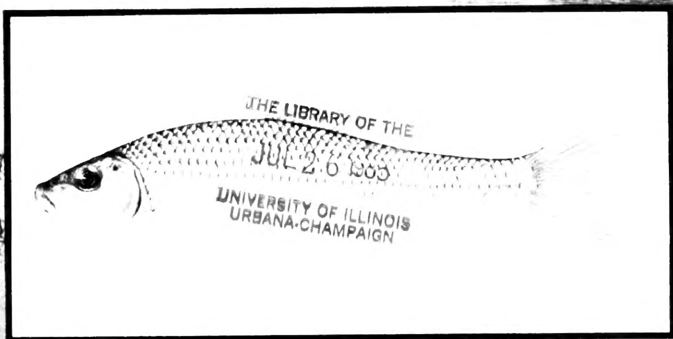
THE LIFE HISTORY OF THE SHORTHEAD REDHORSE, *Moxostoma macrolepidotum*, IN THE KANKAKEE RIVER DRAINAGE, ILLINOIS

Michael J. Sule and Thomas M. Skelly



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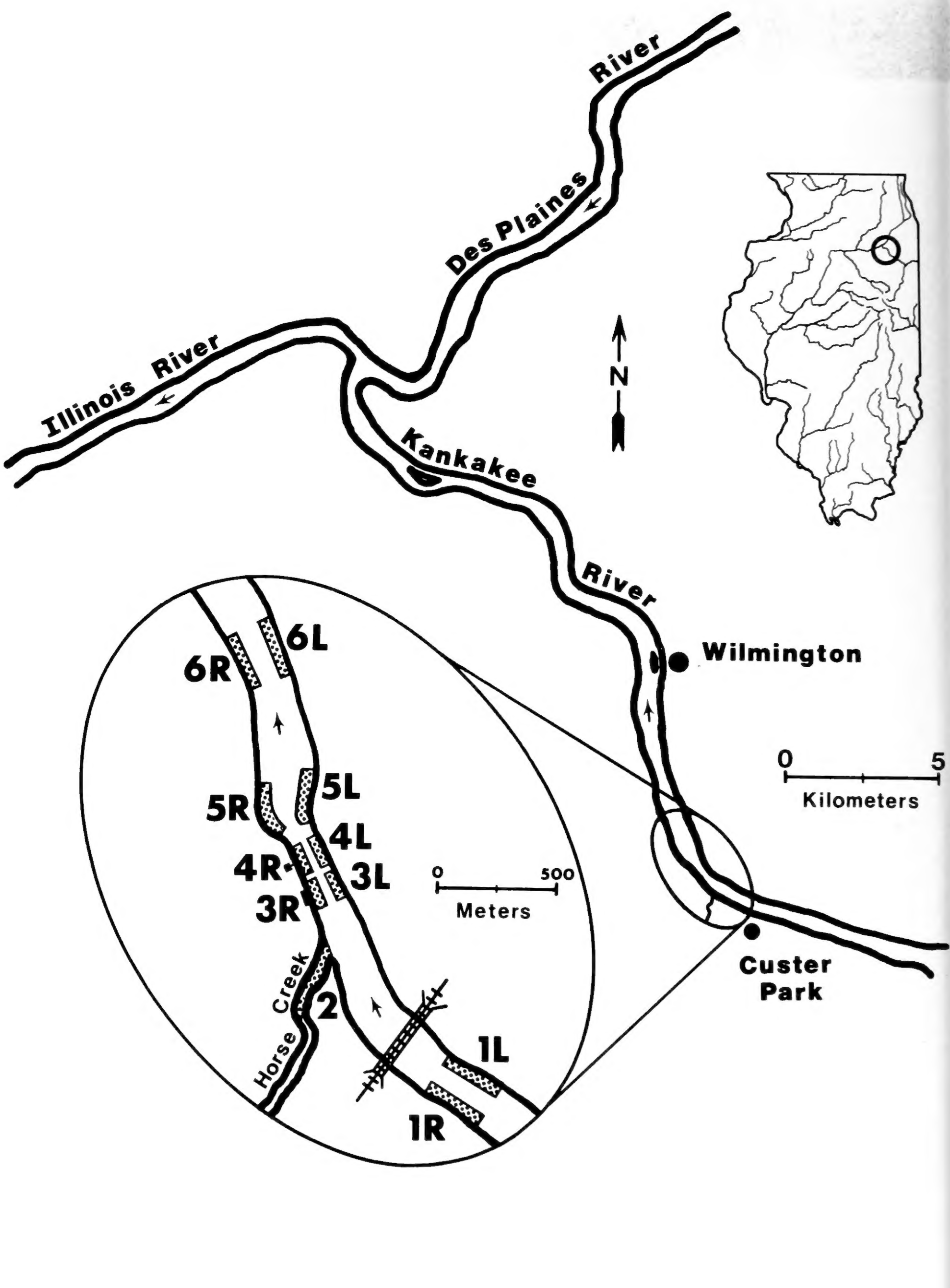

Fig. 1.—Locations of sampling stations within the Braidwood Station Aquatic Monitoring Area of the Kankakee River, Illinois.

COVER — The Kankakee River near Custer Park, Will County, Illinois (PHOTO BY TOM SKELLY). The insert photo is a shorthead redhorse, *Moxostoma macrolepidotum*, as taken from Forbes' and Richardson's, *Fishes of Illinois*.

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ABSTRACT

Shorthead redhorse, *Moxostoma macrolepidotum*, from the Kankakee River near Custer Park, Will County, Illinois, were studied intensively during May, August, and November of 1977, 1978, and 1979 and in August of 1981 and 1982. Supplementary collections were made during other ice-free months. The shorthead redhorse was a dominant fish in electrofishing collections, accounting for 2.1–23.7 percent of the total biomass and 2.1–16.4 percent of abundance. Large numbers of fish collected in August 1981 were the result of two strong year classes and high water levels that increased the susceptibility of the fish to shoreline electrofishing. Preferred habitats were cobble areas in waters 1–2 m deep with velocities of 23–63 cm/sec. Shorthead redhorse began to gather in a tributary, Horse Creek, in early March and spawned in late April and early May. On 30 April 1979, 81 reproducing males and 27 females (18 running eggs, 2 spent, 7 partially spent) were collected in Horse Creek. Approximately 3,000 shorthead redhorse were present in a single raceway-riffle area of Horse Creek at that time. Average fecundity was 18,000 eggs per female. Movements of up to 4 km were demonstrated by tag returns. A low recovery rate of tagged individuals indicated extensive movement and dispersion of this species from the monitoring area. Fish lived 6–7 years and attained a maximum size of 445 mm total length and 835 g. Females were larger than males after age III. Both sexes were mature at age V. The length-weight relationship was ln (weight) = 3.0278 ln (total length) − 11.6899. Mean condition factors (K) were 0.9–1.1. Analysis of stomach contents revealed that the shorthead redhorse consumed items from approximately 60 food categories, primarily ln vertebrate taxa. Larval Chironomidae and Trichoptera were the primary insects eaten. Unidentified materials accounted for 24–68 percent of the diet by weight; only 21–50 percent of unidentified matter, or an average of 13 percent of the total diet, was organic. The foods eaten, types of Chironomidae consumed, and a lack of burrowing mayflies in the diet suggested that shorthead redhorse fed in riffles and riffle margins. Shorthead redhorse were generally free of external macroparasites; Nematoda, Caryophyllaeidae (Cestoda), and Acanthocephala were the major internal parasites found in digestive tracts.

INTRODUCTION

The shorthead redhorse, *Moxostoma macrolepidotum*, has the most widespread distribution of all the redhorses (Jenkins 1970). *M. m. breviceps*, one of three recognized subspecies (Jenkins 1970), is widespread in the Ohio basin. *M. m. pisolabrum* is found in the Ozark uplands and adjacent areas. *M. m. macrolepidotum*, of which the Kankakee River specimens are representative, inhabits most of the remainder of the Mississippi and Missouri basins, Great Lakes-St. Lawrence basin, many drainages of the southwestern Hudson Bay basin, and the Atlantic slope from the Santee drainage north to the Hudson drainage, excluding, perhaps, the Delaware River (Jenkins 1980).

Primary habitat for the shorthead redhorse is clear, fast water in large streams that have gravel bottoms (Forbes & Richardson 1920; Minckley 1963; Pflieger 1975; Smith 1979). This fish is found also in natural lakes commonly in shallow, well-protected localities (Dymond 1926; Becker 1964; Scott 1967), in impoundments (Hall 1954; Fitz 1968; Jenkins 1970; Becker 1983), in shallow pools of small rivers with moderate velocity (Larimore & Smith 1963), in small streams with negligible current (Cross 1967; Pflieger 1975), and rarely in brackish water (Vladykov 1933; Schwartz 1964).

The redhorse species are abundant and make major contributions to the total standing crop in river fish communities (Surber & Seaman 1949; Meyer 1962; Peterka 1978; Curry 1980; Elser et al. 1980). Combined biomass of five redhorse species accounted for 22–51 percent ($\bar{x}$ = 34 percent) of the total biomass of fishes collected by electrofishing at different times during the present study.

The sport fishery for shorthead redhorse is limited but locally popular, especially during spawning runs when fish are snagged, gigged, snared, or caught by hook and line (Moore & Paden 1950; Funk 1953; Funk & Campbell 1953; Harlan & Speaker 1969). The shorthead redhorse was the tenth most abundant fish taken from the Missouri River, where more were creeled from tailwater and channelized areas than from unchannelized areas (Groen & Schmulback 1978). Channel catfish (*Ictalurus punctatus*), smallmouth bass (*Micropterus dolomieui*), and walleye (*Stizostedion vitreum*) were most often the target species of fishermen in the lower Kankakee River; however, shorthead redhorse was the fifth most abundant fish in a creel census (Graham et al. 1984).

Shorthead redhorse contributed significantly to the commercial catches of "mullet" in Ohio and Minnesota

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(Van Meter & Trautman 1970; Eddy & Underhill 1974). This species was taken in substantial numbers only in the spring in the Mississippi River, but was never commercially important because the flesh spoils rapidly, especially in warm weather (Coker 1930). The redhorses were too scarce in the Mississippi and other Illinois rivers to be commercially important (Barnickol & Starrett 1951; Starrett & Parr 1951). Although the flesh of the shorthead redhorse is white, flaky, and considered delicious, its numerous small bones render it undesirable.

Commercial processors rarely separate the suckers by species. When used for human food products, these fish are usually put through a fish deboner which produces a minced fish flesh. Incidental harvests of suckers from Lake Michigan are used along with alewife (*Alosa pseudoharengus*) to produce a fish meal for nonhuman purposes. During spring spawning runs, suckers are harvested and frozen for sale to pet food processors (D. A. Stuiber, University of Wisconsin Extension, personal communication).

Spring spawning runs of shorthead redhorse are important to bald eagles (Dunstan & Harper 1975) and herring gulls (Vermeer 1973), which consume both live and dead fish. Osprey have been observed to eat dead shorthead redhorse scavanged from shorelines (Dunstan 1974). Also, lampreys are known to attack shorthead redhorse (Hall & Moore 1954).

Shorthead redhorse are sensitive to and easily killed by domestic and industrial pollutants (Trautman 1981). The upstream migratory range of shorthead redhorse in a Maryland river decreased due to an increase in chlorinated sewage outfalls (Tsai 1970). Shorthead and golden redhorse (*Moxostoma erythrurum*) populations declined appreciably due to pollution from cattle feedlots (Cross & Braasch 1969). Sensitivities to inorganic sediment (Gammon 1968) and heated effluents (Gammon 1970), and the bioaccumulation of the insecticide chlordane (Roberts et al. 1977) have also been shown for shorthead redhorse. This redhorse has sometimes perished in vast numbers and has been stranded along banks when violent summer rains were followed by long periods of drought that overloaded streams with mud and decaying vegetation (Eddy & Surber 1947).

Although redhorses are common in many rivers, original, comprehensive studies concerning life history information are few. The shorthead, golden, and silver (*Moxostoma anisurum*) redhorses were studied by Meyer (1962). Bowman (1970) examined the life history of the black redhorse (*M. duquesnei*), Hackney et al. (1969) studied the river redhorse (*M. carinatum*) and Hackney et al. (1971) examined several aspects concerning the silver redhorse life history. Life history aspects of the shorthead redhorse in the Kankakee River in Illinois are detailed in this paper.

SITE DESCRIPTION

The primary study area was the 3.2-km Braidwood Station Aquatic Monitoring Area of the Kankakee River near Custer Park, Will County, Illinois (Fig. 1). This area is 23 km upstream from where the Kankakee River's confluence with the Des Plaines River forms the Illinois River. The riverside intake (Station 3R) and discharge (Station 4R) structures for Commonwealth Edison's Braidwood Generating Station, currently under construction, are within the study site. Collections were made both upstream and downstream of the primary study area and in Horse Creek, a third-order stream (Horton-Strahler system), to monitor movements of shorthead redhorse. Additional sampling was done in a spawning area of Horse Creek known as the big riffle, 1.2 km upstream from its mouth.

The Kankakee River flows 239 km from its source near South Bend, Indiana, and drains 13,650 km^2. At Wilmington, Illinois, mean annual discharge is 105 m^3/sec (range: 6–2,149 m^3/sec). Much of the river bed in Illinois is on or near bedrock with some overlying beds of sand and gravel (Barker et al. 1967). The Kankakee-Iroquois system has been classified as excellent, based on species composition of its fishes (Smith 1971). The Kankakee River in Illinois is noted for its healthy quality, diverse aquatic life,and scenic beauty (Ivens et al. 1981).

MATERIAL AND METHODS

The fishes in the primary study area were sampled intensively during May, August, and November from 1977 to 1979 and in August of 1981 and 1982. During these periods fishes were collected by shoreline electrofishing, seining, and hoopnetting to examine differences in species composition, diversity, and spatial and temporal variabilities in abundance and biomass among stations (Fig. 1). Supplemental electrofishing collections were made during other ice-free months to obtain additional life-history data.

Gonads of female shorthead redhorses that had ripened to a stage of maturity (Nikolsky 1963) were preserved in a modified Gilson's Fluid (Simpson 1951). The diameters of 400 eggs from each of five individuals collected in November 1977 were measured. From the frequency distribution of these diameters (Fig. 2) and the appearance of different-sized eggs, a minimum diameter was chosen so that only eggs having an equal or greater diameter would be considered mature, that is, those that would complete development during that year. Estimates of total fecundity were calculated from the numbers of mature ova present in two subsamples of the air-dried egg mass of an individual fish. The estimated fecundity and the natural logarithm of that number were regressed on twelve variables (fish age, length, and weight; their natural logarithms; their squares; and the logarithms of their squares) in a stepwise manner to determine which combination of five variables formed the best predictive expression of fecundity. The F-statistic was used to measure the degree of improvement in r^2 that resulted with the addition of each variable.

Shorthead redhorse were tagged to study seasonal movements. Floy Model 68B anchor tags were inserted into the flesh at the posterior insertion of the dorsal fin in the manner described by Dell (1968).

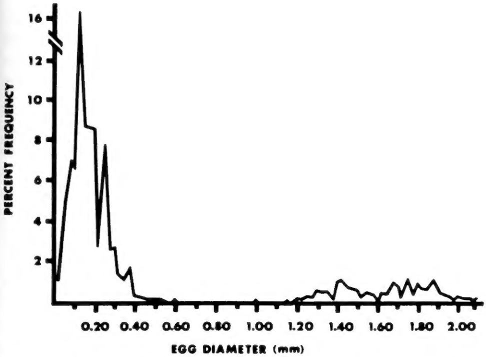

Fig. 2.—Composite frequency distribution of the diameters of 400 randomly sampled ova from each of five mature female shorthead redhorse collected in November 1979.

Scales were taken for aging from the left side of a fish at the posterior extent of the pectoral fin below the lateral line. Scale impressions were made on acetate strips and viewed at 40X on a scale projector. Analysis of variance was used to examine the effects of age, season, and sex on the natural logarithm of length. Measurements to successive annuli were taken for back-calculation of lengths at specific annuli. The body-scale relationship was determined by least squares regression based on the total length of the fish and the anterior scale radius. Adjusted measurements to each annulus, to correct for variation in scale size (Tesch 1971), were then used with the regression to calculate the total length that corresponded to a specific annulus.

A condition factor (K), describing the relative well-being of a fish was calculated by $K = \frac{(Wt.) \times 10^5}{Lt.^3}$, where Wt. = weight in grams and Lt. = total length in millimeters. Analysis of covariance using ln (Lt.) as the covariable was used to examine effects on the length-weight relationship attributable to sex, season, year, and location of capture. Orthogonal contrasts of specific locations were incorporated to compare fish weights relative to lengths of fish from different habitats. Length-weight relationships were calculated by least squares regression using the following equation: ln Wt. = a + b ln Lt.

Whole-gut, gravimetric analyses were made of subsamples of gut contents of adult fish collected in 1979. Invertebrate taxa were identified to the lowest possible level. Large amounts of silty, unidentified matter were quantitatively examined for algal units and then ashed to obtain estimates of organic/inorganic composition.

All statistical procedures were performed using the Statistical Analysis System (SAS 1979); statistical significance refers to the $P<0.05$ level.

OCCURRENCE AND HABITAT

The shorthead redhorse was a prevalent species by both abundance and biomass in Kankakee River electrofishing collections during the study (Table 1). Although best represented in May collections (partly due to their movement through the study area after the spawn), shorthead redhorse were abundant and contributed greatly to the total biomass of fishes throughout the year. The great abundance of shorthead redhorse collected in August 1981, compared with other study years, resulted from two strong year classes of adult fish and higher-than-average river levels that permitted larger-bodied fish to inhabit shoreline electrofishing areas.

Shorthead redhorse were consistently collected at Station 6L. Shoreline habitat was cobble substrate with scattered, emergent stands of water willow (*Justicia americana*).

Fig. 3.—Shorthead redhorse were consistently collected from shoreline areas having cobble substrate and stands of water willow. The best catches occurred during high-flow periods when the emergent stands were inundated with 1–2 m of water.

The best catches of the species occurred when the emergent stands were inundated with 1 – 2 m of water with a surface velocity of 23–63 cm/sec. Station 1L was similar to 6L and also yielded good catches under similar conditions. Large numbers of golden redhorse were occasionally common at these times also. Receding water levels with reduced water velocity yielded poorer catches of both species.

Shorthead redhorse could, at times, be found in a variety of habitats; however, cobble areas and riffle margins

TABLE 1.—Percent abundance and biomass of dominant fishes collected by shoreline electrofishing from all stations in the Kankakee River and Horse Creek.

	1977		1978		1979		1981		1982		Mean	
	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.
May												
Shorthead redhorse	9.1	14.1	14.8	12.7	16.4	23.7	...	...	...	...	13.4	16.8
Golden redhorse	5.4	11.8	11.0	10.0	12.1	7.6	...	...	...	...	9.5	9.8
Silver redhorse	1.5	2.7	2.3	4.9	0.8	2.1	...	...	...	...	1.5	3.2
Carp	7.9	49.8	8.0	42.8	5.2	35.6	...	...	...	...	7.0	42.7
Quillback	2.9	5.4	11.9	17.6	10.4	9.2	...	...	...	...	8.4	10.7
Smallmouth bass	11.5	4.3	9.6	2.5	6.4	2.9	...	...	...	...	9.2	3.2
Rock bass	22.4	5.8	8.5	2.3	11.5	3.7	...	...	...	...	14.1	3.9
Green sunfish	5.9	0.8	3.0	0.2	1.7	0.1	...	...	...	...	3.5	0.4
Longear sunfish	4.6	0.5	5.3	0.4	3.6	0.4	...	...	...	...	4.5	0.4
White crappie	0.9	0.3	4.2	0.2	9.0	1.3	...	...	...	...	4.7	1.2
Gizzard shad	0.3	0.2	1.1	0.6	2.3	0.3	...	...	...	...	1.2	0.4
Bluntnose minnow	2.1	...	4.3	0.1	1.0	...	...	...	...	...	2.5	...
August												
Shorthead redhorse	6.5	9.4	2.1	2.1	3.2	5.1	10.9	21.2	3.1	4.7	5.2	8.5
Golden redhorse	9.1	16.9	3.6	9.9	12.6	15.1	15.5	19.9	11.8	11.8	10.5	14.7
Silver redhorse	0.8	2.4	1.0	9.2	1.4	6.5	2.6	6.8	6.4	17.7	2.5	8.5
Carp	3.8	34.5	1.7	22.8	1.8	14.4	4.3	15.6	7.0	27.0	3.7	22.9
Quillback	1.7	4.1	2.2	15.6	3.4	9.4	2.2	4.1	6.1	9.4	3.1	8.5
Smallmouth bass	11.5	15.2	10.3	12.9	17.0	15.3	8.5	8.0	13.5	10.1	12.2	12.3
Rock bass	8.1	4.5	6.8	7.4	14.7	9.5	8.8	5.1	6.1	1.6	8.9	5.6
Green sunfish	4.3	0.6	8.6	3.1	9.3	1.7	8.6	1.0	10.4	0.6	8.2	1.4
Longear sunfish	7.0	0.8	14.9	4.5	12.3	2.0	6.4	0.8	6.8	0.5	9.5	1.7
White crappie	0.2	0.1	0.1	...	1.7	0.8	3.6	1.4	0.9	0.4	1.3	0.5
Gizzard shad	18.1	1.8	25.4	3.7	1.2	1.4	8.0	2.5	9.2	2.5	12.4	2.4
Bluntnose minnow	2.1	...	4.9	0.2	2.7	0.1	0.8	...	1.1	...	2.3	0.1
November												
Shorthead redhorse	9.5	16.7	7.2	12.3	2.1	4.5	...	...	...	...	6.3	11.2
Golden redhorse	3.3	13.2	6.8	30.9	8.4	13.2	...	...	...	...	6.2	19.1
Silver redhorse	0.2	1.9	0.8	2.7	0.7	6.6	...	...	...	...	0.6	3.7
Carp	1.6	25.9	0.3	3.6	0.9	10.0	...	...	...	...	0.9	13.2
Quillback	3.3	22.3	2.8	19.0	6.0	28.4	...	...	...	...	4.0	23.2
Smallmouth bass	5.5	3.6	8.3	10.3	8.0	9.6	...	...	...	...	7.3	7.8
Rock bass	8.4	2.6	6.2	3.1	6.8	4.7	...	...	...	...	7.1	3.5
Green sunfish	11.5	1.4	10.3	1.8	12.2	2.0	...	...	...	...	11.3	1.7
Longear sunfish	4.9	0.6	7.6	1.3	6.9	0.6	...	...	...	...	6.5	0.8
White crappie	1.5	1.0	1.5	0.8	8.1	3.2	...	...	...	...	3.7	1.7
Gizzard shad	1.8	0.5	0.3	0.1	0.8	0.4	...	...	...	...	1.0	0.3
Bluntnose minnow	2.6	...	16.1	0.1	5.6	0.1	...	...	...	...	8.1	0.1

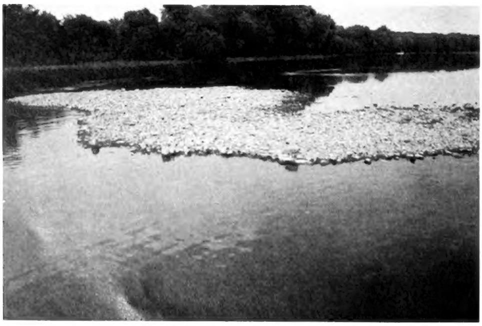

Fig. 4.—Typical summer and autumn habitat of shorthead redhorse was the swift-water upstream and lateral margins of rocky islands that emerged during low-flow periods of the Kankakee River.

were the most productive areas during summer and autumn. In the Marais de Cygnes River, Kansas, they were found most commonly at the uppermost end of riffles where water was swift and approximately 0.6 m deep (Deacon 1961). In Wisconsin this fish was found most frequently in clear to slightly turbid waters at depths of 0.6 m or greater, over substrates of sand (28 percent frequency), gravel (22 percent), mud (19 percent), clay (11 percent), rubble (10 percent), silt (5 percent), boulders (3 percent), and bedrock (2 percent) (Becker 1983). In spring, shorthead redhorse gathered in the raceways and riffles of Horse Creek and in riffles of the Kankakee River. In November 1979, they were not numerous in typical summer areas, but were congregated upstream of the reference stations in deeper pools along with many golden redhorse and channel catfish.

Within the primary study area, the shorthead redhorse has been collected along with 69 other fish species (Table 2) and several sunfish hybrids, a list demonstrative of a high quality fishery. Good water quality and habitat have been important to the maintenance of the diverse assemblage of fishes encountered (Skelly & Sule 1983). Of the five redhorse species found in the Kankakee River, the shorthead and golden redhorses were common, silver and river redhorses were fairly common, but the black redhorse was uncommon.

TABLE 2.—Fishes collected by electrofishing and seine from the Kankakee River and Horse Creek within the Braidwood Station Aquatic Monitoring Area during 1977–1982.

Lepisosteus osseus, longnose gar
Amia calva, bowfin
Anguilla rostrata, American eel [a]
Dorosoma cepedianum, gizzard shad
Salmo gairdneri, rainbow trout
Umbra limi, central mud minnow
Esox americanus, grass pickerel
E. lucius, northern pike
Campostoma anomalum, stoneroller
Carassius auratus, goldfish
Cyprinus carpio, carp
Ericymba buccata, silverjaw minnow
Nocomis biguttatus, hornyhead chub
Notemigonus crysoleucas, golden shiner
Notropis amnis, pallid shiner
N. atherinoides, emerald shiner
N. buchanani, ghost shiner
N. chrysocephalus, striped shiner
N. dorsalis, bigmouth shiner
N. emiliae, pugnose minnow
N. lutrensis, red shiner
N. rubellus, rosyface shiner
N. spilopterus, spotfin shiner
N. stramineus, sand shiner
N. umbratilis, redfin shiner
N. volucellus, mimic shiner
Phenacobius mirabilis, suckermouth minnow
Pimephales notatus, bluntnose minnow
P. promelas, fathead minnow
P. vigilax, bullhead minnow
Semotilus atromaculatus, creek chub
Carpiodes cyprinus, quillback
Catostomus commersoni, white sucker
Erimyzon sucetta, lake chubsucker
Hypentelium nigricans, northern hog sucker
Ictiobus bubalus, smallmouth buffalo
I. cyprinellus, bigmouth buffalo
Minytrema melanops, spotted sucker
Moxostoma anisurum, silver redhorse
M. carinatum, river redhorse
M. duquesnei, black redhorse
M. erythrurum, golden redhorse
M. macrolepidotum, shorthead redhorse
Ictalurus melas, black bullhead
I. natalis, yellow bullhead
I. punctatus, channel catfish
Noturus flavus, stonecat
Aphredoderus sayanus, pirate perch
Fundulus notatus, blackstripe topminnow
Labidesthes sicculus, brook silverside
Morone mississippiensis, yellow bass
Ambloplites rupestris, rock bass
Lepomis cyanellus, green sunfish
L. gibbosus, pumpkinseed
L. gulosus, warmouth
L. humilis, orangespotted sunfish
L. macrochirus, bluegill
L. megalotis, longear sunfish
Micropterus dolomieui, smallmouth bass
M. salmoides, largemouth bass
Pomoxis annularis, white crappie
P. nigromaculatus, black crappie
Etheostoma caeruleum, rainbow darter
E. microperca, least darter
E. nigrum, johnny darter
E. zonale, banded darter
Percina caprodes, logperch
P. maculata, blackside darter
P. phoxocephala, slenderhead darter
Stizostedion vitreum, walleye

[a] Observed, but not collected

SPAWNING PERIODS

The shorthead redhorse is known to spawn in 1 m water over cobble (Gale & Mohr 1976), at the edges of sandbars on shallow (15–21 cm deep) riffles (Burr & Morris 1977), and over medium gravel in riffles 30–60 cm deep with a current velocity of 0.4–0.9 m/sec. (Curry 1980). Spawning dates ranged from late April to 23 May in rivers with water temperatures 8.3° to 22.0°C (Meyer 1962; Jenkins 1970; Burr & Morris 1977; Gale & Mohr 1978; Buynak & Mohr 1979; Fuiman 1979; Becker 1983). Spawning occurred during June in main-river upstream areas and in major tributaries of two Missouri River reservoirs (Walburg 1964; June 1977).

Shorthead redhorse had begun to accumulate near the big riffle spawning area in Horse Creek in late March of 1978 and 1979, shortly after the Kankakee River was ice-free. On 28 April 1978 this area held reproduction-stage (Nikolsky 1963) males and females that, although mature, would not yield eggs when lightly palpated. Both sexes were found releasing sexual products on 5 May 1978 when air and water temperatures were 7.0°C. Twice as many males as females were collected during this period.

In 1979, the primary spawning activity extended from 25 April until 7 May. Milt could be extruded from some males as early as 2 April; however, an indication of males truly releasing sexual products was not evident until 19 April, marking the initiation of the spawning period. Tuberculation of anal and caudal fins of males also began at this time; some males also formed tubercles along the sides of the body. After 19 April and until the spawn was completed, few adult shorthead redhorse were found in the study area outside of Horse Creek. Numerous immature individuals, however, were collected at that time in the Kankakee River. Females extruding eggs were first collected on 25 April when the water temperature in Horse Creek was 14.4°C. On 30 April, 81 reproducing males and 27 females (18 running eggs, 2 spent, 7 partially spent) were collected on or near the big riffle. Skewed sex ratios (75 males:37 females) were also found during spawning in the Des Moines River, Iowa, whereas ratios during other times of the year were 1:1 (Meyer 1962). Actual spawning was never observed during this study because of turbid waters;

however, skewed sex ratios might be explained by the need for two to four males per female during the spawning act as seen by Burr & Morris (1977). Burr & Morris (1977) never observed a single male and female spawning together. Spent individuals began appearing at reference stations in the Kankakee River on 1 May (water temperature = 8.0°C) as the spawning progressed. Numerous spent females began appearing on 7 May (water temperature = 15.6°C), suggesting that the bulk of the spawn had been completed. Congregations of reproducing males and some females were still present in Horse Creek as late as 23 May. Postspawning mortality may be high since several dead redhorse were found in Horse Creek during subsequent collections. These fish were untagged, suggesting that mortality was due to natural causes rather than a result of our handling.

In Horse Creek during 1979, peak drift-density of Catostomidae Group D larvae (Hogue et al. 1976) was 7.62 larvae/m^3 of water and occurred on 19 May (Bergmann et al. 1980). In the Kankakee River, Catostomidae Group D larvae may include, due to overlapping characteristics, all five species of *Moxostoma* as well as *Hypentelium nigricans* and *Catostomus commersoni*. Peak drift-density of these larvae in the Kankakee River occurred 2 weeks after the peak drift in Horse Creek and was only 0.07 larvae/m^3 of water, illustrating the importance of Horse Creek as a spawning area.

FECUNDITY

Examination of the gonads of shorthead redhorse collected in 1977 and 1978 indicated that the eggs of some age IV + females were maturing in November and that these fish would spawn in the spring as age V individuals. All younger females were immature. The youngest reproducing male that was aged was also 5 years old, although most reproducing individuals of both sexes were 6 years old. Numbers of maturing ova (> 0.60 mm in diameter) for 36 fish ranged from 9,491 (a 327-mm, 365-g, age V fish) to 26,550 (a 418-mm, 680-g, age VI fish). Not unlike that found for shorthead redhorse in the Des Moines River (Meyer 1962), fecundity averaged approximately 18,000 eggs for females that were 5–7 years old (Table 3). Six fish from the Wisconsin River (460–537 mm TL, 1.31–1.93 kg), collected 24 April held 22,000–44,000 eggs averaging 1.9 (1.6–2.1) mm in diameter (Becker 1983).

The best predictive model (r^2 = 0.72) of shorthead fecundity incorporating 4 of 12 tested variables was:

$$\ln \text{egg number} = 3.9716\,(\text{Lt.}) - 733.0172 \ln (\text{Lt.}) - 0.0027\,(\text{Lt.}^2) + 0.2686\,[\ln (\text{Wt.}^2)] + 3237.1851.$$

The r^2 value for fecundity expressions was not significantly improved with the inclusion of a fifth independent variable, although it improved significantly with each prior addition.

Mean gonad-somatic indices (GSI)[(gonad weight/fish body weight) × 100] of female shorthead redhorse gradually increased as spawning time approached. Mean GSI values for females were: 8.24 on 29 March, 10.54 on 5 April, 11.68 on 21 April, and 13.90 on 28 April 1978. The mean GSI value for seven males was 6.36 on 29 March 1978. The largest female examined from the Wisconsin River had a GSI of 13.2 on 24 April (Becker 1983). In Lake Oahe, a Missouri River reservoir, ovarian development was continuous from August through October after a late June spawn; ovary indices changed little throughout the winter, but ovarian development was rapid during May prior to the next spawn (June 1977).

MOVEMENT

Thirty-four of the 613 shorthead redhorse tagged during 1979 were recaptured (one fish was recaptured twice) during quarterly and supplementary sampling. One fish, caught 2.7 km upstream of the study area and released 0.6 km upstream of the study area on 3 April 1979, was recaptured 8 days later back at its site of original collection. The manual displacement of this fish downstream toward Horse Creek, a known spawning area, may have been reversed due to a homing response, or possibly it was too early for this fish to move toward a spawning site. It may, however, have intended to spawn somewhere upstream of Horse Creek, possibly near its collection site. A gravid female, collected and released downstream of the study area, was recaptured 14 days later in the pool below the big riffle of Horse Creek, 4 km upstream of its original capture site. The recapture demonstrated that fish moved into the creek from areas of the river below its confluence with the creek. A male that was running milt was captured at the upstream end of Station 2 in Horse Creek on 10 April. On 30 April it was captured 900 m upstream on the big riffle.

TABLE 3.—Fecundity estimates for shorthead redhorse collected from the Kankakee River and Horse Creek during 1977 and 1978.

Age	N	Length (mm)		Weight (g)		Egg Number		Egg No./Fish Weight (g)	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD
5	12	388	21	611	88	18,628	3,270	30	2
6	13	395	14	651	91	18,783	4,041	29	4
7	11	396	20	645	103	17,328	3,620	27	4
5–7	36	393	18	636	93	18,287	3,622	29	4

Fig. 5. and 6.—Approximately 3,000 shorthead redhorse congregated in the pool-raceway area of Horse Creek (left) below this slabrock riffle (right) for spawning in late April and early May 1979 (both photographs were taken during low water in August)

In six sampling periods between 24 April and 23 May 1979, 26 fish were tagged, released,and recaptured at the spawning riffle in Horse Creek. Time between tagging and recapture averaged 5.6 days for females and 11.3 days for males, indicating either a prolonged stay at the spawning site, movement to and from the spawning area, or interrupted spawning. Two males that were running milt when tagged at the big riffle were still in a reproductive state 5 days later when recaptured below the mouth of Horse Creek. The riffle where they were captured was approximately 1.2 km from the tagging site, suggesting that males may move between spawning concentrations.

Migrations or spawning runs of shorthead redhorse are common in the spring (Luce 1933; Elser & Schrieber 1978; Miller & Robison 1980). Spawning runs during this study culminated in concentrations of fish in the riffles and raceways of Horse Creek. Static population estimates (calculated from cumulative mark-and-recapture data from eight collections between 10 April and 23 May) indicated that approximately 3,000 shorthead redhorse were present at the spawning area near the big riffle in Horse Creek, an area of approximately 0.6 ha. This estimate equates to a standing stock of approximately 1,800 kg of shorthead redhorse/ha.

Extensive movement of shorthead redhorse was suggested when none of the 72 tagged specimens was recovered from Illinois rivers (Thompson 1933). Deacon (1961) recovered 4 of 36 clipped specimens: two at the original capture site, one less than 0.8 km downstream of the capture area, and another 1.6 km downstream. A lack of recovery of more than 300 individuals tagged during the present study near the big riffle of Horse Creek illustrates the extensive dispersion of fish from the study area after spawning.

AGE AND GROWTH

Mean observed lengths of aged shorthead redhorse (Table 4) show distinct size ranges for age I and II fish in May and August. Fish collected in November (after the growing season) exhibited some overlap in size between fish that were 2 and 3 years old. Lengths in all older age groups, regardless of season of collection, overlapped extensively. Growth of shorthead redhorse of ages I-III was

TABLE 4.—Empirical age group data for shorthead redhorse collected from the Kankakee River and Horse Creek during May, August, and November 1977–1979.

			Length (mm)			Weight (g)			Condition factor (K)		
Age	Sex	N	Mean	SD	Range	Mean	SD	Range	Mean	SD	Range
						May					
1		23	105	15	79–133	12	5	6–22	1.0	0.2	0.7–1.8
2		84	228	26	158–276	121	40	35–215	1.0	0.1	0.7–2.0
2	M	15	241	21	206–276	144	33	100–215	1.0	0.1	0.7–1.2
3		13	323	16	298–354	336	47	240–420	1.0	0.1	0.9–1.2
3	F	2	336	25	319–354	367	74	315–420	0.9	0.0	0.9–1.0
3	M	3	320	16	307–338	351	26	330–380	1.1	0.1	1.0–1.2
4		45	355	18	307–392	435	62	305–600	1.0	0.1	0.8–1.1
4	F	27	361	16	331–392	449	60	358–600	0.9	0.1	0.8–1.1
4	M	18	347	18	307–381	413	60	305–524	1.0	0.1	0.9–1.1
5		61	371	16	343–406	498	66	365–735	1.0	0.1	0.8–1.3
5	F	29	373	17	343–399	499	62	370–620	0.9	0.1	0.8–1.3
5	M	32	370	15	345–406	497	71	365–735	1.0	0.1	0.8–1.3
6		82	396	16	357–436	573	77	405–835	0.9	0.1	0.8–1.2
6	F	64	399	15	457–436	586	78	405–835	0.9	0.1	0.8–1.2
6	M	14	384	9	371–396	529	39	460–600	0.9	0.0	0.9–1.0
7	F	8	404	20	384–445	606	73	520–715	0.9	0.1	0.8–1.0
8		1	402	...	...	690	...	...	1.1	...	...
						August					
1		36	188	22	131–227	75	23	21–123	1.1	0.1	0.9–1.4
1	F	15	196	20	163–227	83	22	53–123	1.1	0.1	0.9–1.3
1	M	11	189	18	169–221	77	23	51–116	1.1	0.1	1.0–1.3
2		6	309	13	284–319	323	34	270–375	1.1	0.1	0.9–1.2
2	F	3	305	18	284–317	325	53	270–375	1.1	0.1	1.1–1.2
2	M	3	313	6	308–319	321	4	318–235	1.0	0.1	0.9–1.1
3		3	356	32	322–385	443	68	375–510	1.0	0.2	0.8–1.1
3	F	1	360	...	...	510	...	...	1.1	...	...
3	M	1	322	...	...	375	...	...	1.1	...	...
4		30	372	16	342–407	567	70	440–715	1.1	0.0	1.0–1.2
4	F	15	375	16	353–407	586	69	490–715	1.1	0.0	1.0–1.1
4	M	11	371	17	342–401	554	72	440–675	1.1	0.0	1.0–1.2
5		11	386	8	375–398	618	37	570–685	1.1	0.1	0.9–1.2
5	F	9	386	8	375–398	619	41	570–685	1.1	0.1	0.9–1.2
5	M	1	387	...	...	600	...	...	1.0	...	...
						November					
1		91	225	20	176–281	118	34	63–217	1.0	0.1	0.8–1.0
1	F	1	226	...	...	102	...	...	0.9	0.1	...
1	M	7	230	28	176–269	126	59	63–187	1.0	0.1	0.9–1.2
2		10	307	38	227–348	292	100	110–460	1.0	0.1	0.9–1.1
2	M	3	338	9	332–348	379	71	328–460	1.0	0.1	0.9–1.1
3		8	359	13	335–379	478	110	292–645	1.0	0.2	0.7–1.3
3	M	5	355	13	335–370	461	48	390–507	1.0	0.1	0.9–1.1
4		36	384	13	360–417	589	76	442–760	1.0	0.1	0.8–1.2
4	F	10	393	10	379–406	632	46	560–715	1.0	0.0	0.9–1.1
4	M	17	380	14	360–417	561	81	442–760	1.0	0.1	0.8–1.2
5		9	398	18	375–431	645	83	539–795	1.0	0.0	1.0–1.1
5	F	4	393	13	375–407	620	60	550–680	1.0	0.0	1.0–1.1

greater from May to August than from August to November. Fish that were 4 and 5 years old had similar growth increments during both periods. Few fish collected in May had begun adding new scale material beyond the last annulus. In Iowa, young redhorses generally form annuli in June; older and larger redhorses complete annulus formation as late as August (Meyer 1962). Analysis of variance of aged fish from 1977 and 1978 indicated that the length of shorthead redhorse differed significantly by age, season, and sex. Older fish, fish collected late in the year, and females were the largest individuals. Mean observed lengths were generally larger than those reported by Purkett (1958) and Walburg (1964). Lengths of fish at ages III and IV were similar to those observed by Meyer (1962) and to the preimpoundment data of Elrod & Hassler (1971). However, younger fish and fish older than age IV in the Kankakee River were smaller than those reported in other studies. Shorthead redhorse in Iowa (Meyer 1962) and

TABLE 5.—Mean back-calculated total lengths and growth increments with their standard deviations for shorthead redhorse growth from the Kankakee River and Horse Creek, Illinois 1977–1979.

	Annulus															
	1		2		3		4		5		6		7		8	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
All fish	93	22	207	35	295	27	343	23	368	20	390	22	396	19	402	.
Increment	93	22	111	31	93	20	49	16	28	11	23	8	20	6	14	. .
N	650	. . .	500	. . .	397	. . .	371	. . .	260	. . .	161	. . .	23	. . .	1	. .
Males	100	23	210	31	299	19	341	17	364	15	378	13	374	. . .	. . .	. . .
Increment	100	23	108	26	91	21	43	14	25	11	21	7	20	. .	. . .	. . .
N	194	. . .	176	. . .	135	. . .	146	. .	100	. . .	52	. . .	1	. . .	. . .	. . .
Females	105	23	207	37	298	30	348	25	373	21	396	23	398	19	. .	. . .
Increment	105	23	99	28	91	19	51	16	28	10	22	8	19	6	. . .	. . .
N	225	. . .	209	. . .	205	. . .	201	. . .	149	. . .	104	. . .	21	. . .	. . .	. . .

South Dakota (Elrod & Hassler 1971) continued to grow throughout their lifetime, whereas fish in the Kankakee River grew little beyond 400 mm after age V.

Back-calculated lengths (Table 5) indicated growth trends similar to those exhibited by the empirical data. Mean back-calculated lengths were similar for males and females through age III, after which females were consistently larger than males.

Growth histories of individual year classes of shorthead redhorse reconstructed from back-calculated lengths of fish captured in 1977, 1978, and 1979 showed similar trends regardless of the collection year. The calculated size at specific annuli differed slightly depending on the year of the analysis, because calculations were based on different fish; however, the reproducibility of observed growth trends verified that there were growth differences among different year classes. Good first-year growth was not necessarily indicative of continued good growth; growth compensation was suggested by large second-year increments for some classes that were shorter than average after their first year of growth (Fig. 7). Members of the 1972, 1973, and 1977 year classes dominated the catch, whereas fish from 1974 and 1975 were poorly represented. Catch curves for these suckers in 1977–1979 (Fig. 8) illustrated the extreme fluctuations in year-class strength.

The strength of a given year class was not reflected in its growth history, as is often seen in lake situations; both strong and weak classes from the Kankakee River had first-year growth above and below the average. Consequently, competition during the first growing season was probably not a dominant influence in the strength of year-class establishment by shorthead redhorse; whereas, specific environmental conditions, such as temperature and/or rainfall (river discharge) during early life stages, may be important. The fact that periods of strong reproduction were separated by 4 to 5 years may be related to the time that it takes fish from one strong year class to reach sexual maturity. Barring adverse physical conditions, such a cycle of year-class strength could predictably be based on adult abundance.

Strong year classes were also evident in Lake Sharpe, a Missouri River Reservoir (Elrod & Hassler 1971). Catch rates of suckers in a Missouri Ozark stream were significantly higher during one 4-year period than during the years before and after that period (Funk & Fleener 1974). These catch rates indicate the presence and demise of a strong year class of fish. Fajen (1975) attributed fluctuations in the total standing crop of golden redhorse to the erratic recruitment of successive year classes. Dramatic reductions in standing crop occur when these strong year classes leave the population due to natural mortality.

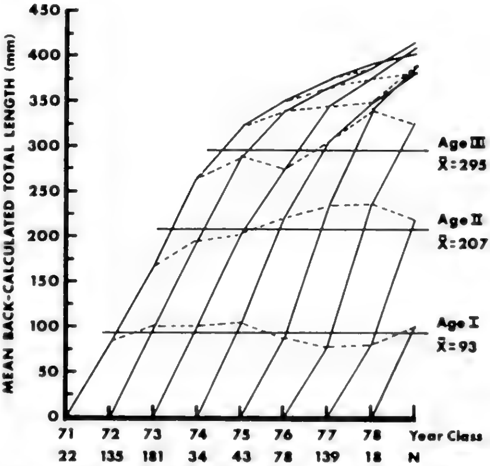

Fig. 7.—Mean back-calculated total length at each annulus for individual year classes of shorthead redhorse collected from the Kankakee River and Horse Creek during 1977–1979.

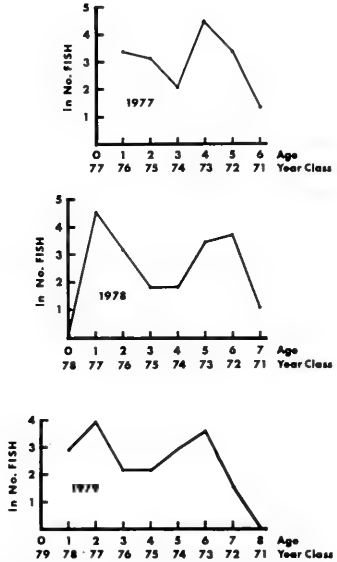

Fig. 8.—Catch curves for shorthead redhorse collected from the Kankakee River and Horse Creek during 1977–1979. Ordinate units are the natural logarithm of the number of shorthead redhorse of a given age in the yearly catch.

Although well represented in 1978, the 1972 year class was nearly absent in 1979, indicating that the lifespan of shorthead redhorse in the Kankakee River was 6 to 7 years. Only one 8-year-old fish was collected during the study. Most shorthead redhorse in Lewis and Clark Lake, Missouri, were less than 5 years old, with none greater than 6 years (Walburg 1964). The fish in northern regions appear to be longer lived, 8 years in Iowa (Meyer 1962), 9 years in Minnesota (Eddy & Carlander 1942), 12 years in North Dakota (Elrod & Hassler 1971) and, although marked by slow growth, 12–14 years in Canada (Scott & Crossman 1973).

Mean condition factors (Table 4) were 0.9–1.1, values similar to those of Iowa fish (Meyer 1962). The widest range of values was found in May, probably due to the presence of spawned and unspawned individuals. No sex or size differences were reflected in condition values.

Analysis of covariance of the ln (weight) of fish, using ln (length) as the covariable, indicated that sex did not have a significant effect on the length-weight relationship for shorthead redhorse during 1977 and 1978. However, analysis of covariance of all the fish weighed and measured from 1977 through 1979 ($N = 954$) indicated that factors such as year, season, and location of capture did significantly affect the ln (weight)-ln (length) relationship. Significant differences in the length-weight relationship existed between fish from riverlike stations (locations 1 and 6) and those from a more lentic area of the river (location 5). Adjusted mean weights (least square means) were greater for shorthead and golden redhorse from the slowly moving waters of lentic areas.

The length-weight relationships also differed among years and differed very significantly ($P < 0.001$) among seasons. Coefficients for the length-weight regression for fish captured during May deviated from those for August and November (Table 6). The lower intercept and slope of the May regression probably reflects the lower weight per length of fish after the spring spawn due to loss of sexual products, decreased feeding, and increased energy requirements for spawning and associated migration.

FOOD HABITS

Approximately 60 invertebrate taxa and other materials were consumed by the bottom-feeding shorthead redhorse. Ten general categories each accounted for at least 5 percent of the diet during at least 1 month (Table 7). Larval Chironomidae and Trichoptera were the primary aquatic insects consumed. These benthic organisms have previously been shown to be important in the diet of shorthead redhorse (Sibley 1929; Rimsky-Korsakoff 1930; Nurnberger 1931; Sibley and Rimsky-Korsakoff 1931; Meyer 1962; Minckley 1963; Bur 1976; Yant 1979). The occurrence of Mollusca (Forbes 1888; Rimsky-Korsakoff 1930; Eastman 1977) and Cladocera (Eaton 1928; Nurnberger 1931) in the diet has been noted also. The sporadic occurrence of foods like *Petrophila (Parargyractis)* and Decapoda is probably the result of the contagious distribution and seasonal availability of benthic invertebrates.

Several authors have noted the abundance of mud and detritus consumed by the redhorses (Sibley 1929; Minckley 1963; Smith 1977). In our study, unidentified materials acounted for 24–68 percent of the total diet by weight. Only

Table 6.—Coefficients and standard errors of the estimates for the length-weight relationship [ln (weight) = a + b ln (length)] for shorthead redhorse from the Kankakee River and Horse Creek, 1977–1979.

Period	N	Length (mm) Mean	Length (mm) Range	Intercept (a)	SE	Slope (b)	SE	Coefficient of Determination (r^2)
May	416	283.9	57 - 445	- 11.6560	0.0522	3.0155	0.0094	1.00
Aug.	254	200.0	43 - 412	- 11.8086	0.0882	3.0595	0.0715	0.99
Nov.	284	199.0	63 - 431	- 11.8597	0.0507	3.0634	0.0099	1.00
1977–1979	954	236.3	43 - 445	- 11.6899	0.0359	3.0278	0.0067	1.00

TABLE 7.—Average percentage weight of gut contents of shorthead redhorse collected in 1979 from the Kankakee River. t = trace occurrence

Stomach content	29 Mar[a]	19 Apr	10 May	19 Jun	7 Aug	14 Sep	16 Oct	12 Nov
Chironomidae	52	2	7	2	17	19	6	66
Trichoptera	11	7	7	28	4	3	1	2
Unidentified organic matter	9	17	13	12	13	16	14	13
Unidentified inorganic matter	17	21	13	12	46	49	54	16
Sand	3	17	38	17	12	4	14	1
Algae	t	1	4	t	1	6	2	1
Aquatic Lepidoptera [Petrophila (*Parargyractis*)]	...	...	10	7	t	...	...	...
Plants	t	13	3	5	t	...	t	...
Decapoda	...	6	...	...	...	...	...	...
Trichoptera cases	t	7	1	7	1	t	t	...
Other	7	8	4	9	5	2	8	t
Full stomachs	9	1	4	6	5	4	4	3
Empty stomachs	0	8	2	0	0	1	0	2

[a]1978 collection

21–50 percent of that material, or an average of 13 percent of the total diet, was organic (ash-free dry weight). Assuming that this 13 percent is the detritus component of the diet, which might be nutritionally valuable, a large portion of the material ingested is poor in energy. The ingestion of bottom materials is probably the most efficient way for these fish to obtain sufficient quantities of invertebrate foods, given their limited feeding morphology.

The food habits of an animal are largely a function of the habitat it occupies and the seasonal availability of foods. Shorthead redhorse were common in Horse Creek in the spring and consumed large numbers of Chironomidae, primarily *Orthocladius* but also Tanytarsini and *Eukiefferiella*. Fish reduced their feeding activities and then ceased feeding in April as the spawn progressed. One fish found in the Kankakee River proper was feeding during this time and consumed an assemblage of chironomids (primarily *Rheotanytarsus*, a swift-water genus) different from those found in Horse Creek. After the spawn, fish could be found both in Horse Creek and in the Kankakee River and were consuming chironomids typical of the habitats occupied. In late summer when shorthead redhorse were typically found near riffles, they fed predominantly on *Xenochironomus*, a chironomid known to occur in swift-water habitats. The specific chironomids eaten changed as different groups became seasonally available. In October, fish were found in a pool upstream of the reference stations and had consumed *Chironomus*, a depositional form. In November 1978, only 1 of 12 shorthead redhorse found in typical summer areas was actively feeding. In November 1979, fish were not in summer habitats but were found actively feeding in that upstream pool area. They were, however, consuming *Orthocladius*, a resource also exploited by golden redhorse. It appears that these fish seek deeper water during the winter but whether they continue feeding is unknown.

Comparative qualitative studies of the food habits of sympatric redhorses (Meyer 1962; Smith 1977) have demonstrated little variation in the diets of those species examined. However, foods eaten in the present study, coupled with the absence of burrowing mayflies in the diet (unlike golden redhorse from the study area which consumed *Hexagenia* sp. and depositional-type Chironomidae), suggest that habitat utilization (riffles and riffle margins), and therefore foods taken by shorthead redhorse, are probably different and spatially distinct from those of other sympatric redhorses. Yant (1979) reached similar conclusions after finding differences in the diets of shorthead, golden, and black redhorses.

The food habits of 14 juveniles (53–180 mm total length) were similar to those of the adults. Catostomidae Group D larvae (see earlier description) from the Kankakee River consumed unidentified matter and diatoms.

PARASITES

External parasites were discovered during a cursory examination of fishes as they were being weighed and measured. Shorthead redhorse were usually free of macroparasites, as were other redhorses although other fishes in this area frequently hosted parasites. In 1979, Myxosporidia occurred on 6 percent of the shorthead redhorse examined during November. In May and August of 1979, those parasitic protozoans occurred on only 1 percent and 2 percent of the specimens, respectively. Leeches were found on only 1 of 222 shorthead redhorse examined in 1979; no other redhorse species hosted leeches. In contrast, depending on the season, 9–20 percent of green sunfish had leeches, as did largemouth bass (11–21 percent), longear sunfish (2–12 percent), rock bass (6–21 percent), smallmouth bass (10–22 percent), and channel catfish

(50–70 percent). Six leech species were among those identified. Digenetic trematodes occurred in seven fish species in 1979; however, no redhorses were hosts.

Internal parasites were found in the digestive tracts of redhorses when these fish were examined for food habits. Shorthead redhorse was the least heavily parasitized of the redhorses examined (Table 8). Robinson & Jahn (1980) found 3 of 10 shorthead redhorse from pool 20 of the Mississippi River infected with *Rhabdochona cascadilla, Camallanus oxycephalus*, and *Cystidicola stigmatura*. The only shorthead redhorse specimen examined by Wenke (1968) contained nematodes. Essex & Hunter (1926) found 5 of 13 shorthead redhorse from the Rock River, Illinois, infected with nematodes and/or Acanthocephala and the one specimen from the Mississippi River had Acanthocephala while none of six golden redhorse from the Rock River was parasitized. In two studies of Lake Erie fish parasites, two of two shorthead redhorse were infected (Bangham & Hunter 1939) and two of three fish hosted parasites (Bangham 1972). Hoffman (1967), Bangham (1972), Margolis & Arthur (1979), and Williams (1980) list numerous parasites known to infect shorthead redhorse. Several parasite specimens from shorthead redhorse in the Kankakee River represented new host and state records.

TABLE 8.—Percent occurrence and numbers of specimens per host (in parentheses) of internal parasites found in redhorse suckers of the Kankakee River.

	Shorthead redhorse	Golden redhorse	Silver redhorse
No. of specimens examined	90	23	7
Nematoda			
Rhabdochona cascadilla	13(>100)	4(>100)[a]	14(>100)[a]
Camallanus ancylodirus	3(1)[a]	43(1-5)[a]	. . .
Caryophyllaeidae (Cestoda)			
Isoglaridacris longus	2(2)[b]	. . .	. . .
I. chetekenis	. . .	. . .	43(2-8)[a]
I. folius	. . .	26(1-3)[b]	. . .
Isoglaridacris sp.	1(2)	. . .	. . .
Glaridarcris catostomi	. . .	13(1-5)[a]	14(2)[a]
Acanthocephala			
Acanthocephalus dirus	8(1-2)[c]	26(1-14)	. . .
Pomphorynchus bulbocolli	2(1-2)	22(1-12)[c]	. . .
Neoechinorynchus sp.	. . .	9(1-2)	. . .

[a]New host and state record
[b]New state record
[c]New host record

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LITERATURE CITED

BANGHAM, R. V. 1972. A resurvey of the fish parasites of western Lake Erie. Bulletin of the Ohio Biological Survey 4(2).

______, and G. W. HUNTER III. 1939. Studies on fish parasites of Lake Erie. Distributional studies. Zoologica 24:385–448.

BARKER, B., J. B. CARLISLE, and R. NYBERG. 1967. Kankakee River basin study. A comprehensive plan for water resource development. State of Illinois Department of Public Works and Buildings, Bureau of Water Resources, Springfield, Illinois.

BARNICKOL, P. G., and W. C. STARRETT. 1951. Commercial and sport fishes of the Mississippi River between Caruthersville, Missouri and Dubuque, Iowa. Illinois Natural History Survey Bulletin 25:267–350.

BECKER, G. C. 1964. The fishes of Lakes Poygan and Winnebago. Wisconsin Academy of Science, Arts and Letters Transactions 53:29–52.

______ 1983. The fishes of Wisconsin. University of Wisconsin Press, Madison, Wisconsin.

BERGMANN, H., J. HUTTON, R. GRAHAM, W. DIMOND, and W. KRAUS. 1980. 1979 fish egg and larvae study. Section 5 *in* Construction and preoperational aquatic monitoring program for the Kankakee River. Braidwood Station third annual report. Illinois Natural History Survey, Champaign, Illinois.

BOWMAN, M. L. 1970. Life history of the black redhorse, *Moxostoma duquesnei* (Lesueur), in Missouri. American Fisheries Society Transactions 99:546–559

BUR, M. T. 1976. Age, growth and food habits of Catostomidae in Pool 8 of the Upper Mississippi River. Master's thesis, University of Wisconsin, LaCrosse.

BURR, B. M., and M. A. MORRIS. 1977. Spawning behavior of the shorthead redhorse, (*Moxostoma macrolepidotum*) in Big Rock Creek, Illinois. American Fisheries Society Transactions 106:80–82.

BUYNAK, G. L., and M. W. MOHR, JR. 1979. Larval development of the shorthead redhorse (*Moxostoma macrolepidotum*) from the Susquehanna River. American Fisheries Society Transactions 108:161–165.

COKER, R. E. 1930. Studies of common fishes of the Mississippi River at Keokuk. Bulletin of the Bureau of Fisheries 45:141–225.

CROSS, F. B. 1967. Handbook of fishes of Kansas. University of Kansas Publications of the Museum of Natural History. Miscellaneous Publication 45. Lawrence, Kansas.

______, and M. BRAASCH. 1969. Qualitative changes in the fish fauna of the upper Neosho River system, 1952–1967. Kansas Academy of Science Transactions 71:350–360.

CURRY, K. D. 1980. Use of a Wabash River tributary for sucker (Catostomidae) reproduction. Dissertation Abstracts International 41B (1):54.

DEACON, J. E. 1961. Fish populations following a drought in the Neosho and Marais de Cygnes rivers of Kansas. University of Kansas Publications of the Museum of Natural History 13:359–427.

DELL, M. B. 1968. A new fish tag and rapid cartridge-fed applicator. American Fisheries Society Transactions 97:57–59.

DUNSTAN, T. C. 1974. Feeding activities of osprey in Minnesota. Wilson Bulletin 86:74-76.

______, and J. F. HARPER. 1975. Food habits of bald eagles in north-central Minnesota. Journal of Wildlife Management 39:140-143.

DYMOND, J. R. 1926. The fishes of Lake Nipigon. University of Toronto Studies, Biological Series 27:1-108.

EASTMAN, J. T. 1977. The pharyngeal bones and teeth of catostomid fishes. American Midland Naturalist 97:68-88.

EATON, H. H. 1928. The Finger Lakes fish problem. Pages 40-66 *in* A biological survey of the Oswego River System. Supplement to the 17th Annual Report of the New York State Conservation Department.

EDDY, S., and K. D. CARLANDER. 1942. Growth rate studies of Minnesota fish. A cooperative research project of the University of Minnesota and the Minnesota Department of Conservation, St. Paul, Minnesota.

______, and T. SURBER. 1947. Northern fishes. Charles T. Branford Company, Newton Centre, Massachusetts.

______, and J. C. UNDERHILL. 1974. Northern fishes, with special reference to the upper Mississippi valley, 3rd edition. University of Minnesota Press, Minneapolis, Minnesota.

ELROD, J. H. and T. J. HASSLER. 1971. Vital statistics of seven fish species in Lake Sharpe, South Dakota, 1964-69. Pages 27-40 *in* G. E. Hall, ed., Reservoir fisheries and limnology. American Fisheries Society Special Publication 8.

ELSER, A. A., and J. C. SCHRIEBER. 1978. Environmental effects of western coal combustion. Part 1.The fishes of Rosebud Creek, Montana. United States Environmental Protection Agency, Ecological Research Series, EPA-600-3-78-098, Duluth, Minnesota.

______, M. W. GORGES, and L. M. MORRIS. 1980. Distribution of fishes in southeastern Montana. Montana Department of Fish, Wildlife, and Parks. United States Department of the Interior, Bureau of Land Management, Mimeo.

ESSEX, H. E. and G. W. HUNTER III. 1926. A biological study of fish parasites from the central states. Illinois State Academy of Science Transactions 19:151-181.

FAJEN, O. 1975. The standing crop of smallmouth bass and associated species in Courtois Creek. Pages 240-249 *in* R. H. Stroud and H. Clepper, editors. Black bass biology and management. Sport Fishing Institute, Washington, D.C.

FITZ, R. B. 1968. Fish habitat and population changes resulting from impoundment of the Clinch River by Melton Hill Dam. Journal of the Tennessee Academy of Science 43:7-15.

FORBES, S. A. 1888. The food of fresh-water fishes. Illinois State Laboratory of Natural History Bulletin 2:433-473.

______, and R. E. RICHARDSON. 1920. The fishes of Illinois, 2nd edition. Illinois Natural History Survey, Champaign, Illinois.

FUIMAN, L. A. 1979. Descriptions and comparisons of catostomid fish larvae: Northern Atlantic drainage species. American Fisheries Society Transactions 108:560-603.

FUNK, J. L. 1953. Management and utilization of the fishery of the Black River, Missouri. University of Missouri Studies 26:113-122.

______, and R. S. CAMPBELL. 1953. The population of larger fishes in the Black River, Missouri. University of Missouri Studies 26:69-82.

______, and G. G. FLEENER. 1974. The fishery of a Missouri Ozark stream, Big Piney River, and the effects of stocking fingerling smallmouth bass. American Fisheries Society Transactions 103:757-776.

GALE, W. F., and H. W. MOHR, JR. 1976. Fish spawning in a large Pennsylvania river receiving mine effluents. Pennsylvania Academy of Science Proceedings 50:160-162.

______, and ______. 1978. Larval fish drift in a large river with a comparison of sampling methods. American Fisheries Society Transactions 107:46-55.

GAMMON, J. R. 1968. The effect of inorganic sediment on macroinvertebrate and fish populations of a central Indiana stream. Indiana Academy of Science Proceedings 78:203.

______. 1970. The response of fish to heated effluents. Indiana Academy of Science Proceedings 79:136.

GRAHAM, R. J., R. W. LARIMORE, and W. F. DIMOND. 1984. Recreational fishing in the Kankakee River, Illinois. Illinois Natural History Survey Biological Notes 120. 13 p.

GROEN, C. L., and J. C. SCHMULBACK. 1978. The sport fishery of the unchannelized and channelized middle Missouri River. American Fisheries Society Transactions 107:412-418.

HACKNEY, P. A., W. M. TATUM, and S. L. SPENCER. 1969. Life history study of the river redhorse, *Moxostoma carinatum*, in the Cahaba River, Alabama, with notes on the management of the species as a sport fish. 21st Annual Conference Southeastern Association of Game and Fish Commissioners Proceedings 21:324-332.

______, G. R. HOOPER, and J. F. WEBB. 1971. Spawning behavior, age and growth, and sport fishery for the silver redhorse, *Moxostoma anisurum* (Rafinesque) in the Flint River, Alabama. Southeastern Association of Game and Fish Commissioners Proceedings 24:569-576.

HALL, G. E. 1954. Observations on the fishes of the Fort Gibson and Tenkiller Reservoir areas, 1952. Oklahoma Academy of Science Proceedings 33:55-63.

______, and G. A. MOORE. 1954. Oklahoma lampreys: Their characterization and distribution. Copeia 1954:127-135.

HARLAN, J. R., and E. B. SPEAKER. 1969. Iowa fish and fishing, 4th edition. Iowa Conservation Commission, Des Moines, Iowa.

HOFFMAN, G. L. 1967. Parasites of North American freshwater fishes. University of California Press. Berkeley and Los Angeles, California.

HOGUE, J. J., JR., R. WALLUS, and L. K. KAY. 1976. Preliminary guide to the identification of larval fishes in the Tennessee River. Tennessee Valley Authority, Division of Forestry, Fisheries, and Wildlife Development, Technical Note B19.

IVENS, J. L., N. G. BHOMIK, A. R. BRIGHAM, and D. L. GROSS. 1981. The Kankakee River yesterday and today. Illinois State Water Survey, Miscellaneous Publications 60.

JENKINS, R. E. 1970. Systematic studies of the catostomid fish tribe Moxostomatini. Part I and Part II. Doctoral dissertation. Cornell University, Ithaca, New York.

______. 1980. *Moxostoma macrolepidotum* (Lesueur), shorthead redhorse. Pages 427-428 *in* D. S. Lee, C. R. Gilbert, S. H. Hocutt, R. E. Jenkins, D. E. McAllister, and J. R. Stauffer, Jr. Atlas of North American freshwater fishes. North Carolina State Museum of Natural History, Raleigh, North Carolina.

JUNE, F. C. 1977. Reproductive patterns in 17 species of warm water fishes in a Missouri River reservoir. Environmental Biology of Fishes 2:285-296.

LARIMORE, R. W., and P. W. SMITH. 1963. The fishes of Champaign County, Illinois, as affected by 60 years of stream changes. Illinois Natural History Survey Bulletin 28:299-382.

LUCE, W. M. 1933. A survey of the fishery of the Kaskaskia River. Illinois Natural History Survey Bulletin 20:71-123.

MARGOLIS, L., and J. R. ARTHUR. 1979. Synopsis of the parasites of fishes of Canada. Fisheries Research Board of Canada Bulletin 199.

MEYER, W. H. 1962. Life history of three species of redhorse (*Moxostoma*) in the Des Moines River, Iowa. American Fisheries Society Transactions 91:412-419.

MILLER, R. J., and H. W. Robison. 1980. The fishes of Oklahoma. Oklahoma State University Press, Stillwater, Oklahoma.

MINCKLEY, W. L. 1963. The ecology of a spring stream, Doe Run, Meade County, Kentucky. Wildlife Monographs 11.

MOORE, G. A., and J. M. PADEN. 1950. The fishes of the Illinois River of Oklahoma and Arkansas. American Midland Naturalist 44:76-95.

NIKOLSKY, G. V. 1963. The ecology of fishes. Academic Press, London and New York. As cited in W. E. Ricker, editor. Methods for assessment of fish production in fresh waters. International Biological Programme. Handbook 3, 2nd edition. Blackwell Scientific Publications, Oxford and Edinburgh, Great Britain.

NURNBERGER, P. K. 1931. The plant and animal food of the fishes of Big Sandy Lake. American Fisheries Society Transactions 60:253-259.

PETERKA, J. J. 1978. Fishes and fisheries of the Sheyenne River, North Dakota. North Dakota Academy of Science Proceedings 32:42.

PFLIEGER, W. L. 1975. The fishes of Missouri. Missouri Department of Conservation, Jefferson City, Missouri.

PURKETT, C. A., JR. 1958. Growth rates of Missouri stream fishes. Missouri Conservation Commission, Dingell-Johnson Series 1.

RIMSKY-KORSAKOFF, V. N. 1930. The food of certain fishes of the Lake Champlain watershed. Pages 88-104 *in* A biological survey of the Champlain watershed. Supplement to the 19th Annual Report of the New York State Conservation Department.

ROBERTS, J. R., A. S. W. DEFRIETAS, and M. A. J. GIDNEY. 1977. Influence of lipid pool size on bio-accumulation of the insecticide chlordane by northern redhorse suckers, *Moxostoma macrolepidotum*. Journal of the Fisheries Research Board of Canada 34:89-97.

ROBINSON, G. L. and L. A. JAHN. 1980. Some observations of fish parasites in pool 20, Mississippi River. American Microscopical Society Transactions 99:206–212.

SCHWARTZ, F. J. 1964. Natural salinity tolerances of some freshwater fishes. Underwater Naturalist 2:13–15.

SCOTT, W. B. 1967. Freshwater fishes of eastern Canada. University of Toronto Press, Toronto, Canada.

______, and E. J. CROSSMAN. 1973. Freshwater fishes of Canada. Fisheries Research Board of Canada Bulletin 184.

SIBLEY, C. K. 1929. The food of certain fishes of the Lake Erie drainage basin. Pages 180–188 *in* A biological survey of the Erie-Niagara system. Supplement to the 18th Annual Report of the New York State Conservation Department.

______, and V. N. RIMSKY-KORSAKOFF. 1931. Food of certain fishes in the watershed. Pages 109–120 *in* A biological survey of the St. Lawrence watershed. Supplement to the 20th Annual Report of the New York State Conservation Department.

SIMPSON, A. C. 1951. The fecundity of the plaice. Fishery Investigations. Ministry of Agriculture, Food and Fisheries, London Series 2, 17:1–27. As cited in W. E. Ricker, editor. 1968. Methods for assessment of fish production in fresh waters. International Biological Programme, Handbook 3. Blackwell Scientific Publications, Oxford and Edinburgh, Great Britain.

SKELLY, T. M., and M. J. SULE. 1983. The pallid shiner, *Notropis amnis* Hubbs and Greene, a rare Illinois fish. Illinois State Academy of Science Transactions 76:131–140.

SMITH, C. C. 1977. The biology of three species of *Moxostoma* (Pisces-Catostomidae) in Clear Lake, Hocking and Fairfield Counties, Ohio, with emphasis on the golden redhorse, *Moxostoma erythrurum* (Rafinesque). Doctoral dissertation. The Ohio State University, Columbus, Ohio.

SMITH, P. W. 1971. Illinois streams: A classification based on their fishes and an analysis of factors responsible for disappearance of native species. Illinois Natural History Survey Biological Notes 76. 14 p.

______. 1979. The fishes of Illinois. University of Illinois Press, Urbana, Illinois.

STARRETT, W. C. and S. A. PARR. 1951. Commercial fishes of Illinois rivers: A statistical report for 1950. Illinois Natural History Survey Biological Notes 25. 35 p.

STATISTICAL ANALYSIS SYSTEM. 1979. SAS user's guide. SAS Institute, Inc. Raleigh, North Carolina. 449 p.

SURBER, E. W., and E. A. SEAMAN. 1949. The catches of fish in two smallmouth bass streams in West Virginia. Conservation Commission of West Virginia, Technical Bulletin 1.

TESCH, F. W. 1971. Age and growth. Pages 98–130 *in* W. E. Ricker, ed. Methods for assessment of fish production in fresh waters. International Biological Programme, Handbook 3, 2nd edition. Blackwell Scientific Publications. Oxford and Edinburgh, Great Britain.

THOMPSON, D. H. 1933. The migration of Illinois fishes. Illinois Natural History Survey Biological Notes 1. 25 p.

TRAUTMAN, M. B. 1981. The fishes of Ohio, 2nd edition. The Ohio State University Press, Columbus, Ohio.

TSAI, C-F. 1970. Changes in fish populations and migration in relation to increased sewage pollution in Little Patuxent River, Maryland. Chesapeake Science 11:34–41.

VAN METER, H. D., and M. B. TRAUTMAN. 1970. An annotated list of the fishes of Lake Erie and its tributary waters exclusive of the Detroit River. Ohio Journal of Science 70:65–78.

VERMEER, K. 1973. Food habits and breeding range of herring gulls in the Canadian prairie provinces. Condor 75:478–480.

VLADYKOV, V. D. 1933. Biological and oceanographic conditions in Hudson Bay. 9. Fishes from the Hudson Bay region (except the Coreogonidae). Contributions to Canadian Biology and Fisheries 8:13–61. As cited in W. B. Scott, and E. J. Crossman. 1973. Freshwater fishes of Canada. Fisheries Research Board of Canada Bulletin 184.

WALBURG, C. H. 1964. Fish population studies, Lewis and Clark Lake, Missouri River, 1956–1962. United States Fish and Wildlife Service Special Scientific Report — Fish 482.

WENKE, T. L. 1968. Abundance of *Crepidostomum* and other intestinal helminths in fishes from pool 19, Mississippi River. Iowa State Journal of Science 43:211–222.

WILLIAMS, D. D. 1980. Caryophyllidean tapeworms. The Museum of Natural History, Stevens Point, Wisconsin, Reports on the Fauna and Flora of Wisconsin 17.

YANT, R. D. 1979. Food habits of three sympatric species of *Moxostoma* Pisces: Catostomidae in the Wabash River, Indiana. Master's thesis. Purdue University, West Lafayette, Indiana.

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