ARTICLE

Habitat, Fish Species, and Fish Assemblage Associations of the Topeka Shiner in West-Central Iowa

Bryan D. Bakevich*

Department of Natural Resource Ecology and Management, Iowa State University, 339 Science II, Ames,
Iowa 50011, USA

Clay L. Pierce

U.S. Geological Survey, Iowa Cooperative Fish and Wildlife Research Unit,
Department of Natural Resource Ecology and Management, Iowa State University, 339 Science II, Ames,
Iowa 50011, USA

Michael C. Quist

U.S. Geological Survey, Idaho Cooperative Fish and Wildlife Research Unit,
Department of Fish and Wildlife Sciences, University of Idaho, 875 Perimeter Drive, MS 1141, Moscow,
Idaho 83844, USA

Abstract

Our goal was to identify habitat, fish species, and fish assemblages associated with the occurrence of Topeka Shiners *Notropis topeka* in stream and off-channel habitat (OCH) of west-central Iowa. Fish assemblages and habitat characteristics were estimated in 67 stream and 27 OCH sites during 2010–2011. Topeka Shiners were sampled in 52% of OCH sites, but in only 9% of stream sites, which supports the hypothesis that OCH is an important component of their life history. Fish assemblages containing Topeka Shiners were different from those that did not contain Topeka Shiners in OCH sites, but this was not evident in stream sites. Results from logistic regression models suggested that Topeka Shiner presence was associated with increased submerged vegetation and abundance of Fathead Minnow *Pimephales promelas*. Contrary to the findings of other studies, the abundance of large piscivorous fishes was not associated with the occurrence of Topeka Shiners. Our results provide new information about the biology and life history of the Topeka Shiner that will guide habitat restoration and other recovery efforts.

The Topeka Shiner *Notropis topeka* is a federally endangered fish species native to streams of Iowa, Kansas, Minnesota, Missouri, Nebraska, and South Dakota (Lee et al. 1980) and when listed it occupied only 20% of its historic range (USFWS 1998). Decline of Topeka Shiners in Iowa has been attributed to hydrologic changes, agricultural impacts on water quality, and increased predation (USFWS 1998), but the specific factors associated with Topeka Shiner occurrence are poorly understood. One recent study investigated how landscape-scale factors (e.g., land cover type, stream slope) affected Topeka Shiner occurrence (Menzel and Clark 2002), yet the habitat associations

of many fishes can occur at a finer scale (Pont et al. 2005). In fact, Wall and Berry (2006) found that the occurrence of Topeka Shiner in South Dakota was associated with factors acting across multiple spatial scales. Investigating reach-scale habitat, fish, and fish assemblage associations could provide novel information about the Topeka Shiner in Iowa, but further study of landscape-scale factors may also be beneficial.

The importance of understanding habitat associations of Topeka Shiners has been highlighted as scientists have made major discoveries regarding their habitat use. Recently, these fish have been documented in off-channel habitat (OCH) sites

such as oxbows and livestock watering ponds (Hatch 2001; Menzel and Clark 2002; Thomson and Berry 2009); however, the role these habitats play in the life history of Topeka Shiners is unknown. Topeka Shiners have been found in equal abundances in stream and OCH sites when streams contain suitable habitat (Ceas and Larson 2010), but they may be more abundant in OCH sites when stream habitats have been degraded or are not suitable (Dahle 2001). This may often be the case in Iowa, and restoration effort should be focused accordingly if OCH continues to be identified as important to Topeka Shiner populations. Traditionally, fish habitat restoration has focused on improving habitat within the stream channel and reducing nutrient or other inputs from the landscape. These actions can be beneficial to a suite of native fishes, but may not improve habitat for Topeka Shiners if they are primarily using OCH. Recognizing this, the U.S. Fish and Wildlife Service (USFWS) has restored over 40 OCH sites in Iowa in hopes of creating suitable habitat for Topeka Shiners (USFWS 2009). During restoration, accumulated sediment is removed to increase the depth of the OCH and reconnect it to groundwater sources. Connections to the stream are sometimes excavated from the OCH to facilitate fish movement between the two habitats. During most years, restoration allows the OCH to retain water year-round and provides overwintering habitat for fish. Since these restorations are a relatively new recovery tool, this study could provide valuable information that could guide Topeka Shiner habitat management and restoration.

To more effectively manage recovery efforts, it is also important to understand the biological associations of Topeka Shiners. Although formal studies of Topeka Shiners in Kansas identified a negative association with piscivorous fishes (Schrank et al. 2001; Mammoliti 2002), other possible biological associations have been suggested through field observations and warrant more rigorous analyses. For example, they are thought to be nest associates of Orangespotted Sunfish *Lepomis humilis* and Green Sunfish *Lepomis cyanellus* (Pflieger 1997), but no formal analysis of this possible association has occurred. Similarly, others have shown that Fathead Minnow *Pimephales promelas* commonly occur with Topeka Shiners (Minckley and Cross 1959; Winston 2002), but again, these results were not obtained through formal quantitative methods. Since they could be associated, either positively or negatively, with a suite of fishes, we decided to identify associations between Topeka Shiners and unique fish assemblages, as well as individual fish species.

Topeka Shiners are very different from other prairie stream fish in their use of habitat, physiological tolerances, and possible symbioses. Therefore, recovery efforts, such as the designation of critical habitat and restoration of habitats, can only be effective if the habitat, fish, and fish assemblage associations of this endangered species are understood. The goal of our study was to determine factors associated with the occurrence of Topeka Shiners in west-central Iowa.

METHODS

Study area.—The study area was confined to the North Raccoon, Boone, upper Des Moines, and upper Iowa river basins
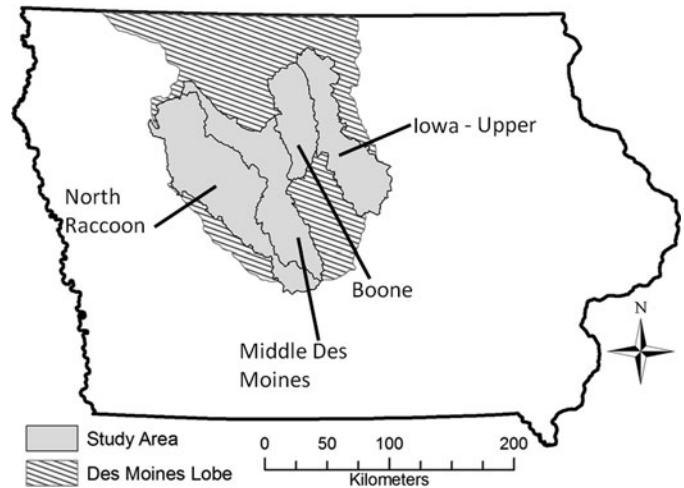

FIGURE 1. Location of eight-digit hydrological unit code (HUC8) study basins within the Des Moines Lobe subecoregion of Iowa.

located on the Des Moines Lobe subecoregion (Griffith et al. 1994) of central Iowa (Figure 1). This landscape is characterized by gently rolling terrain and is dominated by row crop agriculture. Although Topeka Shiners have historically occurred in all of these watersheds (IRIS 2005), recent surveys indicate that significant populations only remain in the North Raccoon and Boone river watersheds (Clark 2000). These two watersheds contain the only known populations of the Topeka Shiner in Iowa that are within the Mississippi River catchment.

Study sites.—Based on our current knowledge of Topeka Shiner habitat use, we chose to sample both stream and OCH sites. Stream sites were typical of those on the Des Moines Lobe with low gradients and riparian areas of grasses, row crops, or pasture. Many streams were channelized and had low habitat complexity. The OCH sites were pond-like bodies of water within the stream floodplain that remained disconnected from the stream channel during normal flow conditions and were characterized by silt substrate, the presence of aquatic macrophytes, and moderate turbidity. Several OCH sites were used to store water for livestock resulting in trampled areas within and around the site. Many of the sites were unrestored, but several USFWS-restored OCH sites occurred in the study area. Since stream and OCH sites differed physically, they were sampled using slightly different protocols.

Because these fish are rare in Iowa, sample sites that had an increased likelihood of Topeka Shiner occurrence were chosen for this study. We used three criteria to select sample sites. First, we selected sites where Topeka Shiners were predicted to occur based on two occurrence models. One model was developed by Menzel and Clark (2002) and the other was the Iowa Aquatic Gap Analysis Program (GAP) model (Loan-Wilsey et al. 2005). Both models used landscape-scale variables (e.g., land cover type, stream gradient) to predict Topeka Shiner occurrence. Second, we selected sites where Topeka Shiner have been previously documented (IRIS 2005). Third, we selected OCH sites that could be identified from aerial photographs taken during

2009 and 2010 since these habitats were rare throughout our study area.

Sampling.—Stream sites were sampled following standard Iowa Department of Natural Resources protocols for wadeable streams (IDNR 2001), but with some modifications to increase the likelihood of Topeka Shiner detection. Each stream site was at least 100 m in length and did not exceed 400 m. We used pulsed-DC electrofishing and seining to sample fish in runs, riffles, and pools. First, the site was sampled by single-pass pulsed-DC electrofishing moving upstream, applying sufficient power to immobilize small-bodied fishes. For small streams, a battery-powered backpack LR-20 electrofishing unit (Smith-Root, Vancouver, Washington) was used. For larger streams, a generator-powered, barge-mounted VVP-15B electrofishing unit (Smith-Root) was used. After the site was sampled by electrofishing, the wetted width of the site was sampled using a bag seine (6.0 × 1.5 m, 6-mm mesh). All fish were identified to species, enumerated, and released. Total lengths (mm) of all piscivores (e.g., Largemouth Bass *Micropterus salmoides*, Channel Catfish *Ictalurus punctatus*) were recorded prior to their release.

The OCH sites were sampled using bag seines (6.0 × 1.5 m, 6-mm mesh) only. Standard sampling protocols are not available for these habitats, but our methods were similar to those of other studies of fish in small OCH (e.g., Thomson and Berry 2009). All fish were identified to species, enumerated, and released. Total lengths of all piscivores were recorded before their release.

For all sampling (i.e., stream and OCH sites), CPUE for each species was calculated as the number of individuals per 100 m². Composite variables were created by summing the relative abundance of two or more fishes. For example, sunfish CPUE was equal to the sum of CPUEs for Green Sunfish and Orangespotted Sunfish. Piscivore CPUE was equal to the sum of CPUEs for Largemouth Bass > 60 mm, Smallmouth Bass *M. dolomieu* > 100 mm, Northern Pike *Esox Lucius* > 60 mm, Channel Catfish > 100 mm, and Flathead Catfish *Pylodictis olivaris* > 80 mm (Mittelbach and Persson 1998).

Habitat characteristics were also measured in streams and OCH. Transects perpendicular to the thalweg were established for each site at 25, 50, and 75% of the site length (Bisson et al. 1982), and wetted width was measured at each transect. Canopy cover was measured with a spherical densiometer facing each bank, and upstream and downstream from the center of each transect. Bank characteristics (e.g., percent woody vegetation, nonwoody vegetation, eroding bank, rip-rap, roots, bare ground) were visually estimated for both stream banks at each transect. Distance to disturbance (e.g., rowcrops, roads) were characterized as on bank, <10 m, >10 m, or absent at each transect. Water depth, substrate type, and stream velocity at 20, 40, 50, 60, and 80% of the wetted width were measured at each transect. Substrate was classified as boulder (>256 mm), cobble (64–256 mm), coarse gravel (16–63.99 mm), gravel (0.2–15.99 mm), sand (0.062–0.19 mm), silt (0.039–0.061 mm), clay (<0.0390 mm), bedrock, hardpan, detritus, wood, soil, vegetation (e.g., submerged grass),

or artificial. Average stream velocity was measured at 60% of water depth with a Marsh–McBirney Flo-Mate model 2000 portable velocity meter (Marsh–McBirney, Frederick, Maryland). All units of submerged cover were classified (e.g., woody debris, macrophyte, terrestrial vegetation, small brush, overhanging vegetation, undercut bank, rip-rap, artificial structure) and measured by taking one length and three width measurements. Average width, depth, and stream velocity were calculated for each site. Average percent canopy cover and average percent of bank characteristic types were also calculated for each site. The percent of each submerged cover type at a site was calculated by dividing the area of the cover unit by the wetted area of the entire site.

Data analysis.—We used two approaches to better understand the abiotic and biotic factors associated with the occurrence of Topeka Shiners in our study area. First, we examined data from the entire fish assemblages across all sites to evaluate the association of Topeka Shiners with other members of the fish assemblage. We then developed multiple logistic regression models to identify reach-scale factors (independent variables) associated with Topeka Shiner occurrence (dependent variable). Each method of analysis was applied to all sites and to stream and OCH sites separately, thereby allowing us to identify important factors associated with Topeka Shiners in both in stream and OCH combined, as well as those that are specific to either stream or OCH.

Nonmetric multidimensional scaling (NMDS) ordination was used to visualize the different fish assemblages in all sites together and those of stream and OCH sites separately. Ordinations were created from distance matrices based on CPUE (number of fish/100 m²) of fishes using the Bray–Curtis distance measure with standardization for site totals (Faith et al. 1987). Habitat variables (e.g., mean depth, canopy cover) correlated with NMDS scores ($r^2 > 0.50$) were fit onto ordinations as vectors using the ENVFIT function in the vegan library (Oksanen et al. 2011) for Program R. Vectors were added to ordinations if its r^2 value was greater than the 95th percentile of 1,000 randomly permuted correlations. We tested for differences in fish assemblages with an ANOVA using distance matrices (ADONIS) in the vegan package of Program R (R Development Core Team 2011).

We used an information theoretic approach (Burnham and Anderson 2002) and logistic regression (Harig and Fausch 2002; Rich et al. 2003; Quist et al. 2005; Fischer and Paukert 2008) to select a set of candidate models that best explained the occurrence of Topeka Shiners. The a priori candidate models were generated using factors presumed to be of biological importance to Topeka Shiners based on previous research, anecdotal evidence, and general stream fish ecology. The following variables were included in these candidate models: percent of vegetation, woody, and total submerged cover; percent of bank vegetation, canopy cover, and eroded bank; percent of each substrate category; average distance to disturbance, stream velocity, wetted width, and width-to-depth ratio; and Fathead Minnow, sunfish,

Largemouth Bass, and piscivore CPUE. To prevent overfitting, the number of variables included in any candidate model was limited to 10% of the number of sites used to build that model. As indicated by Akaike information criterion values corrected for small sample size (AIC_c), only the most parsimonious candidate models were included in the confidence model sets. Only candidate models with a $\Delta AIC_c \leq 2$ were included in the confidence set to ensure that the confidence set contained models that were nearly as parsimonious as one another (Burnham and Anderson 2002). Model-averaged coefficients and 95% CIs were then calculated from the confidence sets of competing models to determine which factors significantly contributed to the prediction of Topeka Shiner occurrence. Model fit was evaluated using McFadden's (1974) pseudo r^2. Three models were constructed to determine habitat and biological associations of the Topeka Shiner: a combined model (using both stream and OCH sites), a stream model, and an OCH model.

A combined model of associations among both site types (stream and OCH) was developed because some associations could exist that were independent of habitat type. Fathead Minnow CPUE, sunfish CPUE, piscivore CPUE, and percent submerged vegetation were used to create a set of candidate models for the combined model. Because stream and OCH differ greatly in physical characteristics (e.g., substrate composition, water velocity, channel morphology), we included additional variables in the stream and OCH models that may be associated with Topeka Shiner occurrence.

RESULTS

A total of 94 sites representing 67 stream and 27 OCH sites were sampled in 2010 and 2011 (Figure 2). We encountered 59 fish species and identified 68,177 individual fish. Topeka Shiners were detected in 6 stream and 14 OCH sites and ranked 24th in total catch, and a total of 790 individual fish were sampled (Table 1).

Topeka Shiner occurrence did not significantly relate to fish assemblage structure across all sites, but Topeka Shiners tended to be present in sites that contained fewer species. The NMDS ordination for all sites (Figure 3) is shown in two dimensions with a stress value of 0.18, indicating a fair match between the pairwise assemblage distances and those distances in the ordination space ($r^2 = 0.86$). Although a three-dimensional ordination had a stress value of 0.13, the general patterns did not differ from the two-dimensional representation, which is more interpretable. No differences in fish assemblages between sites where Topeka Shiners were present and absent were detected after adjusting for site type (ADONIS: $P > 0.49$). A contour surface indicating species richness isobars was added to the ordination, which demonstrated that differences in assemblages were partially attributed to the number of species at each site. Mean species richness was significantly lower in OCH sites than in stream sites (two sample t-test: $t = 5.89$, df $= 62.89$, $P < 0.001$).
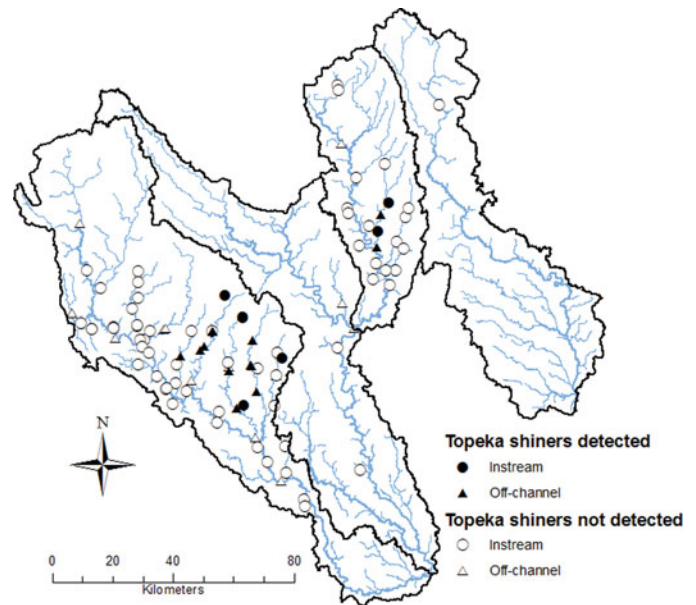

FIGURE 2. Location of stream and OCH sites in the HUC8 study basins where Topeka Shiners were detected and not detected during 2010–2011 in west-central Iowa. [Figure available in color online.]

Another NMDS ordination (stress value $= 0.17$, $r^2 = 0.90$) was created to characterize fish assemblages at stream sites and how they relate to Topeka Shiner occurrence (Figure 4). Fish assemblages in stream sites that contained Topeka Shiners were not significantly different from those lacking Topeka Shiners
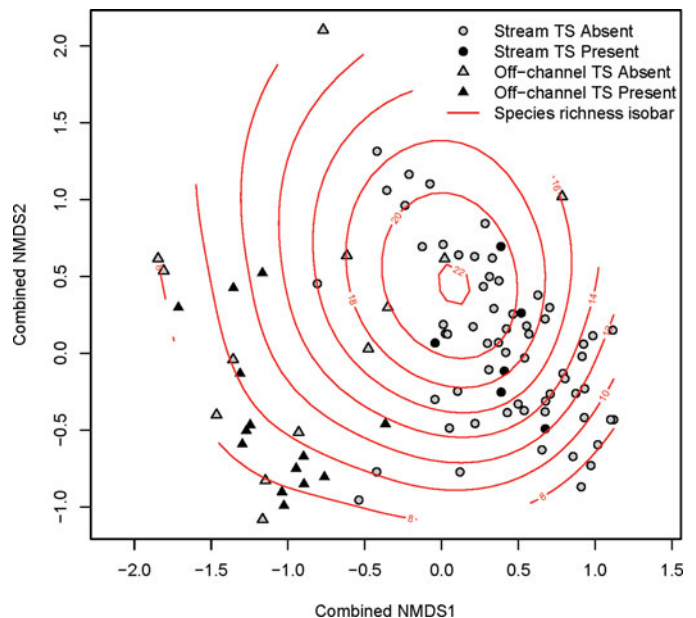

FIGURE 3. Nonmetric multidimensional scaling (NMDS) ordination of fish assemblages in stream (circles) and OCH sites (triangles) combined in relation to Topeka Shiner occurrence. Grey symbols represent sites where Topeka Shiners were not detected and black symbols represent those where Topeka Shiners were present. Isobars represent the differing levels of species richness among all sites. [Figure available in color online.]

TABLE 1. Catch per unit effort (CPUE) of fish species that were detected in over 10% of stream or 10% of OCH sites where Topeka Shiner were detected (TS detected, $n = 20$) and not detected (TS not detected, $n = 74$). Species are listed in decending order of percent occurrence in stream sites.

| Species	CPUE (number fish/100 m^2)			
	TS detected		TS not detected	
	Stream	OCH	Stream	OCH
Bluntnose Minnow *Pimephales notatus*	54.48	4.56	373.00	111.43
Creek Chub *Semotilus atromaculatus*	46.17	2.73	689.09	6.79
Johnny Darter *Etheostoma nigrum*	10.64	0.99	137.11	2.48
Bigmouth Shiner *Notropis dorsalis*	62.22	9.86	720.52	22.98
Blacknose Dace *Rhinichthyes atratulus*	28.75	0	690.58	0
Common Shiner *Luxilus cornutus*	6.98	21.76	336.74	6.70
Central Stoneroller *Campostoma anomalum*	13.28	0	287.03	0
White Sucker *Catostomus commersonii*	18.3	14.04	188.21	18.81
Fathead Minnow *Pimephales promelas*	17.65	385.51	163.85	109.97
Spotfin Shiner *Cyprinella spiloptera*	15.49	2.12	198.10	45.78
Sand Shiner *Notropis stramineus*	34.25	0.43	190.87	265.77
Green Sunfish *Lepomis cyanellus*	4.06	55.14	58.60	28.21
Golden Redhorse *Moxostoma erythurum*	1.92	0.29	23.23	0.12
Blackside Darter *Percina maculata*	2.44	0	24.14	0
Northern Hog Sucker *Hypentelium nigricans*	0.63	0	10.33	0
Brassy Minnow *Hybognathus hankinsoni*	1.37	10.12	67.28	0.07
Shorthead Redhorse *Moxostoma macrolepidotum*	0.25	0	10.07	0.37
Brook Stickleback *Eucalia inconstans*	3.56	32.09	25.25	1.87
Black Bullhead *Ameiurus melas*	0.43	184.38	10.35	109.57
Yellow Bullhead *Ameiurus natalis*	2.01	0.6	8.32	0.03
Smallmouth Bass *Micropterus dolomieu*	0.02	0	4.76	0.12
Fantail Darter *Etheostoma flabellare*	5.83	0	47.17	0
Common Carp *Cyprinus carpio*	0.23	60.55	47.46	19.12
Rosyface Shiner *Notropis rubellus*	5.36	0	51.11	0.15
Hornyhead Chub *Nocomis biguttatus*	2.68	0	35.76	0
Orangespotted Sunfish *Lepomis humilis*	0.56	136.88	3.29	50.21
Channel Catfish *Ictalurus punctatus*	0	0	5.01	0.50
Largemouth Bass *Micropterus salmoides*	0.38	4.99	5.22	6.55
Stonecat *Noturus flavus*	0.05	0	3.89	0
Suckermouth Minnow *Phenacobius mirabilis*	0.07	0	7.15	0
Bluegill *Lepomis macrochirus*	0	0.48	22.20	24.81
River Carpsucker *Carpoides carpio*	0	0	2.43	3.35
Gizzard Shad *Dorosoma cepedianum*	0	0	11.76	0.25
Rock Bass *Ambloplites rupestris*	0.79	0.06	3.58	0
Quillback Carpsucker *Carpiodes cyprinus*	0	0	1.64	0
Highfin Carpsucker *Carpiodes velifer*	0	0	1.07	0.41
Silver Redhorse *Moxostoma anisurum*	0.15	0	0.83	0
Topeka Shiner *Notropis topeka*	2.27	100.18	0	0
Yellow Perch *Perca flavescens*	0	0.26	1.68	2.04
Northern Pike *Esox lucius*	0	0.1	0.24	1.26
Bigmouth Buffalo *Ictiobus cyprinellus*	0	0	1.15	4.22
White Crappie *Pomoxis annularis*	0	0	0.21	0.81
Black Crappie *Pomoxis nigromaculatus*	0	0	0.23	48.54
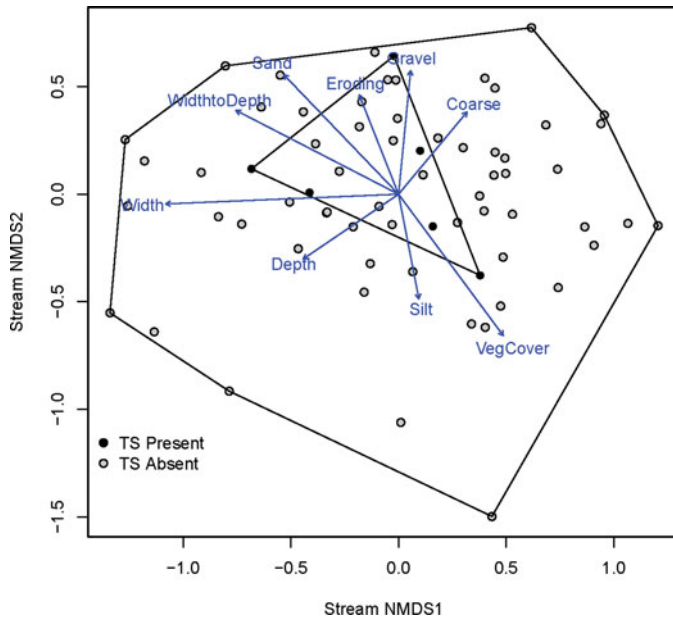
FIGURE 4. Nonmetric multidimensional scaling (NMDS) ordination of fish assemblages in stream sites in relation to Topeka Shiner occurrence. Grey symbols represent sites where Topeka Shiners were not detected and black symbols represent those where Topeka Shiners were present. Minimum convex polygons outline the ranges of ordination axis values for sites where Topeka Shiners were present and not detected. Relationships with habitat variables are shown as vectors; vector lengths indicate relative strengths of relationships. [Figure available in color online.]
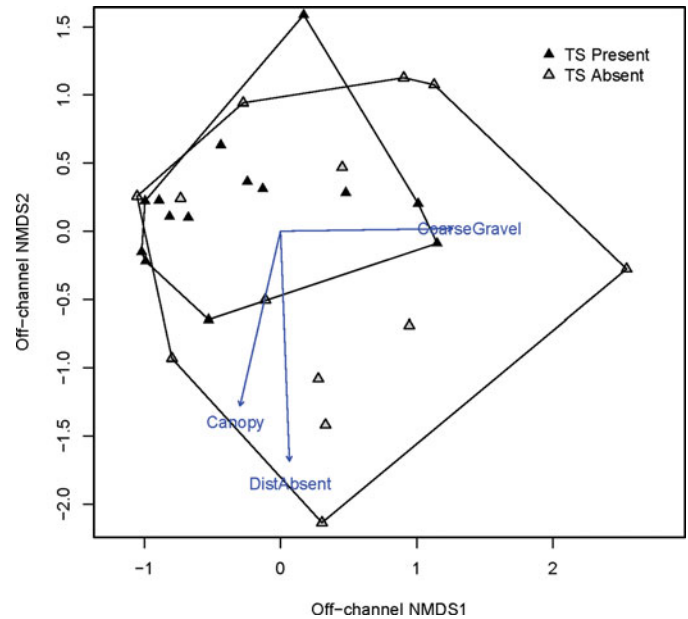

FIGURE 5. Nonmetric multidimensional scaling (NMDS) ordination of fish assemblages in OCH sites in relation to Topeka Shiner occurrence. Grey symbols represent sites where Topeka Shiners were not detected and black symbols represent those where Topeka Shiners were present. Minimum convex polygons outline the ranges of ordination axis values for sites where Topeka Shiners were present and not detected. Relationships with habitat variables are shown as vectors; vector lengths indicate relative strengths of relationships. [Figure available in color online.]

(ADONIS: $P = 0.75$). Several habitat variables (Table 2) were significantly correlated with the NMDS scores and indicated habitat gradients, but Topeka Shiner occurrence did not differ along those gradients.

Fish assemblages at OCH sites were also characterized using NMDS ordination to identify relationships between these fish assemblages and Topeka Shiner occurrence (Figure 5). This ordination reflects the true pairwise distance between assemblages relatively well (stress value = 0.14, $r^2 = 0.94$). Fish assemblages in OCH with Topeka Shiners differed significantly from sites without Topeka Shiners (ADONIS: $P = 0.03$). Assemblages that included Topeka Shiners also contained more lentic species (e.g., Fathead Minnow, Largemouth Bass, Common Carp *Cyprinus carpio*) than did assemblages without Topeka Shiners. The only habitat vectors (Table 2) that were significantly correlated with NMDS scores were mean canopy cover, proportion of site with no visible disturbance, and percent coarse gravel substrate. Decreasing scores on the *y*-axis indicated an increase in forested area and reduced land use disturbance. Sites with Topeka Shiners tended to be in the less-forested areas that had some level of disturbance (e.g., pasture, row crop, road). Decreasing scores on the *x*-axis indicated a decrease in coarse substrate. Topeka Shiners also tended to occur in OCH sites with less coarse substrate.

Results from the logistic regression analyses identified significant habitat and biotic variables associated with Topeka Shiner

occurrence. Confidence model sets for combined, stream, and OCH models contained one, seven, and four candidate models, respectively (Table 3). The combined model (i.e., stream and OCH sites) contained only one model in its confidence model set. All competing models in the combined model had a $\Delta AIC_c > 2$ indicating that no candidate model was nearly as parsimonious as the top model. Fathead Minnow CPUE appeared in the top five candidate models, while percent submerged vegetation and sunfish CPUE only appeared in three of the five. The stream model had seven candidate models in the confidence model set. Each confidence model was similarly parsimonious and no single variable was common to all. The OCH model had four candidate models in its confidence set. The top model containing only Fathead Minnow CPUE had a larger Akaike weight than the other three models. Fathead Minnow CPUE was in all of the confidence models for OCH sites.

The combined model identified two variables (Table 4) associated with Topeka Shiner occurrence (i.e., parameter estimates that were significantly different from zero). Both submerged vegetation and Fathead Minnow CPUE parameters were greater than zero, although the size of the coefficients was relatively small. Sunfish CPUE was not a significant predictor of Topeka Shiner occurrence in the combined model. The stream model contained no parameter estimates significantly different from zero. Similarly, the OCH model contained no parameter estimates significantly different from zero.

TABLE 2. Habitat and biotic variables measured at stream sites ($n = 67$) and OCH sites ($n = 27$) in west-central Iowa and included in the NMDS ordinations and logistic regression analyses. Means were calculated for variables in stream and OCH sites where Topeka Shiners were detected (TS detected) and not detected (TS not detected).

Variable name	Description	TS detected		TS not detected	
		Instream	OCH	Instream	OHC
Habitat variables					
Canopy	Mean proportion of canopy cover (%)	22.51	13.98	25.98	22.08
Coarse	Proportion of substrate > 0.2 cm (%)	43.29	0.95	35.51	4.10
CoarseGravel	Proportion of coarse gravel substrate (1.6–6.4 cm; %)	11.85	0.00	10.61	2.56
Depth	Mean depth (m)	0.42	0.54	0.32	0.63
DistAbsent	Proportion of banks with no disturbance within view (%)	25.00	3.57	32.37	32.05
Eroding	Proportion of bank eroded (%)	27.39	0.71	23.29	0.00
Gravel	Proportion of gravel substrate (0.2–1.6 cm; %)	24.29	0.95	15.20	1.03
Sand	Proportion of sand substrate (0.006–0.2 cm; %)	45.94	0.71	40.59	2.05
Silt	Proportion of silt substrate (0.004–0.006 cm; %)	5.85	88.55	15.57	83.59
VegBank	Proportion of bank covered by woody vegetation and nonwoody vegetation (%)	63.91	83.99	59.96	84.23
VegCover	Proportion of wetted area covered by terrestrial vegetation, aquatic macrophytes or overhanging vegetation (%)	7.16	23.42	7.19	17.99
Width	Mean wetted width (m)	6.37	13.90	7.00	18.33
WidthtoDepth	Ratio of mean wetted width (m) to mean depth (m)	15.57	31.22	23.96	33.06
Biotic variables					
FHMinnow	Number of Fathead Minnow per 100 m^2	2.94	59.17	2.69	8.46
Piscivore	Number of piscivorous fishes (Largemouth Bass, Smallmouth Bass, Channel Catfish, and Northern Pike) per 100 m^2	0.09	0.13	0.12	0.30
Sunfish	Number of Orangespotted Sunfish and Green Sunfish per 100 m^2	0.77	18.20	1.01	6.03

DISCUSSION

Our formal modeling identified several associations between Topeka Shiners and their biotic and abiotic environment. An increase in Fathead Minnow CPUE was associated with occurrence of Topeka Shiners in the combined model. Fathead Minnow CPUE was also present in many of the top candidate models in all three (combined, stream, and OCH) models. One explanation for this association could be that Fathead Minnow and Topeka Shiners have similar physiological tolerances. For example, they both can survive in drought conditions (Minckley and Cross 1959) that other species cannot tolerate. Fathead Minnow may also act as a predation buffer to Topeka Shiners. When a prey species becomes rare, predators may seek prey species that are more abundant (Murdoch 1969). In warm, oxygen-limited habitats, as found during dry years and in OCH, Fathead Minnow is one of the few species that could provide a predation buffer for Topeka Shiners. One study documented Topeka Shiners establishing territories on the periphery of Fat-head Minnow nests (Stark et al. 2002), suggesting they are "nest associates" of Fathead Minnow in addition to Green Sunfish and Orangespotted Sunfish. They also observed groups of Topeka Shiners overwhelming nest-guarding male Fathead Minnow and feeding, presumably, on Fathead Minnow eggs. Since Topeka Shiners spawn slightly later in the year than Fathead Minnow, feeding on nutrient-rich eggs could improve female Topeka Shiner condition prior to spawning (Belles-Isles and FitzGerald 1993). Although we identified an association between Fathead Minnow and Topeka Shiners, further research would be required to identify the specific mechanism underlying the association. For example, identifying the nature of the relationship of Topeka Shiners and Fathead Minnow could help guide recovery efforts. Fathead Minnow presence may only identify suitable habitats for Topeka Shiner reintroduction. However, if there is a symbiotic relationship between the two species, OCH restorations could include the stocking of known symbionts.

TABLE 3. Confidence models selected ($\Delta AIC_c < 2$) from the combined, stream and off-channel candidate set of a priori logistic regression models developed to identify habitat and fish species factors associated with Topeka shiner occurrence as determined by Akaike information criterion for small sample size (AIC_c). Also included are the number of parameters in each model (k) and the Akaike weight (w_i). Descriptions of each variable are contained in Table 2.

Confidence models	k	AIC_c	ΔAIC_c	w_i
Combined model				
VegCover, FHMinnow, Sunfish	4	84.9	0.00	0.46
Stream model				
Coarse, VegCover	3	45.67	0.00	0.17
FHMinnow, Sunfish	3	46.24	0.58	0.13
VegCover, Piscivore	3	46.31	0.64	0.12
VegCover, Sunfish	3	46.31	0.64	0.12
VegCover, FHMinnow	3	46.40	0.73	0.12
Coarse, FHMinnow, Sunfish	4	47.35	1.68	0.07
Coarse, VegCover, VegBank	4	47.36	1.69	0.07
Off-channel model				
FHMinnow	2	37.64	0.00	0.20
Depth, FHMinnow	3	38.83	1.19	0.11
FHMinnow, Piscivore	3	38.90	1.25	0.11
VegCover, FHMinnow	3	39.50	1.85	0.08

TABLE 4. Model-averaged parameter estimates, lower and upper limits to 95% CIs, and relative weights for the combined (pseudo $r^2 = 0.21$), stream (pseudo $r^2 = 0.001$), and off-channel logistic models (pseudo $r^2 = 0.13$) developed to identify habitat and fish species factors associated with Topeka shiner occurrence.

Model parameters	Estimate	Lower and upper limits to 95% CI		Relative weight
Combined model				
VegCover[a]	0.031	0.002	0.059	1.00
FHMinnow[a]	0.041	0.003	0.080	1.00
Sunfish	0.049	−0.075	0.172	1.00
Stream model				
Coarse	0.018	−0.024	0.061	0.39
VegBank	0.016	−0.043	0.075	0.09
VegCover	0.0001	−0.085	0.086	0.75
FHMinnow	0.018	−0.112	0.149	0.39
Piscivore	−0.690	−5.358	3.978	0.15
Sunfish	−0.093	−0.664	0.178	0.40
Off-channel model				
Depth	−1.990	−5.884	1.905	0.22
VegCover	0.014	−0.022	0.051	0.16
FHMinnow	0.030	−0.017	0.077	1.00
Sunfish	0.023	−0.029	0.075	0.22

[a]Coefficients are significantly different from zero.

The positive association between the Topeka Shiner and Green Sunfish and Orangespotted Sunfish (Pflieger 1997) was not apparent in our study. All sites (stream and OCH) that supported Topeka Shiners also included either Green Sunfish or Orangespotted Sunfish. Green Sunfish and Orangespotted Sunfish CPUE was not a significant predictor of Topeka Shiner occurrence, probably because of their ubiquity throughout the study area.

Although a negative association between Topeka Shiner and piscivorous fishes (e.g., Largemouth Bass) has been documented in the Flint Hills of northeastern Kansas (Schrank et al. 2001; Mammoliti 2002), we found no such association in west-central Iowa. In contrast, we found that Largemouth Bass and other piscivorous fishes were often syntopic with Topeka Shiners. This discrepancy could be explained by differences in habitat between the Flint Hills of Kansas and the Des Moines Lobe of Iowa. Streams in the Flint Hills are surrounded by native grasslands, are less eroded, and have high water clarity throughout most of the year. In the Des Moines Lobe, streams and OCH are surrounded by cropland or pasture, considerably eroded, and often highly turbid. Turbidity can affect foraging efficiency of Largemouth Bass (Shoup and Wahl 2009) and other piscivores (Turesson and Brönmark 2007). Therefore, it is possible that visual predators are much more efficient at capturing Topeka Shiners in the clear streams and impoundments of Kansas, and less efficient in turbid conditions that are characteristic of habitats in Iowa. It is important to note that piscivorous fish abundance was low throughout the study area. Although we proved that Topeka Shiners can occur with low densities of piscivorous fishes, the effects of abundant piscivorous fishes on Topeka Shiners were not explicitly examined.

Biotic associations with Topeka Shiner occurrence can exist with individual species, such as Fathead Minnow, but also with fish assemblages. Our analyses show that their occurrence was associated with unique fish assemblages within OCH sites. Not only did lentic species (e.g., Largemouth Bass, Green Sunfish, Common Carp) tend to occur more often in OCH sites, but they also occurred more often with Topeka Shiners than without them. On the other hand, Topeka Shiners were detected less often with fish assemblages containing species typically associated with lotic habitats (e.g., Bigmouth Shiner *Notropis dorsalis*, Sand Shiner *N. stramineus*, Common Shiner *Luxilus cornutus*, Highfin Carpsucker *Carpoides velifer*). Lotic specialists that require flowing water and higher dissolved oxygen could enter an oxbow during a flood event. After flood waters recede, however, these species may perish as conditions become more lentic (Halyk and Balon 1983). For example, species such as Fathead Minnow, Brassy Minnow *Hybognathus hankinsoni*, Black Bullhead *Ameiurus melas*, and Topeka Shiner occurred at higher densities in OCH. These four species are tolerant of high water temperatures and low dissolved oxygen, conditions characteristic of disconnected OCH (Brungs 1971a, 1971b; Copes 1975; Koehle and Adelman 2007). Others have shown that varying

levels of connectivity with the main channel can structure fish assemblages in large oxbows (Miranda 2005; Zeug et al. 2005; Dembkowski and Miranda 2011). Similar findings in small OCH of wadeable streams are lacking. Further research is needed to understand the mechanisms that underlie differences in fish assemblage structure between OCH and their associated wadeable stream systems.

Topeka Shiner occurrence is not only related to the occurrence of other fishes, but also to habitat features. Our results indicate a positive relationship between Topeka Shiner occurrence and submerged vegetation. Juvenile fish of many species are known to use submerged vegetation as nursery habitat (Lobb and Orth 1991; Venugopal and Winfield 1993). In fact, Kerns and Bonneau (2002) observed juvenile Topeka Shiners congregating in areas with submerged vegetation in the shallow margins of pool habitats. The type of vegetation found in streams was slightly different than that of OCH sites. In streams, most of the submerged vegetation consisted of submerged terrestrial bank vegetation and a lesser amount of aquatic macrophytes. Since livestock grazing is very common along wadeable streams in Iowa, measures to reduce overgrazing along stream banks could improve Topeka Shiner habitat, though Wall et al. (2004) suggest that they can survive in streams that experience "moderate" grazing. Submerged vegetation in OCH consisted primarily of aquatic macrophytes but with small contributions of flooded terrestrial vegetation. Increasing or maintaining aquatic vegetation in streams and OCH may not only be beneficial to Topeka Shiners, but to other fish species that may use those areas as rearing habitats.

Our results identified a positive association between Topeka Shiners and OCH. Although this phenomenon has been noted by others (Minckley and Cross 1959; Hatch 2001), there are no clear hypotheses as to why Topeka Shiners were more common in OCH of west-central Iowa. One possibility is that OCH represent a considerable proportion of their total habitat use and, thus, could be considered a floodplain-exploitative species (Ross and Baker 1983). Topeka Shiners can also tolerate low levels of dissolved oxygen and high water temperatures (Koehle and Adelman 2007), which are conditions typical of shallow, unconnected OCH. They are also known to persist during droughts when streams are reduced to a series of deep pools with little or no surface flow (Minckley and Cross 1959). Since OCH are similar to pool habitats during droughts, Topeka Shiners are probably adapted to conditions typical of OCH. Topeka Shiners cannot only survive in OCH, they can also reproduce in these habitats as has been documented at two OCH sites by us and others (Dahle 2001; Thomson et al. 2005). This research provides further evidence that OCH is an important component of Topeka Shiner life history.

Higher sampling efficiency may also explain why Topeka Shiners were more often detected in OCH than in streams. Many of the stream sites had undercut banks, dense bank vegetation, and stream cover that probably made sampling less efficient than it was in the physically homogenous OCH. Topeka Shin-

ers are typically rare in sites where they are detected, so it is possible that this species was present but not detected in some stream sites. Since this species has traditionally been considered a prairie stream fish (Pflieger 1997), previous sampling efforts targeting the Topeka Shiner have generally occurred solely in streams (Bayless et al. 2003). We now know that they often use (Thomson and Berry 2009; this study) and are readily detected in OCH, so future research should incorporate these habitats whenever possible.

In other studies, Topeka Shiner occurrence and abundance has been associated with water depth. One study suggested Topeka Shiner occurrence and abundance are associated with deeper OCH (Thomson and Berry 2009) while others detected them in OCH having less than 1 m of depth (Dahle 2001; Ceas and Larson 2010). Eight of the 14 OCH that contained Topeka Shiners were relatively shallow (mean depth, <0.5 m). Juvenile Topeka Shiners were also abundant in one shallow OCH, suggesting that reproduction is possible in such habitats. Robb and Abrahams (2002) suggested that Fathead Minnow persist by seeking shallow areas in a pond where predators with lower physiological tolerances could not survive. Since Topeka Shiners are similarly tolerant to low dissolved oxygen and high water temperatures, they too could physiologically exclude predators and even competitors.

Although the distribution and abundance of Topeka Shiners does not appear to be increasing, we are beginning to understand some of the physical and biological needs of this imperiled fish. Without such knowledge, costly efforts aimed at Topeka Shiner conservation could provide little return. However, identifying associations should only be the first step in understanding their biology and life history. Identifying the underlying mechanisms behind their biotic and abiotic associations could provide us with valuable information that can be applied to Topeka Shiner conservation.

We identified novel factors associated with the occurrence of Topeka Shiners that can be used to guide restoration and other recovery efforts. Similarly, we reevaluated the results from previous studies and anecdotal evidence to find that they are not necessarily applicable to Topeka Shiner populations in Iowa, or possibly throughout their current distribution. Our formal modeling provided a rigorous evaluation to validate or refute our assumptions about this understudied prairie stream fish while also providing new information that can be applied by fisheries managers to further Topeka Shiner recovery.

ACKNOWLEDGMENTS

REFERENCES

Bayless, M. A., M. G. McManus, and J. F. Fairchild. 2003. Geomorphic, water quality and fish community patterns associated with the distribution of *Notropis topeka* in a central Missouri watershed. American Midland Naturalist 150:58–72.

Belles-Isles, J. C., and G. J. FitzGerald. 1993. A fitness advantage of cannibalism in female Sticklebacks (*Gasterosteus aculeatus* L.). Ethology, Ecology, and Evolution 5:187–191.

Bisson, P. A., J. L. Nielsen, R. A. Palmason, and L. E. Grove. 1982. A system of naming habitat types in small streams, with examples of habitat utilization by salmonids during low streamflow. Pages 62–73 in N. B. Armantrout, editor. Acquisition and utilization of aquatic habitat inventory information. American Fisheries Society, Western Division, Bethesda, Maryland.

Brungs, W. A. 1971a. Chronic effects of constant elevated temperature on the Fathead Minnow (*Pimephales promelas* Rafinesque). Transactions of the American Fisheries Society 100:659–664.

Brungs, W. A. 1971b. Chronic effects of low dissolved oxygen concentrations on the Fathead Minnow (*Pimephales promelas*). Journal of the Fisheries Research Board of Canada 28:1119–1123.

Burnham, K. P., and D. R. Anderson. 2002. Model selection and multimodel inference: a practical information-theoretic approach, 2nd edition. Springer-Verlag, New York.

Ceas, P. A., and K. A. Larson. 2010. Topeka Shiner monitoring in Minnesota: year seven. Final Report to the Division of Ecological Resources, Minnesota Department of Natural Resources, St. Paul.

Clark, S. J. 2000. Relationship of Topeka Shiner distribution to geographic features of the Des Moines lobe in Iowa. Master's thesis. Iowa State University, Ames.

Copes, F. A. 1975. Ecology of the Brassy Minnow, *Hybognathus hankinsoni* (Cyprinidae). Pages 46–72 in G. C. Becker, H. E. Brooke, and C. Long, editors. Reports on the fauna and flora of Wisconsin. Museum of Natural History, University of Wisconsin, Stevens Point.

Dahle, S. P. 2001. Studies of Topeka Shiner (*Notropis topeka*) life history and distribution in Minnesota. Master's thesis. University of Minnesota, St. Paul.

Dembkowski, D. J., and L. E. Miranda. 2011. Comparison of fish assemblages in two disjoined segments of an oxbow lake in relation to connectivity. Transactions of the American Fisheries Society 140:1060–1069.

Faith, D. P., P. R. Minchin, and L. Belbin. 1987. Compositional dissimilarity as a robust measure of ecological distance. Vegetatio 69:57–68.

Fischer, J. R., and C. P. Paukert. 2008. Historical and current environmental influences on an endemic Great Plains fish. American Midland Naturalist 159:364–377.

Griffith, G. E., J. M. Omernik, T. F. Wilton, and S. M. Pierson. 1994. Ecoregions and subregions of Iowa: a framework for water quality assessment and management. Journal of the Iowa Academy of Science 101:5–13.

Halyk, L. C., and E. K. Balon. 1983. Structure and ecological production of the fish taxocene of a small floodplain system. Canadian Journal of Zoology 61:2446–2464.

Harig, A. L., and K. D. Fausch. 2002. Minimum habitat requirements for establishing translocated Cutthroat Trout populations. Ecological Applications 12:535–551.

Hatch, J. T. 2001. What we know about Minnesota's first endangered fish species: the Topeka Shiner. Journal of the Minnesota Academy of Science 65:31–38.

IDNR (Iowa Department of Natural Resources). 2001. Biological sampling procedures for wadeable streams of Iowa. IDNR, Des Moines.

IRIS (Iowa Rivers Information System). 2005. Iowa aquatic gap fish atlas. IRIS, Iowa Cooperative Fish and Wildlife Research Unit, Iowa State University, Ames. Available: maps.gis.iastate.edu/iris/fishatlas/. (February 2011).

Kerns, H. A., and J. L. Bonneau. 2002. Aspects of the life history and feeding habits of the Topeka Shiner (*Notropis topeka*) in Kansas. Transactions of the Kansas Academy of Science 105:125–142.

Koehle, J. J., and I. R. Adelman. 2007. The effects of temperature, dissolved oxygen, and Asian tapeworm infection on growth and survival of the Topeka Shiner. Transactions of the American Fisheries Society 136:1607–1613.

Lee, D. S., C. R. Gilbert, C. H. Hocutt, R. E. Jenkins, D. E. McAllister, and J. R. Stauffer Jr. 1980. Atlas of North American freshwater fishes. North Carolina Museum of Natural History, Raleigh.

Loan-Wilsey, A. K., C. L. Pierce, K. L. Kane, P. D. Brown, and R. L. McNeely. 2005. The Iowa aquatic gap analysis project: final report. Iowa Cooperative Fish and Wildlife Research Unit, Iowa State University, Ames.

Lobb, M. D., III, and D. J. Orth. 1991. Habitat use by an assemblage of fish in a large warmwater stream. Transactions of the American Fisheries Society 120:65–78.

Mammoliti, C. S. 2002. The effects of small watershed impoundments on native stream fishes: a focus on the Topeka Shiner and Hornyhead Chub. Transactions of the Kansas Academy of Science 105:219–231.

McFadden, D. 1974. Conditional logit analysis of qualitative choice behavior. Pages 105–142 in P. Zarembka, editor. Frontiers in econometrics. Academic Press, New York.

Menzel, B. W., and S. J. Clark. 2002. Final report to Iowa Department of Natural Resources on agreement for consultant services for refinements to a habitat model of the Topeka Shiner. Iowa State University, Ames.

Minckley, W. L., and F. B. Cross. 1959. Distribution, habitat, and abundance of the Topeka Shiner *Notropis topeka* (Gilbert) in Kansas. American Midland Naturalist 61:210–217.

Miranda, L. E. 2005. Fish assemblages in oxbow lakes relative to connectivity with the Mississippi River. Transactions of the American Fisheries Society 134:1480–1489.

Mittelbach, G. G., and L. Persson. 1998. The ontogeny of piscivory and its ecological consequences. Canadian Journal of Fisheries and Aquatic Sciences 55:1454–1465.

Murdoch, W. W. 1969. Switching in general predators: experiments on predator specificity and stability of prey populations. Ecological Monographs 39:335–354.

Oksanen, J., F. G. Blanchet, R. Kindt, P. Legendre, P. R. Minchin, R. B. O'Hara, G. L. Simpson, P. Solymos, M. Henry, H. Stevens, and H. Wagner. 2011. vegan: community ecology package, R package version 2.0-1. R Foundation for Statistical Computing, Vienna. Available: CRAN.R-project.org/package=vegan. (May 2011).

Pflieger, W. L. 1997. The fishes of Missouri, revised edition. Missouri Department of Conservation, Jefferson City.

Pont, D., B. Hugueny, and T. Oberdorff. 2005. Modelling habitat requirement of European fishes: do species have similar responses to local and regional environmental constraints? Canadian Journal of Fisheries and Aquatic Sciences 62:163–173.

Quist, M. C., F. J. Rahel, and W. A. Hubert. 2005. Hierarchical faunal filters: an approach to assessing effects of habitat and nonnative species on native fishes. Ecology of Freshwater Fish 14:24–39.

R Development Core Team. 2011. R: a language and environment for statistical computing. R Foundation for Statistical Computing, Vienna. Available: www.R-project.org/. (May 2011).

Rich, C. F., Jr., T. E. McMahon, B. E. Rieman, and W. L. Thompson. 2003. Local-habitat, watershed, and biotic features associated with Bull Trout occurrence in Montana streams. Transactions of the American Fisheries Society 132:1053–1064.

Robb, T., and M. V. Abrahams. 2002. The influence of hypoxia on risk of predation and habitat choice by the Fathead Minnow, *Pimephales promelas*. Behavioral Ecology and Sociobiology 52:25–30.

Ross, S. T., and J. A. Baker. 1983. The response of fishes to periodic spring floods in a southeastern stream. American Midland Naturalist 109:1–14.

Schrank, S. J., C. S. Guy, M. R. Whiles, and B. L. Brock. 2001. Influence of instream and landscape-level factors on the distribution of Topeka Shiners *Notropis topeka* in Kansas streams. Copeia 2001:413–421.

Shoup, D. E., and D. H. Wahl. 2009. The effects of turbidity on prey selection by piscivorous Largemouth Bass. Transactions of the American Fisheries Society 138:1018–1027.

Stark, W. J., J. S. Luginbill, and M. E. Eberle. 2002. Natural history of a relict population of Topeka Shiner (*Notropis topeka*) in northwestern Kansas. Transactions of the Kansas Academy of Science 105:143–152.

Thomson, S. K., and C. R. Berry Jr. 2009. Stream fishes inhabit livestock watering ponds (dugouts) near Six Mile Creek, Brookings County, South Dakota. Proceedings of the South Dakota Academy of Science 88:127–138.

Thomson, S. K., C. R. Berry Jr., C. A. Niehus, and S. S. Wall. 2005. Constructed impoundments in the floodplain: a source or sink for native prairie fishes, in particular the endangered Topeka Shiner (*Notropis topeka*)? Pages 1337–1348 *in* G. E. Moglen, editor. Proceedings of the 2005 watershed management conference—managing watersheds for human and natural impacts: engineering, ecological, and economic challenges. American Society of Civil Engineers, Reston, Virginia.

Turesson, H., and C. Brönmark. 2007. Predator–prey encounter rates in freshwater piscivores: effects of prey density and water transparency. Oecologia 153:281– 290.

USFWS (U.S. Fish and Wildlife Service). 1998. Endangered and threatened wildlife and plants; final rule to list the Topeka Shiner as endangered. Federal Register 63:240(15 December 1998):69008–69021.

USFWS (U.S. Fish and Wildlife Service). 2009. Topeka Shiner (*Notropis topeka*), 5-year review: summary and evaluation. USFWS, Kansas Ecological Services Field Station, Manhattan.

Venugopal, M. N., and I. J. Winfield. 1993. The distribution of juvenile fishes in a hypereutrophic pond: can macrophytes potentially offer a refuge for zooplankton? Journal of Freshwater Ecology 8:389–396.

Wall, S. S., and C. R. Berry Jr. 2006. The importance of multiscale habitat relations and biotic associations to the conservation of an endangered fish species, the Topeka Shiner. Pages 305–322 *in* R. M. Hughes, L. Wang, and P. W. Seelbach, editors. Landscape influences on stream habitats and biological assemblages. American Fisheries Society, Symposium 48, Bethesda, Maryland.

Wall, S. S., C. R. Berry Jr., C. M. Blausey, J. A. Jenks, and C. J. Kopplin. 2004. Fish-habitat modeling for gap analysis to conserve the endangered Topeka Shiner (*Notropis topeka*). Canadian Journal of Fisheries and Aquatic Sciences 61:954–973.

Winston, M. R. 2002. Spatial and temporal species associations with the Topeka Shiner (*Notropis topeka*) in Missouri. Journal of Freshwater Ecology 17:249–261.

Zeug, S. C., K. O. Winemiller, and S. Tarim. 2005. Response of Brazos River oxbow fish assemblages to patterns of hydrologic connectivity and environmental variability. Transactions of the American Fisheries Society 134:1389–1399.