, the bluegill sunfish (82.4%), Pimephales notatus, the blunt nosed minnow (67.7%), and Hypentilium nigricans, the hogsucker (58.8%). Those species most frequently captured in the absence of Moxostoma included Notropis spilopterus (81.8%), Pimephales notatus (59.1%), Notropis atherinoides, the emerald shiner (31.8%), and Ericymba buccata, the silver jawed minnow (31.8%).

Notropis spilopterus ($\bar{x}$ = 65.8), Pimephales notatus ($\bar{x}$ = 34.7), and Notropis atherinoides ($\bar{x}$ = 34.3) averaged higher in number per sample with Moxostoma than other species. Notropis spilopterus ($\bar{x}$ = 11.5) and Pimephales notatus ($\bar{x}$ = 13.7) also averaged highest in samples without redhorses. Ericymba buccata ($\bar{x}$ = 3.0) and Notropis atherinoides ($\bar{x}$ = 1.27) mean values were much lower in samples without than with Moxostoma. However, these values were higher than all other species except Notropis spilopterus and Pimephales notatus. General

Table 14. Species collected in association with Moxostoma ssp. (N, % F, $\bar{x}$) (number of samples = 17).

Family - Genus - species	N	% F	Mean ($\bar{x}$)
Cyprinidae			
Notropis spilopterus	1119	82.4	65.8
Pimephales notatus	590	67.7	34.7
Notropis atherinoides	583	29.4	34.3
Hybognathus nuchalis	269	58.8	15.8
Ericymba buccata	181	29.4	10.6
Hybopsis storeriana	51	23.4	3.0
Notropis umbratilis	36	11.8	2.1
Notropis chrysocephalus	36	17.5	2.2
Notropis rubellus	31	4.9	1.8
Phenacobius mirabilis	17	17.6	1.0
Notropis stramineus	15	17.5	0.9
Campostoma anomalum	14	35.3	0.8
Semotilus atromaculatus	3	5.9	0.2
Cyprinus carpio	2	11.8	0.1
Hybopsis micropogon	1	5.9	0.06
Centrarchidae			
Lepomis macrochirus	46	82.4	2.7
Micropterus salmoides	19	35.3	1.1
Pomoxis nigromaculatus	5	11.8	0.3
Micropterus punctulatus	5	17.6	0.2
Pomoxis annularis	4	17.6	0.2
Lepomis cyanellus	3	11.8	0.2
Lepomis microlophus	2	11.8	0.1
Lepomis gibbosus	1	5.9	0.06
Micropterus dolomieui	1	5.9	0.06
Percidae			
Etheostoma nigrum	15	41.2	0.8
Etheostoma blennioides	10	29.4	0.6
Etheostoma flabellare	3	11.8	0.2
Etheostoma spectabile	1	5.9	0.06
Etheostoma caeruleum	1	5.9	0.06
Percina maculata	1	5.9	0.06
Ictaluridae			
Ictalurus punctatus	57	35.3	3.6
Noturus miurus	9	35.3	0.5
Noturus flavus	2	11.8	0.1
Ictalurus melas	1	5.9	0.06
Pylodictus olivarus	1	5.9	0.06

Table 14 - continued

Family - Genus - Species	N	% F	Mean($\bar{x}$)
Catostomidae			
Hypentilium nigricans	106	58.8	6.2
Carpiodes cyprinus	8	5.9	0.5
Carpiodes velifer	8	5.9	0.5
Catostomus commersoni	1	5.9	0.06
Clupeidae			
Dorosoma cepedianum	31	47.1	1.8
Atherinidae			
Labidesthes sicculus	12	17.6	0.7
Percichthyidae			
Morone chrysops	8	23.6	0.5
Esocidae			
Esox americanus	7	35.3	0.4
Umbridae			
Umbra limi	2	5.9	0.1
Lepisosteidae			
Lepisosteus platostomus	2	11.8	0.1
TOTAL	3324		

Table 15. Total number, mean, percent frequency in samples without *Moxostoma* ssp. of those species averaging greater than 1 per sample with *Moxostoma* ssp.

Family - Genus - Species	N	% F	Mean($\overline{x}$)
Cyprinidae			
Pimephales notatus	302	59.1	13.7
Notropis spilopterus	253	81.8	11.5
Ericymba buccata	65	31.8	3.0
Notropis atherinoides	28	31.8	1.27
Hybognathus nuchalis	23	18.2	1.05
Hybopsis storeriana	--	--	--
Centrarchidae			
Lepomis macrochirus	14	22.7	0.6
Micropterus salmoides	3	9.1	0.1
Ictaluridae			
Ictalurus punctatus	13	18.2	0.6
Catostomidae			
Hypentilium nigricans	22	22.7	1.0
Clupeidae			
Dorosoma cepedianum	26	13.6	1.2
TOTAL	747		

trends in increased and decreased numbers of the various species in association with *Moxostoma* were examined (Table 16). Mean values, both in samples with and without redhorses, were compared by t-test in an attempt to correlate the occurrence of some of the important species to that of the *Moxostoma* species. This might have indicated species that had similar habitat requirements; reacted to similar environmental changes, therefore schooling together; or indicated species that avoided the redhorses suckers.

No pattern emerged in changes in density of any species with changes in numbers of *Moxostoma* except, perhaps, for *Notropis spilopterus* (Table 16). Mean value/sample for species averaging greater than one per sample in the samples with *Moxostoma* was compared by t-test with means for these species in samples in which *Moxostoma* were not taken. Means of 11 species were tested and only *Notropis spilopterus*, the spot fin shiner, was found to vary significantly ($t = 2.08$, $df = 31$). Whether these results indicate similar behavior patterns in response to an environmental stimulus or a direct response of one species to another is not known.

Table 16. Number of individuals of *Notropis spilopterus*, *Lepomis macrochirus*, *Hypentilium nigricans*, and *Moxostoma* sp. per sample.

Sample	Number of *Moxostoma* ssp.	Number of *Lepomis spilopterus*	Number of *Lepomis macrochirus*	Number of *Hypentilium nigricans*
1	1	1	0	0
2	1	0	2	4
3	17	200	0	5
4	1	5	5	7
5	15	1	0	0
6	1	70	2	0
7	1	0	8	6
8	8	30	5	20
9	5	0	2	2
10	5	27	5	3
11	28	73	4	30
12	9	39	1	27
13	8	72	1	0
14	4	1	1	2
15	30	500	8	0
16	7	20	1	0
17	7	80	1	0
Total	148	1119	46	106

CONCLUSIONS

1. Three species of Moxostoma (M. anisurum, M. erythrurum, M. duquesnei) were found to co-occur in two creeks in Vigo County, Indiana, between 1980 and 1983.

2. The redhorses were captured in unexpected low numbers. Habitat comparisons were difficult to make for this reason.

3. Temporal differences in the occurrence of the species were observed. Few redhorses were captured prior to August.

4. Stomach content analysis revealed similar food habits for the three species. Insect larvae, especially chironomids, were the major foods identified.

5. The size of the angle, formed by the meeting of the halves of the lower lips, was the most consistent character for differentiating between the three species.

6. Other morphological characters exhibited much overlap between species.

7. Age classes established by scale reading corresponded well with size classes of fish. This supports the use of aging these species by scales.

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