ROAD CULVERTS ACROSS STREAMS WITH THE ENDANGERED TOPEKA SHINER, *NOTROPIS TOPEKA*, IN THE JAMES, VERMILLION, AND BIG SIOUX RIVER BASINS.

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ABSTRACT

We evaluated 232 installed corrugated pipe culverts at 81 sites where roads cross streams that have a high potential for Topeka shiner presence. Culvert conditions were characterized by the amount of perching, embeddedness, blockage, gradient and water velocity, and rated for potential as a barrier to upstream fish migration. Seven sites were classified as high priority for maintenance or mitigation, 22 were classified as medium priority for mitigation, and 52 were classified as low priority for mitigation. The data allows the Department of Transportation to plan for road crossing maintenance and the conservation of the rare species and associated stream habitat.

Keywords

Stream, culvert, Topeka shiner, *Notropis topeka,* road crossings, barriers, highway, corrugated culvert, stream habitat, fish migration, barrier

INTRODUCTION

Road construction plans for stream crossings usually include management practices that conserve the stream habitat and biota. A free-span bridge eliminates problems associated with culverts (Clay 1995), but culverts are more economical for crossing small streams. During culvert installation, conservation practices protect stream habitat, but maintenance is needed afterwards because culverts can become a barrier to fish migration if they become blocked, perched, or inadequate for flows (Gebhards and Fisher 1972, Lauman 1976, WDFW 2001).

Culverts become inadequate for stream discharge when discharge increases because of land use changes upstream (e.g., wetland drainage, urbanization). High flows can be a velocity barrier to fish migration when velocity through long culverts exceeds fish swimming ability (Lauman 1976, Adams et al. 2000). During low flows the culvert may have inadequate water depths for fish passage, or may be blocked by debris. A perched culvert develops when scouring at the downstream end causes channel incision and a vertical water drop from the culvert to the stream (Gebhards and Fisher 1972).

The listing of the Topeka shiner (*Notropis topeka*) as endangered in 1999 has caused highway departments to review the impacts of construction activities on this rare fish. Topeka shiners inhabit small tributaries to the James, Vermillion, and Big Sioux rivers (Wall et al., 2001). These tributaries are crossed many times by roads over concrete box culverts or corrugated steel pipe culverts that may influence Topeka shiner movements. Topeka shiners undertake localized movements before spawning from mid-May to early August (Kerns 1983, Barber 1986, Stark et al. 1999) and in response to flow variation (Layher 1993, Dahle 2001, Mammoliti 1994). Topeka shiners are small minnows (family Cyprinidae) that reach 6 cm in length (Blausey 2001). Adults can swim up to about 35 cm/second (Adams et al. 2000) but may be blocked by small waterfalls that require leaping.

Our objectives were to assess the condition of culverts at road crossings over streams that were suitable habitat for the Topeka shiner, and to prioritize crossing sites for mitigation or maintenance.

METHODS

Stream and road maps were overlaid for each 11-digit Hydrological Unit watershed in the James, Vermillion, and Big Sioux basins where Topeka shiners have been found or are predicted because of the presence of suitable habitat (Wall et al. 2001). We focused on crossings with corrugated culverts and stream segments with a high or moderate potential for Topeka shiner presence because steel corrugated culverts have the most impact on fish migration in small streams (Warren and Pardew 1998). Road crossings were given high, medium or low priority for maintenance by combining a culvert condition index with a stream habitat suitability index (Table 1).

Culvert Condition Indices

We measured culvert slope, length, perch, counter sink, bed width, and water velocity (Figure 1) as well as many other measures reported elsewhere (Wall and Berry 2002). We indexed culvert condition by scoring the five features for their potential impact on Topeka shiner movement and summed the scores (Table 2). An index of < 6 indicated a poor condition, whereas a score of > 8 indicated a good condition (Table 1). Culvert features were scored as follows.

Table 1. Culvert condition and habitat indices and method of combining two indices to determine maintenance priorities.

CULVERT CONDITION INDEX		HABITAT SUITABILITY INDEX		
Index score	**Condition**	**Index score**	**Suitability**	**Maintenance Priority**
< 6	Poor	≥ 6	High	High
≥ 6 and < 8	Medium	≥ 6	High	Moderate
≥ 8	Good	≥ 6	High	Low
≥ 8	Good	< 6	Low	Low
≥ 6 and < 8	Medium	< 6	Low	Low
< 6	Poor	< 6	Low	Low

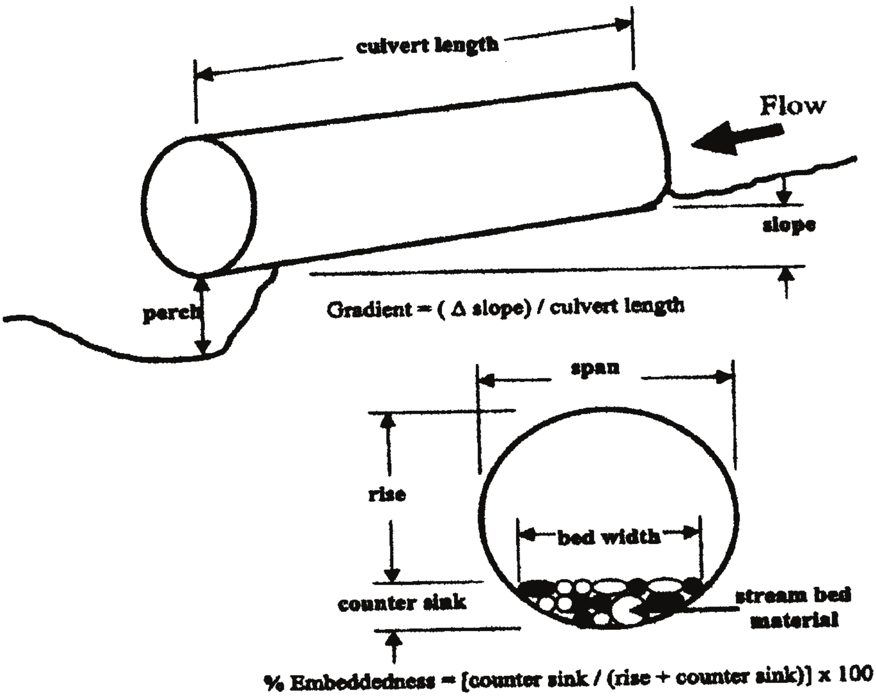

Figure 1. Schematic of a corrugated pipe highway culvert showing long and cross sections, and measurements to index culvert condition in relation to fish passage.

Perch: We speculated that a perch > 6 cm might block Topeka shiner migration. Using seasonal stage data for a wet year and dry year for a stream with Topeka shiners, we calculated that a perch of 6 cm would not occur during wet years but would occur 87% of the time during dry years (Wall and Berry 2002). So, a culvert perched > 6 cm at either the upstream or downstream end scored zero; one perched < 6 cm was scored 2. Sites with multiple culverts are planned with one or more embedded culverts to convey low flows, so we used the best culvert score to represent the crossing.

Embeddedness: A culvert that is embedded 30% has little impact on stream hydrology (WDFW 2001), therefore a culvert embedded ≥ 30% scored 2; one embedded 30 - 15% scored 1.5; one embedded 1 - 15% scored 1; and one not embedded scored zero. Scores for each end of the culvert were averaged.

Table 2. Culvert condition index scores for seven sites classified as high priority for mitigation. All sites had culverts in poor condition (i.e. scores < 6). Site identification number refers to sites in the Big Sioux (BS), James (JR), and Vermillion (VR) river basins (locations given in Wall and Berry, 2002).

Site (ID)	Culvert (#)	Perch (m)	Embeded (%)	Gradient (cm/m)	Velocity (cm/s)	Blocked (Yes/No)	Score (Index)
BS007	1	0.54	0.0	0.5	52	no	
		0	0	2	0	2	4
	2	0.25	9.7	0.7	59	no	
		0	1	2	0	2	5
	3	0.34	0.0	0.2	58	no	
		0	0	2	0	2	4
BS018	1	0.50	3.5	1.2	73	no	
		0	1	2	0	2	5
	2	0.50	7.0	1.1	33	yes	
		0	1	2	0	0	3
JR019	1	0.09	0.0	-0.4	0	yes	
		0	0	2	2	0	4
	2	0.11	22.4	0.2	0	yes	
		0	1.5	2	2	0	5.5
	3	0.09	0.0	-1.0	0	yes	
		0	0	2	2	0	4
	4	0.07	0.0	-0.2	0	yes	
		0	0	2	2	0	4
JR047	1	0.85	0.0	0.4	56	no	
		0	0	2	0	2	4
VR003	1	0.16	0.4	0.0	0	yes	
		0	0.5	2	2	0	4.5
VR005	1	0.24	0.0	***	0	yes	
		0	0	2	2	0	4
	2	0.23	0.0	***	0	yes	
		0	0	2	2	0	4
VR011[1]	*	*	*	*	*	no culvert	0

[1]At VR011 there was no culvert in place and stream was blocked by the road

Blockage: A culvert was scored zero if either the upstream or downstream end was completely blocked by material without spaces allowing fish passage. Open or partially blocked culverts scored 2.
Velocity: We measured velocity with a current meter. The culvert scored 2 if the mean velocity was ≤ 35 cm/s, which is the sustained swimming performance for Topeka shiners (Adams et al. 2000). Scores were zero if velocity was > 35 cm/s. However, a score of 2 was given when velocity was > 35 cm/s in early spring (i.e. April to May 6) but we expected velocity to be < 35 cm/sec by the mid-May to August spawning season.
Gradient: Surveying equipment was used to determine slope. A culvert scored 2 if gradient was ≤ 3 cm/m, which is equivalent to a low stream gradient (WDFW 2001); scores were zero for gradients > 3 cm/m.

Stream Reach Indices

We assessed stream habitat features up and downstream from crossings using standard methods (Wall et al., 2001). Habitat features that are associated with Topeka shiner presence included: low bank height, low bank incision, streambed substrate materials of fine gravel to cobble, presence of pool habitat and submerged macrophytes, riparian zones with grass or pasture and low livestock use, and overhanging vegetation (other than trees) along the stream bank (Blausey 2001). We recorded whether each physical habitat feature was present (score = 1) or absent (score = 0) based on planned criteria (Wall and Berry 2002). Upstream and downstream habitat scores at each site were summed (maximum score of 18 was possible), and the average score was assigned to the site (Table 3). Maximum score was 9 for sites with all desirable habitat features. We classified crossings with scores ≥ 6 as good habitat for Topeka shiners, and crossings with scores < 6 were classified as having low habitat suitability.

RESULTS

We surveyed 36 watersheds with Topeka shiners. In 25 watersheds we found 81 crossings over corrugated steel culverts (n = 232) in reaches of high or moderate Topeka shiner habitat. Of the 81 crossings, 28 had good culvert conditions, 40 had medium conditions, and 13 were in poor condition. Good stream habitat surrounded 49 crossings, whereas 32 sites had habitat features that were not indicative of Topeka shiner presence.

Combined culvert and stream reach index scores classified seven crossings as high priority sites for mitigation (Table 2, Table 3). High priority sites had poor culvert conditions with scores ranging from 3 to 5.5, and reach habitat associated with Topeka shiner presence (scores = 6 and 7). Of the remaining sites, 22 were classified as medium priority for mitigation, and 52 were classified as low priority for mitigation according to combined index scores shown in Table 1.

An example of a high priority mitigation crossing (culvert index = 5) is shown in Figure 2. The culverts are perched 0.25 m above stream level (score = 0). The culvert had no blockage (score = 2) but there was no streambed mate-

Table 3. Stream reach index scores for stream habitat measures at seven sites classified as high priority for mitigation. All sites had habitat indicative of Topeka shiner presence (i.e. scores ≥ 6). US = Upstream from crossing, DS = downstream from crossing.

Site ID	US Bed Mat	DS Bed Mat	US Hd Cut	DS Hd Cut	US LvStk Use	DS LvStk Use	US OH Veg	DS OH Veg	US Tree	DS Tree	US Rip Zone	DS Rip Zone
BS007	SI	SI	low	yes	low	low	yes	yes	yes	yes	yes	yes
	0	0	1	0	1	1	1	1	0	0	1	1
BS018	SI/CB	SI/CB	yes	low	high	med	no	yes	yes	no	yes	yes
	1	1	0	1	0	0.5	0	1	0	1	1	1
JR019	SI / SA	SA / CL	no	yes	med	med	yes	yes	no	no	yes	yes
	0	0	1	0	0.5	0.5	1	1	1	1	1	1
JR047	SA/CB	SA/CB	yes	yes	med	med	yes	yes	no	yes	yes	yes
	1	1	0	0	0.5	0.5	1	1	1	0	1	1
VR003	SI	SI	no	no	med	low	yes	yes	yes	yes	yes	yes
	0	0	1	1	0.5	1	1	1	0	0	1	1
VR005	Grass	BD/SI/CB	no	no	low	high	yes	no	yes	no	yes	yes
	0	1	1	1	1	0	1	0	0	1	1	1
VR011	FG/CB	FG/CB	no	yes	med	high	yes	yes	no	no	yes	yes
	1	1	1	0	0.5	0	1	1	1	1	1	1

[1] Bed Mat = bed material, Hd Cut = Head cutting, LvStk Use = livestock use, OH Veg = overhanging vegetation, Rip Zone = riparian zone consisting of grasses and forbes, Sub Mac = submerged macrophytes, Bnk Ht = bank height, Bnk Incis = bank incision, USS = upstream reach score, DSS = downstream reach score, AVS = mean reach score (rounded), CB = cobble, BD = boulder, SI = silt, CL = clay, FG = fine gravel.

Table 3 continued. Stream reach index scores for stream habitat measures at seven sites classified as high priority for mitigation. All sites had habitat indicative of Topeka shiner presence (i.e. scores ≥ 6). US = Upstream from crossing, DS = downstream from crossing.

Sites ID	US Sub Mac	DS Sub Mac	US Bnk Ht	DS Bnk Ht	US Bnk Incis	DS Bnk Incis	US pools	DS pools	USS	DSS	AVS
BS007	yes	yes	low	low	low	low	no	no			
	1	1	1	0	1	1	0	0	7	5	6
BS018	yes	no	med	med	med	med	no	yes			
	1	0	0.5	0.5	0.5	0.5	0	1	4	7.5	6
JR019	yes	yes	low	med	low	med	no	no			
	1	1	1	0.5	1	0.5	0	0	7.5	5.5	7
JR047	no	no	med	med	med	med	no	yes			
	0	0	0.5	0.5	0.5	0.5	0	1	5.5	5.5	6
VR003	no	no	low	low	low	low	no	no			
	0	0	1	1	1	1	0	0	5.5	6	6
VR005	no	no	low	med	low	low	no	no			
	0	0	1	0.5	1	1	0	0	6	5.5	6
VR011	no	no	low	low	low	low	yes	yes			
	0	0	1	1	1	1	1	1	7.5	6	7

[1] Bed Mat = bed material, Hd Cut = Head cutting, LvStk Use = livestock use, OH Veg = overhanging vegetation, Rip Zone = riparian zone consisting of grasses and forbes, Sub Mac = submerged macrophytes, Bnk Ht = bank height, Bnk Incis = bank incision, USS = upstream reach score, DSS = downstream reach score, AVS = mean reach score (rounded), CB = cobble, BD = boulder, SI = silt, CL = clay, FG = fine gravel.

Figure 2. Downstream view of a stream crossing that is a high priority for maintenance because of excessive perch (> 0.2 m) and high water velocities (> 0.35 m/s) that present a potential passage problem for Topeka shiners.

rial (low bed width) in the culvert. The velocity (52-59 cm/s) exceeded Topeka shiner swimming ability (score = 0).

DISCUSSION

We chose measurements of culvert conditions that others have suggested were important (McKinnon and Hnytka 1985, Belford and Gould 1989, Warren and Pardew 1998, Toepfer et al. 1999, WDFW 2001, Wellman et al. 2000). We introduced the scoring and index protocol to synthesize the many parameters we measured for culverts and stream habitat to create a decision support protocol to help prioritize sites for inspection by highway engineers or for possible maintenance. All crossings would require some degree of mitigation according to our classification system (i.e. all culverts scored < 10). We prioritized the crossings so that maintenance might start at the high priority sites using guidelines for proper culvert placement in general (Clay 1995, Odeh 1999) and in South Dakota specifically (Cunningham 2000, NRCS 2001).

The problem of passage by small fishes in low gradient streams has not been given much attention. Movement of small fishes (ie., *Notropis* sp.) through properly installed box culverts was comparable with or higher than movement through natural stream reaches, whereas corrugated culverts restricted movement somewhat (Warren and Pardew 1998). Two general conclusions have been made for insuring passage of juvenile salmonids: 1) "the low velocities and level of turbulence required for passage of juvenile fish are so low, they are impractical to achieve in design," and 2) "if juvenile passage is desired, it is recommended that a natural channel be built within the culvert" (Bates 2001).

When mitigating or replacing culverts, construction should minimize impacts to the stream and thus the fish community. Standard best management practices need to be clearly stated and planned before road construction begins. Erosion control is important, especially during the spawning season, because sedimentation can reduce the reproductive success of the Topeka shiner and may have contributed to its extirpation in some parts of its range (Minckley and Cross 1959, Tabor 1998). At a crossing with multiple culverts, one culvert should be embedded in the streambed to allow fish passage during low flows. There are many streams with Topeka shiners in South Dakota (Wall et al., 2001), so it is important that guidelines and best management practices for road construction at stream crossings be practiced and improved.

The Topeka shiner is a pioneering species (Blausey 2001) that can be found in intermittent streams (Minckley and Cross 1959, Barber 1986, Dahle 2001). Thus there are times (e.g., drought, late summer) when a stream segment classified as good habitat may be dry at a road crossing where a culvert needs to be mitigated. Current guidelines prohibit in-stream disturbances during the spawning season, which is late-May to early August in headwater streams of the Big Sioux River in Minnesota (Hatch 2001). Dry conditions at road crossings provide the opportunity to maintain culverts with minimum impact on stream habitat.

The Endangered Species Act regulations have caused us to examine our management of streams. The willingness of the South Dakota Department of Transportation to take partial responsibility for fish conservation is an important aspect of South Dakota's conservation plan for this species (Shearer 2003). As construction goes on at dozens of road crossings in the future, an effort will be made to conserve this rare fish and in doing so, conserve stream habitat for all species, including landowners. Erosion, sedimentation, improper installation of culverts or lack of maintenance of road crossings are not only problems for the fish community, but also for landowners upstream because of flooding and downstream because of channel incision and bank sloughing.

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