

Changes in Fish Assemblages, Solomon River Basin, Kansas: Habitat Alterations, Extirpations, and Introductions

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We sampled fishes four times each year at 12 sites on the Solomon, North Fork Solomon, and South Fork Solomon rivers in north-central Kansas during 1996 and 1997. Kirwin and Webster reservoirs are located on the North Fork Solomon River and South Fork Solomon River, respectively, and Wanda Reservoir inundates the confluence of these two rivers at the head of the Solomon River. Multivariate analyses identified two fish assemblages that were related to stream discharge. One fish assemblage was associated with stream segments that had lower discharges, such as those located upstream from Kirwin and Webster reservoirs. This assemblage was characterized by equal numbers of extirpations of native species and introductions of nonnative species. The other fish assemblage was associated with the reservoirs and stream segments that had higher discharges. This assemblage was characterized by a large number of species that were introduced or had immigrated into these areas. For the basin as a whole, 32% of the native species of fishes have been extirpated, and 51% of the present assemblage was comprised of nonnative species. Most of the extirpations and introductions are associated with habitat changes caused by agricultural development and the construction of impoundments. The relatively large component of the fish assemblage comprised of nonnative species reflects the trend toward homogenization of fish assemblages throughout the United States.

INTRODUCTION

General summaries of changes in the fish communities of streams in northwestern Kansas following settlement of the area by EuroAmericans have been provided by Cross and Moss (1987) and Sanders, Huggins, and Cross (1993). These changes include extirpations, range contractions, introductions, and range expansions associated with alterations in physicochemical attributes of the streams as a consequence of agricultural developments and the construction of impoundments.

In smaller tributary streams and river headwaters, the once clear, cool streamflows fed by reliable groundwater sources were altered primarily by agricultural developments that began in the late 1800s. Intensive cultivation increased the silt load (Cross and Moss, 1987; Sanders, Huggins, and Cross, 1993), and agricultural practices that retained runoff contributed to a reduction in streamflows (Jordan, 1982). Further reductions in streamflows resulted from groundwater withdrawals for irrigation (Jordan, 1982), which eliminated much of the groundwater seepage that supported streamflow and led to increased water temperatures in locations where surface water remained (Cross and Moss, 1987; Sanders, Huggins, and Cross, 1993). Changes in mean annual precipitation were only a minor factor in the decreased runoff that occurred in northwestern Kansas from 1940 through 1990 (Ratzlaff, 1994).

Many larger rivers in the region formerly had widely fluctuating, turbid flows over broad beds of shifting sand, but they have been altered by reduced streamflows and the construction of impoundments (Cross and Moss, 1987; Sanders, Huggins, and Cross, 1993). Construction of small dams, usually associated with mills, began in the late 1800s. From the late 1940s through the 1960s, several federal reservoirs were constructed on all of the principal rivers in northwestern Kansas. The reduced peak discharges and generally stable flows produced by regulated releases of water from reservoirs have caused some river channels downstream from the reservoirs to become narrower and deeper with firmer substrates (Cross and Moss, 1987). Impoundments also reduce the sediment load of water released from the reservoir, and they block the upstream movements of aquatic organisms (Cross and Moss, 1987). Diversion of reservoir releases for irrigation can threaten aquatic communities by dewatering stream segments below the diversion structures. Runoff and seepage returning to streams from cropland irrigated by groundwater or surface diversions can carry chemicals harmful to aquatic ecosystems. For example, arsenic and selenium levels in reservoir sediments in the Solomon River basin in north-central Kansas increased significantly during the latter 1900s (Christensen, 1999). Although a number of species of fishes adapted to the original conditions in the large and small streams have been extirpated from northwestern Kansas, the impoundments have made possible the successful introduction of several species of fishes adapted to lentic habitats (Cross and Moss, 1987; Sanders, Huggins, and Cross, 1993).

Both agricultural development and the construction of reservoirs and smaller impoundments have impacted streams in the Solomon River basin in north-central Kansas (Cross and Moss, 1987). The Solomon River basin encompasses 17,176 km² drained by three principal streams: the Solomon River, North Fork Solomon River, and South Fork Solomon River (Fig. 1). Streamflows in all three rivers are regulated partially by federal dams (Fig.

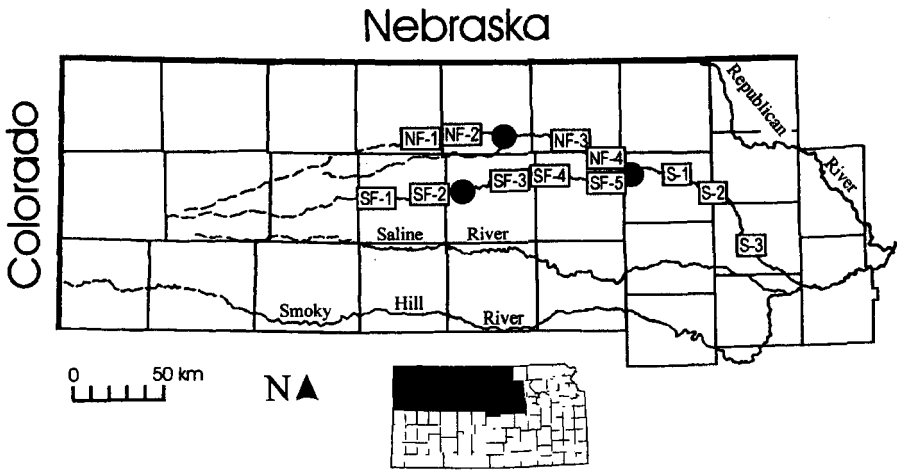


Figure 1. Distribution of sample sites within Solomon River basin. NF = North Fork Solomon River, SF = South Fork Solomon River, and S = Solomon River. Black circles represent Kirwin Reservoir (North Fork Solomon River), Webster Reservoir (South Fork Solomon River), and Waconda Reservoir (confluence of North Fork Solomon and South Fork Solomon rivers).

1). Kirwin Reservoir, on the North Fork Solomon River, was completed in 1952. Webster Reservoir, on the South Fork Solomon River, was completed in 1956. Waconda Reservoir, at the confluence of the North Fork Solomon and South Fork Solomon rivers, was completed in 1967. From Waconda Reservoir, the Solomon River flows into the Smoky Hill River, which is not impounded by any federal reservoirs from this point through the Kansas River and into the Missouri River.

Land use in the Solomon River basin is primarily agricultural. Approximately 7% of the land in the portion of the basin located upstream from Kirwin and Webster reservoirs is irrigated with groundwater (Christensen, 1999). In the sections of the basin located downstream from Kirwin and Webster reservoirs, 1 to 2% of the land is irrigated with groundwater and diversions of surface water (Christensen, 1999).

In 1996 and 1997, we sampled fishes at sites on the main stems of the three rivers above and below the reservoirs in the Solomon River basin. One goal of our study was to assess the extent to which the fish assemblages had changed because of extirpations and introductions in stream reaches impacted to various degrees by agricultural developments and impoundments on the main stems of the rivers.

METHODS AND MATERIALS

We sampled 12 sites on the three rivers within the Solomon River basin: three on the Solomon River, four on the North Fork Solomon River, and

five on the South Fork Solomon River (Fig. 1). Sites were distributed so that two or three sites were located in each of five reaches upstream and downstream from the three reservoirs. When streamflows permitted, we sampled each site four times per year in 1996 and 1997 during April–May, June–July, August–September, and October–November.

We collected fishes with seines (6.4-mm mesh) and with dip-nets and a gas-powered, direct-current, backpack electroshocker. We sampled all habitats less than 1.5 m deep by pulling seines through pools and runs; we kick-seined riffles. At each site, we collected a minimum of 10 seine samples. We also electrofished through all habitats less than 1.5 m deep for 400–500 seconds. Large fish were identified and returned to the stream. Small fish were preserved in 10% formaldehyde solution and returned to the Sternberg Museum of Natural History at Fort Hays State University, where they were identified and placed in the museum collection.

To help us determine the likely native fish assemblages, we reviewed literature accounts of fishes by Hay (1887), Gilbert (1889), Metcalf (1966), Cross (1967), Smith and Fisher (1970), Kansas Department of Wildlife and Parks (1977), Collins (1981), Cross, Mayden, and Stewart (1986), Cross and Moss (1987), and Sanders, Huggins, and Cross (1993). We examined museum records from the University of Kansas Museum of Natural History (KU), the University of Michigan Museum of Zoology (UMMZ), and Sternberg Museum of Natural History (MHP).

We summarized fish data from our samples as presence and absence values for each species within each sample locality, and we entered these values into a binary matrix (12 sample localities \times 35 species). Using data recorded at U.S. Geological Survey gaging stations located in each of the five stream reaches, we compiled mean monthly discharge data for 1996 and 1997 into a continuous data matrix (5 stream reaches \times 24 months). We developed both matrices in Microsoft Excel spreadsheets and subsequently converted them into space-delimited text files for analysis in NT-SYS. We examined species assemblages with principal coordinates (PCo) analysis based on Jaccard similarity matrices. Similarly, we analyzed mean monthly discharge values using principal components (PC) analysis based on a correlation matrix from log-transformed data. We examined relationships among sample localities, stream reaches, and fish assemblages for the PCo with Pearson's product-moment correlation. After derivation of PCo and PC vectors, we examined correlation of the original variables with these vectors (loadings). We considered significantly high loadings to be those greater than 0.3 or less than -0.3 .

RESULTS

Of the 43 species of fishes reported from the Solomon River basin, we determined that 17 native species were extant, 8 native species were extir-

pated, and 18 species were introduced or had immigrated into the basin (Table 1). The number of species living in the basin increased from 25 in the late 1800s to 35 in the late 1900s. The concurrent extirpation of eight species represented a 32% reduction in the native fauna.

Fish assemblages sampled during 1996 and 1997 varied with river discharge. In the PC analysis of mean monthly discharge values for each of the five stream reaches, the first PC axis accounted for 79.3% of the variation in mean monthly discharge and showed a separation among stream reaches that generally corresponded to their locations in the upper and lower portions of the basin (Fig. 2). The PCo analysis of the pooled fish data from each of the 12 sample localities produced two PCo axes that modeled 40.3% of the total variation. A plot of the first PCo axis against the second PCo axis clustered fish assemblages from the 12 sample localities into two principal groups (Fig. 3).

One group of localities with similar fish assemblages was comprised of six stream sites with relatively low discharges. The overall pattern of our site ordination analyses placed fish assemblages at two sites downstream from Webster Reservoir on the South Fork Solomon River (SF-3, SF-4) and the four sites above Kirwin and Webster reservoirs (NF-1, NF-2, SF-1, SF-2) into this group. These six sites were located the farthest upstream in the basin (Fig. 1). Fish assemblages at these sites were characterized by extant native (N) species of fishes, with only a few widespread introduced (I) species (Table 1). Species typical of these stream reaches had high positive loadings on PCo I (Table 2). They included white sucker (*Catostomus commersoni*, N), black bullhead (*Ameiurus melas*, N), plains killifish (*Fundulus zebrinus*, N), logperch (*Percina caprodes*, I), and orangethroat darter (*Etheostoma spectabile*, N). Five native species have been extirpated from the smaller streams in the Solomon River basin (Table 1).

The second group of localities with similar fish assemblages was comprised of six stream sites with relatively high discharge. Included in this group were the lowermost sites on the North Fork Solomon and South Fork Solomon rivers (NF-3, NF-4, SF-5), which were closest to the upper reaches of Waconda Reservoir, plus the three sites on the Solomon River, downstream from Waconda Reservoir (S-1, S-2, S-3) (Fig. 1). These fish assemblages were characterized by a substantial number of nonnative species of fishes (Table 1). The species in this group had high negative loadings on PCo I (Table 2). They included gizzard shad (*Dorosoma cepedianum*, I), flathead catfish (*Pylodictis olivaris*, I), freshwater drum (*Aplodinotus grunniens*, I), white crappie (*Pomoxis annularis*, I), white bass (*Morone chrysops*, I), and stonecat (*Noturus flavus*, N). Three native species have been extirpated from the larger streams (Table 1). Several species occur in all five stream segments, but only three species were collected at all 12 localities (Table 2).

DISCUSSION

Fish assemblages in the five river segments in the Solomon River basin have undergone substantial changes attributable to several anthropogenic impacts on streams in this basin. In the headwater sections of the rivers, agricultural developments have had the greatest impact on the streams and their fish communities. Segments of the historical headwater sections of the rivers and tributary streams originally had clear, cool water maintained by springs and diffuse groundwater seepage. Conversion of grassland to cropland increased turbidity in the small streams (Cross and Moss, 1987). Land treatments that reduced surface runoff and groundwater withdrawals for irrigation caused streamflows to decline (Jordan, 1982; Kansas Water Office, 1993). These changes led to the extirpation of several species in the late 1800s and early 1900s (Cross, 1967; Cross and Moss, 1987). In fact, most of the extirpated species in the Solomon River basin were restricted to these small, clear streams (Table 1). Few species have been added successfully to the fauna of the small streams (Table 1), and these introduced species probably spread into the upper basin from ponds or reservoirs.

The decline in streamflows has shifted the headwaters of the North Fork Solomon and South Fork Solomon rivers toward the east, along with what remains of their small-stream fish assemblage (Cross and Moss, 1987). Land surveys conducted by the federal government from 1865 to 1869 recorded widths of 18 to 30 m near our study sites on the North Fork Solomon and South Fork Solomon rivers. Site SF-2, which had a width of 100 m, was an exceptionally broad section of the river. At the time of these surveys, the water ranged in depth from 5 to 76 cm, and there was sufficient flow to maintain substrates of clean sand, as was also noted in 1885 by Hay (1887). During our survey of 1996 and 1997, these sites generally were 2 to 20 m wide and had substrates comprised primarily of sand and silt, with some areas of gravel and organic muck.

Most of the observed reductions in streamflows in the North Fork Solomon River above Kirwin Reservoir and the South Fork Solomon River above Webster Reservoir have been attributed to decreases in surface runoff and baseflow (Kansas Water Office, 1993). Although the North Fork Solomon and South Fork Solomon river basins upstream from Waconda Reservoir were closed to new water appropriations in the early 1980s, current water use continues to lower watertables in the aquifers and consequently reduces baseflows, particularly upstream from Kirwin and Webster reservoirs (Kansas Water Office, 2000). Most irrigation activity in the Solomon River basin occurs in the upper portion of the basin, and it is based primarily on groundwater withdrawals rather than surface diversions (Christensen, 1999). To handle declines in streamflows above Waconda Reservoir and the low levels of water stored in Kirwin and Webster reservoirs, the Kansas

Table 1. Species assemblages in the Solomon River basin. Species have been placed into categories based on their predominance in low-discharge or high-discharge streams and their status as native or nonnative species within the basin. Assignments into these categories were based on information obtained from the 1996–1997 samples, literature records (cited in the text), and museum records from the University of Kansas Natural History Museum, University of Michigan Museum of Zoology, and Sternberg Museum of Natural History.

Species	Native extant	Native extirpated	Nonnative
Low-discharge streams			
Central Stoneroller, <i>Campostoma anomalum</i>	X		
Bluntnose Minnow, <i>Pimephales notatus</i>	X		
Fathead Minnow, <i>Pimephales promelas</i>	X		
Creek Chub, <i>Semotilus atromaculatus</i>	X		
White Sucker, <i>Catostomus commersoni</i>	X		
Orangethroat Darter, <i>Etheostoma spectabile</i>	X		
Common Shiner, <i>Luxilus cornutus</i>		X	
Redfin Shiner, <i>Lythrurus umbratilis</i>		X	
Topeka Shiner, <i>Notropis topeka</i>		X	
Southern Redbelly Dace, <i>Phoxinus erythrogaster</i>		X	
Johnny Darter, <i>Etheostoma nigrum</i>		X	
Yellow Bullhead, <i>Ameiurus natalis</i>			X
Both streams			
Red Shiner, <i>Cyprinella lutrensis</i>	X		
Sand Shiner, <i>Notropis ludibundus</i>	X		
Suckermouth Minnow, <i>Phenacobius mirabilis</i>	X		
Black Bullhead, <i>Ameiurus melas</i>	X		
Stonecat, <i>Noturus flavus</i>	X		
Plains Killifish, <i>Fundulus zebrinus</i>	X		
Green Sunfish, <i>Lepomis cyanellus</i>	X		
Orangespotted Sunfish, <i>Lepomis humilis</i>	X		
Common Carp, <i>Cyprinus carpio</i>			X
Bluegill, <i>Lepomis macrochirus</i>			X
Largemouth Bass, <i>Micropterus salmoides</i>			X
Logperch, <i>Percina caprodes</i>			X
High-discharge streams			
Longnose Gar, <i>Lepisosteus osseus</i>	X		
River Carpsucker, <i>Carpionodes carpio</i>	X		
Channel Catfish, <i>Ictalurus punctatus</i>	X		
Goldeye, <i>Hiodon alosoides</i>		X	
Plains Minnow, <i>Hybognathus placitus</i>		X	
Shorthead Redhorse, <i>Moxostoma macrolepidotum</i>		X	
Shortnose Gar, <i>Lepisosteus platostomus</i>			X
Gizzard Shad, <i>Dorosoma cepedianum</i>			X
Golden Shiner, <i>Notemigonus crysoleucas</i>			X
Emerald Shiner, <i>Notropis atherinoides</i>			X
Bullhead Minnow, <i>Pimephales vigilax</i>			X
Smallmouth Buffalo, <i>Ictiobus bubalus</i>			X
Bigmouth Buffalo, <i>Ictiobus cyprinellus</i>			X

Table 1. Continued.

Species	Native extant	Native extirpated	Nonnative
Flathead Catfish, <i>Pylodictis olivaris</i>			X
Western Mosquitofish, <i>Gambusia affinis</i>			X
White Bass, <i>Morone chrysops</i>			X
White Crappie, <i>Pomoxis annularis</i>			X
Black Crappie, <i>Pomoxis nigromaculatus</i>			X
Freshwater Drum, <i>Aplodinotus grunniens</i>			X
Total number of species (43)	17	8	18

Water Office (2000) established a goal of achieving sustainable yield from alluvial aquifers in the Solomon River basin by 2010. However, for the High Plains (Ogallala) Aquifer in the upper portion of the basin, the goal was only a reduction in the rate of decline in water levels (Kansas Water Office, 2000). Additional declines in watertables in these aquifers likely will cause the origin of streamflow in the basin to continue its eastward movement and further imperil aquatic communities, including those dominated by introduced species of fishes in Kirwin and Webster reservoirs.

The larger stream reaches in the lower portion of the Solomon River basin also have been impacted by reduced inflows, but construction of federal reservoirs and smaller impoundments (e.g., municipal dams at Beloit and

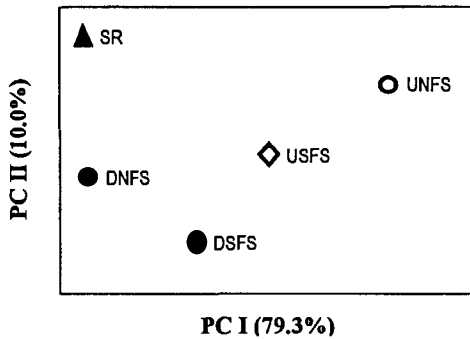


Figure 2. Plot of first two principal components (PC) axes based on 1996-97 mean monthly discharge data pooled for each of five reaches (Fig. 1). Shapes represent Solomon River (black triangle, SR), downstream North Fork Solomon River (black circle, DNFS), downstream South Fork Solomon River (black diamond, DSFS), upstream North Fork Solomon River (white circle, UNFS), and upstream South Fork Solomon River (white diamond, USFS) in Kansas. Percentages represent amount of variation accounted for by each axis. Symbols on right side of plot represent stream reaches located farthest upstream in basin that had relatively lower mean monthly discharge values. Symbols on left side of plot represent stream reaches in lower portion of basin that had relatively higher mean daily discharge values.

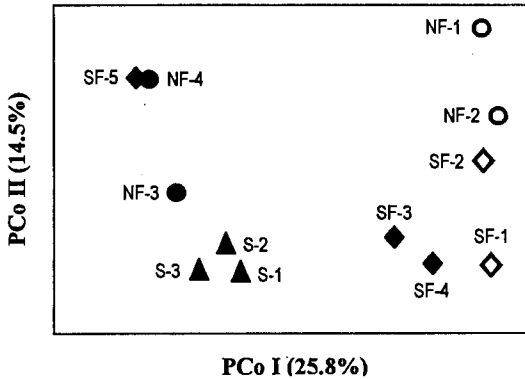


Figure 3. Plot of first two principal coordinates (PCo) axes based on 1996–97 binary (presence/absence) fish data pooled for each of 12 sample localities (Fig. 1). Shapes represent Solomon River sites (black triangles, SR), downstream North Fork Solomon River sites (black circles, DNFS), downstream South Fork Solomon River sites (black diamonds, DSFS), upstream North Fork Solomon River sites (white circles, UNFS), and upstream South Fork Solomon River sites (white diamonds, USFS) in Kansas. Percentages represent amount of variation accounted for by each axis. Symbols on right side of plot represent fish communities at sites located farthest upstream in basin that had relatively lower mean monthly discharge values. Symbols on left side of plot represent fish communities at sites located in lower portion of basin that had relatively higher mean monthly discharge values.

Minneapolis) has had a substantial impact on the downstream reaches of the rivers and their fish communities. Prior to settlement of the area by EuroAmericans, the Solomon River was a moderately sized plains river with often turbid water. Land surveys conducted by the federal government from 1858 to 1861 recorded widths of 32 to 44 m for the Solomon River near our study sites. The surveyors also indicated that “never-failing” springs and clear brooks were present near the river. Some segments of the river probably had a braided flow over a loose sand substrate, although the lower Solomon River probably was more deeply incised and had a few natural gravel bars (Eberle, Wenke, and Welker, 1997). Following construction of the impoundments, several aspects of this riverine habitat changed. The widths of the streams at our study sites were narrower, ranging from about 10 to 35 m. The stream substrates were mainly firm sand and silt, with a few natural gravel bars and accumulations of rubble from collapsed mill dams or other man-made debris. Intact small dams and the larger federal structures created extensive areas of lentic habitat.

Most of the successful introductions or range extensions into the Solomon River basin (Table 1) have involved species generally adapted to reservoirs and riverine pools, which provide large areas of lentic habitat with relatively low turbidity and increased availability of plankton. These conditions favor species of sportfishes, such as largemouth bass (*Micropterus salmoides*),

Table 2. Species loadings on first three principal coordinates (PCo) axes based on binary (presence/absence) fish data pooled for each of the 12 localities sampled in the Solomon River Basin during 1996 and 1997. Numbers in the header row represent the percent of variation accounted for by each axis. Three species noted with an asterisk were collected at all 12 localities and were excluded from the analysis. Species with high negative loadings on PCo I typically inhabited sites in the lower basin that had relatively higher mean monthly discharges. Species with high positive loadings on PCo I typically inhabited sites in the upper basin that had relatively lower mean monthly discharges.

	PCo I 25.8%	PCo II 14.5%	PCo III 11.0%
Longnose Gar	-0.27	-0.30	-0.01
Shortnose Gar	-0.27	-0.30	-0.01
Gizzard Shad	-0.75	-0.05	-0.31
Common Carp	-0.14	-0.09	-0.88
Golden Shiner	-0.15	-0.57	0.02
Creek Chub	0.56	0.09	-0.33
Suckermouth Minnow	-0.50	0.43	0.10
Red Shiner*	—	—	—
Emerald Shiner	-0.27	-0.30	-0.01
Sand Shiner*	—	—	—
Bullhead Minnow	-0.30	-0.38	0.70
Bluntnose Minnow	0.19	-0.19	-0.20
Fathead Minnow*	—	—	—
Central Stoneroller	0.38	-0.36	0.38
Bigmouth Buffalo	-0.31	-0.03	-0.15
Smallmouth Buffalo	-0.18	-0.30	0.29
River Sucker	-0.22	-0.31	-0.65
White Sucker	0.49	-0.16	-0.07
Black Bullhead	0.55	0.39	0.04
Yellow Bullhead	0.34	-0.30	-0.37
Channel Catfish	-0.34	0.30	0.37
Flathead Catfish	-0.86	-0.22	0.02
Stonecat	-0.58	-0.50	0.46
Plains Killifish	0.97	0.06	-0.16
W. Mosquitofish	0.30	-0.35	-0.33
White Bass	-0.61	0.28	-0.13
Largemouth Bass	0.02	-0.48	-0.25
Green Sunfish	0.45	-0.75	0.22
Bluegill	0.36	-0.64	-0.31
Orangespotted Sunfish	0.05	-0.90	0.14
White Crappie	-0.88	0.11	-0.01
Black Crappie	0.38	-0.07	0.05
Logperch	0.51	0.59	0.20
Orangethroat Darter	0.71	0.04	-0.04
Freshwater Drum	-0.88	-0.17	0.05

white bass, and walleye (*Stizostedion vitreum*), that rely on sight to find their prey. Planktivores, such as gizzard shad, also have been stocked successfully in reservoirs as forage for sportfishes. Many species of fishes added to the fauna of the Solomon River basin are attributable to intentional and accidental introductions into reservoirs and ponds, as is true elsewhere on the Great Plains (Cross, Mayden, and Stewart, 1986; Sanders, Huggins, and Cross, 1993). These species became established in pools inundated by the dams and then spread into deeper waters of adjacent stream reaches. In addition to introductions, some nonnative species (e.g., bullhead minnow, *Pimephales vigilax*) immigrated into the Solomon River from the Smoky Hill and Kansas rivers (Eberle, Hargett, and Wenke, 2000).

Although most of the species extirpated from the Solomon River basin inhabited the river headwaters and tributary streams, two of the extirpated species, goldeye (*Hiodon alosoides*) and plains minnow (*Hybognathus placitus*), probably were limited to the broad flows of the larger river reaches. They are present in the Kansas River (Cross and Collins, 1995), and they might occasionally move into the lower Smoky Hill and Solomon rivers; however, dams limit their upstream movements through these basins. The number of goldeyes in the Solomon River probably varied from year to year (Cross and Collins, 1995). The extirpation of the plains minnow in the Solomon River basin has been more dramatic (Eberle, Wenke, and Welker, 1997). These minnows typically inhabit broad streams with shifting sand bottoms and braided flow, and they once occurred in all three rivers in the Solomon River basin (Cross, 1967). Throughout northwestern Kansas, reductions in streamflow and regulation of discharge by dams have eliminated much of this habitat, which has been replaced by narrow streams with firm substrates. As an apparent consequence, the plains minnow has been extirpated from all of the rivers in the Solomon River basin and most other rivers throughout northwestern Kansas (Eberle, Wenke, and Welker, 1997).

The extant native species of fishes in the Solomon River basin (Table 1) are among those with life history attributes that make them generally tolerant of a wide range of environmental conditions (Cross and Moss, 1987; Fausch and Bestgen, 1997). This flexibility served them well prior to settlement, when some streams varied seasonally from broad torrents to narrow flows or isolated pools (Cross and Moss, 1987). These fishes could survive in isolated refuges within the main stems of the rivers or the groundwater-fed tributaries, from which they later could disperse throughout the basin, unimpeded by dams. It is this same resilience incorporated into their life histories that makes it possible for these species to survive under the present stream conditions.

Sanders, Huggins, and Cross (1993) discussed two guilds of native fishes correlated with the two principal types of stream habitat in northwestern Kansas: (1) large, turbid rivers with widely fluctuating flows and shifting

sand substrates and (2) small streams with stable flows of clear, cool water flowing from groundwater sources over substrates of silt, sand, and gravel. Our analyses suggested that there were two identifiable fish assemblages within the main stems of the rivers in the Solomon River basin during 1996 and 1997. One was associated with river segments in the lower basin that had relatively high discharges (or were impounded), and the other was associated with river segments in the upper basin that had relatively low discharges. In terms of relative discharges, these two habitats generally corresponded with the two habitats discussed by Sanders, Huggins, and Cross (1993). However, because of the anthropogenic changes in physicochemical attributes of the streams and the consequent extirpations and introductions of fishes, the species assemblages within these two habitats have changed substantially from the fauna that was present prior to EuroAmerican settlement.

In terms of species richness, extirpations and introductions have equally impacted the species assemblage of fishes identified for the smaller stream segments. In the smaller streams, five of the 19 native species have been extirpated, and five species have been introduced (Table 1). In the larger river segments in the lower portion of the basin, changes in the fish assemblage have been mainly the result of introductions and immigrations. Although three of the 14 native species have been extirpated from the larger stream reaches, the number of species has more than doubled through the addition of 17 species generally associated with lentic habitats (Table 1).

Changes in the fish assemblages in the Solomon River basin exemplify the homogenization of fish faunas occurring among state faunas across the United States (Rahel, 2000). Rahel (2000) compared lists of extant native species, extirpated native species, and introduced species of fishes among the 48 conterminous United States and suggested that introductions, primarily associated with sportfishing, had played a greater role than extirpations in the homogenization of fish faunas on this relatively large geopolitical scale. This generalization seems to fit the results of our analysis for stream sites that had higher discharges (associated with main stem impoundments) on our smaller scale of a single basin. Because native fish communities in the Solomon River basin and the western United States, in general, had relatively few species, the species richness of these communities has increased substantially following the addition of these widely introduced species (Moyle, 1986).

Counter to the conclusions of Rahel (2000) and the changes noted in fish assemblages at our larger stream sites, the situation in the smaller streams in our study suggested that extirpations played an equal role to introductions in the changes in species composition. This probably is the result of the lower availability in these small streams of the deeper pools inhabited by the widely introduced species associated with the enhancement of sportfish-

