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(Contribution from The State Biological Survey, and from the Department of Zoology of The University of Kansas)

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Introduction

The Wakarusa River rises in the eastern edge of the Flint Hills and flows approximately 50 miles in an easterly direction and empties into the Kansas River near Eudora; with its tributaries, the Wakarusa drains 458 square miles in parts of Wabaunsee, Shawnee, Osage, and Douglas counties of northeastern Kansas (Fig. 1). The average gradient is 6.3 feet per mile. Turbidity is consistently more than 100 ppm in the lower portions of the mainstream and major tributaries, but is usually lower in the upper portions of tributaries. The channel of the mainstream is intrenched in its own alluvium (Dufford, 1958:36) and has high, muddy banks and mud- or sand-bottom; the upper parts of tributaries have lower banks and bottoms of gravel, rubble, or bedrock, although a few (such as Cole Creek) have areas of sandy bottom. A fringe forest of deciduous trees occurs along most streams. The topography and geology of the area have been discussed by Todd (1911), Franzen and Leonard (1943), and Dufford (1958).

The five-year period prior to 1957 was the driest in the 70-year history of weather-records in Kansas (Metzler *et al.*, 1958). Streams throughout the Wakarusa Basin suffered intermittency and, according to Mr. Melvon H. Wertzberger, the local Work Unit Conservationist with the Soil Conservation Service, many of them dried completely or contained only a few widely-scattered, stagnant pools. The effect of the drought on stream-flow at the mainstream gaging station 2.1 miles south of Lawrence is presented in Table 1.

According to the Division of Sanitation, Kansas State Board of Health, no untreated domestic sewage or industrial waste is discharged into the Wakarusa River System at this time.

The Wakarusa Watershed Association is in the preliminary stages of establishing a watershed control project in the basin. Objectives of the project are the improvement of land-use practices and the construction of several headwater retention structures. Such a program should have a long-range effect on the physical and biological characteristics of the streams of the basin. With this in mind we think it important to document the nature of the present fish-fauna and to attempt a historical résumé of the fauna, based on collections made in the past sixty years.

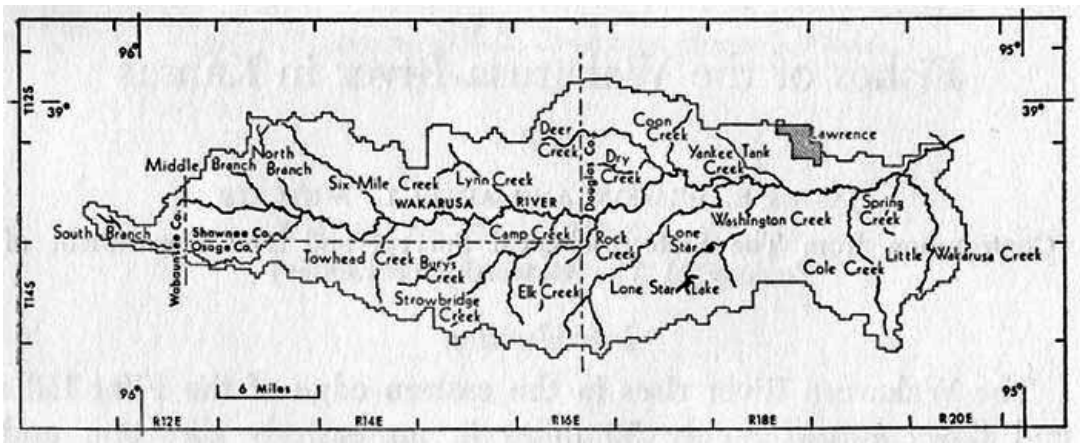

Fig. 1.Map of the Wakarusa River and its principal tributaries.

Methods

Sodium cyanide, a 110-volt (600-watt) A.C. electric shocker, and seines (6, 12, and 25 feet long, 4 to 8 feet deep having ¼-in. mesh) were used to collect fish in 1959. All fishes were preserved and examined in the laboratory with the exception of large, common species that were identified in the field and returned to the stream.

Table 1. Record of Stream-flow, Wakarusa River 2.1 mi. S Lawrence, Kansas.

Water Year (Oct. 1 to Oct. 1)	Days with no flow	Days with flow less than 5cfs	Maximum for year	Mean for year
1951	0	0	22,600	596.0
1952	0	85	5,000	179.0
1953	83	191	685	10.2
1954	194	123	2,010	17.2
1955	116	174	2,630	22.3
1956	122	183	2,550	20.7
1957	141	84	11,700	137.0
1958	0	9	6,370	213.0
1959	0	46	8,000	184.0

Collection Sites

The following collections were made by personnel of the State Biological Survey of Kansas in the 1890's, from 1910 to 1912, and from 1942 to 1953. These collections, all from Douglas County, are deposited in the Museum of Natural History, The University of Kansas. In the annotated list they are designated "KU":

1. Rock Creek, 1898.
2. Washington Creek, 1898.
3. "2½ miles east of Twin Mounds," Rock Creek, Sec. 1, T. 14 S, R. 17 E, 1899.
4. Rock Creek, 1911.
5. Rock Creek, 1912.
6. Washington Creek, 2¾ mi. W and 1 mi. S Lawrence, 1946.
7. Tributary of Yankee Tank Creek, Secs. 4 and 9, T. 13 S, R. 19 E, July 24, 1951.
8. Rock Creek, Sec. 19, T. 13 S, R. 19 E, Aug. 11, 1951.
9. Drainage ditch, tributary to Wakarusa River, Sec. 18, T. 13 S, R. 20 E, Aug. 24, 1951.
10. Wakarusa River, Sec. 20, T. 13 S, R. 20 E, Aug. 24, 1951.
11. Rock Creek, Sec. 27, T. 13 S, R. 18 E, Sept. 28, 1951.
12. Wakarusa River, Secs. 16 and 17, T. 13 S, R. 20 E, June 21, 1952.
13. Little Wakarusa River, Sec. 18, T. 13 S, R. 21 E, June 21, 1952.
14. Rock Creek, Sec. 33, T. 13 S, R. 18 E, Oct. 2, 1952.
15. Wakarusa River, Sec. 14, T. 13 S, R. 20 E, March 28, 1953.

Several collections made between 1912 and 1948 are deposited in the University of Michigan Museum of Zoology. In the annotated list these collections, all from Douglas County, are designated "UMMZ":

1. Rock Creek, June 9, 1912.
2. Oxbow Lake, 6 mi. E Lawrence, 1924 (several dates).
3. Wakarusa River, 7 mi. SE Lawrence, April 9, 1924.

4. Rock Creek, 9 mi. SW Lawrence, April 14, 1924.

5. Rock Creek, 12½ mi. S and 8½ mi. E Topeka, July 4, 1948.

Our collections, all of which were made in 1959, are identified by the letters DM followed by a station-number. Stations are numbered consecutively beginning at the mouth of the Wakarusa River and proceeding up each tributary as it is encountered.

Description of Stations

1. Wakarusa River, Sec. 4, T. 13 S, R. 21 E, March 14 and Oct. 18. Mouth of Wakarusa to one-half mile upstream; width *ca.* 25 feet; depth to 4 feet; bottom mud; banks mud, 10 feet high; current slight; water turbid.

2. Wakarusa River, Sec. 7, T. 13 S, R. 21 E, March 21. Width *ca.* 25 feet; bottom mud; banks mud, 10-20 feet high.

3. Little Wakarusa Creek, Sec. 19, T. 13 S, R. 21 E, May 2. Long sandy riffles, 6-10 inches deep; pools to 3 feet deep; bottom sand and mud; water slightly turbid.

4. Little Wakarusa Creek, Secs. 29 and 32, T. 13 S, R. 21 E, May 2. Riffles 8-10 inches deep having rubble bottom; pools to 4 feet deep having mud bottom; width 15-30 feet.

5. Little Wakarusa Creek, Sec. 7, T. 14 S, R. 21 E, May 2. Riffles 6-8 inches deep having gravel bottom; pools to 3 feet deep; bottom gravel and mud; width 8 to 15 feet; water slightly turbid.

6. Cole Creek, Sec. 21, T. 13 S, R. 20 E, May 2. Riffles 8-12 feet wide, 6 inches deep, bottom of flat, fragmented shale; pools having shale and mud bottom; water slightly turbid.

7. Cole Creek, Sec. 10, T. 14 S, R. 20 E, May 2. Small, shallow creek having sand bottom; water slightly turbid.

8. Cole Creek, Sec. 23, T. 14 S, R. 10 E, May 2. Banks steep, 20 feet high; bottom sand and hard clay; water clear.

9. Tributary to Yankee Tank Creek, Sec. 10, T. 13 S, R. 19 E, May 14. Width 2-10 feet; bottom mud; water turbid.

10. Washington Creek, Sec. 6, T. 14 S, R. 19 E, Feb. 26. Width *ca.* 25 feet; bottom rubble and gravel; water clear.

11. Washington Creek, Sec. 11, T. 14 S, R. 18 E, Feb. 26, March 28, March 30, and Oct. 18. One-half mile below dam at Lone Star Lake; width 10-15 feet; bottom gravel; water clear.

12. Tributary of east arm of Lone Star Lake, Sec. 13, T. 14 S, R. 18 E, March 31. Width 5-7 feet; bottom limestone rubble; water clear.

13. Tributary of southeast arm of Lone Star Lake, Sec. 24, T. 14 S, R. 18 E, March 30.

14. Tributary of southwest arm of Lone Star Lake, Sec. 22, T. 14 S, R. 18 E, March 30.

15. Tributary to Rock Creek, Sec. 34, T. 13 S, R. 18 E, Feb. 26. Width 10 feet; water clear.

16. Rock Creek, Sec. 7, T. 14 S, R. 18 E, July 25 and Oct. 18. Bottom gravel and mud; water clear.

17. Rock Creek, Sec. 23, T. 14 S, R. 17 E, July 25. Rubble riffles; pools having mud and sand bottom; water clear.

18. Wakarusa River, Sec. 14, T. 13 S, R. 18 E, July 23. Rubble riffles; pools having sand and mud bottom; water turbid.

19. Coon Creek, Sec. 27, T. 12 S, R. 18 E, March 21. Bottom rubble and mud; water clear.

20. Dry Creek, Sec. 8, T. 13 S, R. 18 E, May 16. Bottom rubble; water clear.

21. Deer Creek, Sec. 4, T. 13 S, R. 18 E, July. Pools having mud bottom; rubble riffles; water turbid.

22. Deer Creek, Sec. 31, T. 12 S, R. 18 E, March 21. Bottom mud and shale;

water clear.

23. Elk Creek, Sec. 2, T. 14 S, R. 17 E, July 25. Stream intermittent; bottom rubble; water turbid.

24. Wakarusa River, ¼ mi. NE mouth of Elk Creek, Sec. 26, T. 14 S, R. 17 E, Oct. 17. Bottom mud and rubble; water turbid.

25. Camp Creek, Sec. 12, T. 14 S, R. 16 E, Oct. 17. Upland creek having clear, flowing water; rubble riffles alternating with shallow pools.

26. Strowbridge Creek, Sec. 11, T. 14 S, R. 16 E, July 25. Pools having bottom of mud and detritus, emitting malodorous gases; rubble riffles; water turbid.

27. Tributary of Strowbridge Creek, Sec. 29, T. 14 S, R. 16 E, July 30. Bottom rubble and mud; water clear, almost intermittent.

28. Lynn Creek, Sec. 24, T. 13 S, R. 16 E, April 4. Bottom rubble, mud and gravel; depth more than 6 feet; water turbid.

29. Lynn Creek, Sec. 14, T. 13 S, R. 16 E, May 27. Bottom mud and rubble; water turbid.

30. Lynn Creek, Secs. 14 and 15, T. 13 S, R. 16 E, July 28. Pools having sand bottom; rubble riffles; water clear.

31. Lynn Creek, Sec. 10, T. 13 S, R. 16 E, July 28. Bottom sand, rubble and mud; water clear.

32. Tributary to Lynn Creek, Secs. 11 and 12, T. 13 S, R. 16 E, May 16. Bottom rubble; water clear.

33. Burys Creek, Sec. 8, T. 14 S, R. 16 E, July 25. Bottom mud, rubble and detritus; rubble riffles; water turbid.

34. Wakarusa River, Sec. 28, T. 13 S, R. 16 E, July 28. Bottom mud and rubble; rubble riffles; water turbid.

35. Unnamed tributary of Wakarusa River, Sec. 24, T. 13 S, R. 15 E, April 4. Bottom mud; water turbid.

36. Six Mile Creek, Sec. 17, T. 13 S, R. 15 E, May 16. Bottom gravel and rubble; rubble riffles; water clear.

37. Wakarusa River, Sec. 25, T. 13 S, R. 14 E, May 16. Bottom mud and coarse sand; water turbid.

38. South Branch of Wakarusa River, Sec. 8, T. 14 S, R. 14 E, July 30. Bottom rubble and gravel; water clear.

39. South Branch of Wakarusa River, Sec. 5, T. 14 S, R. 13 E, July 30. Bottom bedrock; flow slight; rubble riffles; water turbid.

40. South Branch of Wakarusa River, Sec. 36, T. 13 S, R. 12 E, July 30. Bottom mud; rubble riffles; water turbid.

41. Middle Branch of Wakarusa River, Sec. 21, T. 13 S, R. 14 E, April 4. Bottom mud; gravel riffles; water turbid.

42. Tributary of Middle Branch of Wakarusa River, Sec. 29, T. 13 S, R. 14 E, April 4. Bottom mud and bedrock; rubble riffles; water turbid.

Annotated List of Species

Lepisosteus osseus oxyurus Rafinesque. DM 2. The longnose gar is abundant in most large rivers of Kansas. The scarcity in the Wakarusa is probably attributable to the small size of the stream.

Lepisosteus platostomus Rafinesque. UMMZ 2. The shortnose gar is common in the Kansas River but seems less inclined than the longnose gar to ascend small streams.

Dorosoma cepedianum (LeSueur). UMMZ 2; DM 1. Gizzard shad.

Carpiodes velifer (Rafinesque). UMMZ 2. This record for the highfin carpsucker is based on a single specimen (UMMZ 63182). It was re-examined by Bernard Nelson who stated (personal communication) "The dorsal fin is broken and the 'pea-lip' smashed. A trace of the 'pea' is still discernible. The body is deeply compressed and other measurements agree with [those of] *C. velifer*. It was identified as *C. cyprinus* at first, but later changed by Hubbs." *C. velifer*

probably was more abundant in Kansas during and before the early 1900's than at present. Several early records of the species are available, but the only specimen obtained in Kansas in recent years was captured in the Neosho River by Deacon in 1958.

Moore (1957:80) states that *C. velifer* occurs in the clearer rivers and lakes of the Mississippi valley, westward to Nebraska and Oklahoma. The almost complete disappearance of this species from Kansas probably resulted from an increase in turbidity, of the rivers, accompanying settlement and cultivation of the land.

Carpiodes carpio carpio (Rafinesque). KU 5, 12, 15; DM 1, 16, 21, 37. The river carpsucker occurred at stations scattered throughout the drainage, except in the smallest creeks. The largest numbers were found in the lower mainstream.

Ictiobus cyprinella (Valenciennes). KU 10; UMMZ 2; DM 1. The big-mouth buffalo was taken only near the mouth of the river; black buffalo, *Ictiobus niger* (Rafinesque) and smallmouth buffalo, *Ictiobus bubalus* (Rafinesque), possibly also occur there but were not taken in our survey.

Catostomus commersonnii commersonnii (Lacépède). KU 4, 8, 14; UMMZ 1, 5; DM 10, 11, 15, 16, 21, 23, 25, 26, 27, 29, 34, 42. The white sucker occurs primarily in upstream-habitats in the Wakarusa Basin.

Moxostoma aureolum (LeSueur). KU 15; DM 1. The northern redhorse was taken only in downstream portions of the basin. Minckley and Cross (1960) regard specimens from the Wakarusa River as intergrades between *M. a. aureolum* and *M. a. pisolabrum*.

Cyprinus carpio Linnaeus. KU 9, 12, 15; DM 1, 2. The carp, though most abundant in downstream situations, probably occurs throughout the drainage and is a potential pest in all impoundments likely to be constructed in the basin.

Notemigonus crysoleucas (Mitchill). KU 9; DM 9, 27, 33, 41. The golden shiner was found only in tributaries.

Semotilus atromaculatus (Mitchill). KU 2, 3, 5, 6, 7, 8, 10, 12, 13, 14; UMMZ 4, 5; DM 3, 9, 10, 11, 15, 16, 17, 18, 19, 20, 21, 23, 24, 25, 26, 29, 30, 31, 32, 33. The creek chub was usually abundant in small upland tributaries.

Hybopsis biguttata (Kirtland). KU 1, 3; UMMZ 4. The hornyhead chub seemingly was common in early collections but has not been found since 1924. The fish characteristically inhabits clear streams having gravel-bottom. Disappearance of the species from the Wakarusa may have resulted from increased siltation and intermittency of flow.

Hybopsis storeriana (Kirtland). KU 10; UMMZ 3.

Hybopsis aestivalis (Girard). KU 10; UMMZ 3; DM 1. This species and the preceding one are common in the Kansas River but do not ascend far up the Wakarusa. *Hybopsis gelida* (Girard) and *Hybopsis gracilis* (Richardson) occur in the Kansas River and may be expected in the lowermost portion of the mainstream of the Wakarusa.

Notropis percobromus (Cope). KU 12; DM 1, 2. The plains shiner shows little tendency to move far upstream from the Kansas River, where it is abundant.

Notropis umbratilis (Girard). KU 5, 11, 14; UMMZ 1, 4, 5; DM 9, 10, 11, 16, 17, 18, 21, 22, 23, 24, 25, 26, 29, 32, 33, 34, 35, 37, 38, 39, 41. In our survey the redfin shiner was the most abundant species at several stations, especially at those in the lower and middle portions of tributaries to the mainstream.

Notropis cornutus frontalis (Agassiz). KU 1, 2, 3, 8, 11, 14; DM 16. Judging from the numbers preserved in early collections, the common shiner was more abundant and widespread in the 1890's than in 1959. A watershed improvement program effecting more stable flow and decreased turbidity might benefit this shiner.

Notropis lutrensis (Baird and Girard). KU 1, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15; UMMZ 1, 2, 3, 4, 5; DM all stations *except* 5, 11, 12, 13, 14, 19, 35. The red shiner was ubiquitous, and was the dominant species at a majority of stations.

Notropis stramineus (Cope). KU 7, 8, 10, 11, 12, 13, 14, 15; DM 1, 2, 3, 4, 6, 7, 9, 10, 15, 16, 17, 24, 25, 31, 37. The sand shiner was most common in two environments: (1) near the mouth of the Wakarusa where abundance of the species may be attributed to the close proximity of a large population of *N. stramineus* in the Kansas River, and (2) in upland tributaries that drain areas in which sand is found (especially in Cole Creek).

Notropis topeka (Gilbert). KU 1, 14; UMMZ 1, 4, 5; DM 22, 25, 27, 33.

Minckley and Cross (1959) describe the habitat of the Topeka shiner as pools of clear upland tributaries with slight flow. We found the Topeka shiner in such habitat in Deer Creek, Strowbridge Creek and Burys Creek. The largest population occurred in a tributary of Strowbridge Creek. This stream probably was intermittent in 1958, and Deer and Burys creeks may have been intermittent at some time in 1957-1959. Although Minckley and Cross (1959:215) have stated that Rock Creek is "unsuitable for this species," we suspect that Rock Creek served as a refugium for *N. topeka* in time of drought. It was found there (KU 14) in 1952, and again (DM 16) on April 8, 1960.

Notropis buchanani Meek. UMMZ 3. Inclusion of the ghost shiner is based on two specimens (UMMZ 63107) collected by C. W. Creaser in 1924.

Phenacobius mirabilis (Girard). KU 6, 7, 8, 10, 11, 12, 13, 15; UMMZ 4; DM 3, 6, 16, 18, 21, 22, 34. The suckermouth minnow occurred in several collections but was nowhere dominant. The largest populations were at DM 3, 6, and 22.

Hybognathus nuchalis Agassiz. KU 8, 15; UMMZ 3; DM 1, 6. The silvery minnow was taken only in the downstream portion of the Wakarusa and its lower tributaries.

Pimephales promelas Rafinesque. KU 6, 7, 8, 9, 10, 11, 13, 14, 15; UMMZ 1, 4, 5; DM all stations *except* 1, 8, 10, 11, 13, 14, 30. The fathead minnow was ubiquitous, and was dominant at several stations on the smallest creeks.

Pimephales notatus (Rafinesque). KU 1, 6, 11, 12, 14, 15; UMMZ 1, 4, 5; DM 6, 8, 10, 12, 16, 17, 18, 24, 25, 26, 37, 41. The bluntnose minnow occurred at several stations on tributaries but was not common.

Campostoma anomalum (Rafinesque). KU 7, 8, 10, 11, 12, 13, 14; UMMZ 4, 5; DM 3, 9, 10, 11, 13, 15, 16, 17, 18, 19, 20, 21, 22, 24, 25, 30, 32, 33, 34. The stoneroller was usually abundant at upstream stations and was found in the mainstream of the Wakarusa River.

Ictalurus punctatus (Rafinesque). KU 6, 8, 10, 11, 12, 13, 15; DM 1, 2, 18, 24. Channel catfish were taken by us only in the mainstream; anglers sometimes catch channel catfish in several of the tributaries.

Ictalurus melas (Rafinesque). Black bullhead. KU 1, 2, 5, 6, 9, 14; UMMZ 2, 5; DM 5, 6, 7, 16, 17, 21, 25, 26, 31, 32, 33, 38, 39, 40.

Ictalurus natalis (LeSueur). Yellow bullhead. KU 9, 14.

Pylodictis olivaris (Rafinesque). KU 8, 10; DM 18. The flathead catfish comprises a small but consistent part of the sport fishery of the Wakarusa, especially in the mainstream.

Noturus flavus Rafinesque. Stonecat. KU 10, 11, 12.

Noturus exilis (Nelson). DM 11. The slender madtom is recorded only from riffles in Washington Creek below Lone Star Lake. These riffles, because of the influence of the reservoir, are probably the most permanent in the drainage at present. The slender madtom may become more widespread if other reservoirs are built that stabilize stream flow in the basin.

Perca flavescens (Mitchill). The yellow perch is present in Lone Star Lake, and probably will become established in future reservoirs that are constructed.

Percina caprodes (Rafinesque). Log perch. KU 11, 14, 15; DM 11, 12, 16, 37, 41.

Etheostoma nigrum Rafinesque. KU 8, 14; UMMZ 1, 3, 4, 5; DM 16, 17. The johnny darter, like the common shiner, has been taken recently only in Rock Creek, where darters flourish. Often, ten to fifteen johnny darters were taken with one sweep of a 6- or 12-foot seine in shallow pools having mud bottoms. Watershed improvement may benefit this species.

Etheostoma spectabile pulchellum (Girard). KU 7, 10, 12, 14; UMMZ 4, 5; DM 10, 11, 12, 13, 14, 16, 17, 21, 22, 23, 24, 26. The orangethroat darter was most abundant in Deer Creek, Rock Creek and Washington Creek.

Micropterus salmoides salmoides (Lacépède). DM 16, 17, 21, 30, 32, 34, 37. The largemouth bass occurs throughout the drainage at present, and should become established without supplemental stocking in future reservoirs. The absence of this species in early collections suggests that widespread stocking of bass in various impoundments in the area in recent years has increased populations in the streams. An anomalous individual, lacking a right pelvic fin, was found in Lone Star Lake.

Chaenobryttus gulosus (Cuvier). The warmouth is present in Lone Star Lake.

This species typically inhabits lakes and probably will establish itself in other reservoirs.

Lepomis cyanellus Rafinesque. Green sunfish. KU 6, 8, 9, 10, 11, 13, 14, 15; UMMZ 2, 4, 5; DM all stations *except* 11, 12, 13, 14, 27, 30, 31, 39, 40.

Lepomis macrochirus Rafinesque. KU 6; DM 10, 16, 17, 24, 31, 33, 37, 41, 42. Both bluegill and green sunfish are common throughout the drainage and will contribute to the sport fishery of any reservoir constructed. The absence of the bluegill in early collections suggests that its population has increased recently owing to introductions in many impoundments.

Lepomis humilis (Girard). Orangespotted sunfish. KU 6, 9, 11, 14, 15; UMMZ 1, 2, 4, 5; DM 4, 6, 16, 17, 21, 23, 24, 25, 26, 32, 33, 34, 37, 38, 39, 40, 41, 42.

Lepomis megalotis breviceps (Rafinesque). Longear sunfish. KU 8 (one individual taken in Rock Creek, 1951).

Pomoxis annularis (Rafinesque). KU 9, 15; UMMZ 2. White crappie occur in Lone Star Lake and in farm ponds in the basin.

Pomoxis nigromaculatus (LeSueur). Specimens of black crappie were obtained from Lone Star Lake and in farm ponds in the basin.

Aplodinotus grunniens Rafinesque. Drum. KU 12.

Discussion

Our data show that the present fish-fauna of the Wakarusa River has three major components:

(1) A group of species that are mainly restricted to the lower mainstream; all of them are common in the Kansas River (*Lepisosteus osseus*, *Carpiodes carpio carpio*, *Ictiobus cyprinella*, *Moxostoma aureolum*, *Cyprinus carpio*, *Hybopsis storeriana*, *Hybopsis aestivalis*, *Notropis percobromus*, *Hybognathus nuchalis* and *Pylodictis olivaris)*.

(2) A group of species that are ubiquitous; they comprised the entire fauna in some tributaries, despite the existence of habitats that seemed suitable for other species (*Notropis lutrensis*, *Pimephales promelas*, *Ictalurus melas*, and *Lepomis cyanellus*).

(3) A group of species having distributions centered in Rock Creek, Washington Creek, Deer Creek, and some nearby tributaries (*Catostomus commersonnii*, *Semotilus atromaculatus*, *Hybopsis biguttata*, *Notropis cornutus*, *Notropis topeka*, *Notropis umbratilis*, *Phenacobius mirabilis*, *Pimephales notatus*, *Campostoma anomalum*, *Noturus exilis*, *Percina caprodes*, *Etheostoma nigrum* and *Etheostoma spectabile*).

The distributions of groups (2) and (3) provide clues to the effect of drought on the fish-population, and on the relative ability of various species to repopulate areas where they have been extirpated.

Larimore *et al.* (1959) studied the re-establishment of stream-fish following drought in Smiths Branch, a small warmwater stream in Illinois. They found that 21 of the 29 species regularly occurring there reinvaded most of the stream-course within two weeks after the resumption of normal flow, and that all but three species were present by the end of the first summer. Our study indicates a much slower rate of dispersal by many of the same species. This is presumably attributable to the ecological barrier presented by the Wakarusa mainstream.

During the drought (1952-1956) the mainstream with its turbid water and mud bottom could hardly have served as a refugium for species requiring the clear water and gravel bottom of upland tributaries. Probably the main refugia for these species [group (3)] were in the upper portions of Rock Creek, Washington Creek and possibly Deer Creek. While collecting we observed that these creeks had larger proportions of gravel-rubble bottom, clearer water, deeper pools, and appeared to be more stable than other creeks in the drainage. In Washington Creek, Lone Star Lake enhanced stability of flow.

At the end of the drought, fishes in group (3) probably were extirpated or decimated in other tributaries of the Wakarusa. After normal flow recommenced in 1956, fishes re-entered the previously uninhabitable streams or stream-segments. The rate of redispersal by various species probably depended upon their innate mobility, and upon their tolerance of the muddy mainstream of the Wakarusa.

Our observations suggest that certain species in group (3) dispersed rapidly from refugia in Rock Creek, Washington Creek, and possibly Deer Creek. These species may, of course, have survived in a few remaining pools in tributaries throughout the basin, thereby

necessitating only minor redispersal within these tributaries following drought.

Species of group (3) that were most tolerant of drought or that dispersed most rapidly are *Catostomus commersonnii*, *Notropis umbratilis*, *Pimephales notatus*, and *Percina caprodes*; these were present in the uppermost portions of the basin in 1959. Fishes having lesser capacity for survival or dispersal are *Semotilus atromaculatus*, *Notropis topeka*, *Phenacobius mirabilis* and *Campostoma anomalum*; in 1959, they were not found farther upstream than Burys Creek. *Etheostoma spectabile*, the orangethroat darter, was taken in Rock Creek, Washington Creek, Deer Creek, Strowbridge Creek, Elk Creek, and at station 24 on the Wakarusa. This is a riffle-dwelling, comparatively sedentary fish, not a strong swimmer. These traits, coupled with the long, muddy pools and infrequent riffles of the Wakarusa mainstream, provide a reasonable explanation of the comparatively slow rate of dispersal by the orangethroat darter.

Several species showed no tendency for redispersal following drought, in that they were confined to Washington Creek or Rock Creek in 1959. *Noturus exilis* was taken only in Washington Creek immediately below Lone Star Lake. Rock Creek is the last stream in the Wakarusa Basin in which *Notropis cornutus*, *Hybopsis biguttata* and *Etheostoma nigrum* have survived. These species require comparatively permanent streams having pool-and-riffle habitats and gravelly bottoms for spawning. *Hybopsis biguttata* has been recorded only from Rock Creek, where it was last taken in 1924. It is interesting to note that this species had not reinvaded Smiths Branch, in Illinois, three years after the resumption of stream-flow (Larimore *et al.*, 1959). *Notropis cornutus* and *Etheostoma nigrum*, although formerly more widespread in the Wakarusa Basin, have been taken recently only in Rock Creek.

Faunal changes that have occurred in the basin in the past 60 years indicate a decrease in extent of clear, continuously flowing stream-habitat.

Comparisons with Faunas of Nearby Streams

Minckley (1959) reported 13 species from the Big Blue River Basin that were not taken in our survey of the Wakarusa. Most of the 13 are fishes that probably occur throughout the lower mainstream of the Kansas River and might enter the lower Wakarusa occasionally. *Chrosomus erythrogaster* and *Notropis rubellus* were reported by Minckley but have not been found in the Kansas River Basin east of the Flint Hills, either in recent or in early collections. On the other hand, five species have been reported from the Wakarusa but not from the Big Blue River. Two of these, *Notemigonus crysoleucas* and *Chaenobryttus gulosus*, may have been introduced by man. The remaining three, *Hybopsis biguttata*, *Noturus exilis* and *Percina caprodes*, have not been taken farther west than Mill Creek, Wabaunsee County. In general the faunas of the two systems are similar; forty species are common to both.

Comparison of the faunal list reported from the Cottonwood River drainage (Arkansas River System) by Cross (1954) with that here reported reveals 26 species in common, 19 found only in the Wakarusa and 15 species found only in the Cottonwood.

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