Topeka shiner *(Notropis topeka*) Species Status Assessment

Version 1.0

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U.S. Fish & Wildlife Service

This species status assessment report provides the best available information on the ecological requirements, current conditions, stressors, future needs, and conservation actions for the endangered Topeka shiner (*Notropis topeka*). Updates to this version are anticipated as additional information becomes available.

This SSA was drafted primarily by the U.S. Fish and Wildlife Service's South Dakota Field Office, with considerable time, effort, guidance and data provided by U.S. Fish and Wildlife Service personnel from Headquarters, Mountain-Prairie Regional Office (R6), and Ecological Services Field Offices in Illinois, Kansas, Minnesota, Missouri, and Nebraska. Substantial time, resources, and data were also contributed by State personnel from Iowa Department of Natural Resources; Kansas Department of Wildlife, Parks and Tourism; Minnesota Department of Natural Resources; Missouri Department of Conservation; Nebraska Game and Parks Commission; and South Dakota Department of Game, Fish and Parks. Additionally, important contributions were provided by individuals from Aquatic Kansas Images, EcoCentrics, Iowa Geological Survey, Montana State University, South Dakota State University, University of Kansas, University of Minnesota, and U.S. Geological Survey. Much gratitude goes to all of the individuals involved in the process of developing this document.

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EXECUTIVE SUMMARY

The Topeka shiner is a small minnow that lives and breeds in graveled pools of low-order prairie streams in the Great Plains states of South Dakota, Minnesota, Nebraska, Iowa, Kansas and Missouri. It was listed as endangered under the Endangered Species Act in 1999 as a result of significant population declines due primarily to alteration of prairie stream hydrology and habitat degradation. Post-listing, increased survey efforts revealed additional extant populations, particularly in South Dakota and Minnesota, while population losses and/or reductions appear to continue in other states despite listing protections afforded by the ESA. Since 1999, the Topeka shiner has been documented as occupying 223 small to mid-size streams, composing 87 populations (HUC10 watersheds), and 13 population complexes (groups of hydrologically connected HUC10 watersheds) distributed among the six states known to harbor the species. The majority of Topeka shiners are within northern populations where the species has persisted despite threats occurring on the landscape. Northern populations herein are identified as those occurring in South Dakota, Minnesota, and Iowa, which have in common a relatively recent glacial history resulting in a hydrological regime that may be a key to the persistence of Topeka shiners in these areas despite threats occurring on the landscape. Southern states within the species' range (defined herein as those in Nebraska, Kansas, and Missouri) with older glacial records and relatively well drained hydrologic systems have experienced greater Topeka shiner population losses. Exceptions, such as the Flint Hills area of Kansas, have fared better than other areas, likely due likely to the relative lack of habitat impacts that have occurred since European settlement of the Great Plains. The Topeka shiner's current (defined herein as 1999 and later, based on the species' listing date and subsequent uptick in survey efforts since that time) six-state distribution, is generally patchy and isolated particularly in the southern parts of the range. Many populations and population complexes are separated by insurmountable distances, impassible structures, and/or unsuitable habitats. Genetic variability in the species exists at a fine scale; adjacent populations existing seemingly without barriers between them can exhibit differences indicative of long-term isolation, perhaps partly due to the species' typical association with relatively small streams While the Topeka shiner occupies a similar type of habitat across its range (small, low-flowing prairie streams, with sand/gravel/cobble pools), the six-state area composing its range affords some local variation of geophysical conditions. More Topeka shiner population complexes occur in southern states (n=7) than in northern states (n=6) while more populations exist in the north (n=57) than in the south (n=20). Overall resiliency of both populations and population complexes as determined via resiliency modeling is greater in northern states compared to southern. Future scenarios developed for the species herein are based on implementation of comprehensive, effective conservation measures to be applied by states, with progressive improvements in viability realized when the majority of southern states apply such measures.

The ecological requirements of the species, its current condition (based on stream collection records beginning in 1999, when the species was listed and survey efforts increased, through 2017), and projected future conditions based on conservation scenarios are summarized in Table 1 in terms of the "3Rs" (resiliency, redundancy, and representation) that are the cornerstones of species viability. This Species Status Assessment will serve as a basis for consultations under the ESA, and to inform Topeka shiner recovery planning.

Table 1. Ecological Requirements, current condition, and projected future conditions in terms of Topeka shiner resiliency, redundancy and representation.

3Rs	REQUIREMENTS	CURRENT CONDITION	FUTURE CONDITIONS - Projections based on conservation scenarios over next 10-20 years
RESILIENCY: populations able to withstand stochastic events	**Typically low-order prairie streams with pools, low flows, floodplain connectivity, gravel, sunfish** **Connectivity within/among HUC10 and HUC12 watersheds for recolonization and access to refugia**	**Resiliency of northern populations and complexes is higher than southern** **Ongoing threats continue to degrade habitat, reduce resiliency, particularly in southern states** **Conservation actions include off-channel habitat creations in MN/IA; reintroductions in MO; some general habitat improvement programs in other states**	**Scenario A (status quo – few States implement few conservation actions): No additional conservation strategies are implemented in any states; ongoing threats continue; populations and complexes become less resilient; species viability is not improved** **Scenarios B and C (increasing number of states implement numerous conservation actions): Status and viability of the species improves, particularly in southern states, as threats are abated with majority of southern states implementing effective long-term conservation actions** **Scenario D (best case- all states implement numerous conservation actions): All states implement numerous,**

			effective long-term conservation actions that improve population and complex resilience, persistence, and expansion throughout the range. Long term viability is substantially improved
REDUNDANCY: number and distribution of populations to withstand catastrophic events	**Numerous resilient populations and population complexes in majority of states within the range of the species**	**223 occupied streams with 1999-2017 records compose 87 HUC10 populations within 13 population complexes distributed among six states** **72 of the 87 populations (82%) are ranked in the three middle resiliency ranking categories** **11 of 13 (85%) of population complexes are rated in the lower 50% of weighted population complex rankings** **Northern states harbor 67 populations; southern states harbor 20 populations; overall northern populations and complexes exhibit greater resiliency rankings than southern**	**Scenario A (status quo – few states implement few conservation actions): Populations and complexes continue to decline; those most vulnerable (particularly in south) may be extirpated; reduced redundancy; species viability does not improve** **Scenarios B and C (increasing number of states implement numerous conservation actions): Existing populations expand, additional populations are added; redundancy is progressively increased and population complexes improved as more states implement more effective measures. Additional resilient populations/complexes contribute to improved viability** **Scenario D (best case- all states implement numerous conservation actions): Populations and complexes expand rangewide, redundancy is significantly improved in**

			southern states and increases in northern states; species viability is significantly improved
REPRESENTATION: genetic and/or ecological diversity to maintain adaptive potential	**Occupancy in a range of ecologically diverse drainages and physiogeo-graphic areas (ecoregions)** **Retention of current genetic diversity**	**Genetic variation has been reduced with population losses, but genetic variation exists within populations, between populations, and among population complexes** **Species retains a breadth of physiogeo-graphical diversity due to distribution within 6 states, albeit likely reduced due to population losses**	**Scenario A (status quo – few states implement few conservation actions): Genetic diversity continues to decline as populations and/or complexes are lost; adaptive ability declines; increased susceptibility to catastrophic events and changing climate; species viability does not improve** **Scenarios B and C (increasing number of states implement numerous conservation actions): Existing populations expand and additional populations are added; population complex conditions improve; species adaptive capacity increases; overall viability improved** **Scenario D (best case- all states implement numerous conservation actions): highest levels of adaptive capacity are achieved and maintained**

			throughout the range; species viability significantly improved

BACKGROUND

The Topeka shiner is a small minnow that occupies small prairie streams in six states within the central U.S.: South Dakota, Minnesota, Nebraska, Iowa, Kansas and Missouri (Figure 1). The Topeka shiner was listed as federally endangered under the Endangered Species Act (ESA) in 1998 (effective in January 1999), by the U.S. Fish and Wildlife Service (Service) (63 FR 69008-69021, December 15, 1998). The Service also designated critical habitat for the Topeka shiner in 2004 in Minnesota, Nebraska, and Iowa; the states of South Dakota, Missouri and Kansas were exempt from the designation due to the existence of management plans (69 FR 44736-44770, July 27, 2004). A Topeka Shiner Recovery Team was formed, and with invaluable assistance provided by team members and other knowledgeable individuals who contributed considerable time/effort/expertise, draft recovery plans were developed. The most recent draft, dated 2003, established criteria for down-listing and de-listing the species based on numbers of watershed recovery units harboring populations that were increasing or stable over a ten year timeframe. However, the plan was not finalized and remained in its agency technical draft stage form.

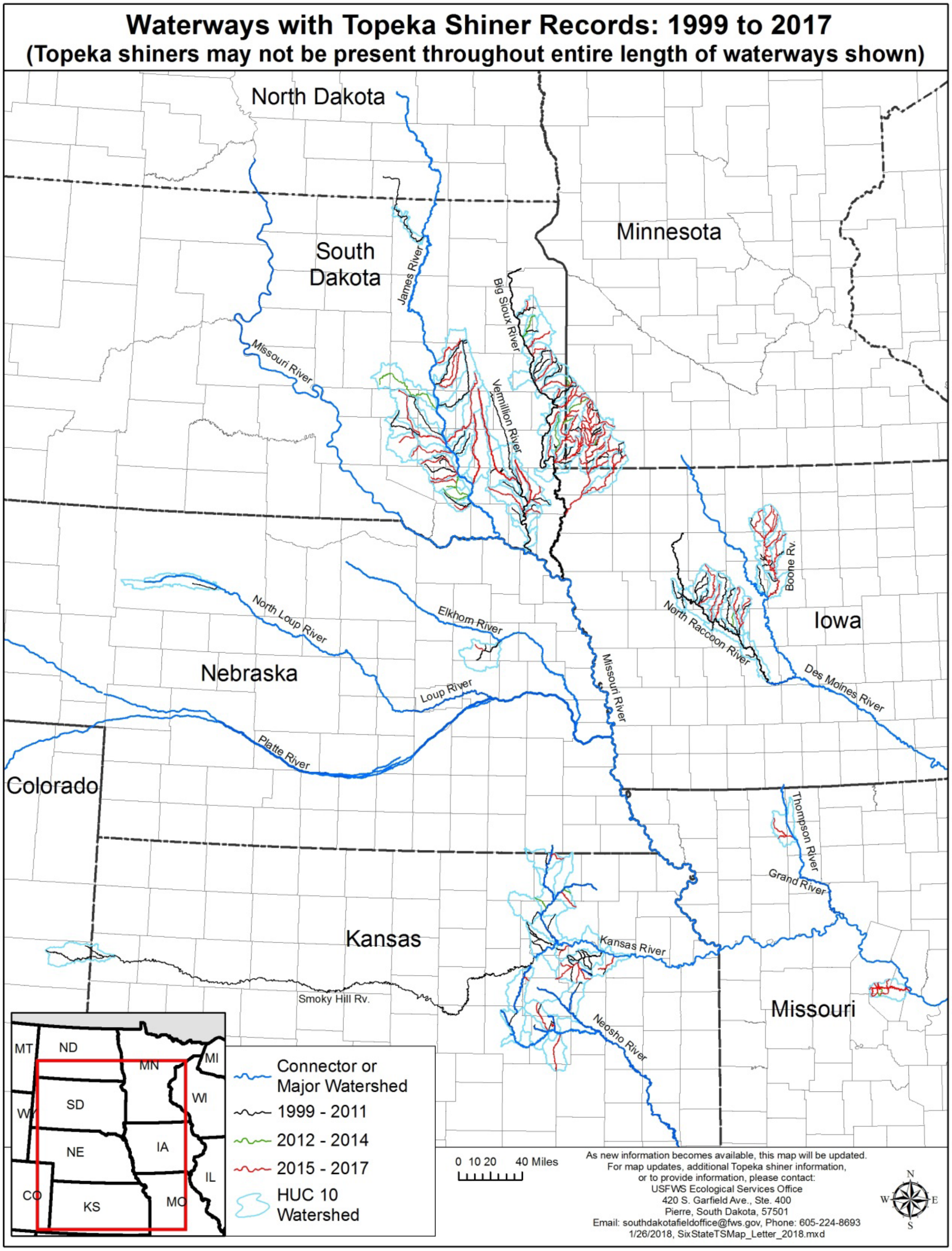


Figure 1. Streams with Topeka shiner collection records, 1999-2017.

At the time of listing, the Topeka shiner's known occupied range was thought to have declined by approximately 80 percent (%), with about 50% of that having occurred in the 25 years prior, due primarily to anthropogenic factors (particularly agricultural activities), which have negatively affected the quality of prairie stream habitats since the European settlement of the prairie (Cross 1967, Pfleiger 1997, 63 FR 69008-69021). Post-listing surveys revealed a significantly broader distribution of the Topeka shiner than was known at the time of listing, primarily within South Dakota and Minnesota (indicating the range had not significantly declined from prior known boundaries there), while population losses continued in the southern portions of its range. The states of South Dakota and Minnesota are estimated to contain 70% of the post-listing Topeka shiner range, but these areas contain only 20% of the estimated former range of the species (USFWS 2009). Note that in past Topeka shiner-related documents (e.g. 5-year review of 2009 (USFWS 2009)), these two states alone were considered the northern part of the Topeka shiner's range, while the "south" was defined as Nebraska, Iowa, Kansas and Missouri. Herein, the addition of Iowa as a northern state is based on common glacial history and resulting hydrology among the three states. Topeka shiner populations appear to be persisting in these northern areas while populations in many other areas of the range (including portions of Iowa) have experienced declines.

As part of the information gathering effort for this SSA, a workshop was held in Sioux Falls, South Dakota, September 15-17, 2014 (See Appendix A: Topeka Shiner Species Status Assessment Workshop, Information Sharing, Final Meeting Notes, September 15-17, 2014). All State wildlife agencies within the Topeka's six-state range were represented at the 2014 workshop either in person or via online conferencing, and other experts on the species (and/or factors affecting it) attended. Prior to the workshop, attendees received information on the SSA framework and purpose so the SSA process and the role of the SSA in decision-making could be understood. Also, pre-workshop, a genetics community of practice within the Service was consulted regarding genetic diversity of the species given the existing studies; their review of the relevance of those studies was provided to workshop participants before the meeting. Additionally, early input from the states supported the development of a Topeka shiner conceptual population resilience model, a draft of which was presented to the states prior to the workshop and has since been refined. At the workshop, attendees provided updates on the status of populations, primary threats to those populations and the species, and any population trend information available (e.g. whether populations were stable, in decline, or expanding), as well as valuable input regarding genetics and the resiliency model.

This coordination with the states within the species' range revealed that the Topeka shiner is still declining overall. Survey and trend data in South Dakota was inadequate to state with certainty status of the species there; Topeka shiner persistence over time is documented in many South Dakota streams, but due to the high number of occupied streams in the state, new methods are needed to specifically identify trends. Outside of South Dakota, however, populations not formerly of concern in Minnesota were noted to be in an apparent decline at that time, and the States of Nebraska, Kansas, Iowa, and Missouri reported continued declines of the species. Iowa notably has lost populations that existed outside the recently glaciated portion of that state (see Physical Environment section).

The Topeka shiner lacks a final recovery plan. Thus, coordination with the states and the effort to undergo the SSA process was a means to move forward with more cohesive and comprehensive recovery planning for the species and to guide needed conservation efforts.

Using information from this SSA, the Service will be developing a Topeka shiner Recovery Plan pursuant to the Service's new recovery planning process: Recovery Planning and Implementation (RPI) (see https://sites.google.com/a/fws.gov/recovery-planning-and-implementation/what-is-RPI). RPI allows for a streamlined recovery plan that contains only the statutory elements (recovery criteria, recovery actions and estimates of the time and costs to implement those actions) to achieve recovery and remove the species from the list. The recovery plan can then be streamlined because it is directly informed by the SSA. In addition to the RPI recovery plan, one or more Recovery Implementation Strategies (RIS) will be developed in collaboration with partners that will describe on-the-ground activities; identify specific conservation partners, stakeholders, and others who will implement the actions; and activities necessary to achieve the recovery goals, along with a timeline. A new Topeka shiner recovery plan developed via the RPI strategy will be a shorter, more concise document than our 2003 agency technical draft recovery plan. Although the 2003 plan was never finalized, it may still provide valuable insight to past vetted approaches, recovery actions, and timeframes that may supplement this SSA and prove useful, particularly as we develop one or more RIS for the Topeka shiner. We anticipate continued coordination with state agencies in the species' range as we apply the RPI strategy, including some past Topeka Shiner Recovery Team members, albeit not necessarily in the same role as in the past.

INTRODUCTION TO THE SPECIES STATUS ASSESSMENT

This Topeka shiner SSA report provides a scientific review of the best available information related to the biological status of this minnow. It is intended to provide the biological support for all Service status decisions in regard to this species. The SSA will serve as the basis for recovery planning, ESA consultations in the Service's Region 3 and 6 where the species resides, and conservation measures. For development of the SSA, we utilized the latest version of the framework: SSA Framework version 3.4, (USFWS 2016). Figure 2 illustrates the framework's basic components.

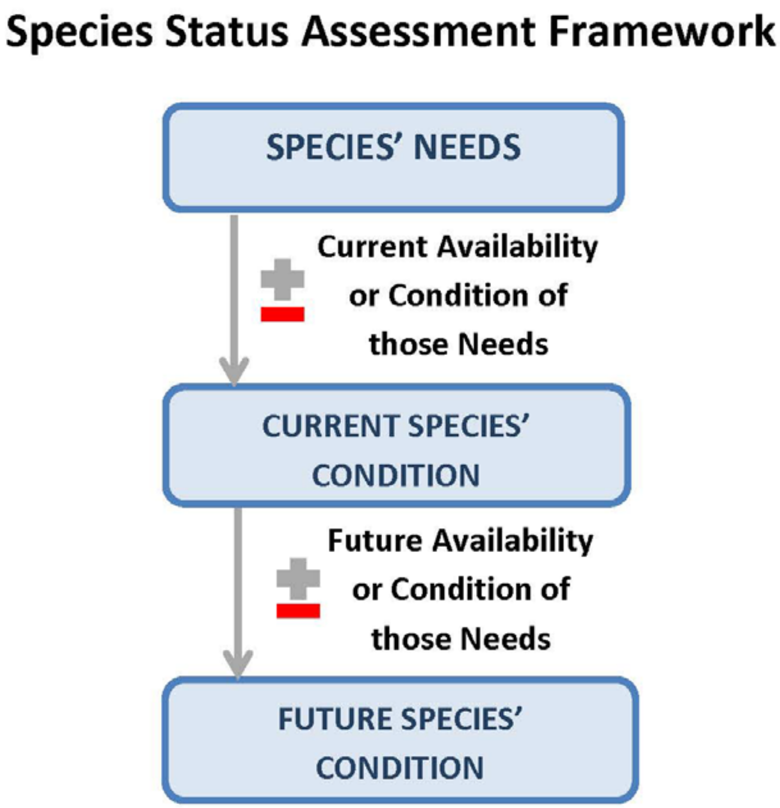


Figure 2. The Species Status Assessment Framework's three basic stages.

An SSA is a biological risk assessment that provides a scientifically rigorous characterization of a species' status by focusing on the likelihood that the species will sustain populations within its ecological settings over time. It includes a clear presentation of the key uncertainties or gaps in data as part of this characterization. The SSA does not result in a decision, but rather provides the best available scientific information for comparison to standards and policy to guide ESA decisions. The Service now uses this framework to inform all new candidate assessments, listing determinations and recovery plans, and encourages its use in other ESA decisions.

An SSA uses the conservation biology principles of **resiliency**, **redundancy**, and **representation** (collectively known as the "3Rs") as a lens through which we evaluate the current and future condition of species' long-term viability. "Viability" is defined as the ability of a species to sustain populations in the wild over time. "Over time" means time periods that are as long as possible given our ability to predict future conditions that are biologically meaningful considering the life history of the species. We summarize the 3Rs (see SSA Framework, Version 3.4, USFWS 2016) and what they mean below:

- **Resiliency** is defined as the ability of the species to withstand stochastic events (arising from random factors). We can measure resiliency based on metrics of population health, for example, birth versus death rates (*i.e.* population growth rate), and population size. Healthy populations are more resilient and better able to withstand stochastic disturbances such as random fluctuations in birth rates (demographic stochasticity), variations in rainfall (environmental stochasticity), or the effects of anthropogenic activities.

- **Redundancy** is defined as the ability of a species to withstand catastrophic events: rare destructive natural events or episodes involving many populations and occurring suddenly/unexpectedly. Redundancy is about spreading the risk and can be measured through the duplication and distribution of resilient populations across the range of the species. The greater the number of resilient populations a species has distributed over a larger landscape, the better able it can withstand catastrophic events.
- **Representation** is defined as the ability of a species to adapt to changing environmental conditions. Representation can be measured through the breadth of genetic diversity within and among populations and the ecological diversity (also called environmental variation or diversity) of populations across the species' range. The more representation, or diversity, a species has, the more it is capable of adapting to changes (natural or human caused) in its environment. In the absence of species-specific genetic and ecological diversity information we evaluate representation based on the extent of, and variability of habitat characteristics within, the species' geographic range.

To evaluate the biological status of the Topeka shiner both currently and into the future, we assessed a range of conditions to allow us to consider the species' resiliency, redundancy, and representation. This SSA report compiles the best available information to provide a thorough assessment of the biology and life history of the Topeka shiner and assesses demographic risks, threats, and limiting factors in the context of determining the viability and risk of extinction for the species.

CHAPTER 1: TOPEKA SHINER BIOLOGY, LIFE HISTORY, AND NEEDS

I. Species Overview

The Topeka shiner is a minnow endemic in small to medium sized prairie streams within six states: South Dakota, Minnesota, Nebraska, Iowa, Kansas, and Missouri (Figure 1 above). Most of the streams occupied by the Topeka shiner are low-order (1-3; Strahler 1957) although some populations exist in 4th order streams (Keith Gido, Kansas State University, personal communication 2017). Occupied habitats generally have relatively small channels which may flow perennially or intermittently into larger downstream streams or rivers.

High mortality during the first year results in only a small fraction of Topeka shiner individuals reaching the species' maximum age of three years (see Survival section below). The Topeka shiner exhibits an "opportunistic" life history strategy (Winemiller 1989, Winemiller and Rose 1992). Species with this life history are generally small, rapidly maturing, short-lived fishes with early maturation, frequent reproduction over an extended spawning season, rapid larval growth, and rapid population turnover rates, all leading to a large intrinsic rate of population increase (Winemiller 1989). Small fishes exhibiting these features are also able to repopulate habitat over relatively small spatial scales following disturbances despite high mortality, and frequently maintain dense populations in marginal habitats, often experiencing high predation mortality during the adult stage. The opportunistic life history strategy is essentially a division of the more familiar r-selected life history strategy (MacArthur and Wilson 1967) represented by high fecundity, small body size, early maturity onset, short life span, the ability to disperse, and short life spans).

Topeka shiners are omnivorous (eating both plants and animals). They help control insect pest species by preying on aquatic larvae, and by consuming detritus (decaying plant and animal material) they help further break down organic stream matter and provide accessible nutrients to the surrounding environment and community. Topeka shiners are also a prey species to larger fish, thus helping support other species in the prairie stream ecosystem.

The Topeka shiner uses pools with little or no flow that occur either within the stream channel or off-channel (Hatch 2001). It is generally tolerant of harsh conditions that can occur in these pools (*i.e.* high temperatures, low dissolved oxygen) (Koehle and Adelman 2007), and it can survive in these habitats even when other portions of the stream become dry. The species typically occupies pools with substrates relatively free of sediments (*i.e.* sand, gravel, cobble, rubble) (Pflieger 1975, Barber 1986) though it can be found at sites of lesser quality (Hatch

2001), and often spawns on the periphery of sunfish nests within these pools (Pflieger 1975, Campbell *et al.* 2016).

Occupation of headwater habitats tend to result in naturally isolated Topeka shiner populations (Michels 2000). Gene flow is very low, even for populations that have no obvious barriers and are separated by relatively small distances (94 km/58 mi) (Michels 2000). Anthropogenic barriers such as dams have further contributed isolation in many areas (Mammoliti 2002). Thus, most populations of Topeka shiners today are genetically distinct from all others. In the past, flooding events that formed connections between headwaters may have supported dispersal between streams in separate watersheds (Bailey and Allum 1962, Michels 2000), connections that do not necessarily exist today.

II. Morphological Description

The Topeka shiner is a stout, silvery to olive-colored minnow, small in size; adults do not usually exceed 3 in (7.6 centimeters (cm)) in total length, but males up to 3.15 in (8 cm) have been recorded (Dahle 2001) while females are typically smaller and may reach 2.56 in (6.5 cm) (Dahle 2001) (Figure 3).

Figure 3. Adult male (left) and female Topeka shiners in breeding colors.

The head of Topeka shiners is short with a small, moderately slanted/sloping mouth. The eye diameter is equal to or slightly longer than the snout. The dorsal (back) fin is large, with the height more than one half of the pre-dorsal length of the fish, originating over the leading edge of the pelvic fins. Dorsal and pelvic fins each contain 8 rays. The anal and pectoral fins contain seven and 13 rays, respectively, and there are 32 to 37 lateral line scales. Dorsally the body is olive green, with a distinct dark stripe preceding the dorsal fin. Individuals captured from turbid waters have a less prominent lateral stripe and pigmentation, appearing “washed-out” or pale (Vernon Tabor, USFWS, personal communication, 2014). During the breeding season, males exhibit red-orange coloration on their fins, abdomen, and cheeks while the females retain silvery/olive hues. A dusky stripe is exhibited along the entire length of the lateral line. The scales above this line are darkly outlined with pigment, appearing crosshatched. Below the lateral line the body lacks pigment, appearing silvery-white. A distinct chevron-like spot exists at the base of the caudal (tail) fin (Cross 1967, Pflieger 1975, USFWS 1993).

Some of these characteristics are observed in other minnow species, making the Topeka shiner somewhat difficult to discern from some other minnows found within prairie streams. Without breeding coloration, accurately identifying females, juveniles, and males may require knowledge of more subtle characteristics such as the tinge of pigmentation, spacing of scales behind the head, or mouth placement and shape. Particularly when sampling in areas where the Topeka shiner has not been previously documented, verification by species experts, and sometimes lab examination of voucher specimens is required to correctly identify the species.

III. Taxonomic History and Relationships

The Topeka shiner was first described in 1884 using type specimens collected from Shunganunga Creek in Shawnee County, Kansas and was originally named *Cliola (Hybopsis) topeka* (Gilbert 1884). The genus *Cliola* was changed to *Notropis* shortly thereafter, and while there has been some debate over the appropriate nomenclature for this species (Mayden and Gilbert 1989, Cross and Collins 1992, Mayden and Gilbert 1993), the scientific name *Notropis topeka* is now widely accepted for the Topeka shiner. The species can be difficult to identify (see Morphology section above). At least one 1887-identified species (*Notropis aenelous*) was later determined to be the Topeka shiner (Gilbert 1978). Hybridization may also cause confusion; *Notropis umbrifer*, also identified in 1887, may have actually been a hybrid with one parent a Topeka shiner (Gilbert 1978). The Topeka shiner may interbreed with the sand shiner (*Notropis stramineus*) (Cunningham 1999), although this hybridization is based on observations that remain genetically unverified. The sand shiner is more ubiquitous than the Topeka shiner, but both species are morphologically similar, do at times occupy the same habitats, and are often difficult to distinguish from each other. Additionally, the two species are genetically similar, thus the sand shiner has been called a “sister species” to the Topeka shiner (Schmidt and Gold 1995).

IV. Physical Environment

Glaciation and the dynamic nature of prairie streams that have shifted course, merged, and disconnected over millennium likely shaped the current distribution of the Topeka shiner (Cross *et al.* 1986). With the exception of an occupied central Missouri stream and its seven occupied streams (Moniteau Creek watershed, which falls within the Eastern Temperate Forests Level I Ecoregion), the Topeka shiner’s 6-state range falls within the central and eastern portion of the

Great Plains Level I Ecoregion, extending from eastern South Dakota and southwestern Minnesota, south to central Kansas and including northern Missouri (U.S. Environmental Protection Agency (U.S. EPA) 2017). Ecoregions are areas where ecosystem and environmental resources are generally similar; components include mosaics of biotic, abiotic, terrestrial and aquatic ecosystems (U. S. EPA 2017). The Great Plains Ecoregion is characterized by relatively little topographic relief, dominated by grasslands, a general lack of forests, and a sub-humid to semiarid climate (Commission for Environmental Cooperation (CEC) 1997). Much of the landscape has been shaped by a variety of glacial deposits consisting mostly of undulating and kettled glacial till, and level to gently-rolling lacustrine deposits. The climate is relatively dry, characterized in the north by short, hot summers and long, cold winters. Generally, the climate is drier in more westerly portions of the species' range. Most of the rivers in the northern and central portion of this ecoregion have their origins in the Rocky Mountains, receiving rainfall, snowmelt and glacial runoff (CEC 1997). High winds are an important climatic factor, and periodic, intense droughts, and frosts occur. Agriculture is the most important economic activity, the dominant land use, and the main stressor on the Great Plains and their streams (CEC 1997).

Prairie streams are an important part of the prairie ecosystem that provide habitat for native fish such as the Topeka shiner that have evolved with, and adapted to, the natural processes and environmental extremes of this ecosystem. The Topeka shiner generally shares its ecological niche with relatively few species. This is not always the case in Topeka shiner occupied areas, but its headwater habitats experience climatic extremes thus interspecific diversity in these areas tends to be lower than larger stream systems with more environmental stability (Dodds *et al.* 2004). These headwaters also dictate the quality of downstream waters and habitats on which human communities rely (Dodds *et al.* 2004).

The headwater prairie streams occupied by the Topeka shiner (prior to human settlement of the prairie) have been described as clear and cool, fed by a mixture of groundwater and drainage from prairie uplands (Minckley and Cross 1959). Conditions in some of these streams are dynamic and can be harsh, with variable physical, hydrological, and chemical fluctuations (Matthews 1988, Fausch and Bestgen 1997). Natural disturbances on the Great Plains prairies, particularly floods and droughts, can be severe in this region (Dodds *et al.* 2004). Flooding can physically displace Topeka shiners from an area (Barber 1986, Adams *et al.* 2000) and also cause mortality of such small fishes (Harvey 1987), although individuals may escape to areas of lesser flow in the floodplain, including off-channel habitats (Bakevich *et al.* 2013) which reduce the impacts from flooding. Drought that dries or reduces flows of prairie streams can cause direct mortality of fish, but many species, including the Topeka shiner, may persist under these conditions by accessing refugia, either in the form of groundwater-fed pools within intermittent streams, or by moving downstream where greater flows exist (Barber 1986, Dodds *et al.* 2004, Larimore *et al.* 1959). Survivors from these areas can then repopulate extirpated sites when conditions improve (Larimore *et al.* 1959, Barber 1986, Davey and Kelly 2007). Topeka shiners have also been observed to expand their distribution after drought (Minckley and Cross 1959).

Topeka shiner presence has been associated with streams occurring in glacial deposits in northern areas such as eastern South Dakota (Wall *et al.* 2001). These deposits are often conducive to groundwater input to streams, and provide coarse substrates for spawning – factors positively influencing continued presence of the Topeka shiner in South Dakota (Berg *et al.* 2004, Wall *et al.* 2001). The most recent glacial activity in this area, approximately 11,700 years ago, was that of the Wisconsin Glacial Episode when lobes of the North American Laurentide Ice Sheet (James Lobe, Des Moine Lobe) covered most of eastern South Dakota, Minnesota, and central Iowa (Sherburn *et al*. 2008). The area formed by these lobes is also known as the Prairie Pothole Region, named for the numerous shallow wetlands (potholes) left by the retreating glaciers. In Iowa, remaining populations of Topeka shiners are those that exist within the Des Moine Lobe (Clark 2000; Bakevich *et al*. 2013), as well as the Loess Prairies Ecoregion in the northwest corner of Iowa, southeast South Dakota and southwest Minnesota (U.S. EPA 2017). The Loess Prairies also harbor glacial till; this Ecoregion is a transitional zone between the Wisconsin and pre-Illinoian glacial deposits (Anderson 2000). Areas outside of these glaciated regions in Iowa and Minnesota (*e.g*. Cedar River watershed) no longer harbor Topeka shiners. South Dakota Topeka shiner populations are found within several divisions of the Northern Glaciated Plains Ecoregion, including the Glacial Lakes Basins, Drift Plains, Prairie Coteau, Big Sioux Basin, and James River Lowland (U. S. EPA 2017). The landscape in these northern glacial areas is one of poor drainage and relatively wet prairie compared to drier areas in the more southerly and western states within the Topeka shiner's range that have well-developed drainage systems (Anderson 2000). Relative to other parts of the Topeka shiner's range, stream drying appears to be more common in the western and southern Great Plains, particularly as subsurface input declines. Prior to European settlement, subsurface waters provided base flows in some prairie streams systems as well as late summer refugia which are critical in supporting persistence of aquatic life in these streams; however, subsurface flows are subsiding due to lowered water tables and shrinking aquifers resulting from overuse of groundwater (Fausch and Bestgen 1997, Falke *et al.* 2011) and may have impacted Topeka shiner populations. States in the southern and western portion of the Topeka shiner's range that were not covered by glaciers in the most recent glacial advances (Flint 1955) have experienced the most losses of Topeka shiner populations. In short, north-south differences in glaciation effects to groundwater input and landscape drainage patterns could be a significant factor determining the species' current persistence pattern.

Pools of dynamic headwater prairie streams are the primary habitats occupied by Topeka shiners. These pools may occur within, or adjacent to (*i.e.* off-channel), the stream (Figure 4).

Figure 4. A Topeka shiner stream in South Dakota with intact upland area, sinuous stream, and side pool (off-channel habitat).

Off-channel habitats include old oxbows, wetlands, or livestock dugouts that connect at least periodically with the main stem. The species has also been found in closed basin ponds (Dahle 2001; Vernon Tabor, USFWS, personal communication, 2014) and has been successfully captive reared in ponds with no flow (Campbell *et al.* 2016). Off-channel habitats are not ubiquitous throughout the Topeka shiner's range – these areas are available to the species primarily in Iowa, Minnesota, and South Dakota (Bakevich *et al.* 2013, Hatch 2001, Thomson and Berry 2009) and may be a remnant of the recent glacial action in northern areas as described above. Topeka shiners use both instream and off-channel pools for feeding, breeding, and sheltering at all life stages. Subsurface flow is an important habitat component in prairie streams, lowering temperatures and sustaining pools (refugia) during drought that are critical to Topeka shiner survival (Cross and Collins 1995, Pflieger 1997, Minckley and Cross 1959, Barber 1986). These flows often support off-channel habitats (Berg et al. 2004).

Within the pools occupied by Topeka shiners, optimal substrates are typically clean gravel, cobble, or sand bottoms, but siltation is common in Topeka shiner streams today, primarily due to agricultural runoff (Cross 1967, Kerns and Bonneau 2002, Hatch 2001). Streams draining intact grasslands tend to preserve natural habitat conditions (meandering, clear, cool, gravel substrates) (Pflieger 1997). An association of Topeka shiners with instream vegetation has been noted in some studies, particularly with juveniles (Bakevich 2012, Kerns and Bonneau 2002). Generally, streams where Topeka shiners occur have relatively low flows; pools where individuals occur may be completely isolated with no flow at all (Blausey 2001; Hatch 2001; Dahl 2001; Vernon Tabor, personal communication, 2014).

V. Life Stages

Topeka shiners exhibit the five general life stages of all fish: eggs – larvae – fry –juvenile – adult (Figure 5). The eggs have their own nutritional source, and when they hatch into larvae they rely on the yolk sac for continued nutrition. As larvae, they are initially unable to feed themselves or swim efficiently. As the larvae grow and absorb the yolk sac, their fins develop, their swim bladder becomes operational, and they begin eating external food sources, at which point they may be called fry. The transition from fry to juvenile is reached when the young fish develop characteristics resembling the adults (scales and well-developed fins). Adulthood is considered achieved when the juveniles transition to sexually mature individuals. Since little information is available for the Topeka shiner relative to each of these stages, collectively, the larval, fry, and juvenile stages are hereafter referred to as juveniles.

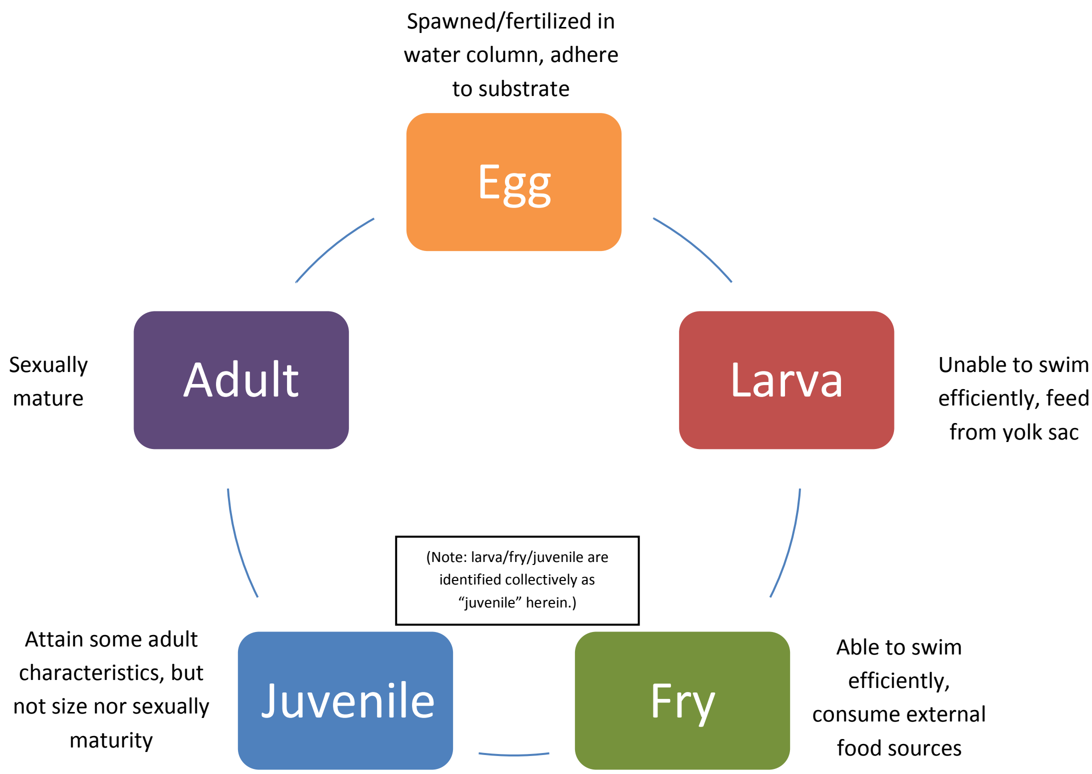


Figure 5. Topeka shiner life cycle.

VI. Survival

Egg survival rates have not been reported for Topeka shiner, but annual survival rates for young and adults are known to be low. In Minnesota, adult abundance was found to be greatest in spring; seasonal mortality of adults older than 1 year (Age I) occurred in late summer not long after spawning and before young-of-the-year reach a size where they may be captured with sampling gear (Dahle 2001). Percentage by age class of 927 Topeka shiners sampled by Dahle (2001) in Minnesota between April and October of 1998 and 1999 were: Age 0 (from hatching to 1 year old) – 17 %, Age I (between 1-2 years old) – 55 %, Age II (between 2-3 years old) – 26 %, and Age III (3 years and older) – 2 %. However, September and October sampling of 189 fish revealed an increase in young-of-the-year as they were recruited to the sampling gear, and a decrease in Age I and older adults due to the post-breeding die-off: Age 0 – 83 %, Age I – 14 %, and Age II – 3 % (Dahle 2001).

Kerns and Bonneau (2002) reported age class percentages of 549 Topeka shiners collected in Kansas from a single pool during January, April and October, 1980 as: Age 0 to I – 90 %; Age I to II - 9.8 %; and Age II and older - 0.2 %. These percentages from Kansas are indicative of low annual survival rates of this species as noted in Minnesota (above), and the number of juveniles collected by Kerns and Bonneau (2002) in October (380) far surpassed the number collected either in January (n=43) or April (n=71), indicating a similar jump in fall captures of juveniles in Kansas as in Minnesota (Dahle 2001). While it is apparent with this higher catch of juveniles in the fall that many larvae/fry survive to this stage, actual survival rates of eggs/larvae/fry are unknown. Kerns and Bonneau (2002) did not identify a post-breeding season die-off of adults in Kansas; their highest number of adults collected occurred in October, though notably their collections were limited to only one pool.

A difference in the number of Topeka shiners surviving to Ages II and III has been detected between northern and southern Topeka shiners; however, research on this topic is limited to a comparison of only two studies. Dahle (2001) noted that 13% of Topeka shiners collected during his study in Minnesota were between 2 and 3 years old, while in Kansas, Kerns and Bonneau (2002) found that only 3 % of adults reached that age. Dahle (2001) noted this discrepancy could be due to bias in sampling between the two studies. After the fish reach Age III, the number of surviving Topeka shiners continues to decrease, but the proportion was still found to be higher in northern populations: Dahle (2001) found 20 Age III fish of 927 sampled (2.2 %) and Kerns and Bonneau (2002) reported 6 of 1002 individuals (0.6 %) reached Age III.

Longevity by gender appears to be variable: in Kansas, Kerns and Bonneau (2002) reported that males may live longer, while in Minnesota, Dahle (2001) noted females may have greater longevity. Overall, regardless of latitude or gender, very few individuals survive to three years.

Topeka shiners exhibit some drought tolerance; increases in abundance (Barber 1986) and expansion of populations (Minckley and Cross 1959) have been reported after drought conditions. As pools desiccate, Topeka shiners may survive long enough to outlast predators and/or potential competitors and rebound when moisture returns (Barber 1986). This resistance is key to continued persistence in such environments (Davey and Kelly 2007). Juvenile Topeka shiners may exhibit more drought tolerance than adults; young Topeka shiners have been noted as the final occupants of a pool in Kansas that dried completely within 24 hours after the observation (Kerns and Bonneau 2002). The species is not immune to the effects of drying, however, and do not always recolonize post-drought (Whitney *et al*. 2016). As they become trapped in isolated pools of intermittent streams, they become increasingly vulnerable to mortality from predation, lack of dissolved oxygen, and desiccation.

VII. Reproduction

A. Reproductive Strategy

Topeka shiners are broadcast spawners; they release eggs or sperm into the water and fertilization occurs externally. Topeka shiner spawning has been observed in an aquarium setting, captive rearing ponds, and in the wild (Katula 1998, 2015; Campbell *et al.* 2016; Stark *et al.* 2002). Males defend a small territory (0.25 square meters (m^2) to less than 1 m^2; Kerns and Bonneau 2002, Campbell *et al.* 2016) against other males, allowing females to access the center of the area, where the two pause side-by-side, the male vibrates, release of gametes occur from each individual simultaneously in the water column, and the eggs drop some distance to the bottom where they adhere to the substrate (Katula 1998, 2105; Stark *et al.* 2002).

Topeka shiners do not guard their eggs or larvae, and broadcast spawning without parental protections can result in relatively high egg mortality. However, in addition to being broadcast spawners, Topeka shiners are multiple clutch spawners; females produce clutches at different times and can have various stages of mature/immature ova during a single breeding season (mid-May to early August) (Hatch 2001, Dahle 2001). This prolonged spawning season and ability to have multiple clutches increases their chances of successful reproduction. Females lay hundreds of eggs but this can be highly variable. Counts of mature, unlaid eggs range from 140 – 1,712 with averages in the 300s, 500s and 800s, and vary according to female size (the largest and heaviest females producing the most eggs) (Kerns and Bonneau 2002, Dahle 2001). Younger females may have relatively lower fecundity, but since there are more of them than Age II or III females, Age I females may provide greatest reproductive output (Kerns and Bonneau 2002). Changes in fecundity over time have not been detected; Topeka shiner fecundity in Minnesota 1997-2000 (Dahle 2001) was similar to information collected 1979-1981 (Kerns and Bonneau 2002) and older data is lacking. However, Topeka shiners in completely isolated habitats may have reduced fecundity compared to individuals in streams (Dahle 2001).

It is not known how many times an individual Topeka shiner may spawn in a season. It is also not known whether Topeka shiners reproduce one season and then die, or are able to spawn in multiple years, but the latter seems more likely as an advantageous reproductive strategy for this short-lived species (Vernon Tabor, USFWS, personal communication, 2015; Jay Hatch, University of Minnesota, personal communication, 2015).

B. Nest Associates

Topeka shiner reproduction is also enhanced via the shiner’s relationship with specific co-inhabitants of the prairie streams: sunfish (Figure 6).

Figure 6. Topeka shiner (foreground) and orangespotted sunfish in captive rearing ponds at the University of Kansas Field Station (photo credit: Garold Sneegas).

Topeka shiners often lay their eggs within, or along the edge of, the nests of orange-spotted sunfish (*Lepomis humilis*) or green sunfish (*L. cyanellus*) – two known nest associates of the Topeka shiner (Pflieger 1997, Kerns and Bonneau 2002). Topeka shiners may also use fathead minnow (*Pimephales promelas*) "nests" for spawning (Stark *et al.* 2002) although the fathead minnow "nest" is typically the underside of submerged items where the female lays her adhesive eggs which are subsequently defended by the male (Unger 1983). Defense of long-ear sunfish nests has also been reported (Mammoliti 2004), but less information is available on these potential associates compared to the orange-spotted and green sunfish.

Adult male sunfish create their nests by clearing away sediments with their tails (Pflieger 1997), thus exposing spawning substrate, and this action also aerates their eggs (Witte *et al.* 2009). Sunfish generally tolerate adult Topeka shiners around their nests. The act of spawning by Topeka shiners can actually be triggered by spawning activity of sunfish; when the sunfish spawn, Topeka shiners have been observed to spawn at the nest edge at the same time (Campbell *et al.* 2016). The species have similar incubation rates (about 5 days) (Katula 1998, 2015, Campbell *et al.* 2016) thus eggs spawned by the shiners and sunfish simultaneously would hatch at about the same time. Topeka shiners abandon their eggs after spawning, but sunfish guard their nests, affording protection for both species' eggs. This behavior is protective against other species of aquatic inhabitants (*e.g.* crayfish) that might prey on the eggs, and also from other Topeka shiners; cannibalism of eggs occurs at an increased rate in the absence of sunfish (Campbell *et al.* 2016). The adult sunfish also afford protections at the nest for larval fish post-hatching (Campbell *et al.* 2016).

This association of breeding Topeka shiners with nesting sunfish has been observed during field studies of Topeka shiners (*e.g.* Pflieger 1997, Stark *et al.*, 2002, Kerns and Bonneau 2002, Dahle 2001). The species does not require the presence of sunfish to spawn; captive-reared Topeka shiners in tanks supplied with abundant clean gravel are known to do so (Katula 1998, 2015; Witte *et al.* 2009; Campbell *et al.* 2016) thus the relation is facultative, not obligatory. However, the lack of a sunfish nest associate results in relatively low reproductive output for the Topeka shiner as observed at a University of Kansas Topeka shiner captive rearing center; when sunfish were placed in the tanks with Topeka shiners, the shiners nearly always chose to spawn in sunfish nest depressions and their reproduction was overall much more successful (*i.e.* greater fall recruitment) in the presence of these nest associates compared to output under conditions lacking sunfish (Campbell *et al.* 2016). This was thought to be due to the male sunfish guarding the nest which reduced the opportunity for cannibalism of eggs and fry that otherwise occurred frequently in the absence of sunfish (Campbell *et al.* 2016). Other hatcheries also use sunfish to improve Topeka shiner reproduction; methods involving only male sunfish and portable spawning mats have been developed at Lost Valley Fish Hatchery in Missouri resulting in more effective production of Topeka shiners (for details, see Conservation Considerations section).

C. Reproductive Maturation and Sex Ratios

Topeka shiners are considered adults when they reach sexual maturity, but not all Topeka shiners mature at the same rate. While many reach sexual maturity by their second summer of life (Age I), the majority of them do so by Age II, and all reach this milestone by Age III (Kerns and Bonneau 2002, Dahle 2001). Size, rather than age may be a determining factor as lengths below the thresholds of 47 mm total length (TL) (36 mm standard length (SL)) for males and 37 mm TL (27 mm SL) for females have been correlated with lack of sexual maturity in Kansas (Kerns and Bonneau 2002). Similarly, in Minnesota Dahle (2001) recorded minimum sizes of about 51 mm TL (41 mm SL) for mature males, and about 36 mm TL (29 mm SL) for mature females.

Gender plays a role in maturity as well. Although females grow slower than males, more females become sexually mature at an earlier age than males. Ratios documented in Minnesota show that 20% of male Topeka shiners become mature at Age I compared to 52% of females (Dahle 2001). Subsequently, 86% of males and 93% of females reached that stage at

Age II, and by Age III all surviving individuals are sexually mature (Dahle 2001).

Overall sex ratios may not differ significantly from 1:1 (Kerns and Bonneau 2002, Dahle 2001), but discrepancies have been noted within age classes with both predominance of males noted among Age II fish (3.3:1 ratio (76% males); Kerns and Bonneau 2002) and among females (59% and 62% of Age I and II fish, respectively; Dahle 2001). It is not known what may have driven those sex ratio discrepancies.

VIII. Variations in Biology, Life History, and Occupied Habitats across the Range

Topeka shiners are biologically similar throughout the species' range. Topeka shiners in the northern part of the range may be longer than those in the southern parts of the species' range, which may have implications for differential survival in these areas (Dahle 2001), but this has not been explored in detail. Additional differences were noted by Dahl (2001), including somewhat lower fecundity, but bigger and longer-lived females in Minnesota versus those studied in Kansas (Kerns and Bonneau 2002). These differences could be due to sampling bias, but if valid, they may offset each other in terms of reproductive output, resulting in similar productivity in northern and southern parts of the species' range. Available information indicates age composition, feeding habits, and the habit of spawning on the periphery of sunfish nests are similar in northern and southern states.

Differences in Topeka shiner habitat in the northern vs southern areas may be more important in terms of Topeka shiner viability (USFWS 2009). As shown by survey data, the species is more widespread in northern areas (particularly within South Dakota and Minnesota where the species occupies most of its previously known range) than in more southerly parts of its range (USFWS 2009). Groundwater availability may be key in the north: geologic morainal features in the north may have positively influenced groundwater inputs to streams and perennial pools in intermittent streams benefitting the species' ability to persist (Clark 2000, Berg *et al.* 2004, Wall *et al.* 2001). The species has also been found to be more tolerant of degraded conditions than previously thought (Hatch 2001) and has in some cases been identified as a "tolerant" species (Krause 2013) that has been collected at times in highly degraded habitats (Chelsey Pasbrig, South Dakota Department of Game Fish and Parks, personal communication 2017). Refugia from the harsh prairie stream conditions are critical to individual survival and population persistence (Barber 1989, Kerns and Bonneau 2002). Additionally, the availability of off-channel sites in South Dakota, Minnesota, and Iowa (Ceas and Larson 2008, Thompson and Berry 2009, Bakevich *et al.* 2013) is notable as this type of habitat is not generally present in Nebraska, Kansas, and Missouri.

IX. Topeka Shiner Ecological Levels

Within this Chapter we identify the ecological requirements (needs) of Topeka shiner individuals, populations, and the species as a whole, but it is important to define those various levels. The individual level is straightforward, however, defining populations (and their subpopulations) as well as the larger scale of population complexes (herein a surrogate for metapopulations as explained below) is more complex due primarily to our limited knowledge of connectivity and movements by the Topeka shiner on the landscape. Below we provide definitions for these ecological levels (beyond the individual level), and associated caveats, for the purposes of this SSA.

A. Populations/Subpopulations

A population can generally be defined as interbreeding individuals living in the same place at the same time. Populations are the functional unit most pertinent to determining the current status of the Topeka shiner. At this scale, individuals interact and reproduce with naturally (or unnaturally) occurring contractions and expansions of occupied areas.

Scientific experts at the Topeka shiner 2014 workshop helped define the metric for Topeka shiner populations used in this SSA. The experts identified an overlap between existing Topeka shiner occupied streams, generally in stream orders 1-3 (Strahler 1957), and a particular size of Hydrologic Unit Code (HUC) that include these streams (USGS 2016), the 10-digit HUC or HUC10. The HUC10 unit had already been used in 2010-2011 as a spatial unit to document distributional status of the species in Iowa (Bakevich *et al.* 2015). Thus, for the purposes of this SSA, we define populations as each individual watershed, inclusive of all streams within the HUC10 boundary (Figure 7), where Topeka shiners have been documented since 1999. We only consider HUC10 units with detections since 1999 (the species' listing date) because data were somewhat limited prior to that time, and survey efforts increased after that time.

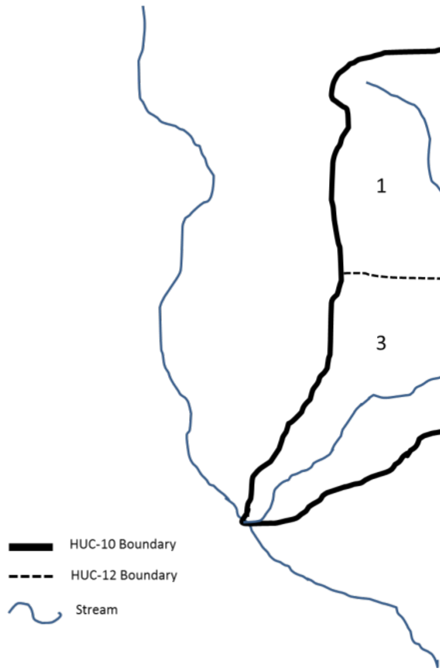


Figure 7. Example of a HUC 10 (population) boundary relative to three associated HUC 12 (subpopulation) boundaries and their drainage into a larger watershed.

This population definition includes an assumption: Topeka shiners are able to (and do) move and interact within each HUC10. Factors such as quality of existing habitats, or stream barriers that may act on individuals either temporarily or permanently complicate our ability to determine exactly how/whether individuals interact within a given HUC10. The workshop experts determined that using HUC10s was the best proxy for precise knowledge of actual interbreeding Topeka shiners living in the same place at the same time.

The HUC10 watersheds often consist of smaller, HUC12, watersheds with small streams that also harbor the Topeka shiner (Figure 7 above). Given the association with headwaters and tendency to remain relatively sedentary, it is likely that many individuals complete their life cycle within streams of these HUC12 watersheds, without moving to other stream in the HUC10. The potential for mixing at the larger HUC10 scale exists, however. If it does not occur regularly, it may at least occur periodically, and perhaps is most likely during stochastic events such as floods or drought.

Acknowledgement of subpopulations is important because numerous subpopulations likely contribute to persistence of the larger populations. The existence of multiple small occupied streams represent more potential habitat and provides source areas for repopulation of sites when local extirpations may occur. Increased redundancy of subpopulations improves population resiliency. Increased redundancy of resilient populations improves species viability.

Thus for the purposes of this SSA, we define subpopulations as each individual HUC12 watershed in which the species has been detected since the 1999 listing date, inclusive of all streams within the HUC12 boundary that compose a larger HUC10 population.

As with populations, the assumption with subpopulations is that individuals can and do move to different areas with suitable habitat within the HUC12 watershed, and may also move to adjacent connected streams within the larger HUC10. Instream barriers reduce access to suitable habitats and refugia, and are important factors to consider when determining population resiliency. When precise information on movements is lacking, continued occupation of streams within HUC10s and the HUC12s that compose them serves as a proxy for habitat suitability and connectivity within these areas.

It is important to note that not all occupied Topeka shiner streams fit neatly into HUC10 or HUC12 watershed categories. Specific examples are provided below in the Population Complexes section.

B. Population Complexes - Surrogates for Metapopulations

Metapopulations are groups of populations of a species separated by space, interacting when individuals move from one population to another. While some data exists regarding Topeka shiner movements within populations (*e.g.* Barber 1986), knowledge of Topeka shiners movements between populations, particularly under current prairie stream conditions, is limited. The species occurs in a patchy distribution with widely separated areas isolated by insurmountable distances (*e.g.* over 300 miles), impassible barriers (*e.g.* dams), and/or unsuitable habitats (*e.g.* the Missouri River). In some cases only single occupied streams remain of what likely were former groups of populations in several/numerous occupied streams. Some evidence of movements may be deciphered from genetic studies on relatedness of existing Topeka shiner populations (Michels 2000), but there are limitations to this data regarding the potential timeframe and the existence of plausible movement pathways under today's fragmented prairie stream conditions.

However, hydrologic connections may be identified that have the *potential* to serve as conduits for such interactions. Populations that exist in proximity (*e.g.* within the same larger (usually HUC8) watershed) and are hydrologically connected are referred to herein as population complexes. Delineating Topeka shiner population complexes with accuracy is complicated by the level of fragmentation among and within extant populations today, as well as lack of precise knowledge of the species' movements and limits of known occupancy prior to listing. Anthropogenic barriers exist within many of these complexes that could completely or partially preclude fish movement, but these have not all been identified, quantified, or evaluated for their ability to allow fish passage over time or under various conditions. In the absence of barriers, the assumption is that individuals currently have, or did have, the ability to move between populations that compose the complex. Such movements may be facilitated only by sufficiently large disturbance events (*e.g.* floods). For the purposes of this SSA, Topeka shiner population complexes are intended to identify those areas (generally groups of populations in a larger watershed) that still harbor the species, are highly unlikely to have connectivity with other groups, but have the potential for population connections within their group (at an unknown rate or time scale) that could increase their resiliency over time.

Population interactions within complexes can be important for persistence of the species in the same manner that connections among subpopulations and populations can, affording increased abundance and sources for repopulation. Although we cannot currently confirm population interactions within population complexes (evaluation, quantification, and mapping of barriers might lend further insight to help define actual metapopulations), the complexes represent groups of populations with the potential to interact and serve as surrogates for true metapopulations.

X. Topeka Shiner Ecological Requirements

The SSA framework includes determining the specific ecological requirements, or needs of the Topeka shiner from the perspective of individuals, populations, and the species as a whole.

A. Individuals

This section focuses on the ecological requirements of individuals at each life stage. The Topeka shiner exhibits the typical life stages of fish: egg; larva/fry/juvenile (these three are lumped herein as "juvenile" due to lack of information regarding larva and fry); and adult. Table 2 demonstrates the timeframes each life stage may be present in occupied streams.

Table 2. Months of the year that each life stage of the Topeka shiner is present in occupied streams.

Life Stage	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Egg												
Juv.												
Adult												

All life stages of the Topeka shiner need pool habitats of various sizes either instream or adjacent to low-order (typically 1-3; Strahler 1957) prairie streams with little to no flow, although they may not be present in the uppermost headwater portions of many of the lowest order stream as these may be temporary or intermittent and unable to sustain fish (Wall *et al.* 2001). Individuals may be present occasionally in larger, higher order streams when their occupied smaller tributaries dry up or when flooding moves individuals downstream, but these larger waterways do not typically provide suitable habitat. Optimal occupied habitat typically has relatively clean water and sand/gravel/cobble substrates.   Individuals have been found in less suitable conditions, indicative of some tolerance of Topeka shiners to degraded conditions including low oxygen and high temperatures (for which thresholds have been defined) and sedimentation (which has no defined threshold); however, highly while the species has been collected from within highly degraded habitats such as channelized, incised, and/or sediment-laden streams lacking pools and refugia, these areas are generally do not support completion of the life cycle. As noted earlier, sunfish may be an important component to improved reproductive success. Warm temperatures (22°C/71.6°F) are needed to induce spawning. Flows of < 0.3 m/s (discharge rate of < 0.28 m^3/s) are needed to avoid displacement, although high flows may facilitate movements that otherwise would not occur. Adequate amounts (thresholds unknown) of a variety of aquatic food sources are needed for adults and juveniles. Off-channel habitats are important to individuals in parts of the species' range where it occurs.

What we know about the ecological requirements of the Topeka shiner at each life stage is summarized in Table 3, and described in more detail below in the context feeding, breeding, and sheltering requirements of individuals.

Table 3. Summary of Topeka shiner individual ecological requirements by life stage.

RESOURCE NEED	LIFE STAGE		
	EGG	JUVENILE	ADULT
POOLED WATER	Headwater streams (typically orders 1-3) with instream or off-channel pools. Pool dimensions match adults.	Headwater streams (typically orders 1-3) with instream or off-channel pools. Pool dimensions likely similar to adults.	Headwater streams (typically orders 1-3) with instream or off-channel pools. Average instream pool depths: ~0.20-0.60 m. Off-channel: avg. 0.5 m in IA, 0.78 m in MN; range 0.6-2 m in SD). Instream width: range ~2-4 m in KS; ~7 m avg. in MN. Length: highly variable.
LOW FLOWS/DISCHARGE	Range from zero to unknown threshold for displacement	Range from zero to unknown threshold for displacement, likely lower than for adults	Flows: range from zero to < 0.3 m/s to avoid displacement Discharge: < 0.28 m^3/s to avoid displacement (decreased probability of occurrence at discharges >2.0 m^3/s)

WATER TEMPERATURES	At least 22°C/71.6°F (temperature at which spawning occurs)	Optimal for growth: 27°C/80.6°F; thermal maximum: 39°C/102.2°F	17-18°C /62.6-64.4°F to attain reproductive readiness; minimum water temperature of 22°C/71.6°F to induce spawning (still occurs at 31°C/87.8°F, but maximum unknown)
DISSOLVED OXYGEN	Necessary levels unknown	Lethal for 50% of fish at 1.26 mg/L; at least 2 mg/L needed for some growth; optimal growth levels occur at ≥ 4 mg/L	Necessary levels unknown, may require more than juveniles
STREAM SUBSTRATE	Adhere to exposed sand, gravel, cobble, rubble – same as adults	Vegetated during early larval stage, then exposed sand, gravel, cobble, rubble – likely similar to adults	Exposed sand, gravel, cobble, rubble for spawning (optimal ≥ 50%)
FOOD	Embryonic yolk sac	Larval yolk sac, then omnivorous diet likely similar to adult - small food items of increasing size with continued growth	Opportunistic and omnivorous: small immature aquatic insects, microcrustaceans, larval fish, fish eggs, algae, vascular plant matter, detritus
CONNECTIVITY	N/A	Movements due to reduced water levels, displacement by predators, displacement by floods, required access to suitable habitat for overwintering, extirpated area repopulation	Movements due to reduced water levels, displacement by predators, displacement by floods, required access to suitable habitat for overwintering, extirpated area repopulation, required access to breeding pools
REFUGIA	Protection from displacement by floods and extirpation due to drought	Protection from displacement by floods and extirpation due to drought; affords overwintering areas	Protection from displacement by floods and extirpation due to drought; affords overwintering areas
SUNFISH	Expose substrate for egg adhesion; affords protection from predators	Early protection from predators while in sunfish nest	Expose substrate for spawning, stimulate spawning, increase reproductive success

1. Eggs

Topeka shiner spawning occurs in the water column and the eggs drop some distance to the bottom (Katula 1998, 2105; Stark *et al.* 2002) (Figures 8-9).

Figure 8. Photo A - Topeka shiner eggs in gravel in captive rearing ponds at the University of Kansas Field Station (photo credit: Garold Sneegas).

Figure 9. Photo B - Topeka shiner eggs in gravel in captive rearing ponds at the University of Kansas Field Station (photo credit: Garold Sneegas).

The eggs may require relatively warm water temperatures to develop; spawning in captivity has been observed to commence only after the water temperature was gradually raised from 21.1°Cto 24.4°C (70° to 76°) (Katula 1998, 2015) and is not initiated by the adults in the wild until waters reach 22°Celsius (C) (71.6°Fahrenheit (F) (Hatch 2001, Kerns and Bonneau 2002). Eggs in captivity have been observed to hatch at a steady temperature of 22.2°C (72°F) (Katula 1998, 2015). Spawning continues during warmer months of mid-late summer (Hatch 2001, Kerns and Bonneau 2002). Prairie stream water temperatures have been reported as ranging between 17°C (62.6°F) and 27°C (80.6°F) from June through August in South Dakota (Blausey 2001), and 5.0°C (41°F) to 28.5°C (83.3°F) during a year-round study in Kansas (Kerns and Bonneau 2002) although larger extremes have likely occurred. Egg development or survival rates at various temperatures have not been studied, but eggs have been observed to hatch into larvae within 5 days after spawning at 22.2°C (72°F) in captivity (Katula 1998, 2015). Eggs may still be released when water temperatures reach 31°C (87.8°F) (Hatch 2001); however, the upper thermal limit, beyond which egg survival is reduced, is not known.

a) Feeding

The egg yolk provides the nutrition and energy for the egg as it develops into a larval fish.

b) Sheltering

When the eggs fall to the streambed after spawning, they adhere to the substrate (Katula 1998, 2015), which usually consists of sand, gravel, or cobble although other types (*e.g.* silt-covered rubble, boulder, and concrete riprap at the margins of scour pools and slow runs (Hatch 2001)) may be used. Pool habitats where the eggs are laid, either instream or off-channel, typically have relatively low (or absent) flow rates compared to adjacent stream habitats (see "Sheltering" under the "Adult" section below for observed flow rates in Topeka shiner streams).

Topeka shiner eggs often benefit from the protections of sunfish species, particularly the orangespotted sunfish. The sunfish expose gravel by fanning the substrate in order to lay their own eggs, and Topeka shiner eggs are often laid on the periphery of these nests, where are aerated with continued fanning by adult sunfish and they receive protections by the parent sunfish as it guards its own eggs (Campbell *et al.* 2016).

2. Juvenile

For the purposes of this analysis, the stages between egg and adult (larva/fry/juvenile) are combined herein as "juvenile". Limited information is available on young Topeka shiners, and most studies with information on this general age do not distinguish the larval, fry, and juvenile stages, thus we are unable to provide specific information on each stage herein. Larvae reach the fry stage when they can swim efficiently and feed themselves; fry reach the juvenile stage when resembling adult fish with developed fins, yet are not sexually mature (Figure 10).

Figure 10. Adult (left) and juvenile Topeka shiners captures in Iowa (photo credit: Aleshia Kenney).

a) Feeding/Growth

Topeka shiners emerge from their eggs with a yolk sac. The benthic (bottom-dwelling) larvae absorb the sac as they grow, and within only a few days (documented as four days post-hatching for captive Topeka shiners (Katula 1998, 2015) they gain efficient swimming and feeding capabilities. Various stages of larval development can be defined using yolk sac absorption and development of fins (Holland-Bartels *et al.* 1990), but no information is available to describe these stages specifically in the Topeka shiner.

Topeka shiner larvae are known to be able to eat larval crustaceans at approximately 2-3 weeks of age in an aquarium setting (Katula 1998, 2015), but specifics of food requirements of larvae and juveniles have not been studied beyond that observation. Since adult diet studies have shown the species is omnivorous (Hatch and Besaw 2001), larval and juvenile Topeka shiners may also obtain a variety of plant and animal foods (such as detritus and plankton that can be gleaned from the streambed, aquatic vegetation, or in the water column), but likely of a relatively smaller size than adult foods (and/or are easier to obtain), graduating to larger items as they grow. Quantity of food required for sustenance of larvae, juveniles (or adults) has not been identified, but likely varies by age, size, and/or season. Given the omnivorous habits of this species, food may not be a limiting factor.

In addition to food availability, water temperature and dissolved oxygen levels may affect the rate of successful transformation of larva to juvenile, and juvenile to adult, as well as overwintering survival. Assuming adequate food availability, the optimal temperature for growth of juvenile Topeka shiners is about 27°C (80.6°F), with an upper lethal temperature of 39°C (102.2°F) (Koehle and Adelman 2007). Growth rates are relatively stable when dissolved oxygen levels are 4 milligrams per liter (mg/L) or higher, but the growth rate slows below that level (Koehle and Adelman 2007). Dissolved oxygen levels in the field have been recorded within a range of 3.9 - 9.9 mg/L (Blausey 2001).

The overwintering requirements of Topeka shiners of any age are poorly understood. Food likely becomes more limited during winter. Individual Topeka shiners grow very little if at all; they experience the majority of their annual growth in spring and summer (Dahle 2001, Kerns and Bonneau 2002). Some Topeka shiners exhibit signs of growth in April, with the peak period of growth in most fish likely occurring in May, and growth slows again in August through October (Dahle 2001). Some juvenile fish will reach maturity at Age I (see Adult section below).

b) Sheltering

Like Topeka shiner eggs laid in sunfish nests, larval Topeka shiners also receive protections by the protective adult sunfish for a few days post-hatching (Campbell *et al.* 2016). After dispersal from the sunfish nest, sheltering information for Topeka shiner larvae/juveniles is sparse, but in Kansas, young Topeka shiners have been observed to occupy shallow pool margins with other minnow species, often associated with vegetation if available, and at the end of the first summer, juveniles leave the shallow pool margins to join schools of adults (Kerns and Bonneau 2002). Barber (1986) found a negative relationship between densities of young Topeka shiners and the percentage of silt substrate. Stark *et al.* (2002) reported young-of-the-year Topeka shiners in vegetation of the genus *Nasturtium* (watercress) with fathead minnow (*Pimephales promelas*) young.

In the fall, young of the year may move downstream, or at times they may be displaced downstream by high flows (Barber 1986). Swimming strength of a fish is proportional to its size, thus, juveniles (and smaller species like the Topeka shiner) are less resistant to displacement in high flows (Harvey 1987). Voluntary or involuntary downstream movements may allow juveniles access to refugia during periods of drought as streams dry or winter when streams can freeze solid; such movements may be precluded if stream obstructions, such as dams, are in place. Access to such refugia is critical to Topeka shiner individual survival in these low-order prairie streams.

3. Adult

Many Topeka shiners, but not all, reach adult stage (become sexually mature) (Figure 11) near the end of their first year of life.

Figure 11. Adult Topeka shiner at the University of Kansas Field Station (photo credit: Garold Sneegas).

Females generally mature faster; in Minnesota, only 20% of Age 1 males were mature, while 52% of Age I females reached that stage (Dahle 2001). At Age II, the number of mature males and females increased to 86% and 93%, respectively, and all individuals reach sexual maturity by Age III.

a) Feeding

Hatch and Besaw (2001) found that Topeka shiner adults in Minnesota are opportunistic diurnal omnivores, eating over 25 different categories of food items including aquatic insects, microcrustaceans, worms, larval fish, filamentous green algae, vascular plant matter, and detritus. They feed both at the benthic (along the stream bottom or within the substrate) and nektonic (in the water column) levels (Hatch and Besaw 2001). Blausey (2001) suggests riffles within Topeka shiner occupied streams may serve as an important source of aquatic invertebrates in the Topeka shiner diet, while Barber (1986) indicated some level of siltation (as long as it does not dominate the substrate) is beneficial for the same reason. We have no information to suggest that food availability is currently a limiting factor for this omnivorous species.

b) Breeding

Adults use pool habitats of small prairie streams – either in main stems or off-channel areas (see more on off-channel habitats in Sheltering section below) – spawning over sand/gravel substrates. Reproductive output is greatly enhanced with the presence of sunfish (Campbell *et al.* 2016). Adult sunfish fan sediments to expose gravel for their nests, tolerate Topeka shiner spawning activity on their periphery of their nests, and guard/fan the nest after laying eggs, protecting young of both species and increasing Topeka shiner reproductive success (Campbell *et al.* 2016).

Male and female Topeka shiners look similar in early fall and winter, but begin to exhibit sexually dimorphic reproductive characteristics by mid-May (Dahle 2001). Most obvious of these are the red-orange coloration in the fins/abdomen/cheeks of males, and a distended abdomen in females. The first appearance of breeding coloration in males coincides with water temperatures of 17-18°C (62.6- 64.4°F) preceding the temperature at which spawning begins (22°C/71.6°F)) (Hatch 2001). Temperature has been observed to be a limiting factor to spawning in captive-reared Topeka shiners; females with distended abdomens in a tank were observed to release eggs only after water temperature was gradually increased from 21.1°C to 24.4°C (70°F to 76°F) (Katula 1998, 2015). Whether an upper threshold for spawning exists is not known, but spawning has been documented at up to 31°C (87.8°F) (Hatch 2001).

c) *Sheltering*

Like all life stages of the Topeka shiner, the adults primarily inhabit pools associated with typically low order (1-3; Strahler 1957) prairie streams. Barber (1986) and others have emphasized that spring-fed pools are havens that serve as refuge for Topeka shiners during critical times of stream intermittency. Groundwater delivery to streams is a known indicator of Topeka shiner presence (Blausey 2001). Homogenous, channelized, and incised streams typically do not provide suitable habitats for this species. Small streams that wind through upland prairies with groundwater input generally describe the best habitats, with natural sinuosity and substrate that results in a variety of pools, riffles, and runs.

Indicators of Topeka shiner presence may include low bank height (lack of stream incision), low stream-bank depositional zones (indicative of high sediment load), fine gravel and cobble substrates, groundwater input, and low animal (livestock) use of riparian vegetation (no/minimal bank erosion) (Blausey 2001). Riparian vegetation most often consists of grasses and forbs (rather than trees and brush), and serve to filter runoff, provide shade overhanging the stream, provide surfaces for aquatic invertebrates, are a source of detritus, and perhaps afford shelter from predators (Blausey 2001). Bakevich *et al*. (2013) documented positive associations of Topeka shiner adults with vegetative cover in both streams and off-channel habitats. Thresholds for most of these indicators that, if exceeded, would result in exclusion of Topeka shiners have not been measurably defined.

Instream habitats occupied by the species have been described as largely silt-free (Pflieger 1975), or at least not dominated by silt (Blausey 2001). The species can be found over silt and sand substrates, but Blausey (2001) noted that clay, silt, and sand substrates were dominant in streams where Topeka shiners were absent. Substrates of 50% or greater rubble have been suggested as an optimal range for Topeka use, with the presence of some silt potentially important as a substrate for Topeka prey items (Barber 1986). Others note that gravel substrates used by Topeka shiners also support food production (Blausey 2001). In a Kansas study, sites with Topeka shiners tended to have more gravel substrate and greater mean stream length, whereas sites without Topeka shiners generally had higher proportional impoundment area and proportional urban land area (Gerkin and Paukert 2013).

In contrast to typical instream habitat where Topeka shiners may be found, occupied off-channel habitats (Figure 12) in northern parts of the range often have high silt deposition which may compose 75% of the substrate (Dahle 2001).

Figure 12. A Topeka shiner streams in Minnesota with off-channel habitat circled (Ceas and Larson 2010).

Thomson and Berry (2009) also found winterkill in a 0.3 m-deep off-channel South Dakota livestock dugout used by Topeka shiners, thus, while these areas can afford benefits to the Topeka shiner, it should be noted that off-channel sites can act as sinks for species when individuals become trapped within them and site habitat conditions decline. Still, successful breeding occurs in off-channel habitat (Hatch 2001, Thomsen and Berry 2009, Bakevich 2012), potentially due to the presence of orange-spotted or green sunfish, albeit fecundity may be reduced (Dahle 2001). In areas of Minnesota and Iowa, the species often occurs in greater abundance in off-channel sites compared to in-stream pools (Hatch 2001, Bakevich *et al.* 2013).

Topek shiners generally inhabit low-velocity streams or low-velocity areas within/adjacent to streams. In occupied headwater streams that may have relatively high gradients, pool-riffle complexes can afford low-velocity habitat for the species. Many streams inhabited by Topeka shiners have low gradient (Wall *et al.* 2001) and are slow-moving; Blausey (2001) observed that most occupied areas exhibited velocities at or near 0.1 m/s in South Dakota with mean velocities ranging from 0.04 to 0.34 m/s. In Minnesota, Dahle (2001) found mean flow ranges to be between 0.07 and 0.44 m/s, and Kuitenan (2001) noted that Topeka shiners "preferred" velocities within the range of 0.2 – 0.6 m/s. Instream habitats may contain areas with zero flow, and isolated off-channel habitats typically do. Three wild populations in Kansas' Cottonwood drainage exist in ponds (Keith Gido, Kansas State University, personal communication 2017), and captive reared Topeka shiners in Kansas are currently held in artificial ponds with no flow (Campbell *et al.* 2016). The species has also been raised (and reproduced) in aquariums (Katula 1998, 2015), and documented in zero-flow ponds separated from nearby streams (Dahle 2001, Hatch 2001, Thompson and Berry 2009). There are limits to the amount of discharge Topeka shiners can tolerate. Blausey (2001) found that at lower discharge levels (< 1.0 m^3/s) there was an equally likely chance Topeka shiners would be present, while at higher discharge levels (> 2.0 m^3/s) the likelihood of Topeka shiner presence decreased. Barber (1986) indicated discharges < 0.28 m^3/s are likely needed to avoid displacement by higher flows.

Laboratory experiments have specified the limited swimming abilities of the Topeka shiner (Adams *et al.* 2000). Individuals are able to tolerate velocities of 0.35 to 0.50 m/s, but only for short periods of time, and they often exhibit oral grasping (using their mouths to gain hold of sedentary structures while they stop moving their fins) at those speeds (Adams *et al.* 2000). Optimal speeds for the Topeka shiner are those at which individuals can swim continuously without fatigue and without the need to perform oral grasping; this occurs (determined in a laboratory setting) at velocities of less than 0.3 m/s (Adams *et al.* 2000). At speeds greater than 0.55 m/s, oral grasping ability declines and fatigue occurs quickly (Adams *et al.* 2000). In prairie streams, those speeds would likely allow individuals to be displaced downstream and/or harmed if they cannot find refuge. However, velocities and discharges associated with Topeka shiner presence should be interpreted cautiously. Velocity is lower at margins of flooded areas and among riparian cover, and velocity/discharge measurements during floods are rare thus knowledge of conditions during those events is limited.

Barber (1986) found that Topeka shiners can be sedentary, remaining in the same pool for 8-9 months. Some adults, particularly males, moved upstream or downstream typically between

March and May, before the spawning period, when precipitation typically increased in spring and raised stream levels; however, those individuals often later move back to their original pool (Barber 1986). Movements of juvenile Topeka shiners were usually downstream, while adult fish moved in either direction (Barber 1986). Movements by Topeka shiners of distances greater than 2.4 km (1.5 mi) were documented (Barber 1986). Despite their relatively sedentary nature, the ability to move upstream and downstream is an important requirement for individuals to move into spawning habitats, find refugia during low water conditions or freezing, and reoccupy extirpated areas.

Pool size occupied by Topeka shiners has been measured. Optimum pool depths in Kansas were suggested to be 0.20 - 0.40 m, with maximum no greater than 1.5 m, and optimum average widths between 2-4 m (Barber 1986). In Minnesota, one study identified preferred areas as “medium pool habitat with depths of 0.5 - 2 feet” (0.2-0.6 m) (Kuitenan 2001). In Iowa, Bakevich (2012) found instream habitats averaged 6.95 m wide with a 23.21 width to depth ratio, while off-channel habitats averaged 16.03 m width with a 32.11 width to depth ratio. The majority of off-channel habitats occupied in that study averaged a mean depth of 0.5 m or less (Bakevich 2012). Existing off-channel habitat (livestock dugouts) in a South Dakota study ranged from 0.06 m to 2 m deep, averaging 37 m long and 18 m wide, and dugouts created for the study were excavated to generally standard size of 20 m wide by 40 m long with a maximum depth of 3 m (Thomson and Berry 2009). Dahle (2001) found Topeka shiner sites in Minnesota had a mean depth of 0.50 m in instream habitats, but most off-channel habitats were deeper, averaging 0.78 m. The off-channel habitats had greater surface area and total volume than average instream habitats (Dahle 2001). Only one stream segment in that study contained large pool habitat, a 660 m^2 scour pool which was the only instream habitat in which Topeka shiner relative abundance was equivalent with the off-channel habitat (Dahle 2001). Natural instream and off-channel pools may have been deeper than those existing in modified prairie streams today, before excessive sedimentation became a major factor affecting these habitats. Note that the above measurements may not necessarily reflect preference, but simply conditions at sites where individuals have been found in recent years.

The importance of off-channel habitats to the Topeka shiner has been determined recently to be of relatively greater importance than previously thought. Off-channel habitats may be crucial to the long-term survival of this species in areas where it exists (Hatch 2001). Densities of Topeka shiners in off-channel habitats can be orders of magnitude higher than that of their associated main-channel stream pools (Dahle 2001, Bakevich 2012). The reasons are not yet clear; this may be due to a preference for off-channel sites, greater availability of off-channel sites vs instream pools, or other factors such as relative ease of capture in off-channel vs instream habitats. Regardless of the factors at play, it is clear that off-channel sites are present and used by the species in South Dakota, Minnesota, and Iowa (Thomson and Berry 2009, Hatch 2001, Bakevich 2012), while this habitat type is generally absent in Nebraska, Kansas, and Missouri (George Cunningham, personal communication, 2014; Kerns and Bonneau 2002; Paul McKenzie, USFWS, personal communication, 2014).

Benefits are afforded to individuals via use of off-channel habitats. Topeka shiners are tolerant of high temperatures and low dissolved oxygen (see Juvenile: *Feeding/Growth* section above), and such conditions in off-channel sites may exceed the tolerance levels of larger predatory species, and/or some competitors, resulting in protection of Topeka shiners via physiological exclusion (Bakevich 2012). With lack of flows, off-channel sites may, at times, also provide less turbid, vegetated conditions (Kuitinen 2001) for sheltering juveniles (despite often having a greater sediment layer within them), and lower/no flows to minimize downstream displacement/mortality of the fish during flood conditions. These habitats may be supported by groundwater input (Berg et al. 2004). The species is known to occupy, breed, move between, and overwinter in off-channel sites (Bakevich 2012, Thomson and Berry 2009).

B. Populations

When individual ecological requirements of individual Topeka shiners are met, populations can develop. However, in order for populations to persist on the landscape long-term, factors such as genetics, distribution, and disturbance play a role on a larger scale. Figure 13 demonstrates the relationships of these needs and their overall contribution to population resiliency.

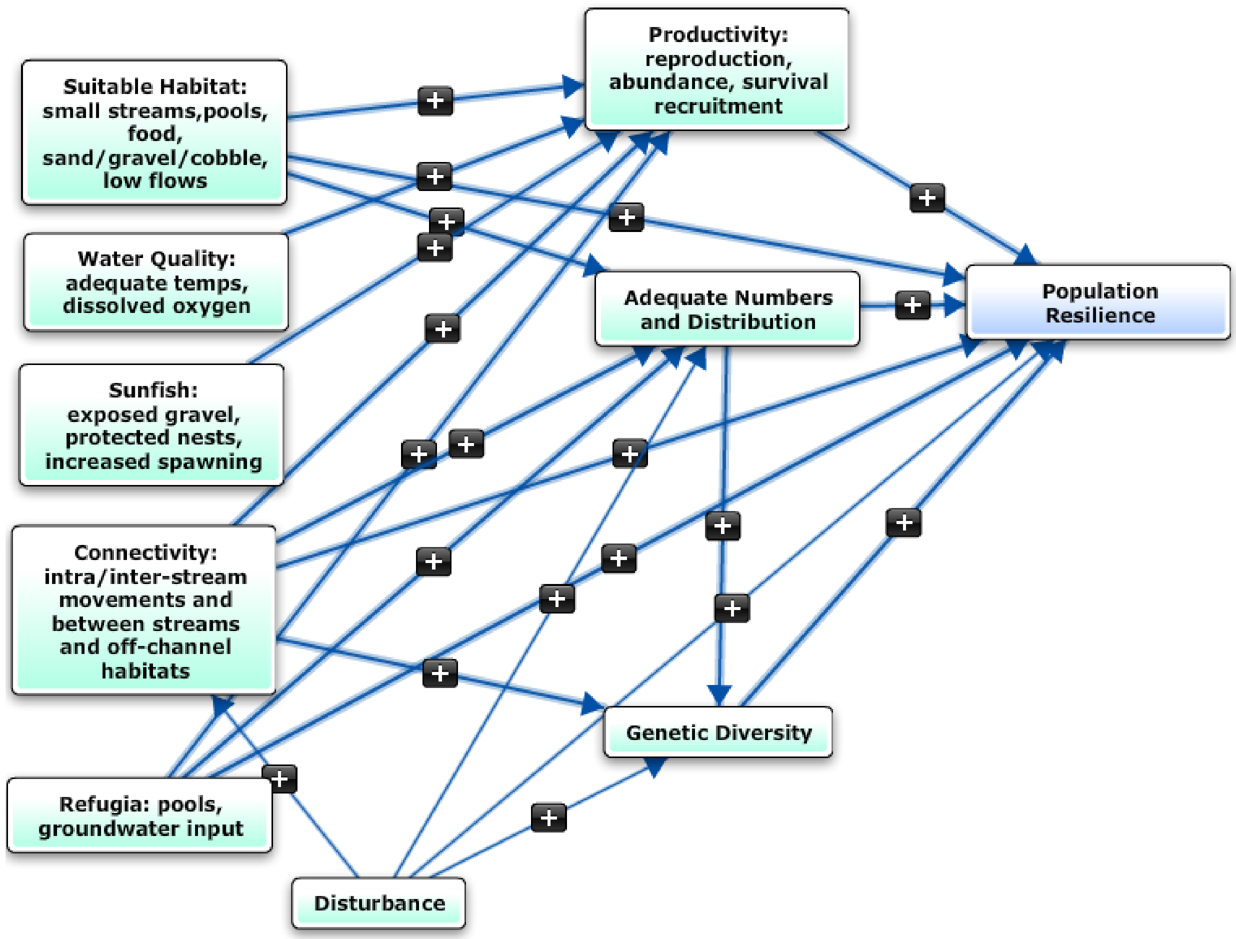


Figure 13. Model of Topeka shiner population resilience.

Note that "Disturbance" is portrayed above, for the purposes of this SSA report, as having positive effects (which could potentially occur in some instances), while "disturbance" in the typical use of the word relative to aquatic systems is known to have negative impacts.

Being short-lived, relatively sedentary, and living in dynamic prairie stream systems, subpopulations and populations of Topeka shiners are vulnerable to stochastic events. Their relatively high reproductive rate and extended breeding season mitigate this risk, as does their relative hardiness (*e.g.* resistance to high temperatures and low oxygen conditions), but ultimately they must annually produce enough breeding adults that successfully reproduce to preclude population declines and retain their ability to recolonize after local extirpations. Adequate habitat conditions must be present to complete their life cycle and allow source populations to move to suitable habitats. Recruitment of juveniles to the adult breeding population, connectivity among suitable habitats, and access to refugia are vital. Additionally, while disturbances such as floods or drought can negatively impact Topeka shiner populations, those factors may benefit populations in some instances (as in the case of floods) by improving connectivity between them. These topics are discussed further below.

1. Productivity

The exact reproduction, abundance, recruitment, and survival rates needed for Topeka shiner populations to be resilient and persist over time are unknown. Low survival rates, particularly among Age 0 and Age I (see Survival section, Chapter 1), have been documented in both Minnesota and Kansas. The Topeka shiner life span is ≤ 3 years and given high levels of annual mortality that occur, Topeka shiner populations must have adequate annual reproduction and recruitment to preclude declines. When mortality and productivity rates are the same, population sizes remain static. When mortality exceeds productivity, population size decreases as does its ability to persist over time (its resiliency is reduced), particularly during stochastic events. Persistence of Topeka shiner populations requires that survival rates do not fall below recruitment rates for long due to their short life span. Enough individuals must survive to adulthood over their short life span to lay enough eggs that also survive to adulthood in order for populations to: a) avoid falling so low as to preclude long-term viability, b) remain steady, or c) increase. Species that are already in danger of extinction typically have populations far less tolerant of continued diminishment before extinction forces such as genetic bottlenecking due to genetic drift or extirpation from random weather events become a greater risk.

2. Connectivity

Local extirpation of populations may occur as a result of stochastic events impacting prairie streams. If the stressor(s) that cause local extirpations are temporary and adequate habitat remains within an extirpated area, connectivity between that location and nearby occupied streams or stream reaches becomes vital so that individuals within source populations are able to reach the extirpated areas and recolonize. In streams with complete obstructions to fish passage (*e.g.* impassable dams) individual Topeka shiners may be unable to reach downstream refugia during drought and will perish if the upstream reach dries completely. Alternatively they may be forced into the only refugia available, the ponded areas formed by a dam, which may contain high numbers of stocked predators such as largemouth bass (*Micropterus salmoides*), resulting in extirpation of upstream Topeka shiner populations (Mammoliti 2002). Further, when conditions improve upstream, individuals downstream of such obstructions are typically precluded from recolonizing suitable upstream habitat and the distribution and/or size of the Topeka shiner population is reduced. Other means of fragmentation may have similar results (*e.g.* channelization). Movements and interactions of Topeka shiners within the stream length are vital to their survival and persistence in dynamic prairie stream habitats.

3. Refugia

Connectivity will not benefit population persistence if source populations are not available to recolonize extirpated areas. In this regard, refugia (instream and off-channel pools, particularly with groundwater input) are critical to allow individuals to survive the dynamics of these prairie stream systems until better conditions return (Barber 1986). If some portion of a population manages to find a groundwater-fed pool and survive a critical situation such as prolonged drought, the post-crisis environment may (at least temporarily) be relatively free of predators and/or competitors less tolerant to harsh conditions than the Topeka shiner. Topeka shiner populations have been reported as becoming more widespread in post-drought conditions (Minckley and Cross 1959). The amount of refugia required to sustain populations over time is not known, and quantifying it among all extant streams in the six occupied states within the species' range is highly difficult in stream systems that are subject to constant change with a variety of factors acting upon them at any given time (flows, water quality, predators, accessibility, substrate changes, morphological changes, food availability). Regardless, refugia are clearly critical to population resilience.

4. Suitable Habitat

Even if connectivity to an extirpated area is maintained and refugia are available to afford source populations, recolonization cannot occur if the cause of the extirpation results in permanent loss of suitable habitat, generally described as pools (in or off-channel), with low flows, gravel substrates and often groundwater input. Removal of pools (*e.g.* channelization), introduction of predators, losses of spawning substrate, impact to food sources, or other factors negatively affecting the physical and biological environment can result in permanent loss of Topeka shiners from formerly suitable areas, putting populations at risk. Adequate habitat also is needed for reproduction, survival and eventual recruitment of juveniles to the adult population as described above so that an adequate number of individuals may be added annually to populations and subpopulations. The resilience of populations is reduced when habitat quality and availability are reduced.

5. Genetic Variability

The Topeka shiner is not naturally a far-ranging species and gene flow has been found to be very low, even for proximal populations with no obvious barriers separated by relatively small distance (94 km/58 mi) (Michels, 2000)). Given environmental challenges of the future, including changes in climate, high genetic diversity would likely provide this species with opportunities to adapt. Thus, preservation of existing populations with existing genetic diversity (representation) is important from the standpoint of conserving as much adaptability as possible, particularly given the level of past losses (see more regarding genetic variability in the Resiliency section).

6. Adequate Distribution

As described in the Populations and Subpopulations segment above, streams in HUC12-sized watersheds function as subpopulations that compose the larger HUC10 watershed units that habor the species and are used herein to define Topeka shiner populations. Generally speaking, the existence of subpopulations broadens the distribution of individuals within a given population, spreads the risk of stochastic events that may impact to the population as a whole, and provides sources of repopulation when a given subpopulation is lost, assuming connectivity and adequate habitat exist to allow recolonization. The more subpopulations that exist within a population, the broader the population's distribution, and the more likely that population will be able to withstand localized impacts over time (improved resilience). Although the optimal number of subpopulations necessary to ensure long-term population persistence is unknown, the presence of multiple subpopulations within a population will improve the likelihood of that persistence.

7. Disturbance

Natural disturbances – particularly droughts and floods – are recurring conditions in the prairie streams inhabited by the Topeka shiner and the species has evolved and adapted to these disturbances. Severe drought can dry streams completely and result in local extirpations of Topeka shiners if refugia is lacking. Without nearby populations and connectivity to them, such local extirpations can, will, and have resulted in permanent extirpations. This is clearly a threat to the species in southern areas of its range. However, as noted earlier, drought may not always have lasting negative impacts on populations and Topeka shiners have been noted to become more widespread (Minckley and Cross 1959) or abundant (Barber 1986) post-drought. Topeka shiners can survive the relatively low dissolved oxygen levels and warm temperatures that occur with low water levels (Koehle and Adelman 2007) that many potential competitors and predators cannot. Topeka shiners may be the last fish species to survive in a given pool before the pool dries completely (Kerns and Bonneau 2002), allowing it to quickly recolonize unoccupied areas with less competition once more favorable water conditions return.

Data on the effect of flooding to the Topeka shiner is limited, although flooding during the breeding season can result in detrimental effects to fish in general such as egg displacement or high mortality of young minnows (Harvey 1987). Thus local subpopulations and populations of Topeka shiners are likely negatively impacted during such events, particularly if they occur during such sensitive life-history stages. Yet, if displaced individuals survive, flooding may be a mechanism for colonization or recolonization of unoccupied suitable habitats, allowing for greater dispersal distances and potentially larger occupancy than the populations would normally achieve. Overland headwater connections during flooding is the mechanism suspected in colonization of northern Missouri River watersheds from the Des Moines watershed in Iowa (Michels 2000) It also provides the opportunity for Topeka shiners occupying main stem habitats to move into, or out of, adjacent off-channel habitats when floodwaters connect these areas.

Thus, while droughts and floods are certainly detrimental to individuals, and sometimes entire populations, in some cases these events may also afford some long-term benefits to populations that would not otherwise be realized. Notably, current conditions are different than in the past, and the extent to which these potential beneficial effects could be overshadowed by other factors in today's highly modified, typically degraded Topeka shiner stream systems is unknown. Yet given these degraded conditions, the possibility exists that such disturbances, particularly flooding, may be the only means possible to achieve movements that were not problematic in the unmodified streams of the past.

C. Species

When individual ecological requirements are met, populations may develop, and these persist over time when population-level ecological requirements are met (*i.e.* populations become resilient). For the species to persist, the requirements are scaled up. Many of the ecological requirements of the Topeka shiner as a species are the same as the population needs described above, such as connectivity, refugia, habitat, genetic diversity, and in some cases disturbance - but with a larger perspective. Species persistence requires adequate numbers of resilient Topeka shiner subpopulations/populations within population complexes distributed within the species' range. Sufficient genetic and ecological diversity to allow adaptations to varying habitat conditions are important at this larger scale, contributing to population viability and likelihood of species persistence (Figure 14).

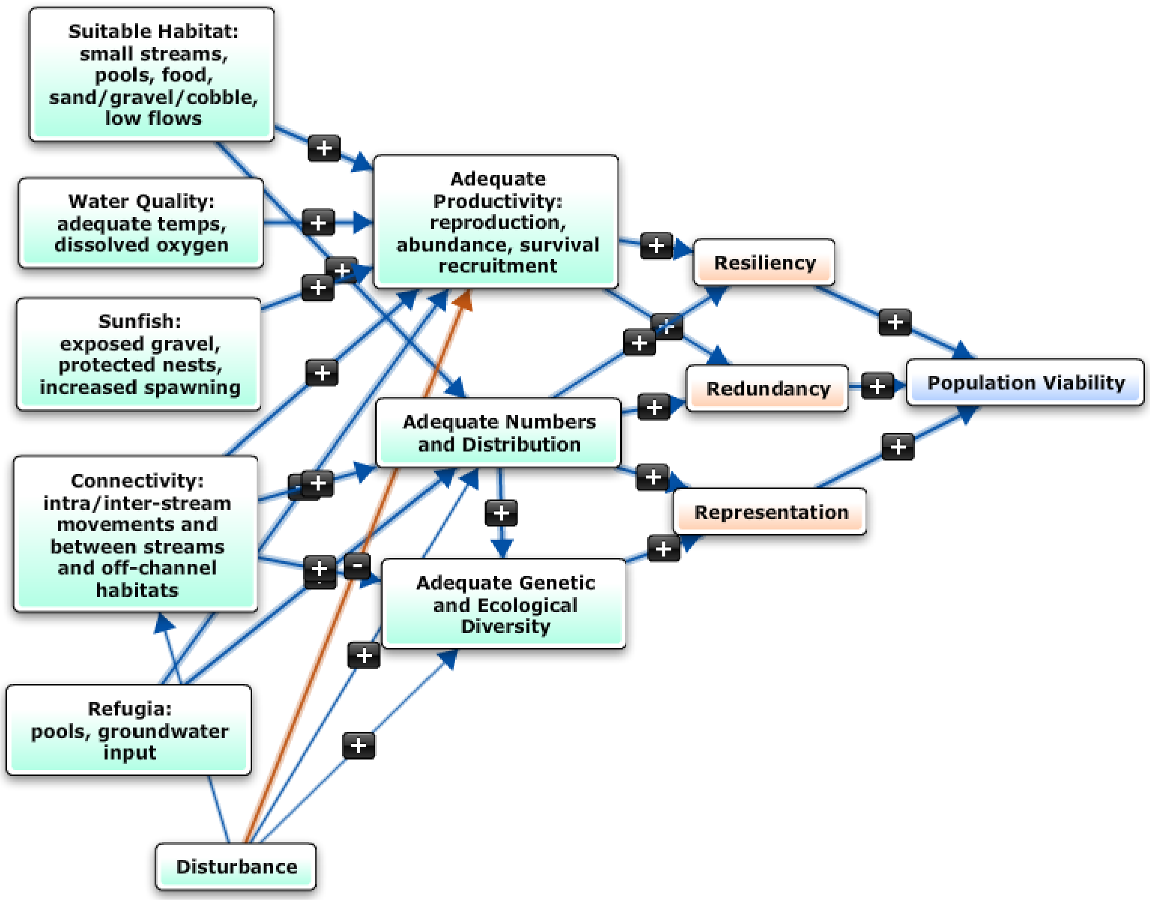


Figure 14. Model of factors contributing to Topeka shiner viability.

Note that "Disturbance" is portrayed above, for the purposes of this SSA report, as having both positive and negative effects to the Topeka shiner with positive impacts potentially occurring in some instances, while "disturbance" in the typical use of the word relative to aquatic systems is known to have negative impacts.

In this section we use the 3Rs - resiliency, redundancy, and representation – to generally describe the requirements of the species as a whole. The 3R construct takes into account demographic factors, distribution or spatial structure, along with diversity. Demographic factors (abundance, survival, productivity, and ultimately intrinsic population growth rate) contribute to the species ability to absorb disturbance and persist (resiliency). Spatial structure contributes to redundancy through increased distributional extent by spreading species risk across the broader landscape and adds to resiliency by increasing connectivity among populations. Diversity, as represented by genetic and ecological variation, contributes to adaptive capacity and the species' ability to adapt to novel changes (representation).

Collectively, the 3Rs are used to evaluate species viability. These are summarized in Table 4 and described further below.

Table 4. Summary of Topeka shiner ecological requirements as a species.

3 Rs	Description	Requisites for long-term viability
Resiliency (***to withstand stochastic events***)	Resiliency of Topeka shiner populations increase with adequate habitat quality, quantity and components present for completion of individuals' life cycle, as well as connectivity, refugia, and (at times) disturbances to allow for long-term recolonization, survival and long-term occupancy.	Resilience must be relatively high in most populations and population complexes to ensure mortality rates do not surpass survival rates, allow populations/complexes to remain stable or expand over time, and achieve long-term persistence.
Redundancy (***to withstand catastrophic events***)	Topeka shiners exist in subpopulations, populations, and population complexes that exhibit varied levels of resiliency and isolation. The more resilient subpopulations and populations that exits, the better the resiliency of the population complexes distributed across the range. The more resilient complexes that exist, the lower the risk of catastrophic effects from significant events (*e.g.* widespread drought).	Numerous resilient populations composing numerous population complexes over a broad area, in both northern and southern portions of the range, are needed to support long-term viability.
Representation (***to maintain adaptive potential***)	The Topeka shiner exhibits genetic diversity at a relatively small scale, with little mixing among proximal populations; less at population complex level. Much has been lost with extirpated populations and complexes; the greater the genetic diversity, the better the species' ability to adapt to changing environmental conditions.	At minimum, retention of existing genetic variability and widespread distribution among stream systems exhibiting varying biological, physical, climatic conditions in population complexes as representative units to preclude declining genetic diversity and associated loss of potential adaptive traits.

1. Resiliency

The ability of the species to withstand stochastic events (arising from random factors)

Resiliency can often be measured using population metrics such as population growth rates or population size; healthy populations are more resilient and better able to withstand stochastic disturbances such as random fluctuations in birth rates (demographic stochasticity), variations in rainfall (environmental stochasticity), or the effects of anthropogenic activities. While numbers of adult and juvenile Topeka shiners found in surveys (relative abundance), or numbers of collections yielding the species (presence/absence) can provide insight, data is currently lacking to define population metrics. Gathering the necessary information across the species' range would be complicated by the relatively high variability in annual, seasonal, locational, and event-driven factors that impact various life stages and ecological levels of this short-lived species; efforts to obtain necessary population metrics to accurately determine resiliency have not yet been undertaken.

As a proxy to population demographics, we look to the habitat characteristics that support Topeka shiner populations to describe the needs of the species in terms of resiliency. Habitats that retain their pre-European settlement characteristics are most apt to support healthy Topeka shiner populations. These are generally unobstructed streams surrounded by intact grasslands and/or adequate riparian buffers to protect instream habitat quality, supporting the natural prairie stream hydrology and morphology. The streams are typically sinuous with gravel-lined pools, and groundwater input (affording critical refugia), adequate food sources, optimal temperatures for reproduction/growth/survival, good water chemistry (*e.g.* low contaminant levels, adequate dissolved oxygen), low flow rates, and connectivity among and within stream channels. Natural disturbances affecting these streams (floods and droughts) may impact the species negatively at a local scale, but under certain conditions have the potential to improve the species' distribution.

Topeka shiner resiliency requires numerous streams with instream habitats that support healthy subpopulations and populations, which combine to form numerous population complexes. Since population complexes are groups of populations that exist in proximity within a larger watershed, numerous functional complexes (*i.e.* complexes with adequate refugia and connectivity) afford resiliency at a species level. When one population is negatively impacted or extirpated, other populations nearby have the potential to bolster the impacted population or recolonize. The Topeka shiner is not a migratory fish; its relatively sedentary nature and tendency to occupy headwaters (as well as current anthropomorphic influences) mean that neither full occupation within a population complex nor recolonizations are guaranteed. Disturbances in some cases that are detrimental to individuals can be beneficial to the species at the population and population complex scale when environmental events (particularly flooding) facilitate movements. When numerous populations exist in proximity to form a complex, and suitable habitat/refugia exist without barriers to movement, the potential for long-term persistence (resiliency) of the species is improved.

Based solely on continued persistence, some populations and population complexes of the Topeka shiner appear to have been more resilient over time than others. Numerous factors affect the species' resilience and are described elsewhere herein, but to improve the Topeka shiner's long-term viability as a species, persistence must at least be maintained in areas where they are currently doing relatively well and improved in areas where they have been reduced in number to the point of tenuous persistence or have been extirpated.

2. Redundancy

The ability of a species to withstand catastrophic events: rare destructive natural events or episodes involving many populations and occurring suddenly/unexpectedly.

Redundancy is about spreading the risk. This can be measured through the duplication and distribution of resilient populations across the range of the species. At a species level, the population complex becomes an important unit for measuring redundancy. The greater the number of resilient Topeka shiner population complexes distributed across the species' range, the better it is able to withstand catastrophic events.

Before European settlement, the Topeka shiner occupied a relatively large range across six states in the Great Plains. Redundancy for this species has been in decline since the Topeka shiner was first described; subpopulations, populations, and population complexes have been shrinking or have been completely extirpated over time, particularly in the southern parts of the range. Northern areas of South Dakota and Minnesota are estimated by the Service to contain 70% of extant populations, but only 20% of the species' former range (USFWS 2009). This disparity, and the decline of redundancy in the southern states, has decreased the ability of the species to withstand catastrophic events. Drought in particular can be widespread across the Great Plains, potentially negatively affecting large parts of the Topeka shiner's range. Despite the drought tolerance exhibited by the species (Topeka shiners have been documented to expand and become more abundant under conditions created by drought (Minckley and Cross 1959, Barber 1986)), when drought becomes severe (*e.g.* no refugia) or if degraded habitat conditions or other factors exacerbate stressors on the species, loss of Topeka shiner populations will result. The existence of many, broadly distributed populations and population complexes across the range serve to buffer the risk of catastrophic effects to the species. To persist long-term on the landscape and decrease future risk of declines/extirpations, the species needs numerous healthy (resilient) populations that compose resilient population complexes that are distributed throughout the Topeka shiner's six-state range.

Relatively high redundancy among northern populations has been maintained over time – particularly in South Dakota and Minnesota Topeka shiners continue to occupy the majority of their previously known range. In contrast, redundancy among more southern populations has declined significantly and this trend is ongoing. In order for the Topeka shiner to be viable long-term, subpopulation/population and perhaps population complex redundancy would need to remain stable or increase in northern populations and increase in southern areas.

3. Representation

The ability of the species to adapt to changing environmental conditions.

Representation can be measured through the breadth of genetic diversity within and among populations, and the ecological diversity (also called environmental variation or diversity) across the species' range. The more representation, or diversity, a species has, the more it is capable of adapting to changes (natural or human-caused) in its environment. Loss of representation can lead to lower viability because of diminished adaptive capacity.

a) Genetic Representation

Being a relatively sedentary, small, and non-migratory fish, the Topeka shiner is limited (barring outside influences) in its movements to within the connected suitable habitats within the branched waterway system of its respective watersheds of occurrence. At a small scale (subpopulations and populations) movements and mixing of individuals within HUC12 and HUC10 streams may often occur under conducive conditions; yet genetic differentiation among individuals at these levels is known to exist, suggesting long-term isolation sometimes occurs (Blank et al. 2011).

At a larger scale (within population complexes), the potential for movement and mixing between HUC10 streams is reduced. Distribution maps (Figure 1 above, Appendix B) indicate such movements have occurred in the past (*i.e.* numerous adjacent HUC10s are occupied within their larger watersheds), but genetic differentiation is known at the HUC10 level as well, demonstrating the generally isolative tendencies of this species (Michels 2000). Without additional information, however, we cannot rule out the potential for movements between HUC10s within population complexes in many instances. Further, the existence of a number of occupied HUC10s within these population complexes is likely important to the long-term persistence of the species on the landscape.

When considering interactions scaled up to the level of population complexes across the range of the Topeka shiner, however, it becomes clear that complexes are separated by insurmountable distances (*e.g.* 300+ miles), barriers (*e.g.* impassible dams) and/or unsuitable habitats (*e.g.* Missouri River) that are highly unlikely to be overcome by the Topeka shiner given its known life history. Given the physical isolation of most population complexes and the genetic differentiation demonstrated at a fine scale within them, it is likely that genetic distinctions between population complexes will become increasingly differentiated over time.

The degree to which Topeka shiner representation, and therefore adaptive capacity, has been reduced via past losses of populations and population complexes potentially harboring unique genetic characteristics is unknown. Given the estimated 80% reduction in formerly known occupied areas, the majority of which has occurred in southern states within the range, the reduction could be significant. The traits in the species that may have been affected by those losses – as well as traits affected by current genetic diversity – are also unknown. High genetic diversity would provide this species with increased opportunity to adapt to environmental challenges of the future, including changes in climate. To preclude further decline in Topeka shiner representation and conserve the highest level of adaptive capacity, existing genetic variability in the species across its range would have to be preserved.

b) Ecological Representation

The range of the Topeka shiner includes six states, but is generally confined to the Great Plains Level I Ecoregion (U.S. EPA 2017). Within this area, additional ecological subdivisions exist (Ecoregion Levels II, III and IV (U.S. EPA 2017)) that cross borders between northern and southern states. In our endeavor to identify representative units, an analysis of Level III and IV Ecoregions overlaid with existing occupied Topeka shiner watersheds was conducted, but did not reveal a clear correlation between Ecoregion type and ecological representation of the species (Table 5). Various Ecoregions overlapped portions of various known occupied watersheds, and with exception of the recent glaciation in northern areas discussed earlier, no known adaptations in the Topeka shiner could be linked to the different ecological conditions that may occur within the Ecoregions.

Table 5. Level III and IV Ecoregions (U.S. EPA 2017) overlapping extant Topeka shiner occupied streams and watersheds.

STATE	EcoRegion Level III No.	EcoRegion Level III Title	EcoRegion Level IV No.	EcoRegion Level IV Title	Topeka Streams/Areas
South Dakota	46	Northern Glaciated Plains	46c	Glacial Lakes Basin	Part of Elm River
			46i	Drift Plains	Most of Elm River
			46k	Prairie Coteau	Headwaters of Big Sioux River Tribs.
			46m	Big Sioux Basin	Big Sioux River Tribs.
			46n	James River Lowland	Most James and Vermillion River Tribs.
	47	Western Corn Belt Plains	47a	Loess Prairies	Southern Big Sioux River Tribs.
Minnesota	46	Northern Glaciated Plains	46k	Prairie Coteau	Headwaters of Big Sioux River Tribs.
	47	Western Corn Belt Plains	47a	Loess Prairies	Most of Rock River Tribs.
			47b	Des Moines Lobe	Some Rock River Tribs. and Little Rock River headwaters.
Iowa	47	Western Corn Belt Plains	47a	Northwest Iowa Loess Prairies	Rock and Little Rock Rivers

			47b	Des Moines Lobe	Raccoon and Boone Rivers
Missouri	40	Central Irregular Plains	40a	Loess Flats and Till Plains	Sugar Creek
	39	Ozark Highlands	39k	Prairie Ozark Border	Portions of some Moniteau Creek Tribs.
	72	Interior River Valley and Hills	72f	River Hills	Most of Moniteau Creek Tribs.
Nebraska	44	Nebraska Sand Hills	44a	Sand Hills	Most of Big Creek
			44d	Lakes Area	Part of Big Creek
	47	Western Corn Belt Plains	47L	Transitional Sandy Plain	Taylor and Union Creeks
Kansas	25	Western High Plains	25c	Moderate Relief Rangeland	Willow Creek
	28	Flint Hills	28	Flint Hills	Cottonwood, Lyon and Southern Big Blue Tribs.
	47	Western Corn Belt Plains	47i	Loess and Glacial Drift Hills	Northern Big Blue Tribs.

Currently, climatic conditions, habitat availability and use, and threats can be somewhat differentiated generally on a north-south gradient, with the northern states of South Dakota, Minnesota and Iowa generally affording relatively better conditions conducive to population persistence:

- Cooler, wetter conditions often exist in the north and are anticipated with continued climate change.
- Groundwater input to streams appears to be more prevalent in the north, perhaps due to the most recent glaciation that did not reach southern areas.
- Off-channel habitats, which may be an important factor in Topeka shiner persistence, are present in the north, but generally not the south, with exception of central Iowa.
- Human activities such as construction of dams and stocking of predatory fish species, instream gravel mining, and groundwater extraction are relatively more prevalent in the south.

Other differences likely exist between northern and southern units, *e.g*. riparian buffers along northern Topeka shiner streams have been observed to be more intact in some northern areas than in the south (Vernon Tabor, USFWS, personal communication, 2017); empirical study of this observation may lend insight to the thresholds (amount of riparian habitat) needed for Topeka shiner persistence.

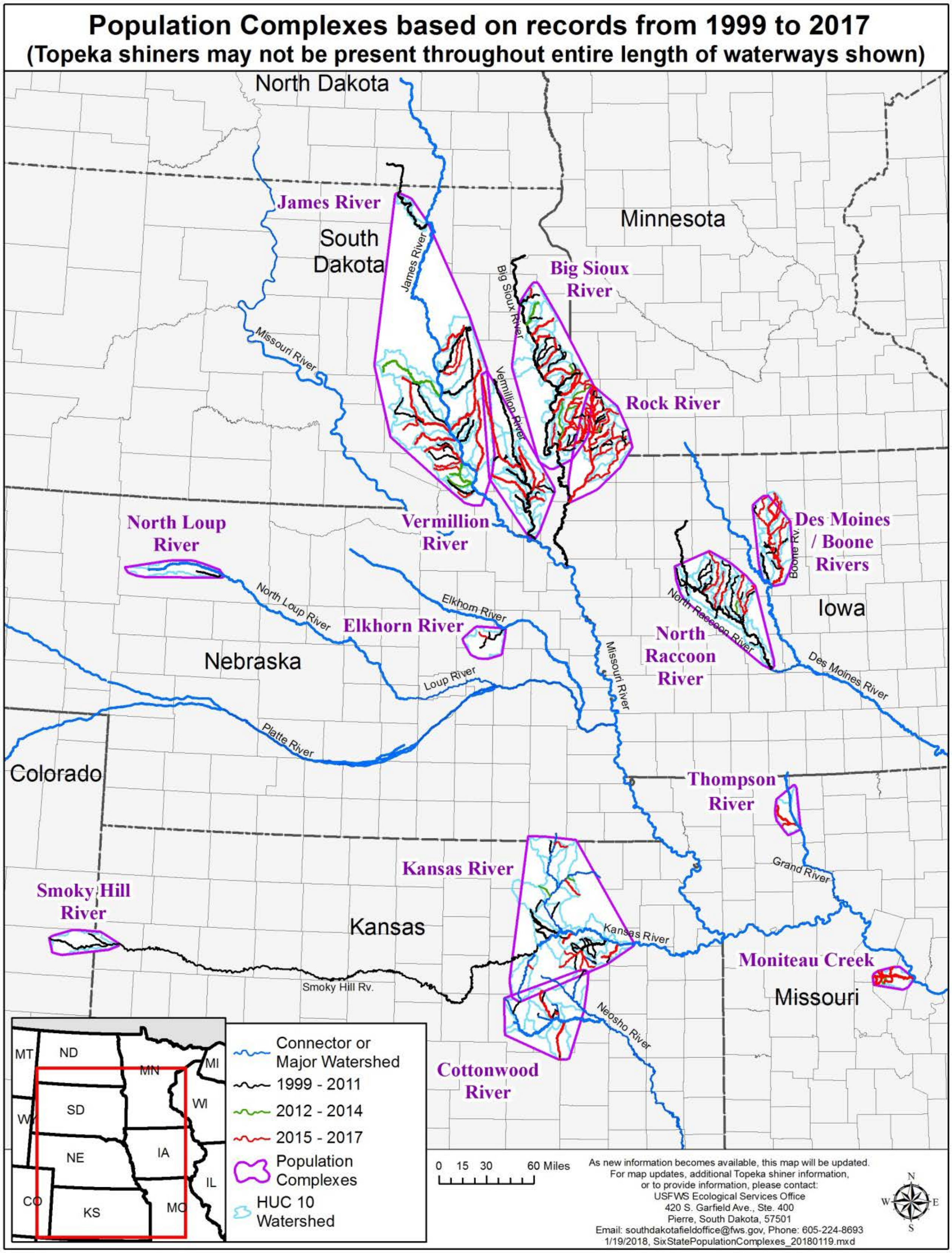
However, exceptions exist to the north-south dichotomy in areas such as the Flint Hills – a portion of Kansas known for its relatively intact upland habitats that have likely precluded extirpations of Topeka shiners that occurred elsewhere in Kansas. Topeka shiner declines have occurred in the Flint Hills, but the species persists in many streams there. Similarly, Iowa and Minnesota have lost Topeka shiner populations/complexes which did not fall within the landscape subject to the recent glaciation (Des Moine Lobe of the Laurentide Ice sheet). The poor drainage and off-channel habitats that resulted from glaciation and formed the watersheds may be key to species persistence in the Rock, Des Moines/Boone, and North Raccoon watersheds, despite landscape-level impacts such as agriculture, stream channelization, and drain tile. These cases demonstrate the potential for watershed-level factors to mitigate impacts of landscape-level threats.

c) Representative Units

In the SSA, we assess the species relative ability to adapt to changing environmental conditions over time. We look at past, current and projected distribution of populations across the range to evaluate whether and to what extent the species' adaptive capacity has changed and is forecasted to change into the future. There is no set number of representative areas to ensure species viability. Rather, we evaluate the various components of genetic or ecological diversity that we think contributes to the adaptive capacity of the species. Identifying representative units that demonstrate ecological and genetic diversity for the species help us to identify where we can preserve adaptive capacity and why.

The Topeka shiner exhibits a relatively fine scale of genetic differentiation. Mixing of genetic material is generally presumed to occur within most subpopulations and populations, may occur between populations (within population complexes), but is highly unlikely to occur between population complexes. As a result, genetic differentiation is anticipated to increase between population complexes over time. Topeka shiner persistence requires the basic habitat characteristics that allow individuals to complete their life cycle, plus factors such as connectivity, refugia, and some types/levels of disturbance that allow subpopulations and populations to move and occupy/reoccupy suitable habitats in all parts of the range. If those needs are not met, the species declines and ultimately extirpations may occur. While conditions overall appear to be more favorable for persistence of the species in northern, recently glaciated areas, site-specific conditions within the larger watersheds in other areas appear to have the potential to mitigate landscape-level threats to the species as well.

For the purposes of this SSA, representation is best evaluated at the population complex level, and the representative units are the thirteen population complexes identified in Figure 15.



Population Complexes based on records from 1999 to 2017
(Topeka shiners may not be present throughout entire length of waterways shown)
North Dakota
Minnesota
South Dakota
Nebraska
Iowa
Colorado
Kansas
Missouri
James River
Big Sioux River
Rock River
Vermillion River
North Loup River
Elkhorn River
North Raccoon River
Des Moines / Boone Rivers
Thompson River
Kansas River
Smoky Hill River
Moniteau Creek
Cottonwood River
Missouri River
Vermillion River
Boone Rv.
Des Moines River
North Loup River
Loup River
Platte River
Grand River
Kansas River
Smoky Hill Rv.
Neosho River
Connector or Major Watershed
1999 - 2011
2012 - 2014
2015 - 2017
Population Complexes
HUC 10 Watershed
MT
ND
MN
MI
WI
SD
NE
IA
IL
CO
KS
MO
0 15 30 60 Miles
As new information becomes available, this map will be updated.
For map updates, additional Topeka shiner information,
or to provide information, please contact:
USFWS Ecological Services Office
420 S. Garfield Ave., Ste. 400
Pierre, South Dakota, 57501
Email: southdakotafieldoffice@fws.gov, Phone: 605-224-8693
1/19/2018, SixStatePopulationComplexes_20180119.mxd
N
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S

Figure 15. Topeka shiner representative units: thirteen population complexes.

Topeka shiner occupied streams are shown in Figure 15 in the context of their HUC10 watersheds (light blue outlines) and their population complexes (purple outlines) which are the representative units. Table 6 below, identifies the HUC10s that compose the population complexes by number and name, and lists them according to their respective population complex/representative unit as well as whether they exist in northern (recently glaciated) areas of the range, or southern areas of the range.

Table 6. Population complex names, and the number, name, and HUC10 identification numbers of populations that compose the complexes in northern and southern portions of the Topeka shiner's range.

	POPULATION COMPLEX NAME (and # of populations within each)	POPULATION NAME	POPULATION I.D. (HUC10)
Northern (recently glaciated) Complexes (n=6)	BIG SIOUX RIVER COMPLEX (n=16)	Beaver Creek-Split Rock Creek	1017020315
		Brookfield Creek-Big Sioux River	1017020306
		Deer Creek-Medary Creek	1017020209
		Flandreau Creek	1017020303
		Hidewood Creek	1017020204
		Medary Creek	1017020210
		Ninemile Creek-Big Sioux River	1017020317
		North Deer Creek	1017020207
		Pipestone Creek	1017020313
		Sixmile Creek	1017020206
		Split Rock Creek	1017020316
		Spring Creek	1017020301
		Stray Horse Creek	1017020108
		Upper Big Sioux River	1017020211
		West Pipestone Creek	1017020314
		Willow Creek	1017020107
	DES MOINES/ BOONE RIVER COMPLEX (n=7)	Boone River	0710000507
		Brushy Creek	0710000405
		Ditch 3-Boone River	0710000506
		Eagle Creek	0710000504
		Headwaters Boone River	0710000502
		Otter Creek	0710000503
		Prairie Creek	0710000501
	JAMES RIVER COMPLEX (n=18)	Dawson Creek	1016001117
		Dry Creek	1016001113
		Dry Run-James River	1016001104
		Enemy Creek	1016001110

		Firesteel Creek	1016001109
		Firesteel Creek-James River	1016001114
		Lonetree Creek	1016001116
		Lower Elm River	1016000408
		Pearl Creek	1016000611
		Pierre Creek	1016001111
		Pleasant Lake	1016001107
		Redstone Creek	1016000612
		Rock Creek	1016001106
		Sand Creek	1016000613
		Shue Creek	1016000607
		Twelvemile Creek	1016001112
		West Branch Firesteel Creek	1016001108
		Wolf Creek	1016001115
	NORTH RACCOON RIVER COMPLEX (n=11)	Buttrick Creek	0710000612
		Camp Creek	0710000605
		East Buttrick Creek	0710000611
		Elk Run-North Raccoon River	0710000608
		Hardin Creek	0710000610
		Indian Creek	0710000604
		Lake Creek	0710000606
		Buttrick Creek	0710000612
		Camp Creek	0710000605
		East Buttrick Creek	0710000611
	ROCK RIVER COMPLEX (n=4)	Champepadan Creek-Rock River	1017020403
		Headwaters Rock River	1017020401
		Kanaranzi Creek	1017020402
		Little Rock River	1017020406
	VERMILLION RIVER COMPLEX (n=10)	Blind Creek	1017010213
		Frog Creek	1017010214
		Hurley Creek	1017010209
		Long Creek	1017010210
		Lower East Fork Vermillion River	1017010204
		Lower Vermillion River	1017010220
		Lower West Fork Vermillion River	1017010206
		Turkey Ridge Creek	1017010212
		Upper Vermillion River	1017010211
		Upper West Fork Vermillion River	1017010205
Southern Complexes (n=7)	COTTONWOOD RIVER COMPLEX (n=5)	Clear Creek-Cottonwood River	1107020202
		Diamond Creek-Cottonwood River	1107020302
		Middle Creek-Cottonwood River	1107020301

		Rock Creek-Neosho River	1107020102
		South Fork Cottonwood River	1107020303
	ELKHORN RIVER COMPLEX (n=1)	Union Creek	1022000301
	KANSAS RIVER COMPLEX (n=11)	Big Blue River-Tuttle Creek Lake	1027020505
		Deep Creek-Kansas River	1027010205
		Fancy Creek	1027020506
		Headwaters Mill Creek	1027010203
		Horseshoe Creek-Big Blue River	1027020502
		Lyon Creek	1026000807
		Mill Creek-Kansas River	1027010204
		Mission Creek-Kansas River	1027010207
		Outlet Black Vermillion River	1027020504
		Tuttle Creek Lake-Big Blue River	1027020507
		Wildcat Creek-Kansas River	1027010102
	MONITEAU CREEK COMPLEX (n=1)	Smiley Creek-Moniteau Creek	1030010208
	NORTH LOUP RIVER COMPLEX (n=1)	Big Creek-North Loup River	1021000601
	SMOKY HILL RIVER COMPLEX (n=1)	Willow Creek-Smoky Hill River	1026000101
	THOMPSON RIVER COMPLEX (n=1)	Sugar Creek-Thompson River	1028010210

These Topeka shiner population complexes vary in many ways. Some complexes are relatively large, with numerous highly-ranked subpopulations and populations located adjacent to each other (*e.g.* Big Sioux River complex in South Dakota/Minnesota), indicative of relatively high overall population complex resilience. In contrast, several complexes are now apparent remnants, represented by one or two occupied streams (*e.g.* North Loup, Thompson), and are isolated to a degree that makes recolonization of adjacent areas unlikely which lowers their resilience (regardless of model scoring of their populations). Such areas challenge the use of the term “complex” to describe them. The assumption is that the remaining/fragmented populations were once part of larger groups of occupied streams and they represent the potential for growth and development of complexes in the future. We acknowledge that the above identified population complexes may warrant further modifications if additional information becomes available in the future. For example, various Topeka shiner occupied watersheds exist within the currently delineated Kansas River population complex, but areas separated by the Kansas River itself may actually function, or have the potential to function, as individual population complexes. Our knowledge of movements of Topeka shiners within complexes (between populations) is limited. It is apparent that such movements between streams within large watersheds (HUC8 or larger) occurred in the past given their current distribution; however, given today’s levels of fragmentation and anthropomorphic influences on Great Plains prairie streams, such movements may occur very rarely today, or not at all.

Lack of knowledge about movement of Topeka shiners within complexes is a substantial information gap for this species.

CHAPTER 2: TOPEKA SHINER CURRENT CONDITION

The current condition was assessed using the best available information from peer reviewed literature and unpublished materials from the six states and other experts within the range of the Topeka Shiner, as well as information gathered from experts before, during and after the 2014 Information Sharing Workshop (See Appendix A for workshop meeting notes). The participants at the workshop presented expertise on the species and/or perceived threats to the species. Information on current populations, trends (if documented), and ongoing conservation actions was provided by State agency staff. Occupancy was mapped for each state using ArcMap 10.3 developed by ESRI of Redlands, California, and these were combined into a range wide map of extant populations, using Topeka shiner records collected 1999-2017.

I. Change from Historical Conditions

The species' current range is better understood in the context of the past; we briefly describe changes in the range and occupancy of the Topeka shiner from known previous conditions below.

A. Habitat

The prairie ecosystem in which the Topeka shiner evolved was a sea of grass and forbs, mostly treeless with exception of riparian areas, and the small streams occupied by this species were generally meandering, cool, clear, fed with groundwater, and lined with gravel or sand. Any instream obstructions were likely temporary, perhaps caused by beaver activity or fallen trees. Grasslands held the upland soil intact, and despite natural disturbances such as post-fire runoff events, herds of bison moving across the streams, floods, or droughts, the streams remained resilient with their habitat intact, conserving the species within them.

The system today is highly altered from its natural state. Human actions such as plowing of the prairie sod, replacement of native grazers with livestock, concentrating livestock in small areas, drainage of wetlands, and other human activities/developments all affect the streams occupied by the Topeka shiner. Direct modifications include channelization, rerouting or shortening of channels, diverting and/or consuming instream water, depleting aquifers, disconnecting streams from their floodplains and off-channel habitats, filling floodplains, instream mining of sand/gravel, installing dams, installing culverts and bridges, stocking non-native or predatory fishes, and polluting the water with pesticides/herbicides/tile effluent/livestock runoff/urban pollutants/industrial pollutants. These actions have had adverse impacts to Topeka shiners by reducing the habitat's ability to support the life history needs of this species. The natural hydrology of prairie streams (flow patterns, temperature, water chemistry, water availability) has been altered in every Topeka shiner stream today, to varying degrees. Similarly, the morphology (sinuosity, bank stability, refugia, connectivity) has also been modified in the majority, if not all, of these streams.

B. Range

Given the Topeka shiner's past known distribution, available genetic information, and our knowledge of past drainage patterns, the mechanism by which the species came to occupy areas within its Great Plains range may be due to one or more of the following factors:

- the advance and retreat of glaciers that modified the drainage patterns of occupied waterways, causing connections/disconnections that could have allowed movement of the species among streams in watersheds that are separated today (Cross 1970)
- floods and/or droughts that may have displaced Topeka shiners downstream from their occupied habitats into larger, usually unsuitable, waterways from which they could move back into typically occupied habitats (not necessarily their habitat of origin) when more optimal conditions returned, and
- floods that resulted in stream connections between normally separate watersheds at their headwaters (Michels 2000), allowing Topeka shiners to move among low-order streams.

While the above conditions may have created the baseline range of the Topeka shiner, we are limited in knowledge of this range to collection records beginning in 1884 when the species was first identified. The historical range was estimated in the five year review for the Topeka shiner (USFWS 2009) and contraction in the species' range, particularly in Kansas, Missouri, Nebraska, and Iowa, is demonstrated in Figure 16.

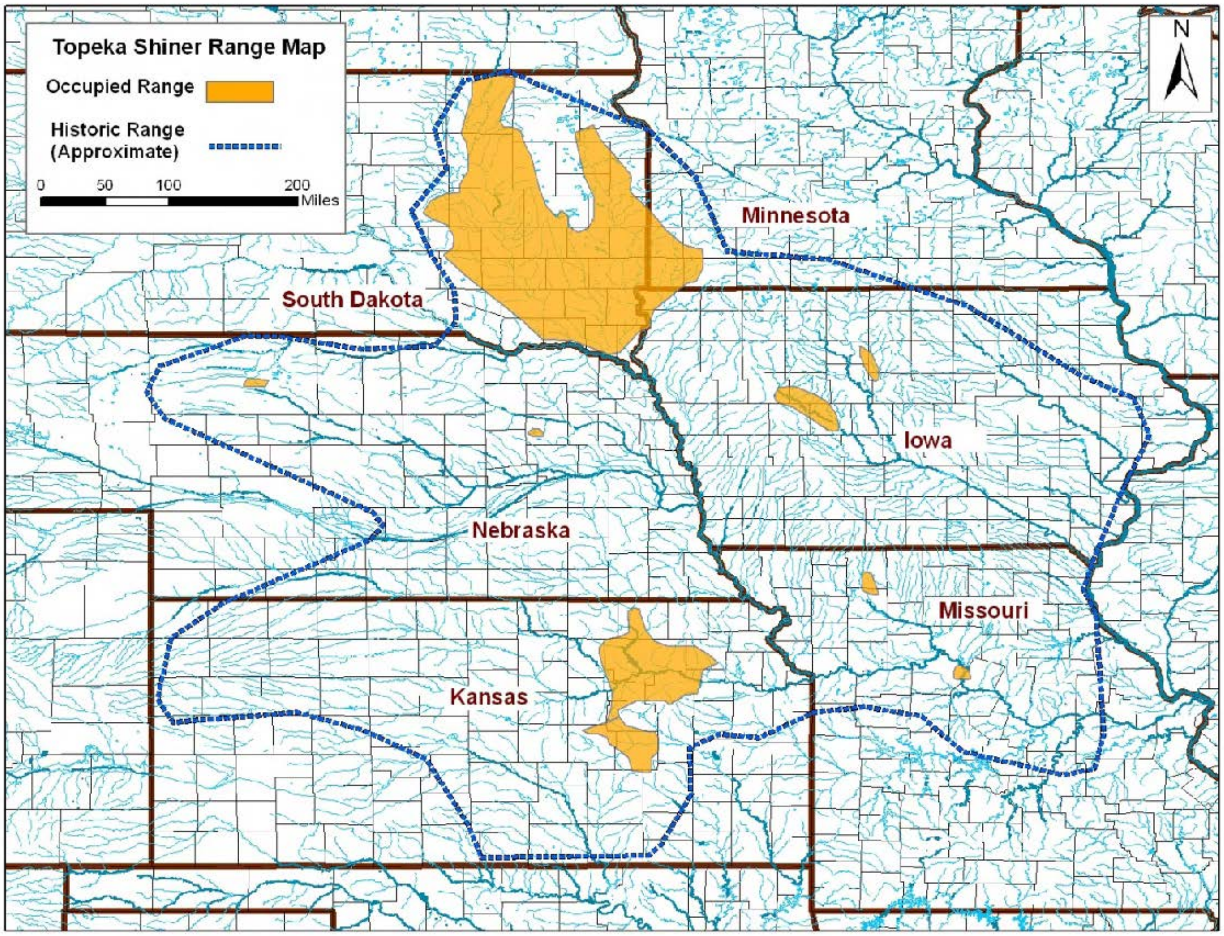


Figure 16. Approximate Topeka shiner historical distribution versus current distribution (USFWS 2009).

Post-listing surveys revealed the majority of known large (*e.g.* HUC8) watersheds in northern populations of South Dakota, Minnesota and northwest Iowa remain occupied (James, Vermillion, Big Sioux, and Rock Rivers) with central Iowa Topeka shiners (North Raccoon and Des Moines/Boone watersheds) also persisting as other populations in Iowa became extirpated. Two historical Topeka shiner records in Minnesota – a 1947 record in the Des Moines watershed and an 1890 record in the Cedar River watershed (both shared with Iowa) - have not been reconfirmed in Minnesota (Hatch 2001) indicating the larger range may have contracted in that state, although the exact extent is unknown.

Losses have continued in more southerly portions of the Topeka shiner's range. The 1993 Status Report (USFWS 1993) identified known/presumed extirpated populations at that time with the majority of losses identified in the states of Kansas and Missouri, although the Kansas Flint Hills region continues to harbor a relatively high number of occupied streams. In 2009, populations in South Dakota and Minnesota were the only two states considered to be in the "northern" part of the range (note that while part of Minnesota's Rock River watershed flows into northwest Iowa, Iowa was generally grouped with southern states in the range). The north at that time was estimated to contain 70% of extant populations, while harboring only about 20% of the historical range of the species (USFWS 2009). Conversely, Nebraska, Iowa, Kansas and Missouri harbored the majority (80%) of past occupied habitat, but only 30% of post-listing Topeka shiner populations at that time (USFWS 2009). In this SSA report, northwestern and central Iowa extant populations (*i.e.* all extant populations remaining in the state) are included as part of the northern populations due to this area's shared glacial history with South Dakota and Minnesota and resulting hydrology. While percentage estimates from the five-year review (USFWS 2009) have not been revisited for this SSA, Figure 16 (above) remains relevant and clearly demonstrates significant range reduction, most of which has occurred in areas outside the recently glaciated regions of the north.

C. Occupancy

Existing survey data in combination with the current altered landscape and degraded conditions of prairie streams indicates Topeka shiner occupancy has been reduced in most (if not all) of the habitats previously known to be occupied by the species. Hatch (2001) indicated the species occupied roughly 175 low-order prairie streams in the six Great Plains states that compose its range. Exact past occupancy is difficult to determine; as mentioned above, the species was first described late in 1884, after impacts to prairie streams due to heavy grazing and cropping had been occurring for some time. Collection efforts during the 1950's indicate the species was already in decline, and the species was often detected in low numbers (Cross 1954, Minckley and Cross 1959, Bailey and Allum 1962). The location of the type locality (where the species was first identified), Shunanunga Creek in Kansas, has been not been known to harbor Topeka shiners since that time (Minckley and Cross 1959). In 1993, the Service compiled a status report for the Topeka shiner (USFWS 1993) that listed known extant and possible/known/likely extirpations of the species rangewide. The report identified 37 streams in Kansas, 30 in Missouri, and 7 in Nebraska that were thought to be extirpated (USFWS 1993). Some streams (*e.g.* Wildcat Creek in Kansas) have since been shown to continue to harbor the species, but additional extirpations (*e.g.* Bonne Femme Creek in Missouri) appear to have occurred since that time.

The Status Report noted only five extant streams in South Dakota in 1993 with no known extirpations (USFWS 1993). By the time the species was listed, eleven South Dakota streams were identified as occupied (63 FR 69008-69021, December 15, 1998), and the current occupied stream total in the state is 72 (10 shared with Minnesota)(see Distribution and Trends South Dakota (below)). Without the benefit of comprehensive historic survey data, it is impossible to know how or if actual stream occupancy has changed between pre- and post-listing in South Dakota, but on a larger scale (*e.g.* the James, Vermillion and Big Sioux River watersheds) the known range boundaries for this species remain intact in South Dakota.

Similarly, in Minnesota, post-listing surveys revealed more occupied streams than were known at the time of listing within the Rock River watershed. The 1993 Status report identified only four known extant populations at that time (USFWS 1993); today 66 streams have been identified as occupied in Minnesota (10 shared with South Dakota and 3 shared with Iowa)(see Distribution and Trends, Minnesota (below)). As mentioned above, two records in streams of the Des Moines (1947) and Cedar River (1890) watersheds of Minnesota have not been reconfirmed (Hatch 2001). Thus, some range contraction has occurred there, but without benefit of past Topeka shiner occupancy in those watersheds, the degree cannot accurately be quantified.

It should be noted that extirpations of Topeka shiners must be surmised at times; it is difficult to determine with certainty that a rare minnow is gone from an entire stream and/or watershed. Streams are linear systems; individual Topeka shiners can and do occur at various locations and at various times within a given stream dependent up on available suitable habitat and other instream conditions that are conducive (or not) to their presence. Barring passage barriers, populations, and thus the population complexes comprising them, also naturally expand and contract due to conditions within prairie stream ecosystems, so local occupancy is an ever-changing variable for this species. However, when repeated efforts to reconfirm known populations are not successful, determinations that Topeka shiners are no longer present (*e.g.* Bonne Femme watershed in Missouri) have been made. Anthropogenic stream modifications (*e.g.* dams and perched culverts) have clearly precluded Topeka shiners from recolonizing many formerly occupied areas, and may be used to support the determination that streams are extirpated. Overall occupancy by this species has clearly been reduced over time, particularly in the southern portion of its range. Currently, the Service does not have a protocol for determining Topeka shiner extirpations. Until one is developed, we rely on the best currently available scientific information to make such determinations.

II. Current Species Range

The Topeka shiner's current range – the perimeter that encompasses all known occupied watersheds that harbor streams occupied by species today, based on the post-listing (1999-2017) count of occupied streams (Figure 1 above) is in stark contrast to its past estimated range (Figure 16), even though the species remains extant in the same six Great Plains states.

As of December 2017, the known number of occupied streams throughout the species range is 223 (Figure 1 above, Appendix D). These are defined as individual streams, occurring mostly within HUC10 and HUC12 watersheds (with exceptions such as the Rock River itself which is a HUC8 comprising multiple HUC10s), that have had a collection of Topeka shiner(s) from within them between 1999 and 2017. In the northern glaciated portion of the species' range (South

Dakota, Minnesota, and Iowa) 167 low-order streams have had such records, while in the reminder of the range (Kansas, Missouri, Nebraska) there 56 streams meeting that definition with the majority (42) occurring in Kansas. While these streams may have had Topeka shiners within them as of 1999 or later, not all have been recently confirmed as continuing to harbor the species today. Thus, the totals simply represent a baseline count of occupied individual streams since the species was listed, defining the current distribution of the species.

For the purposes of this SSA, 13 population complexes have been identified and are represented in Figure 15. Note that any further divisions, expansions, or otherwise altered population complex boundaries as dictated by future additional information will be included in updates of this SSA report. The currently identified complexes are distributed throughout the range and are generally geographically isolated or separated from each other by unsuitable habitat and unlikely to interact among each other. Some of these complexes are essentially remnants where only a few, or a single, occupied stream remains of what was once a larger group of occupied streams/watersheds. Thus, while identified as complexes herein, they may not function in that capacity today. Similarly, occupied streams in adjacent watersheds may not actually function as part of the complex in which they are identified (*e.g.* no movement between them may occur), due to factors such as the species' own association with headwaters, physical obstructions to movement, low abundance/occupancy levels, etc.. Thus, the population complexes herein represent the potential for interactions among populations, but not necessarily known interactions. Some physically separated populations were grouped with others in streams within their larger watersheds (*e.g.* Elm River population lumped with James River Complex; Big Blue River populations above Tuttle Dam lumped with Kansas River Complex) based on a watershed-level evaluation. As part of their respective larger watersheds, those populations most likely had previous connectivity with other populations in the complex which infers a shared genetic and evolutionary history, despite barriers existing today. These population complexes fall into one of three major drainages in the central U.S.: the North Raccoon and Des Moines/Boone River population complexes drain to the Upper Mississippi River; the Cottonwood River population complex in Kansas is part of the Arkansas-White-Red River system which eventually connects with the Lower Mississippi River; and the remaining Topeka shiner populations and complexes drain into the Missouri River.

A. Distribution and Trends by State

Extant populations in five states exhibited declining trends at the time of our 2014 workshop; South Dakota had not conducted surveys at a scale or frequency to allow detection of trends in more than a few streams, although persistence has been documented in many South Dakota occupied streams over time via occasional repeated survey efforts. Also note that 2015-2017 Minnesota survey results have documented improvements in Topeka shiner detections since the workshop. Should downward trends continue in the majority of states, however, loss of populations and reduced distribution will result in further isolation of populations and population complexes range wide. Before European settlement of the Great Plains, populations likely would have occasionally had connectivity when flooding occurred and individuals moved or were displaced and then able to colonize alternate suitable habitat. Today, connections and successful dispersal events between populations during flood events are hampered by lengthy distances between extant populations, unsuitable habitat, or complete/partial physical instream barriers. The chances of dispersing individuals finding refuge, suitable habitat to continue their life cycle, and/or another population to join are more limited than in the past, as is the Topeka shiner's ability to recolonize areas post-extirpation. This contributes to declining trends in many areas.

State collection records dated 1999-2017, which are considered herein to be in the relatively recent to recent past, are used herein to identify current Topeka shiner occupancy of low-order streams within each state in the Topeka shiner's range. Survey efforts increased when the species was listed with many new streams documented in northern areas at that time. We acknowledge that some collection records are relatively old (*e.g.* no records since the 1999 listing) and without updated collections, continued occupancy cannot be confirmed in some streams. However, particularly in areas infrequently sampled, continued occupancy may not necessarily be ruled out. Defining specific criteria to determine extirpation of Topeka shiner populations would be helpful in establishing future occupancy. Future survey results will be used to update occupancy.

Maps of streams occupied between 1999 and 2017 in each state are provided below in the state-by-state summaries and compiled in Appendix B. Topeka shiners are not necessarily present throughout the mapped streams, and as noted above, some identified streams without current collection records could be unoccupied today. Also, the 1999-2017 extant Topeka shiner streams are listed by state in Appendix D which provides the state in which each streams occur, their major watersheds, the location of each stream outlet to provide identification of the correct waterway (note that these coordinates are not collection sites), and the last known recorded date that Topeka shiners were located in each stream.

Information presented at the 2014 workshop included Topeka shiner population status updates and major factors influencing that status in each occupied state. Additional coordination post-workshop with state agency representatives and others further clarified the state-by-state summaries below, which include 1999-2017 collection records totaling 223 occupied streams (167 in northern glaciated states of South Dakota, Minnesota and Iowa, 56 in southern states of Nebraska, Kansas and Missouri). Topeka shiner survey protocol and periodicity varies among the states from standardized annual monitoring by state agencies to occasional random records from a variety of sources. However, trends were surmised for all states but South Dakota (more information on that below). The information was documented in workshop meeting notes (See Appendix A, pages 3-13 of the workshop notes).

1. Iowa

a) Occupancy/Status/Trends

Topeka shiners appear to have been extirpated from past known occupied areas in the eastern half of Iowa. From 1999-2017, Iowa surveys documented 42 occupied streams; three of those are shared with Minnesota in the Rock River watershed (Figure 17, Appendices B and C).

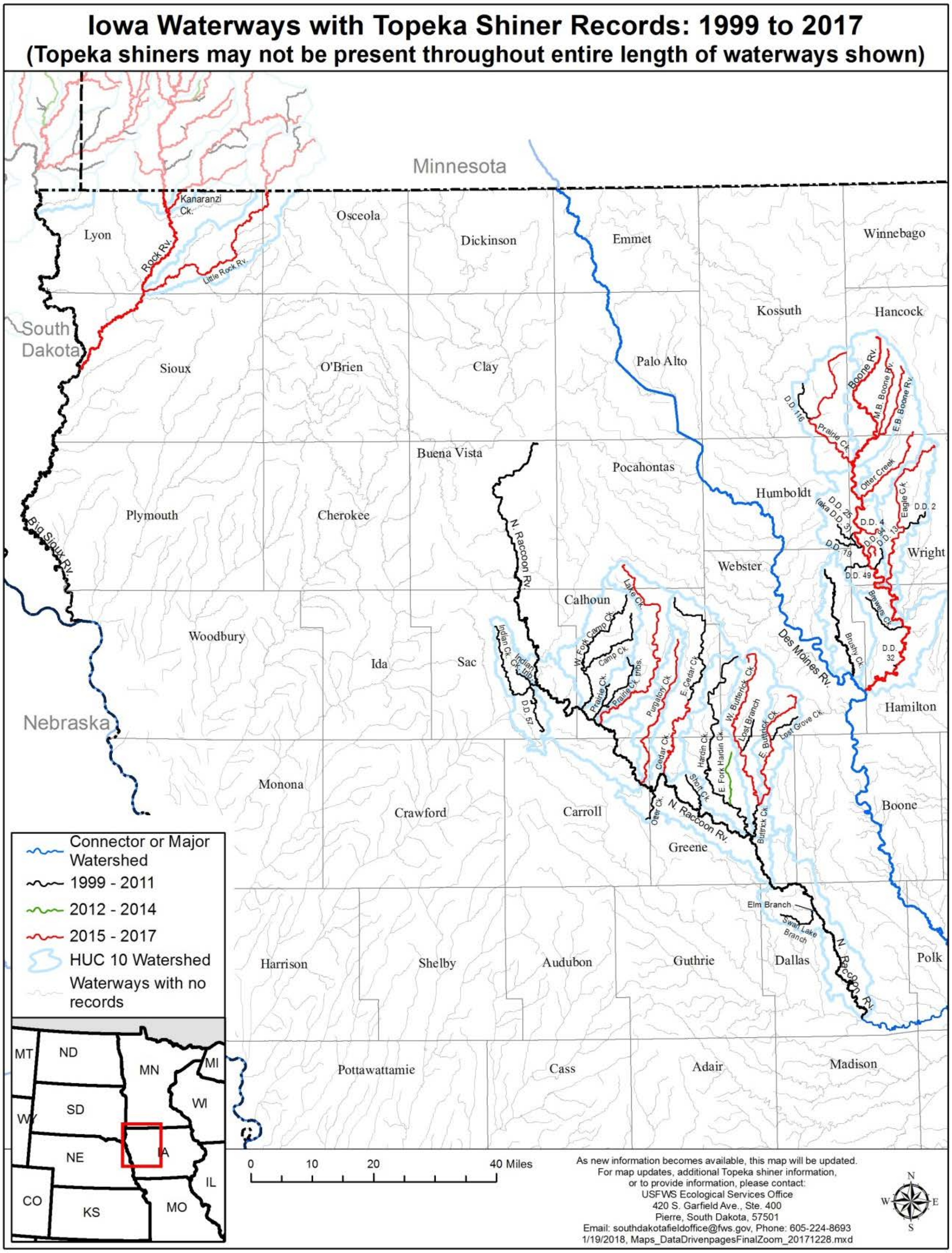


Figure 17. Iowa streams with Topeka shiner records, 1999-2017.

Iowa Topeka shiner extant streams identified by the Iowa Department of Natural Resources, the Service, and others include:

- 22 streams within the North Raccoon River watershed, including the North Raccoon River main stem
- 16 streams within the Boone River watershed, including the Boone River main stem
- 1 stream within the Des Moines River watershed
- 3 streams within the Rock River watershed, including the Rock River main stem (all shared with Minnesota)

These streams combine into three population complexes: the Rock River population complex (shared with Minnesota), the Des Moines/Boone River population complex, and the North Raccoon River population complex (Figure 15 above). The Rock River watershed drains to the Missouri River, but the North Raccoon and the Des Moines/Boone River population complexes drain into the Mississippi River system.

At the time of the 2014 workshop, the results of research project surveys (Clark 2000, Bakevich 2012, 2015) indicated Topeka shiners have declined by 73% in central Iowa since listing. The Rock River watershed was not resurveyed by Bakevich (2012), but the species was located there in 2016. Surveys in 2016 confirmed current occupancy in 8 streams previously known to be occupied, and in 2017, seven were reconfirmed and four new streams were identified, but not all of Iowa's known Topeka shiner streams were sampled either year.

b) Reasons for decline

Agricultural activities are a significant factor affecting Topeka shiners and their habitats in Iowa. The Iowa Department of Natural Resources specifically identified ongoing loss of riparian habitat as a current issue affecting the species. Tile drainage, and channelization/incision are common throughout Iowa's Topeka shiner occupied watersheds, as are confined animal feeding operations (CAFOs) which cause fish kills in the state (202 documented between 1995-2011; Bakevich 2012). Predator stocking and irrigation occur in Iowa as well, but these factors are likely less impactful to Topeka shiner streams than agricultural land use. Overall, main channels of occupied Iowa streams today appear less suitable for the species than their associated off-channel habitats; Bakevich (2012) documented Topeka shiner presence in only 9% of stream sites sampled, but found them in 52% of off-channel sites surveyed.

c) Conservation Actions

Iowa's primary conservation action regarding the Topeka Shiner is oxbow restoration in streams within two HUC-8 watersheds within the middle Des Moines River basin: the North Raccoon River watershed (HUC 07100006) and the Boone River watershed (HUC 07100005). These watersheds are in the most recently glaciated portion of Iowa (Des Moines Lobe ecoregion) and have the only known Topeka Shiner populations in west-central Iowa (Bakevich *et al*. 2015). Iowa's only other known populations of Topeka Shiner occur in the Rock River basin in extreme northwest Iowa. Although no restored oxbows yet exist in the Iowa portion of the Rock River basin, several naturally-occurring oxbows exist, and potential oxbow restoration sites have been identified. Several oxbow restorations/reconstructions are present in the Minnesota portion of the Rock River basin (Bybel *et al*. 2016).

The Service and partners (*e.g*., The Nature Conservancy (TNC), Iowa Soybean Association, and USDA Natural Resources Conservation Service) have been restoring off-channel habitats (oxbows) in Iowa since 2000 by excavating sediments to reach the groundwater lens, thus providing refugia for Topeka shiners (Kenney 2013, 2014; Johnson 2009,). Since many of Iowa's in-stream habitats are significantly degraded with few or no naturally-occurring off-channel habitats, this effort has been highly successful in affording the species habitats in which to reproduce and overwinter. Topeka shiners may be more abundant in these off-channel sites than in their associated main stems, although the potential exists for off-channel restorations to entrap the species if the areas lack adequate depth, groundwater input, or occasional reconnections to the stream. Through 2017, 77 off-channel sites have been restored along streams in the watersheds of the North Raccoon and Boone rivers in north-central Iowa (Aleshia Kenney, USFWS, and Susanne Hickey, The Nature Conservancy, personal communications, 2017). Future plans include additional off-channel restorations in these watersheds (Clay Pierce, Iowa State University, personal communication, 2017). Given the lack of good-quality off-channel habitats in these areas, and the prevalence of Topeka shiner occurrence in restored off-channel habitats, such restorations may be key for persistence of this species in Iowa.

Recent surveys in the Boone River basin have found Topeka shiners in both oxbow and in-stream habitats (Simpson *et al.* 2016). Results of these surveys suggest that two of the basin's seven HUC-10 watersheds harbor streams in which Topeka Shiner populations are showing signs of recovery and that streams in three HUC-10 watersheds have populations that are potentially stable or stable. Despite the present of several restored oxbows, Topeka Shiner populations in the remaining two HUC-10 watersheds in the Boone basin are at risk of extirpation or are possibly extirpated.

Oxbow restorations are also playing a role in reducing nutrients with research indicating from 37 to 45% reductions in nitrate in tile water or other water flowing into reconstructed oxbows in the Boone River basin (Schilling *et al*. 2017). Interest in multiple ecosystem benefits of oxbow restoration, in particular the water quality benefits, has the potential to bring additional financial resources for oxbow restorations.

2. Kansas

a) Occupancy/Status/Trends

The Topeka shiner extant streams in Kansas known to be occupied 1999-2017 include 42 streams in three major drainages (Figure 18, Appendices B and C).

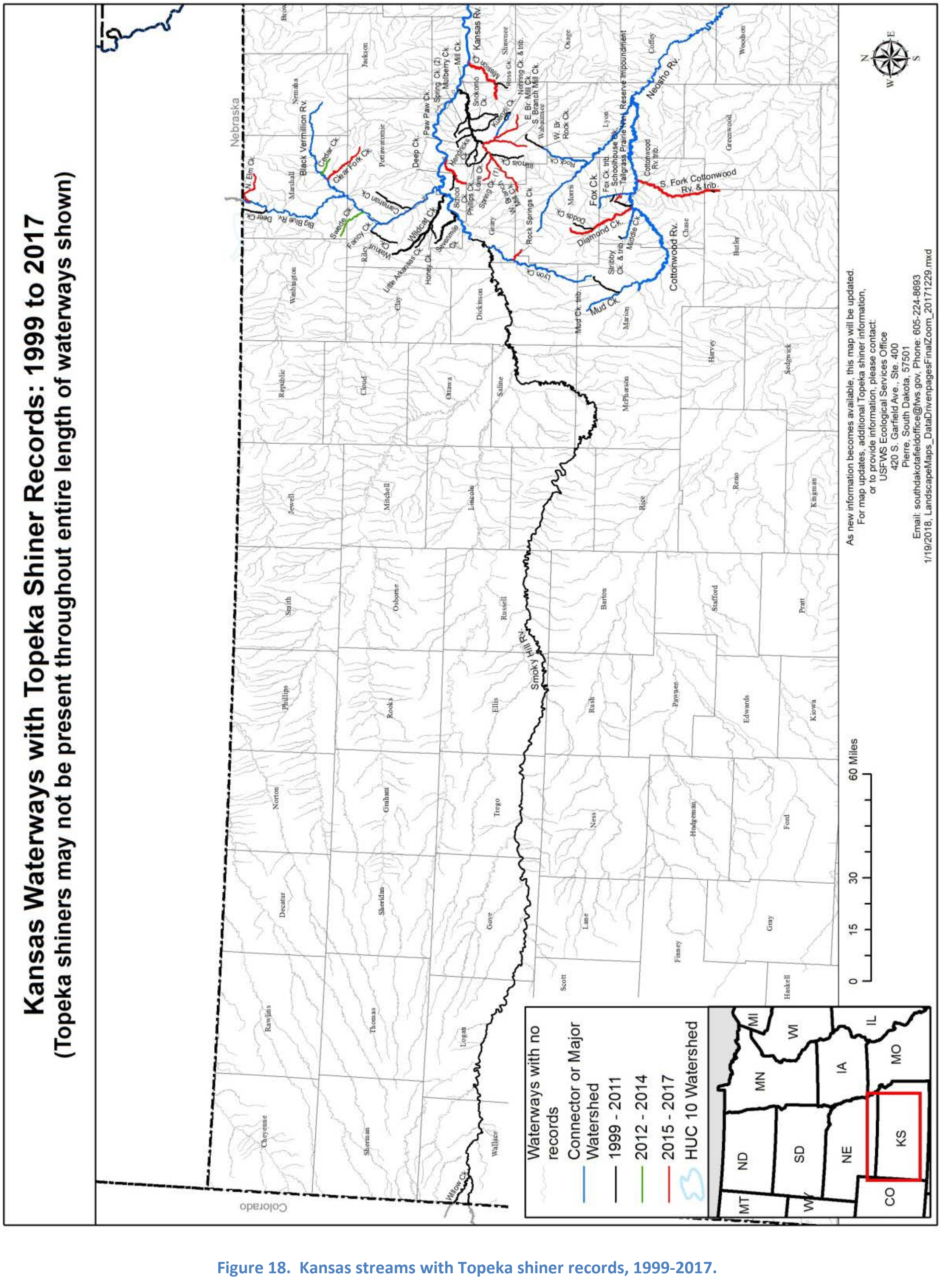


Figure 18. Kansas streams with Topeka shiner records, 1999-2017.

Kansas Topeka shiner extant streams identified by the Kansas Department of Wildlife, Parks and Tourism; the Service; and others include:

- 10 streams within the Cottonwood River and Neosho watersheds (not including the Cottonwood River main stem)
- 31 streams within the Kansas River watershed (not including the Kansas River main stem)
- 1 stream within the Smoky Hill River watershed (not including the Smoky Hill River main stem)

These streams compose three population complexes: the Kansas River population complex, the Cottonwood River population complex, and a remnant of the Smoky Hill River population complex (Figure 15 above). We recognize herein that the Smoky Hill River stream, Willow Creek, may no longer be occupied due to documented stocking of predatory sportfish and associated observed reduction in native fishes in the Creek (Campbell *et al.* 2016). As noted earlier, criteria to establish extirpations of Topeka shiner populations is needed. Live specimens of Willow Creek collected in 2002 were placed at the University of Kansas Field Station for captive rearing and conservation of their genetic material. Their progeny may be used for future replenishment of the Willow Creek population. The Cottonwood River complex is the only area in the Topeka shiner's range that drains into the Arkansas River watershed.

Those remaining occupied streams lie generally in the region of Kansas known as the Flint Hills, which are rocky and relatively unsuitable for grassland conversion to cultivated crops. Watersheds that still harbor Topeka shiner occupied streams display two apparent characteristics: lack of agriculture and intact groundwater. While Kansas noted Topeka shiner declines in the state, specific trend data could be improved, as surveys are typically random in nature, and resurvey data is not consistent, although the proportion of occupied sites in the Mill Creek watershed was observed to be relatively constant over several years (Gerkin and Paukert 2013). The Kansas Department of Wildlife, Parks and Tourism indicate local extirpations are occurring based on lack of Topeka shiner records during efforts to capture the species, combined with known landscape and instream impacts (*e.g.* construction of dams) (See Appendix A, pages 10-11 of workshop meeting notes).

b) Reasons for Decline

At the 2014 workshop, Kansas staff indicated drought has been a factor in Topeka shiner declines in the state; the loss of hydrologic connections equates to direct effects to the species. Impoundments with stocking of predatory fish and road/bridge construction projects are considered problematic by the Kansas Department of Wildlife, Parks and Tourism. Agriculture in the riparian zone of occupied streams, land conversion, water withdrawals, and poor land practices were also noted to be factors problematic for the species.

c) Conservation Actions

While Kansas has a Topeka shiner Recovery Plan (Mammoliti 2004), much land (98%) (Appendix A, pages 10-11 of workshop meeting notes) exists in private ownership in the state, and water laws prioritize agricultural use and flood control, thus management for Topeka shiners is difficult and activities known to impact populations (*e.g.* dams) continue.

In Kansas, approximately 98% of the land is under private ownership with approximately 90% of those lands are currently used for agricultural purposes. Working to conserve and enhance these lands is critical for habitat improvements for the Topeka Shiner. Funding for private lands habitat management has been limited for the Topeka Shiner; therefore it is critical to improve the delivery and effectiveness of technical and financial assistance on private lands and to successfully deliver habitat management practices to private landowners. Efforts are underway in Kansas to increase financial and technical assistance to private landowners that will benefit wildlife species such as the Topeka Shiner. In 2017, these efforts focused on changes to the Environmental Quality Incentive Program (Wildlife category) by providing higher ranking scores for management activities implemented areas within the Aquatic Focus Areas as identified in the State Wildlife Action Plan; for priority management practices that benefit aquatic systems as well as additional points; and for management practices that benefit threatened or endangered species. This effort also included additional management practices that will not only benefit the landowner’s needs but also address habitat needs for the Topeka Shiner. The practices include stream habitat improvement and management, aquatic organism Passage, obstruction removal, stream crossing, access control, fencing, watering facility, livestock pipeline, range planting, forest stand improvements, riparian herbaceous cover, riparian forest buffer, wetland restoration, wetland wildlife habitat management, prescribed grazing, prescribed burning, wetland and upland wildlife habitat management, critical area planting, brush management and tree removal, and forest stand improvement.

3. Minnesota

a) Occupancy/Status/Trends

Two Topeka shiner collection records in the Des Moines (in 1947) and Cedar River (in 1890) watersheds have not been reconfirmed in Minnesota (Hatch 2001), but the Big Sioux and Rock River watersheds continue to harbor the Topeka shiner and additional occupied streams have been identified since the species was listed. Minnesota shares some of its Topeka shiner occupied streams with two other states: Iowa and South Dakota. Including 2017 survey data, the state’s occupied stream tally is 66 (Figure 19, Appendices B and C).

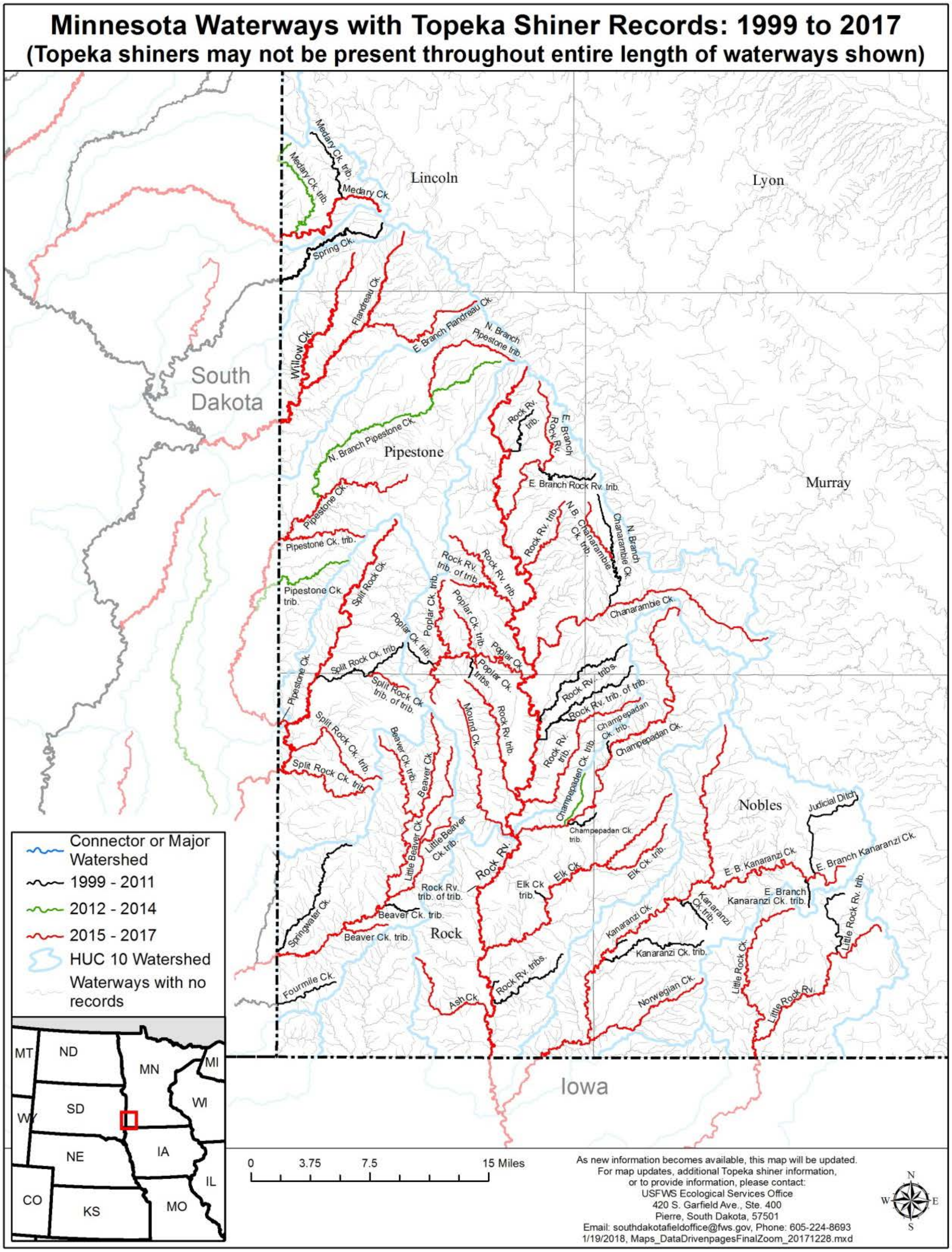


Figure 19. Minnesota streams with Topeka shiner records, 1999-2017.

Minnesota Topeka shiner extant streams identified by the Minnesota Department of Natural Resources, the Service, and others include:

- 24 streams within the Big Sioux River watershed (10 of those shared with South Dakota, 14 occurring entirely within MN)
- 42 streams within the Rock River watershed, including the Rock River main stem (the Rock River main stem and two Rock River tributaries are shared with Iowa)

These streams combine into two population complexes: the Big Sioux River population complex (shared with South Dakota) and the Rock River population complex (shared with Iowa), which is connected to the Big Sioux River yet is identified herein as its own population complex (Figure 15 above). Distance and physical barriers are presumed to preclude interactions between these complexes today. Both of these large watersheds are part of the greater Missouri River watershed.

All of Minnesota's occupied streams that cross the borders with South Dakota and Iowa originate in Minnesota and eventually flow into the Big Sioux River, which flows into the Missouri River.

In Minnesota, off-channel habitats are used by Topeka shiners and the species is successful there as long as sediment is not too deep, sunfish are present, groundwater input exists, and predators are absent or in low abundance. This habitat type is considered important for the species' persistence in the state (Hatch 2001).

Since 2004, the Minnesota Department of Natural Resources has conducted standardized, nearly annual (exception: 2011), presence/absence monitoring in 20 randomly-selected 1-mile stream segments formally designated as Critical Habitat. All of these are in the Rock River watershed. A declining trend in percentage of sites with Topeka shiner was detected by the time the Workshop of 2014 was held (Figure 20).

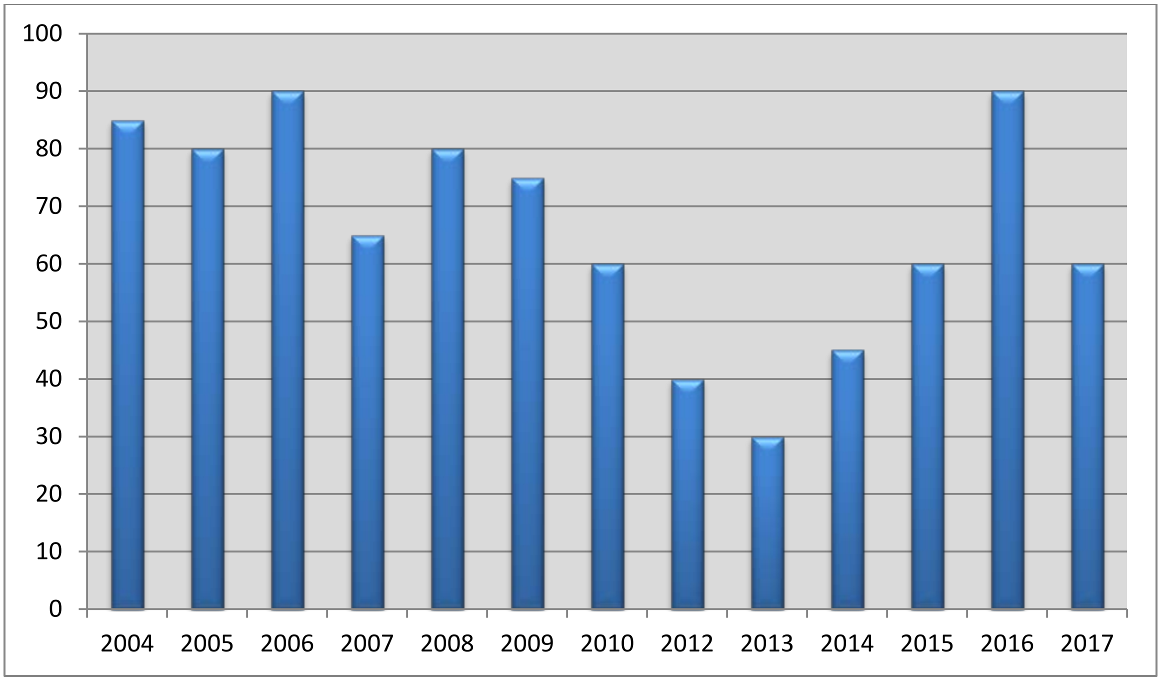


Figure 20. Percentage of randomly selected stream segments with Topeka shiners per Minnesota's standardized surveys conducted 2004-2017 (exception: 2011) (Cunningham 2017).

Topeka shiners were present in an average of 76% of sites surveyed 2004-2010, but that began to drop in 2009, reaching a low of 30% in 2013 (Nagle and Larson 2014). Since 2013, however, Topeka shiner collections in Minnesota have improved. Surveys in 2014 revealed an uptick in detections as Topeka shiners were located at 45% of sites surveyed (Nagle and Larson 2014), and 2015 surveys also indicated a rise as 65% of surveyed locations harbored the species (Cunningham 2015). In 2016 four new unnamed streams were found to be occupied in Minnesota (Richard Baker, MNDNR personal communication 2017), and occupancy was confirmed in another 20 other streams, including four shared with South Dakota (Rich Baker, MNDNR personal communication, 2017; Chelsey Pasbrig SDGFP, personal communication, 2016). During Minnesota's 2016 survey, 90% of the randomly selected stream segments contained Topeka shiners (Cunningham 2016). Finally, in 2017, Topeka shiners were detected at 12 of the 20 sites sampled (60%) (Cunningham 2017).

Protocol included qualitative assessment of abundance in early years of sampling, but by 2010, surveyors established categories to define whether the Topeka shiner was "common", "abundant" or merely "present. These are defined in Minnesota Department of Natural Resources Topeka shiner monitoring reports as follows:

- Common: Topeka shiner individuals appeared in low numbers relative to other species, or 5-10 individuals were captured in the initial seine haul
- Abundant: Topeka shiner was the most numerous species present, or >10 individuals

were collected in the initial seine haul at capture site

- Present: <5 individuals captures after substantial sampling effort

As the number of sites where Topeka shiners were detected declined, so generally did the number of sites in Minnesota where Topeka shiners were considered common or abundant (Figure 21).

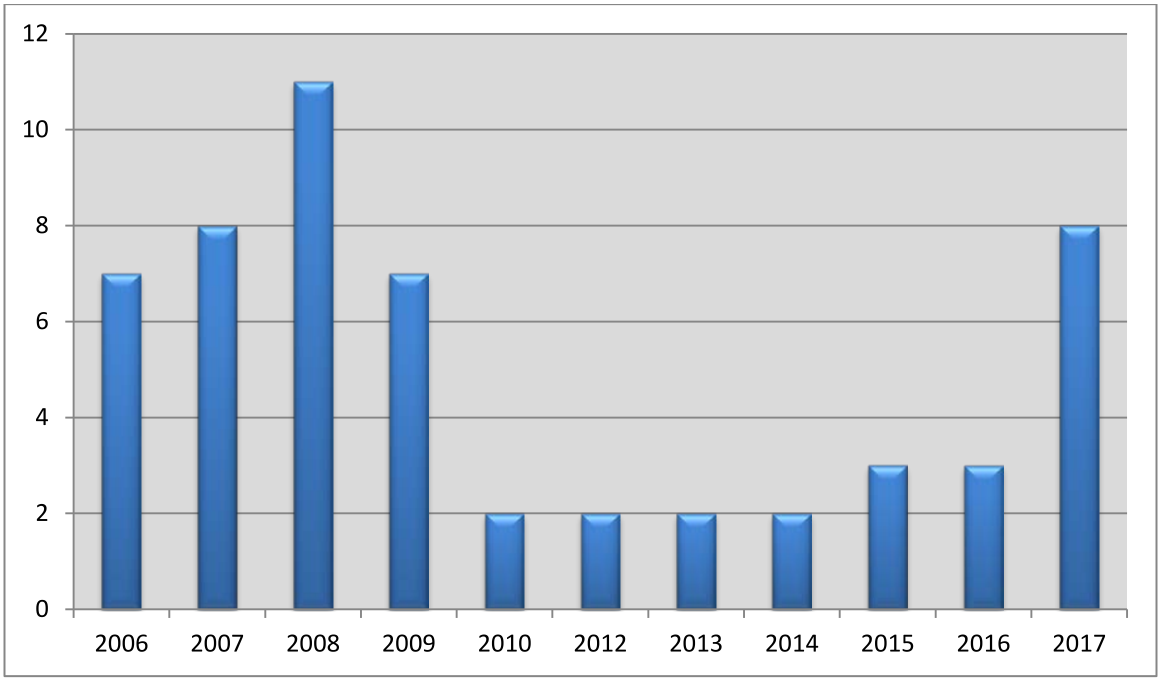


Figure 21. Number of sites surveyed where Topeka shiners were considered "Abundant" or "Common" as defined in Minnesota Department of Natural Resources Topeka shiner monitoring reports per standardized surveys conducted 2004-2017 (exception: 2011) (Cunningham 2017).

Generally speaking, during the 2009-2013 decline referenced above, Minnesota surveys documented less prevalence and abundance of Topeka shiners over time, and more effort was required to capture the species (see Appendix A, pages 8-9 of workshop notes). Populations were not known to have been extirpated in the Rock River watershed, but a trend of general contraction from headwater areas was noted. The prevalence of Topeka shiners subsequently increased annually 2014-2016 with another drop detected in 2017, while the abundance observations remained low 2010-2016, but rose in 2017 (note that standardized collection methodology has not been used to determine abundance based on a standard unit of effort (Cunningham 2016)). Exact causes of these fluctuating detection and relative abundance rates over time in Minnesota are currently unexplained.

b) Reasons for decline

Minnesota Topeka shiner stream hydrology is affected by numerous factors. Minnesota Department of Natural Resources submits that runoff rates are increasing, aquifer use is intensifying, upland conversion to agriculture is ongoing, ditching/tiling/irrigation are all increasing, impervious surfaces are more prevalent, erosion and sedimentation have increased, and summer base flows in have lowered while winter base flows have risen. While it is not known for certain how temperature increases due to climate change will affect the Topeka shiner in Minnesota, increased intensity and fluctuations in precipitation are expected to exacerbate erosion, sedimentation, and channel incision, and increase extirpations within off-channel habitats (see Appendix A, pages 8-9 of workshop notes). The specific changes in conditions responsible for the documented decline of Topeka shiner during 2009-2013 annual surveys, and the subsequent rise in detections are not known.

c) Conservation Actions

No specific conservation actions for the Topeka shiner were identified by Minnesota at the 2014 Workshop. However, the Service began restoring off-channel habitats (*e.g.* oxbows) in Minnesota in 2015 by removing the sediment layer at strategically placed depressions in the floodplain, restoring groundwater input, and providing refugia for Topeka shiners. Similar to the experience in Iowa, restoring off-channel habitat has been very successful in Minnesota. More than 60 off-channel sites have been restored with three dams removed, reconnecting more than 30 miles of upstream habitat. Of these restorations, more than 65% are already inhabited by large numbers of spawning Topeka shiners (Nick Utrup, USFWS, personal communication, 2017). Because of this success, the Service will be doubling the number of off-channel restorations in Minnesota over the next couple years.

In 2015, the Minnesota legislature passed and the Governor signed a Buffer Law (see https://mn.gov/portal/natural-resources/buffer-law/ and http://bwsr.state.mn.us/buffers/) that requires perennial vegetation buffers with an average width of 50 feet and a minimum width of 30 feet along rivers and streams, and a buffer of 16.5 feet along ditches. Topeka shiners will benefit from this new law, since more seasonally flooded stream habitat will be vegetated and protected. The 2nd edition of the Minnesota Prairie Conservation Plan (see http://www.dnr.state.mn.us/prairieplan/index.html) has recently been completed, and places emphasis on the protection of riparian areas along streams. Also of note is a recent decision by the Minnesota Department of Natural Resources to create almost a mile of Topeka shiner habitat by restoring a reach of Mound Creek within Blue Mounds State Park.

4. Missouri

a) Occupancy/Status/Trends

Topeka shiners in Missouri experienced a fast decline within the 25 years prior to listing, and the species was lost from one occupied watershed (Bonne Femme) in the state in the 1990's. As of 2017, 11 streams have harbored the Topeka shiner since 1999 (Figure 22, Appendices B and

C). Few streams remain extant in Missouri, thus annual monitoring is possible in all known occupied areas.

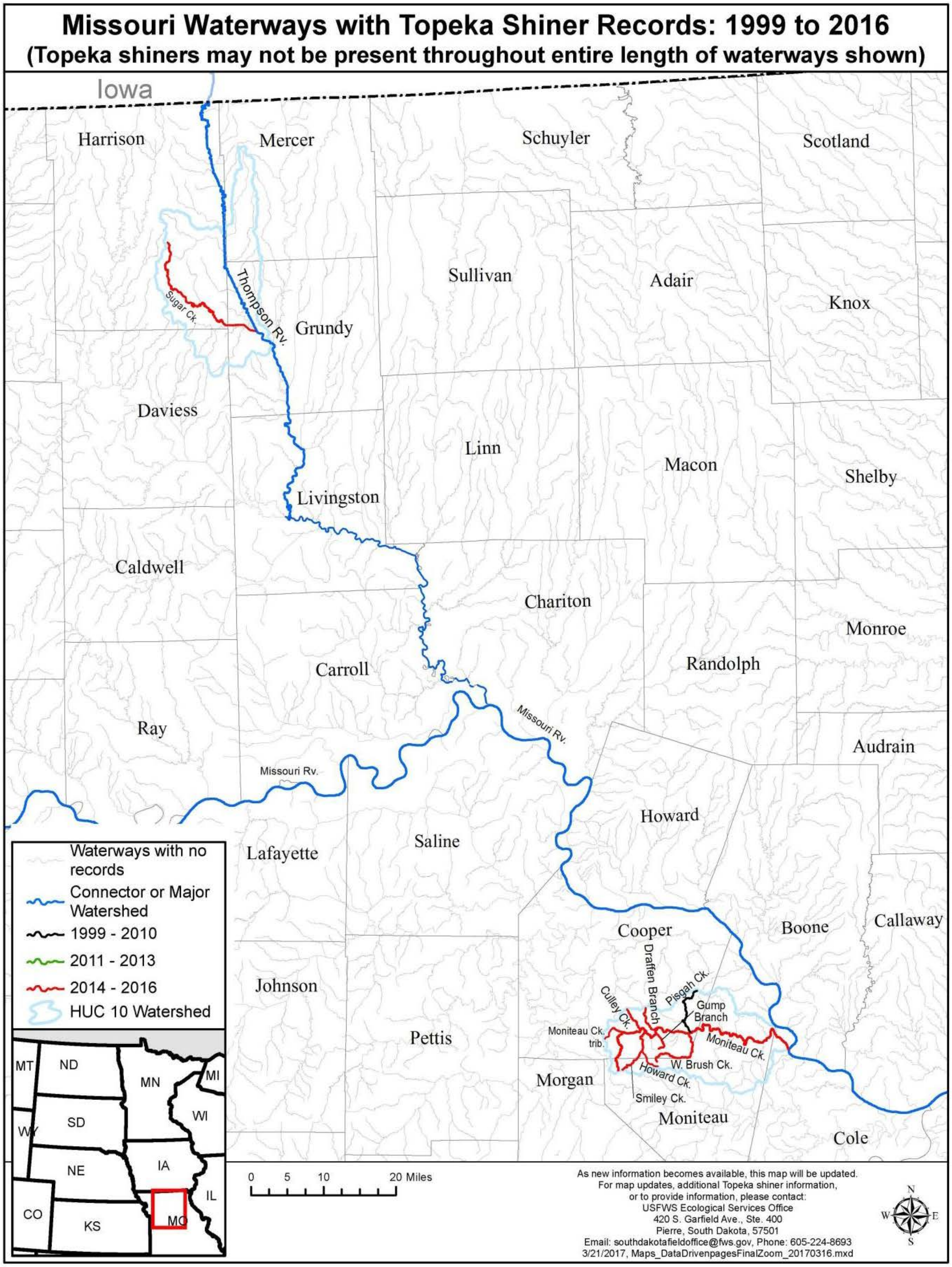


Figure 22. Missouri streams with Topeka shiner records, 1999-2017.

Missouri's Topeka shiner extant streams identified by the Missouri Department of Conservation include:

- 2 streams within the Thompson River watershed (not including the Thompson River main stem)
- 9 streams within the Moniteau Creek watershed (including the Moniteau Creek main stem)

These occupied streams represent two population complexes: a remnant of the Thompson River population complex and the Moniteau Creek population complex (Figure 15 above), both of which are part of the larger Missouri River watershed.

Sugar Creek in the Thompson River watershed is considered by the MDC to be susceptible to extirpation due to the relatively low numbers of individuals typically captured during sampling efforts and few sites with collection records (see Appendix A, pages 3-4 of workshop notes). The agency has completed annual monitoring of occupied Topeka shiner streams since 1999. Of 180 seining events in Sugar Creek during 1999-2013 (12 standardized sites surveyed annually for 15 years), only 13 resulted in capture of 10 or more individuals at a time, the number of sites with Topeka shiners present has not exceeded the number of sites without Topeka shiners since 2000, and in two years (2008 and 2009) no Topeka shiners were located at any of the 12 monitored locations in Sugar Creek (the species was found again in low numbers 2010-2013) (Missouri Dept. of Conservation, unpublished data). Tombstone Creek was identified as occupied in 2017. Comparatively, the Moniteau Creek watershed appears to have a more stable population of Topeka shiners, with relatively consistent Topeka shiner collections annually within its occupied habitats, and typically higher numbers of individuals are collected during surveys.

b) Reasons for Decline

Missouri streams have been impacted by agriculture and other anthropogenic activities (dams, culverts, etc.) that occur in all states in the Topeka shiner's range, but while the MDC submits that occupied streams may have more rock than others that may have prevented incision, overall it is not clear what factors have allowed the species to persist in currently extant areas and not others.

c) Conservation Actions

Guided by two successive 10-year management plans (MDC 1999, 2010), MDC staff conducts annual surveys, implements habitat improvements, and conducts research on the Topeka shiner. Some conservation measures have also been implemented on private lands in Topeka shiner watersheds, such as establishment of riparian buffers, cattle exclusion, grade control, streambank stabilization, and removal of fish passage barriers.

MDC personnel have also successfully reared the species and recently initiated the first Topeka shiner reintroductions within the state. Topeka shiners collected from the extant population in north Missouri (Sugar Creek, Harrison County) were used as brood stock to produce fish for reintroductions in selected (north Missouri) watersheds where habitat and land management are believed best suited for the species. In 2013, within the Grand River watershed in Harrison County, Topeka shiners were stocked into Little Creek and five isolated nursery ponds (three in the Little Creek watershed and two in nearby East Fork Big Muddy Creek Watershed). In 2014, Topeka shiners were reintroduced into a third watershed (Spring Creek) in the Chariton River basin in Adair and Sullivan counties. All three watersheds where reintroductions occurred are recognized as Non-essential Experimental Populations (NEPs) under section 10j of the ESA.

Follow-up surveys in 2014 showed initial success of the reintroduction efforts; pond and stream survey results indicated Topeka shiners had survived, grown, and were in good condition at all release sites (Wiechman 2014). Reintroductions continued in 2014 as Topeka shiners were stocked into East Fork Big Muddy Creek itself, additional shiners were added to Little Creek to supplement the 2013 reintroduction, plus a third nursery pond was established in East Fork Big Muddy Creek watershed.

In 2015, monitoring surveys showed survival, reproduction, and expanded distrubtion within each of the three NEP watersheds. Surveys within the Spring Creek watershed documented movement of Topeka shiners about a mile upstream of stocking locations in Savannah Branch (Thornhill 2015). Surveys in Little Creek and East Fork Big Muddy Creek watersheds found Topeka shiners in pools on conservation lands (release sites under prairie management) and in pools on adjacent private pasturelands (Wiechman 2015).

Surveys in 2016 were limited to the Little Creek and Spring Creek NEPs. In Little Creek the species appeared to be increasing in abundance; 321 individuals were collected from 10 sites within 22 pools in that watershed. Prolonged dry conditions in Spring Creek during 2016 limited survey efforts to only a few sites where about 40 Topeka shiners (mostly juveniles) were identified.

Results of monitoring in the NEP watersheds are clearly positive, although it is not yet known whether reintroductions into the creeks will result in stable and self-sustaining populations; for that reason these streams are currently not included in Missouri’s tally or map of extant Topeka shiner streams.

5. Nebraska

a) Occupancy/Status/Trends

In Nebraska only three streams (existing within two widely separated HUC10s) were identified as potentially still harboring the species (Figure 23, Appendices B and C).

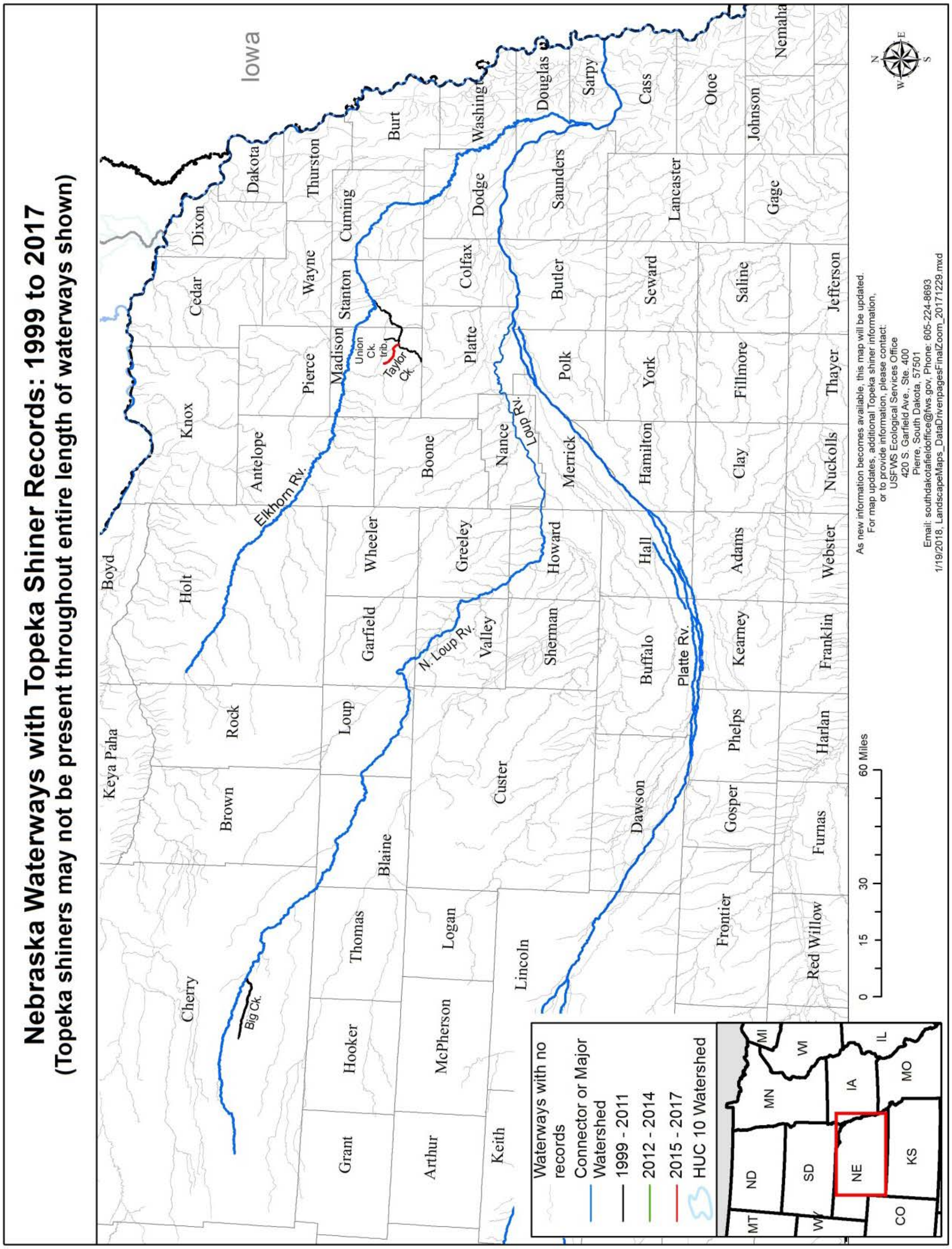


Figure 23. Nebraska streams with Topeka shiner records, 1999-2017.

Nebraska’s Topeka shiner extant streams identified by the Nebraska Game and Parks Commission and others include:

- 2 streams within the Elkhorn River watershed
- 1 stream within the North Loup River watershed

These creeks likely represent remnants of two population complexes that harbored more populations in the past. They are identified herein as the Elkhorn River population complex and the North Loup River population complex (Figure 15 above), each containing a single occupied stream. Both of these are tributaries of the Platte River which drains into the Missouri River.

The Nebraska Game and Parks Commission indicated that one additional stream in the North Loup watershed, Brush Creek, may also occupied. This stream has not been surveyed for Topeka shiners since 1989. Brush Creek exists in the Sandhills Region of Nebraska where cultivated cropland is not prevalent, thus it is suspected (but cannot be verified) that the species remains extant there. The area is privately owned, and access to the site has been denied to surveyors. Big Creek, Taylor Creek, and Union Creek are located on privately owned land as well; however, these streams have had Topeka shiner collection records dated 1999 or later, with Topeka shiner documented in Taylor Creek as recently as 2016.

b) Reasons for Decline

As with all states within the Topeka shiner’s range, Nebraska land use is dominated by agriculture. Instream habitat conditions have become increasingly degraded with increased irrigation, establishment of dams, and stocking of predatory gamefish occurring recently in known occupied subpopulation watersheds. Depletion of groundwater via irrigation was identified as problematic in this state at the 2014 Workshop, but continues unregulated, along with intensification of agricultural land use.

c) Conservation Actions

There are currently no specific conservation actions currently being implemented in Nebraska for the Topeka shiner. However, the Topeka shiner is listed as Endangered under the Nebraska Nongame and Endangered Species Conservation Act, administered by the Nebraska Game and Parks Commission (NGPC). Any action that is conducted, funded, or authorized by a state agency is reviewed by NGPC to ensure that it does not jeopardize the Topeka shiner, thus affording protections for the species.

6. South Dakota

a) Occupancy/Status/Trends

The Topeka shiner occurs in nearly all previously known occupied streams in South Dakota, but pre-listing records of the species are lacking in the state. The known distribution of Topeka shiners in South Dakota changed post-listing due to increased sampling effort that lead to discovery of 61 more occupied streams than were known prelisting. The current (1999-2017) tally of occupied streams in South Dakota is 72 (Figure 24, Appendices B and C).

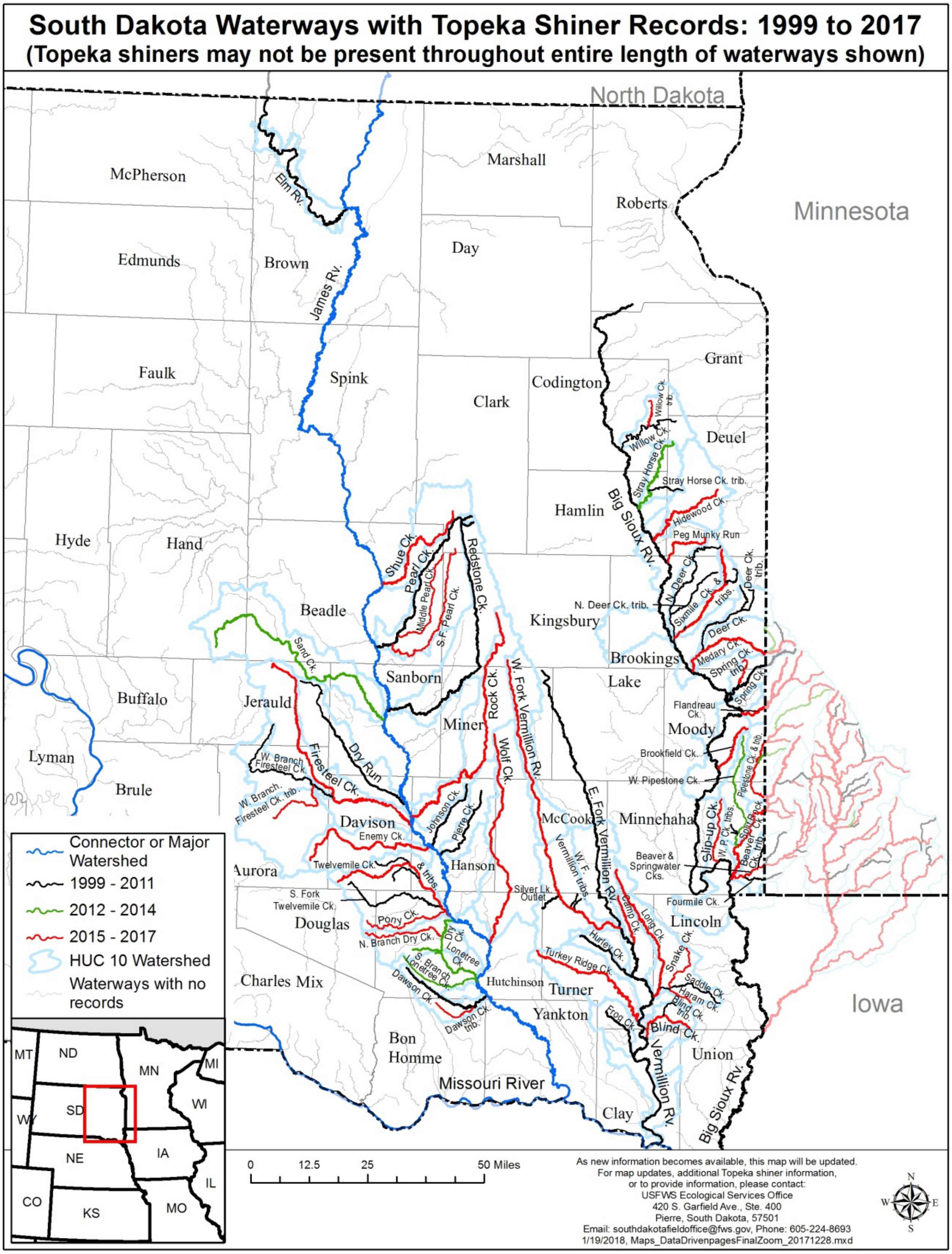


Figure 24. South Dakota streams with Topeka shiner records, 1999-2017.

South Dakota's Topeka shiner extant streams identified by the South Dakota Department of Game, Fish and Parks; the Service; and other include:

- 27 streams within the James River watershed, not including the James River main stem
- 15 streams within the Vermillion River watershed, including the Vermillion River main stem
- 30 streams within the Big Sioux River watershed (10 shared with Minnesota) , including the Big Sioux River main stem (note that although Topeka shiner records exist from the Big Sioux River main stem, the river generally lacks suitable habitat for the Topeka shiner to complete its life cycle)

These streams combine into three population complexes: the Big Sioux River population complex (shared with Minnesota), the Vermillion River population complex, and the James River population complex (Figure 15 above) which are all part of the larger Missouri River watershed.

At the 2014 workshop, South Dakota indicated there are gaps in Topeka shiner location information. Sixty –six occupied streams in South Dakota were reported by South Dakota Game, Fish and Parks at that time, and 28 of those streams were defined as Topeka shiner occupied streams as a result of only a single collection location in a single year. Twenty-five of these single-locale stream records were dated 2006 or earlier, and eight were dated 1999 or earlier. South Dakota Game, Fish and Parks personnel followed a standard monitoring protocol at three sites within each of 11 streams (total 33 sites), performing two rounds of sampling (total 66 collection efforts) since 2004 (Wall and Thomson 2007, Pasbrig and Lucchesi 2012). Topeka shiners were documented in all 11 streams during both of the formal rounds of sampling, although the number of sites yielding Topeka shiners was reduced by 18% in round two (Pasbrig and Lucchesi 2012). Non-standardized sampling efforts were conducted in 2015-2017. This random sampling confirmed continued presence of the species in 5 streams that had collection records 10 years or older, and identified three new occupied streams (Chelsey Pasbring, SD GFP, personal communication 2015, 2017). Continued occupancy over time can be indicative of some resilience to natural and anthropogenic activities. However, sampling all of South Dakota's Topeka shiner streams is a significant undertaking due to the high number of streams involved. Continued presence in the 11 streams monitored via standardized surveys (Wall and Thomson 2007, Pasbrig and Lucchesi 2012) does indicate persistence in those streams, but they represent only about 16% of South Dakota's 70 occupied streams. Since information on many streams is limited, definitive population trends at a state-wide level are currently lacking in South Dakota.

b) Reasons for Decline

Due to the lack of data described above, it is not clear whether South Dakota is experiencing any declines of their Topeka shiner populations. Surveys in many formerly known occupied streams continue to document the species; while some relatively old post-listing records (*e.g.* 1999) have not been recently confirmed. Minnesota's recent decline (see above) was some cause for concern for South Dakota populations as the two states share 10 streams, and many occupied streams/rivers in both states are subject to the same stressors (primarily agricultural). Agricultural tiling was recognized as having significantly increased in recent years in South Dakota, and numerous factors (grassland conversion, dams, wetland losses, etc.) likely cumulatively influence the species in the state, but no other specific factor(s) were identified at the 2014 workshop, or since the workshop, as causes of any Topeka shiner declines in South Dakota.

c) Conservation Actions

South Dakota Game, Fish and Parks completed the *Topeka shiner (Notropis topeka) Management Plan for the State of South Dakota* in 2003 (Shearer 2003) with a focus on factors that affect Topeka shiner habitat integrity: hydrology, geomorphology, and water quality. Although many tasks have yet to be implemented in the plan, SDDGFP did initiate two rounds of standardized monitoring. However, monitoring was not at the level recommended in the plan due to staff and funding limitations.

Other conservation actions completed in the state include funding to establish genetic markers for the species (Anderson and Sarver 2008) and studying the impact of fish passage ladders on movement of small fishes in prairie streams (Lorenzen 2016). Additionally, South Dakota secured federal funds/technical assistance to conduct additional Topeka shiner surveys in the state and modify several road crossing structures to improve Topeka shiner passage (Cunningham 2000, Wall and Berry 2002). Passage for Topeka shiners at road crossings is also a focus of a formal programmatic consultation under the ESA with the Federal Highway Administration, implemented by the South Dakota Department of Transportation (http://www.sddot.com/business/environmental/endangered/docs/FishandWildlifeServicePeteGober0808.pdf). The state recently initiated a Buffer Strip Incentive Program offering tax relief for lands with riparian buffers (http://dor.sd.gov/bufferstrips.aspx), and a Seasonal Riparian Area Management program to promote habitat improvements in the Big Sioux River watershed (http://denr.sd.gov/dfta/wp/NWQIskunkcreek.aspx).

The Topeka shiner is monitored by the South Dakota Natural Heritage Program. Location information for this species is entered into the Natural Heritage Database, which is an important environmental review tool for SDGFP. This species is also listed as a species of greatest conservation need in South Dakota's Wildlife Action Plan, thus State Wildlife Grant funding can be used for Topeka shiner conservation actions.

III. Current Large-Scale Vulnerability

Topeka shiner population complexes are generally isolated from each other by distances, barriers, and/or unsuitable habitats (Figure 15 above), but they are also relatively widespread. While their isolation makes them more vulnerable to permanent extirpation (without connectivity they lack the ability to recolonize), the large distances between occupied areas also serves to reduce the risk of catastrophic impacts to the species as a whole (*i.e.* the likelihood of catastrophic events affecting all populations in all six occupied states is relatively low). Yet if populations continue to be lost, or if entire population complexes are extirpated, the species' overall vulnerability to catastrophic events increases. In unaltered prairie streams, local extirpations were likely common due to the naturally harsh conditions characteristic of headwater areas, which still occur today. However in the past, recolonization was often possible due to available refugia, lack of barriers, and the existence of numerous subpopulations and populations that acted as sources for repopulating streams, thus sustaining the species on the landscape – which is not necessarily true now. With current degradation of hydrologic conditions, predominantly due ongoing anthropogenic factors, the negative effects of natural stochastic events are exacerbated. The species' association with headwaters further limits the likelihood of recolonization as individuals tend not to purposefully migrate into adjacent streams, and headwater connections via flooding may also be precluded in many cases due to anthropogenic structures (*e.g.* elevated roads). In some cases, extirpations may also be directly human-caused (*e.g.* construction of a dam, stream channelization, introduction of predatory species), rendering habitat unsuitable or inaccessible to Topeka shiners. Extirpations thereby become permanent.

Continued population and population complex losses will continue to decrease the ability of the species to adapt and evolve lowering its ability for self-sustaining populations in the wild into the future.

IV. Threats Leading to Current Condition

Prairie streams of the Great Plains are considered "highly endangered" systems (Dodds *et al.* 2004). Many cool, clear, clean-bottomed streams flowing sinuously through upland prairies and receiving groundwater input, have become been channelized, fragmented, dried, polluted, and filled with sediments, and these are increasingly vulnerable to further degradation (Cross 1967, Dodds *et al.* 2004, 63 FR 69008-69021). Numerous anthropogenic sources have affected the hydrology, morphology, and biological aspects of prairie streams. These sources have resulted in loss of suitable habitat, refugia, and connectivity that sustains Topeka shiner populations. Ultimately, populations have expired, recolonization has not occurred, and the range has contracted significantly.

The proposed rule to list the species was published in October 1997 (62 FR 55381-55388) and the final listing rule was published in December 1998, effective in January 1999 (63 FR 69008-69021). Within these rules were detailed descriptions of the factors known to impact the Topeka shiner; these factors still impact the species today. Topeka shiner populations suffer from habitat destruction, degradation, modification, and fragmentation, resulting from siltation, reduced water quality, stream impoundment, stream channelization, and stream dewatering, caused primarily by agricultural practices (63 FR 69008-69021). The final rule also notes that the species is impacted by introduced predaceous fishes (63 FR 69008-69021).

In 2009, a five-year review of the species provided updated information on Topeka shiner threats (USFWS 2009), which included the above factors, as well as climate change with details of its likely effects to prairie streams and Topeka shiners and a discussion of the potential impacts of agricultural tiling. The five-year review also identified "hydrologic changes" as a catch-all category for the agricultural-caused habitat modifications that have occurred to prairie streams, noting that maintaining natural hydrology in northern areas is critical to sustaining existing Topeka shiner populations, while altered hydrology has severely impacted the species in southern states.

An examination of the current range of the species reveals a discrepancy between northern and southern areas, indicating factors affecting the species are not acting equally on it throughout its range. The five-year review includes a table (Table 2 (USFWS 2009)) of known and potential factors affecting the species and the level of threat posed by those factors in each of the six states harboring Topeka shiners. With the exception of climate change, none of the 14 sources identified as threats to the species were characterized in South Dakota and Minnesota as having anything higher than a "moderate" overall threat level (*e.g.* requiring action to remedy, but the remedy need is not immediate nor essential to species survival). In contrast, row-crop agriculture/grassland conversion, urbanization, dams/stream hydrology, dredging/gravel mining, predation, population fragmentation/drought, and/or climate change were deemed to have overall threat levels of moderate to high (defined respectively as "action needed" and "immediate action needed") in at least two, and as many as all four of the other states in the Topeka shiner's range (USFWS 2009). As discussed above, the effects of recent glaciation in South Dakota, Minnesota and parts of Iowa (northeastern/north-central extant populations), may be mitigating the level of impacts ongoing threats have on the Topeka shiner in these areas. Generally greater prevalence of vegetated stream buffers in the two northern states has also been observed (Vernon Tabor, USFWS, personal communication, 2014), providing protections for instream habitat, but this has not been quantified as of this writing.

We developed conceptual cause and effect models using the factors found to impact the Topeka shiner through investigation of literature and conversations with experts prior to and during the 2014 workshop. At the workshop, the experts were asked which natural or anthropogenic factors were mostly likely to be the main drivers of population level and thus species level trends in their states. The experts were to take into account the severity of the effect of stressors, their geographical extent, ongoing nature, and likelihood of continuance, in light of the species trends observed in their state. This expert assessment provided us with the relative ranking of the major drivers of the species current condition. Although several factors were identified, and the ranking of the factors varied locally, the experts at the workshop determined that the most pervasive result of stressors to the Topeka shiner causing the species to decline may be lumped under one large umbrella, already identified in the five-year review: altered hydrology (see: Topeka shiner Species Status Assessment Workshop, Information Sharing, Final Meeting Notes, September 15-17, 2014).

A. Altered Hydrology

Hydrology includes the sources, volume, timing, availability, chemistry, temperature, and quality of the stream water. When natural hydrologic regime of base, peak flows, flood flows and other conditions of streams are altered, morphological and biological components are also altered (Novak *et al.* 2015). The hydrology of prairie streams today is far from its natural conditions to which the Topeka shiner has adapted (Hatch 2001).   One simple and obvious problem for the Topeka shiner is that it needs water, and many prairie streams, particularly in some southern portions of the species' range, no longer have enough of it to sustain aquatic life (Dodds *et al.* 2004, Falke *et al.* 2011). The current highly modified agricultural landscape both demands water and sends it through the system at significantly increased rate; a water cycle that once took 500 years to complete, may now take less than 30 (Keith Schilling, 2014 Workshop meeting notes, p. 18) as wetlands are drained, streams are channelized, fields are tiled, and aquifers are depleted (McGuire 2014).

As water availability and flow is impacted, other related factors come into play or are exacerbated by these altered flow regimes. Connectivity required to reach refugia and repopulate extirpated areas may be reduced or entirely precluded. Poor water quality resulting from agricultural/heavy grazing runoff or direct pollution within streams is exacerbated, and may kill Topeka shiners directly if physiological tolerance levels are exceeded or if indirect impacts occur that affect ecological requirements of the species. The availability of instream pools, gravel substrates, groundwater-fed refugia, and off-channel habitats needed for Topeka shiner reproduction and survival may be reduced or lost entirely.

When the habitats and conditions that Topeka shiners have adapted to and rely on exhibit these changes, and the magnitude, frequency, severity, and/or cumulative effects of these changes are great enough, a threshold is eventually reached beyond which individuals do not survive, extirpations occur, repopulation is not possible, populations are permanently lost, and the range of the species contracts. While measurable criteria that define the thresholds at which Topeka shiner population extirpations occur have not been established, they have clearly been surpassed in many areas of the Topeka shiner's range.

Figure 25 demonstrates the how altered hydrology (some of the causes, stressors, effects) impacts the Topeka shiner and its habitat. The stressors alter the physical environment of the Topeka shiner, which in turn incur biological changes. Ultimately the changes lead to impacts to Topeka shiner reproduction or survival which decreases population size and may lead to loss of entire populations. The sources, stressors, causes and effects that impact the Topeka shiner, described further below, are often multiple, intertwined, and sometimes complex; there could be additional categories of each that may be significant to Topeka shiner populations.

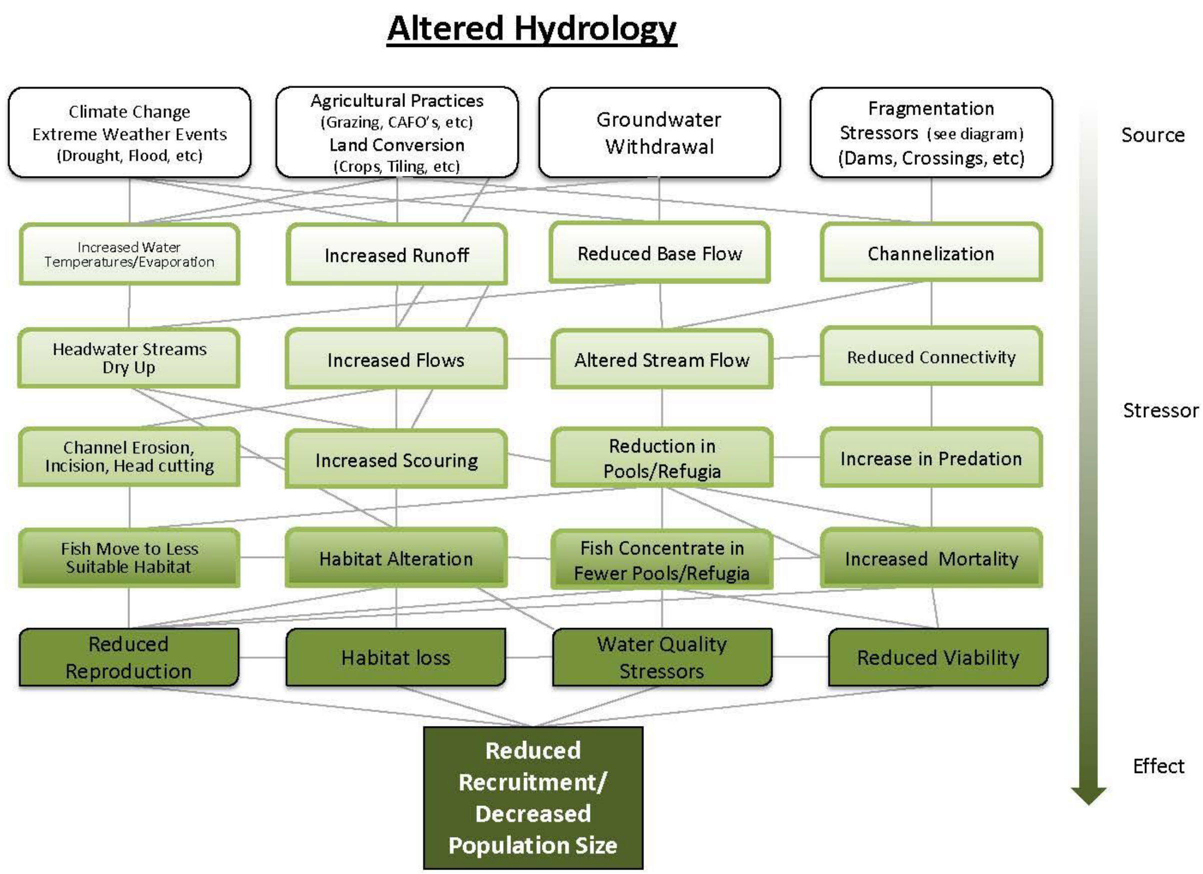


Figure 25. Altered hydrology factors, effects, and impacts to the Topeka shiner.

1. Extreme Weather Events

Extreme weather events were identified at the 2014 workshop as another top factor affecting the Topeka shiner across its range, but such events not separate from altered hydrology – they are part of its cause. The five-year review (USFWS 2009) provides additional details of climate change impacts to the Topeka shiner, and the table mentioned above (Table 2 (USFWS 2009)) that ranked the level of threats posed in each state identified climate change as the only moderate to high-level threat (again defined respectively as “action needed” and “immediate action needed”) occurring in every state. Extreme weather events, typically affecting Great Plains streams in the form of either floods or droughts, have always been a component of the prairie stream ecosystems in which the Topeka shiner evolved, but climate change has exacerbated – and is expected to continue to exacerbate – the severity of these events (USFWS 2009). Rising ambient air and water temperatures, increased frequency of heavy precipitation events, increased intensity of droughts, longer growing seasons, and reductions in snow and ice, are expected to continue in the coming years and decades (Karl *et al.* 2009 *in* Novak *et al.* 2015).

Within the Topeka shiner’s range, climate change effects will likely vary by region. Higher temperatures may be anticipated throughout the range, and although precipitation levels are less predictable, they are currently expected to increase in northern states but decrease in southern areas of the range (2014 Workshop Meeting Notes, Dennis Todey, page 14). Particularly in southern states that irrigate heavily, future greater temperatures and less precipitation will likely result in increased irrigation demand, causing aquifers (already depleted to the point of lost connections with streams that Topeka shiners rely on for refugia) to be drawn down further. The timing of the precipitation may also change – for example, South Dakota may receive relatively greater precipitation, but it may occur more in spring and fall, not in summer (2014 Workshop Meeting Notes, Dennis Todey, page 14), which could lead to increased prevalence of stream intermittency. High flows and flooding in prairie streams have the potential to mobilize the substrate and/or detach the eggs which could result in egg mortality, although occasional higher flows in prairie streams likely also expose spawning habitat, and provide access to off-channel areas where eggs may be laid (Craven *et al.* 2010). Adults or juveniles may also be displaced downstream by high flows (Barber 1986) which can also cause injury, death, or increase susceptibility to predation (Harvey 1987, Craven *et al.* 2010).

Increased severity of weather events alone may or may not pose an extinction threat to the Topeka shiner. However, with the highly modified state of the species’ prairie stream habitats and numerous stressors acting on them, severe weather events will serve to exacerbate existing problems.

2. Fragmentation

Another component of the altered hydrology model that warrants further analysis is fragmentation. This stressor was also ranked high by workshop experts as a leading factor in the decline of the Topeka shiner (2014 Workshop Meeting Notes, page 22-24), and again, it is a cause contributing to the altered hydrology problem. Fragmentation of Topeka shiner streams is caused by activities such as dams, low-water crossings, road crossing structures (culverts or bridges), and channelization. These structures and activities often impose physical barriers or create unsuitable habitats that preclude Topeka shiners from reaching upstream suitable habitats, recolonizing extirpated areas, or finding downstream refugia during stream drying. The activities that cause fragmentation also alter the flows, water quality and morphology of the streams, typically negatively impacting the Topeka shiner beyond the footprint of the barrier (Mammoliti 2002). Where populations manage to persist upstream of an impassible obstruction, genetic isolation occurs. Structures such as dams and culverts also result in instream aggradation and sedimentation that affect suitable spawning substrates and refugia. Actions often associated with barriers often place additional stressors on the species*, e.g.*, stocking of predatory fish above dams that consume Topeka shiners and cause behavioral avoidance of suitable habitat (Knight and Gido 2005, Campbell *et al.* 2016). Small dams, low-water crossings, perched culverts, excessive rip-rap and other instream obstructions likely affect, on some level, every Topeka shiner stream within the species' range. Fragmented populations of Topeka shiners are also affected more quickly by small-scale climate conditions – lack of spawning or loss of an entire year class has severe impacts to short-lived species like the Topeka shiner that rarely survive to a third spring (Mammoliti 2002). Figure 26 depicts some of the sources, stressors, and effects of fragmentation on the species.

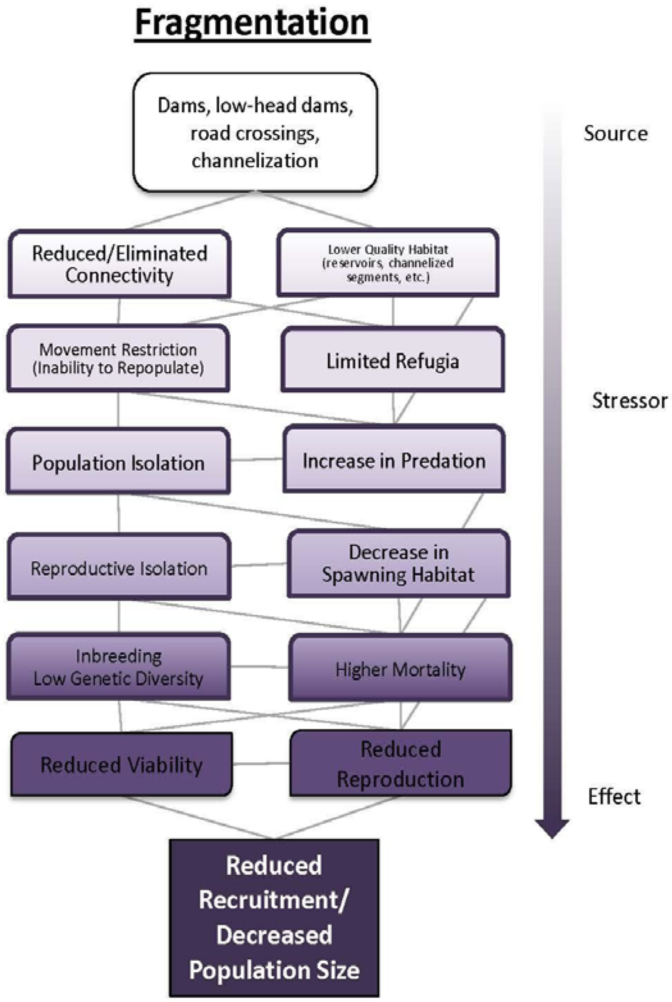


Figure 26. Fragmentation factors, effects, and impacts to the Topeka shiner.

3. Reduced Water Quality

Experts at the 2014 workshop ranked reduced water quality lower than overall altered hydrology, fragmentation, and extreme weather events when evaluating the top known stressors to the Topeka shiner. However, water quality partly defines hydrology, thus it fits (along with the aforementioned factors) under the umbrella of altered hydrology of prairie streams. Water quality includes factors such as temperature, contaminants, and turbidity/sedimentation which ultimately modify other components of the morphological and biological components of prairie streams. Changes in prey base and substrate types, algal blooms, reduced dissolved oxygen levels, and increased contaminants, can result in reduced growth rates, reduced reproductive output, increased susceptibility to disease and other adverse impacts, both direct and indirect, to aquatic life (Novak *et al.* 2015) including Topeka shiners. Great Plains streams in general have been - and are currently – negatively affected due to land use activities dominated by agriculture (including heavy grazing and CAFOs) that send sediments, excessive nutrients, and chemicals directly to these surface waters. Urban runoff and chemical spills add additional pressures in populated areas and along transportation corridors, but typically occur on a local, relatively small scale, and are secondary to the widespread agricultural impacts across the species' range.

Topeka shiner streams are often the receiving waters of agricultural and urban watersheds which contribute chemicals, sewage, and other contaminants. Although Topeka shiners are thought to be tolerant of some poor water quality conditions, they do have some known limits at which their feeding and reproductive successes are compromised; a maximum temperature threshold of 39°C (102.2°F)(above which Topeka shiners die) and a concentration of dissolved oxygen levels at 1.26 mg/L that result in 50% mortality after 96 hours have been established (Koehle and Adelman 2007). Mott (2017) identified Topeka shiner lethal temperatures in a similar range as Koehle and Adelman (2007) at 37.7 to 40.3° C, depending on acclimation temperatures. Sublethal behavioral effects of reduced dissolved oxygen (Topeka shiners moving upward in the water column, presumably to use aquatic surface respiration) have been observed as well, with surface respiration by 50% of tested individuals occurring at 1.65 mg/L (Mott 2017). Adelman *et al.* (2009) tested toxicity of ammonia, nitrate and nitrite on the Topeka shiner. The maximum acceptable toxicant concentrations (above which effects to Topeka shiners are detected) was determined to be 5.63 mg/L of total ammonia/nitrogen, 3.97 mg/L of Nitrite, and 360 mg/L of Nitrate (Adelman *et al.* 2009). Mott (2017) reported sublethal effects of ammonia and chloride (reduced swimming speeds of Topeka shiners) at concentrations well 50% mortality levels (7.6 mg/L of ammonia, 1993 parts per million of sodium chloride). Legal thresholds set by the EPA of these toxicants are sometimes exceeded in prairie streams, although these conditions are not known to be chronic, and may arise with incidents such as chemical fertilizer spills or overflow from CAFO waste facilities.

In addition to chemical contamination of the water, physical contamination (*e.g.* sedimentation) has had significant effects on the Topeka shiner. Prairie streambeds once lined with sand and gravel are now covered in layers of fine sediments, resulting in direct and indirect reduction/elimination of suitable spawning habitat for the species. Topeka shiner eggs are adhesive, staying in place where they land in the gravel until they hatch. Without the proper substrate, eggs may sink into the sediments and/or be smothered by additional sediments and die. The Topeka shiner is recognized as being more tolerant of degraded habitats than previously thought, existing in periodically turbid streams with silt/detritus covered streambeds (Hatch 2001). Their affinity for sunfish nests helps alleviate this issue for spawning purposes, but exact tolerance levels by Topeka shiners of fine sediment depths in the streambed, or in the water column, have not been clearly defined for any life stage of the species.

Whether water quality stressors negatively affect Topeka shiner populations likely depends on several factors including the severity of the contamination's effects (*e.g.* whether individuals die immediately, or perhaps become more susceptible to disease after exposure); the cumulative, synergistic or additive nature of the contaminant(s) with other conditions (*e.g.* substances may have more severe effects in the presence of another stressor such as warm temperatures); the scale, frequency, and exposure time of the contaminant; and the life stages that are affected. Degraded water quality likely works in concert with fragmentation and other components of altered hydrology to the detriment of individuals and populations by killing individuals (resiliency) and removing or reducing populations (representation and redundancy). While numerous studies have associated lack of Topeka shiners with reduced water quality, additional research is needed to define specific tolerance limits of Topeka shiners to various water quality parameters.

In Figure 27, we outline some of the primary stressors contributing to poor water quality in Topeka shiner streams and their likely effects to the species. As with other components of altered hydrology, extreme weather events and fragmentation, reduced water quality is likely a reality in every Topeka shiner stream due to the agriculturally dominated landscape of the Great Plains.

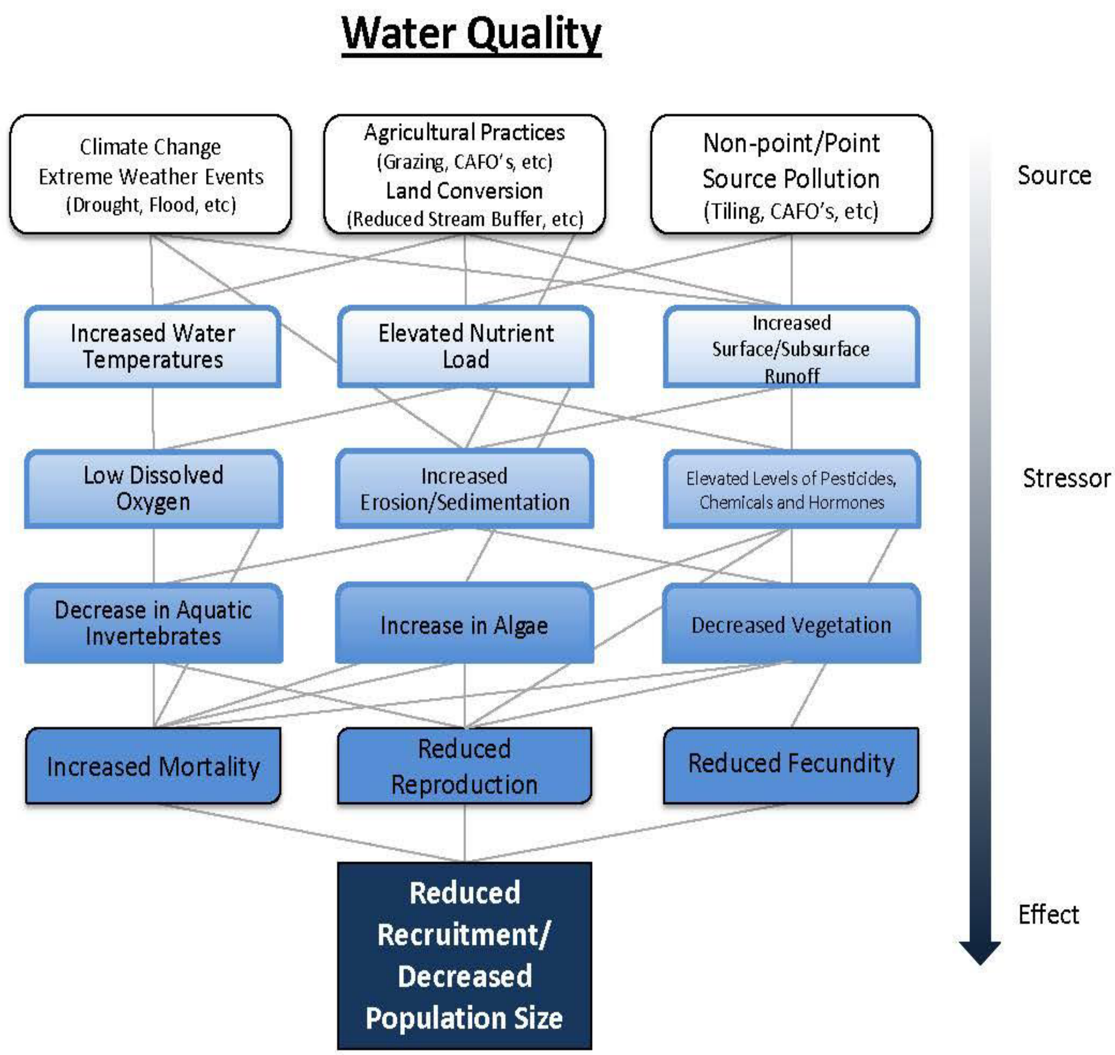


Figure 27. Water quality factors, effects, and impacts to the Topeka shiner.

B. Sources and Stressors

The primary cause of Topeka shiner decline is altered hydrology, and various components of it were identified in the previous section. Here, we identify and briefly describe the primary sources and stressors and how they affect Topeka shiners and their habitats. Most of these factors are also described in additional detail in the proposed (62 FR 55381-55388) and final (63 FR 69008-69021) rules to list the species and within the five year review (USFWS 2009).

1. Agriculture

The most widespread and impactful activities exerting stressors to the Topeka shiner may be assigned to one general category: agriculture, including grazing. As the dominant land use of the Great Plains, agriculture is the most significant factor driving widespread degradation of Topeka shiner habitat (Cross and Collins 1995, Richter *et al.* 1997), and as described above, the impacts can be aggregated under the single umbrella of altered hydrology. Agriculture has been negatively correlated with stream habitat quality and biotic integrity of streams, with obvious declines occurring in each when agricultural land use in watersheds reaches 50% (Wang *et al.* 1997). The vast majority of counties in the Topeka shiner's range contain more than 60% cropland and many contain over 80% cropland (2014 Workshop Meeting Notes, Ryan Reker, page 16).

Conversion of native land cover to crops and livestock on the land are the most obvious agricultural activities, but associated actions include wetland drainage, channelization, tiling, application of chemicals and fertilizers, water withdrawals, water crossings, and dam construction, among others. Since the late 19th century agricultural practices have resulted in reduced ranges and losses of many fish species, including the Topeka shiner (Richter *et al.* 1997, Cross and Collins 1995). Below we describe the nature of some specific agricultural activities and their effects on the species.

a) Land Conversion

Replacement of the carpet of deep-rooted native grasses with shallow-rooted agricultural crops destabilizes Great Plains soils and removes protective vegetative cover that holds soil in place. As a result, surface runoff increases, quickly transporting sediments, nutrients and agricultural chemicals to the nearest waterbody, particularly when vegetative buffers are lacking. When crops are placed directly at the edge of streams, the loss of riparian vegetation destabilizes the stream banks, causes bank-slumping and increases the rate and severity of stream degradation. Input of pollutants decreases the water quality of prairie streams declines. Sedimentation and poor water quality may kill Topeka shiners directly, depending on the contaminant type, concentration, and duration (see Adelman *et al.* 2009) or eggs may be smothered by sedimentation. Sedimentation can also interfere with groundwater recharge of streams as springs are buried beneath sediments. Pools and groundwater-fed refugia are reduced or eliminated, spawning substrates are covered, shade from riparian vegetation is removed reducing herbaceous input to streams, altering prey base for the Topeka shiner and causing water temperatures to rise, and off-channel habitat may be lost (Cross and Moss 1987, Hatch 2001). Topeka shiner reproduction may be reduced with lack of available spawning sites, and survival is reduced without refugia to sustain individuals during low water periods. Ultimately population declines or extirpations occur. Land conversion has been cited as a factor in the Topeka shiner's decline for some time (Minckley and Cross 1959, Pflieger 1975) and recent work in Kanasas (Gerkin and Paukert 2013) identified higher proportional urban land area as an indicator of sites lacking Topeka shiners. At the 2014 workshop, an analysis of percentage of cropland in watersheds with occupied Topeka shiner streams revealed higher percentages of cropland in northern populations compared to southern (2014 Workshop Meeting Notes, Roger Auch, page 15), yet it is primarily southern populations that are being lost. Multiple factors likely influence Topeka shiner declines, of which land use is a part.

b) Grazing

Intensive livestock grazing and/or grazing in riparian areas incurs numerous impacts to water quality and instream habitat of prairie streams; consumption and trampling of riparian vegetation and the streambed are the most obvious. Livestock often concentrate in riparian areas, attracted to the water, shade, and/or more succulent forage, which exacerbates the impacts to the streams. They also wallow directly in the streams, trample the streambed, stir up sediments, and add waste to the water. Decimation of vegetative cover exposes upland and riparian soils, increases overland runoff (sediments and other contaminants), and causes slumping of banks into the streambed. The results are sedimentation/contamination in the streams, channel widening, channel aggradation, lowering of water tables (reducing flow during critical base flow periods), increased water temperatures, altered stream morphology, and altered food supply for aquatic life (see Armour *et al.* 1990). Riparian vegetation protects stream water quality, morphology, hydrology, and specific habitat features that fulfill Topeka shiner life history needs. Low levels of grazing are not known to incur negative effects to the Topeka shiner, but as grazing pressure increases and riparian vegetation in particular becomes increasingly impacted, Topeka shiner presence decreases (Blausey 2001).

c) Tiling

Tiling is the practice of draining water from an area via underground pipes. The pipes may be installed to drain specific water bodies or to lower the water table of agricultural fields (pattern tiling) (Hubbard 2011) to allow earlier planting and increase crop production. Excess water enters the pipes as it seeps downward and instead of recharging groundwater, it is carried directly to the nearest ditch or waterbody. This moves water out of the area at much higher rates (in combination with wetland drainage, ditching/channelization, and loss of vegetative cover) than the intact prairie ecosystem allowed (Appendix A - 2014 Workshop Meeting Notes, Keith Schilling, page 18; Blann and Filipiak 2013). Tiling is currently not subject to any regulatory authority, thus, while there are methods (aerial photos, field location of pipes, landowner surveys) to determine location and extent of tiling on a local scale, there is currently no comprehensive database of tiled areas.

The effects of tiling on the hydrology and morphology of streams have been studied, but the effects are complex, depend on numerous factors, and are difficult to separate from other agricultural impacts (Hubbard 2011, Blann *et al*. 2009). Overall, tiling may contribute approximately an extra 10% yield in water flowing out of the system that would otherwise have been stored in wetlands, evaporated or transpired, and can reduce the average travel time of water in a watershed by half (Appendix A - 2014 Workshop Meeting Notes, Keith Schilling presentation page 18). Both peak and base flow changes can result in erosion, incision, and disconnection of streams from their floodplain, as well as lowering of groundwater tables (Hubbard 2011). Peak discharges to streams after precipitation events can increase, but this is variable, and dependent on various existing conditions, while the amount and timing of base (channel-forming) flows is typically increased and extended (Blann *et al.* 2009; Appendix A - 2014 Workshop Notes, Keith Schilling, page 18).

Tiling may reduce sediment and sediment bound contaminants (phosphorous) in overland flow (Blann *et al*. 2009, Hubbard 2011). However, pesticides (atrazine, neonicontinoids), nutrients (nitrates, dissolved phosphorous) and elemental contaminants (selenium, aluminum) are often discharged to streams in tile effluent at concentrations above water quality standards or benchmarks (Blann *et al.* 2009, Johnson 2010, Schwarz 2017 unpublished data).

Although specific studies of tiling effects to the Topeka shiner do not exist, at a minimum, the known effects of tiling contribute to the altered hydrology of Topeka shiner streams primarily in Iowa, Minnesota, and South Dakota. As a headwater species, Topeka shiners may be more susceptible to tiling activity, since low-order streams with high percentages of drain tile are likely to experience negative effects (Hubbard 2011); tiling contributes to altered hydrology, exacerbating loss of suitable instream habitat, refugia, off-channel habitat access, and further reduces water quality in Topeka shiner streams, ultimately affecting individuals and perhaps contributing to reduced populations.

d) Channelization

Channelization involves excavating and straightening of streams to move water from a location more quickly, often to create or access additional lands for agriculture, but also for other reasons such as flood control and controlling bank erosion (Brooker 1985). Channelization eliminates the natural riffle-pool sequence (Brooker 1985) and this direct morphological change results in immediate loss of pools and substrate key to the Topeka shiner's life history requirements (63 FR 69008-69021). Channelization changes the flow and velocity of water (Brooker 1985), thus channelizing a section of stream causes instability in upstream and downstream portions of the waterway, resulting in head-cutting and bank slumping, affecting habitats beyond the channelized portion. Channelized sections of stream may therefore result in habitat loss and increased fragmentation. Modification of waterbodies in this manner has generally not been a widespread practice in South Dakota (Hubbard 2011, Johnson and Higgins 1997), but the activity is common in other states such as Nebraska, Iowa, and Minnesota. The effect of this practice to the species typically eliminates Topeka shiner populations from the area (63 FR 69008-69021) by eliminating or altering pools, groundwater input, gravel substrates, prey base, and overall natural hydrologic regime to which the species is adapted. It is possible for Topeka shiners to occur in channelized streams; in Iowa, for example, several ditches are identified as harboring the species. This may be due to the relatively poor drainage, existence of off-channel habitats, and groundwater input to streams in the area resulting from the recent glacial influences (discussed above). Barring such circumstances, however, channelized streams generally do not support Topeka shiner populations (63 FR 69008-69021).

e) Irrigation

Surface and ground extraction of water to grow crops is known to reduce groundwater input to streams. When groundwater is depleted, connectivity with surface waters is reduced or eliminated as is refugia. Rather than surviving in spring-fed pools within the system when drought hits, fish may instead become trapped in drying pools and die (Kerns and Bonneau 2002). Topeka shiners are relatively tolerant of low dissolved oxygen and high temperatures (Koehle and Adelman 2007), but they cannot survive without water. Without survivors, post-drought recolonization from other sites may be precluded either by prohibitive distance to the nearest population, or physical stream obstructions (Falke *et al.* 2011), and extirpations therefore can become permanent. Lack of groundwater input to Topeka shiner streams has likely worked against the species cumulatively with other actions on the landscape (land conversion, wetland conversion, tiling, channelization, etc.) typical of the agricultural setting of the species' range (Hatch 2001).

Irrigation is a prevalent practice in agricultural states, particularly Nebraska and Kansas; areas more arid than more northern and easterly states in the Topeka shiner's range. The Topeka shiner has not fared well in such areas as groundwater depletions have caused streams to become increasingly dry and contribute to significant changes in aquatic life (Perkin *et al.* 2015). Aquifers beneath some parts of the Topeka shiner's former range have been over-exploited, "literally sucking dry many streams of the Great Plains" (Dodds *et al.* 2004). In areas such as western Kansas, springs from aquifers that once fed some Topeka shiner streams and likely sustained populations instead today become completely dry (or nearly so) due to the steady decline of groundwater (McGuire 2014, Falke *et al.* 2011). Irrigation and other water uses have caused that the High Plains (Ogallala) aquifer to drop an average of 25.5. feet in western Kansas (McGuire 2014) where the Topeka shiner has largely been extirpated (USFWS 2009). Irrigation was noted as a key stressor to the species in Nebraska, where an irrigation moratorium by water management districts has largely been ignored (Appendix A – 2014 Workshop Meeting Notes, George Cunningham, page 5). Irrigation does not appear to be as problematic for the species in relatively wetter areas of the range, although the activity is known to cause local impacts, reducing instream flows even in these areas (Wall *et al.* 2001; Jesse Wilkins, SDDENR, personal communication, 2014).

f) Confined Animal Feeding Operations – CAFOs

CAFOs occur throughout the Topeka shiner's range and vary from large corporate operations producing hogs and poultry to small scale winter feeding areas on family farms (USFWS 2009). The primary impact of these facilities to the Topeka shiner is discharge of pollutants via manure lagoon failures, failure to control discharge during precipitation events, or accidents during which large amounts of sediments and nutrients enter the streams, causing catastrophic impacts to stream habitat and organisms, including fish kills in some stream segments (USFWS 2009). Additionally, waste from CAFOs is often applied to adjacent lands as fertilizer. While CAFOs were not identified specifically at the Topeka shiner 2014 Workshop as a major driver of the species' decline in all states, CAFOs were noted to be a significant issue in Iowa, where hundreds of fish kills (with the implication that Topeka shiners are among those affected since spills are known from occupied Topeka shiner watersheds) have occurred as a result of CAFO discharges (Aleshia Kenney, USFWS, personal communication, 2014). Their primary impact is degradation of water quality – a component of the altered hydrology factor as described above. Direct loss of individuals via mortality due to reduced water quality is possible, as is the loss of suitable habitat due to sedimentation and reduced food availability. Burkholder *et al.* (2007) found that generally accepted livestock waste management practices are inadequate in their protection of water resources from contamination by excessive nutrients, microbial pathogens, and pharmaceuticals present in the animal waste. Given the potential impact in Iowa and the presence of CAFOs throughout the Topeka shiner's range, this issue may warrant further analysis, and coordination with state entities regulating CAFOs via the National Pollutant Discharge Elimination System (Section 402 of the Clean Water Act) to mitigate adverse impacts to the species.

g) Contaminants

Given the widespread use of herbicides and pesticides on the agricultural landscape that makes up the majority of the Topeka shiner's range, further study on the effects of contaminants specifically to the Topeka shiner is warranted. Contaminants are known to exceed aquatic life water quality standards and/or benchmarks in Topeka shiner streams. Recent tests of agricultural tile effluent discharged into South Dakota Topeka shiner streams revealed contains selenium, pesticides (atrazine and neonicotinoids) and nutrients (nitrate-nitrogen) (Schwarz 2017 unpublished data).

Selenium is a naturally occurring element present in sedimentary rocks, shales, coal and phosphate deposits and soils, but due to its bioaccumulative nature, it is a concern for aquatic life. Concentrations of selenium in water samples from tile effluent and Topeka shiner streams in South Dakota often exceed the 3.1 micrograms per liter (µg/L) national aquatic life criterion for selenium in lotic waters (U.S. EPA 2016; Schwarz 2017 unpublished data) and are potentially harmful to the species. Concentrations of selenium in tile effluent discharged to Topeka shiner streams has been detected as high as 70 µg/L (Schwarz 2017 unpublished data), but such discharges are unregulated and do not require a permit. Permitting does not necessarily address the potential problem, however; discharge from a permitted ethanol facility in South Dakota was found to contain selenium concentrations as high as 11 ug/L, yet the permit currently does not include monitoring requirements or concentration limits for selenium (Matt Schwarz, U.S. Fish and Wildlife Service, personal communication, 2017). While we are not aware of any selenium toxicity data specifically for Topeka shiners, another Cyprinid species, the zebrafish (*Danio rerio*) is the most selenium-sensitive fish species studied to date (Thomas and Janz 2015). Selenium exposure to fish can result in deformities of developing offspring, reduced growth, decreased swimming activity, reproductive failure and increased mortality (U.S. Department of the Interior 1998, Hamilton 2003, Tashjian *et al.* 2006). Future assessments that measure selenium in Topeka shiner tissues and diet are needed to adequately evaluate risk from selenium exposure and effects.

Atrazine is a widely used herbicide to control weeds in corn, sorghum, and sugarcane fields. It is applied pre- and post- crop emergence and is both persistent and highly mobile in the environment. The Environmental Protection Agency (EPA) has determined that atrazine is likely to adversely affect Topeka shiner populations (U.S. EPA 2007). The likely effects of atrazine to Topeka shiners include direct chronic effects and indirect effects to terrestrial and aquatic vegetation that provide important habitat used by the Topeka shiner to breed, feed, and shelter (U.S. EPA 2007). Streams draining agricultural areas with high atrazine use can result in concentrations of atrazine above water quality benchmarks for the protection of aquatic life (Frenzel *et al.* 1998, U.S. EPA 2007). Although we are unaware of any atrazine toxicity testing specifically with Topeka shiners, direct adverse effects of atrazine exposure to fish include endocrine disruption (Moore and Waring 1998, Moore and Lower 2001, Spanó *et al.* 2004, Suzawana and Ingraham 2008), altered kidney morphology (Fisher-Scherl *et al.* 1991, Oulmi *et al.* 1995) , reduced larval growth (Alvarez and Fuiman 2005), decreased egg production (Tillitt *et al.* 2010), and altered behavior (Saglio and Trijasse 1998). Indirect effects to fish that may result from atrazine exposure include habitat modification and decreased availability of prey. For example, red shiners exposed to 10 µg/L atrazine at 23◦C and 30 ◦C had a significantly lower Critical Thermal Maximum compared to controls, which may result in decreased survival (Messadd *et al.* 2000). Female fathead minnows exposed to 0.5, 5, and 50 µg/L atrazine had higher levels of ovarian atresia, as well as a 19 - 39 percent reduction in egg production (Tillitt *et al.* 2010). Studies of atrazine effects on the Topeka shiner are needed.

Neonicotinoids are the most widely used insecticides in the world and have been detected in streams at concentrations potentially harmful to fish and their aquatic invertebrate prey (Alexander *et al*. 2007 and 2008, Mason *et al.* 2013, Hladik *et al*. 2014, Bonmatin *et al.* 2015). Most neonicotinoids are applied to corn and soybean fields as seed treatments during planting, but they can also be applied in agricultural fields as foliar sprays or soil amendments. It is estimated that in the United States, 34 - 44 percent of soybeans and 79 - 100 percent of corn were treated with neonicotinoids in 2011 (Douglas and Tooker 2015). Clothianidin, imidacloprid and thiamethoxam are the most commonly applied neonicotinoids on corn and soybeans and have been detected at concentrations above water quality benchmarks in Iowa and South Dakota streams (Hladik *et al.* 2014; Schwarz 2017 unpublished data). A 35 ug/L chronic benchmark for the protection of aquatic invertebrates (Morrissey *et al*. 2015) was frequently exceeded in tile discharges that directly enter into South Dakota streams with known occurrence records for Topeka shiners (Schwarz 2017 unpublished data). There are currently no known water quality standards to protect aquatic life from neonicotinoid exposure. Given neonicotinoid widespread use and toxicity at low concentrations, further assessment is warranted to evaluate neonicotinoid exposure and effects to Topeka shiners. Nitrate toxicity testing with Topeka shiners indicate that they are not likely to encounter nitrate concentrations that are directly toxic (Adelman 2009). However, excessive nitrate loading may be harmful to Topeka shiners indirectly through habitat modification. Nitrate is quickly assimilated by aquatic vegetation and can contribute to excessive nutrient loading. Excessive nutrient enrichment can cause toxic algal blooms, reduced water clarity, dissolved oxygen depletion, fish kills, and excessive macrophyte growth (EPA 2000). A review of published scientific literature on the direct toxic effects of nitrate on freshwater invertebrates, fish, and amphibians suggested a protective benchmark of 2 mg/L nitrate (Carmargo *et al.*2005). Minnesota's draft chronic water quality criterion for nitrate is 4.9 mg/L (Monson et al. 2010). In comparison, nitrate concentrations in tile effluent discharged to Topeka shiner streams in South Dakota averaged 20.3 mg/L (range of 0.7 - 46 mg/L), with instream nitrate concentrations as high as 21 mg/L (Schwarz 2017 unpublished data). The Topeka shiner has at times been found areas with obviously poor water quality (*e.g.* areas heavily used by cattle with algal blooms) and periodically turbid, sediment laden areas, which has led to the perception that the species is hardier than previously thought (Hatch 2001). However, populations do decline with habitat degradation. Contaminants have the potential to induce disease in the species, negatively affect food sources, reproduction or growth, and result in direct mortality.

h) Wetland Drainage

Millions of acres of wetlands have been lost since European settlement of the Great Plains. These waterbodies have been drained (ditched), filled, and plowed to grow additional commodities. Wetlands retain water on the landscape, recharging groundwater and filtering impurities. With their conversion to agriculture, surface runoff that once was retained in wetlands instead moves overland, contributing to the agricultural runoff to the streams, increasing erosive peak (flood) flows and channel-forming base flows (Blann and Filipiak 2013), and resulting in transport of additional sediments, nutrients and chemicals to streams. When aquifer recharge is reduced, input of groundwater to streams is reduced or lost. The greatest degree of wetland drainage has occurred where the greatest number of wetlands once existed: in the northern and eastern portions of the Topeka shiner's range. Of states within the Topeka shiner's range, Iowa has experienced almost total wetland loss – 99% (2014 Workshop Notes, Keith Schilling, page 18, Appendix A). Wall and Berry (2006) noted that South Dakota has relatively fewer drained wetlands than other states in the Topeka shiner's range and may be a corresponding factor in relatively high abundance of the species in South Dakota and Minnesota compared to other areas of the species' range. While the effects of wetland drainage to the Topeka shiner have not specifically been studied, it is known that the effects of wetland losses are similar to land conversion: increased overland runoff and pollutants reach the streams, groundwater recharge is reduced, chemical and morphological changes to habitat are incurred, Topeka shiner key resources (*e.g.* spawning sites, refugia) are impacted, Topeka shiner individuals experience reduced reproduction/survival, and populations decline. Wetland conversion has coincided with land conversion throughout the Great Plains. Wetland drainage itself has not necessarily been identified as a threat to the Topeka shiner, but the practice contributes to altered hydrological condition of prairie streams today, which is the primary factor impacting the species.

2. Dams and Road Crossings

Due to human activities the hydrology of Great Plains streams has been greatly altered (Dodds *et al.* 2004) degrading Topeka shiner habitats and causing population losses (63 FR 69008-69021). As described above as a cause of the current condition of the Topeka shiner, fragmentation, primarily caused by anthropogenic actions, is a considerable factor in the altered hydrology of prairie streams and the primary activities causing fragmentation are structures such as dams and culverts that result in impassible barriers, insurmountable distances, or unsuitable habitats for the Topeka shiner. For a species that occupies headwaters and moves relatively little, the result is varying levels of isolation within populations, between populations, and among population complexes. Many isolated extant Topeka shiner populations today likely cannot reconnect without human intervention.

Although dams are presented here as separate from agricultural practices, they are often constructed for agriculture-related activities which today may be authorized by the U.S. Army Corps of Engineers under Clean Water Act Nationwide Permit 27. Dams and low-water crossings are often placed Topeka shiner streams to facilitate livestock use, irrigation, or allow access to areas otherwise inconvenient, difficult or impossible to reach with agricultural equipment. Dams have been promoted via some Federal programs and particularly in southern areas of the Topeka shiner's range (*e.g.* Kansas) have coincided with stocking of predator game fish such as largemouth bass (USFWS 2009), but dams exist on known or formerly occupied Topeka shiner streams throughout its range.

Determining thresholds for lack of connectivity that result in Topeka shiner population loss is difficult, as numerous factors affect stream systems including the amount of suitable habitat available, the severity of drought conditions, predator numbers, etc.. Perkin and Gido (2011) examined fragment length of streams as related to fish population declines and determined fragmented lengths averaging 136 ± 21 river kilometers (rkm) resulted in species extirpations, while 226 ± 69 rkm of fragmentation lead to species declines, and systems with 458 ± 137 rkm of fragmentation harbored stable populations, however the focus of that study was on large river prairie fishes. *Notropis* species were examined in that study, but those values have not been related specifically to persistence of Topeka shiners nor their relatively small prairie stream habitat. Perkin and Gido (2012) found that fish communities in stream segments isolated by road crossings had reduced species richness relative to communities that maintained connectivity with the surrounding dendritic ecological networks and isolated communities had greater dissimilarity to downstream sites not isolated by road crossings during summer and fall.

Higher proportional impoundment area has been identified as an indicator of sites lacking Topeka shiners in Kansas (Gerkin and Paukert 2013). As with increasing density of predatory largemouth bass (see Predation section below), the number of small impoundments per watershed area (mean 57 per extirpated stream vs. 23 per extant stream) has been identified as a predictor of extirpation of Topeka shiner from streams (Shrank *et al.* 2001). The effects of dams on Topeka shiner streams are numerous, with perhaps the most obvious effects being alteration of sinuous stream habitat via pooling water upstream of the structure and precluded or altered passage of the structure. Isolation may result in genetic alteration of populations upstream if they manage to survive, but without access to downstream refugia, upstream populations may perish as the stream dries; populations are then reduced in size or lost entirely when lack of post-drought upstream access precludes recolonization (Mammoliti 2002).

The alteration of habitat by impoundments generally includes a shift in aquatic organisms from those occurring in stream habitats to those occurring in ponded habitats, including predatory species (Mammoliti 2002). During low water periods, Topeka shiners may also be forced into the impounded area where they may be more susceptible to those predators, which generally occur in low numbers in unaltered prairie stream habitats (Mammoliti 2002).

The altered hydrologic regime of impoundments incurs seasonal changes in flows, reduces incidence and severity of flooding and scouring flows, and alters downstream base flows which in turn cause physical alteration of instream habitat (Mammoliti 2002). Downstream changes also include increases in sediments that may cover spawning substrates, decrease invertebrate populations, increase turbidity for sight feeders like the Topeka shiner, and inhibit or prevent subsurface flow or seepage. Downstream formerly permanent pools may also dry completely when dams preclude discharge (Mammoliti 2002).

While not intended to obstruct the flow of water, stream crossing structures associated with roads (bridges and culverts) have been installed throughout the Topeka shiner's range with little or no consideration for fish passage and often without effective sediment/erosion controls. In some instances these structures may impede passage and act much as a dam would in terms of impacts to the stream described above, although passage (at least downstream) is more likely as culverts are intended to convey water. Upstream passage is precluded, however, when the velocity of water through the structure surpasses the swimming abilities of the fish, when flows are too low and spread too thin to provide a passable channel, when obstructions such as rip-rap are inappropriately placed in a manner that blocks the structures, or when structures have been improperly placed or sized and become elevated above the streambed (perched). Degradation and aggradation also occur with placement of these structures, impairing the water quality and altering the morphology of streams, often reducing the availability of suitable habitat (pools and gravel substrate for spawning). Passage through these crossings is not always precluded. Blank *et al*. (2011) documented Topeka shiners passing through crossings with a range of conditions including water depths from 0.15 ft to 1.51 ft, average water velocities ranging between 0.03 ftls and 2.6 ft/s, outlet drops up to 0.1 ft, culvert slopes between 0.55% and 2.12%, and lengths from 53 ft to 70.3 ft. Large concrete box culverts spanning streams and set deep in the streambed generally afforded conditions more conducive to Topeka shiner passage than corrugated metal pipes or culverts of structural steel plate materials, likely due to improper design, construction or maintenance of the latter (Blank *et al*. 2011). Genetic analysis at some culvert sites in that study identified statistically significant genetic differences above and below some (not all) culverts (Blank *et al*. 2011). Bouska and Paukert (2010) described stream-crossing structures as semipermeable barriers to Topeka shiners as some individuals in their mark-recapture study were found to move upstream through box culverts. Their laboratory testing of Topeka shiners indicated the species can navigate velocities of 1.1 m/s through culverts 1.86 m long (perhaps a greater endurance and swimming performance than reported by Adams *et al*. 2000) (Bouska and Paukert 2010). In that study, low-water crossings were identified as a potentially more significant barrier to Topeka shiner passage than box culverts (Bouska and Paukert 2010). Mosey's (2017) study of several box culverts in Minnesota detected reduction, but not prevention of passage by Topeka shiners through the culverts. Additionally, lack of light in culverts- in field and lab experiments - could not be isolated as a factor affecting Topeka shiner passage, although the study identified several limitations that could affect those results (Mosey 2017).

The Topeka shiner is not a highly mobile species. Its affinity for headwaters limits movements between populations much more than it limits movements within populations (Michels 2000). Its habitat is also commonly subject to flooding and drying, which means local extirpations and recolonizations are part of the life history strategy of the Topeka shiner. When obstructions fragment the stream habitat, habitat becomes more limiting, access to suitable habitat (including refugia) is lost, recolonization (population expansion) opportunities are lost, and extirpations may become permanent, resulting in population losses and range contraction. While dams on Topeka shiner streams occur throughout the species' range, they are generally more prevalent in southern areas, particularly Kansas and Missouri, where the practice is followed by predatory fish stocking for recreational benefits.

3. Climate Change

As described in the Extreme Weather Events section above, climate change has and will contribute to changes in prairie stream hydrology, water quality, and fragmentation. Rising temperatures, increasing drought severity, increased severity of precipitation events and altered timing of precipitation events are occurring with climate change, and the alterations were noted decades ago as a factor contributing to Topeka shiner declines (Minckley and Cross 1959). This factor was explained in detail within the Topeka shiner five year review (USFWS 2009) as a significant future threat to the species across its range. Some climate change effects are difficult to separate from other anthropogenic impacts such as irrigation and impoundments (Covich *et al.* 1997), although it has been demonstrated that climate change contributes to increased base flows in Iowa (Tomer and Schilling 2009) which can destabilize and degrade Topeka shiner streams. Climate change has likely exacerbated the land-use activities above, and vice versa; *e.g.* streams already suffering from water depletion become more so with warming temperatures and reduced precipitation and the warmer and drier conditions increase the need for irrigation, further depleting the streams (Covich *et al*. 1997). In contrast, some portions of the Topeka shiner's range (*e.g.* eastern South Dakota, central Iowa) have been warmer, but wetter over the past century and this trend is anticipated to continue (Millet *et al.* 2009; Appendix A - 2014 Workshop Notes, Dennis Todey, page14). Impacts to the species resulting from climate change likely have not, and will not be, uniform throughout its range as described above in the Extreme Weather Events section. Increased precipitation in northern areas may impact Topeka shiners and their habitats via effects such as displacement due to increased peak flows in streams - a factor that the species may be somewhat more resilient to (Franssen *et al.* 2006) as opposed to drying of streams in southern parts of the range (fish may survive displacement, but not lack of water). With warming temperatures and increased desiccation in much of the southern portion of the species' range, however, many small streams of today are anticipated to lack water year-round, becoming uninhabitable for any fish (Covich *et al.* 1997). Extirpation rates may increase and additional populations, further contracting the range and causing further decline of the species.

4. Urbanization

The Topeka shiner five-year review (USFWS 2009) identifies urbanization as a moderate to high threat to the species only in the States of Kansas and Missouri. This is not a widespread issue for the species, although local impacts typically do occur wherever Topeka shiner streams coincide with development of cities, towns, or suburbs (*e.g.* Sioux Falls, South Dakota). Factors affecting Topeka shiner streams that coincide with urbanization include increased input of sediments and other pollutants, alteration of the natural flow regime (*e.g.* channelization, bank stabilization), and specific local factors such as predaceous fish releases from impoundments. These stressors impair water quality of Topeka shiner habitats, incur loss of instream pool habitats and gravel substrates, modify flows, and generally tend to degrade streams, in some cases resulting in local extirpation of the species. Due to the localized scale at which it occurs, however, urbanization was not identified by experts at the 2014 Workshop as a primary cause of Topeka shiner declines throughout the range of the species.

5. Predation

Predation was ranked lowest by experts at the 2014 workshop among the top factors impacting the Topeka shiner, identified as problematic only in Kansas and Nebraska (see Appendix A). This factor was also not identified as the top threat to the species in the final listing rule, but was noted as important in the decision to list the species (63 FR 69008-69021).

Yet predation is known to have significant impacts to Topeka shiners when stocking of predatory fishes occurs in headwater areas where the Topeka shiner exists (Schrank *et al.* 2001, Mammoliti 2002). Gerken and Paukert (2013) found increased relative abundance of largemouth bass and increased proportional impoundment area were factors associated with Topeka shiner absence. Catch-per-unit-effort of largemouth bass in pools (mean 0.4 C/*f* vs 0.1 C/*f* in extant streams) is a known predictor of extirpation of Topeka shiner from streams (Shrank *et al.* 2001).). The obvious impact of predator stocking is increased predation mortality of Topeka shiners. Although predators do not necessarily select for Topeka shiners over other prey species, increased predation rates on an already rare minnow likely incurs negative effects by further reducing its abundance (Knight and Gido 2005).

The presence of predatory fish also results in behavioral changes in Topeka shiners that can affect reproduction and population persistence. Knight and Gido (2005) found that Topeka shiners reduced their use of pool habitats due to the presence of bass, forcing them into less suitable areas. Campbell *et al.* (2016) documented complete elimination of Topeka shiners from captive rearing ponds to which largemouth bass were added, and observable changes in behavior: Topeka shiners in ponds with bass present, in order to avoid predation, diverted their spawning efforts and interactions with orangespotted sunfish to such an extent as to severely compromise reproduction (Campbell *et al.* 2016).

Thus, the impact of predators in Topeka shiner habitats may be at least twofold – direct mortality due to increased predation rates, and reduced reproduction as a result of behavioral response to predators - and has been documented to result in extirpation of existing Topeka shiner populations, particularly above impoundments which exacerbate the threat of predation (Prophet *et al.* 1981, Mammoliti 2002). As with nearly all threats to the Topeka shiner, predation may also be compounded by other factors affecting the species simultaneously. Such mortality may have disproportionate effects to Topeka shiners, for example, when low water conditions result in predator and prey trapped and/or concentrated within isolated refugia.

Largemouth bass densities and associated Topeka shiner declines do not apply to all areas of the Topeka shiner range. Predation risk in Minnesota has been determined to be low with black bullheads (*Ameiurus melas*) identified as predators that consume low numbers of Topeka shiners (Dahle and Hatch 2002). In Iowa, Bakevich (2012) did not observed declines of Topeka shiners where largemouth bass were prevalent, potentially due to lower visibility for these visual hunters in Iowa streams and the presence of fathead minnows as a prey buffer species for Topeka shiners. In South Dakota, predator densities have been estimated to be in the single digits (approximately 5.4% in Upper Big Sioux for example; Milewski 2001 *in* Wall *et al*. 2001); most small prairie streams in eastern South Dakota where the Topeka shiner resides have not been impounded and/or stocked with predatory species (Wall *et al*. 2001).

However, predation is a factor that can affect Topeka shiners on a local or population scale, particularly in the southern states as widespread construction of dams and predator species stocking has been common practice (USFWS 2009). While it may not be the most prominent threat to the species throughout its range, stocking of predator species and/or modification of prairie streams to favor predators can have severe effects on Topeka shiner populations.

6. Instream mining/dredging

Instream and floodplain gravel and sand mining or dredging impacts the Topeka shiner primarily in the southern portions of the range, with the greatest activity levels occurring in Kansas and Missouri (USFWS 2009). When streambed materials are excavated from a waterway, stream elevations are lowered, pool-riffle complexes are lost, materials important for invertebrates and spawning fish are lost, and heavy equipment activity results in releases of large sediment loads affecting downstream habitat (Kondolf 1997, Brown *et al.* 1998, USFWS 2009). Post-dredging/mining effects include headcutting, channel widening, loss of riparian habitat, increased instream temperatures, and altered stream flows (Kondolf 1997, Brown *et al.* 1998). Pool sizes and depths change and their distribution within the predictable pool-riffle complex change (Brown *et al.* 1998). Sedimentation may continue to be a factor when inappropriately placed dredged materials wash into the stream during precipitation events (Kondolf 1997, USFWS 2009). Increased turbidity resulting from instream dredging/mining can alter the efficiency of sight feeding fishes, reduce fish tolerance to diseases and increase overall physiological stress, and limit reproduction via smothering of eggs on the streambed (Femmer 2002). Fish densities and/or abundances may decrease as a result (Brown *et al.* 1998, Meador and Layher 1998), and fish assemblages become altered (Paukert *et al.* 2008). Although impacts specific to the Topeka shiner as a result of gravel mining/dredging have not been studied, instream mining/dredging is known to affect the physical, chemical, and biological characteristics of streams (Meador and Layher 1998). Impacts to pool habitats and gravel substrates within those pools is the most obvious direct effect of dredge impacts to Topeka shiners – equating to direct and indirect loss of habitat. Long-term degradation of the stream above and below the dredge site likely result in reduced refugia, reduced food sources, and lowered reproduction. However, instream gravel mining, while obviously detrimental to the Topeka shiner and its habitat is not a widespread activity, occurring most commonly in southern portions of the species range.

7. Disease and Hybridization

Disease and hybridization have not been identified as major stressors to the Topeka shiner. Asian tapeworm infections have been shown to limit growth in the species (Koehle and Adelman 2007) and scoliosis was observed in Topeka shiners in the mid-1990s from a stream in Missouri (USFWS 2009) which likely has growth inhibiting effects. Additional information on diseases of Topeka shiners is not available.

Hybridization of Topeka shiners has been reported in old (1887) records (Gilbert 1978) and very recently (Cunningham 2015, 2016) (see Taxonomic History and Relationships section), but such hybridization is based solely on field observations and as of this writing genetic testing of such hybrids has not been conducted. Hybridization may be most likely to occur with the sand shiner, the “sister species” to which the Topeka shiner is most closely related. The extent that hybridization may threaten Topeka shiner populations or affect genetic diversity is not known; however, in light of infrequent reporting it is not currently considered to be a significant factor affecting the species.

C. Summary of Threats

Altered hydrology of prairie streams occupied by the Topeka shiner is the biggest factor contributing to the decline of the species. The anthropogenic landscape-level changes incurred to prairie streams since European settlement of the Great Plains have severely altered the physical, chemical, biological, and ecological processes to which the Topeka shiner has adapted. Habitats have been negatively affected to such an extent as to permanently extirpate entire populations/population complexes where recolonization is physically precluded, resulting in significant contraction of the species' range.

Agriculture and its associated activities are the primary drivers of these hydrological changes across the entire range of the species, although other landscape-scale human development activities (*e.g.* dams, road crossings) have also contributed significantly to the species' decline.

Factors influencing altered hydrology are not necessarily ubiquitous across the species' range. Some are more prevalent in certain areas of the Topeka shiner's range than others, and/or occur at localized scales rather than range wide - *e.g.* gravel mining, irrigation, and dams/predator stocking in KS, NE, and MO; tiling in MN, SD, and IA; urban development in certain cities (such as Sioux Falls, SD or Manhattan, KS).

Additionally, numerous factors may work in concert to the detriment of the Topeka shiner. As an example, a single stream may be affected when: crops are planted to the stream's edge removing the protective riparian zone, upland tiling effluent is discharged directly into the same waterway, undersized and perched road-crossings inhibit or preclude movement of fishes among available instreams habitats, and an impoundment is installed and stocked with predatory fish. Add a stochastic event such as drought to the situation, and Topeka shiners may be permanently extirpated from all or a portion of that waterway. Not all prairie streams are subject to such level of disturbances and resulting habitat degradation, but there are few (or perhaps no) prairie streams in the range of the Topeka shiner left unaffected by one or more of the sources and stressors described in the paragraphs above.

The closer a stream system is to adhering to its natural hydrologic and ecological patterns and processes, the more likely it is to harbor its native aquatic inhabitants, including the Topeka shiner. Uncertainty lies in exactly what level of degradation due to the above factors - or combination of those factors - can be tolerated by the species before it can no longer survive in the modified habitat. It is clear, that the level of degradation has been exceeded in a large portion of the species' range based on loss of populations and degree of range contraction. Conversely, such thresholds have not been exceeded, and/or have been mitigated, in some southern areas (*e.g.* Flint Hills of Kansas) and the majority of northern areas (South Dakota, Minnesota and northeastern/northcentral Iowa) where Topeka shiner populations persist despite ongoing threats.

V. Current Resiliency, Redundancy, and Representation

A. Resiliency

Current resiliency of Topeka shiner populations is difficult to assess as we lack information on many of the habitat and species-specific metrics needed to accurately evaluate extant populations such as amount of suitable habitats available to the species (*e.g.* the number of gravel-lined pools, pools with groundwater input, off-channel pools, etc.), population sizes, reproductive rates, and recruitment rates. Necessary metrics to define resiliency of populations and population complexes would be highly difficult to obtain range-wide, and are highly variable relative to this short lived species that lives in the dynamic habitat afforded by small prairie streams.

1. Population Resiliency Model

To help examine the species' resiliency at the population level, we developed the *Population Resiliency Model, Topeka shiner (Notropis topeka)* (see resilience model report in Appendix D) as an effort to assign relative value to extant occupied streams in HUC12 and HUC10 watersheds and help define the potential resiliency of populations in response to future stochastic events. The 223 occupied streams known to have been occupied at some time since 1999 are condensed into 87 HUC10 populations and assigned a relative ranking.

Through work with the State agencies and other experts, the following were identified as most influential on population resiliency:

- Consistency of Presence (Occupancy over Time)
- Habitat Availability/Complexity (Presence of Refugia)
- Habitat Conditions/Quality
- Habitat Connectivity

Due to the lack of specific data on these parameters, we used publicly available data for the resiliency model, throughout the species' range, to evaluate factors influencing the quality of the habitat and/or the persistence of populations and ranked extant populations accordingly. This information is described below, along with the information it is intended to represent.

- Records of continued occupancy serve as the proxy for habitat conditions. Based on the continued presence of the species in a given waterway, the assumption is that the basic life history needs of the species are being met at some level.

- Stream length and sinuosity are used as proxy measurements for habitat complexity. Generally speaking, a long, sinuous stream is likely to have relatively more intact habitat than a short, channelized stream and is also more likely to afford refugia.
- Stream crossings and dams are proxies for habitat availability/connectivity. As more potential obstructions occur on a given stream, the likelihood of accessibility to all of the stream decreases.

The resiliency model uses a scoring system whereby points are assigned to available demographic and habitat information for each extant Topeka shiner subpopulation and those scores are combined into a composite score for each population (Figure 28).

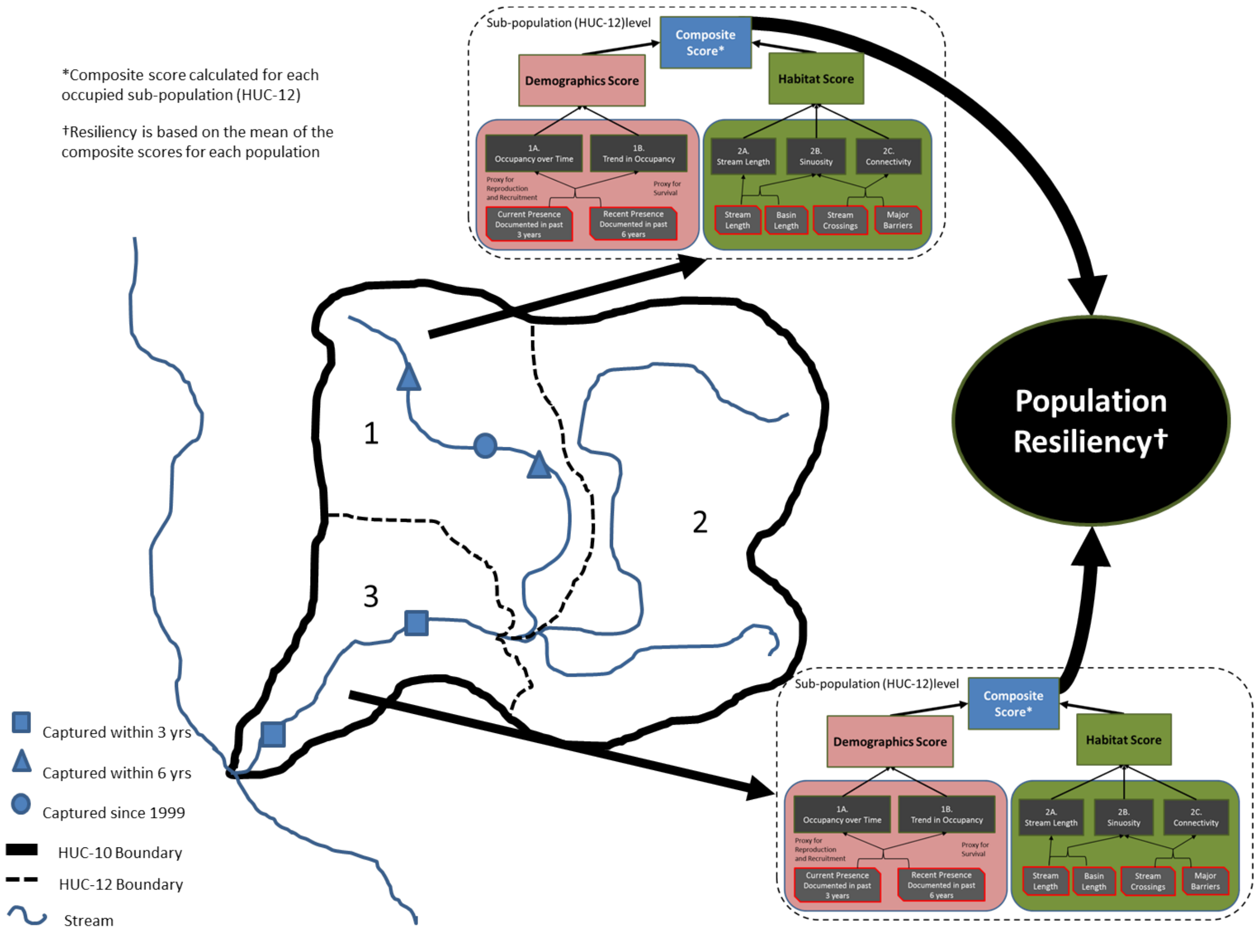


Figure 28. Illustration of how measurable population characteristics of Topeka shiners and their habitat likely contribute to population resiliency. The Composite Score is the sum of the measures variables within each occupied subpopulation (HUC12) , and Resiliency is the mean of all composite scores within the population (HUC10).

A ranking category was established for the scores (Table 7) and assigned to each population as appropriate.

Table 7. Population Composite Score categories and assigned rankings (1 (highest) to 7 (lowest) with standard deviation.

Composite Score	Rank and Standard Deviation
> 3.66	1 (> 2.5 SD)
> 2.77 to ≤ 3.66	2 (1.5 to 2.5 SD)
> 1.89 to ≤ 2.77	3 (0.5 to 1.5 SD)
> 1.0 to ≤ 1.89	4 (-0.5 to 0.5 SD)
> 0.12 to ≤ 1.0	5 (-0.5 to -1.5 SD)
> -0.77 to ≤ 0.12	6 (-1.5 to -2.5 SD)
≤ -0.77	7 (< -2.5 SD)

The model is a rough means to compare extant populations using the best information currently available. The means to evaluate overall population resiliency and rank each population are described in further detail in the resiliency model report, Appendix D.

Spatial data used for the resiliency model came from a proprietary database of fish passage barriers via the Service's Environmental Conservation Online System (ECOS) (GeoFIN) as well as three publicly available sources: 1) the National Hydrography Dataset (NHD) 10 and 12-digit HUCs, 2) NHD stream flowlines, and 3) the U.S. Census Bureau's TIGER roads data. Topeka shiner collection records were gathered from Service offices, state agencies, Universities and consultants.

The first version of the resiliency model analyzed populations known to be occupied since 1999 through 2014, but was missing updated information obtained after 2015. Thus in January 2018, as this first version of the SSA was completed, the resiliency model was updated (Version 2) with data through December 2017 and the information is presented herein. Additional updates to the resiliency model – and this SSA - are anticipated in the future as additional information becomes available.

a) Uncertainties within the Resiliency Model

While the resiliency model provides a relative ranking of Topeka shiner streams based on the best available information rangewide, we recognize that the results do not necessarily depict actual conditions in all areas. The model scope is limited primarily to publicly available information collected across the species' range, and while the data does provide some insight (and relative comparison of Topeka shiner streams), impacts to Topeka shiner populations due to other activities impacting the hydrology of occupied streams (droughts, floods, tiling effluent, pollutants, sedimentation, groundwater connections, lack of riparian buffers, etc.) are lacking and not included in the model.

Additionally, data that is included in the model has limitations. For example, stream crossing structures such as perched culverts that limit movements of Topeka shiners and habitat availability can substantially lower population resiliency, while bridges may not present this problem. Yet, the type of each structure and whether or not it actually poses a barrier for Topeka shiners is data not currently available rangewide and is not analyzed in the model. Road crossings are instead used as an indication of the potential for obstructions to fish passage. Similarly, collection records used in the model to represent the presence of habitat conducive to the species' persistence do not measure true quality or quantity of habitat nor any actual population parameters or trends. That level of data is also not currently available rangewide.

It is important to note that these resiliency rankings are relative to each other, not compared to pristine (pre-European settlement) conditions.   Additionally, due to the small range of points used for scoring, addition or subtraction of a point or two (*e.g.* a recent record is collected or another year passes without a detection) can alter the ranking value of a subpopulation and could lead to a ranking promotion or demotion of a given population.

In short, assumptions made by using these proxy measurements can be significant and lend to inaccuracies in the current model. Ground-truthing and/or the collection of additional habitat/population parameters range wide is needed to improve accuracy. If we are able to acquire more specific range wide data on variables important to the Topeka shiner, that data will incorporated into future versions of the model and updates to this SSA.

b) Results

The results of the resiliency model for each population determined to be occupied 1999-2017 is presented in Table 3 of the resiliency model report (Appendix D, pg 15) and reprinted below (Table 8). Each population is identified by its HUC10 number, name, and the state(s) in which it occurs, with its associated composite score and resiliency ranking. A rank of "1" is the top relative ranking possible (a score higher than 3.66; note that none of the populations attained that ranking), while a rank of "7" (score of ≤ -0.77) is at the bottom of the ranking system.

Table 8. Resiliency model populations: HUC10 identifier, population name, state, resiliency score, and resiliency ranking category.

Population ID (HUC 10)	Population Name	State	Score	Ranking
0710000405	Brushy Creek	IA	-1.00	7
0710000501	Prairie Creek	IA	1.67	4
0710000502	Headwaters Boone River	IA	1.25	4
0710000503	Otter Creek	IA	1.00	5
0710000504	Eagle Creek	IA	1.00	5

0710000506	Ditch 3-Boone River	IA	1.00	5
0710000507	Boone River	IA	0.50	5
0710000604	Indian Creek	IA	0.50	5
0710000605	Camp Creek	IA	1.00	5
0710000606	Lake Creek	IA	2.00	3
0710000607	Purgatory Creek	IA	2.00	3
0710000608	Elk Run-North Raccoon River	IA	-0.33	6
0710000609	Welshs Slough-Cedar Creek	IA	1.33	4
0710000610	Hardin Creek	IA	1.00	5
0710000611	East Buttrick Creek	IA	1.50	4
0710000612	Buttrick Creek	IA	1.33	4
0710000614	Otter Creek-North Raccoon River	IA	0.50	5
0710000615	Swan Lake Branch-North Raccoon River	IA	1.00	5
1017020402	Kanaranzi Creek	IA	1.80	4
1017020403	Champepadan Creek-Rock River	IA	2.17	3
1017020406	Little Rock River	IA	2.00	3
1026000101	Willow Creek-Smoky Hill River	KS	1.00	5
1026000807	Lyon Creek	KS	3.00	2
1027010102	Wildcat Creek-Kansas River	KS	1.00	5
1027010203	Headwaters Mill Creek	KS	0.25	5
1027010204	Mill Creek-Kansas River	KS	0.33	5
1027010205	Deep Creek-Kansas River	KS	2.00	3
1027010207	Mission Creek-Kansas River	KS	2.50	3
1027020502	Horseshoe Creek-Big Blue River	KS	2.50	3
1027020504	Outlet Black Vermillion River	KS	2.50	3
1027020505	Big Blue River-Tuttle Creek Lake	KS	2.00	3
1027020506	Fancy Creek	KS	1.00	5
1027020507	Tuttle Creek Lake-Big Blue River	KS	0.00	6
1107020102	Rock Creek-Neosho River	KS	1.00	5
1107020202	Clear Creek-Cottonwood River	KS	0.00	6
1107020301	Middle Creek-Cottonwood River	KS	0.00	6
1107020302	Diamond Creek-Cottonwood River	KS	1.50	4
1107020303	South Fork Cottonwood River	KS	0.00	6
1017020303	Flandreau Creek	MN	2.25	3
1017020313	Pipestone Creek	MN	2.40	3
1017020315	Beaver Creek-Split Rock Creek	MN	1.50	4
1017020316	Split Rock Creek	MN	2.00	3
1017020401	Headwaters Rock River	MN	1.90	3
1028010210	Sugar Creek-Thompson River	MO	1.50	4
1030010208	Smiley Creek-Moniteau Creek	MO	1.50	4

1021000601	Big Creek-North Loup River	NE	1.00	5
1022000301	Union Creek	NE	2.00	3
1016000408	Lower Elm River	SD	1.50	4
1016000607	Shue Creek	SD	3.00	2
1016000611	Pearl Creek	SD	2.00	3
1016000612	Redstone Creek	SD	2.00	3
1016000613	Sand Creek	SD	1.00	5
1016001104	Dry Run-James River	SD	1.00	5
1016001106	Rock Creek	SD	1.67	4
1016001107	Pleasant Lake	SD	2.00	3
1016001108	West Branch Firesteel Creek	SD	1.00	5
1016001109	Firesteel Creek	SD	2.00	3
1016001110	Enemy Creek	SD	2.00	3
1016001111	Pierre Creek	SD	0.00	6
1016001112	Twelvemile Creek	SD	1.00	5
1016001113	Dry Creek	SD	2.00	3
1016001114	Firesteel Creek-James River	SD	-1.00	7
1016001115	Wolf Creek	SD	1.00	5
1016001116	Lonetree Creek	SD	2.50	3
1016001117	Dawson Creek	SD	2.00	3
1017010204	Lower East Fork Vermillion River	SD	1.00	5
1017010205	Upper West Fork Vermillion River	SD	1.50	4
1017010206	Lower West Fork Vermillion River	SD	1.00	5
1017010209	Hurley Creek	SD	0.00	6
1017010210	Long Creek	SD	2.00	3
1017010211	Upper Vermillion River	SD	1.50	4
1017010212	Turkey Ridge Creek	SD	2.50	3
1017010213	Blind Creek	SD	2.00	3
1017010214	Frog Creek	SD	0.00	6
1017010220	Lower Vermillion River	SD	2.00	3
1017020107	Willow Creek	SD	3.00	2
1017020108	Stray Horse Creek	SD	1.50	4
1017020204	Hidewood Creek	SD	3.00	2
1017020206	Sixmile Creek	SD	2.00	3
1017020207	North Deer Creek	SD	0.67	5
1017020209	Deer Creek-Medary Creek	SD	2.00	3
1017020210	Medary Creek	SD	2.33	3
1017020211	Upper Big Sioux River	SD	2.00	3
1017020301	Spring Creek	SD	2.00	3
1017020306	Brookfield Creek-Big Sioux River	SD	3.00	2
1017020314	West Pipestone Creek	SD	2.00	3

1017020317	Ninemile Creek-Big Sioux River	SD	2.00	3

A color map of the range-wide distribution of those populations is provided in the resiliency model report (Appendix D) and is also reprinted below (Figure 29).

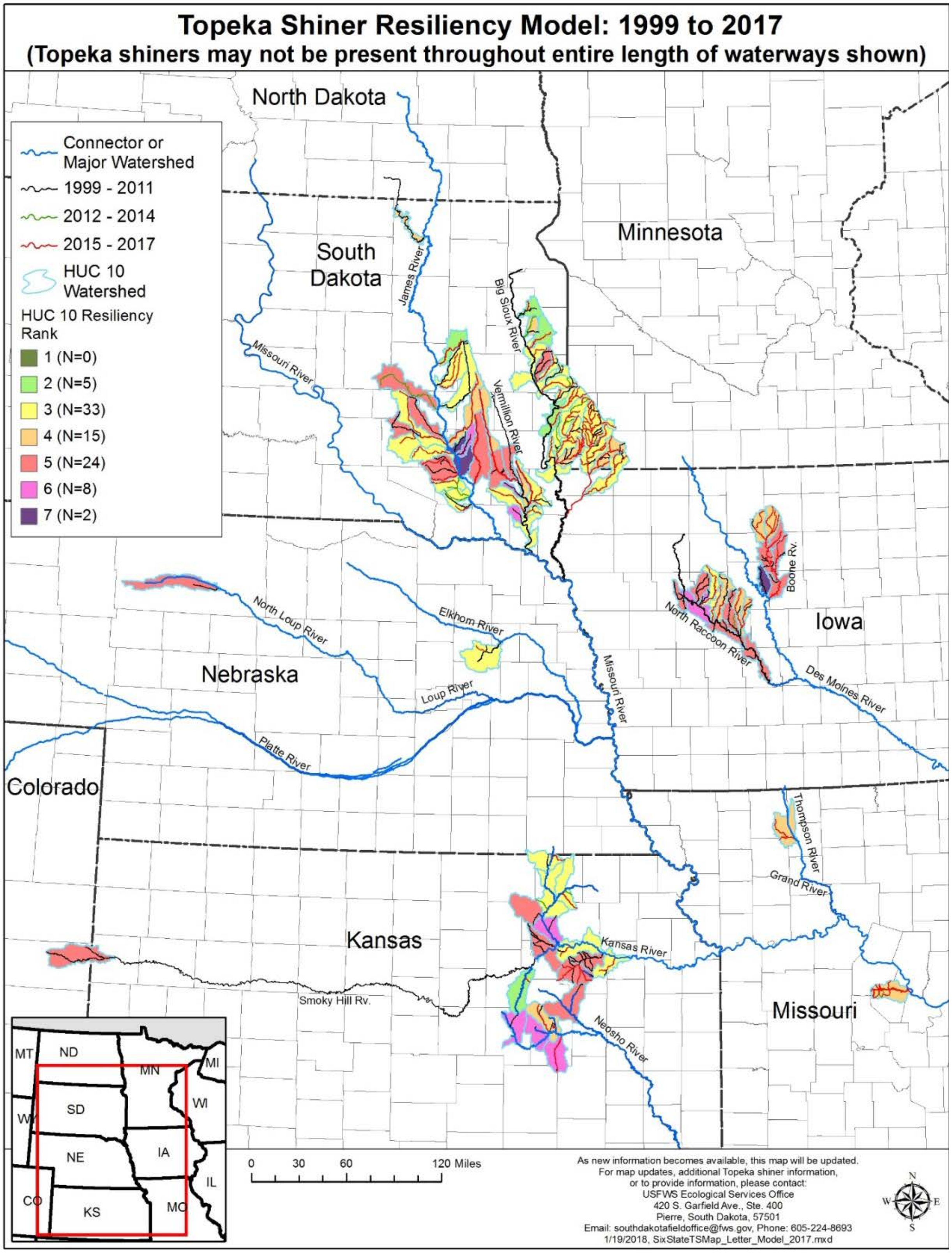


Figure 29. Topeka shiner range wide resiliency scores; broad view comparing all known extant populations, 1999-2017, per the Population Resiliency Model, Topeka shiner (Notropis topeka), Version 2.

For color maps of subpopulations and populations analyzed by state, refer to the resiliency model report (Appendix D).

2. Population Complex Resiliency

The resiliency model incorporated information about subpopulations (HUC12s) and populations (HUC10s), but the model was not scaled up to the level of population complexes. Resiliency of population complexes as a surrogate for metapopulations is an important consideration. Metapopulations of the Topeka shiner are defined in the resiliency report as: "Populations within a larger watershed (*i.e.*, HUC-8 or larger) that have potential connectivity at some unknown level and frequency via existing waterways, but separated by habitat, conditions, and/or substantive obstructions not typical to the species". Because we cannot be certain of the interactions within these areas, herein we use the proxy of population complexes (based on existing or potential hydrologic connections that could allow movements between populations) for true metapopulations. Population complexes could afford sources for recolonization after extirpations, or bolster extant populations (assuming the presence of suitable habitat, refugia, and connectivity among the populations), and improve the overall resiliency of the group, increasing the probability of long-term persistence.

We have delineated 13 Topeka shiner population complexes for the purposes of evaluating their current resiliency (Figure 15 above) and; the complexes comprise the 87 populations evaluated in the resiliency model. To rank the population complexes, we used population scores from the resiliency model and number of populations composing each population complex to establish a normalized relative ranking of the complexes (Table 9). This method was applied when it became clear that using simple average composite scores to determine the resiliency ranking of the population complexes would result in high scores for those complexes with very few, but relatively highly scored individual populations. The results were not reflective of the relative status of those population complexes. Our alternative method included the following steps:

- First, we tabulated the number of populations composing each population complex and the average resiliency model composite score of their populations.
- We then calculated a weighting factor based on the number of populations within each complex divided by the total number of populations across the Topeka shiner range (n=87). Our assumption is that populations with more complexes should rank higher relative to population complexes with fewer populations.
- The resulting values were then multiplied by the average composite score to determine a weighted average composite score for each population complex.

- To simplify the ranking, we normalized the weighted average composite score: the highest score was assigned a value of 100 and the lowest score was assigned a value of 0 with those in-between scored proportionately.
- Finally, population complexes were sorted from highest to lowest based on their normalized average resiliency ranking weighted by the redundancy of populations within each complex.

Table 9. Population complexes in northern and southern parts of the range, number of HUC10 populations that compose each complex, average score of those populations, and resulting resiliency ranking per the Population Resiliency Model, Topeka shiner (Notropis topeka), Version 2.

Population Complex (Northern or Southern)	Number of Populations (HUC10s) within Complex	Average Composite Score of Populations within Complex	Complex Weighting (# Complex Pops./# Total Pops)	Weighted Average Composite Score (Complex Weighting x Average Composite) Score)	Normalized Rank (0-100)
Big Sioux River (Northern)	16	2.10	0.18	0.39	100
James River (Northern)	18	1.48	0.21	0.31	79
Kansas River (Southern)	11	1.55	0.13	0.20	49
Vermillion River (Northern)	10	1.35	0.12	0.16	38
North Raccoon River (Northern)	11	1.076	0.13	0.14	33
Rock River (Northern)	4	1.97	0.05	0.09	21
Des Moines / Boone Rivers (Northern)	7	0.77	0.08	0.06	14
Cottonwood River (Southern)	5	0.50	0.06	0.03	5
Elkhorn River (Southern)	1	2.00	0.01	0.02	3
Thompson River (Southern)	1	1.50	0.01	0.02	2
Moniteau Creek (Southern)	1	1.50	0.01	0.02	2
North Loup River (Southern)	1	1.00	0.01	0.01	0
Smoky Hill River (Southern)	1	1.00	0.01	0.01	0

To further evaluate the context of the above rankings, they were divided into quartiles as a means to demonstrate the distribution of rankings among the complexes (Table 10).

Table 10. Number of population complexes per normalized population rank quartile.

Normalized Population Complex Rank Quartiles	Number of Population Complexes within each Quartile
1 (75-100)	2
2 (50-75)	0
3 (25-50)	3
4 (0-25)	8
Total	13

The majority of all population complexes (11 of 13, 85%) occur in the bottom 50% of the population complex ranking system. Further, a majority (8 of 13, 62%) of population complexes are also fall within the fourth (lowest; 0-25%) quartile. A categorical break in the normalized ranking exists as the two top-ranked population complexes are separated from the next lowest ranked complexes by a 30 point margin. The large gap between the top two ranked complexes and the complexes below them, as well as the high number (a majority) of complexes within the lowest quartile, appear to demonstrate most population complexes fall short of their potential.

B. Redundancy

State tallies of populations and subpopulations are summarized above in Chapter 5 and occupied streams are listed in Appendix C. The total number (as of December 2017) of occupied streams throughout the entire species range where the species has been detected at least once between 1999 and 2017 is 223. The corresponding number of occupied HUC10 populations that encompass those streams is 87. The number of delineated population complexes that comprise those populations is 13.

1. Population Redundancy by Rank

Using the resiliency model, the number of Topeka shiner populations assigned each resiliency ranking category are shown below in Figure 30.

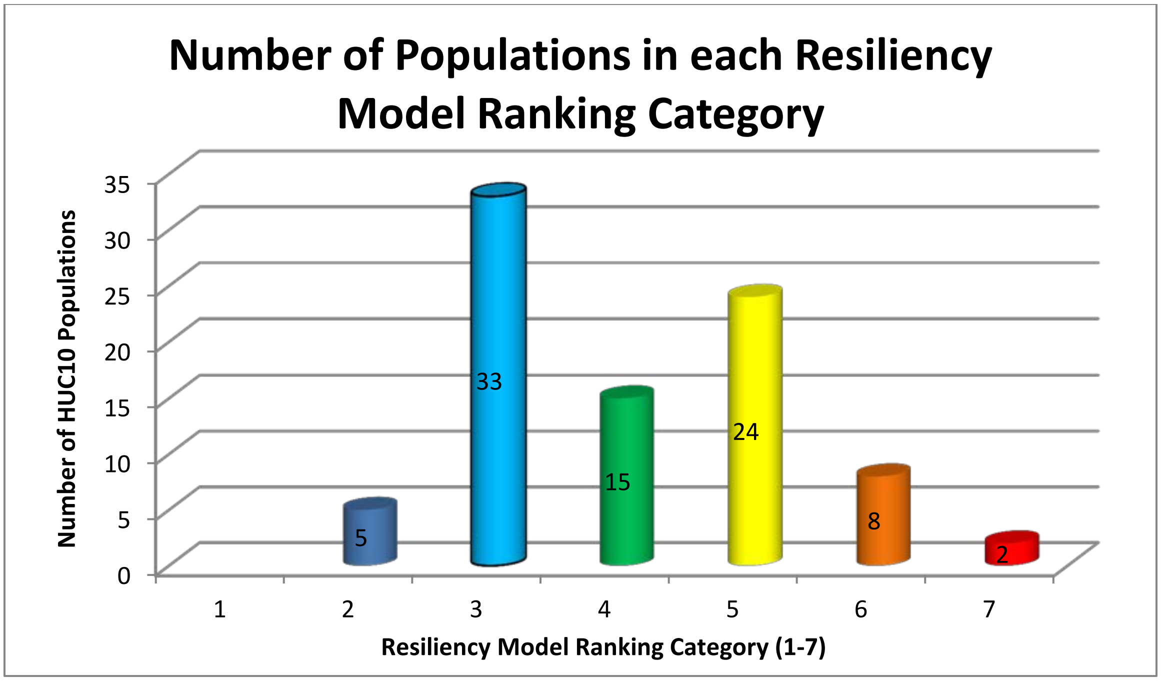
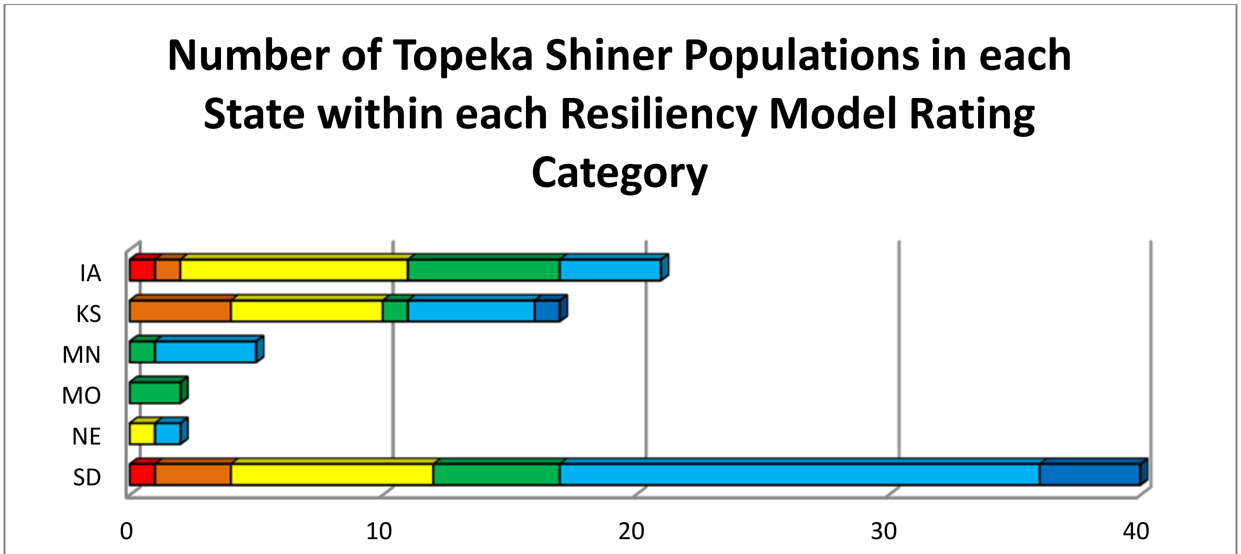


Figure 30. Number of Topeka shiner populations within each resiliency ranking category (1 (highest rank) to 7 (lowest rank)) per the Population Resiliency Model, Topeka shiner (Notropis topeka), Version 2.

The majority (72 of 87; 83%) of Topeka shiner populations across the range fall within the three middle categories of the resiliency model ranking system: 3 (n=33, 38%), 4 (n=15, 17%), and 5 (n=24, 28%). Lower categories of 7 (n=2, 2%) and 6 (n=8, 9%) applied to ten (11%) of populations, while the top ranked categories of 1 and 2 (combined because no population attained a rank of 1) were composed of only 5 (6%) of the populations. These rankings are relative to each other, not compared to pristine conditions, and as noted in the resiliency model report (Appendix D), they are based on publicly available data which is used as a proxy for site specific, ground-truthed information.

The majority of populations are contained entirely within a given state, although some cross state borders between Minnesota/South Dakota and Minnesota/Iowa (see state-by-state summaries under Distribution and Trends section above). Figure 31 indicates the number of extant Topeka shiner populations in each of the resiliency model ranking categories by state, with those populations that cross state borders assigned to only one state to avoid double-counting.

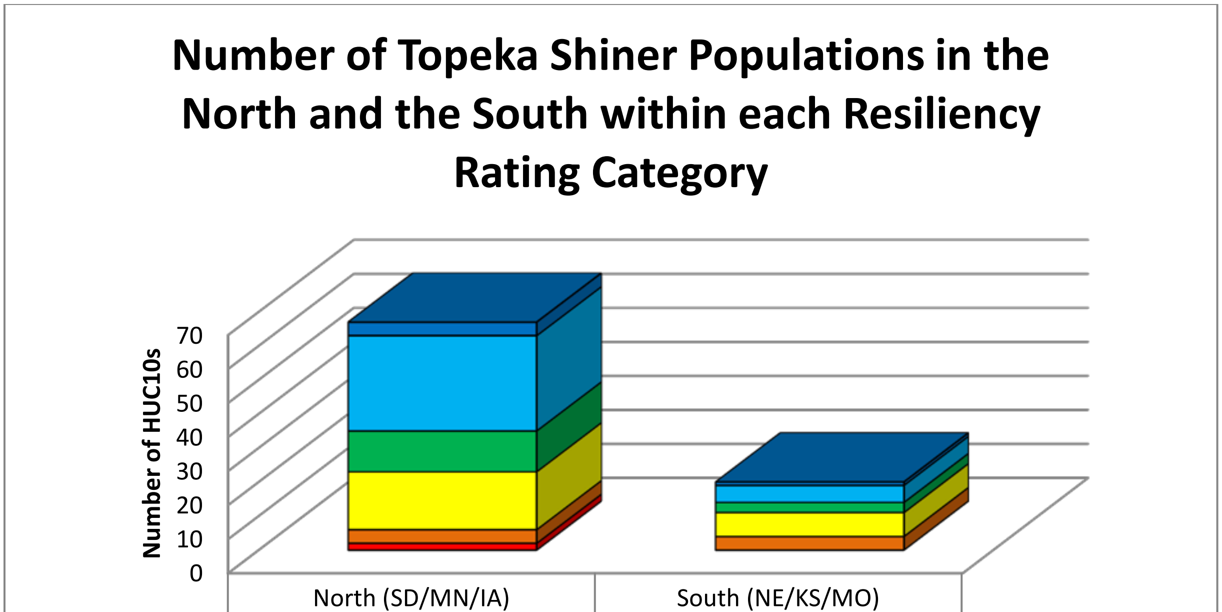


	SD	NE	MO	MN	KS	IA
7	1					1
6	3				4	1
5	8	1			6	9
4	5		2	1	1	6
3	19	1		4	5	4
2	4				1	

Figure 31. Number of Topeka shiner populations by state within each resiliency ranking category per the Population Resiliency Model, Topeka shiner (Notropis topeka), Version 2.

Note that no populations achieved the top rank of “1” and populations that cross state lines are assigned to only one of the states in which they occur to avoid duplication.

Given the long-recognized discrepancy in persistence of northern Topeka shiner populations compared to southern, analysis by these regions is warranted. Figure 32 uses the state tallies above, and combines them into northern glaciated areas (South Dakota, Minnesota, Iowa) and southern areas (Nebraska, Kansas, Missouri).



	North (SD/MN/IA)	South (NE/KS/MO)
1		
2	4	1
3	28	5
4	12	3
5	17	7
6	4	4
7	2	

Figure 32. Number of Topeka shiner populations within each resiliency ranking category per the Population Resiliency Model, Topeka shiner (Notropis topeka), Version 2, that occur in northern versus southern areas.

Of the 87 populations evaluated in our resiliency model, 67 (77%) are within the northern part of the range (South Dakota, Minnesota, Iowa) that were subject to the most recent glaciation in North America, with the remaining 20 populations (23%) in the south (Nebraska, Kansas and Missouri) which did not experience this glaciation. Other observations include the following:

- As noted above, no populations in either part of the range achieved the top (1) resiliency model ranking.
- Five were assigned the second highest ranking (2): four in the north, one in the south.
- Populations assigned middle ranking values of 3, 4, and 5 (n=28, 12, and 17 respectively) compose 85% of northern populations and 75% of southern populations (n=5, 3, and 7 respectively).
- The second-lowest ranking value was assigned to eight populations: four in the north and four in the south.
- Two populations were ranked lowest on the resiliency scale (7), both in the north.

The distribution across the landscape of the various resiliency rankings is somewhat balanced (*i.e.* the majority of populations in both areas are assigned middle rankings with some upper and lower rankings occurring in both areas as well). However, the north does harbor a greater number and proportion of populations ranked higher on the resiliency scale than the south. This type of skewed redundancy could be problematic; catastrophic events in the north could have a disproportionate impact to the resiliency of the species as a whole.

2. Population Complex Redundancy by Rank

Thirteen Topeka shiner complexes have been identified herein and at least two complexes remain within each of the six states in the Topeka shiner's range, thus the redundancy of population complexes themselves, without consideration of their resiliency, is relatively uniform (Figure 15 above). However, as described above, the resiliency of these complexes was determined by incorporating the number of populations within each complex and their weighted average resiliency scores. Population complexes scores were then obtained, ranked, and normalized on a scale of 0-100, and the normalized scores were divided into quartiles for further evaluation. Redundancy of ranked population complexes, expressed as number of population complexes per quartile distributed within each state and in northern/southern areas is provided below (Table 11).

Table 11. Number of population complexes ranked within each resiliency ranking quartile, per state, in northern and southern parts of the Topeka shiner's range.

	STATE	NORMALIZED POPULATION COMPLEX RESILIENCY RANKING QUARTILES and NUMBER OF COMPLEXES IN EACH				TOTAL
		1 (75-100)	2 (50-75)	3 (25-50)	4 (0-25)	
Northern Areas	South Dakota	2	-	1	-	3
	Minnesota	-	-	-	1	1
	Iowa	-	-	1	1	2
Southern Areas	Nebraska	-	-	-	2	2
	Kansas	-	-	1	2	3
	Missouri	-	-	-	2	2
-	TOTAL	2	-	3	8	13

Note: Two population complexes cross state borders between states: the Big Sioux River complex (SD and MN) and the Rock River complex (MN and IA). To preclude double-counting, the Big Sioux River was evaluated as occurring in SD but not MN, and the Rock River was evaluated as occurring in MN but not IA.

While population complexes are distributed relatively evenly throughout the range, the resiliency of those complexes varies significantly; more population complexes with higher resiliency rankings occur in northern areas than southern. Northern complexes occur in greater proximity than southern complexes as well (Figure 15 above). However, the distribution of all

13 population complexes is relatively widespread and the risk of the species to a single catastrophic event is likely low as a result.

C. Representation

1. Genetic Diversity

Representation of the Topeka shiner was assessed using existing genetics literature and an interpretation of that literature provided by conservation genetics staff within the Service. At this time, available Topeka shiner genetics literature included papers from the following authors (a one-line summary of each work is provided): listed with a short summary of their work):

- Bruce (1988) – evaluated Topeka shiners from three Kansas drainages using starch-gel electrophoresis
- Li and Gold (1991) – used chromosomal nucleolar organizer regions to show relatedness among three minnow species, including Topeka shiner
- Schmidt and Gold (1995) – used sequences from Topeka shiner cytochrome *b* gene to determine systematics
- Bergstrom *et al.* (1999) – used several methods to determine systematics and genetic distinctness among Topeka shiners in three occupied areas of Missouri
- Michels (2000)- applied mtDNA to evaluate population structure and phylogeography of Topeka shiners rangewide
- Anderson and Sarver (2008) – developed polymorphic microsatellite loci for Topeka shiners
- Sarver (2007) – used microsatellites to evaluate genetic health of Topeka shiners rangewide
- Blank *et al.* (2011) – used microsatellites to determine variation within/among Topeka shiner populations in South Dakota

Not all of the genetic studies above were pertinent to representation of the Topeka shiner; two publications (Schmidt and Gold 1995, Li and Gold 1991) focused on taxonomy of Topeka shiners and other species. These were informative papers, but not directly applicable to the question of Topeka shiner adaptability.

While not all of the remaining studies above yielded perfectly aligned results (*e.g.* Michels' (2000) mtDNA study lumped Topeka shiners in the Rock River with those in the Big Sioux River, while Sarver's (2007) microsatellite results indicate individuals in those basins could be separated), four studies (Bruce 1988, Bergstrom *et al.* 1999, Michels 2000, Blank *et al.* 2011) found significant population structure in Topeka shiners at a fine scale, meaning individuals among sampling point or points in a local area were typically found to be genetically distinct from other local sampling point(s). Some exceptions exist, but small sample sizes were noted as complicating factors, and the pattern of differentiation at the fine scale was noted in each state within the Topeka shiner's range with exception of Nebraska (no genetic information is available from Topeka shiners in Nebraska). As noted earlier, the species' own tendency to occupy small streams rather than the larger rivers that connect them likely contributes to this genetic differentiation (Michels 2000), as does the addition of anthropogenic factors that further restrict Topeka shiner movements (*e.g.* dams).

Significant differences in population structure were also noted at a larger (major watershed) scale by Michels (2000) and Blank *et al.* (2011). Michels (2000) noted three distinct groups of Topeka shiners with nearly complete lack of shared haplotypes (Arkansas, Kansas/Lower Missouri, and Upper Missouri/Des Moines), indicating complete isolation of these groups. The Arkansas group and the Kansas/Lower Missouri group fall within the southern range of the Topeka shiner, while the Upper Missouri/Des Moines group is in northern part of the range. This information provided insight to relatedness of Topeka shiners in these regions and shed light on how the species may have moved historically into its known established range. However, lack of specimens from Nebraska, and additional results determined after the Michels (2000) document was completed (Anne Michels, personal communication, 2014) indicated some adjustments to the grouping in Michels (2000) may be warranted.

Blank *et al.* (2011) noted further genetic divisions among Topeka shiners within the Upper Missouri River Basin: James, Vermillion and Big Sioux River watersheds. Both of these studies noted that genetic diversity of Topeka shiners in the Upper Missouri River (northern) populations was relatively low, although a more thorough understanding of genetic diversity across the Topeka's range is needed.

As of this writing, a Topeka shiner genetic study is ongoing at Iowa State University in Ames, Iowa, with the results anticipated by the spring of 2018 (Kevin Roe, Iowa State University, personal communication 2017). Topeka shiner genetic samples for that study were obtained from most of the range, with exception of Kansas, but the study does include Topeka shiner samples from Nebraska. Nebraska Topeka shiner populations have not yet, to our knowledge, been genetically analyzed. The project goals are to use microsatellite markers to examine the species' genetic structure at the range-wide population level, at the basin level in Iowa and Minnesota, and to test for metapopulation structure within basins in Iowa. The genetic information obtained from that study may be useful in recovery planning for the Topeka shiner, particularly to refine representative units described herein, if appropriate.

It is important to note that genetics do not necessarily dictate boundaries of populations; the population structure across the landscape must be examined and genetic diversity within that structure must be estimated. While differentiation between sampling localities appears to be established for the Topeka shiner, little information is available regarding the amount of genetic diversity within each population.

Genetic diversity (heterozygosity and number of alleles) is an important component to long-term viability of populations. Average heterozygosity is a good measure of the expected response of a population to natural selection and can also provide an estimate of individual inbreeding coefficient. The number of alleles remaining in a population is important for the long-term response to selection and survival of populations and species (more genetic combinations in the face of environmental change is better than none or a few) – hence a larger more genetically diverse population should be more resilient to deterministic environmental changes such as habitat loss, overexploitation, global climate change etc. than a small population lacking genetic diversity.

Similarly, a more genetically diverse population typically coincides with a larger population size, and a decreased potential for inbreeding (which can lead to reductions in fitness even in the absence of environmental stresses). The locality doesn't matter as much as the status and diversity of the population and or species as a whole – hence the necessity to define populations across the landscape. The more populations that are resilient via genetic diversity across the landscape, the more resilient the species as a whole will be.

It is rare to actually be able to link traits/genes with specific environmental conditions. If it were possible, managing for specific traits is akin to tinkering without knowing how all the parts work and could lead to problems. Therefore, retaining the total diversity within populations and the entire species is recommended, while limiting artificial selection.

Genetic diversity is created by mutations or introduced into a population through gene flow (*e.g.* individuals interbreeding between populations). To increase the genetic diversity of an isolated population would be arduous because the mutation rate is often extremely low for most organisms and gene flow would be unlikely or extremely rare. Artificial gene flow (stocking fish from another genetically distinct population) carries the risk of outbreeding depression and may actually do more harm than good through reductions in fitness. As mentioned above, there is an inverse relationship between maintenance of genetic diversity and population size; therefore, maintaining or increasing the population size over time for isolated populations, and ensuring connectivity in maintained between currently connected populations are likely the few ways to provide the greatest probability of adaptability of the Topeka shiner in the future. Thus, understanding critical habitat *[note: critical habitat in this context is used descriptively, not in terms of its formal designation under ESA]* will be important, as well as maintaining it or increasing it over time (increasing habitat should increase carrying capacity and hence minimize loss of genetic diversity). In contrast, declines in population sizes due to habitat degradation, etc., are predicted to result in loss of genetic diversity and increased inbreeding is likely to cause reductions in reproductive performance of the population. This in turn is likely to cause a further reduction in population size and would in theory be less likely to adapt to environmental changes due to the reduction in genetic diversity.

Existing studies do not cover the entire range of the Topeka shiner; genetic samples are not available from every occupied stream. No genetic information is available from Topeka shiners in Nebraska, although given the genetic differentiation found elsewhere and the isolative nature of Nebraska populations, for purposes of this SSA assessment, Nebraska populations are likely distinct from each other and from populations in other states as well.

As mentioned previously, via their association with headwaters Topeka shiners exhibit a level of self-isolation, precluding mixing with other surface-water-connected populations as they avoid inhabiting downstream waters unsuitable for their life-history needs. Existing genetic studies reflect this, as distinctions have been detected between populations that are located adjacent to each other yet connected via surface waters (Michels 2000). Gene flow among populations has undoubtedly been further restricted by anthropogic actions that impede movement, create unsuitable habitats, and reduce population size. Additional genetic analysis could be applied to this species that may shed more light on the definition of a population that we have applied herein, potentially redefining it at a smaller scale than we have proposed for the purposes of this SSA.

The primary take home messages regarding Topeka shiner representation:

- much genetic diversity in the Topeka shiner as a species has likely been lost as populations, particularly in the south, have been extirpated,
- genetic differentiation exists between extant populations at fine (localities), intermediate (watersheds that harbor those localities), and large (basins that cross state boundaries and combine major drainages) scales,
- information regarding genetic diversity is limited within populations, but differences occur between populations
- northern populations may exhibit less variation than southern
- the greatest conservation benefit to the species, genetically, includes ensuring additional diverse populations are not eliminated

Opportunities exist for additional research studies with application of additional methods to help increase the level of confidence of population structure in the studies that used mtDNA and microsatellites. Additional analysis of raw data from studies such as those by Michels (2000), Sarver (2007) and Blank *et al.* (2011) could potentially result in a clearer picture of Topeka shiner population structure.

2. Ecological Diversity

The Level I Ecoregion overlaying the vast majority of the Topeka shiner's range is the Great Plains Ecoregion (U.S. EPA 2017), but there is variability within this Ecoregion. Nested within the Level I Ecoregions, are higher numbered Ecoregions with increasingly finer scales of differences between them. The Topeka shiner occupies five Level II Ecoregions, eight Level III Ecoregions, and fourteen Level IV Ecoregions all with some variations in the existing mosaic of biotic, abiotic, terrestrial and aquatic ecosystem components (see Table 5 for Level III and IV Ecoregions that overlap with Topeka shiner populations). The general habitat type used by the Topeka shiner is similar across its range (*i.e.* prairie streams with pools, gravel, low flows), yet to survive, the Topeka shiner would have had to adapt to the fine differences of nested Ecoregions within the Great Plains during its evolutionary history. Such adaptation affords diversity that is beneficial to the species.

Generally, the temperatures of northern occupied areas are lower than within southern areas, and eastern portions of the range receive greater precipitation than more westerly areas. Future climate models predict precipitation differences may be exacerbated within the Topeka shiner's range in the future (*e.g.* wetter in the north, drier in the south) (Appendix A, 2014 Workshop Notes, Dennis Todey). The most recent glaciation may also have contributed to more groundwater input to streams in northern populations compared to southern areas that were not impacted during the last glacial period (Wall *et al.* 2001). Off-channel habitats are utilized by the species in northern areas (Thompson and Berry 2009, Bakevich *et al*. 2013, Hatch 2001), but these habitats are not generally present in the south (Nebraska, Kansas, or Missouri) (George Cunningham, personal communication, 2014; Kerns and Bonneau 2002; Paul McKenzie, USFWS, personal communication, 2014). The cooler and wetter climate of the north, coupled with relatively more groundwater input and additional pools outside the channel, may partially explain why there have been fewer losses of populations in northern areas than in the south.

Thus, although small, headwater prairie streams with gravel substrate and low flows are the general habitat type required by the Topeka shiner, the species' six-state range includes some variation in the biological, geological, physical, and climatic features to which the species has adapted.

CHAPTER 3: TOPEKA SHINER FUTURE CONDITIONS

I. Conservation Considerations

Although the Topeka shiner has declined overall since listing, ESA protections have resulted in beneficial actions taken throughout the range that otherwise would not have occurred, including the development of State management plans and monitoring efforts, individual and programmatic consultations that avoid/minimize impacts resulting from federal actions, research studies on life history/habitat/physiology/genetics, construction of off-channel habitats, captive rearing of the species, and reintroductions.

More actions are required, however, to contribute to long-term viability of the species. One item currently lacking that would serve as a basis for conservation actions is a standard monitoring protocol for the Topeka shiner. While Minnesota, South Dakota, and Missouri have implemented monitoring plans, their efforts have varied in timing, methods, and amount/type of data gathered. South Dakota harbors the highest number of occupied streams, making surveying all streams annually infeasible, but the monitoring efforts to date have not allowed the identification of trends in Topeka shiner populations. The ability to observe trends over time is critical to determining the status of the species and the effectiveness of any management actions taken. Minnesota's sampling protocol, established based on discussions among Topeka shiner Recovery Team members, included 20 randomly chosen 1-mile segments on an annual basis has allowed identification of trends, as have the annual surveys of established locations in each of Missouri's occupied streams. However the methods, timing, and protocol of these two State monitoring efforts differ substantially and are not necessarily comparable. Although occasional surveys are conducted in the States of Kansas, Nebraska, and Iowa that document continued presence of the species in some streams, these states currently do not implement systematic monitoring. A standard monitoring protocol to be implemented throughout the Topeka shiner's range is needed to establish reliable data collection regarding species presence and trends comparable among the states and populations, allowing for high confidence in the future status of the species. Given differences that exist among states (*e.g*. habitat differences, staffing, climate, funding) there may be a need to maintain some flexibility within this protocol, yet ensure the data collected is comparable and useful in tracking Topeka shiner populations.

Additional information is also needed regarding Topeka shiner habitat conditions throughout the range, which would allow for identification of areas in most need of conservation efforts. Information is lacking regarding the amount, quality, and accessibility of habitat available for this species. Further investigation into the impacts of altered stream hydrology on the Topeka shiner is particularly relevant as this has been identified as the dominant factor in the species' decline. Improving our understanding of Topeka shiner genetics would also be helpful in understanding connectivity that led to today's occupied range, and help guide potential future reintroductions and/or augmentations.

Beyond data gathering, efforts to continue and improve upon ongoing conservation actions and protections for the species and its habitat are needed. In order to fill gaps in the species' range, more captive rearing facilities may be necessary to facilitate reintroductions in areas formerly occupied by the species that are inaccessible now. Private landowner involvement will likely be critical, both for habitat improvements and reintroduction efforts; expansion of landowner education and incentives programs are needed to allow partnerships for the improvement and management of streams and riparian zones to benefit the Topeka shiner. Efforts to achieve more natural instream habitat conditions within current and former occupied areas are needed to increase occupancy, allow greater survival, and restore source populations for recolonization after stochastic and catastrophic events; reintroductions would be required to overcome current barriers of physical and geographic nature.

Long-term viability of the Topeka shiner range-wide would require improvements relative to:

- habitat quality
- habitat quantity
- habitat accessibility
- barriers
- predators
- refugia
- isolation

Potential conservation actions may include, but are not limited to the following:

- Install, conserve, and/or protect vegetated stream buffer strips on Topeka shiner streams
- Restore sinuosity and natural morphology of channelized streams in Topeka shiner occupied watersheds
- Enforce water quality standards and mitigation strategies to protect Topeka streams from surface and subsurface runoff
- Apply technologies to reduce tiling impacts by controlling drainage: install artificial ponds to receive tile water, filter contaminants, meter water out to the streams/groundwater or place control structures on tile outlets to manage flows and reduce hydrologic impacts to streams
- Regulate irrigation or other water withdrawals in Topeka shiner watersheds to ensure

stream flows and refugia for the species

- Fence cattle to preclude instream/riparian zone over grazing of Topeka streams; promote off-channel water sources for livestock
- Revise CAFO regulations to preclude stream contamination; regulate overland spreading of CAFO waste as fertilizer
- Cease installation of dams and/or remove existing dams or other barriers in Topeka shiner occupied habitats
- Install fish-passage friendly stream crossings and replace existing problematic structures
- Cease stocking of predatory fish in Topeka shiner occupied watersheds and/or remove from Topeka shiner habitat
- Create off-channel habitats in occupied streams with connection to groundwater
- Develop additional captive rearing facilities and implement reintroductions and population augmentations
- Preclude instream gravel mining from Topeka shiner streams
- Develop urban management plans to avoid/minimize/mitigate development impacts to Topeka shiner streams

Partnerships with Federal agencies, such as the Natural Resources Conservation Service (NRCS) or Farm Services Agency (FSA) to promote existing programs and/or develop additional incentives to conserve prairie streams and their riparian zones would benefit the species. Within the Service, the Partners Program works with landowners to implement projects that improve habitats for the Topeka shiner. State partnerships also are necessary components of conservation efforts; state and local landowner support are keys to implementation of conservation measures in each of the six-state range, particularly regarding monitoring and reintroduction efforts. Non-government organizations may also play a role, particularly those such as the National Fish Habitat Partnership which focuses on protecting, restoring and enhancing aquatic communities for fish conservation.

Many conservation activities for the Topeka shiner would not be required by law, but some can be accomplished by existing legal means. Enforcement of conservation laws that would benefit the Topeka shiner is an important factor in the success of such efforts. Minnesota had enacted a progressive shoreland management rule with a 50-ft buffer along public waterways (http://www.dnr.state.mn.us/waters/watermgmt_section/shoreland/index.html). While this rule could have provided substantial benefits to aquatic life, including the Topeka shiner, poor compliance was determined to be problematic (EWG 2014). In 2015, Minnesota enacted a Buffer Law (https://mn.gov/portal/natural-resources/buffer-law/), amended in both 2016 and 2017, which established a 50-foot average/30-foot minimum vegetated buffer along public waters and a 16.5 buffer adjacent to public drainage systems. This law establishes penalties and enforcement actions and has the potential to be much more effective than the early shoreline buffer rule. South Dakota's buffer law could also afford benefits to Topeka shiners but only if enrollment in the program is significant; the law applies to buffers along many Topeka shiner streams in eastern South Dakota. This law is dependent on voluntary actions; property tax breaks are provided to landowners who choose to register their riparian buffer properties, but the law itself does not require anyone to establish riparian buffers.

As noted in the Current Conditions section, off-channel habitats are being created in Iowa and Minnesota as year-round habitat and refugia for the Topeka shiner. The use of off-channel habitats by the species is known to occur primarily in northern parts of the range (South Dakota, Minnesota, and Iowa) where such habitat already exists and re-creating off-channel sites with groundwater input has been a successful effort in attracting and harboring the species. Application of this strategy to improve reproduction, recruitment, and survival in Nebraska, Kansas, and Missouri has not yet occurred, and off-channel habitat is generally lacking in these states, potentially due to differences in geologic history with the more recent glaciation in northern areas having resulted in conditions conducive to this type of habitat with groundwater input. In southern areas lacking recent glaciation, or areas where streams are incised and unlikely to support surface waters in the floodplains, off-channel habitat creation may not be possible. Topeka shiner would likely use these areas if available, however, and created off-channel areas could serve as a particularly useful conservation tool in southern areas most impacted by low flows and lack of refugia, provided conditions are amenable to off-channel habitat establishment.

Captive rearing methods for the Topeka shiner have recently been improved. The Lost Valley Fish Hatchery in Missouri applied two new propagation measures, beginning in 2015: (1) portable cemented-gravel spawning mats, and (2) male (only) orangespotted sunfish. The individual spawning mats, approximately 1 x 2 ft. (0.3 – 0.61 m) in size, are made of cemented gravel and placed atop coconut fiber textile mats within brood-stock ponds. Male orangespotted sunfish are then introduced, along with both male and female Topeka shiners. Despite the absence of female sunfish, the male sunfish establish and defend nest sites. This behavior allows the Topeka shiners to reproduce normally, spawning on the periphery of the sunfish nests. When Topeka shiner eggs are observed on the gravel mats (and/or textile mats which capture any fall-outs from the gravel substrate) the structures are removed from the brood stock pond and placed in a nursery pond where eggs can hatch and the young Topeka shiners can develop without risk of predation. Since no sunfish eggs are spawned and the Topeka shiner eggs are isolated prior to hatching, sorting of Topeka shiner fry from orangespotted sunfish fry is unnecessary, improving efficiency and further reducing Topeka shiner losses. These methods are overall more effective than traditional measures in producing

Topeka shiners at the Lost River Valley hatchery (Lost Valley Hatchery 2016). The Neosho National Fish Hatchery in Missouri also adopted these techniques at their facility in 2017 (USFWS 2017).

II. Future Scenarios

In this part of the SSA, we develop future scenarios to project what the species status may look like in the future in terms of the 3Rs, given various threats and conservation actions.

After the Topeka shiner was listed in 1999, additional populations were discovered in South Dakota which led to a more optimistic view of species viability; however, Topeka shiner populations have continued to decline since that time, particularly in southern parts of the range. Some conservation measures implemented since listing have focused on improving and expanding Topeka shiner populations (*e.g.* reintroductions in Missouri, off-channel habitat creations in Iowa and more recently in Minnesota). Generally speaking, however, most Topeka shiner ESA actions to date have been the result of consultations under section 7(a)(2)of the ESA. This ESA section requires federal agencies to consult with the Service and ensure their activities (including those they conduct themselves as well as those they may fund, authorize or permit) do not jeopardize the continued existence of the species. The focus in the consultation process is often limited to avoidance and minimization of impacts of activities subject to federal purview, with limited actions to proactively improve the status of the species.

Because the Topeka shiner is already listed and receiving ESA protections, the future scenarios herein relate to the potential implementation of possible future conservation actions focused on fostering long-term viability of the species. These future scenarios assume that some level of conservation actions would be taken within the states harboring the species, and likely involve partnerships at multiple levels to improve the long-term resiliency, redundancy and representation of the Topeka shiner throughout its range. The extent to which these actions are implemented will significantly affect the potential for long-term viability of the species. Thus, in this section we evaluate the species status in terms of the degree to which the benefits from anticipated future conservation efforts are realized, or not.

The scenarios also identify portions of the range where conservation measures would be most beneficial in terms of improving the species' status. Many of the actions identified in the *Conservation Considerations* section (above) would be appropriate for application in all of the states with occupied Topeka shiner streams. For example, the majority of occupied Topeka shiner watersheds are dominated by agricultural land use which is the primary overarching activity that has, and continues to, negatively impact Topeka shiner streams. Other threats to the species (*e.g.* improperly sized/placed stream crossings) are ubiquitous across the range as well.

However, some activities are more problematic for the Topeka shiner in certain states or parts of the range (*e.g.* dams and predatory fish stocking in the south), and the most significant losses of populations, population complexes, and retraction of range to date have occurred in southern portions of the species' range (Nebraska, central Iowa, Kansas, and Missouri). Most Topeka shiner populations are contained within a single state; the only Topeka shiner populations that cross State lines are limited to those within streams originating in Minnesota (10 shared with South Dakota and 3 shared with Iowa). This is important because each state has demonstrated their own varied approaches to Topeka shiner conservation ranging from annual monitoring of every occupied stream and active reintroductions (Missouri) to no action (Nebraska). Further, the Topeka shiner geographic range covers a large portion of the Great Plains, with climatic and geologic differences that may support the need for a variety of conservation approaches.

Given these factors, the future scenarios described below are based on potential conservation actions to be applied by federal, state, and/or local agencies; landowners; non-government organizations; and any other potential partner willing to undertake conservation within each State that harbors the Topeka shiner. The more actions implemented within additional states, the better the conservation benefit to the Topeka shiner.

One assumption is inherent in the scenarios below: the current baseline of activities continues into the future. Ongoing conservation actions not necessarily targeted to improve conditions for the Topeka shiner (*e.g.* NRCS programs designed to improve water quality, or Corps of Engineers permit requirements regarding countersinking culverts to prevent perching) are expected to continue. Actions designed to improve the Topeka shiner status (*e.g.* off-channel habitat creations by the Service) are also expected to continue, as will projects that currently negatively impacting the species (*e.g.* irrigation depletion of groundwater in Kansas and Nebraska or continued existence of dams that modify hydrology and harbor stocked predators). The scenarios below assume conservation actions would be implemented in addition to the current level of project activities (which would be designed to counteract threats to the species) with focused and prioritized efforts to foster Topeka shiner viability.

A projected timeline is an important consideration for these future scenarios, and for the Topeka shiner, it is likely viability could be improved within 10-20 years if effective actions are taken in the majority of the Topeka shiner's range. Given the ongoing threats and increasing vulnerability of the Topeka shiner to stochastic and catastrophic events, delays in implementing conservation actions for the Topeka shiner will result in increased difficulty of achieving species long-term viability. Yet the high reproductive capability of the species means populations have the ability to respond relatively quickly to effective conservation actions. If such actions are implemented long-term over the majority of the species range – particularly in areas that have experienced the most significant Topeka shiner declines – long-term viability of the species may be attainable in the relatively near future, 10-20 years from now. This timeline would encompass about 3-6 generations of Topeka shiners. This is likely long enough to be able to observe/measure significant conservation gains for the species. Realistically, some conservation actions will take longer to implement than others, and will yield results more quickly (*i.e.* removing a dam could allow access to miles of habitat immediately, while attempting to remediate a channelized stream could take years). Programs may need to be established with incentives to garner support. Outreach to educate the public and/or potential partners regarding the benefits of proposed conservation actions may also be needed. With adequate effort, the benefits could be realized within the 10-20 year timeframe.

While the below scenarios examine the benefits of cumulative conservation actions across the range to the Topeka shiner, there is one possibility not discussed in our scenario analysis: loss of all southern populations. Given the north-south dichotomy currently recognized for this species, the possibility of extirpation of all populations in Nebraska, Kansas, and Missouri has been raised as a potential future situation. European settlement of the prairie and subsequent (ongoing) threats significantly reduced the occupied range of the species, particularly in the south. Many of the southern population extirpations occurred in the quarter century leading up to the federal listing of the species (63 FR 69008-69021, December 15, 1998). If all southern populations/complexes were lost, viability of the species would rest solely with occupied areas of the north. Topeka shiner populations in the north overall have exhibited greater persistence over time, are identified via the resiliency model as better able to withstand stochastic events, exhibit relatively greater redundancy, and each northern population complex (like all complexes) is isolated from the others and spread among states. However, if the Topeka shiner range were reduced so that the species only persisted in South Dakota, Minnesota and Iowa, the trend would be toward an "all eggs in one basket" situation. This would pose an increased risk of catastrophic impacts to the entire remaining occupied range. While hydrology in the north currently appears to be less impacted than in the south and may mitigate some threats to the species, future conditions or threats could potentially override the buffer afforded by northern (glaciated) hydrology.

However, the loss of all southern populations/complexes does not necessarily appear to be an imminent situation, if it were to occur at all. The current resilience of some southern population complexes identified herein (*e.g.* Kansas River complex) and ongoing conservation efforts (*e.g.* reintroductions in Missouri), as well as protections currently afforded by the ESA may serve to reduce the likelihood that all southern populations would be extirpated in the near future, or at least not within the 10-20 year timeframe of the future scenarios discussed below. The currently relatively wide distribution of southern population complexes (all isolated and split among three states) also likely reduces the risk of total southern extirpation. It is possible that some populations/complexes have, or will soon, reach a critical tipping point (albeit such a threshold has not been defined for the Topeka shiner) and losses of the least resilient populations and/or complexes (*e.g.* Smoky Hill River (possibly already extirpated), Elkhorn River, North Loup River, Thompson River complexes) could occur within the next decade or two. This would be detrimental to the species' long-term viability by negatively impacting resiliency, redundancy, and representation of the species. However, since complete extirpation of all southern populations and complexes seems unlikely in the context of the 10-20 year timeframe of the scenarios below, and the scenarios themselves are based on cumulative improvements resulting from increasing application of conservation actions, the loss of all Topeka shiners occurring in Nebraska, Kansas and Missouri is not further addressed herein. Revisions to this SSA report may revisit this potential situation if warranted by future conditions.

Thus, four future scenarios (Scenarios A-D) are presented below that outline potential levels of participation by engaged parties needed at the state level to incrementally improve the status of the species along with their expected results:

- Scenario A: Conservation actions continue at present levels - minimal benefit
- Scenario B: One or two severely affected states actively implement multiple focused, prioritized conservation actions - improved conditions
- Scenario C: A majority of severely affected states actively implement multiple focused, prioritized conservation actions - substantially improved conditions
- Scenario D: All/nearly all states actively implement multiple focused, prioritized conservation actions – maximum benefit

Table 12 expands on the four conservation-based future scenarios by including the types of actions that may move the Topeka shiner toward long-term viability over the next 10-20 years, focusing on areas known to have ongoing severe threats. While these four scenarios could occur as described below, realistically a continuum likely exists among and between the scenarios where various combinations of actions and involved states could be enacted. As noted above, a myriad of state, federal, and private partners will likely be needed to work on conservation and landowner participation will be key as most Topeka shiner streams flow through private lands. State agencies could be a driving force, however, and likely would be the entity to develop and carry out monitoring plans critical to determining the success of any implemented conservation measures. Our future recovery planning efforts and documents will define roles and actions more specifically.

Table 12. Conservation measures and the level of state participation under each Topeka shiner future scenario.

CONSERVATION ACTION	SCENARIO A – minimal benefit	SCENARIO B – improvement	SCENARIO C – substantial improvement	SCENARIO D – maximum benefit
RIPARIAN BUFFERS	Implement Minnesota Buffer Law, no other states require buffers	Nebraska, Kansas implement buffer requirements, South Dakota voluntary buffer law has adequate registration to show benefit; Minnesota Buffer Law is effective	Missouri, Nebraska, Kansas, Iowa implement and enforce riparian buffer requirement; South Dakota buffer program is effective; Minnesota Buffer Law is effective	All states implement and enforce riparian buffer requirements
STREAM RESTORATION	Little or no active stream restoration in any state	Stream restorations occur in Nebraska, Missouri	Stream restorations occur in Nebraska, Missouri, Iowa, Kansas	All states implement stream restoration projects
WATER QUALITY STANDARDS	No change to existing regulations	Water quality standards result in improved habitat conditions in at least two southern states	Water quality standards result in improved habitat conditions in four southern states	Water quality standards result in improved conditions in all states
TILING	Few or no tile projects in Iowa, Minnesota or South Dakota include mitigative measures	New and existing tile projects in Iowa implement mitigative measures to manage flows and contaminants	New and existing tile projects in Iowa and Minnesota implement mitigative measures to manage flows and contaminants	New and existing tile projects in Iowa, Minnesota and South Dakota implement mitigative measures to manage flows and contaminants
WATER WITHDRAWALS	Irrigation continues unabated	Nebraska, Kansas limit irrigation to improve base	Missouri, Iowa join Kansas, Nebraska to limit	All states implement and enforce irrigation

		flows	irrigation, improve base flows	restrictions to improve base flows
GRAZING	No additional actions to prevent stream degradation by livestock	Grazing exclusion programs in two states	Grazing exclusion programs in four states	All states implement measures to exclude livestock degradation of Topeka streams
CAFOS	Existing levels of regulations and standards remain in place	Regulations improved and enforced in two states to address runoff to streams from CAFOs and associated overland manure spreading	Regulations improved and enforced in four states to address runoff	All states
DAMS	No dams are removed, additional dams are installed	Kansas, Nebraska, Missouri implement dam removals, do not repair failed dams nor install new	Iowa, Kansas, Nebraska, Missouri implement dam removals, do not repair failed dams nor install new	All states implement dam removals, do not repair failed dams nor install new
STREAM CROSSINGS	Occasional stream crossing remediation, infrequent or no replacements of inadequately sized/placed structures	Two states prioritize and replace of obstructions with adequately sized/placed structures	Four states prioritize and replace obstructions with adequately sized/spaced structures	All six states prioritize and replace obstructions with adequately sized/spaced structures
PREDATORS	Heavily predator stocked areas above dams in Kansas, Missouri and Nebraska remain intact	Kansas and Missouri begin predator removal projects above dams	Kansas, Missouri and Nebraska, remove dams	All states begin removals of dams and stream restorations

OFF-CHANNEL HABITAT	Iowa and Minnesota continue or cease creating OCH, no efforts by other states	Two southern states implement OCH creation in addition to IA and MN	All southern states (Nebraska, Iowa, Kansas, Missouri implement OCH creation in addition to IA and MN	All states implement OCH creation
REINTRODUCTIONS	Only Missouri continues, or MO stops and no other states attempt	Nebraska joins Missouri to fill large gap in range	Kansas and Iowa join Nebraska and Missouri to repopulate extirpated areas	All states implement reintroduction into depleted/extirpated areas
INSTREAM GRAVEL MINING	Instream gravel mining activities continue in all four southern states at current rate	Instream gravel mining decreases in Kansas	Instream gravel mining decreases in Kansas and Missouri	Instream gravel mining decreases in all four southern states (generally (n/a in northern states)
DEVELOPMENT	Continued urban development affects streams on local levels	Development impacts to streams in Kansas and Missouri are reduced	Development impacts to streams in Kansas, Missouri, South Dakota and Minnesota are reduced	Development impacts in all states are reduced

Scenario A: Conservation actions continue at present levels - minimal benefit

Under future Scenario A, little would change in terms of conservation activities designed to promote viability of the Topeka shiner. Efforts beyond ESA-related actions would continue as they are without additional conservation measures being implemented. At present, ongoing conservation actions specifically for the Topeka shiner include construction of off-channel habitats in Iowa and Minnesota, and captive rearing of Topeka shiners in Kansas and Missouri, with reintroductions occurring in Missouri. While these are important conservation actions which have been successful to date, they are not occurring across the species range. Some non-targeted actions, such as Minnesota's Buffer Law, likely will afford benefits to the specie's habitat, but such laws do not exist in the other five states of the Topeka shiner's range. Scenario A does not involve new conservation actions for the Topeka shiner in any state, thus benefits to the species as a whole are minimal due to the small scale of these efforts. If Topeka shiners continue to decline as a species, these conservation actions may serve to slow the losses, but likely cannot sustain the Topeka shiner alone. Additional efforts would be needed to substantially foster Topeka shiner viability.

1. Condition of Individuals – Scenario A

While few individual Topeka shiners would benefit under Scenario A, their condition would be improved. Newly created off-channel habitats are being utilized by Topeka shiners in Minnesota and Iowa; and individuals can be more abundant within these habitats than within the adjacent main stem habitats. With exception of those off-channel habitats that may act as a sink under some conditions (*e.g.* become disconnected from the stream and drought or other factors impact the isolated area), the off-channel projects provide additional suitable habitat for individuals – critical in areas where main stem habitats are poor quality. Those Topeka shiners in the vicinity of the projects with the ability to access them likely benefit from the refugia, spawning areas and overwintering sites these areas provide. Individuals may benefit via increased fitness, improved reproductive success, and increased survival rates, particularly in areas where main stem stream habitat is significantly degraded. However the number of individuals affected under this scenario is very small. No such benefits are extended to Topeka shiners in the remaining states that are not implementing conservation measures. Stressors impacting individuals currently would continue and likely lead to fewer individuals over time.

The current reintroductions in Missouri by themselves do not necessarily affect the condition of individuals, but expands Topeka shiner occupancy within the state as individuals obtained from other populations in Missouri have been raised and stocked in these new areas. The reintroductions have included some management actions, such as predator removals, that are beneficial to the individual stocked Topeka shiners, and the reintroductions have taken place in streams with suitable habitat to allow individuals to prosper, compared to Topeka shiners existing in more degraded streams in Missouri, so it is possible that these reintroduced individuals may be better off than their counterparts in some other areas. As with the off-channel habitat creation, however, the number of individual Topeka shiners benefitting from this action is relatively small; reintroductions have occurred in only three localized areas in Missouri. Individual Topeka shiners in other states would remain subject to ongoing actions, many of which have negatively impacted the hydrology and habitat on which individuals rely, resulting in reduced fitness and survival of individuals over time. Particularly in southern areas, as hydrology and habitat continues to decline, individuals will be lost. Without stocking efforts to replenish or reintroduce individuals extirpated areas would remain void and the result over time is a permanent reduction in the number of individuals on the landscape.

2. Condition of Populations - Scenario A

With improved survival and reproduction of individual Topeka shiners in Iowa and Minnesota as a result of off-channel habitat creation, some populations in those states may be able to grow, improving their resiliency. Reintroductions in Missouri are intended to establish additional, self-sustaining populations, improving redundancy there. Currently, augmentations in the reintroduction areas and associated management actions also improve resiliency of these populations as their size is increased and occupancy is expanded. The new populations are not connected to the other extant populations in Missouri; this may lead to additional genetic diversity (representation) over time as the newly established populations genetically diverge over time from their origins. However, as with benefits to individual Topeka shiners, population benefits under this scenario occur for only a small number of populations in relatively few areas of just three states.

Populations in northern areas may continue to persist, barring unforeseen changes in the next 10-20 years that could override current resiliency mechanisms. Climate change will undoubtedly affect these areas within that timeframe and beyond, but while southern portions of the range may experience population-threatening droughts as a result of climate change, northern populations may be more affected by increased precipitation, perhaps facilitating inter-intra population movements and potentially extending some benefits to the species. Drought can also occur in northern areas, but the existence of off-channel habitats and groundwater input to streams in these areas - two factors deemed critical to current resiliency in the northern populations – appear more likely to sustain them than in southern areas.

Alternatively, should the current level/lack of conservation actions continue, it is possible that southern populations would continue to shrink. In this case, source populations would become more fragmented and isolated, the species may eventually become unable to recolonize extirpated areas, and the result is further losses of populations over time. Not all southern areas appear to be at equal risk (*e.g.* portions of the Flint Hills in Kansas may be more resilient due to geology and lack of agricultural impacts), but some appear near this tipping point in the near future (*i.e.* small, isolated populations in Nebraska (Taylor Creek, Union Tributary, Big Creek), Missouri (Sugar and Tombstone Creeks), and Kansas (Willow Creek)). Losses of any populations (lowered redundancy) at this point would further reduce the existing genetic diversity (representation) known to exist among Topeka shiners.

3. Condition of Species Rangewide – Scenario A

The conservation benefit to the Topeka shiner as a species under Scenario A is minimal. The current conservation actions may be moving the species incrementally in the direction of improved viability, and with continued success, will afford small localized improvements that can contribute to long-term persistence of the species. However the contribution may not be sufficient (*i.e.* likely not rising to the level of population complex improvements) to significantly improve long-term viability of the species. Areas without current conservation actions may

may shrink, or even be extirpated, as populations within them are lost, particularly in southern areas that are currently small, harbor few individuals (*e.g.* Nebraska populations or Sugar Creek in Missouri). Benefits gained in the few areas currently implementing conservation actions could also potentially be overridden by threats to the species not addressed by these measures, and/or declines in resiliency and redundancy of populations elsewhere. The current actions must continue, must be successful, and the benefits realized must be greater than current impacts at a population complex level in order to improve the status of the species and stem continued declines, particularly in southern areas. This seems unlikely without additional conservation actions and involvement of additional states. The species is not expected to be lost entirely from all southern populations currently in existence within the timeframe of this analysis (10-20 yrs into the future); however, greater reliance on northern populations could result if current tenuous southern population complexes are not bolstered and southern declines are not halted.

Scenario B: One or two additional severely affected states actively implement multiple focused, prioritized conservation actions - improved conditions

Under Scenario B, a level of incremental benefit above current actions (Scenario A) would be realized for the Topeka shiner, as areas targeted for additional conservation actions would be in states most severely impacted (*e.g.* Nebraska where the species continued presence is tenuous). Table 12 (above) identifies states where conservation actions could be focused and are indicative of where specific activities have caused widespread and/or severe impacts to the species. For example, dams with stocked predatory fish impacted much of Kansas; thus, a priority conservation action may be to remove predators and dams and restore habitat in that state. Effective conservation actions focused on increasing or expanding the number of individuals, occupied areas, populations, and population complexes in the most severely impacted areas are needed to fill gaps in the range, improve connectivity, and buffer the effects of stochastic and catastrophic events. Under Scenario B, in addition to the off-channel habitat projects in Iowa and Minnesota and reintroductions in Missouri, progress would be made in at least one or two other states in the range where Topeka shiner declines have occurred, and the incremental improvement in this greater area would likely boost the status of the species and contribute to viability. However, as with Scenario A, other ongoing threats and lack of conservation in other states would still reduce the likelihood of actually achieving long-term viability.

1. Condition of Individuals – Scenario B

The condition of more individual Topeka shiners would be improved in Scenario B over Scenario A as one or two states would join the States of Missouri, Minnesota and Iowa in implementing enhancements to habitats that still remain occupied by the Topeka shiner, and/or remediate habitats where the species has been extirpated and pursue future reintroductions. Actions in these additional states such as removal of dams or replacing stream-crossing obstructions would help restore natural hydrology and instream processes, improving individual fitness, allowing recolonization of extirpated areas, improving individuals' breeding opportunities and increasing individuals' survival with access to more refugia. Installation of riparian buffers, predator control actions, livestock grazing management or removal from riparian zones, reduced groundwater withdrawals, and restoration of channelized streams will all serve to improve the habitat and increase survival and fitness of individual Topeka shiners in an expanded area where the species has experience the most severe declines. Augmentations would boost the number of individuals in currently occupied areas and reintroductions would add new individuals to unoccupied areas. Levels of improvement will depend on the type and number of effective conservation actions that are implemented, however. Prioritized and focused actions should be well thought out to achieve the greatest conservation benefit.

2. Condition of Populations – Scenario B

Resiliency and redundancy of populations would improve under Scenario B as higher numbers and better conditions of individual Topeka shiners within those populations allow for greater capacity to survive, reproduce, expand occupancy and/or repopulate areas post-extirpation. Reintroduction efforts in additional states would further close gaps between and among populations and over time would raise the level of representation. The level of improvement would again relate to the number and type of effective conservation measures implemented in the one or two additional states that actively pursue Topeka shiner viability beyond current efforts. However, while conditions of local populations would improve with focused, effective conservation measures, this scenario still subjects the majority of extant Topeka shiner populations in other states to many of the ongoing threats that led to the species' listing.

3. Condition of Species Rangewide – Scenario B

Because this Scenario does not include benefits to populations in the majority of states within the Topeka shiner's range, the overall benefit at the population complex level would remain relatively low. Improved resiliency, redundancy and representation of populations in a few states will improve the overall condition of the species, will somewhat bolster population complexes, and will contribute to Topeka shiner viability. However, this scenario is not of a scope and scale necessary to achieve significant improvements.

Scenario C: A majority of severely affected states actively implement multiple, focused, prioritized conservation actions – substantially improved conditions

Targeted, successful conservation actions addressing the biggest threats to the species in the majority (3) of the four states that have experienced the most severe Topeka shiner declines would occur under Scenario C. Conditions for Topeka shiners in the northern States of South Dakota and Minnesota (including NW Iowa), while not pristine, have allowed the species to persist in nearly all of its past known range there. In contrast, degraded conditions in the southern States of Nebraska, Iowa, Kansas, and Missouri have led to extirpations and reduced the species to such low numbers and so few populations in some areas that state-wide extirpations (Missouri and Nebraska) are possible. If at least three of the states in the species range that have experienced the most severe Topeka shiner declines were to implement targeted, successful, long-term measures to improve conditions of Topeka shiner individuals/populations/population complexes, long-term viability would be possible. This assumes that Topeka shiners in northern states do not experience significant negative impacts and the species continues to persist in its current (1999-2017) range in South Dakota, Minnesota and northwest Iowa.

4. Condition of Individuals – Scenario C

As with Scenario B, states that successfully implement threat-addressing conservation measures would improve conditions for individual Topeka shiners in their targeted areas. In Scenario C, however, the portion of the range where such actions would occur would be increased with the addition of another one to two southern states, reaching a majority of those hardest hit by Topeka shiner declines. This would increase the number of individual Topeka shiners benefitting from conservation measures. Improved fitness, reproduction, and survival of individual Topeka shiners from actions that restore natural stream hydrology, improve water quality, provide access to additional suitable habitat/refugia, reduce predation, and address other threats would then be occurring in most of the states that have experienced the greatest declines. Restoration activities and reintroductions in formerly occupied areas of these states would also return individuals to the landscape and begin to fill gaps in the range.

5. Condition of Populations – Scenario C

With effective and focused conservation actions improving the condition and number of individual Topeka shiners in the majority of states that have suffered significant declines in Topeka shiner populations, Scenario C would likely result in expanded and/or additional populations of the species as well, significantly improving resiliency and redundancy in at least three southern states. More populations established through reintroductions, ideally proximally placed to create population complexes, as well as augmentations to existing populations would reduce the risk of extirpation due to stochastic events. With reintroductions, depending on the location and level of isolation, representation levels would also be increased as populations become genetically diverse over time.

6. Condition of Species Rangewide – Scenario C

Scenario C would result in significant improvements in the condition of the Topeka shiner as a species. With focused and effective conservation actions occurring in the majority of states where the species has experienced the greatest declines, the incremental benefits to the species would likely reach a cumulative level (with assumed continued persistence in the northern states) that could sufficiently bolster population complexes and result in substantial improvements to long-term viability of the species. Expanded or reintroduced populations, with habitat improvements and other actions to effectively address the most significant threats each area, would result in levels of population resiliency and redundancy that could also improve conditions of population complexes and allow the species to become self-sustaining long-term. With the addition of reintroduced populations, the potential for greater representation exists, perhaps including additional population complexes, increasing the adaptive capacity of the species over a relatively broad area. Results under Scenario C would likely result in a significant increase in species viability over the 10-20 year timeframe.

Scenario D: All/nearly all states actively implement multiple focused, prioritized conservation actions - maximum benefit

Scenario D is the optimistic scenario, envisioning all or nearly all of the states actively engaged in conservation efforts. With five or six states in the species' range implementing focused, effective conservation measures to address threats to the species and expand the populations in their states via enhancement of existing habitats and/or reintroductions of Topeka shiners into formerly occupied areas, the greatest benefits to the Topeka shiner will be realized. Since the species continues to occupy the majority of past known occupied areas of South Dakota, Minnesota and northwest Iowa, priorities in those areas would focus on habitat improvements to increase the number of individuals within existing populations and expand current occupancy. The southern states' focus would similarly include habitat enhancements to increase the number of individuals and occupancy within extant populations, but would also include reintroductions of populations in extirpated areas, filling gaps in the range. Ideally, all of the four southern states that have experienced the most severe Topeka shiner declines would engage in active conservation under this scenario. Actions would be implemented effectively in all or most areas occupied by the species within each state, improving conditions to the maximum extent possible. Constraints due to anthropogenic influences would exist, but the biggest threats would be abated, allowing the species to persist and/or thrive in currently occupied areas and in reintroduction areas long-term.

1. Condition of Individuals – Scenario D

Under all of the scenarios herein, condition of Topeka shiner individuals would improve; differences relate to the type or level of improvements and numbers of individuals that benefit from those improvements. Under Scenario D, with effective conservation actions occurring in five or six states, the condition of individual Topeka shiners would improve throughout all or nearly all of the species' range. Habitat restoration, enhancement, creation, and preservation would increase the survival, fitness and reproduction of Topeka shiners resulting in substantial increases in number of individuals over time.

2. Condition of Populations – Scenario D

As with all of the above scenarios, improved condition of individuals leads to improved conditions of populations. Scenario D increases the resiliency and redundancy of nearly all extant Topeka shiner populations and results in establishment of new populations needed to fill in gaps in the range adding to species representation to the extent possible. Scenario D would result in the greatest level of improvements possible to the majority of populations in all or nearly all of the states within the species' range.

3. Condition of Species Rangewide – Scenario D

This scenario would result in the best possible realistic outcome for the Topeka shiner: a high level of improvement in the species' condition even greater than that achieved under Scenario C. However, this scenario does not assume utopic conditions are achievable. Some levels of ongoing detrimental anthropogenic influences are anticipated to continue on the landscape that cannot be fully mitigated, and the species would still occupy fewer areas, with less connectivity, available habitat, and refugia than was available relative to pre-European settlement conditions. Under Scenario D, those influences would be addressed to the point where population resiliency and redundancy afford high levels of resistance to stochastic events and concurrent improvements to population complex resiliency and redundancy would afford similarly high resistance to catastrophic events, and increased representation would substantially improve the species' adaptive capacity, attaining the best feasible and reasonably attainable outcome for the species throughout its range.

E. Summary of Future Scenarios

The future scenarios presented above indicate the types of actions and level of participation by the six states in the Topeka shiner's range needed to benefit the species and ensure improvement of Topeka shiner viability within the next 10-20 years. Significant assumptions and unknowns are inherent in each scenario: including the number of states that would enact conservation measures, the number and types of conservation actions they may implement, the resources (personnel, costs, tools, programs) needed to enact the activities, the effectiveness of the actions, the level of participation by partners, overall public/private/political support for conservation actions within individual states, and possible changes in threats and/or mitigating factors. Exact quantitative requirements for success are not provided herein, but gradations in the conservation-focused scenario are intended to illustrate the cumulative nature of successful implementation of conservation measures and the resulting benefits to the species. Table 13 summarizes these scenarios; the potential future resiliency, redundancy and representation of the Topeka shiner; and possible effects on species viability.

Table 13. Summary of future scenarios, their resulting changes to the 3Rs (resiliency, redundancy, representation) for populations and implications for Topeka shiner viability.

SCENARIO	RESILIENCY	REDUNDANCY	REPRESENTATION	VIABILITY IMPLICATIONS
A: Conservation actions continue at present levels	Resiliency of most populations and/or complexes not improved. Local benefits occurring in few areas	Redundancy increased in small area of Missouri	Representation increased in two areas in Missouri (reintroductions)	Continued species decline, no net conservation gain
B: One or two southern states actively implement multiple focused, prioritized conservation actions	Resiliency of most populations and/or complexes remain unimproved. Local benefits expanded to additional areas, but still limited	Redundancy increased in additional areas if reintroductions are implemented or populations improve to levels to allow expansion and improvements to complexes; area still limited	Representation increased with additional reintroductions or population and complex expansions, but area still limited	Species decline abated, but low net species conservation gain due to limited area
C: A majority of southern states actively implement multiple focused, prioritized conservation actions	Resiliency improved in majority of most-impacted states	Redundancy increased in majority of most-impacted states with reintroductions and/or population and/or complex expansions	Representation increased in majority of most-impacted states	Species decline abated, substantial net conservation gain over significant area
D: All/nearly all states actively implement multiple focused, prioritized conservation actions	Resiliency improved in majority of species' range	Redundancy increased in most of species' range	Representation increased in most of species' range	Species decline abated, high net conservation gain, substantial improvements

In the above future scenarios, improving the viability of the Topeka shiner via the 3Rs depends on implementation of effective long-term conservation actions that address the threats to the species in the majority of states where the Topeka shiner resides, particularly southern states in the range where most population losses have occurred. We have defined 10-20 years as a timeframe for achieving measurable improvements for the species, but acknowledge that enacting conservation actions depends on a variety of factors (willing partners, funding, agency priorities, etc.) that are unrelated to the biological response time to such measures, thus results in 10-20 years may not be uniformly achievable. If declining trends continue in southern areas, future persistence of many populations - those that appear most tenuous - is in doubt. Such losses would negatively impact the 3Rs for the Topeka shiner, reducing its overall long-term viability. While information pre-listing was lacking regarding exact historical occupation in northern areas, it is not apparent that the species range in northern areas has contracted to the degree the southern range has. If conservation actions in southern areas are not implemented in the future, it may become more important moving forward to sustain and perhaps improve northern populations, should southern conditions continue to result in population losses - even though relying on northern areas alone to sustain the species has associated risks. The conservation actions presented above are not purported to be the only means to achieve conservation benefits for the species, and the described scenarios are not the only potential future paths that may be taken. It is likely true, however, that a range of enlisted partners committed to ensuring long-term viability of the species will be necessary in order to make significant improvements in the long-term viability of the Topeka shiner.

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APPENDIX A: Topeka Shiner Species Status Assessment Workshop, Information Sharing, Final Meeting Notes, September 15-17, 2014

Topeka Shiner Species Status Assessment Workshop, Information Sharing

Final Meeting Notes

September 15-18, 2014
USGS EROS Data Center,
Sioux Falls, South Dakota

Topeka Shiner
Species Status Assessment Workshop
Information Sharing
Sept 15-18, 2014
Sioux Falls, SD

FINAL WORKSHOP MEETING NOTES
(Revised by Natalie Gates with input from meeting attendees)
December 19, 2014

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Topeka Shiner
Species Status Assessment Workshop
Information Sharing
Sept 15-18, 2014
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MONDAY, SEPTEMBER 15, 2014 (2pm start)

Natalie Gates– welcome
Roger Auch/Ryan Reker – EROS logistics
Seth Willey – purpose of meeting
Heather Bell – SSA overview/FACA – (repeat of webinar info, deemed unnecessary, FACA handout provided)

LIFE HISTORY/SPECIES OVERVIEW

Vernon Tabor, USFWS, Kansas
Vernon provided Topeka shiner listing and review history, plus reproductive, feeding and sheltering info. Dispersal is one item we don't know much about. Topekas have been found in ephemeral sections during spring high water, and in high order mainstem riverine systems. A mark-recapture study was done (but not published) in KS. Range map was shown. Have: highly variable data collection from each state, good knowledge of range/life history/habitat, past/present threats, and general genetics from parts of range. Don't have: long-term trend or viability analysis, working knowledge of future threats, climate change stressors, rangewide genetics, or movements. Ann Michels did some genetic work (Michels 2000). Western KS population was relocated to Kansas University due to high risk of extirpation and genetic stock is being maintained at KU. Variation exists in north vs south parts of the Topeka's range in soils, topography, and differing threats. Topekas seem to be present in north in poor water quality areas, but in the south they're only persisting in the best quality streams. NRCS program 566 flood protection dams had impact – Kansas and Nebraska has many of these, most stocked with fish in streams that did not naturally have bass. Grassland conversion threat differs north vs south (more in north).

STATE PRESENTATIONS

Missouri: Doug Novinger and Jerry Weichman of MDC (via WebEx)
Doug: Missouri is down to just 2 populations: Sugar and Moniteau. Bonne Femme was occupied until mid-90's. MO is guided by their 10 year plan. One goal is to stabilize and enhance pops in seven streams (that's 1/2 of the populations sampled since 1960). Missouri staff are doing annual surveys, habitat improvements, research/biology/propagation and reintroductions. It is tough to detect trends by monitoring abundance, so the survey protocol was changed to focus on distributions via probability of occupancy rather than abundance - can sample more sites. Moniteau Creek is the only MO population that appears stable, albeit only in upper ½ of watershed. Low numbers occur at all sites, but are quite variable, and not declining. They are measuring occupancy probability. The 2012 drought dropped Topeka occupancy to 20% (down from 60%). Two new occupied tributaries were found in Moniteau watershed in past three years. Occupied tributaries in upper Moniteau are small and often intermittent. Sugar

creek is much more limited. Have gone some years without finding fish there, but in recent years have found hundreds. Small number of sites though, very vulnerable to stochastic events. MO is using this population for development of experimental reintroductions. Topekas were found in pools with the **lowest conductivity (<450 mS/cm) than in other pools – a new finding.** Not sure what could be driving conductivity, nor why Topekas would be in low conductivity sites. They will be doing some further research on conductivity and other physical tolerances (Coop unit at MU, Amanda Rosenberger). Overall: limited resiliency in MO. Sparse, small populations & just 2 or 3 poor spawning seasons could result in loss of populations. With only two populations remaining, redundancy is low. Representation is high – genetic variation shows distinctiveness between the Sugar and Moniteau.

Jerry: Reintroductions are occurring near Sugar Creek in northern MO (primary sites). There are secondary and tertiary sites near Moniteau in central MO with fifteen streams overall, and stocking is occurring in ponds and stream reaches. They are introducing orangespotted sunfish too, of Sugar Creek origin. Fish were reared in ponds at MDC Lost Valley Hatchery. Production varies – may be reduced in hotter summers, better in cooler weather. Up to 10,000 fish have been produced per year. The first reintroductions were done in 2013 on MDC or TNC properties. They're using old stock ponds as drought refugia. They stocked 3,300 Topekas plus 125 orangespotted sunfish (males only to avoid overabundance issues). Goal is to: establish self-sustaining populations in three primary watersheds with a distribution in at least 50% of suitable stream habitat. Big Muddy and Little Creek are the two reintroduction sites from last fall (2013). The populations will be monitored at randomly selected survey locations later as fish hopefully move to other parts of the stream. Private lands are a challenge…to conserve habitat they will have to work with landowners on riparian buffers, limiting grazing. MDC is offering low-water stream crossings that tend not to be a barrier to passage & using them as a carrot to establishing stream buffers by landowners. MO will have another nonessential experimental population (NEP) reintroduction this fall (2014) for a total of three NEP reintroductions since 2013. Will monitor habitat preferences to inform future introductions. Bedrock & limestone may have prevented channelization and perhaps groundwater connection, but not exactly sure why they're in Sugar Creek and not others. Similar with Moniteau Creek. Moniteau is a little larger, perhaps more complex than other streams and more spawning habitat than other streams. More rock, less incision, less siltation, less development, but nothing really jumps out to distinguish Moniteau from others.

Nebraska – Steve Schainost, NE GPC, and George Cunningham, EcoCentrics
Steve: gave historic information on Nebraska pops (Meek 1891, Evermann and Cox 1893, Johnson 1939-41). Have three recent collections in NE: 1) Big Creek 2006 - 1 fish collected, 2) Brush Creek 1989 - 1 fish collected (permission to access and survey has since been denied), and 3) Taylor Creek in 1996 and 2014 - lots of spring flow, very unusual, 10 cfs in 4 miles. [Note: Steve did not mention unnamed tributary to Union Creek, Madison Co., NE – George provided update below].

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George: completed a 2009 compliance survey on unnamed tributary of Union Creek, 2.5 miles from Taylor Creek. Dam on west branch was built 2 years prior with no T & E species review, within a spring area. He found one Topeka. Spring Creek, Madison County, NE - another compliance survey in 2010, no Topekas found. Golf course at Taylor Creek (at Madison) in 2009, no Topeka's found in ½ hour effort although previous attempts did find them in 5-10 min…channel eroding now. Returned to unnamed tributary of Union during 2012 surveys (assisting USFWS Grand Island office, NE), and did not find any Topekas, but stream is dominated by centrarchids now. Also revisited Taylor Creek in 2012, found perhaps 2-3 small Topekas, did not voucher (current permit does not allow it). In July 2014, George looked at Taylor Creek and Bazille Creek with Lourdes Mena (Grand Island FWS). No shiners found in Taylor Creek at previous years location, but did find some upstream in Taylor. Property has springs, cool water, but center creek pivot is installed. Bazille Creek: no Topekas found, lots of irrigation, silt laden conditions over what had been gravel. Natural Resource Districts in NE manage groundwater. There was supposed to have been a moratorium on groundwater extraction, but clearly it is still occurring. Checked North Elm Creek in KS too in May 2013, no Topekas, while in previous years would find some. KU found some at this site in 2006. Overall: future for Topekas is dim in NE. Few fish within Taylor Creek and one in Big Creek in 2006.

Biggest threat is groundwater reduction (altered hydrology) - very deep soils, regulators don't do anything until depleted. NE leads the nation in land conversion. Tiling is not a problem in NE, but irrigation is major problem along with agricultural land use intensification. Climate change: warmer temps and less stream flow, intensified by water withdrawals will be problematic. Conservation measures: need no more irrigation flows, prohibition on stocking predatory fish. No conservation efforts have been applied for the Topeka shiner in Nebraska since listing – species receives very little attention. Driving force in NE: Federal farm policy & renewable fuel standards, leading to Topeka problems. Have found only four or five Topekas in NE since 2006. Topekas may have been a lot more common in 1890s than today, though actual records are limited. Watersheds today look nothing like they did historically. Deep soils with lots of water allowed vegetation to come out quickly in a big way. Water flows through the system in hours rather than days. Springs have dried up. Historic surveys were very spotty, done in a very short time and little effort was expended, yet they found Topekas – surmise that they must have been more common then. Have no information on abundance in Nebraska – no historical info. Used to be found rapidly, but aren't now. Most of historic range would have been in eastern 1/3 of the state. Big challenge: what does it mean to find one individual? Can't get to certainty of population size without tremendous effort.

Bottom line: Topeka populations in Nebraska are presumed to be about extirpated. Level of effort needed to establish population size is big. No discussions in NE now about captive rearing and even if they did, they would have to look at introductions into different streams than historic because the historic streams are degraded. Best bet would be in Sandhills area – North Loup - the best streams in the state are there.

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Iowa: John Olson, IA DNR
There is a poor understanding of the pre-1999 Topeka shiner distribution and abundance in IA, but, based on historical information (primarily field notes from the late 1930, 1940s & early 1950s (summarized in Iowa Rivers Information System (IRIS) database) populations in Iowa were stronger historically than today. In mid-1990s, Iowa DNR Topeka surveys had poor success. USFWS (Vernon Tabor) had good success in 1994 survey of North Raccoon basin. In 1996, IADNR resampled same North Raccoon basins, but found Topekas only in East Buttrick Creek. Surveyors may have been looking in the wrong places (i.e. only stream channels; collection success has improved considerably with sampling of off-channel habitats).

Bruce Menzel and Steve Clark (Clark 2000) sampled historic Topeka sites (Des Moines Lobe, Rock River basin, upper Iowa River basin) from 1997-2000. In 2010-2011 Brian Bakevich (2012) studied Topekas in West central IA (same area of Des Moines Lobe as Menzel and Clark). Harlan et. al 1987 (Iowa Fish and Fishing) shows historic distribution. There are verified Topeka specimens from a small portion of lower Des Moines River basin in extreme SE IA. Clark 2000 and Bakevich (2012) show most current distribution of Topekas in IA. Based on comparisons to Clark 2000 survey results, Bakevich's (2012) conclusions were: no new Topeka locations; no Topekas found at many historic sites; no increase in range; possible recent (2000-2012) decline in distribution. Bakevich (2012, Table 1) found Topekas in many fewer locations than Clark (2000) (i.e., a 46% decline in number of HUC 10s where Clark found Topekas) and a 73% decline in HUC 10s on the Des Moines Lobe (includes Des Moines, Raccoon, Boone and Iowa river basins) that historically had Topekas.

The North Raccoon River basin (on Des Moines Lobe) currently has strongest populations in IA. Boone River basin populations are at risk; Eagle Creek is the only Boone River basin stream with recent (post-2000) Topeka records suggesting a very fragile (potentially easily eliminated) Boone River basin population. Possibly extirpated from middle Des Moines basin (Beaver, Lizard and Brushy creeks) where Starrett (1950) reported Topekas as common. No Topekas have been reported in 60+ years in upper portion of Iowa River basin (where species was found pre-1950). Based on lack of recent IA records and on information from state of Missouri Dept. of Conservation (J. Wiechman & D. Novinger at the SSA workshop, and Bob Hrabik, personal communication to John Olson), the SE IA (and the corresponding NE MO) populations are likely gone. Rock River: anecdotal decline, based on qualitative comparisons of samplings in late 1990s with more recent samplings.

Caveat: as with most stream fish populations, significant year-to-year variability occurs in the size and distribution of Topeka Shiner populations. Climate (primarily annual differences in precipitation) has huge impacts on Topeka Shiner populations in IA. This variability may bias the conclusions of 2-year MS studies. Two-year MS projects might not be useful for accurately determining Topeka Shiner status due to the relatively short-term nature of such studies. A long-term focus is required with some type of routine annual monitoring to determine what's really going on in terms of Topeka Shiner status in IA.

Trends over next 10, 20, 40 years – hard to predict. Existing information (Bakevich 2012, Table 1) does suggest a decline. North Raccoon and Rock basin populations may persist as long as off-channel habitats and connectivity persist. At least in recent decades, river and stream in-channel habitats appear not conducive to Topeka presence in IA. Bakevich (2012) found very few in main stream channels, but many more in off-channel sites (mainly cut-off oxbows).

Drivers of viability in IA: riparian integrity and connectivity. Personal experience: Topekas prefer off-channel habitats in prairie/pasture, not necessarily totally undisturbed, but not with row crop right up to stream bank. More work is needed on riparian conditions where Topekas are found in IA (i.e., the species may need more than just a buffer strip). In IA, Topeka viability depends on off-channel habitat with connectivity to main stream. Oxbow restoration project may be the key to Topeka shiner persistence in IA; such projects are helping tremendously in the North Raccoon basin.

Trends in grassland conversion: statewide about a 20% (400,000 acres) loss from 2007- 2014. There are declines in CRP enrollment, including Topeka counties, although those counties seem to have had low CRP enrollment to begin with. High corn/soybean prices are having an impact. Grassland/CRP conversion in Topeka shiner watersheds is occurring but relatively low compared to other watersheds in IA. CRP enrollment is leveling off in Calhoun Co IA (currently one of the two most Topeka-rich counties in IA). There is a decline in Rock River basin in CRP enrollment. However, Lyon County in the Rock River basin (NW IA's most Topeka-rich county) has the 2nd lowest CRP acreage of 99 counties in the IA portion of the Rock River basin. Trends and predicted rates – no information on irrigation. Much conversion of riparian areas to row crop, but have no statistics on that.

Hydrologic modifications have occurred and continue today. Quicker movement of water to streams (e.g., via tiling) dries off-channel areas which encourages more conversion to cropland. In addition, hydrologic modifications continue to adversely impact connectivity to off-channel areas through stream channel degradation (i.e., lowering), thus adversely affecting Topeka viability in the state.

Climate change: Topeka's are more tolerant of thermal impacts and low dissolved oxygen than many IA fishes. Precipitation could be a key factor, but altered hydrology of IA's stream systems and alteration of riparian corridors seem to be bigger threats to Topekas than climate change in the short term. Conservation measures to improve Topeka viability in IA include improved quality of riparian corridors (i.e. preservation). Wetland restorations will help some, but oxbow restorations are currently the most effective conservation measure to protect Topeka shiner. USFWS is doing the oxbow restoration in IA.

Question: Regarding the repeat of studies, anything jump out that might help explain differences? Answer: The 2012 Bakevich study might have been more intense than Clark (2000) study due to the use of both electrofishing and seining gear types in the Bakevich study as opposed to only seining in the Clark study. This increased sampling intensity likely serves to add weight to Bakevich's conclusions regarding decline of the Topeka shiner over the 2000-2012 period. In terms of ambient conditions, Bakevich had one wet and one dry year. The 1997-2000 study by Menzel and Clark was similar, with the tail-end of both studies leading into a drought. The thought at that time was that if oxbows were deep enough to connect to groundwater, they would serve as refugia. This is what they're finding with restored oxbows – streams can be totally dry, and fish survive in oxbows.

Minnesota: Rich Baker, MNDNR

No statewide population estimate in Minnesota, but they have 10 years of standardized monitoring. Did a 2013 recheck of sites with historic Topeka abundance. Conducted surveys annually since 2004, but skipped 2011. MNDNR survey protocol includes random selection of 20 one-mile reaches of designated critical habitat for survey; stop when Topekas are found. Surveys do not quantify abundance (instead provide a qualitative assessment of relative abundance); its mainly presence-absence data. At least 10 locations are checked within one mile if Topekas aren't found. Declining population trend was demonstrated in the percentage of stream reaches harboring Topeka shiners in each monitoring year. Species was present in an average of 76% of sites surveyed 2004-10, but has dropped to average of 38% since 2012. Map of 2004-2014 detections from survey reports was shown. Before 2012-13 there was 100% presence on Pipestone Creek, in all reaches sampled – but found none in recent years. Similar situation at Kanaranzi Creek: almost all sites contained the species until 2012. Several examples show a slow decline in Topeka prevalence. Many reaches where the species was not found were in headwaters in 2014. Notable exceptions exist in Lower Rock River. The 2012 drought may have been a factor in detection declines (like Pipestone Creek). Can get some sense of whether Topekas were common or abundant…very dramatic drop in sites where fish was noted as common or abundant since 2009. Given results of 2013, went back to recheck 2008-2010 sites, selecting 25 sites where fish had been collected in earlier years, stratified across the state. Results of revisit of sites where they had once been abundant showed decline in detections.

Summary: Topeka surveys show less prevalence over time, less abundance over time, and more effort is required to obtain a capture in a reach over time (takes more searches of more reaches to find the fish now). Even at sites where species was found in the 2013 recheck, it was found in lower numbers. Chart shows that detections did go back up slightly in 2014, but overall a declining trend.

Drivers of viability: Topekas are adapted to flashy prairie stream hydrology. The species moves to slower standing water, gets trapped in off-channel habitat during spring floods and does well there. Does well with temperature and DO issues, but sediment can't be too deep, co-nesters must be present, groundwater supply must be present, piscivores absent (or not abundant). If they find bass in pools, they don't find shiners. Grassland conversion: percent of total cropland acres in conservation programs (CRP/CREP/RIM/WRP) in Topeka shiner counties has declined (see table in presentation: total decline 8.6% over all counties)

Hydrology: double mass curve handout showed cumulative runoff to cumulative precipitation in Rock River. More rainfall is running off the land. A 1911-1914 extrapolation showed minimal runoff with dramatic change since, trending upward. Annual usage by aquifer type: surficial aquifer withdrawal has increased since 1980's. If off-channel habitats are important, and groundwater is necessary for those off-channel habitats, things are troubling. <u>Summary of trends affecting hydrology</u>: loss of grassland, wetlands, rangeland; increase in row crop; reduced grains/alfalfa with increased corn/soybeans; increased ditching/tiling; increased irrigation and other uses; more impervious surfaces; more erosive hydrology; lower summer base flows; higher winter base flows, increasing sedimentation.

Climate change: increase in intensity and fluctuations in precipitation will increase erosion, sedimentation, channel incision. Longer droughts will increase extirpations of off-channel habitats. Temperature increases not likely to have much of an effect on Topekas.

<u>South Dakota: Chelsey Pasbrig, SDGFP</u>
Noted Topeka habitat preferences, but indicated the species has been documented in degraded habitats with silty substrates. Reasons for rangewide decline were noted – can't be attributed to a single factor. Loss of groundwater input is important. SD lacked distribution information pre-listing (only 14 total tributaries; 11 mainstem tributaries known in 1997), but extensive post-listing surveys revealed 66 total streams (25 in James, 13 in Vermillion, 28 in Big Sioux); 35 mainstem tributaries. Many streams are grazed, very few impoundments (8 among three drainages) exist, channelization is minimal. Based on the USFWS Topeka shiner range map for SD (dated 6-24-14), occupied streams comprise approximately 2,300 stream miles in the state. Topekas are found in >90% of tributaries previously known to be occupied, and since listing the number of known occupied tributaries have increased more than 4-fold.

Land use changes: most riparian grassland loss has occurred outside of Topeka shiner areas. Net grassland loss from 2006 compared to 2011 is 0.39%. Some limitations in data: different methods in National Land Cover databases [R. Auch later noted 2006 and 2011 should be comparable, but earlier years may not be]. Grassland loss can be due to a number of factors besides agriculture (e.g. urban areas, increases in water (growing lakes)). CRP loss: CRP borders only 4.6% of the riparian area along Topeka streams. Over past 5 years SD has seen a 0.7% increase due to new enrollments in SE SD, but overall trend is decline (since 2007).

SD Topeka Shiner Management Plan (2003) outlined inter-agency cooperation, set state recovery goals, aimed to maintain habitat integrity, etc. Refer to 2003 plan. Monitoring program within state plan includes 33 sites, 11 tributaries (5 in Big Sioux watershed, 3 in James, 3 in Vermillion). Monitoring results: in 2004-2006 the species was present in all 11 tributaries with individuals located at 76% of sites surveyed; in 2010-2012 the species was again present in all 11 tributaries, but individuals were located at 58% of sites surveyed. Note that extreme weather conditions existed during the 2010-2012 effort (flood in 2010, drought in 2012), making sampling difficult. Peg Munky Run is the best tributary for habitat and consistent presence of Topekas. Several sites only had intermittent pools remaining and 2 sites were completely dry in 2012.

The breakdown of miles of Topeka streams in each drainage was provided (note: group discomfort arose over presentation of stream miles, but SD did not imply all miles are occupied by Topeka shiners, merely quantified lengths of Topeka streams per pre-workshop request by N. Gates): 1) Big Sioux – 480 stream miles, 27 total tributaries (11 mainstem tributaries) and Big Sioux itself, Topekas located at a single site on 13 of those 27 tributaries with no vouchers, and 7 of the 27 tributaries have vouchers; 2) Vermillion: about 420 stream miles, 12 total tributaries (8 mainstem tributaries) including Vermillion itself, 7 of 12 tributaries have a single Topeka location site, 2 of 12 tributaries have vouchers; 3) James: 1,100 stream miles, 25 total tributaries (16 mainstem), 8 of 25 contain a single site, 7 of 25 tributaries have vouchers. Twenty eight of 66 total tributaries (8 of 35 mainstem tributaries) have reports from only one site in one year.

Lack of repeat sampling and voucher specimens adds uncertainty to current occupancy status of streams. Topeka shiner is a difficult species to identify. Standard protocols are needed for identifying tributaries as occupied, historic, and/or extirpated. A 2014 recheck of 10 sites this year yielded only 1 Topeka in 1 creek (Johnson Creek). Have limitations in SD data and monitoring program (only a subset of tributaries is sampled and only two sampling rounds have been completed). SD would like to conduct annual sampling, similar to MN, perhaps do 10 random 1-mile segments, while continuing to survey monitoring sites on an annual rotation. Recommendations for USFWS: establish standard protocol for listing tributaries as occupied or extirpated, could perhaps use the Aquatic Infested Waters program criteria. Is pit tagging an option? Need to define "historic" vs "current", need a national recovery plan with recovery goals, a minimum rangewide standard sampling protocol to obtain better trend/comparison data, and continued section 6 funding support.

TUESDAY, SEPTEMBER 16, 2014

STATE PRESENTATIONS (concluded)

Kansas: Jason Luginbill, KS Dept of WPT

Topeka was state threatened in 1978, but downlisted to species in need of conservation in 1987, then was relisted as threatened in 1998. Dewatering and land conversions are issues. KS recovery plan was signed in 2004. Topeka shiners observed eating fathead minnow eggs. Will spawn outside of sunfish nests, but inhibited when large predators are around. Precipitation causes boom and bust years in KS. Last couple of years: bad drought. Loss of hydrologic connections = direct effects. Impoundments w/predators and road/bridge construction are problematic. Farming right up to stream edge, land conversion, water withdrawals (KS is 98% private lands), poor land practices are problematic. Uncertainties: spatial and temporal variation of populations during wet and dry years, recolonization mechanisms, refugia strategies, early life history stages and recruitment. Landscape changes relating to species/population level changes are unknown. Aquifer loss, groundwater withdrawals, climate change effects not modeled yet in KS. Don't have data to quantitatively determine historic and predicted effects. Looked at range reduction, what's going on in streams where fish still exists? Answer: lack of agriculture & intact groundwater. KS is lacking trend data…random surveys in state do not reveal trends. From early 90's, may have had an 80% reduction from historic range. Rocky in northern Flint Hills, not practical to crop, but may have ranching issues (overstocking livestock). No criteria for establishing extirpation, but just going by what they see - can find them in some, can't in others - they're thinking Topekas are gone. Resurvey data is not consistent. KS Topeka Shiner Recovery Plan calls for instream flows, connectivity, identifies important populations (Flint Hills are priority), has delisting goals, but difficult to reach in a privately owned landscape. Still seeing impoundments. Water law in KS is for agricultural use and flood control. Private landowners own the stream itself (same in Nebraska). PL566 program: 100% federally funded dams, done right up until listing. Producers think that the dams improve water recharge. KS tops the list of states with number of impoundments. Considerable pesticide use as well…atrazine. Hard droughts mixed with fragmentation (dams) are problematic.

STATE INFORMATION SUMMARIES:

Iowa Summary

- Trend: Decline in distribution in North Raccoon and Boone basins (current literature providing best data: Clark 2000 and Bakevich 2012). Severe drought since Bakevich surveys suggest decline could be more significant than documented (streambeds totally dry, off-channel sites were the only refugia).
- Overall decreased distribution since listing (1999) of 46% (everything except NW (Rock) population). Compared to all historic locations on the Des Moines Lobe, 2010-11, work by Bakevich (2012) suggests a 74% decline.
- Rock River basin data are relatively poor for determining trends, but expert opinion indicates declines (based on sampling visits and data, thus, not just a "best guess").
- North Raccoon basin (core population): showing some signs of restriction in range. The 2010-11 surveys of Bakevich (2012) were more robust than Clark (2000) in terms of sampling gear types. Conclusion: Topekas are at risk of extirpation at many of these streams. Have restored approximately 58 off-channel (oxbow) areas, helping keep Topekas in Cedar and Buttrick creeks, now acting as source populations.
- Boone basin: one occupied stream (Eagle Creek), not much data, remained occupied during 2010-11 period. Beginning to restore off-channel sites there.
- SE IA population presumed extirpated

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Minnesota Summary

- Trend: Recent decline apparent (strong data). Less prevalence over time. May be losing headwaters (uncertain of declining range, qualitative). Reduced abundance throughout the range. More distributional gaps in the range.
- Persisting in 4 major tributaries of Big Sioux (Medary, Flandreau, Split Rock Creek, Rock River), with subpopulations within them.
- Most complete data set, able to determine trends over time.
- Of the four Big Sioux tributaries, Flandreau is not doing well, marginal.
- Rangewide, its taking more effort to catch fish than a decade ago, appear to be declines in what would have been considered core populations: Pipestone creek, Kanaranzi Creek. Rock River, not catching as often as in past. Cannot detect distribution changes.
- Places where large numbers had been captured are not yielding large numbers now, and it is taking longer to find them.
- 2004 – 2010 = 76% average occupancy; down to average of 38% occupancy 2012 – 2014

Missouri Summary

- Trend: Significant reduction in range pre-listing and continuing reduction since (strong data). Lost one of three remaining core populations since listing.
- 85% reduction overall from 1960's to 1990s
- Reduction in abundance – forced to change sampling scheme from Power Analysis to Occupancy Modeling.
- Sugar Creek barely hanging on; given current trend, without artificial propagation will likely become extirpated.
- Moniteau creek appears to be persisting (albeit low numbers), but is vulnerable to stochastic events due to restricted distribution. Per occupancy modeling the probability of detection around 50% (but rises and falls).

Nebraska Summary

- Trend: Tenuous existence. Decline continues. Taylor Creek has data (multiple collections over 20 years, in past few years 1 or none); Big and Brush creek status unknown (data poor).
- Sandhills (North Loup): Big and Brush Creeks status unknown. No access to Brush anymore (last record in 80's). Looked in Big Creek (last record 2006) recently and not found them.
- Elkhorn watershed: two small tributaries, 2009
  - Taylor creek – found fish in 2014, one or two individuals
  - Now extirpated from unnamed tributary of Union, confident.

Kansas Summary

- Trend: Reduction in numbers (sites and perhaps individuals). Sites lost and decline in range since listing (Willow Creek gone in 2002, presence data supported)
- Three main areas that still have fish (1999 – 2013)

- Cottonwood – in areas that can be accessed they appear to be declining in distribution and numbers. Some sites had dams installed prelisting, no access since, cannot ascertain presence – likely extirpated based on results of other areas where dams have been put in.
- Blue river drainage – isolated and fragmented above a reservoir. Two populations persist, common.
- Kansas River drainage – two drainages, Mill Creek and Deep Creek, reduced where they persist, still maintain numbers at some level. Seven Mile, Clear Fork, Wildcat, and Lyon creeks: spotty presence; may be present one survey and not the next. Clark and Mission, not many surveys past 20 years, assume they are still persisting due to lack of changes.
- From historic, an 80% overall decline. Contraction in range. Declined since early 90's intensive sampling, but can't quantify.

South Dakota Summary

- Trend: Data limited. 16 mainstem tributaries documented as occupied in last 3 years. Eleven streams (subset of the 16) monitored during two rounds of sampling (2004-2006 and 2010-2012) continue to persist. Number of sites occupied during the monitoring plan surveys were76% (2004-2006) and 58% (2010-2012).
- Abundance information lacking: wide ranges of numbers, when reported, CPUE sampling not completed.
- Increased survey effort since listing significantly increased known occupied tributaries. All current/historic records exist within 3 major drainages: James, Vermillion and Big Sioux (some Big Sioux tribs cross MN/SD border).
  - Pre-listing (1997): 11 known mainstem occupied tributaries (14 streams total)
  - Post-listing: increased surveys, consultations, etc., resulted in identification of 35* mainstem tributaries occupied (total 66 streams*): 16 in James watershed; 11 in Big Sioux (excludes Big Sioux); 8 in Vermillion (excludes Vermilllion). 8 of the 35 have reports from a single site from only one year when Topeka shiners were documented.

*Discussion ensued regarding how occupied areas are counted. To be more comparable with other states, the 66 tributaries in South Dakota can be reduced to 35 by counting only direct tributaries of the James, Big Sioux and Vermillion rivers. The other 31 tributaries could be considered subpopulations of the primary 35 streams.

EFFECTS DIAGRAMS

Briefly shown, the handout of contaminants diagram was provided. Effects diagrams are to be shared with meeting attendees later for review and comment.

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THREATS PRESENTATIONS

Climate Change

Dennis Todey, State Climatologist, SDSU, South Dakota:
Overall, further north is likely to be better for Topeka shiners than southern areas. Climate change will somewhat change what is grown where (e.g. corn grown in southern Canada). Water withdrawals are another issue – NE and KS especially are big water users. SD started to do that when corn prices were high, but has slowed down with dropping corn prices. Could be a bigger demand in future. SD has permitting of groundwater (NE does too, but is regulated to the point of depletion). 30 year average precipitation: Topeka range sits on change of rapid transition, pushing west. 30 year temperature change 1981-2010 shown – has been cooler in north (logically). Climate is not static. Precipitation over SD shown since 1900 – has been highly variable. (For good assessment of current knowledge base, see: http://nca2014.globalchange.gov/). Impacts of climate change are regional….includes warming temperatures & lengthening of growing season. Temperatures are rising in the Midwest. Precipitation is increasing in SD/MN and other states in Topeka range too, mainly due to increases in very heavy precipitation events. Flood events are increasing. USGS streamflow recently released (see USGS's John Stamm et al. 2014 publication) showed increased flows in Topeka range. The timing matters. Dennis suggests we work with a modeler to do more regional scale modeling in the Topekas range. The temperature models are pretty good, but climate change people are less confident in precipitation models. Changes are complex: it's not just overall warming, it's regional….when and where we have storms, maximum/minimum temperatures at different times. Could be as much as 8-9 degrees higher under high emission scenarios, or 4-5 degrees under low emission scenarios. North will have better chances of precipitation, but winter/spring may have more water than summer. Dry temperatures + less water in summer = greater evaporation. Changes in soil moisture, linked to groundwater, are likely to decrease, but in eastern SD, may stay a wetter area overall. Groundwater is affected by how quickly you get groundwater recharge and what withdrawals will be. NE, KS, MO could have major issues; less problematic in the north (see National Climate Assessment document). http://www.ncdc.noaa.gov/cag/time-series/us. Temperatures from past 115 years in SD: not a huge change. In IA maximum temperatures have decreased, but minimum temperatures have increased. Highs are getting lower, lows are getting higher. Overall minimum temperatures are increasing in wintertime. Overall trend is toward warmer winters in SD. Overall increased precipitation in MN. Timing of precipitation in SD: spring and fall are seeing bigger increases in precipitation than summer. Dew points: increasing (more humid, reduced evaporation) especially in summer. Evapotranspiration: decreasing over time. Good news for farmers if water is limiting, but if you have excess water, it's a problem. Expect bigger extremes. More specifics would require downscaling/regional modeling. Variability issues will continue, and could get worse. Overall warming will continue. Precipitation will increase with large variability and shifting seasons.

Climate change/hydrology/prairie fish in Montana

Kathy Chase, USGS Hydrologist, Montana:
Prairie fish natives mostly, experience boom and bust conditions with flows. Kathy (and co-researchers) used a regional climate model to look at present day climate and future climate. Put climate model into hydrology model and get stream flow. Precipitation-runoff modeling system (PRMS) model uses inputs of daily precipitation and daily maximum/minimum temperatures to simulate daily streamflows; however project is focusing on mean monthly changes in streamflow. Then relate the hydrology to the fish. Goal: to determine relative change, magnitude and location of fish changes across eastern MT. They're creating a PRMS model for the entire US. They modeled their predictions for three future periods: 2030s, 2055s, and 2080's. In eastern MT they have higher precipitation in summer, but higher flows in winter-spring (due to snowmelt and ice-jams and snowmelt on frozen ground). Running climate scenarios through their streamflow models showed different results (increases and decreases in streamflow). Problem: their model doesn't reflect snowmelt/frozen ground/ice jam issues. Adds doubt to parts of the model. Lots of variability exists between months. Preliminary results show increases in stream flow in two basins and decreases in stream flow in others. Increases in precipitation are overwhelmed by increases in temperatures showing overall decrease flows for some watersheds and some future periods. As Dennis mentioned, more variability exists in precipitation than in temperatures. They modeled changes in stream flow in seven different basins and had variability there. PRMS doesn't simulate pool habitats retaining water when rest of stream dries. The preliminary fish model includes 1433 sites and 60 species, 89 hydrology variables and 22 basin variables. Ran 10 rounds of 10-fold cross-validation. The models include a "full model" (with both basin characteristics and streamflow), and a "hydrology only" model (with only streamflow). They showed examples of interactive maps showing baseline and future conditions.

Grassland conversion

Roger Auch, Research Geographer, USGS, EROS Data Center, South Dakota:
Roger looked at NLCD (National Land Cover Data) in Topeka watersheds – says he should probably have buffered Topeka streams instead to get better idea of land use and effects on local scale, but have regional compositions. 70-80% accuracy is adequate for NLCD. Hard to detect changes from grass to crops (forests are easier to detect). NLCD data are comparable for 2001, 2006 and 2011, but hard to compare 1992 NLCD to newer ones. In the south the leading landcover in Topeka watersheds is grassland [*editor's note: this is potentially because grasslands are where remnant Topeka populations have survived in the south*]. North and middle sections have cropland as #1 land use cover. In north, grassland is 2nd most dominant. Regional land cover may not be very important. The map product doesn't show the scale we need, nor incorporate factors that we need (e.g. sedimentation, tiling). Roger showed Landsat data 1972 vs 2010 – small grains changed to row crops. The changes are in crop land use.

Change in crop types can change evapotranspiration. Used LiDAR (Light Detection and Ranging) system. Wheat has gone from dominant crop to corn and soybeans today as lead. Some land not converted – why not? Too sloped, rocky, sandy, wet, pasture needed as part of operation. Pasture is left in steep slopes next to streams. Flat dry pasture is at highest risk. Ethanol is a player, overseas exports, combination of biophysical changes, human drivers (enhanced crop insurance), more diseases in small grains due to wet years, lots of factors.

Ryan Reker, Geographer, Contractor, EROS Data Center, South Dakota:
Ryan presented county-level USDA Ag Census statistics to highlight changes in cultivated cropland extent over time in the Topeka Shiner range. Macro-scale patterns and trends were presented with acknowledgement that this audience may be more interested in watershed scale analysis or more localized information such as stream buffers. Ag Census statistics indicated over 80% of the landscape was used for cropland in SE SD/SW MN. Maps were shown highlighting the maximum amount of area in agricultural production at any one time, year of maximum agricultural extent, and decadal changes in agricultural extent since 1850. In general, more land has been cropped in the past than is under cultivation now; in the Des Moines Lobe, the maximum cropping level was reached in recent years whereas in other regions the maximum agricultural extent was frequently seen in the first half of the 20th century. Contemporary agricultural extent is generally below maximum ever seen but the area difference between the two is pretty small. Ryan presented information from the recent EWG Broken Streambanks report on MN stream buffers, highlighting streams in Rock County that appear to be some of the least buffered in the state while also containing Topeka Shiners. To portray potential future land use trends, USDA 10-year projections were presented that indicate slight increases in agricultural output, however it is unknown how much of the increase will be due to land use change or yield improvements. An overview of future land use scenarios (2005-2100) from the recently completed USGS LandCarbon project was provided. Four land use change scenarios were completed to provide a range of potential future land use conditions (see presentation). In the Great Plains, there were few large wholesale changes in land under cultivation in either the economic or environmentally-oriented scenarios. Economic focused scenarios maintain or increased agricultural production while the more environmentally focused scenarios retained ag production, with potentially small gains in natural cover. More marginal agricultural areas west of Topeka Shiner range or potentially in the Flint Hills may see gains in natural cover in future environmental scenarios, but much of the Topeka range is prime agricultural land (IA) and will likely remain in production to meet future population/economic needs in any future scenario.

Contaminants

Michell Hladik, Research Chemist, USGS, California:
Pesticide use is constantly changing: new compounds, new pest pressures (soybean rust risk for example), crop types change, application techniques change. Insecticides, fungicides and more can be coated onto the seed. Seed coating was supposed to reduce application, but now nearly 100% of corn planted is seed-coat treated, rather than treating problems as they arise (i.e.,

prophylactic treatment rather than Integrated Pest Management). Neonicotinoids (neonics) bind more strongly in insects – the binding is nearly irreversible leading to chronic issues in insects. Noenics are taken up by plant and end up in pollen and nectar – high profile neonic issue exists with pollinators. While agricultural use of neonics is primarily as seed coating, it also includes foliar sprays, and in-furrow treatments. Neonics are in home and garden products, pet flea meds. Neonics are highly water soluble, aqueous half-lives in months; soil half-life can be years. About 10% of seed coating application is taken up by plant – the rest goes somewhere else (soil, water). Entire Topeka shiner range is the area of highest use of neonics - where they grow corn/soybeans. Use is still on the increase, has been exponential since early 2000's. Study in IA streams detected neonics frequently and throughout the growing season. Stream concentration peaks in May/June, which matches with planting time and rain/runoff events. Toxicity: high level for acute aquatic toxicity. Any Topeka shiner effects may be indirect via reduced invertebrate prey. EPA benchmarks (acute and chronic) were orders of magnitude above what they detected in IA streams (but other researchers have set lower levels than EPA benchmarks). Getting more detections, longer in persistence. Matt Schwarz (USFWS – SDFO) conducted passive sampling (POCIS) in SD: tile drains are an exposure pathway to surface waters and wetlands. Wetlands that receive tile outfalls had higher relative concentrations of neonics than wetlands that only receive surface agricultural runoff or reference wetlands that are more isolated from agricultural drainage. Neonic concentrations in water grab samples from tile outfalls exceeded recently established benchmarks for the protection of aquatic life that are much lower than the EPS's current non-regulatory benchmark that has received much criticism as not protective. In one sample thiamethoxam was above EPA's benchmark for aquatic life. EPA indicates some neonics are practically non-toxic to fish, but could have chronic effects, could have immune suppression in fish, reduces invertebrate prey & could lead to impaired growth of fish. Other contaminants: fipronil is very highly or highly toxic to fish (not a seed coating, not used as much as neonics). Adverse effects from atrazine are likely direct (chronic: survival growth and reproduction) and indirect effects (plants). EPA has made an atrazine effects determination for Topeka shiner: likely to adversely affect, based on indirect effects. Selenium (natural), birds and fish are most sensitive to selenium toxicity. Nitrates. Sampled 6 sites from floods in IA in 2014 – got sample from Big Sioux: fungicides are understudied, but frequently detected. Atrazine and metolacholor were in relatively high concentrations. Des Moines lobe study on amphibians in wetlands (restored vs others) where restored wetlands were fed by tile drains: analyzed livers of chorus frogs, and detected fungicides that they didn't detect in the water and sediment as well as other toxins. Checked whole body too. Not much difference in pesticides in restored vs reference wetlands. Matt found 14 pesticides, fertilizer, etc. in drain tile effluent. Tile drains are discharging selenium at concentrations that exceed the chronic aquatic life criterion of 5 micrograms/liter. CAFOs can be a huge issue (hormones, antibiotics). Human wastewater could also be potential source of contaminants.

Tiling

Keith Schilling, Geographer, IA Geological Survey:
Don't know where field tiles are, but can estimate with hydric soils. Do know where some wetland drains are. Estimate using soils, however, is a total underestimate of how much tile is out there. Big tiles are mapped – can be huge. The problem is the field tile. They used aerial photography after a rain that showed dry lines where the tile lines were. Other factors, in addition to tile, are affecting hydrology: channelized areas, ditches, dams, etc. Cited the Blann et. al (2009) paper: it's hard to separate drainage from other agricultural effects. Croplands store less water and contribute to higher runoff and flashier stream flow. It's hard to pick out tile drainage as a single factor. Changes in Iowa stream flow: change in base flow part of hydrograph (increasing). Base flow is groundwater seeping into the streams over time; tile drainage is added to that. Overall base flows are increasing in IA. Greatest base flow change is in April/May through July, when tile drain is working most (crops not planted yet, with spring rains). Effects of tile are complex and vary in response to many local factors. Timing and amount of precipitation, antecedent moisture, soil type, depth to water table, topography, drainage, management factors all vary. Peak flows: surface drainage increases peak flows, tiling can reduce peak flows, but depends on soil texture. More permeable soils can increase peak flows. If there's a large rain event, the overland flow is a larger problem than tile input. Drainage will increase the mean annual basin yield, but varies seasonally and it's difficult to estimate amount. Keith's own observations: studied various questions in IA. There's tile discharge in streams, but there is also surface runoff when there is a rain event. Phosphorous and sediment are delivered in first hours of flow after event (conduit flow). How does tile affect base flow and stream recession? With no tile drain, most of water in an event is runoff. It does increase base flow in April/May/June. Less hydrologic variability in tile areas – this is another way to detect it. Water passage throughout the system: tiling can cut mean travel time of water in a watershed by ½. The more tile drain, the greater contribution to base flow you have. Does flow from tile affect baseflows or stormflow? Answer: primarily baseflow. How does it affect streamflow recession? Answer: recession curves are more linear. Reduces groundwater travel times. Tile is complicated, effects are variable, yields more water, reduces groundwater travel times. In Missouri they have terrace tile – flow will arrive later than surface flow. Will have more sediments and phosphorous from terrace tiles, but will likely have similar effects of tile, perhaps elevated base flows and linear recession and increased nitrates. Pattern tiling is increasing in IA despite a lot of it already in existence; producers are adding it to areas that don't need it in the first place, or replacing old tiling, sometimes at shallower depths than previous systems.

Ray Finnochiaro, Ecologist, USGS NPWRC, North Dakota:
Wanted to characterize tile going in, where, why, and where it will go. His focus is on wetlands, doing a field study to assess NRCS setback distances by comparing two sites that are tiled to two sites that aren't tiled and measuring water balance of water input and output of wetlands. Trying to determine whether there were any determining factors for why people put tile in. It's not

necessarily the soils; people just put it in anywhere they can. Ray developed a tile map on tile permits gathered from counties in ND/SD. Tried to use other methods (e.g. satellite info), but permit was best information they could find. Had 4,300 in April 2012, which went up to 4,900 in Dec 2013 in SD based on two counties. High proportion of tile is undocumented and underestimated. Tile permits are given in ND only when tile is 80 acres in size. Information on permits is becoming scarcer by the month. Tile information is available through Science Base Catalog or USGS NPWRC. What's driving tile usage? Tile is going in in conjunction with corn and soybeans. Ray did an informal tile installer survey and the primary motivation was profitability (100%) while 50% indicated increasing the amount of land to till was also a motivation. Asked whether in last 5 years there's been an increase in tile installed – answer: yes, mainly in Midwest, done often because neighbors do it (made them want to try it as well). When asked by what percentage they think tile has increased in past 5 years, one couldn't say, but the others stated by 30-40% UP TO 100%. When asked if it's more likely for landowners to tile only wet spots or pattern tile their entire fields, 75% said pattern (25% said it depends). Common soil types or landscapes they tile: 100% indicated there's no "typical" type of land, but 1 said agricultural land on table top. Typical acreage tiled? 80 acres. Most common tile diameter? 75% said 4 inch tiles, 25% 3 inch tiles. Depths? 75% said 3-4 ft deep, 25% said 2-2.5 ft deep. Comments: a) setbacks are too far from wetlands, b) setbacks are reasonable, c) farmers are being environmentally friendly, d) tile business is booming and tile is good for environment by getting rid of excess and decreasing erosion. Question: what happens if 50% of watershed is tiled? Ray thinks it will affect the hydrology. Straight line recession means you have more water in the stream after an event for longer timeframe. How does tile drainage effect groundwater recharge? Not sure yet, but Ray's information will help, and Keith will be doing some modeling exercises to get at that question. People are tiling because of corn and beans, which arguably are a greater issue. Or there could be a synergistic effect. With greater storm events, the tile won't be a big factor because the surface runoff will be so significant. The recession could be significant. And during drought, excess water that could've been used will not be available. Temperature of the water coming from tile could be another factor. Tile outfalls cause incision/headcutting too.

GROUP DISCUSSION ON PRESENTATIONS/EFFECTS DIAGRAMS

Presence of neonics and potential effects on shiner is an area not previously examined before for Topeka. Has anyone noticed reductions in prey base? No, but not studied either. Sublethal affects could be a problem (like suppressed immune systems) but we tend not to get that information. General thought: "chemical soup" exists in Topeka streams.

Addition of so much more tiling is just adding more to the downcutting and in IA where they need those off-channel habitats, this could be a bigger concern. Hoped that IA hydrology was coming into equilibrium, but after hearing tiling, and conversion information today, its not looking good. 52 miles of tile within 2 square miles of land is disconcerting. Riparian pastures have shown a marked reduction of cattle, have been tilled since 1999 and even last 5 years. In a 2 year period in IA there was 100,000 acres of trees lost to corn.

One thought: we've heard a lot about potential threats, but presence of a stressor is not enough to make the case that it is a threat to the species. Need good data, science on species response. In absence of that, need a compelling and direct chain to infer a species response. That's been lacking here, conversation on that would be useful. Effects diagrams are still theoretical….looking for data.

Response: our effects diagrams have been started, and still have questions, but these are our way of capturing our information for the SSA, attaching literature that supports the relationship between these factors.

INTEGRATE INFORMATION INTO SSA FRAMEWORK/RESILIENCY MODEL

Lack of good data is big problem. Overall, what we've heard so far is that things don't look like they're getting better. Resilience criteria were explained to the group. Definition of populations given – vague and general because the populations are all different, but we've given the textbook version of it. Population complex: mixing, but not frequently. Isolated populations – could be downstream (dam), but not upstream. Substantial barriers defined. Effective barriers could exist (where they could move, but aren't). These definitions are our groundwork. Stream diagrams depict these. Need to determine what components are populations in the stream diagrams. Resiliency broken down into three categories: 1) stream characteristics 2) habitat conditions 3) population characteristics. Showed the group the FWS approach to resilience criteria on Big Sioux River streams in excel file – putting numbers for resilience criteria on each stream. Tough to do this with all of the variability in the streams and the lack of exactly what a population is (genetics would tell us). We have to have some measurable unit to apply to the criteria. FWS needs assistance in determining how to group the occupied areas. We're lacking so much data, we need to use surrogates or proxies for the data we need. If the shiner is still in a stream then something is "right" in its habitat. Those "right things" need to be measureable. That's what the resilience criteria are. We're working to simplifying the model. We're also trying to find measures across all states to compare apples to apples. We're trying to get at how resilient the species is; its ability to bounce back. If it comes back after some adverse event, it has some resilience. Have to decide what that level of resilience is. In Missouri, they've seen situations with no Topeka's in headwaters during drought, but the species then reappears after water returns. Haven't seen this in MN. In KS, the issue of fish being absent one time then reappearing another isn't apparent. This has been noticed in SD. Resilience criteria: stream length would have some bearing on available habitat. Number of occupied streams could mitigate stochastic events. If you had a fish in the stream at listing, but no information since, would you call it occupied? Most say no, should call that "unknown". What if the last record was 10 years ago? Depends on stream (judgement call as to whether there have been big changes on individual streams). Perhaps would be more comfortable saying a stream is occupied if there had been several previous records. Want the habitat to be intact. Five years was mentioned as a comfortable range of years – positive finding in past 5 years with no change of habitat on the landscape. What if there's no previous record from a stream? Yes, if found within 5 years, would consider occupied. But what if there have been recent negative surveys? Call it unknown. From a biological perspective the species lives a maximum of three years - what if we use that timeframe? Could categorize these with confidence –"high" confidence in occupancy if found within past 3 years and go down from there. SSA is how we as biologists predict changes in viability over time, using scenarios. We might use a series of graphs to show number of streams occupied under various scenarios. Say we had 50 populations. Under climate change scenario of X along with land use change of Y, we would anticipate the species to do what? Then if we get additional information, we can use the same model with updated info. First cut might be: species detected since listing in a stream. We put population characteristics first in our resilience criteria because whether it was found since 1999 will define which populations are run through our model. Then score it based on when it was last noted in the stream. Perhaps go with 3 year intervals (lifespan of the species). We don't have all information we want/need (e.g. low head dams, culverts) so all we can do is note that this information would change our analysis. Some of our resilience criteria (nutrient enrichment and introduced predators) are more stressors, rather than habitat components…perhaps take those out. Suggest we use HUC units as our populations. HUC 10 seems to fit the streams. Could give it a lower score if there's a dam, but not have the dam define the population. Water quality determinations have criteria, have to meet certain thresholds to say whether a waterway is impaired (Matt Schwarz), can that same model be applied to occupation? HUC 10 found since 1999 would be first cut to run stream through resiliency model. Use last detections in last 3 years and last 6 years, but longer than that is not important so go with 6 or greater. Then determine whether there is more than one HUC occupied within that unit. Next criteria could be the number of HUC 12's that are occupied within that HUC 10 since 1999.

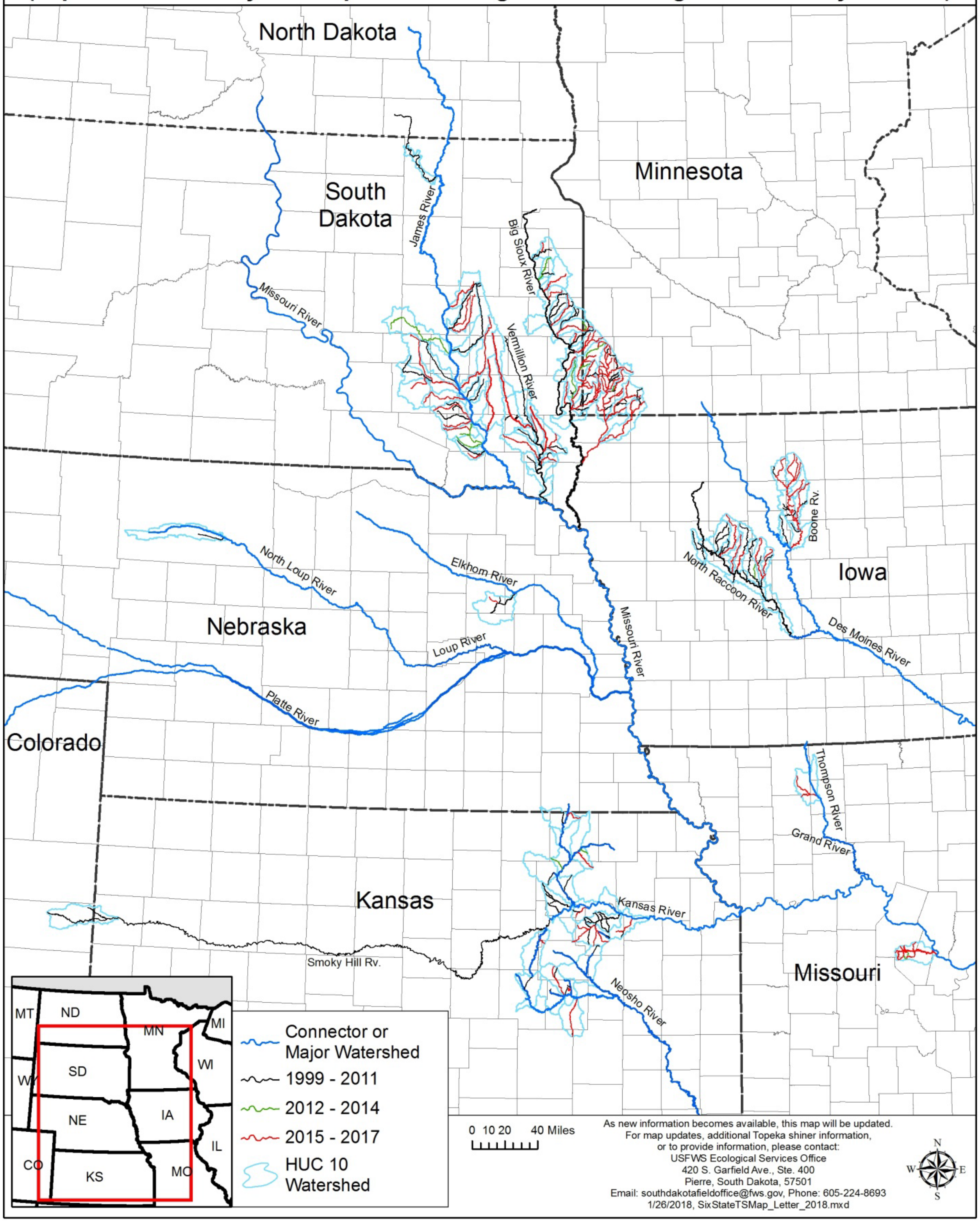
WEDNESDAY Sept 17, 2014 – ALL GROUP

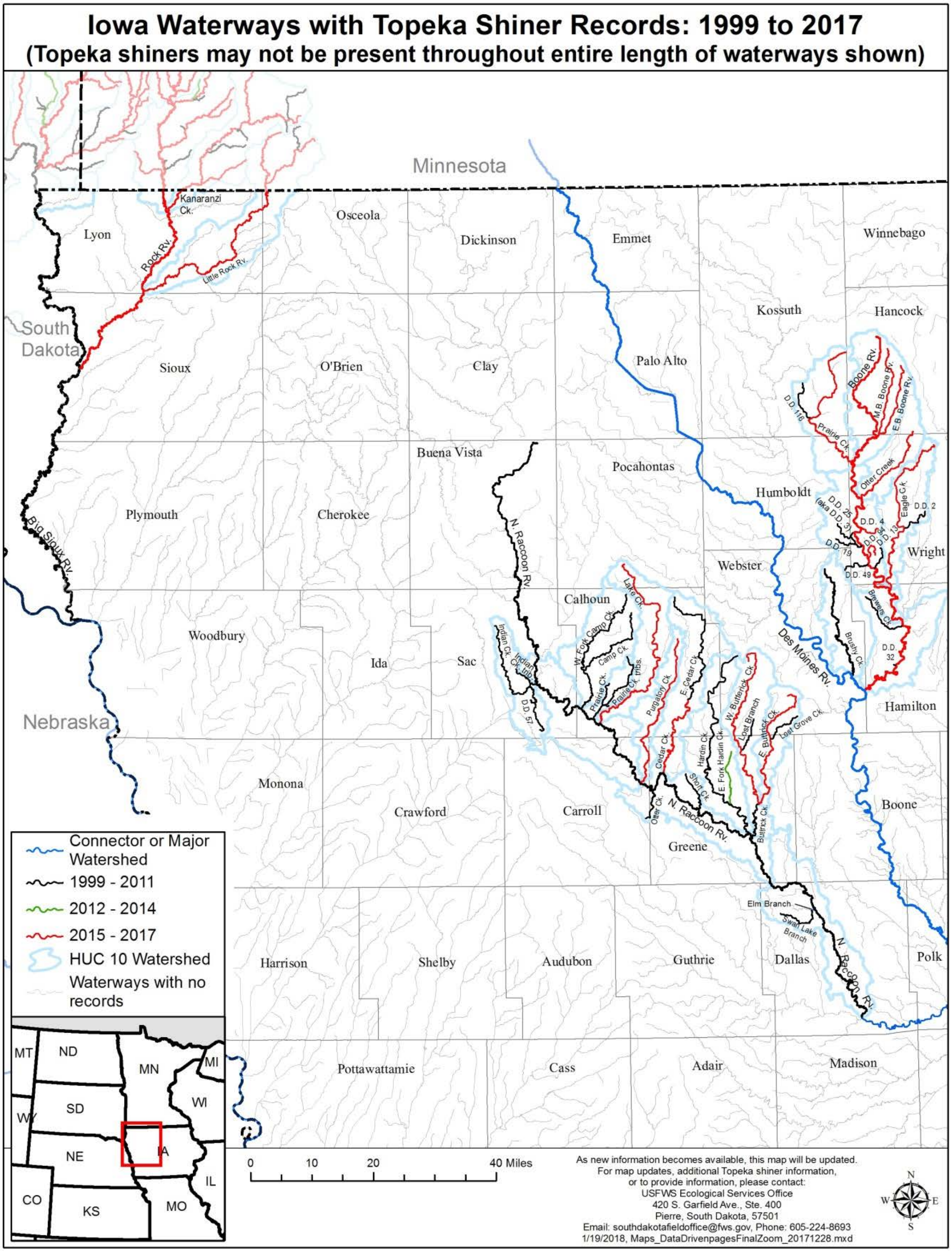
CONTINUE INTEGRATING INFORMATION INTO SSA, ETC.

Question: what is the big question here, what are we ultimately trying to do? Answer: States have suggested we've got the status wrong, so this is our focus on the biology of the species to determine the status. And it seems different interpretations came out of the presentations we've had so far. Need to get on the same page. Concern was voiced that we're lacking the data to fit information into our SSA. Using proxies, making decisions when we don't have the data, this is cause for concern.

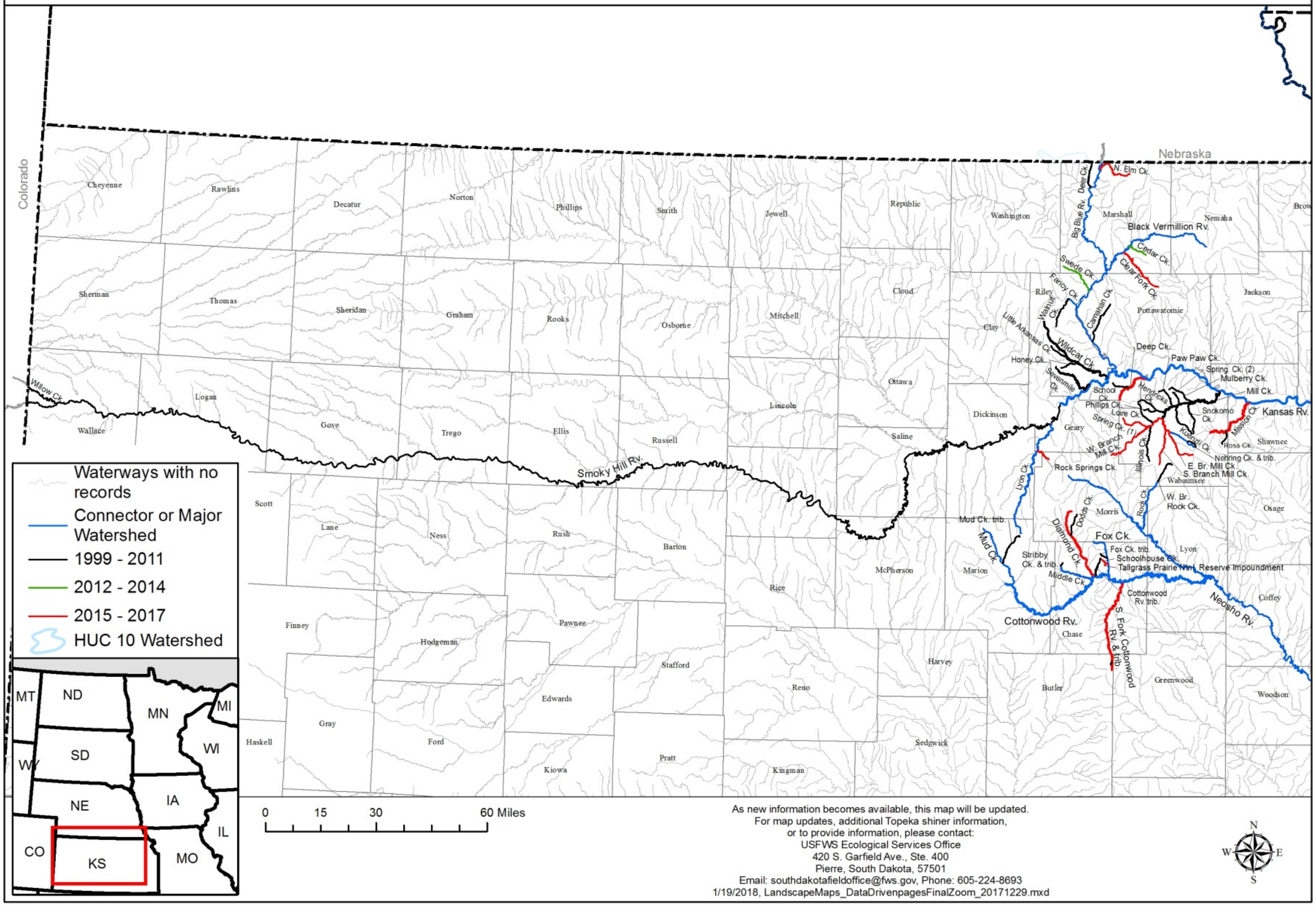
APPENDIX B: Topeka Shiner Occupied Stream Maps (Rangewide and by State), 1999-2017

Waterways with Topeka Shiner Records: 1999 to 2017
(Topeka shiners may not be present throughout entire length of waterways shown)




Iowa Waterways with Topeka Shiner Records: 1999 to 2017
(Topeka shiners may not be present throughout entire length of waterways shown)
Minnesota
South Dakota
Nebraska
Lyon
Osceola
Dickinson
Emmet
Winnebago
Kossuth
Hancock
Sioux
O'Brien
Clay
Palo Alto
Buena Vista
Pocahontas
Humboldt
Wright
Plymouth
Cherokee
Webster
Calhoun
Woodbury
Ida
Sac
Hamilton
Monona
Crawford
Carroll
Greene
Boone
Harrison
Shelby
Audubon
Guthrie
Dallas
Polk
Pottawattamie
Cass
Adair
Madison
Kanaranzi Ck.
Rock Rv.
Little Rock Rv.
Big Sioux Rv.
N. Raccoon Rv.
Des Moines Rv.
Boone Rv.
Connector or Major Watershed
1999 - 2011
2012 - 2014
2015 - 2017
HUC 10 Watershed
Waterways with no records
0 10 20 40 Miles
As new information becomes available, this map will be updated.
For map updates, additional Topeka shiner information,
or to provide information, please contact:
USFWS Ecological Services Office
420 S. Garfield Ave., Ste. 400
Pierre, South Dakota, 57501
Email: southdakotafieldoffice@fws.gov, Phone: 605-224-8693
1/19/2018, Maps_DataDrivenpagesFinalZoom_20171228.mxd

Kansas Waterways with Topeka Shiner Records: 1999 to 2017
(Topeka shiners may not be present throughout entire length of waterways shown)



As new information becomes available, this map will be updated.
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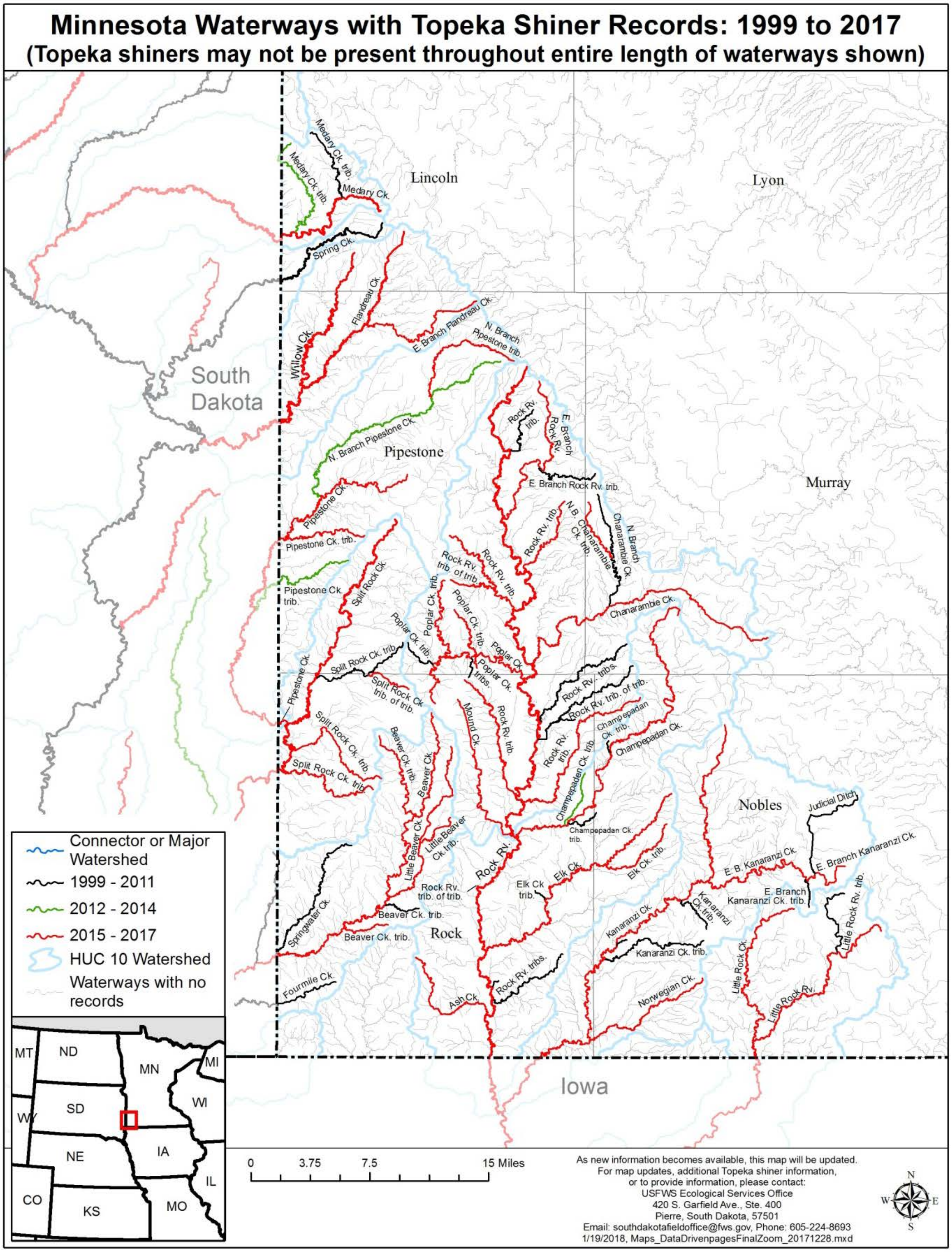
or to provide information, please contact:
USFWS Ecological Services Office
420 S. Garfield Ave., Ste. 400
Pierre, South Dakota, 57501
Email: southdakotafieldoffice@fws.gov, Phone: 605-224-8693
1/19/2018, LandscapeMaps_DataDrivenpagesFinalZoom_20171229.mxd


Minnesota Waterways with Topeka Shiner Records: 1999 to 2017
(Topeka shiners may not be present throughout entire length of waterways shown)
Lincoln
Lyon
Pipestone
Murray
Nobles
Rock
South Dakota
Iowa
Medary Ck. trib.
Medary Ck. trib.
Medary Ck.
Spring Ck.
Flandreau Ck.
Willow Ck.
E. Branch Flandreau Ck.
N. Branch Pipestone trib.
N. Branch Pipestone Ck.
Pipestone Ck.
Pipestone Ck. trib.
Pipestone Ck. trib.
Split Rock Ck.
Split Rock Ck. trib.
Split Rock Ck. trib. of trib.
Split Rock Ck. trib.
Split Rock Ck. trib.
Rock Rv. trib.
E. Branch Rock Rv.
E. Branch Rock Rv. trib.
Rock Rv. trib.
N.B. Chanarambie Ck. trib.
N. Branch Chanarambie Ck.
Chanarambie Ck.
Rock Rv. trib. of trib.
Rock Rv. trib.
Poplar Ck. trib.
Poplar Ck. trib.
Poplar Ck.
Poplar Ck. tribs.
Poplar Ck.
Mound Ck.
Rock Rv. trib.
Rock Rv. tribs.
Rock Rv. trib. of trib.
Rock Rv. trib.
Champepadan Ck. trib.
Champepadan Ck.
Champepadan Ck. trib.
Champepadan Ck.
Champepadan Ck. trib.
Beaver Ck. trib.
Beaver Ck.
Little Beaver Ck.
Little Beaver Ck. trib.
Rock Rv.
Rock Rv. trib. of trib.
Beaver Ck. trib.
Beaver Ck. trib.
Springwater Ck.
Fourmile Ck.
Ash Ck.
Rock Rv. tribs.
Elk Ck. trib.
Elk Ck.
Elk Ck. trib.
Kanaranzi Ck.
Kanaranzi Ck. trib.
Kanaranzi Ck. trib.
Norwegian Ck.
E. B. Kanaranzi Ck.
E. Branch Kanaranzi Ck. trib.
E. Branch Kanaranzi Ck.
Judicial Ditch
Little Rock Ck.
Little Rock Rv.
Little Rock Rv. trib.
Connector or Major Watershed
1999 - 2011
2012 - 2014
2015 - 2017
HUC 10 Watershed
Waterways with no records
MT
ND
MN
MI
SD
WI
WY
NE
IA
IL
CO
KS
MO
0
3.75
7.5
15 Miles
As new information becomes available, this map will be updated.
For map updates, additional Topeka shiner information,
or to provide information, please contact:
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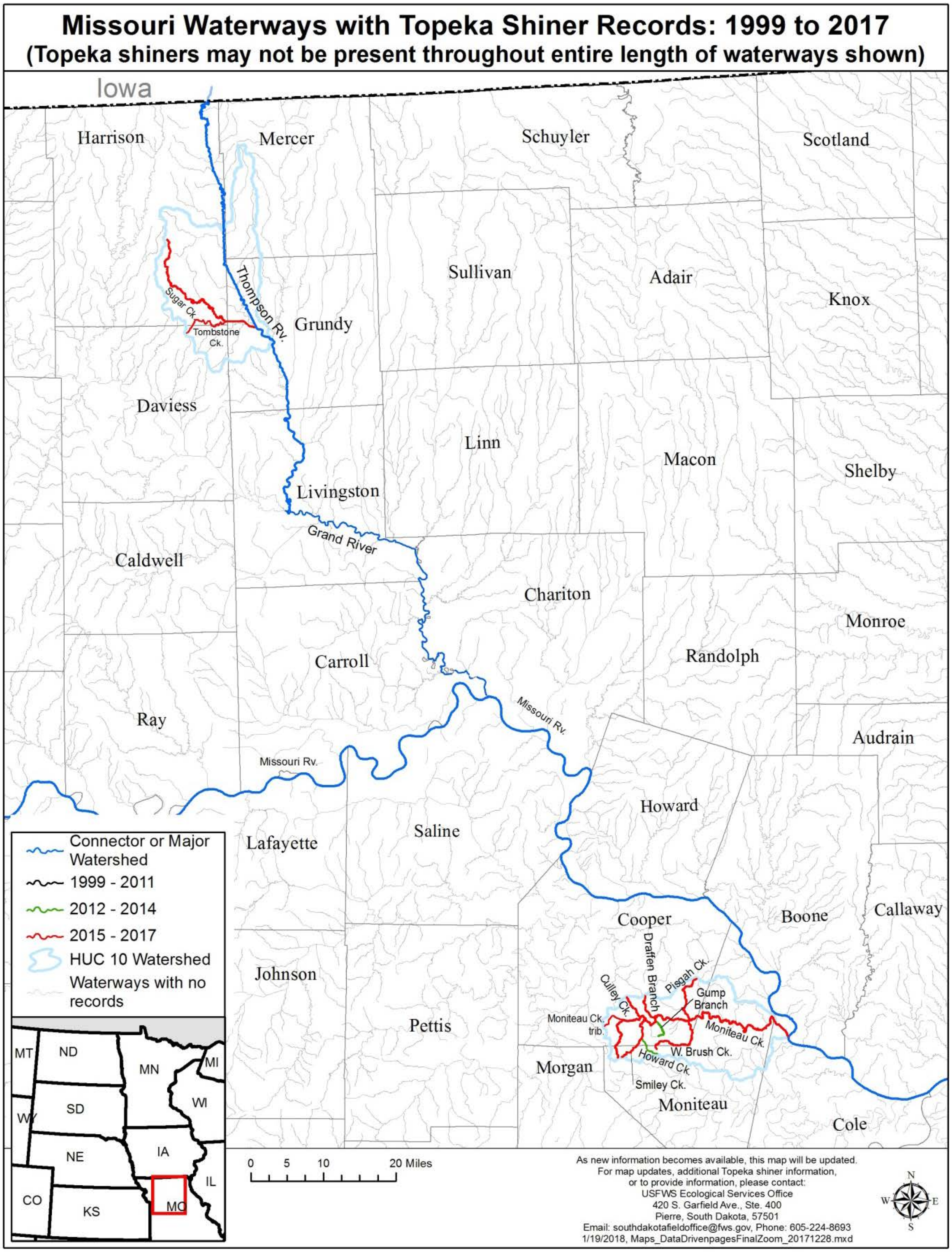
420 S. Garfield Ave., Ste. 400
Pierre, South Dakota, 57501
Email: southdakotafieldoffice@fws.gov, Phone: 605-224-8693
1/19/2018, Maps_DataDrivenpagesFinalZoom_20171228.mxd
N
S
E
W


Missouri Waterways with Topeka Shiner Records: 1999 to 2017
(Topeka shiners may not be present throughout entire length of waterways shown)
Iowa
Harrison
Mercer
Schuyler
Scotland
Sullivan
Adair
Knox
Grundy
Thompson Rv.
Sugar Ck.
Tombstone Ck.
Daviess
Linn
Macon
Shelby
Livingston
Grand River
Caldwell
Chariton
Monroe
Carroll
Randolph
Ray
Missouri Rv.
Audrain
Howard
Lafayette
Saline
Cooper
Boone
Callaway
Johnson
Draffen Branch
Pisgah Ck.
Culley Ck.
Gump Branch
Moniteau Ck. trib.
Moniteau Ck.
W. Brush Ck.
Howard Ck.
Smiley Ck.
Pettis
Morgan
Moniteau
Cole
Connector or Major Watershed
1999 - 2011
2012 - 2014
2015 - 2017
HUC 10 Watershed
Waterways with no records
MT
ND
MN
MI
SD
WI
WY
NE
IA
IL
CO
KS
MO
0 5 10 20 Miles
As new information becomes available, this map will be updated.
For map updates, additional Topeka shiner information,
or to provide information, please contact:
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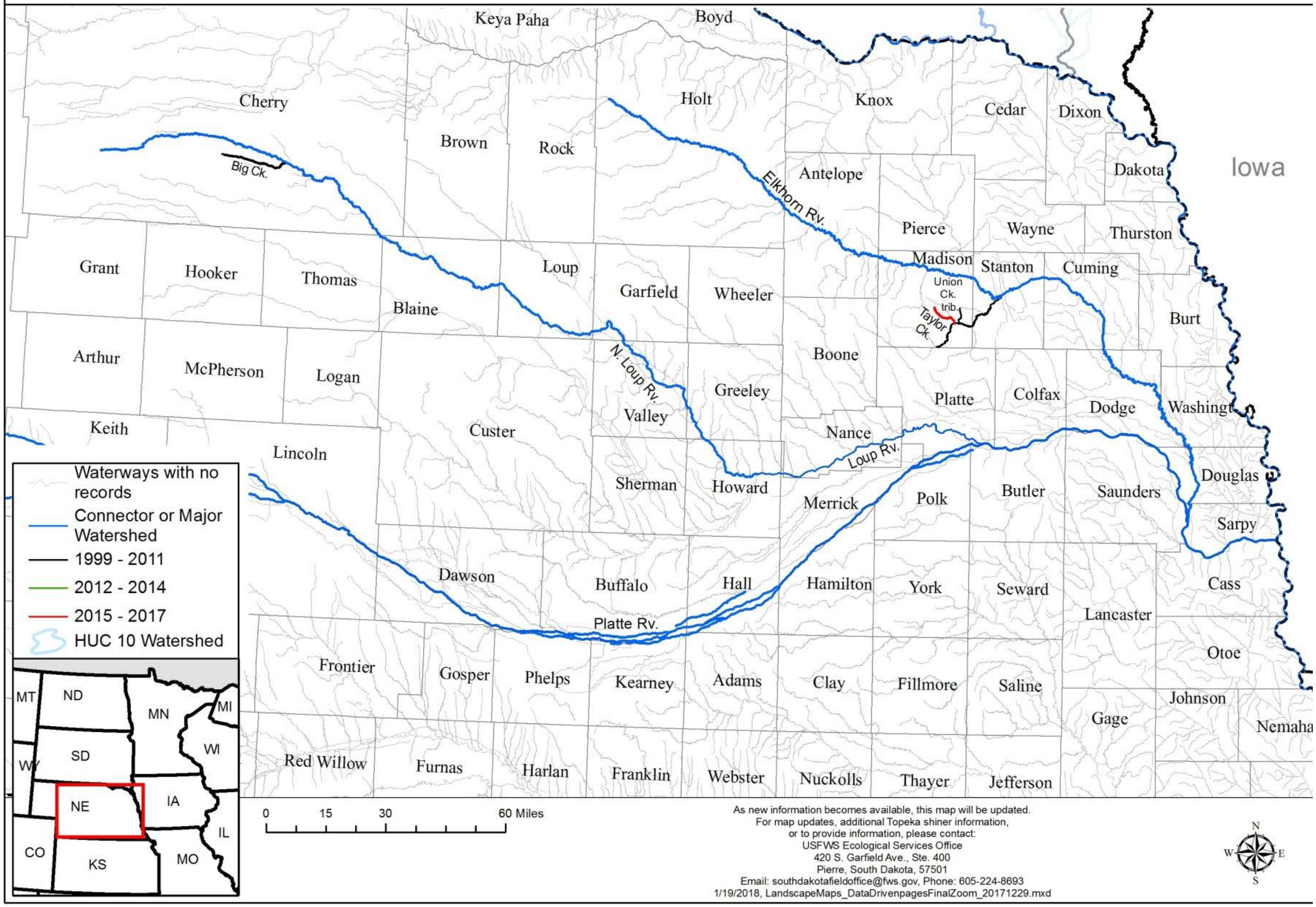
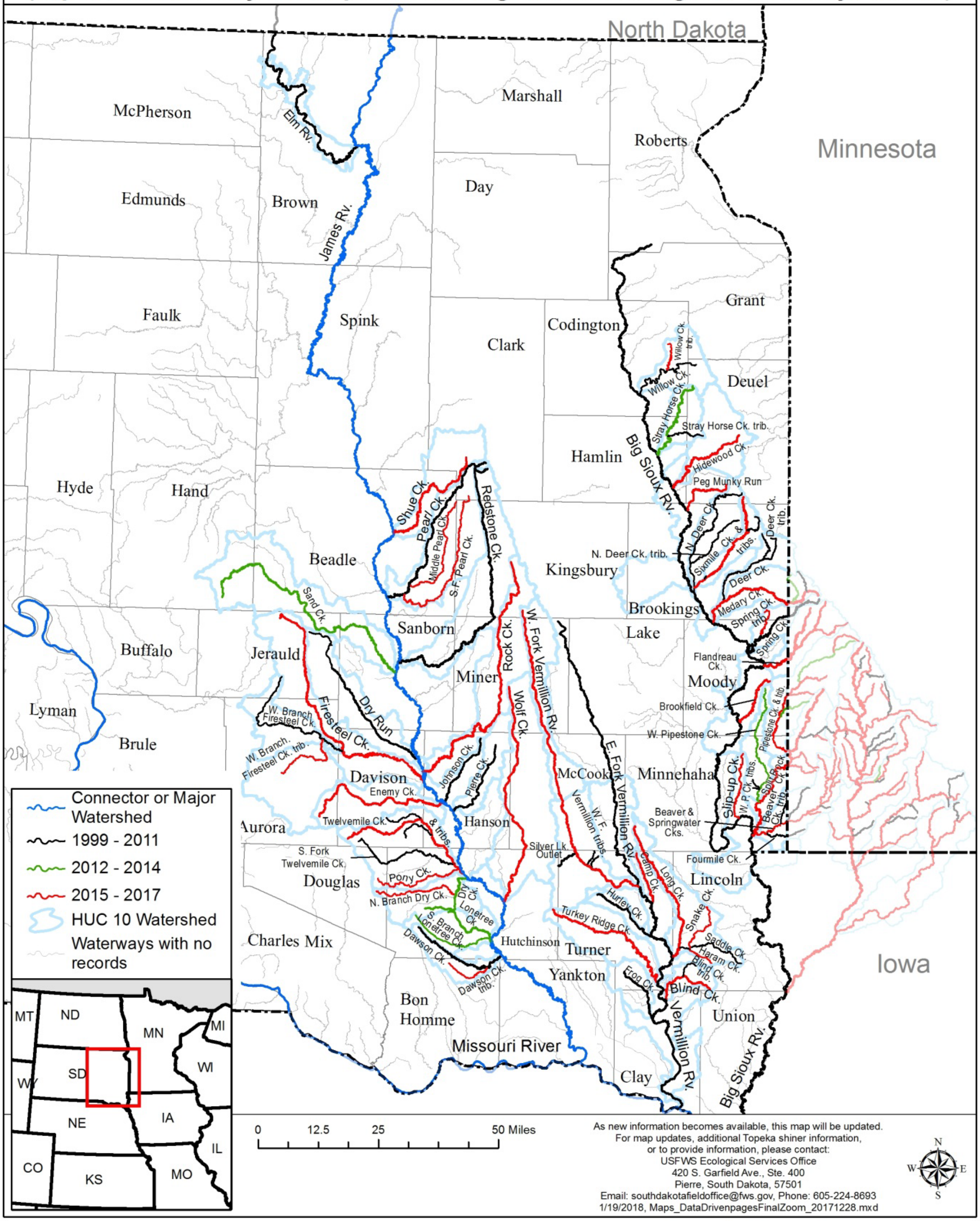
Pierre, South Dakota, 57501
Email: southdakotafieldoffice@fws.gov, Phone: 605-224-8693
1/19/2018, Maps_DataDrivenpagesFinalZoom_20171228.mxd
N
S
E
W

Nebraska Waterways with Topeka Shiner Records: 1999 to 2017
(Topeka shiners may not be present throughout entire length of waterways shown)



South Dakota Waterways with Topeka Shiner Records: 1999 to 2017

(Topeka shiners may not be present throughout entire length of waterways shown)



APPENDIX C: Table of known Occupied Topeka Shiner Streams, 1999-2017

KNOWN OCCUPIED TOPEKA SHINER STREAMS
1999-2017

The table below lists the streams throughout the Topeka shiner's range known to harbor the species since its 1999 listing under the Endangered Species Act through2017. Watersheds and occupied streams within them are listed by state, along with the counties in which those streams occur. Streams that cross state borders are not repeated for each state, but rather are identified in the far left column as occurring in the two states listed, to avoid double-counting. To further identify occupied streams, latitude/longitude are provided in decimal degrees of a random location near the outlet of each waterway as it joins with the next higher order stream (note that these locations are not actual collection sites). Finally, the year of the most recent known collection within each waterway is provided in the last column.

Note that this table presents the best available information regarding Topeka shiner occupancy 1999-2017, however, some streams on this list, particularly those with relatively old last known records (near 1999), may no longer harbor the species. Additionally, some streams not included in the table below (*e.g.* streams with records prior to 1999, and/or those designated as critical habitat but without known records) may be occupied today, but recent collection efforts are lacking thus these streams are not represented here. Additional sampling is needed to confirm or determine current occupancy of those streams.

Further, in 2013 the State of Missouri initiated reintroductions of Topeka shiners in several Missouri streams which are not listed in this table. Overwintering and persistence of the stocked fish has been observed in those streams as of this writing, thus these reintroduced sites in Missouri may be identified as extant populations that may be included in future versions of this table.

STATE	MAJOR WATERSHED(S)	OCCUPIED STREAMS	LOWER ORDER OCCUPIED STREAMS	COUNTIES IN WHICH THE OCCUPIED STREAMS OCCUR	APPROX. LOCATION OF OUTLET TO NEXT HIGHER ORDER STREAM (decimal LATITUDE/ LONGITUDE)	YEAR OF LAST KNOWN TOPEKA SHINER RECORD
South Dakota	James River	Dawson Creek		Hutchinson, Bon Homme	43.181196°/-97.631842°	2017
			Dawson Creek unnamed tributary	Bon Homme	43.143317°/-97.690325°	2017
		Dry Creek		Hutchinson	43.409149°/-97.780626°	2017
			North Branch Dry Creek	Hutchinson, Douglas	43.362630°/-97.830377°	2017
		Dry Run Creek		Davison, Sanborn, Jerauld	43.767260°/-97.999857°	2006
		Elm River		Brown	45.601683°/-98.309138°	2009
		Enemy Creek		Hanson, Davison, Aurora	43.635875°/-97.890491°	2017
		Firesteel Creek		Davison, Aurora, Jerauld	43.697194°/-97.970104°	2017
			West Branch Firesteel Creek	Davison, Aurora	43.785046°/-98.310434°	1999
			West Branch Firesteel Creek unnamed tributary	Aurora	43.789540°/-98.400381°	2015
		Johnson Creek		Hanson	43.641601°/-97.875851°	2011
		Lonetree Creek		Hutchinson	43.222616°/-97.674959°	2014
			South Branch Lonetree Creek	Hutchinson	43.230922°/-97.682518°	2012
		Pearl Creek		Beadle, Clark	44.250728°/-98.134726°	2009
			Middle Pearl Creek	Beadle	44.281359°/-98.047987°	2017
			South Fork Pearl Creek	Beadle, Clark, Kingsbury	44.256764°/-98.065334°	2017
		Pierre Creek		Hanson	43.613681°/-97.840329°	2006
		Redstone Creek		Sanborn, Miner, Kingsbury, Clark	44.055560°/-98.082403°	2010
		Rock Creek		Hanson, Miner,	43.728504°/-97.970016°	2017

			Kingsbury, Davison		
	Sand Creek		Sanborn, Jerauld, Beadle, Hand	44.024080°/-98.094886°	2012
	Shue Creek		Beadle, Clark	44.444215°/-98.113427°	2017
	Twelvemile Creek		Hutchinson, Hanson, Davison	43.424476°/-97.800252°	2015
		South Fork Twelvemile Creek	Hutchinson, Douglas, Davison	43.453002°/-97.834935°	2006
		Twelvemile Creek unnamed tributary	Hanson	43.538746°/-97.931443°	2004
		Twelvemile Creek unnamed tributary	Davison	43.588413°/ -97.980489°	2002
		Pony Creek	Hutchinson, Douglas	43.441463°/-97.820391°	2015
	Wolf Creek		Hutchinson, McCook, Hanson, Miner	43.345432°/-97.625769°	2015
Vermillion River			Clay, Turner	42.735773°/-96.884730°	2005
	East Fork Vermillion River		Turner, McCook, Lake, Miner	43.395251°/-97.069915°	2006
	West Fork Vermillion River		Turner, McCook, Miner, Kingsbury	43.394406°/-97.071060°	2015
		West Fork Vermillion unnamed tributary	Turner	43.450009°/-97.262476°	2006
	Blind Creek		Clay, Turner, Lincoln	43.055801°/-96.950455°	2016
		Blind Creek unnamed tributary	Lincoln	43.127208°/-96.879855°	1999
	Camp Creek		Turner	43.346399°/-97.010156°	2017
	Frog Creek		Clay, Turner	43.003749°/-97.008561°	2011
	Hurley Creek		Turner	43.246834°/-97.019720°	2011
	Long Creek		Lincoln, Turner, Minnehaha	43.183273°/-96.923619°	2015
		Saddle Creek	Lincoln	43.211672°/-96.897319°	1999
		Snake Creek	Lincoln	43.211968°/-96.852572°	2016
		Haram Creek	Lincoln	43.207248°/-96.855760°	2016
	Silver Lake		Hutchinson, Turner	43.491812°/-97.328555°	2000

	Outlet				
	Turkey Ridge Creek		Hutchinson, Turner	43.106815°/-96.986989°	2016
Big Sioux River			Bookings, Codington, Grant, Hamlin, Lincoln, Minnehaha, Moody, Roberts, Union	42.492647°/-96.456738	2004
	Brookfield Creek		Moody	43.892466°/-96.652140°	2016
	Hidewood Creek		Hamlin, Deuel	44.594122°/-96.942838°	2016
	Medary Creek	Deer Creek	Brookings	44.252208°/-96.726040°	2007
		Deer Creek Unnamed tributary	Brookings	44.376795°/-96.559888°	2000
	Peg Munky Run		Brookings, Deuel	44.524783°/-96.879052°	2017
	Sixmile Creek		Brookings, Deuel	44.279903°/-96.848870°	2017
		Sixmile Creek unnamed tributary (1)	Brookings	44.464177°/-96.627968°	2004
		Sixmile Creek unnamed tributary (2)	Brookings	44.319281°/-96.805494°	2010
		North Deer Creek	Brookings, Deuel	44.295701°/-96.848987°	2011
		North Deer Creek unnamed tributary (a.k.a. South Fork North Deer Creek)	Brookings	44.361095°/-96.864330°	2000
	Slip-up Creek		Minnehaha	43.602351°/-96.654946°	2016
	Split Rock Creek	West Pipestone Creek	Minnehaha, Moody	43.651505°/-96.572308°	2012
		West Pipestone Creek unnamed tributary (1)	Minnehaha	43.689682°/-96.569453°	2004
		West Pipestone Creek unnamed tributary (2)	Minnehaha	43.686686°/-96.571531°	2004
	Spring Creek	Spring Creek unnamed tributary	Brookings, Moody	44.149500°/-96.566214°	2016

	Stray Horse Creek		Hamlin, Codington, Deuel	44.690466°/-97.005595°	2014
		Stray Horse Creek unnamed tributary	Hamlin, Deuel	44.746097°/-96.965007°	2004
	Willow Creek		Codington, Deuel	44.869200°/-97.085664°	2005
		Willow Creek unnamed tributary	Codington	44.947861°/-96.971666°	2017
South Dakota <u>and</u> Minnesota (streams that cross the states' borders)	Flandreau Creek		Moody/Pipestone, Lincoln	44.061819°/-96.549260°	2016
	Medary Creek		Brookings, Moody/ Lincoln	44.189351°/-96.766760°	2017
	Split Rock Creek		Minnehaha/Rock, Pipestone	43.549419°/-96.592585°	2017
		Beaver Creek	Minnehaha/ Rock	43.559752°/-96.584537°	2017
		Beaver Creek unnamed tributary	Minnehaha/Rock	43.586437°/-96.479175°	1999
		Springwater Creek	Minnehaha/ Rock	43.594889°/-96.453650°	1999
		Four-mile Creek	Minnehaha/ Rock	43.556194°/-96.535503°	1999
		Pipestone Creek	Minnehaha, Moody/Rock, Pipestone	43.805049°/-96.442128°	2017
		Pipestone Creek unnamed tributary	Moody/Pipestone	43.926763°/-96.470243°	2012
	Spring Creek		Moody, Brooking/Lincoln	44.102546°/-96.620029°	2000
Minnesota	Flandreau Creek	East Branch Flandreau Creek	Pipestone	44.166588°/-96.342081°	2017
		Willow Creek	Pipestone, Lincoln	44.110143°/-96.421459°	2017
	Medary Creek	Medary Creek unnamed tributary (1)	Lincoln	44.286642°/-96.376533°	1999
		Medary Creek unnamed tributary (2)	Lincoln	44.252121°/-96.433552°	2013
	Rock River	Ash Creek	Rock	43.540784°/-96.187774°	2017

	Champepaden Creek	Rock, Nobles	43.701885°/-96.151177°	2017
	Champepaden Creek unnamed tributary (1)	Nobles	43.782856°/-96.034744°	2006
	Champepaden Creek unnamed tributary (2)	Rock, Nobles	43.712496°/-96.082644°	2008
	Champepaden Creek unnamed tributary (3)	Rock	43.717552°/-96.086218°	2013
	Chanarambie Creek	Rock, Pipestone, Murray	43.858870°/-96.130021°	2017
	East Branch Kanaranzi Creek	Nobles	43.659717°/-95.908005°	2015
	East Branch Kanaranzi Creek unnamed tributary	Nobles	43.661256°/-95.785927°	2006
	East Branch Rock River	Pipestone	43.990456°/-96.167355°	2015
	East Branch Rock River unnamed tributary	Pipestone	44.036664°/-96.123114°	2005
	Elk Creek	Rock, Nobles	43.597320°/-96.188573°	2017
	Elk Creek unnamed tributary (1)	Rock	43.671728°/-96.028393°	2016
	Elk Creek unnamed tributary (2)	Rock	43.646701°/-96.117170°	2008
	Kanaranzi Creek unnamed tributary (1)	Nobles	43.641884°/ -95.934819°	2010
	Kanaranzi Creek unnamed tributary (2)	Nobles	43.589279°/-96.036891°	1999
	Judicial Ditch	Nobles	43.668481°/-95.774630°	2006
	Little Rock Creek	Nobles	43.515314°/-95.852700°	2015

		(a.k.a. West Branch Little Rock River)			
		Little Rock River unnamed tributary	Nobles	43.609177°/ -95.738958°	2006
		Mound Creek	Rock	43.702088°/-96.156764°	2017
		North Branch Chanarambie Creek	Murray	43.912429°/-96.033578°	2017
		North Branch Chanarambie Creek unnamed tributary	Murray	43.957550°/-96.031630°	2017
		Norwegian Creek	Nobles	43.515995°/-96.056560°	2017
		Poplar Creek	Pipestone	43.845179°/-96.145115°	2016
		Poplar Creek unnamed tributary (1)	Pipestone	43.858691°/-96.259017°	2007
		Poplar Creek unnamed tributary (2)	Pipestone	43.864409°/-96.239172°	2015
		Poplar Creek unnamed tributary (3)	Pipestone	43.866737°/-96.204394	2017
		Poplar Creek unnamed tributary (4)	Pipestone	43.861311°/-96.206566°	2008
		Rock River unnamed tributary (1)	Pipestone	44.052571°/-96.158026°	2006
		Rock River unnamed tributary (2)	Rock	43.943836°/-96.139605°	2016
		Rock River unnamed tributary (3)	Pipestone	43.909516°/-96.154865°	2017
		Rock River	Rock	43.739764°/-96.151306°	2016

		unnamed tributary (4)			
		Rock River unnamed tributary (5)	Rock	43.732452°/-96.141633°	2017
		Rock River unnamed tributary (6)	Rock	43.552264°/ -96.179042°	2010
		Rock River unnamed tributary (7)	Rock	43.565650°/ -96.180058°	2010
		Rock River unnamed tributary (8)	Rock	43.776090°/-96.122240°	1999
		Rock River unnamed tributary (9)	Rock	43.806931°/-96.120959°	2001
		Rock River unnamed tributary of unnamed tributary (1)	Pipestone	43.925701°/-96.180715°	2017
		Rock River unnamed tributary of unnamed tributary (2)	Rock	43.656218°/-96.200784°	2016
		Rock River unnamed tributary of unnamed tributary (3)	Rock	43.807583°/-96.077694°	1999
	Split Rock Creek	Beaver Creek unnamed tributary (1)	Rock	43.638.61°/-96.3080879°	2005
		Beaver Creek unnamed tributary (2)	Rock	43.720118°/-96.278474°	2017
		Beaver Creek	Rock	43.618205°/-96.366716°	2017

			unnamed tributary (3)			
			Little Beaver Creek	Rock	43.646243°/-96.309657°	2017
			North Branch Pipestone Creek	Pipestone	44.010927°/-96.400366°	2013
			North Branch Pipestone unnamed tributary	Pipestone	44.101677°/-96.260489°	2017
			Pipestone Creek unnamed tributary (1)	Pipestone	43.971725°/-96.441987°	2017
			Split Rock Creek unnamed tributary (1)	Rock, Pipestone	43.846224°/-96.401603°	2016
			Split Rock Creek unnamed tributary (2)	Rock	43.779122°/-96.430437°	2017
			Split Rock Creek unnamed tributary (3)	Rock, Pipestone	43.759988°/-96.443946°	2015
Minnesota and Iowa (streams that cross the states' border)		Rock River		Rock, Pipestone/ Lyon, Sioux	43.082112°/-96.449828°	2017
			Kanaranzi Creek	Rock, Nobles/Lyon	43.451379°/-96.164994°	2017
			Little Rock River	Nobles/ Lyon, Osceola	43.264407°/-96.243412°	2017
Iowa	Des Moines	North Raccoon River		Dallas, Greene, Carroll, Calhoun, Sac, Buena Vista,	41.553099°/-93.964151°	1999
			Buttrick Creek	Greene	41.971628°/-94.307107°	2001
			Camp Creek	Calhoun	42.280967°/-94.842007°	1999
			Cedar Creek	Greene, Calhoun	42.126090°/-94.583145°	2017
			Drainage Ditch #57 (aka Outlet Creek)	Sac	42.330287°/-95.006703°	1999
			East Buttrick Creek	Greene, Webster	42.050068°/-94.280117°	2017
			East Cedar Creek	Calhoun	42.297442°/-94.499431°	2010
			East Fork Hardin	Greene	42.049645°/-94.370568°	2010

		Creek			
		Hardin Creek	Greene, Calhoun, Webster	41.982273°/-94.314612°	2010
		Indian Creek	Sac	42.336984°/-94.989476°	2000
		Indian Creek unnamed tributary	Sac	42.339561°/-95.007178°	1999
		Lake Creek	Calhoun	42.244311°/-94.783032°	2016
		Lost Branch (of West Buttrick Ck)	Greene, Webster	42.177195°/-94.330666°	2000
		Lost Grove Creek	Greene, Webster	42.200841°/-94.236082°	2011
		Otter Creek	Carroll, Greene	42.088286°/-94.627859°	2007
		Prairie Creek	Calhoun	42.255710°/-94.804196°	1999
		Prairie Creek Unnamed Tributary	Calhoun	42.285873°/-94.772535°	1999
		Purgatory Creek	Carroll, Greene, Calhoun	42.104442°/-94.657178°	2017
		Short Creek	Greene	42.045518°/-94.470207°	1999
		Swan Lake Branch	Dallas	41.795587°/-94.118052°	1999
		West Buttrick Creek	Greene, Webster	42.051625°/-94.282146°	2016
		West Fork Camp Creek	Calhoun	42.370150°/-94.837541°	1999
	Boone River		Webster, Hamilton, Wright	42.312747°/-93.932830°	2017
		Brewers Creek	Hamilton	42.457753°/-93.814514°	2000
		Eagle Creek	Hamilton, Wright	42.547904°/-93.844482°	2016
		East Branch Boone River	Hancock, Wright	42.911436°/-93.868054°	2017
		Drainage Ditch 2	Wright	42.688157°/-93.795744°	2011
		Drainage Ditch 3 (aka Drainage Ditch 25)	Wright, Humboldt, Webster	42.647289°/-93.938233°	2000
		Drainage Ditch 4	Wright	42.691814°/-93.935733°	2017
		Drainage Ditch 13	Wright	42.598118°/-93.893600°	2000

			Drainage Ditch 19	Humboldt	42.651945°/-93.983791°	2000
			Drainage Ditch 32	Hamilton	42.367540°/-93.837156°	2000
			Drainage Ditch 49	Wright, Webster	42.603373°/-93.921285°	2002
			Drainage Ditch 94	Wright	42.621557°/-93.913753°	2017
			Drainage Ditch 116	Kossuth	42.951635°/-94.093765°	2000
			Middle Branch Boone River	Hancock	42.914029°/-93.871340°	2017
			Otter Creek	Hancock, Wright	42.764886°/-93.932334°	2017
			Prairie Creek	Kossuth, Humboldt, Wright	42.839137°/-93.959619°	2017
		Brushy Creek		Webster	42.346657°/-93.973840°	2000
Nebraska	Elkhorn River		Taylor Creek	Madison	41.832107°/-97.456693°	2016
		Union Creek	Union Creek unnamed tributary	Madison	41.847290°/ -97.432960°	2009
	North Loup River	Big Creek		Cherry	42.331890°/-100.760266°	2006
Kansas	Cottonwood River	Cottonwood River unnamed tributary		Chase	38.388475°/-96.618079°	2002
		Diamond Creek		Chase, Morris	38.393842°/-96.623599°	2017
			Dodds Creek	Morris	38.546512°/-96.740654°	2001
		Fox Creek	Tallgrass Prairie National Reserve Impoundment	Chase	38.434050°/-96.563437°	2014
			Schoolhouse Creek	Chase	38.435920°/-96.554107°	2016
			Fox Creek unnamed tributary	Chase	38.459733°/-96.556552°	1999
		Middle Creek	Stribby Creek unnamed tributary	Chase	38.426065°/-96.788635°	2005
		Mud Creek	Unnamed Mud Creek tributary	Marion	38.436232°/-97.082197°	2009
		South Fork Cottonwood River		Greenwood, Butler, Chase	38.362519°/-96.477297°	2017
	Neosho River	West Branch Rock River		Wabaunsee	38.765022°/-96.297942°	2004

Kansas River	Big Blue River	Carnahan Creek	Pottawatomie	39.343891°/-96.628417°	1999
		Cedar Creek	Marshall	39.671427°/-96.452495°	2012
		Clear Fork Creek	Marshall, Pottawatomie	39.647532°/-96.478550°	2016
		Deer Creek	Marshall	39.900761°/-96.654097°	2010
		North Elm Creek	Marshall	39.972619°/-96.601313°	2017
		Swede Creek	Riley, Marshall	39.498862°/-96.660228°	2012
		Walnut Creek	Riley	39.463596°/-96.767113°	2000
	Deep Creek		Wabaunsee, Riley	39.156987°/-96.365477°	2017
		School Creek	Riley	39.122858°/-96.455018°	2005
	Lyon Creek	Rock Springs Creek	Geary, Dickinson, Morris	38.873597°/-96.910524°	2017
	Mill Creek		Wabaunsee	39.106831°/-95.991849°	2002
		East Branch Mill Creek	Wabaunsee	38.960928°/-96.264176°	2017
		Hendricks Creek	Wabaunsee	39.034076°/-96.270481°	2010
		Illinois Creek	Wabaunsee	38.972881°/-96.341162°	2009
		Kuenzli Creek	Wabaunsee	39.054768°/-96.203702°	2009
		Loire Creek	Riley, Wabaunsee	38.983709°/-96.328761°	2008
		Mulberry Creek	Wabaunsee	39.071275°/-96.141121°	2010
		Nehring Creek unnamed tributary	Wabaunsee	38.924692°/-96.144400°	1999
		Paw-Paw Creek	Wabaunsee	39.052454°/-96.229764°	2008
		Phillips Creek	Wabaunsee	39.034837°/-96.313404°	2008
		Snokomo Creek	Wabaunsee	39.060411°/-96.146591°	2009
		South Branch Mill Creek	Wabaunsee	39.001628°/-96.280152°	2017
		Spring Creek (1)	Wabaunsee	38.974286°/-96.351171°	2017
		Spring Creek (2)	Wabaunsee	39.063416°/-96.196351°	2008
		West Branch Mill Creek	Wabaunsee	39.001712°/-96.282513°	2017
	Mission Creek		Shawnee, Wabaunsee	39.063289°/-95.842243°	2017
		Ross Creek	Wabaunsee	38.951100°/-95.954700°	1999
	Sevenmile Creek		Riley	39.133936°/-96.657543°	2000

		Wildcat Creek		Riley	39.161981°/-96.563272°	2011
			Little Arkansas Creek	Riley	39.239622°/-96.769729°	2008
			Honey Creek	Riley	39.220853°/-96.719729°	2003
	Smoky River	Willow Creek		Wallace	38.941324°/-101.759419°	2002
Missouri	Thompson River	Sugar Creek		Grundy, Harrison	40.127291°/-93.691156°	2017
			Tombstone Creek	Harrison, Daviess	40.138779°/-93.772410°	2017
	Moniteau Creek			Moniteau, Cooper	38.696247°/-92.366980°	2017
		Culley Creek		Cooper	38.740103°/-92.743797°	2016
		Draffen Branch		Cooper	38.741476°/-92.701385°	2015
		Gump Branch		Cooper	38.729636°/-92.702954°	2014
		Pigsah Creek		Cooper	38.754688°/-92.632706°	2017
		Moniteau Creek unnamed tributary		Cooper	38.736500°/-92.793830°	2016
		Smiley Creek		Cooper, Moniteau	38.734523°/-92.732048°	2017
			Howard Creek	Cooper, Moniteau	38.695845°/-92.739763°	2014
		West Brush Creek		Cooper, Moniteau	38.725347°/-92.619094°	2017

APPENDIX D: Population Resiliency Model, *Notropis topeka*, Version 2, January 2018

Population Resiliency Model

Topeka Shiner (*Notropis topeka*)

Version 2

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January, 2018

This document covers methods coordinated by the Minnesota/Wisconsin Ecological Services Field Office and Kansas Ecological Services Field Office, in partnership with the Environmental Online Conservation System (ECOS) unit of the U.S. Fish & Wildlife Service, to determine resiliency ratings for both Topeka Shiner sub-populations and populations at 12 and 10 digit hydrologic unit coded watersheds, respectively. The purpose is to identify all extant populations range-wide and to compare resiliency, in a standardized way, through an index based assessment at the sub-population scale. This report also outlines the data and processes used to derive the model results and provides recommendations to better streamline geospatial and analytical processing for improved repeatability and continued application toward species recovery.

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1 Introduction

Topeka shiner populations require survival and recruitment such that persistence over time is supported (USFWS 2009). The exact relationship between survival, recruitment, and the Topeka shiner population's ability to persist over time are unknown. However, one can assume that in general the higher the two rates, or at a minimum zero or higher over perhaps a few years, are required for population persistence (Falke et al. 2010; Fausch et al. 2002). If, however, rates are at or below zero for some timeframe the species probability of persistence is likely to diminish. Species that are already in danger of extinction have less tolerance for continued diminishment before extinction forces, such as genetic bottlenecking due to genetic drift or extirpation from random weather events, become a higher risk. Therefore, we looked at what variables drive Topeka shiner in a positive direction, i.e. toward resiliency, and investigated variables that could be measured in order to look at current condition and predict future changes to resiliency.

Through work with the States and experts, the following were identified as indicative of population resiliency:

- Consistency of Presence (Occupancy over Time)
- Habitat Availability/Complexity (Presence of Refugia)
- Habitat Conditions/Quality
- Habitat Connectivity

A population is generally defined as "interbreeding individuals with suitable habitat and conditions for the species, and no or only minor physical obstructions present". However, data for evidence of interbreeding, suitable habitat and conditions, and population connectivity was limited on a range wide scale. Because individuals have been found to inhabit smaller hydrological watershed units on the landscape, and to better facilitate a more standardized range-wide assessment, population characteristics were defined as follows:

Population – Each individual 10-digit Hydrologic Unit Code (HUC-10) watershed, and inclusive of all waterways within that HUC-10 boundary, where individuals have been documented since 1999 (Figure 1.1). We only consider HUC-10 units with detections since 1999 because data were limited prior to listing.

Sub-population (i.e., occupied streams within a population) – Each individual 12-digit Hydrologic Unit Code (HUC-12) watershed, and inclusive of all waterways within that HUC-12 boundary, with a positive detection since 1999 (Figure 1.1).

Meta-population – Populations within a larger watershed (i.e., HUC-8 or larger) that have potential connectivity at some unknown level and frequency via existing waterways, but separated by habitat, conditions, and/or substantive obstructions not typical to the species.

Isolated Population – A population bounded by substantive obstructions/barriers; and/or extended reaches of habitat and conditions not typical to the species. These obstructions and conditions are presumed to overwhelmingly preclude movement of Topeka shiners to or from other populations.

Major Barrier – Substantive barriers such as low-head dams, mainstem high dams, impoundments, or other structures (or significantly large distances/habitats not suitable to the species) that preclude upstream passage of Topeka shiners.

Conditions not typical to the species – (1) stream reaches with broad, shallow, braided channels, typically with sand or mud substrates; (2) reaches with deeper, high velocity and volume of flows, often with highly manipulated flow regimes; (3) reaches typically of lacustrine nature, lacking pool, riffle, run stream habitat components; (4) reaches highly impacted by channelization and sedimentation with highly altered hydrographs, often lacking pool, riffle, run stream habitat components; or (5) reaches with various combinations of these.

These definitions and population needs were used to develop a Topeka Shiner Population Resiliency Model (Figure 1.1) to assist in assessing the resiliency of populations across the species current range, and to assist in forecasting future conditions of resiliency. The definition "Conditions not typical to the species" was not used in the Resiliency Model. Also, "Meta-populations" and "Isolated Populations" were not included in the Resiliency Model because we don't have data to discern interactions or relationships at these scales.

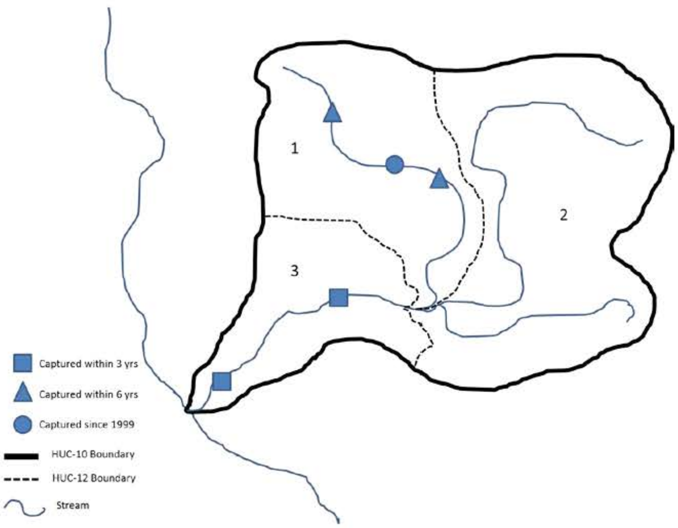

Figure 1.1 Population Boundary Example

Example of a HUC-10 boundary relative to the HUC-12 boundaries (which are bound within the HUC-10) and how they all drain into a larger watershed. The HUC-10 watershed is defined as the population and, in this example, is composed of three HUC-12 watersheds (defined as sub-populations). To qualify as an extant population, and as defined above, we only consider populations and sub-populations that have had a positive detection of Topeka shiners since 1999.

Note: It is our intent to refine the model as more information or measurable characteristics become available. The current model only incorporates basic information that can be applied to all populations throughout the entire range. Any significant refinements, such as adding or removing a measured element of the model, would be detailed in an updated version of the model. We anticipate a revision within the next few years.

2 Methods

Based on available data that support characteristics identified as most influential to the species, we developed measures based upon population demographics and available habitat to evaluate overall population resiliency (Figure 2.1). Population demographics are measures used to understand the status and trend of the population since listing in 1998 (effective in 1999), and are based on observation records obtained from field offices within the Topeka shiner range. Habitat measures are used to understand and evaluate conditions important to the species, and are based on readily available data derived from national databases (Appendix 6.9 and 6.10). The measures in the Resiliency Model were selected based on availability, allowing for a standardized approach and repeatability across the entire Topeka shinerrange.

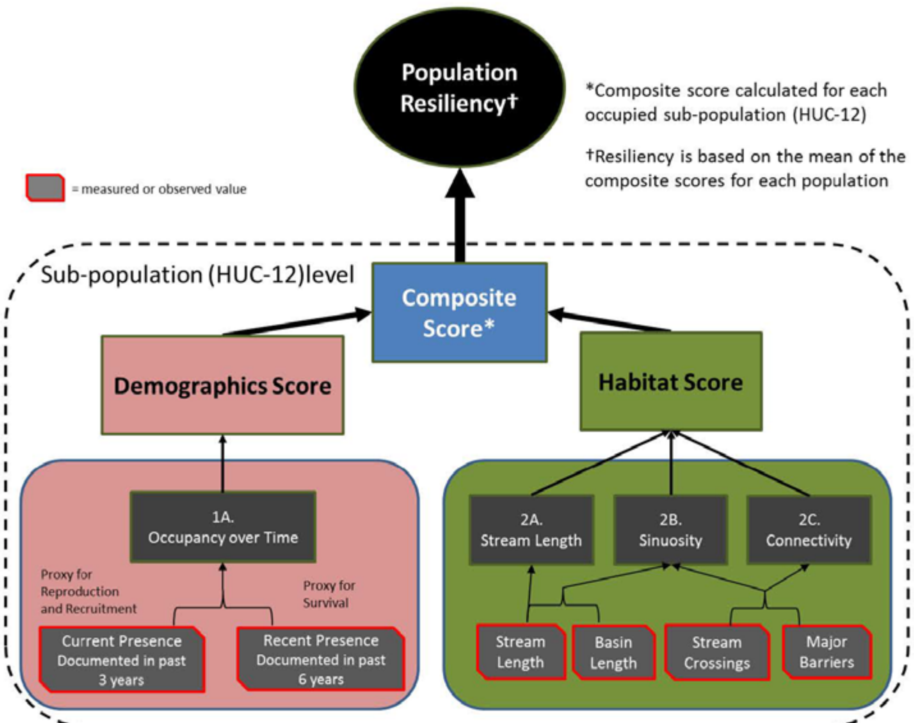

Figure 2.1 Population Resiliency Model

A simplified visual diagram that illustrates how measureable characteristics of each population (e.g., occupancy over time) and their habitat (e.g., sinuosity, connectivity, etc…) likely contribute to population resiliency. The Composite Score is calculated as the sum of measured variables within each occupied sub-population (defined as occupancy at the HUC-12 level). Resiliency is based on the mean of all the composite scores within the population.

Topeka shiner demographic data are based on presence/absence surveys conducted since 1999 in each state within the species' range. Because habitat data are not consistently recorded, we use proxy measurements that can be consistently applied to all populations. Stream length, sinuosity and connectivity are used as proxy measurements for refugia availability and habitat complexity/quality. For each population, we only include sub-populations (defined as occupied HUC-12 watersheds) where Topeka shiners have been documented since 1999.

ESRI's ArcGIS version 10.3.1 was used to conduct GIS processing and run sub-model calculations for the first version of this Model. Individual field calculations conducted in ArcMap primarily used conditional statements written using Python 2.7 scripts to reference other fields. This model's description (beginning in Section 2.1) is adapted from the ODD (Overview, Design concepts, Details) protocol (Grimm et al. 2006).

For version 2 of this model, ArcGIS 10.3.1 Model Builder tools were used to automate the processes defined herein. This was done so that data inputs, including the dates used to define consistency of presence could be easily changed. Additionally, this allows the model to be re-run as new data become available.

Defining accurate stream flowlines was one of the most challenging aspects of the model. We used recorded observation locations and stream names to map individual streams and tributaries, and select stream flowlines from the National Hydrologic Dataset (NHD). Stream names were initially used to select flowlines when available, but manual selection was required for all unnamed streams in the NHD. A rule was agreed upon for unnamed tributaries, whereby the longest tributary length was selected from all mapped tributaries. This method changed the input flowlines significantly from version 1, which included just one computer generated major flowline in the model for each HUC-12. Instead, version 2 used all flowlines where Topeka shiners have been documented. While this new method attempts to capture all observed stream habitat, we note that occurrence sampling bias, including convenience sampling, and a non-randomized sampling framework across the range, may lead to human bias in observations, and thus influence the selection of model stream habitat. Additionally, we note that while all streams included had documented observations, Topeka shiners may not be present throughout the entire length of waterways included.

2.1 Model Lineage

Version 1

- Observation records 1999 – 2014.
- A single NHD flowline was selected per HUC-12 based upon reach dominance and observation record using a sub-model.
- Missouri generalized stream locations to the HUC 12 where Topeka shiners were identified. The HUC 12 centroid, was used to geolocate these observations.
- Index based scores used to assess resiliency.

Version 2

- Model Builder toolset built to process the model (see appendix).
- Observation records 1999 – 2017.
- Missouri generalized stream locations to the HUC 12 where Topeka shiners were identified. The HUC 12 centroid, or an outlet at a named stream were used to geolocate these observations.
- Multiple NHD flowlines were selected per HUC-12, based upon observation records. The sub-model (version 1), which generated a single NHD flowline per HUC-12, was not used.
- Standard deviation scores were used to assign resiliency categories (e.g., High, Medium, and Low).

2.2 Data

Data to support this model came from three publicly available sources and a propriety database from ECOS with distribution limitations. Publicly available data include the NHD 10 and 12-digit HUCs, NHD stream flowlines, and the U.S. Census Bureau's TIGER roads data. The ECOS data used for determining passage barriers is more comprehensive than other publicly available sources (i.e., NHD Barriers) however, due to the nature of data contained within the database and its designed purpose as decision support and planning apparatus, the data isn't made publicly available for download. In general, these data were chosen with the intent of future application requiring their ease of access and comprehensive nature. Use of less comprehensive data likely would not impact this model's processes but may affect the outcome.

2.2.1 Hydrography

The National Hydrography Dataset (NHD) is available as pre-packaged sub-regional downloads which proved a convenient way to obtain all pertinent data in a single instance. The NHD point barriers dataset is also used for comparison to the ECOS GeoFIN dataset.

The National Hydrography Dataset (NHD) is a feature-based database that interconnects and uniquely identifies the stream segments or reaches that make up the nation's surface water drainage system. NHD data was originally developed at 1:100,000-scale and exists at that scale for the whole country. This high-resolution NHD, generally developed at 1:24,000/1:12,000 scale, adds detail to the original 1:100,000-scale NHD. Local resolution NHD is being developed where partners and data exist. The NHD contains reach codes for networked features, flow direction, names, and centerline representations for areal water bodies. Reaches are also defined on waterbodies and the approximate shorelines of the Great Lakes, the Atlantic and Pacific Oceans and the Gulf of Mexico. The NHD also incorporates the National Spatial Data Infrastructure framework criteria established by the Federal Geographic Data Committee (USGS 2010).

2.2.2 Roads

Road layers are obtained from the U.S. Census Bureau as a national dataset. The census website states that this layer provides all the roads in a single shapefile with types defined in the attribute table. This model is updated to include roads data through 2016.

2.2.3 Barriers

A comprehensive database of barriers to fish movement along waterways was retrieved from the Environmental Conservation Online System's (ECOS) GeoFIN application, including data through March 9th, 2017.

2.3 Data Validation

For the initial development of the model, data validity assessments were performed where it was feasible to do so. The GeoFIN database was checked against the NHD barrier features and found 50% record agreement between the datasets (Figure 3). GeoFIN included five more barriers than the NHD barriers dataset, which is to be expected because the GeoFIN database includes sources outside of those contributing to the NHD. Location agreement was accurate to approximately 30m with NHD barriers generally being located closer to the flowlines as would be expected for a consolidated geodatabase. This accuracy is sufficient to accomplish the model's goal. No assessment was conducted for the roads layer.

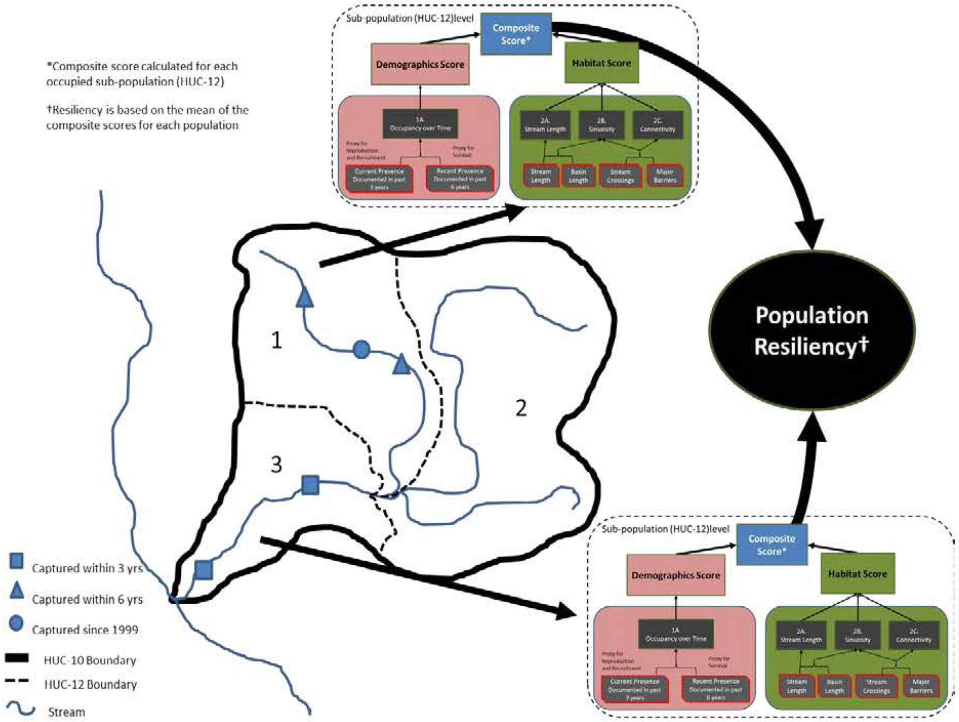

Figure 2.2.1 Creating Population Resiliency Ratings

A conceptual diagram that illustrates how resiliency was calculated for each population. By definition, we only included populations with documented occupancy since 1999. For each population, we only included sub-populations (defined as occupancy at the HUC-12 level) where Topeka shiners have been documented since 1999. Resiliency is based on the mean of all the composite scores within the population.

2.4 Resiliency Model Overview

2.4.1 Model Purpose

The Topeka shiner Resiliency Model identifies all extant populations of the Topeka shiner range-wide and compares resiliency, in a standardized way, through an index based assessment at the sub-population scale. This model draws from nationally available datasets provided by the U.S. Government and uses GIS processing methods that reduce biased selection in order to increase the defensible nature of the resiliency rating. To that end, ECOS determined there are sufficient standard national geospatial elevation, road, flowline, and barrier data available for this to be conducted. The GIS analysis focused solely on deriving the habitat score and relied on tabular data from observation records provided by state partners to produce the demographic score.

2.4.2 Model Entities, Variables, and Scales

This model is solely a product of GIS processing of spatial data and observation records. No entities are programmed onto these features. Model processing is conducted at the HUC-12 watershed scale. Time scale is represented by observation records from January 1999 through November 2017. Observation records allowed this model to assess populations within six states; Iowa, Kansas, Minnesota, Missouri, Nebraska, and South Dakota.

HUC10 – The 10-digit watershed associated with populations that had an observed occurrence within its boundary. This is considered the "Population" level.

HUC-12 – The 12-digit watershed associated with sub-populations that had an observed occurrence within its boundary. This is considered the "Sub-population" level.

Predominant Channel – This model defines both main streams and tributaries as Topeka shiner habitat. NHD named streams corresponding to streams with recorded Topeka shiner records were selected, and unnamed streams were selected manually as the longest length of tributary upstream from recorded outlet points.

Present Since 1999 but not within past 6 years – Sub-population (HUC-12) watershed areas are chosen for further processing if they contain an observation record since January 1999. This returns a true value if it meets the condition that an observation record since January 1999 but before January 2012 occurred within the HUC-12 watershed. No points are awarded for true values.

Present 2012-2014 – This binary variable returns a true value if it meets the condition that an observation record since January 2012 but before January 2015 occurred within the HUC-12 watershed. A point is awarded for true values.

Present 2015-2017 – This binary variable returns a true value if it meets the condition that an observation record since January 2015 but before January 2018 occurred within the HUC-12 watershed. A point is awarded for true values.

Stream Length – This is the sinusoidal form of a stream. It is used as a measure of habitat availability and potential for refugia. A point is awarded for occupied HUC-12 stream reaches totaling greater than 30.5 kilometers in length. The assumption is that a longer stream reach provides more opportunity for refugia (e.g., pools). This model selects 30.5 km because it was the median length recorded for all occupied HUC-12 streams within the Topeka shiner range.

Basin Length – This is the straight-line form of a watershed measured from its headwaters to its outlet within the occupied HUC-12 watershed. The length is recorded and used during sinuosity calculation.

Sinuosity – Sinuosity is a ratio of stream length to basin length and is a measure of the bendiness, or lack of channelization, of a stream. In this context, sinuosity is used as a proxy measure for stream complexity, with the assumption that higher complexity means more opportunities for refugia and pool habitat. Points are awarded based on increasing sinuosity of the stream, with a maximum score (relatively high sinuosity) of 1 and a minimum score (relatively low sinuosity) of -1. No points are awarded for streams determined to be of average sinuosity. Calculation of sinuosity is explained in Figure 2.4.3.2.

Major Barriers – Barriers fragment stream reaches into smaller lengths and impede river species to freely move along the entire stream length. A point was subtracted if a barrier was within 500 meters of the chosen channel. 500 meters was chosen to account for potential errors in barrier location.

Stream Crossings – Roads that crossed the predominant stream were considered stream crossings. No distinction is made for different road crossing types. The total number of crossings along the entire stream length was recorded for calculation of crossing density (number of crossings per km of stream).

2.4.3 Model Process

Sub-population (HUC-12) watershed areas are chosen for further processing if they contain an observation record since January 1999. Scores for each presence category are calculated for each HUC-12. Predominant channels for each HUC-12 are chosen based upon observation records associated with NHD flowlines. Basin length, stream length, and sinuosity are calculated for the channel in each HUC-12. The length score sub-model is run referencing stream length and a defined parameter threshold (see section 2.4.2) to calculate scores for further processing. The sinuosity score sub-model is run referencing sinuosity to calculate scores for further processing. Barriers are chosen if they are within occupied HUC-12 boundaries and a binary score is assigned if the barrier is within 500 meters of the predominant channel. Stream crossings are created where the predominant channel is crossed by a road. The crossing density sub-model is run to calculate scores for further processing. The connectivity sub-model is run referencing related major barriers, crossing density, and a parameter defined as the median of all calculated crossing densities. The composite score sub-model is run referencing score results from the occupancy over time, stream length, sinuosity, and connectivity sub-models. The resiliency rating references the composite score to assign a textual rating and color scheme on the HUC-12 watershed boundary (Table 2.5.3.1.).

Crossing Density Sub-model

Stream crossings are determined by using the intersect function in ArcMap to create point geometries where the road and flowline layers intersected (Figure 2.4.3.1). Major barriers became associated with the selected flowlines using a spatial join.

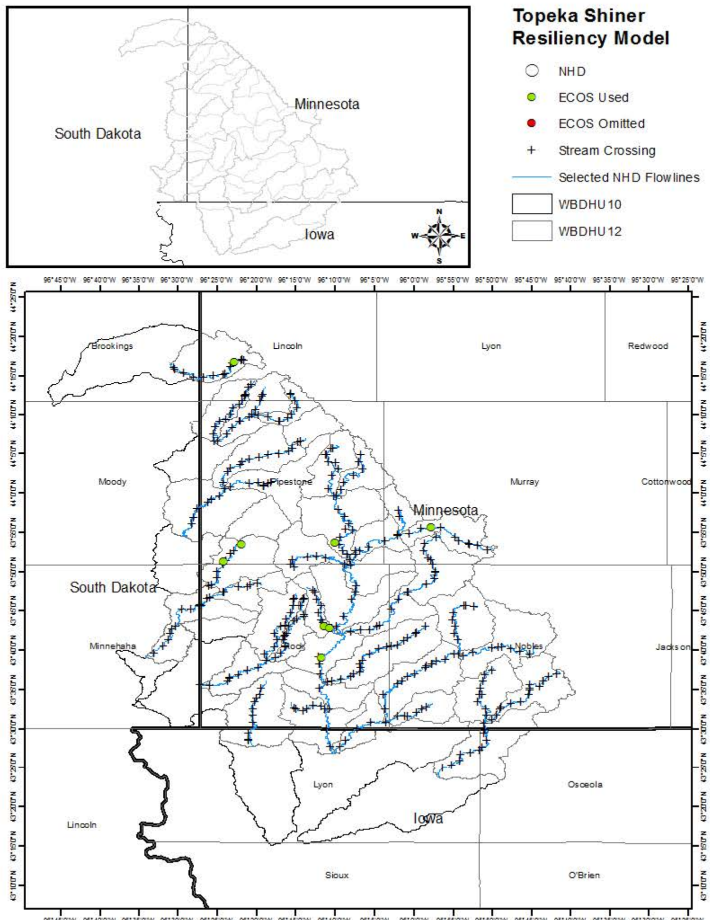

Figure 2.4.3.1 Stream Crossings
Stream crossings, using Minnesota as an example, derived using the intersect function in ArcMap to create point geometries where the road and flowline layers intersected.

Sinuosity Sub-model

Sinuosity (Mueller 1968) was determined using a calculator provided by ESRI which required altering its calculation in the Python script to match the method used in the model (stream length / basin length; Figure 2.4.3.2). All scoring calculations were determined using the methods outlined in the model's guidelines (see Section 2.5).

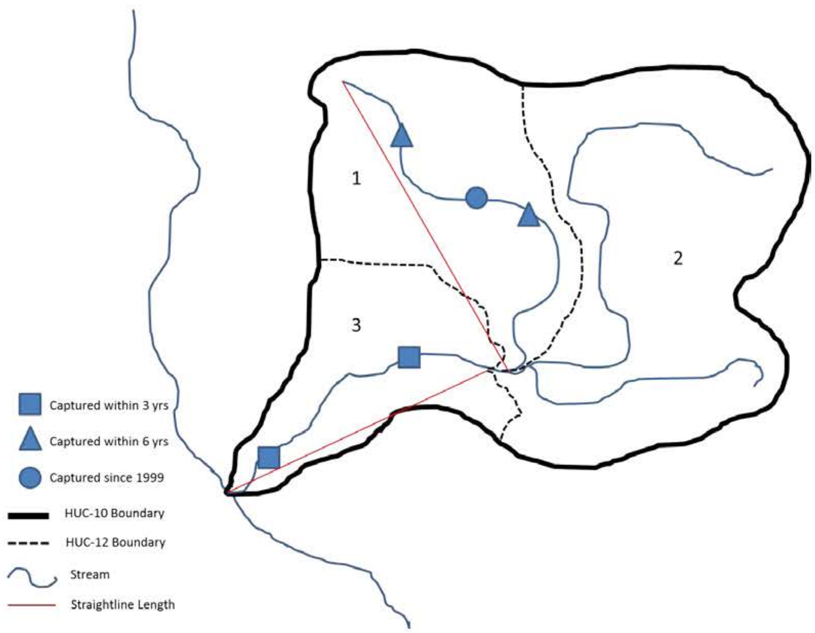

Figure 2.4.3.2 Calculating sinuosity
Simplified example of a sinuosity calculation for a conceptual population. In this example, Topeka shiners were captured in two of the three HUC-12 streams since 1999. This example requires calculation of HUC-12 stream #1 and HUC-12 stream #3.

2.5 Resiliency Measures

2.5.1 Population Demographics

This measure is used to understand the status and trend of the population since listing in 1999. Model inputs include:

1A. Occupancy over Time

Values calculated here are used to determine the occupancy since listing in December, 1998 and within one life span (within 3 years) and two life spans (within 6 years) of the Topeka shiner. By definition, we only included populations where Topeka shiners have been documented since January 1999 through November of 2017. A population can get a maximum score of 2 if documented during the two most recent life spans. The population would score 0 points if not detected within the past 6 years. Points are allocated as follows:

a.	Detected within the past 3 years, 2015-2017	1 Point
b.	Detected 2012-2014	1 Point
c.	Detected 1999-2011	0 Points

2.5.2 Habitat

Habitat conditions have not been documented consistently throughout the range. However, these criteria are generally important to Topeka shiners and should be evaluated to get a better understanding of habitat quality.

Because habitat data are not consistently recorded during Topeka shiner surveys, we used proxy measurements that can be consistently applied to all populations. Stream length, sinuosity, and connectivity are used as proxy measurements for refugia availability and habitat complexity/quality. For each population, we only included sub-populations where Topeka shiners have been documented since 1999. Model inputs include:

2A. Stream Length

Used as a measure of habitat availability and potential for refugia. A point is awarded for occupied HUC-12 stream reaches greater than 30.5 kilometers in length. The assumption here is; the longer the stream reach, the more opportunity for refugia (e.g., pools). We selected 30.5 kilometers because it is the median length of all occupied HUC-12 streams in the Topeka shiner range. Points are allocated as follows:

a.	Streams length ≥ 30.5 kilometers for each occupied HUC-12	1 Point
b.	Stream length < 30.5 kilometers for each occupied HUC-12	0 Points

2B. Sinuosity

Sinuosity (SI) is a ratio of stream length to basin length and is a measure of the bendiness, or channelization, of a stream (Mueller 1968). In this context, sinuosity is used as a proxy measure for stream complexity, with the assumption that higher complexity means more opportunities for refugia and pool habitat. A point is awarded based on level of sinuosity, with a maximum score of 1 point. A point is lost for streams determined to be fairly straight. The logic here is that a perfectly straight channel will have an SI value of 1 (essentially an even ratio of valley length versus stream length). Therefore, a point is either awarded or subtracted based on the ratio of valley length and stream length (in this context, an SI greater than 2 would indicate a channel that bends laterally more than longitudinally and would be considered of high sinuosity). Calculation of sinuosity is explained in Figure 2.4.3.2. Points are allocated as follows:

a. Total SI of each sub-population (SI=Actual stream length/Basin length)
b. Categories of Total Sinuosity:
   i. Fairly Straight (SI < 1.5) -1 Point
   ii. Moderate Sinuosity (SI between 1.5 and 2.0) 0 Points
   iii. High Sinuosity (SI > 2.0) 1 Point

2C. Connectivity

Stream crossings are easily quantified in GIS and can predict potential impediments to Topeka shiner movement or modification of habitat. In addition, major obstructions can be identified in a GIS layer as a dam or impoundment. A maximum of 1 point and minimum of -1 points can be awarded in this category based on total number of potential impediments (e.g., road crossings and dams). Because each HUC-12 is sized differently, we standardized based on density of crossings (crossings/km) for each HUC-12. The median crossing density throughout the range was calculated to be 0.54 crossings per km of stream. Therefore, a point is added with a crossing density < 0.54 crossings/km. No points are gained or lost if the crossing density is ≥ 0.54. A point is automatically subtracted if a Major Barrier is present within the 500m of flowlines within the occupied sub-population. Points are allocated as follows:

a. Less than 0.54 crossings/km and no Major Barriers 1 Points
b. Greater than or equal to 0.54 crossings/km and no Major Barriers 0 Points
c. Major Barrier(s) Present, regardless of density of stream crossings -1 Points

2.5.3 Resiliency Scoring

Based on measured criteria illustrated in the Resiliency Model (Figure 2.1), and the weighted scores described above in the Resiliency Measures, a Composite Score can be derived (ranging from -2 to 5). The Composite Score is the sum of the two main components of population resiliency; population demographics and habitat conditions. The formula for calculating resiliency is the sum of the following:

1. Demographics (Total of 2 points possible; Ranging from 0 to 2)
    a. Occupancy over Time (2 = Detections within past three years AND six years; 1 = Detected at least once within the past six years; 0 = no detections within the past six years)

2. Habitat (Total of 3 points possible; Ranging from -2 to 3)
    a. Stream Length (1 = ≥ 30.5 kilometers; 0 = < 30.5 kilometers)
    b. Stream Sinuosity (1 = High; 0 = Medium; -1 = Low)
    c. Connectivity (1 = < 0.54 stream crossings/km; 0 = ≥ 0.54 stream crossings/km; -1 = Major Barrier(s) present, regardless of number of stream crossings)

Each occupied Sub-population is scored based on the above criteria. For each Population, the scores for all the occupied Sub-populations are averaged to get a Resiliency Score. Based on the scoring breakdown, each extant population can be rated relative to the rest using a standard deviation classification (Table 2.5.3.1). This method finds the mean and standard deviation of the resulting composite scores and creates categories grouping the data by one standard deviation increments centered on the mean. Because the composite scores for the Populations and their Sub-populations will have different mean and standard deviation values, their classification ranges will be different.

Table 2.5.3.1. Rating of population scores based on the scoring system described in Section 2.4.

Composite Score	Rank and Standard Deviation
> 3.66	1 (> 2.5 SD)
> 2.77 to ≤ 3.66	2 (1.5 to 2.5 SD)
> 1.89 to ≤ 2.77	3 (0.5 to 1.5 SD)
> 1.0 to ≤ 1.89	4 (-0.5 to 0.5 SD)
> 0.12 to ≤ 1.0	5 (-0.5 to -1.5 SD)
> -0.77 to ≤ 0.12	6 (-1.5 to -2.5 SD)
≤ -0.77	7 (< -2.5 SD)

3 Results

Table 3. All extant Topeka shiner Populations documented from 1999 through 2017, and their relative resiliency scores as calculated by the Resiliency Model (Figure 3.1). Resiliency is based on an average of Composite Scores, based on the Resiliency Model (Figure 2.1) and derived from the formula described in Section 2.4.

Population ID (HUC 10)	Population Name	State	Score	Rating
0710000405	Brushy Creek	IA	-1.00	7
0710000501	Prairie Creek	IA	1.67	4
0710000502	Headwaters Boone River	IA	1.25	4
0710000503	Otter Creek	IA	1.00	5
0710000504	Eagle Creek	IA	1.00	5
0710000506	Ditch 3-Boone River	IA	1.00	5
0710000507	Boone River	IA	0.50	5
0710000604	Indian Creek	IA	0.50	5
0710000605	Camp Creek	IA	1.00	5
0710000606	Lake Creek	IA	2.00	3
0710000607	Purgatory Creek	IA	2.00	3
0710000608	Elk Run-North Raccoon River	IA	-0.33	6
0710000609	Welshs Slough-Cedar Creek	IA	1.33	4
0710000610	Hardin Creek	IA	1.00	5
0710000611	East Buttrick Creek	IA	1.50	4
0710000612	Buttrick Creek	IA	1.33	4
0710000614	Otter Creek-North Raccoon River	IA	0.50	5
0710000615	Swan Lake Branch-North Raccoon River	IA	1.00	5
1017020402	Kanaranzi Creek	IA	1.80	4
1017020403	Champepadan Creek-Rock River	IA	2.17	3
1017020406	Little Rock River	IA	2.00	3
1026000101	Willow Creek-Smoky Hill River	KS	1.00	5
1026000807	Lyon Creek	KS	3.00	2
1027010102	Wildcat Creek-Kansas River	KS	1.00	5
1027010203	Headwaters Mill Creek	KS	0.25	5
1027010204	Mill Creek-Kansas River	KS	0.33	5
1027010205	Deep Creek-Kansas River	KS	2.00	3
1027010207	Mission Creek-Kansas River	KS	2.50	3
1027020502	Horseshoe Creek-Big Blue River	KS	2.50	3
1027020504	Outlet Black Vermillion River	KS	2.50	3
1027020505	Big Blue River-Tuttle Creek Lake	KS	2.00	3
1027020506	Fancy Creek	KS	1.00	5
1027020507	Tuttle Creek Lake-Big Blue River	KS	0.00	6
1107020102	Rock Creek-Neosho River	KS	1.00	5
1107020202	Clear Creek-Cottonwood River	KS	0.00	6

Population ID (HUC 10)	Population Name	State	Score	Rating
1107020301	Middle Creek-Cottonwood River	KS	0.00	6
1107020302	Diamond Creek-Cottonwood River	KS	1.50	4
1107020303	South Fork Cottonwood River	KS	0.00	6
1017020303	Flandreau Creek	MN	2.25	3
1017020313	Pipestone Creek	MN	2.40	3
1017020315	Beaver Creek-Split Rock Creek	MN	1.50	4
1017020316	Split Rock Creek	MN	2.00	3
1017020401	Headwaters Rock River	MN	1.90	3
1028010210	Sugar Creek-Thompson River	MO	1.50	4
1030010208	Smiley Creek-Moniteau Creek	MO	1.50	4
1021000601	Big Creek-North Loup River	NE	1.00	5
1022000301	Union Creek	NE	2.00	3
1016000408	Lower Elm River	SD	1.50	4
1016000607	Shue Creek	SD	3.00	2
1016000611	Pearl Creek	SD	2.00	3
1016000612	Redstone Creek	SD	2.00	3
1016000613	Sand Creek	SD	1.00	5
1016001104	Dry Run-James River	SD	1.00	5
1016001106	Rock Creek	SD	1.67	4
1016001107	Pleasant Lake	SD	2.00	3
1016001108	West Branch Firesteel Creek	SD	1.00	5
1016001109	Firesteel Creek	SD	2.00	3
1016001110	Enemy Creek	SD	2.00	3
1016001111	Pierre Creek	SD	0.00	6
1016001112	Twelvemile Creek	SD	1.00	5
1016001113	Dry Creek	SD	2.00	3
1016001114	Firesteel Creek-James River	SD	-1.00	7
1016001115	Wolf Creek	SD	1.00	5
1016001116	Lonetree Creek	SD	2.50	3
1016001117	Dawson Creek	SD	2.00	3
1017010204	Lower East Fork Vermillion River	SD	1.00	5
1017010205	Upper West Fork Vermillion River	SD	1.50	4
1017010206	Lower West Fork Vermillion River	SD	1.00	5
1017010209	Hurley Creek	SD	0.00	6
1017010210	Long Creek	SD	2.00	3
1017010211	Upper Vermillion River	SD	1.50	4
1017010212	Turkey Ridge Creek	SD	2.50	3
1017010213	Blind Creek	SD	2.00	3
1017010214	Frog Creek	SD	0.00	6
1017010220	Lower Vermillion River	SD	2.00	3
1017020107	Willow Creek	SD	3.00	2

Population ID (HUC 10)	Population Name	State	Score	Rating
1017020108	Stray Horse Creek	SD	1.50	4
1017020204	Hidewood Creek	SD	3.00	2
1017020206	Sixmile Creek	SD	2.00	3
1017020207	North Deer Creek	SD	0.67	5
1017020209	Deer Creek-Medary Creek	SD	2.00	3
1017020210	Medary Creek	SD	2.33	3
1017020211	Upper Big Sioux River	SD	2.00	3
1017020301	Spring Creek	SD	2.00	3
1017020306	Brookfield Creek-Big Sioux River	SD	3.00	2
1017020314	West Pipestone Creek	SD	2.00	3
1017020317	Ninemile Creek-Big Sioux River	SD	2.00	3

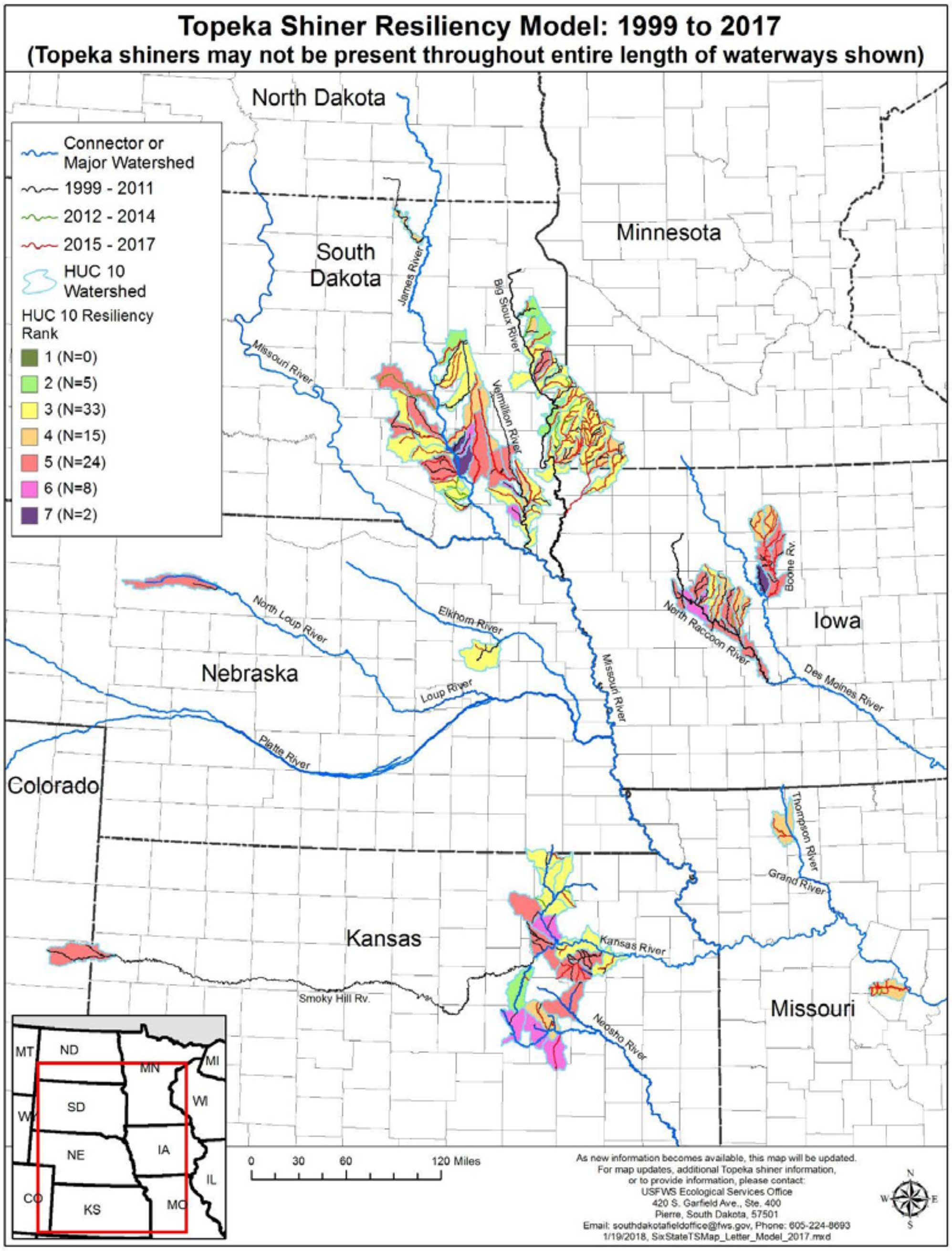

Figure 3.1 Topeka shiner Range-wide Resiliency Scores

Broad view comparing Topeka shiner resiliency scores across all known extant populations as of November, 2017.

4 Discussion

The Resiliency Model described in this report represents the most standardized approach currently known that compares each population in a level and consistent way across the entire range of the species. However, there is always room for improvement and it is likely that several changes will need to be made to this model in the next iteration. The intention of this version, and its results, is to provide a solid baseline for future model iterations and potential for predicative modeling.

4.1 Observations

The most critical factor in determining the resiliency score is flowline selection. Flowlines affect how many crossings occur, whether barriers are selected for use, sinuosity, and overall habitat length. This suggests that every effort should be made to reduce the potential for biased selection of the predominant stream channel in each population and sub-population. We used point measured observation data instead of watershed identification to choose the flowline within close proximity to observed records by GIS and manual efforts. GIS may be used to define the primary flowline of watersheds where local knowledge and observational evidence is limited.

In this model, multiple flowlines are included per HUC-12 watershed to realistically capture Topeka shiner habitat. Resiliency ratings resulting from this method are based on aggregated sinuosity values calculated to derive a final watershed scale sub-population rating. Given the paucity and inconsistency of field data throughout the range, it was necessary for the model to use the most inclusive of datasets to reach a standardized value. Therefore, delineation based on HUC-12 watersheds was the finest scale attainable with the data used for this version of the model.

Site level habitat conditions have not been documented consistently throughout the range. These criteria are generally important to Topeka shiner and should be evaluated to get a better understanding of habitat quality and as a way to "ground truth" the model results.

4.2 Recommendations

This Resiliency Model can be used to document a baseline condition, compare baseline conditions among populations and sub-populations, and document trends in resiliency over time. To achieve the ability to detect changes and trends over time, it is recommended that the model be reran with current data every three years (at a minimum). Also, accuracy of the model would likely improve if habitat data were collected in the field on a consistent basis. Therefore, the implementation of a standardized survey method across the Topeka shiner range is recommended. Many of the inputs to the existing model are proxy measurements used to approximate field conditions based on coarse spatial data that are readily available for all sub-populations. For example, sinuosity is used as a proxy for stream habitat complexity in this model but may be an inappropriate measure in certain landscapes. This measure could be replaced or adjusted based on a more precise field measurement (e.g., number of oxbows). More precise field measurements or inputs in general could make the model more accurate and responsive to changes.

Recommendations that could assist future iterations of the model:

- Search for presence/absence in all HUC-12s within each extant population (listed in Table 3).
- Collect presence/absence survey data for each extant sub-population (listed in Appendix 7.1) every three years, at a minimum, to better detect changes in survival and recruitment.

- Assess and classify all stream crossings within each extant sub-population to better evaluate impacts to connectivity.
- Assess all major barriers within each extant sub-population to determine whether they meet the definition of an absolute impediment to fish passage.
- Document and classify all oxbow and off-channel habitat available and used by Topeka shiners within each extant sub-population.
- Measure a portion of captured Topeka shiners in each extant sub-population to better document potential reproduction and recruitment.
- Perform sensitivity analysis on model inputs to better determine appropriate measures and score weight.

5 References

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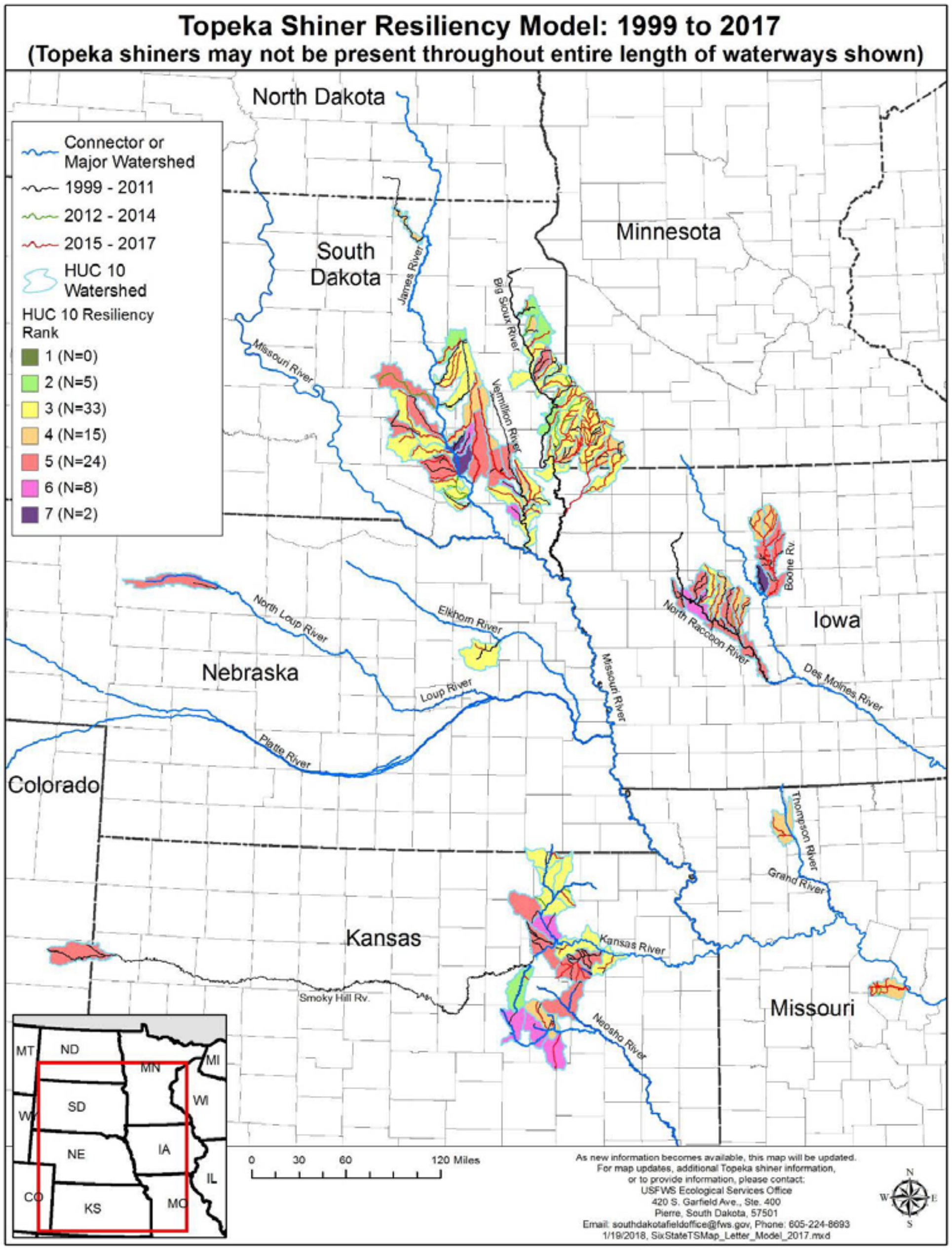
USGS (U.S. Geological Survey). 2009. National Elevation Dataset (NED) Metadata. http://atlas.ca.gov/casil/elevation/ned/36117/grid/metadata.htm (Accessed May 2016)

6 Acknowledgements

Version 2 was completed with the assistance of Lara Juliusson, Region 6 Regional Office, Ecological Services, Decision Support Branch. For this version, Lara automated the model using ArcGIS 10.3 Model Builder tools, verified and ran the model. She then updated report methodology, and created model output figures and tables found in this report.

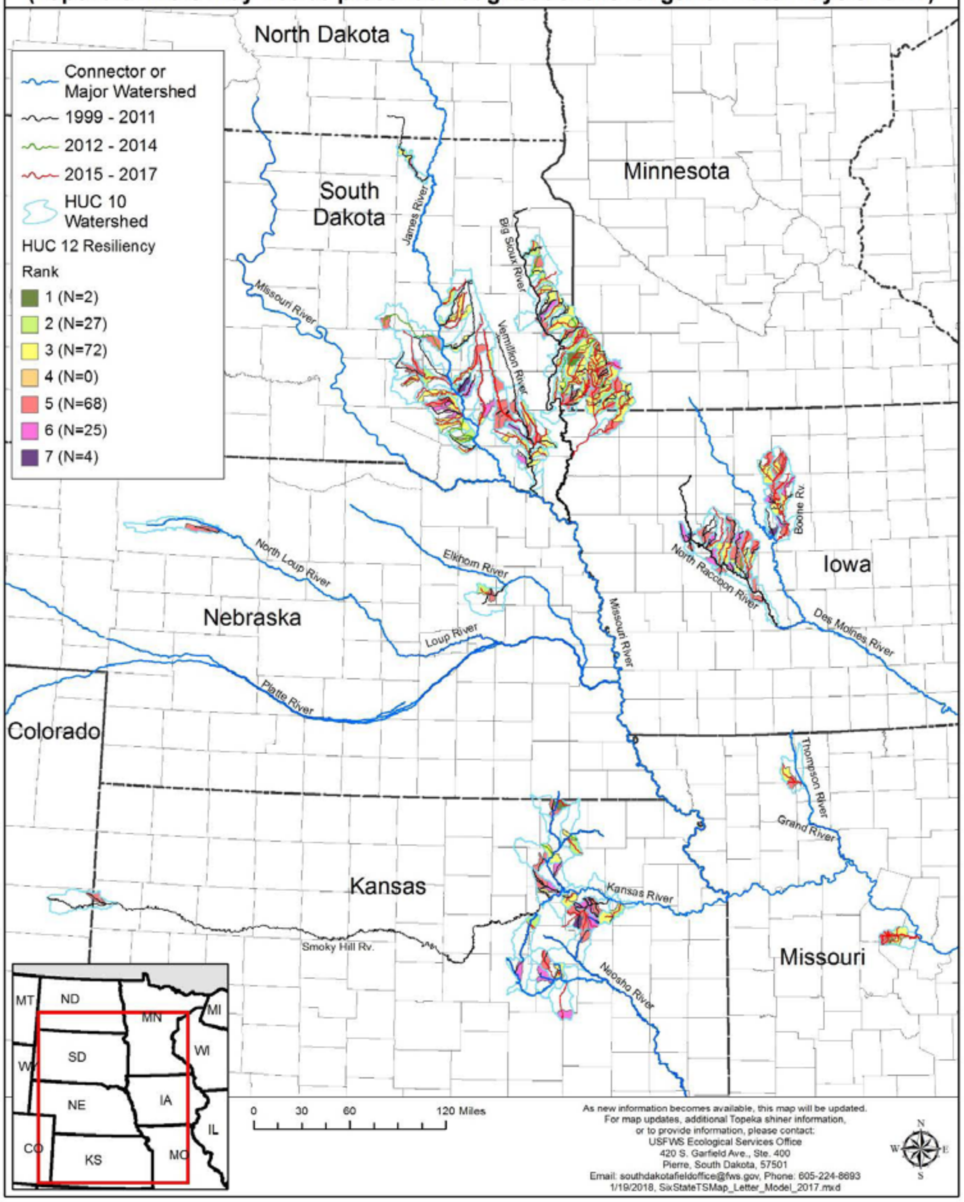
7 Appendices

7.1 Populations throughout Entire Range

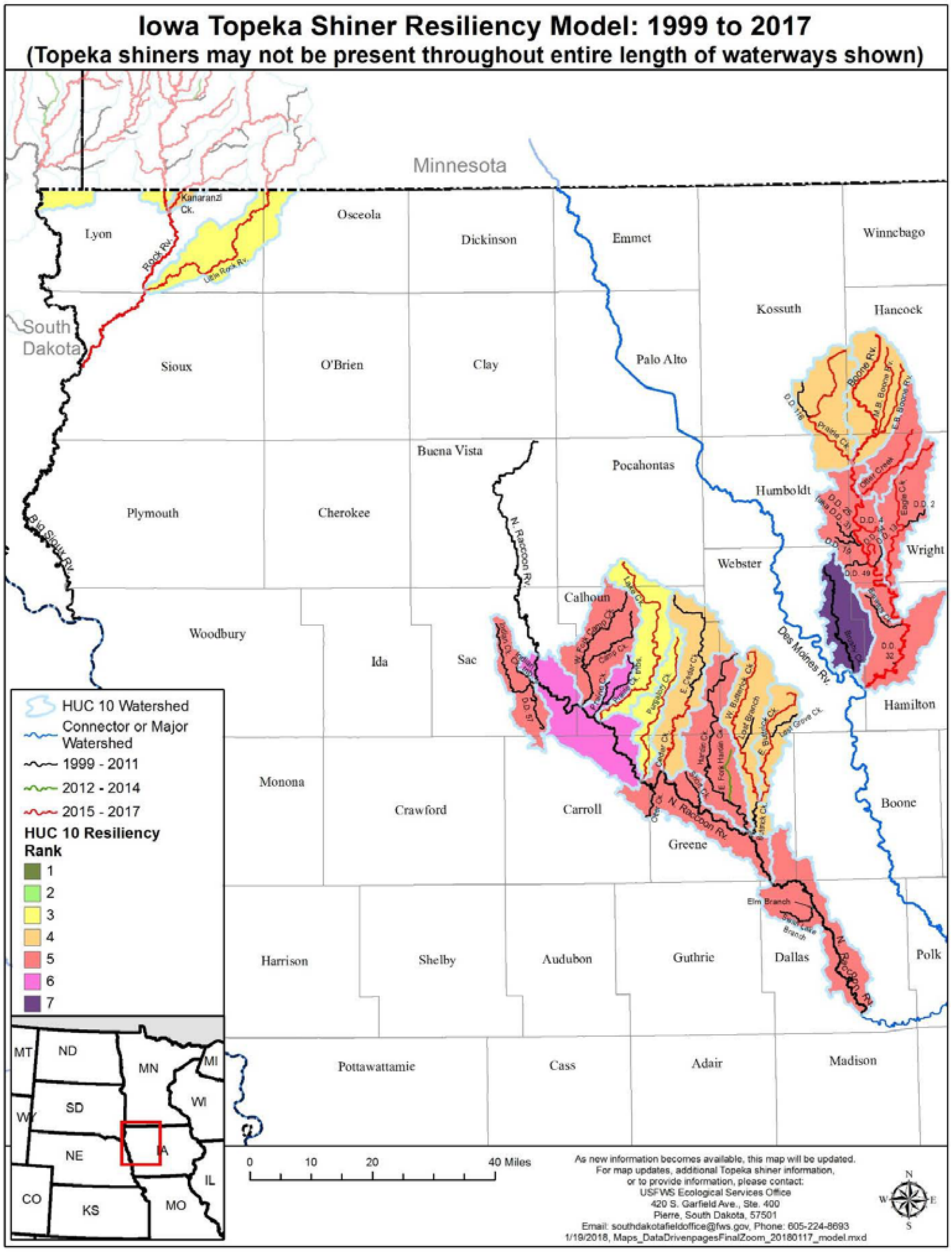


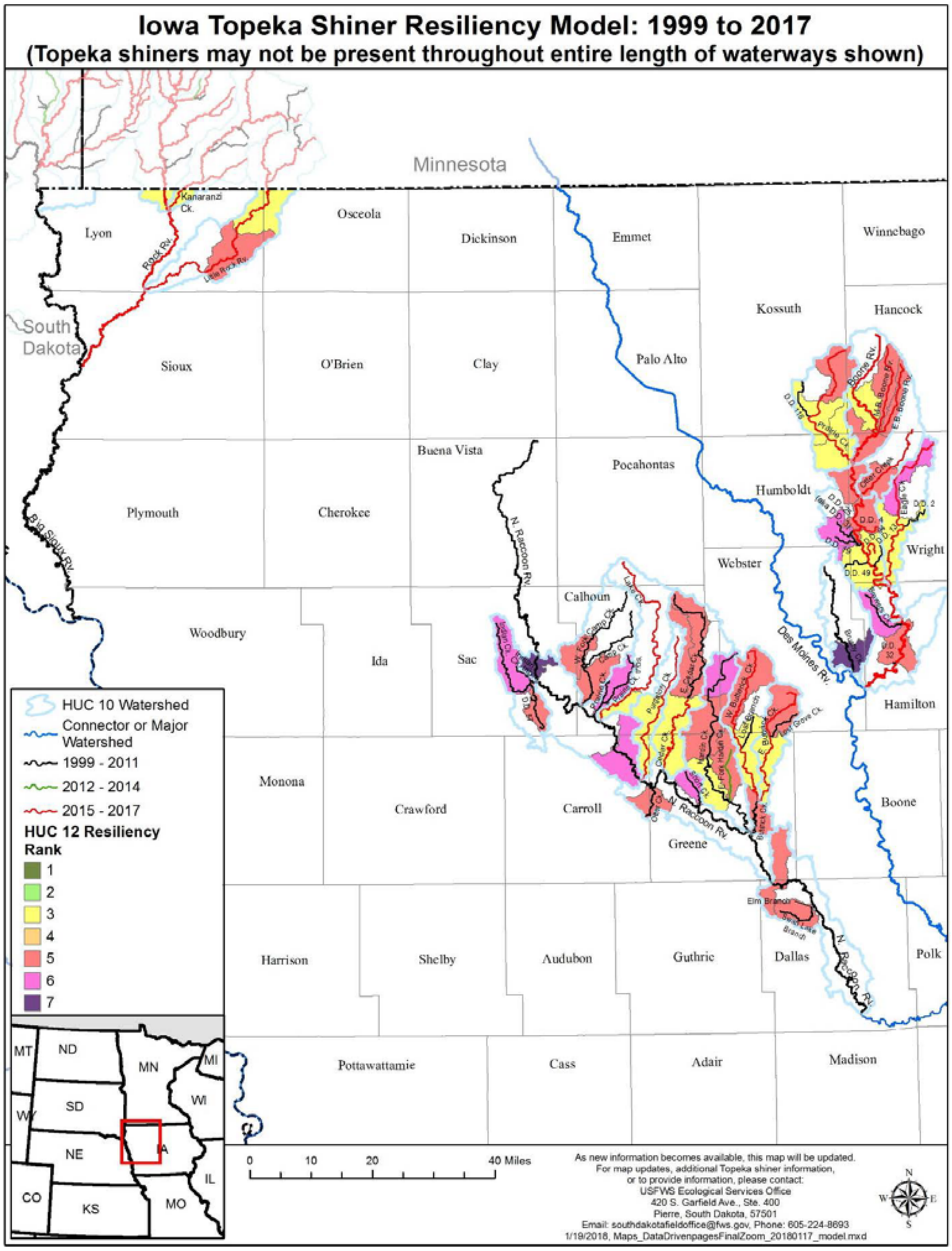
7.2 Sub-populations throughout Entire Range

Topeka Shiner Resiliency Model: 1999 to 2017
(Topeka shiners may not be present throughout entire length of waterways shown)

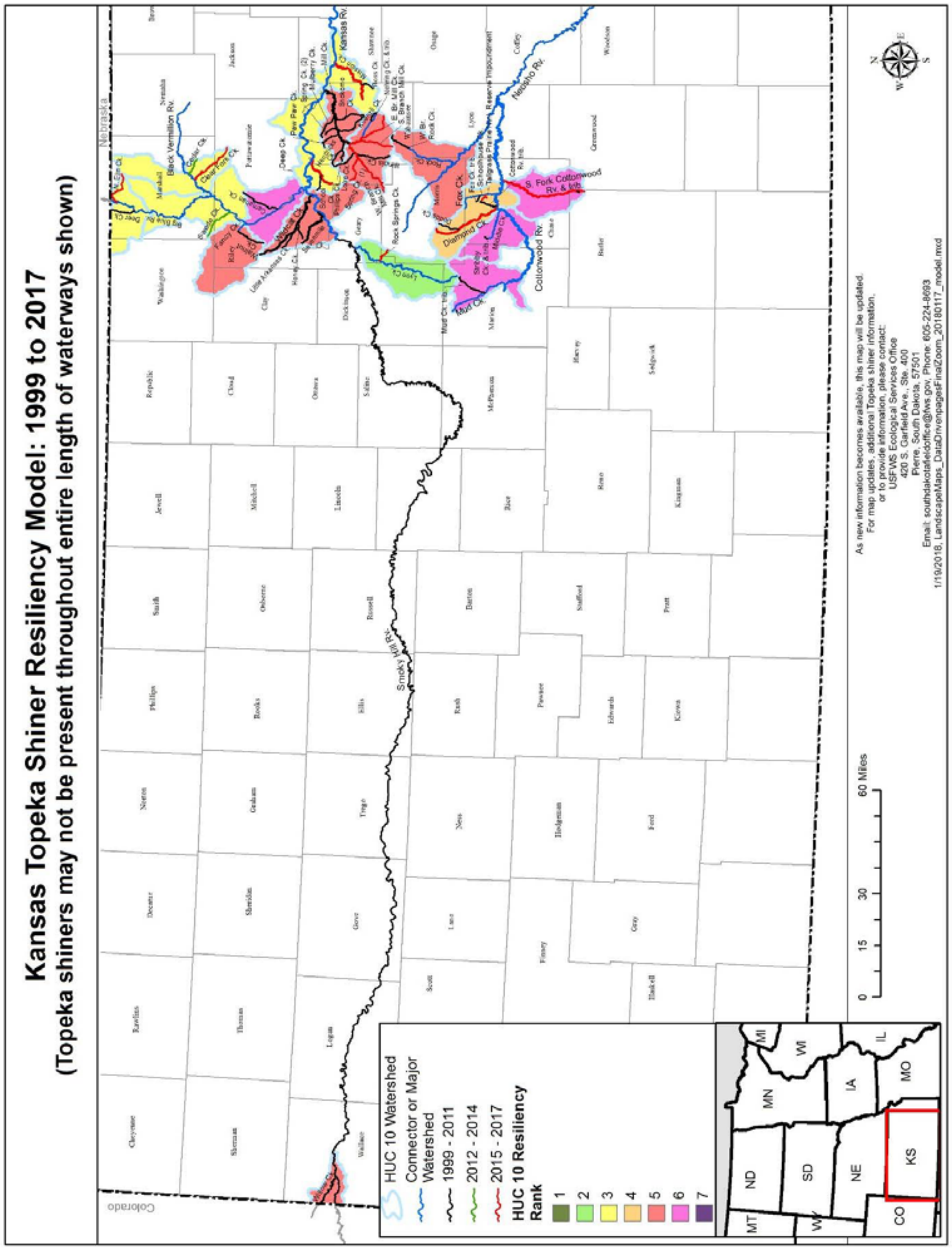


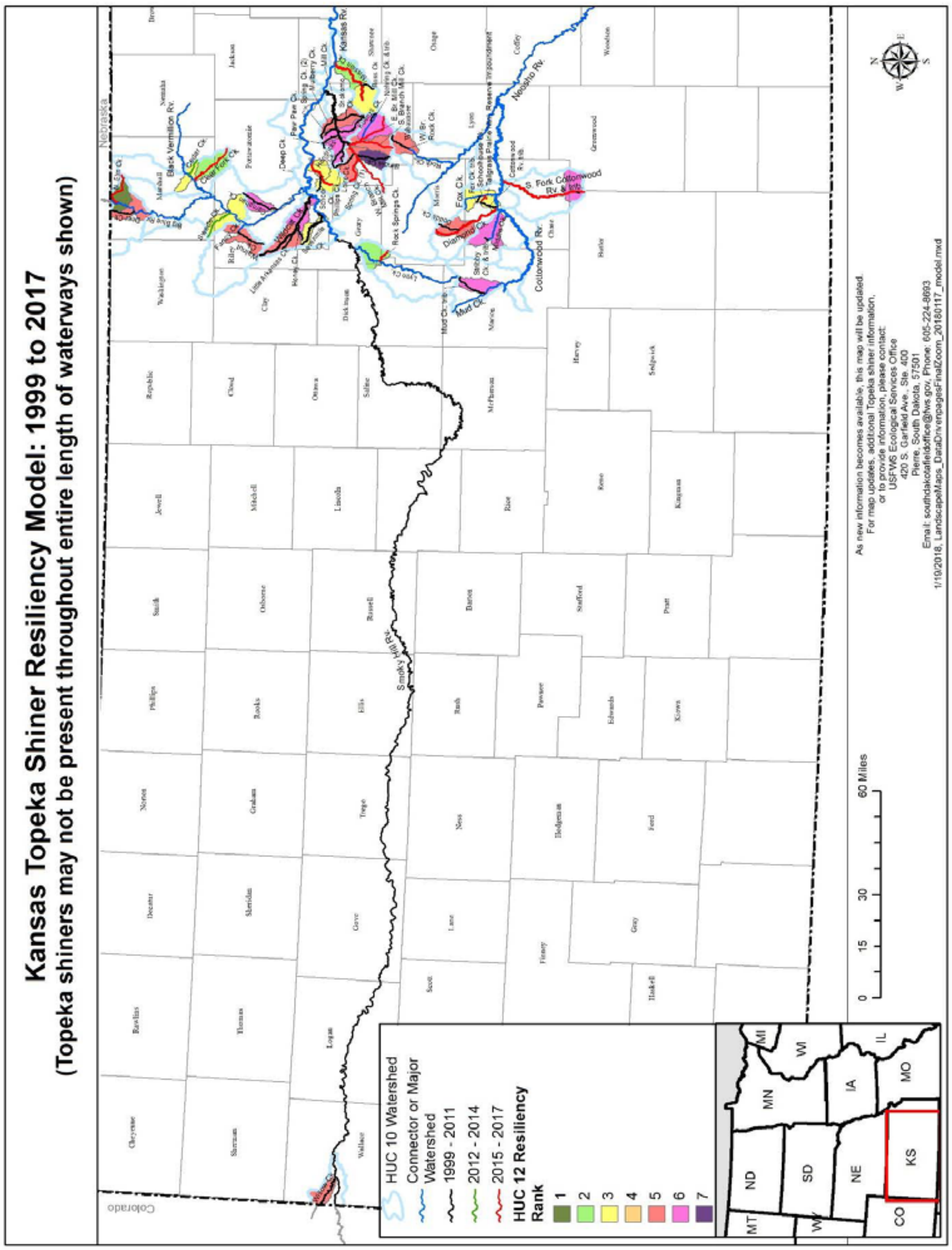
7.3 Iowa Populations and Sub-populations




Iowa Topeka Shiner Resiliency Model: 1999 to 2017
(Topeka shiners may not be present throughout entire length of waterways shown)
Minnesota
South Dakota
Lyon
Osceola
Dickinson
Emmet
Winnebago
Kossuth
Hancock
Sioux
O'Brien
Clay
Palo Alto
Buena Vista
Pocahontas
Humboldt
Plymouth
Cherokee
Wright
Webster
Calhoun
Woodbury
Ida
Sac
Hamilton
Monona
Crawford
Carroll
Greene
Boone
Harrison
Shelby
Audubon
Guthrie
Dallas
Polk
Pottawattamie
Cass
Adair
Madison
Rock Rv.
Big Sioux Rv.
N. Raccoon Rv.
Des Moines Rv.
Boone Rv.
Elm Branch
HUC 10 Watershed
Connector or Major Watershed
1999 - 2011
2012 - 2014
2015 - 2017
HUC 12 Resiliency Rank
1
2
3
4
5
6
7
MT
ND
MN
MI
WI
SD
WY
NE
IA
IL
CO
KS
MO
0
10
20
40 Miles
As new information becomes available, this map will be updated.
For map updates, additional Topeka shiner information,
or to provide information, please contact:
USFWS Ecological Services Office
420 S. Garfield Ave., Ste. 400
Pierre, South Dakota, 57501
Email: southdakotafieldoffice@fws.gov, Phone: 605-224-8693
1/19/2018, Maps_DataDrivenpagesFinalZoom_20180117_model.mxd

7.4 Kansas Populations and Sub-populations




Kansas Topeka Shiner Resiliency Model: 1999 to 2017
(Topeka shiners may not be present throughout entire length of waterways shown)
HUC 10 Watershed
Connector or Major Watershed
1999 - 2011
2012 - 2014
2015 - 2017
HUC 12 Resiliency Rank
1
2
3
4
5
6
7
0
15
30
60 Miles
As new information becomes available, this map will be updated.
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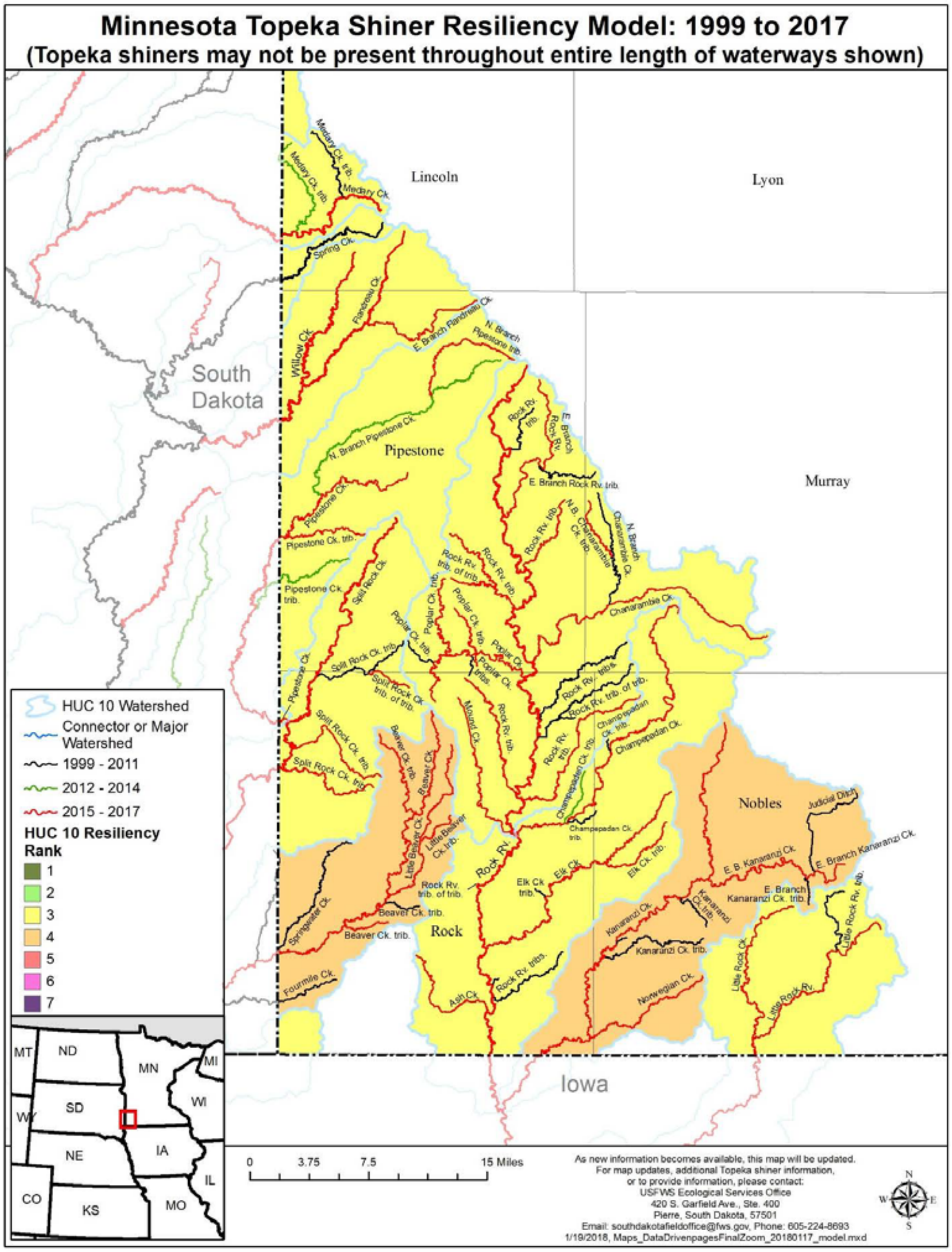
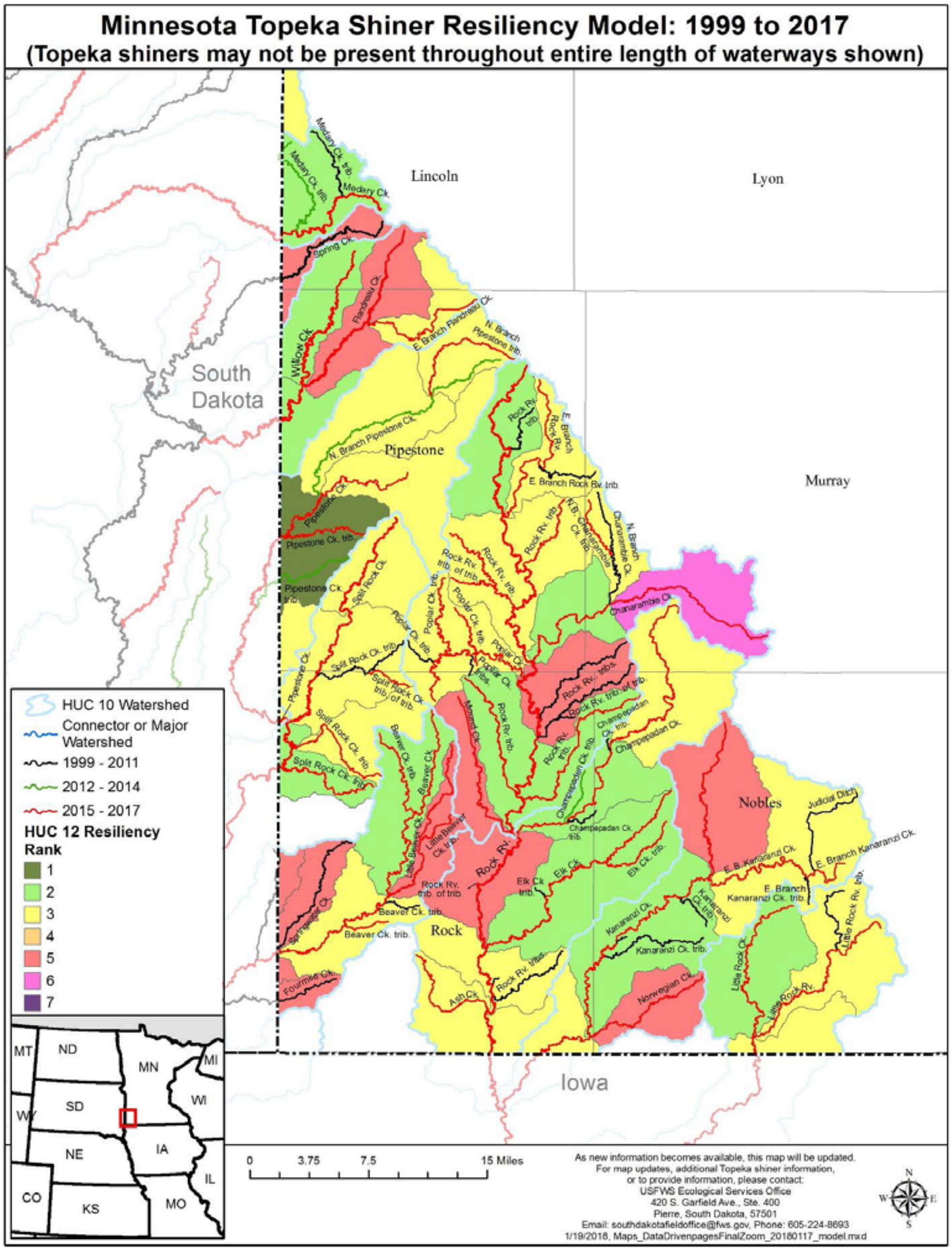
7.5 Minnesota Populations and Sub-populations




Minnesota Topeka Shiner Resiliency Model: 1999 to 2017
(Topeka shiners may not be present throughout entire length of waterways shown)
Lincoln
Lyon
Pipestone
Murray
Nobles
Rock
South Dakota
Iowa
HUC 10 Watershed
Connector or Major Watershed
1999 - 2011
2012 - 2014
2015 - 2017
HUC 12 Resiliency Rank
1
2
3
4
5
6
7
0 3.75 7.5 15 Miles
As new information becomes available, this map will be updated.
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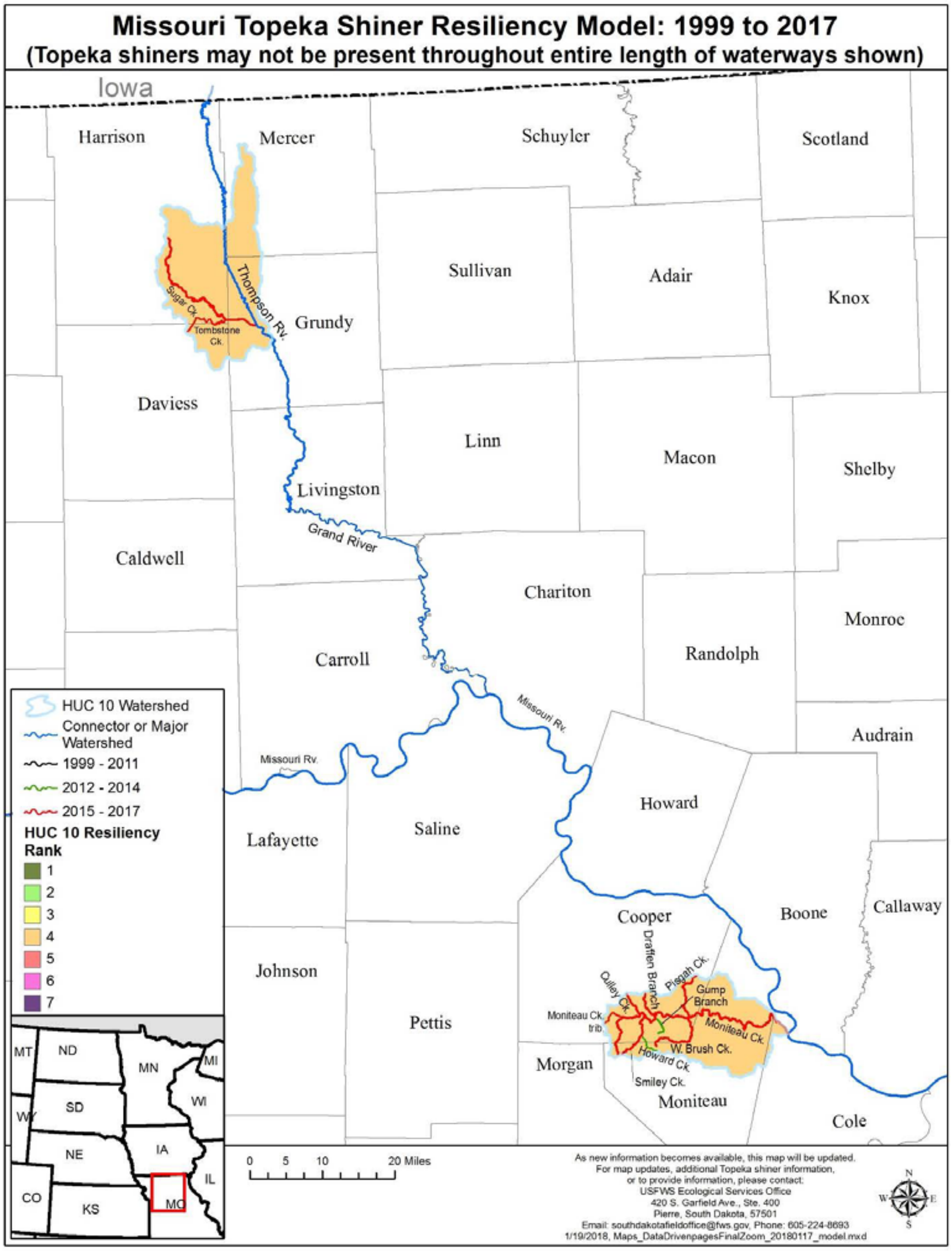
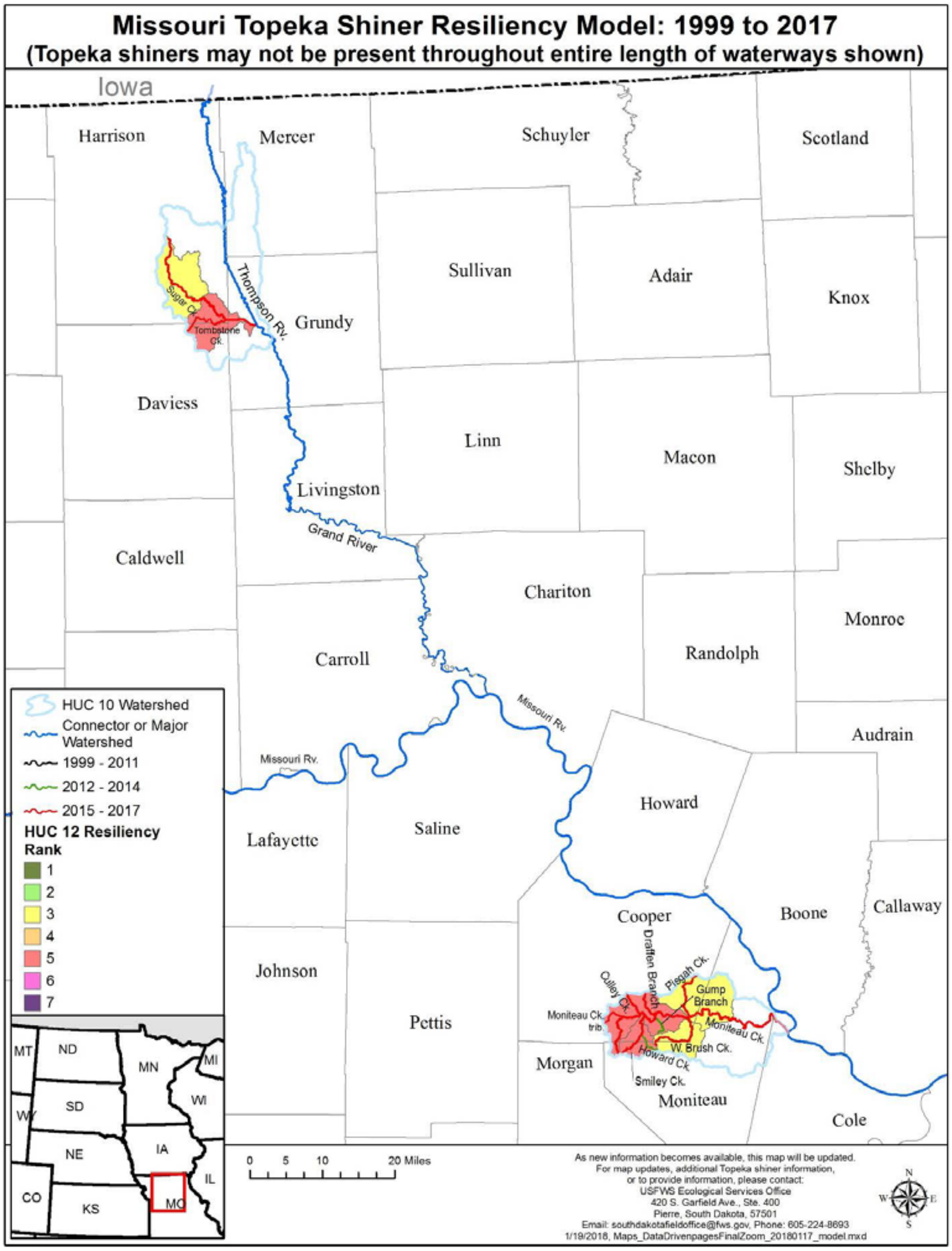
1/19/2018, Maps_DataDrivenpagesFinalZoom_20180117_model.mxd

7.6 Missouri Populations and Sub-populations





Missouri Topeka Shiner Resiliency Model: 1999 to 2017
(Topeka shiners may not be present throughout entire length of waterways shown)
Iowa
Harrison
Mercer
Schuyler
Scotland
Sullivan
Adair
Knox
Grundy
Thompson Rv.
Sugar Ck.
Tombstone Ck.
Daviess
Linn
Macon
Shelby
Livingston
Grand River
Caldwell
Chariton
Monroe
Randolph
Carroll
Missouri Rv.
Audrain
Howard
Lafayette
Saline
Cooper
Boone
Callaway
Johnson
Pettis
Morgan
Moniteau
Cole
Draffen Branch
Pisgah Ck.
Culley Ck.
Gump Branch
Moniteau Ck. trib.
Moniteau Ck.
W. Brush Ck.
Howard Ck.
Smiley Ck.
HUC 10 Watershed
Connector or Major Watershed
1999 - 2011
2012 - 2014
2015 - 2017
HUC 12 Resiliency Rank
1
2
3
4
5
6
7
MT
ND
MN
MI
SD
WI
WY
NE
IA
IL
CO
KS
MO
0 5 10 20 Miles
As new information becomes available, this map will be updated.
For map updates, additional Topeka shiner information,
or to provide information, please contact:
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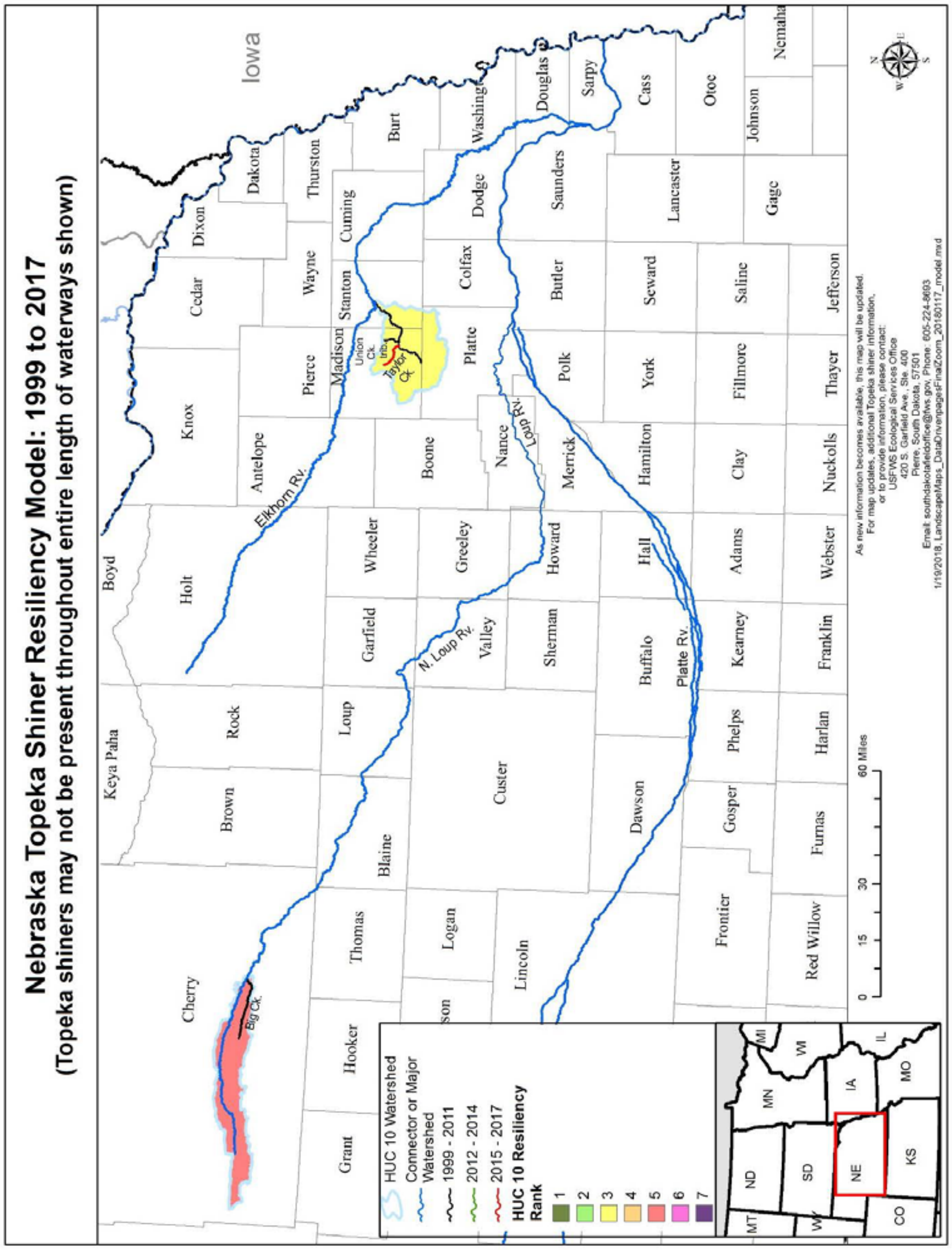
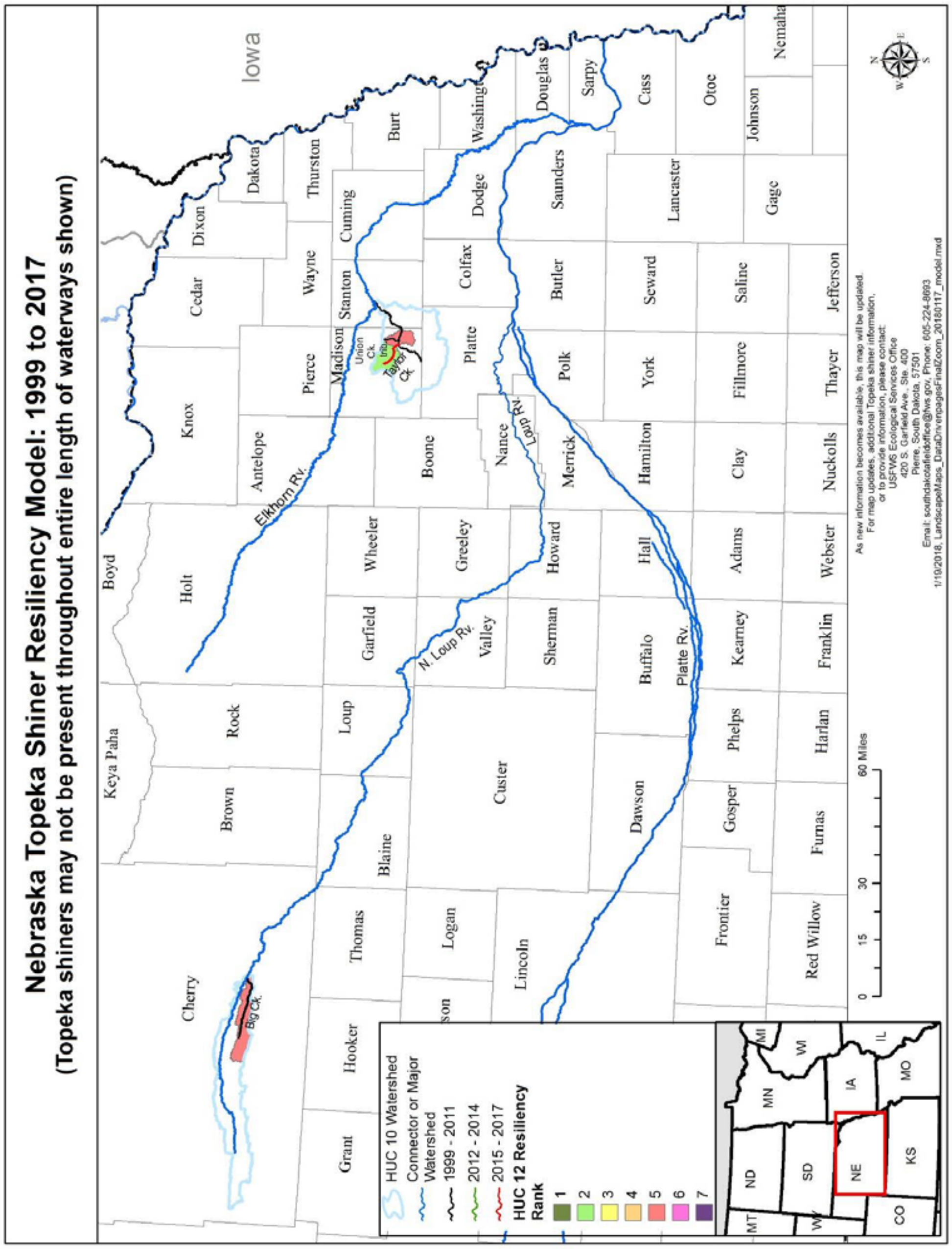
1/19/2018, Maps_DataDrivenpagesFinalZoom_20180117_model.mxd
N
W
E
S

7.7 Nebraska Populations and Sub-populations




Nebraska Topeka Shiner Resiliency Model: 1999 to 2017
(Topeka shiners may not be present throughout entire length of waterways shown)
HUC 10 Watershed
Connector or Major Watershed
1999 - 2011
2012 - 2014
2015 - 2017
HUC 12 Resiliency Rank
1
2
3
4
5
6
7
Iowa
Big Ck.
Union Ck.
Taylor Ck.
Elkhorn Rv.
N. Loup Rv.
Loup Rv.
Platte Rv.
0 15 30 60 Miles
As new information becomes available, this map will be updated.
For map updates, additional Topeka shiner information, or to provide information, please contact:
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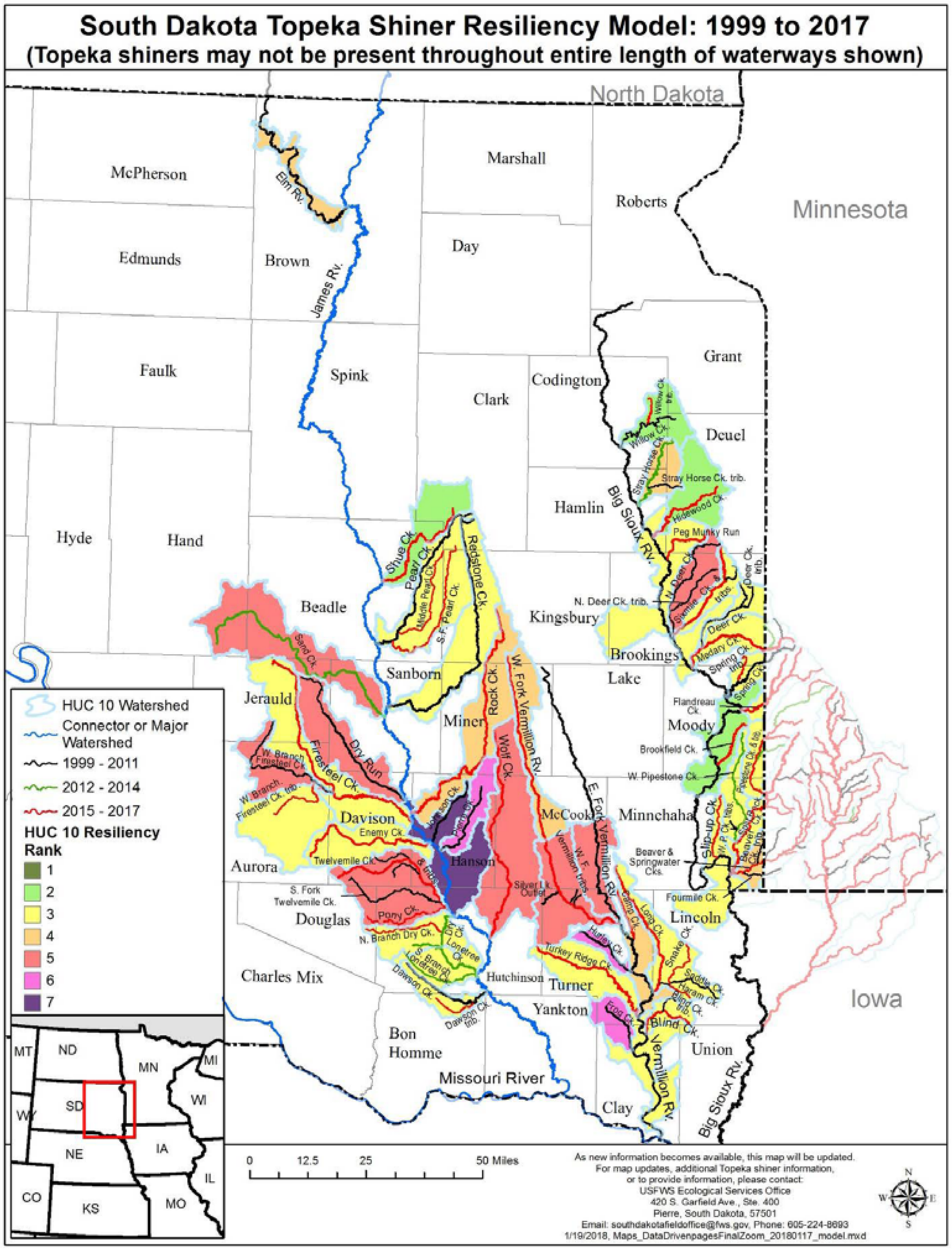
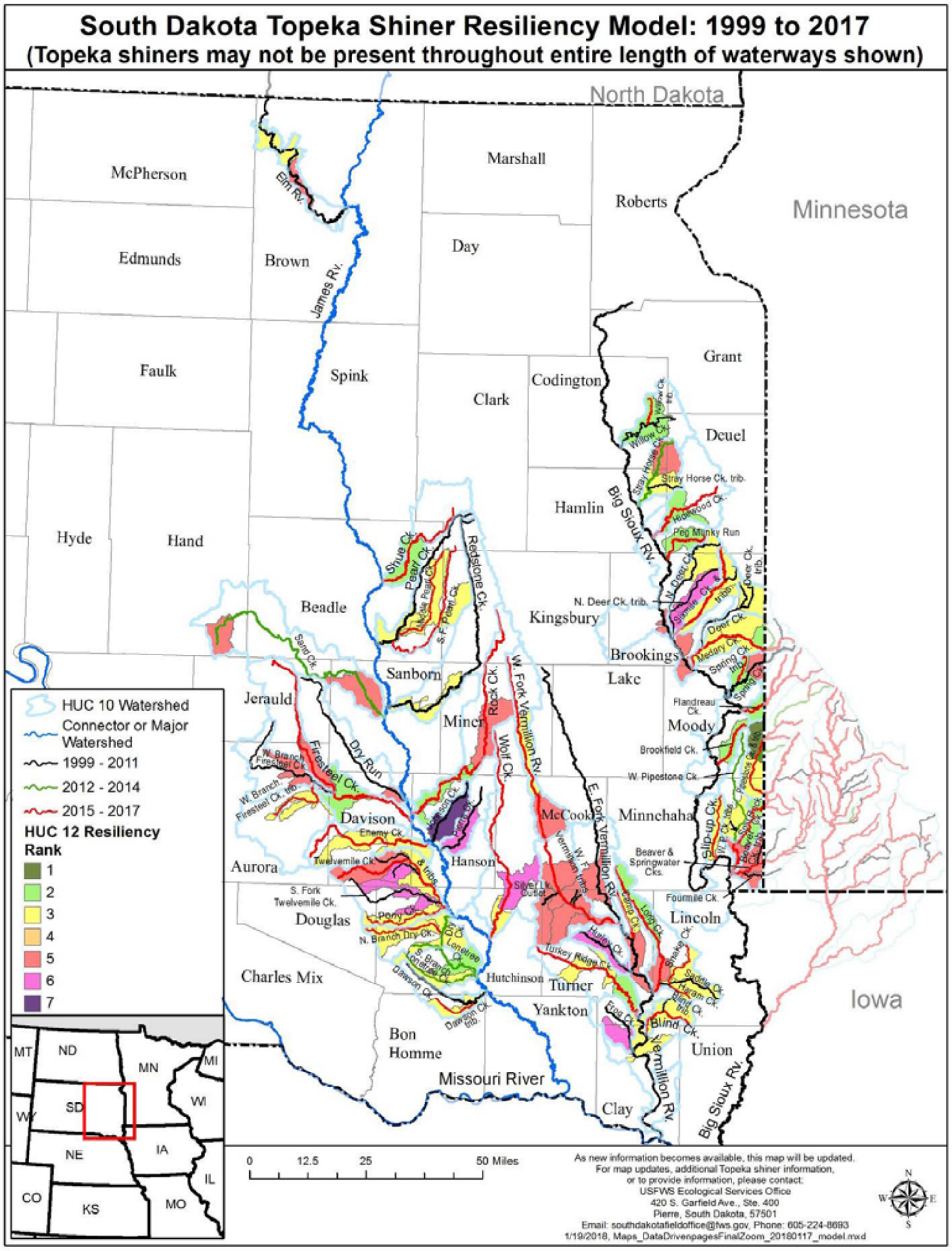
1/19/2018, LandscapeMaps_DataDrivenpagesFinalZoom_20180117_model.mxd

7.8 South Dakota Populations and Sub-populations




South Dakota Topeka Shiner Resiliency Model: 1999 to 2017
(Topeka shiners may not be present throughout entire length of waterways shown)
North Dakota
Minnesota
Iowa
McPherson
Edmunds
Faulk
Hyde
Hand
Brown
Spink
Beadle
Jerauld
Aurora
Davison
Douglas
Charles Mix
Bon Homme
Hutchinson
Hanson
Miner
Sanborn
Marshall
Day
Clark
Codington
Hamlin
Kingsbury
Roberts
Grant
Deuel
Brookings
Lake
Moody
Minnehaha
McCook
Turner
Lincoln
Yankton
Clay
Union
Missouri River
James Rv.
Big Sioux Rv.
Vermillion Rv.
Elm Rv.
HUC 10 Watershed
Connector or Major Watershed
1999 - 2011
2012 - 2014
2015 - 2017
HUC 12 Resiliency Rank
1
2
3
4
5
6
7
MT
ND
MN
MI
WY
SD
WI
NE
IA
IL
CO
KS
MO
0
12.5
25
50 Miles
As new information becomes available, this map will be updated.
For map updates, additional Topeka shiner information,
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7.9 Resiliency Model Attributes Table

This table contains the data breakdown for each sub-population (where Topeka shiners have been documented 1999 to 2017) and their individual scores. Each sub-population composite score is the sum of all measurable criteria (columns identified by number). Measurable criteria are described in Section 2.4. The population score is based on the average of all the HUC-12 composite scores within each population. Resiliency rankings are based on these scores and can be found in Table 2.5.3.1.

HUC 10	Population (HUC 10)	HUC 12	Sub-population (HUC 12)	State(s)	Occupancy Score	Stream Length (m)	Length Score	Basin Length (m)	Sinuosity Score	Crossing Density (#/km)	Major Barriers (w/in 500 m)	Connectivity Score	Composite Score	Population Average Score
0710000405	Brushy Creek	071000040504	Brushy Creek	IA	0	12,131	1	8,139	-1	0.25	1	-1	-1	-1.00
0710000501	Prairie Creek	071000050102	Headwaters Prairie Creek	IA	1	21,322	1	15,004	-1	0.89	0	0	1	1.67
		071000050103	Drainage Ditch 116-Prairie Creek	IA	1	32,650	1	21,532	0	0.70	0	0	2	1.67
		071000050104	Drainage Ditch 18-Prairie Creek	IA	1	16,627	1	9,674	0	0.60	0	0	2	1.67
0710000502	Headwaters Boone River	071000050202	Middle Branch Boone River	IA	1	25,446	1	23,608	-1	0.83	0	0	1	1.25
		071000050203	East Branch Boone River	IA	1	25,538	1	20,644	-1	0.94	0	0	1	1.25
		071000050204	Drainage Ditch 44-Boone River	IA	1	22,518	1	13,702	0	0.62	0	0	2	1.25
		071000050205	Drainage Ditch 1-Boone River	IA	1	19,332	1	10,142	0	0.62	2	-1	1	1.25
0710000503	Otter Creek	071000050303	Otter Creek	IA	1	15,848	1	11,556	-1	0.50	0	0	1	1.00
0710000504	Eagle Creek	071000050402	Headwaters Eagle Creek	IA	0	29,068	1	21,395	-1	0.76	0	0	0	1.00
		071000050403	Eagle Creek	IA	1	42,574	1	26,017	0	0.68	0	0	2	1.00

HUC 10	Population (HUC 10)	HUC 12	Sub-population (HUC 12)	State(s)	Occupancy Score	Stream Length (m)	Length Score	Basin Length (m)	Sinuosity Score	Crossing Density (#/km)	Major Barriers (w/in 500 m)	Connectivity Score	Composite Score	Population Average Score
0710000506	Ditch 3-Boone River	071000050601	Joint Drainage Ditch 3-Boone River	IA	1	12,957	1	8,713	-1	0.39	0	0	1	1.00
		071000050603	Drainage Ditch 3	IA	0	21,753	1	15,528	-1	0.97	0	0	0	1.00
		071000050604	Drainage Ditch 4-Boone River	IA	1	27,158	1	17,551	0	0.70	1	-1	1	1.00
		071000050605	Drainage Ditch 46-Boone River	IA	1	49,694	1	27,745	0	0.44	0	0	2	1.00
0710000507	Boone River	071000050702	Brewers Creek	IA	0	16,803	1	12,253	-1	1.01	0	0	0	0.50
		071000050704	Drainage Ditch 32-Boone River	IA	0	21,398	1	12,782	0	0.37	0	0	1	0.50
0710000604	Indian Creek	071000060402	Drainage Ditch 57	IA	0	20,970	1	12,912	0	0.67	0	0	1	0.50
		071000060403	Indian Creek-North Raccoon River	IA	0	45,307	1	26,212	0	0.64	1	-1	0	0.50
0710000605	Camp Creek	071000060503	West Fork Camp Creek	IA	0	15,707	1	8,904	0	0.76	0	0	1	1.00
		071000060505	Camp Creek	IA	0	15,801	1	9,914	0	0.57	0	0	1	1.00
0710000606	Lake Creek	071000060605	Lake Creek	IA	1	19,871	1	11,924	0	0.60	0	0	2	2.00
0710000607	Purgatory Creek	071000060702	Purgatory Creek	IA	1	36,474	1	22,882	0	0.52	0	0	2	2.00
0710000608	Elk Run-North Raccoon River	071000060801	Drainage Ditch 73-North Raccoon River	IA	0	9,995	1	7,515	-1	0.40	1	-1	-1	-0.33
		071000060803	Prairie Creek	IA	0	35,640	1	26,278	-1	0.90	0	0	0	-0.33
		071000060806	Marrowbone Creek-North Raccoon River	IA	0	16,871	1	11,277	-1	0.36	0	0	0	-0.33
0710000609	Welshs Slough-Cedar Creek	071000060902	West Cedar Creek	IA	0	0	1	0	-1	0.00	0	1	1	1.33
		071000060903	East Cedar Creek	IA	0	44,055	1	27,139	0	1.04	0	0	1	1.33

		071000060904	Cedar Creek	IA	2	40,587	1	20,401	0	0.52	1	-1	2	1.33
HUC 10	**Population (HUC 10)**	**HUC 12**	**Sub-population (HUC 12)**	**State(s)**	**Occupancy Score**	**Stream Length (m)**	**Length Score**	**Basin Length (m)**	**Sinuosity Score**	**Crossing Density (#/km)**	**Major Barriers (w/in 500 m)**	**Connectivity Score**	**Composite Score**	**Population Average Score**
0710000610	Hardin Creek	071000061001	Headwaters Hardin Creek	IA	0	18,740	1	13,666	-1	0.85	0	0	0	1.00
		071000061002	Happy Run-Hardin Creek	IA	0	24,293	1	16,149	0	0.78	0	0	1	1.00
		071000061003	East Fork Hardin Creek	IA	1	15,687	1	13,835	-1	1.02	0	0	1	1.00
		071000061004	Village of Farlin-Harrdin Creek	IA	0	27,060	1	13,157	1	0.55	0	0	2	1.00
0710000611	East Buttrick Creek	071000061101	Headwaters East Buttrick Creek	IA	1	31,585	1	21,371	-1	0.98	0	0	1	1.50
		071000061102	East Buttrick Creek	IA	1	28,288	1	17,249	0	0.60	0	0	2	1.50
0710000612	Buttrick Creek	071000061202	Headwaters West Buttrick Creek	IA	0	32,987	1	18,623	0	0.70	0	0	1	1.33
		071000061203	West Buttrick Creek	IA	2	40,825	1	28,874	-1	0.59	0	0	2	1.33
		071000061204	Buttrick Creek	IA	0	16,498	1	9,054	0	0.42	0	0	1	1.33
0710000614	Otter Creek-North Raccoon River	071000061401	Otter Creek	IA	0	14,177	1	7,850	0	0.92	0	0	1	0.50
		071000061403	Short Creek	IA	0	14,012	1	9,708	-1	0.64	0	0	0	0.50
0710000615	Swan Lake Branch-North Raccoon River	071000061501	Fannys Branch-North Raccoon River	IA	0	6,792	1	4,351	0	0.29	0	0	1	1.00
		071000061502	Swan Lake Branch	IA	0	15,535	1	8,134	0	0.64	0	0	1	1.00
1016000408	Lower Elm River	101600040801	Elm River-Maple River	SD	0	54,526	1	23,474	1	0.28	0	0	2	1.50
		101600040802	Elm River-Willow Creek	SD	0	24,435	1	14,268	0	0.53	0	0	1	1.50
1016000607	Shue Creek	101600060704	Lower Shue Creek	SD	1	36,970	1	17,244	1	0.41	0	0	3	3.00

HUC 10	Population (HUC 10)	HUC 12	Sub-population (HUC 12)	State(s)	Occupancy Score	Stream Length (m)	Length Score	Basin Length (m)	Sinuosity Score	Crossing Density (#/km)	Major Barriers (w/in 500 m)	Connectivity Score	Composite Score	Population Average Score
1016000611	Pearl Creek	101600061103	Center Pearl Creek	SD	1	57,897	1	32,680	0	0.59	0	0	2	2.00
		101600061107	Lower Pearl Creek	SD	0	37,959	1	17,952	1	0.37	0	0	2	2.00
		101600061105	Middle South Fork Pearl Creek	SD	1	9,579	1	5,932	0	0.42	0	0	2	2.00
1016000612	Redstone Creek	101600061208	Outlet Redstone Creek	SD	0	74,414	1	27,322	1	0.28	0	0	2	2.00
1016000613	Sand Creek	101600061301	Rose Hill Lake-Sand Creek	SD	1	21,827	1	11,213	0	0.55	1	-1	1	1.00
		101600061309	Outlet Sand Creek	SD	0	37,041	1	18,680	0	0.57	0	0	1	1.00
1016001104	Dry Run-James River	101600110406	Outlet Dry Run	SD	0	13,602	1	7,785	0	0.66	0	0	1	1.00
1016001106	Rock Creek	101600110605	Burke Slough-Rock Creek	SD	0	22,078	1	12,470	0	0.41	0	0	1	1.67
		101600110608	Outlet Rock Creek	SD	1	71,421	1	27,418	1	0.34	0	0	3	1.67
		101600110604	Town of Vilas-Rock Creek	SD	0	15,996	1	10,212	0	0.50	0	0	1	1.67
1016001107	Pleasant Lake	101600110707	City of Plankinton	SD	1	42,263	1	23,523	0	0.54	0	0	2	2.00
1016001108	West Branch Firesteel Creek	101600110804	Lower West Branch Firesteel Creek	SD	0	38,927	1	18,018	1	0.41	1	-1	1	1.00
1016001109	Firesteel Creek	101600110905	101600110905	SD	0	36,378	1	19,810	0	0.47	0	0	1	2.00
		101600110906	West Branch Firesteel Creek-Firesteel Creek	SD	1	31,246	1	13,209	1	0.13	0	0	3	2.00
1016001110	Enemy Creek	101600111002	Middle Enemy Creek	SD	1	28,570	1	14,873	0	0.39	0	0	2	2.00
		101600111005	Lower Enemy Creek	SD	0	29,667	1	14,485	1	0.30	0	0	2	2.00

1016001111	Pierre Creek	101600111102	Lower Pierre Creek	SD	0	28,824	1	19,043	0	0.62	1	-1	0	0.00
HUC 10	**Population (HUC 10)**	**HUC 12**	**Sub-population (HUC 12)**	**State(s)**	**Occupancy Score**	**Stream Length (m)**	**Length Score**	**Basin Length (m)**	**Sinuosity Score**	**Crossing Density (#/km)**	**Major Barriers (w/in 500 m)**	**Connectivity Score**	**Composite Score**	**Population Average Score**
1016001112	Twelvemile Creek	101600111205	Lower South Fork Twelvemile Creek	SD	0	27,710	1	13,876	0	0.43	1	-1	0	1.00
		101600111206	Pony Creek	SD	1	50,005	1	26,967	0	0.70	0	0	2	1.00
		101600111207	Lower Twelvemile Creek	SD	1	37,828	1	22,955	0	0.42	0	0	2	1.00
		101600111201	Upper Twelvemile Creek	SD	0	62,447	1	36,999	0	0.53	0	0	1	1.00
		101600111202	Ethan Lake	SD	0	17,010	1	8,611	0	0.59	1	-1	0	1.00
1016001113	Dry Creek	101600111302	North Branch Dry Creek	SD	1	49,303	1	26,521	0	0.55	0	0	2	2.00
		101600111303	Dry Creek	SD	1	35,708	1	20,762	0	0.48	0	0	2	2.00
1016001114	Firesteel Creek-James River	101600111401	Johnson Creek	SD	0	33,465	1	23,996	-1	0.75	1	-1	-1	-1.00
1016001115	Wolf Creek	101600111508	Rasmussen Cemetery-Wolf Creek	SD	0	22,192	1	12,905	0	0.36	1	-1	0	1.00
		101600111511	Outlet Wolf Creek	SD	1	19,433	1	10,853	0	0.72	0	0	2	1.00
1016001116	Lonetree Creek	101600111602	South Branch Lonetree Creek	SD	1	46,381	1	26,008	0	0.60	0	0	2	2.50
		101600111603	Lower Lonetree Creek	SD	1	23,173	1	11,164	1	0.47	0	0	3	2.50
1016001117	Dawson Creek	101600111702	Lower Dawson Creek	SD	1	46,113	1	22,608	1	0.46	1	-1	2	2.00
1017010204	Lower East Fork Vermillion River	101701020404	Rumpus Ridge-East Fork Vermillion River	SD	0	28,348	1	17,174	0	0.53	0	0	1	1.00

HUC 10	Population (HUC 10)	HUC 12	Sub-population (HUC 12)	State(s)	Occupancy Score	Stream Length (m)	Length Score	Basin Length (m)	Sinuosity Score	Crossing Density (#/km)	Major Barriers (w/in 500 m)	Connectivity Score	Composite Score	Population Average Score
1017010205	Upper West Fork Vermillion River	101701020503	City of Howard-West Fork Vermillion River	SD	1	44,834	1	27,911	0	0.47	0	0	2	1.50
		101701020504	City of Salem-West Fork Vermillion River	SD	1	22,770	1	15,766	-1	0.53	0	0	1	1.50
1017010206	Lower West Fork Vermillion River	101701020602	Stanley Corner-West Fork Vermillion River	SD	0	15,605	1	9,977	0	0.58	0	0	1	1.00
		101701020603	Silver Lake	SD	0	11,917	1	7,354	0	0.67	0	0	1	1.00
		101701020605	Bethesda Church-West Fork Vermillion River	SD	0	20,769	1	12,134	0	0.63	0	0	1	1.00
		101701020606	Outlet West Fork Vermillion River	SD	0	22,004	1	11,112	0	0.50	0	0	1	1.00
		101701020604	West Vermillion Cemetery-West Fork Vermillion River	SD	0	17,567	1	11,105	0	0.80	0	0	1	1.00
1017010209	Hurley Creek	101701020901	Hurley Creek	SD	0	32,813	1	22,601	-1	0.67	0	0	0	0.00
1017010210	Long Creek	101701021001	Upper Long Creek	SD	2	64,185	1	35,206	0	0.81	0	0	3	2.00
		101701021004	Snake Creek	SD	1	24,403	1	14,713	0	0.90	0	0	2	2.00
		101701021005	Saddle Creek	SD	1	51,350	1	30,590	0	0.86	0	0	2	2.00
		101701021006	Lower Long Creek	SD	0	26,179	1	13,251	0	0.50	0	0	1	2.00

1017010211	Upper Vermillion River	101701021101	Camp Creek	SD	1	27,026	1	17,417	0	0.63	0	0	2	1.50
		101701021103	Hurley Creek-Vermillion River	SD	0	53,552	1	28,442	0	0.43	0	0	1	1.50
HUC 10	**Population (HUC 10)**	**HUC 12**	**Sub-population (HUC 12)**	**State(s)**	**Occupancy Score**	**Stream Length (m)**	**Length Score**	**Basin Length (m)**	**Sinuosity Score**	**Crossing Density (#/km)**	**Major Barriers (w/in 500 m)**	**Connectivity Score**	**Composite Score**	**Population Average Score**
1017010212	Turkey Ridge Creek	101701021206	Outlet Turkey Ridge Creek	SD	1	31,198	1	14,603	1	0.54	0	0	3	2.50
		101701021204	Swan Lake-Turkey Ridge Creek	SD	1	32,994	1	17,317	0	0.55	0	0	2	2.50
1017010213	Blind Creek	101701021301	Blind Creek	SD	2	42,444	1	25,487	0	0.71	1	-1	2	2.00
1017010214	Frog Creek	101701021403	Lower Frog Creek	SD	0	11,110	1	7,590	-1	0.45	0	0	0	0.00
1017010220	Lower Vermillion River	101701022003	Blind Creek-Vermillion River	SD	0	39,408	1	19,066	1	0.25	0	0	2	2.00
1017020107	Willow Creek	101702010702	Willow Creek	SD	1	69,604	1	30,710	1	0.45	0	0	3	3.00
1017020108	Stray Horse Creek	101702010802	Lower Stray Horse Creek	SD	1	42,393	1	24,011	0	0.57	0	0	2	1.50
		101702010801	Upper Stray Horse Creek	SD	0	24,484	1	13,662	0	0.74	0	0	1	1.50
1017020204	Hidewood Creek	101702020404	Lower Hidewood Creek	SD	1	33,070	1	15,378	1	0.45	0	0	3	3.00
1017020206	Sixmile Creek	101702020601	Upper Sixmile Creek	SD	0	46,868	1	22,183	1	0.53	0	0	2	2.00
		101702020602	Lower Sixmile Creek	SD	1	42,692	1	21,514	0	0.80	0	0	2	2.00
1017020207	North Deer Creek	101702020704	Lower North Deer Creek	SD	0	10,326	1	9,306	-1	1.45	0	0	0	0.67
		101702020701	Upper North Deer Creek	SD	0	45,707	1	17,813	1	0.53	0	0	2	0.67
		101702020702	Saint Pauls Church	SD	0	32,863	1	22,539	-1	0.76	0	0	0	0.67
1017020209	Deer Creek-Medary Creek	101702020901	Upper Deer Creek-Medary Creek	MN,SD	0	36,731	1	17,316	1	0.41	0	0	2	2.00

1017020210	Medary Creek	101702021002	Middle Medary Creek	MN,SD	0	21,658	1	9,560	1	0.37	0	0	2	2.33
		101702021001	Upper Medary Creek	MN,SD	2	68,636	1	34,007	1	0.42	1	-1	3	2.33
		101702021003	Lower Medary Creek	SD	0	33,015	1	16,353	1	0.61	0	0	2	2.33
HUC 10	**Population (HUC 10)**	**HUC 12**	**Sub-population (HUC 12)**	**State(s)**	**Occupancy Score**	**Stream Length (m)**	**Length Score**	**Basin Length (m)**	**Sinuosity Score**	**Crossing Density (#/km)**	**Major Barriers (w/in 500 m)**	**Connectivity Score**	**Composite Score**	**Population Average Score**
1017020211	Upper Big Sioux River	101702021103	Peg Munky Run	SD	2	28,681	1	15,474	0	0.52	0	0	3	2.00
		101702021110	Medary Creek-Big Sioux River	SD	0	40,912	1	20,595	0	0.73	0	0	1	2.00
1017020301	Spring Creek	101702030101	Upper Spring Creek	MN,SD	0	30,516	1	18,690	0	0.52	0	0	1	2.00
		101702030102	Lower Spring Creek	SD	1	50,292	1	18,977	1	0.54	0	0	3	2.00
1017020303	Flandreau Creek	101702030302	Upper Flandreau Creek	MN	0	32,920	1	19,151	0	0.70	0	0	1	2.25
		101702030304	Lower Flandreau Creek	MN,SD	1	33,018	1	12,084	1	0.27	0	0	3	2.25
		101702030303	Willow Creek-Flandreau Creek	MN,SD	1	31,273	1	14,594	1	0.58	0	0	3	2.25
		101702030301	East Branch Flandreau Creek	MN	1	20,872	1	11,431	0	0.77	0	0	2	2.25
1017020306	Brookfield Creek-Big Sioux River	101702030603	Brookfield Creek	SD	1	34,330	1	16,828	1	0.58	0	0	3	3.00
1017020313	Pipestone Creek	101702031301	County Ditch A-Pipestone Creek	MN	1	17,989	1	9,055	0	0.78	0	0	2	2.40
		101702031302	Upper North Branch Pipestone Creek	MN	1	33,432	1	17,331	0	0.69	0	0	2	2.40
		101702031303	Lower North Branch Pipestone Creek	MN	0	31,922	1	14,920	1	0.60	0	0	2	2.40

		101702031305	Pipestone Creek	MN,SD	0	32,494	1	11,934	1	0.43	0	0	2	2.40
		101702031304	South Branch Pipestone Creek-Pipestone Creek	MN,SD	2	69,010	1	32,157	1	0.45	0	0	4	2.40

HUC 10	Population (HUC 10)	HUC 12	Sub-population (HUC 12)	State(s)	Occupancy Score	Stream Length (m)	Length Score	Basin Length (m)	Sinuosity Score	Crossing Density (#/km)	Major Barriers (w/in 500 m)	Connectivity Score	Composite Score	Population Average Score
1017020314	West Pipestone Creek	101702031402	Lower West Pipestone Creek	SD	1	34,473	1	20,077	0	0.55	0	0	2	2.00
1017020315	Beaver Creek-Split Rock Creek	101702031501	Upper Beaver Creek-Split Rock Creek	MN	2	48,416	1	28,181	0	0.72	0	0	3	1.50
		101702031502	Little Beaver Creek	MN	1	30,720	1	21,194	-1	0.85	0	0	1	1.50
		101702031503	Middle Beaver Creek-Split Rock Creek	MN,SD	1	39,451	1	21,161	0	0.58	0	0	2	1.50
		101702031504	Springwater Creek	MN,SD	0	22,254	1	13,349	0	0.90	0	0	1	1.50
		101702031505	Fourmile Creek	MN,SD	0	21,541	1	12,677	0	0.65	0	0	1	1.50
		101702031506	Lower Beaver Creek-Split Rock Creek	MN,SD	0	44,504	1	23,349	0	0.54	0	0	1	1.50
1017020316	Split Rock Creek	101702031601	Headwaters Split Rock Creek	MN	1	19,095	1	10,656	0	0.94	0	0	2	2.00
		101702031603	101702031603	MN	1	16,238	1	9,351	0	0.74	0	0	2	2.00
		101702031602	City of Jasper-Split Rock Creek	MN,SD	2	44,379	1	27,435	0	0.86	2	-1	2	2.00
		101702031605	Palisades of Split Rock Creek	MN,SD	2	51,669	1	30,391	0	0.48	0	0	3	2.00
		101702031606	Split Rock Creek	SD	0	22,124	1	11,652	0	0.81	0	0	1	2.00
1017020317	Ninemile Creek-Big Sioux River	101702031701	Slip-up Creek	SD	1	41,401	1	21,886	0	0.53	0	0	2	2.00

HUC 10	Population (HUC 10)	HUC 12	Sub-population (HUC 12)	State(s)	Occupancy Score	Stream Length (m)	Length Score	Basin Length (m)	Sinuosity Score	Crossing Density (#/km)	Major Barriers (w/in 500 m)	Connectivity Score	Composite Score	Population Average Score
1017020401	Headwaters Rock River	101702040106	City of Edgerton-Rock River	MN	2	78,060	1	39,619	0	0.58	1	-1	2	1.90
		101702040107	Poplar Creek	MN	1	65,653	1	33,581	0	0.73	0	0	2	1.90
		101702040102	Headwaters Rock River	MN	1	41,280	1	20,216	1	0.61	0	0	3	1.90
		101702040108	Town of Leota-Rock River	MN	0	61,797	1	36,625	0	0.58	0	0	1	1.90
		101702040109	Mound Creek	MN	1	22,537	1	14,856	0	0.75	2	-1	1	1.90
		101702040110	City of Hardwick-Rock River	MN	2	69,064	1	40,113	0	0.64	0	0	3	1.90
		101702040104	Headwaters Chanarambie Creek	MN	1	23,151	1	16,336	-1	0.48	1	-1	0	1.90
		101702040101	East Branch Rock River	MN	1	38,174	1	20,769	0	0.52	0	0	2	1.90
		101702040103	North Branch Chanarambie Creek	MN	1	28,910	1	17,896	0	0.55	0	0	2	1.90
		101702040105	Chanarambie Creek	MN	1	23,190	1	9,897	1	0.39	0	0	3	1.90
1017020402	Kanaranzi Creek	101702040205	Kanaranzi Creek	IA,MN	1	22,986	1	11,746	0	0.35	0	0	2	1.80
		101702040202	Headwaters Kanaranzi Creek	MN	0	26,429	1	15,989	0	0.38	0	0	1	1.80
		101702040204	City of Adrian-Kanaranzi Creek	MN	2	65,657	1	37,053	0	0.58	0	0	3	1.80
		101702040201	East Branch Kanaranzi	MN	1	48,620	1	26,579	0	0.53	0	0	2	1.80

			Creek											
		101702040203	Norwegian Creek	MN	1	19,251	1	13,049	-1	0.62	0	0	1	1.80

HUC 10	Population (HUC 10)	HUC 12	Sub-population (HUC 12)	State(s)	Occupancy Score	Stream Length (m)	Length Score	Basin Length (m)	Sinuosity Score	Crossing Density (#/km)	Major Barriers (w/in 500 m)	Connectivity Score	Composite Score	Population Average Score
1017020403	Champepadan Creek-Rock River	101702040306	Ash Creek-Rock River	IA,MN	1	32,857	1	19,599	0	0.58	0	0	2	2.17
		101702040305	Ashwood Cemetery-Rock River	MN	1	26,119	1	17,184	0	0.65	0	0	2	2.17
		101702040301	Upper Champepadan Creek	MN	0	34,717	1	14,544	1	0.43	0	0	2	2.17
		101702040302	Lower Champepadan Creek	MN	2	39,393	1	24,752	0	0.66	0	0	3	2.17
		101702040304	City of Luverne-Rock River	MN	1	20,358	1	13,325	0	0.29	1	-1	1	2.17
		101702040303	Elk Creek	MN	2	63,964	1	35,740	0	0.61	0	0	3	2.17
1017020406	Little Rock River	101702040604	Whitney Creek-Little Rock River	IA	0	25,489	1	13,567	0	0.39	0	0	1	2.00
		101702040603	Snow Creek-Little Rock River	IA,MN	1	30,391	1	15,425	0	0.46	0	0	2	2.00
		101702040602	Headwaters Little Rock River	MN	1	43,249	1	25,128	0	0.55	0	0	2	2.00
		101702040601	Little Rock Creek	MN	2	27,950	1	14,043	0	0.43	0	0	3	2.00
1021000601	Big Creek-North Loup River	102100060107	Horse Creek-Big Creek	NE	0	46,340	1	25,924	0	0.04	0	0	1	1.00
1022000301	Union Creek	102200030103	Taylor Creek	NE	2	17,368	1	10,458	0	0.46	0	0	3	2.00

		102200030107	Middle Union Creek	NE	0	24,367	1	14,165	0	0.66	0	0	1	2.00
1026000101	Willow Creek-Smoky Hill River	102600010110	Willow Creek	CO,KS	0	35,375	1	22,465	0	0.17	0	0	1	1.00
1026000807	Lyon Creek	102600080706	Geary County State Lake-Lyon Creek	KS	2	12,722	1	6,750	0	0.63	0	0	3	3.00
HUC 10	**Population (HUC 10)**	**HUC 12**	**Sub-population (HUC 12)**	**State(s)**	**Occupancy Score**	**Stream Length (m)**	**Length Score**	**Basin Length (m)**	**Sinuosity Score**	**Crossing Density (#/km)**	**Major Barriers (w/in 500 m)**	**Connectivity Score**	**Composite Score**	**Population Average Score**
1027010102	Wildcat Creek-Kansas River	102701010202	Sevenmile Creek-Kansas River	KS	0	39,485	1	17,025	1	0.53	0	0	2	1.00
		102701010205	Headwaters Wildcat Creek	KS	0	58,189	1	31,561	0	0.41	0	0	1	1.00
		102701010206	Kitten Creek-Wildcat Creek	KS	0	43,125	1	22,726	0	0.58	1	-1	0	1.00
1027010203	Headwaters Mill Creek	102701020302	Illinois Creek	KS	0	21,887	1	15,312	-1	0.18	1	-1	-1	0.25
		102701020303	Lake Wabaunsee-Mill Creek	KS	1	34,062	1	24,697	-1	0.44	3	-1	0	0.25
		102701020304	Spring Creek-West Branch Mill Creek	KS	1	48,369	1	29,816	0	0.23	2	-1	1	0.25
		102701020305	Alma City Reservoir-Mill Creek	KS	1	33,024	1	20,462	0	0.18	1	-1	1	0.25
1027010204	Mill Creek-Kansas River	102701020402	Kuenzli Creek-Mill Creek	KS	0	55,692	1	32,929	0	0.57	2	-1	0	0.33
		102701020403	Snokomo Creek-Mill Creek	KS	0	50,967	1	29,961	0	0.37	0	0	1	0.33
		102701020401	Hendricks Creek-Mill Creek	KS	0	39,760	1	25,176	0	0.40	3	-1	0	0.33
1027010205	Deep Creek-Kansas River	102701020502	Headwaters Deep Creek	KS	1	11,508	1	5,561	1	0.17	1	-1	2	2.00
		102701020503	Deep Creek-Kansas River	KS	2	31,040	1	16,585	0	0.39	1	-1	2	2.00

1027010207	Mission Creek-Kansas River	102701020702	Upper Mission Creek	KS	1	28,432	1	14,900	0	0.25	0	0	2	2.50
		102701020703	Lower Mission Creek	KS	1	31,697	1	14,844	1	0.41	0	0	3	2.50
1027020502	Horseshoe Creek-Big Blue River	102702050201	North Elm Creek-Big Blue River	KS,NE	2	29,670	1	12,984	1	0.34	0	0	4	2.50
		102702050204	Deer Creek-Big Blue River	KS,NE	0	21,334	1	11,637	0	0.66	0	0	1	2.50

HUC 10	Population (HUC 10)	HUC 12	Sub-population (HUC 12)	State(s)	Occupancy Score	Stream Length (m)	Length Score	Basin Length (m)	Sinuosity Score	Crossing Density (#/km)	Major Barriers (w/in 500 m)	Connectivity Score	Composite Score	Population Average Score
1027020504	Outlet Black Vermillion River	102702050404	Clear Fork	KS	2	41,273	1	21,107	0	0.34	0	0	3	2.50
		102702050405	Cedar Creek-Black Vermillion River	KS	1	13,392	1	8,208	0	0.45	0	0	2	2.50
1027020505	Big Blue River-Tuttle Creek Lake	102702050506	Swede Creek-Tuttle Creek Lake	KS	1	24,600	1	15,740	0	0.65	0	0	2	2.00
1027020506	Fancy Creek	102702050606	Walnut Creek-Fancy Creek	KS	0	22,054	1	13,325	0	0.54	0	0	1	1.00
1027020507	Tuttle Creek Lake-Big Blue River	102702050701	Booth Creek-Tuttle Creek Lake	KS	0	22,724	1	16,745	-1	0.31	0	0	0	0.00
1028010210	Sugar Creek-Thompson River	102801021005	Fox Creek-Sugar Creek	MO	2	27,125	1	15,288	0	0.63	1	-1	2	1.50
		102801021007	Sugar Creek	MO	1	36,174	1	26,001	-1	0.39	0	0	1	1.50
1030010208	Smiley Creek-Moniteau Creek	103001020803	Kelley Branch-Moniteau Creek	MO	2	57,985	1	42,372	-1	0.40	1	-1	1	1.50
		103001020801	Smiley Creek	MO	2	19,658	1	15,110	-1	0.46	1	-1	1	1.50
		103001020802	West Brush Creek	MO	1	17,173	1	9,349	0	0.35	0	0	2	1.50
		103001020805	Pisgah Creek-Moniteau Creek	MO	1	31,438	1	19,598	0	0.35	0	0	2	1.50
1107020102	Rock Creek-Neosho River	110702010204	Horse Creek-Rock Creek	KS	0	25,039	1	15,713	0	0.20	0	0	1	1.00

1107020202	Clear Creek-Cottonwood River	110702020204	City of Pilsen-Mud Creek	KS	0	18,999	1	13,696	-1	0.68	0	0	0	0.00
1107020301	Middle Creek-Cottonwood River	110702030103	Outlet Middle Creek	KS	0	2,430	1	1,732	-1	0.00	0	0	0	0.00
1107020302	Diamond Creek-Cottonwood River	110702030202	Headwaters Diamond Creek	KS	1	49,221	1	29,108	0	0.22	1	-1	1	1.50
		110702030204	Fox Creek-Cottonwood River	KS	2	22,425	1	15,489	-1	0.31	0	0	2	1.50
HUC 10	**Population (HUC 10)**	**HUC 12**	**Sub-population (HUC 12)**	**State(s)**	**Occupancy Score**	**Stream Length (m)**	**Length Score**	**Basin Length (m)**	**Sinuosity Score**	**Crossing Density (#/km)**	**Major Barriers (w/in 500 m)**	**Connectivity Score**	**Composite Score**	**Population Average Score**
1107020303	South Fork Cottonwood River	110702030301	Thurman Creek-South Fork Cottonwood River	KS	1	15,489	1	10,428	-1	0.26	2	-1	0	0.00

8 ArcGIS Model Builder Toolset

ArcGIS includes a collection of utility tools that support building flexible and powerful models. Models allow complex sequential processes to be easily and consistently rerun, minimizing the chance of error. Additionally, values used in the model may be exposed as parameters that may be changed at runtime, which allows flexibility and the ability to test output. For the Topeka shiner resiliency model, separate tools were built for deriving population and sub-population output (Figure 8.1).

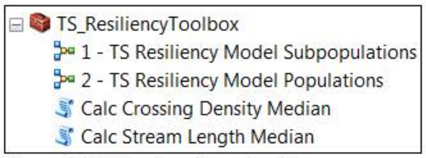
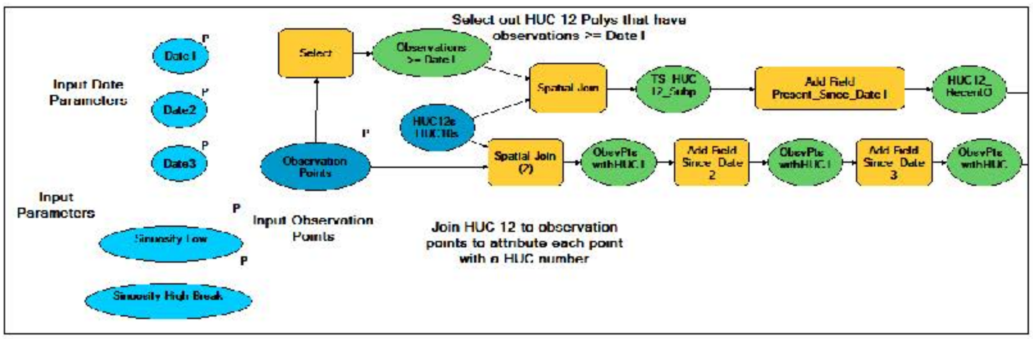
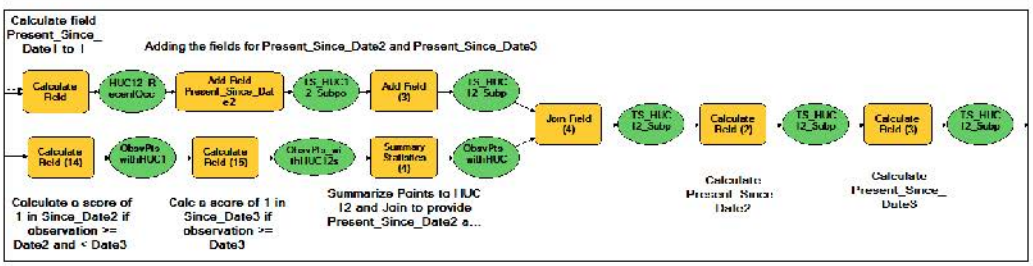


Figure 8.1. Topeka shiner toolbox.

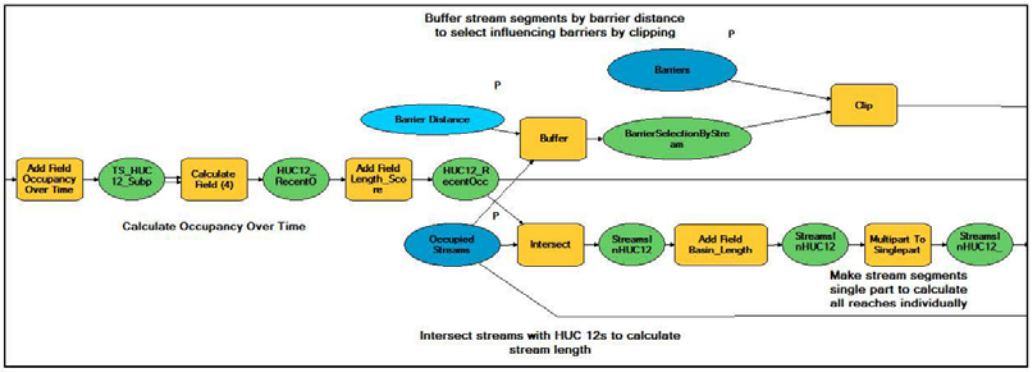
8.1 Topeka Shiner Resiliency Sub-population Model Tools

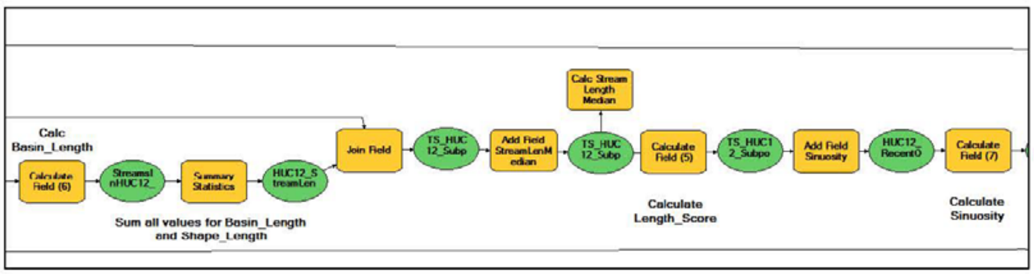
Set input parameters and select HUC 12 polygons that are 1999 or later. Attribute each observation point with a HUC 12 code. Add fields to calculate and store occurrence information.



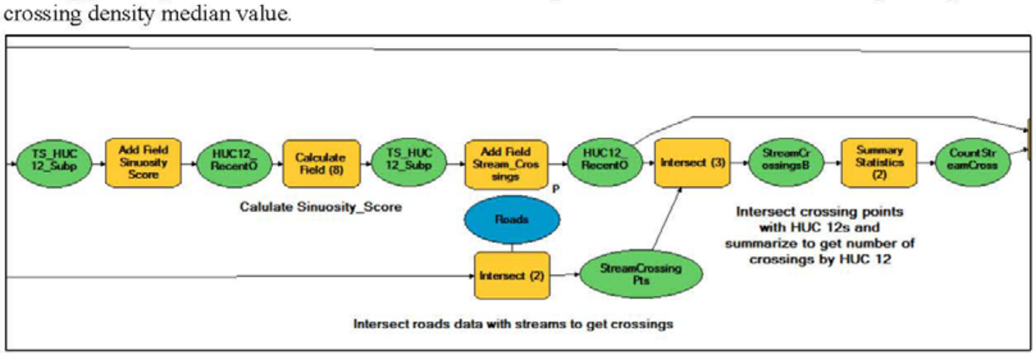


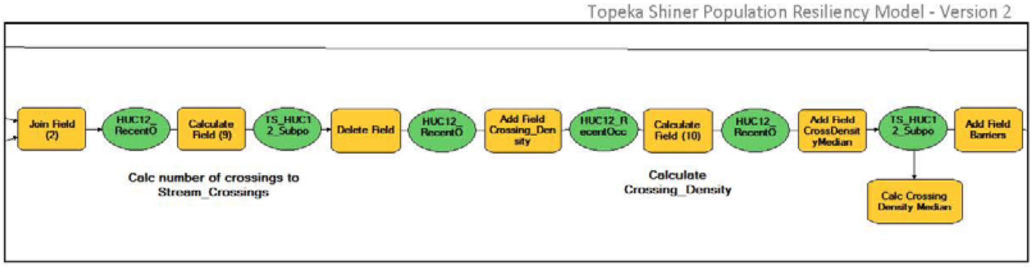
Calculate Occupancy over time and add occupied streams layer. Create a buffer from a user entered barrier distance around streams, and clip out barriers within this distance. Calculate stream length and basin length, and join to HUC 12 polygons. Calculate the stream length median score, and then the length score. Calculate sinuosity.



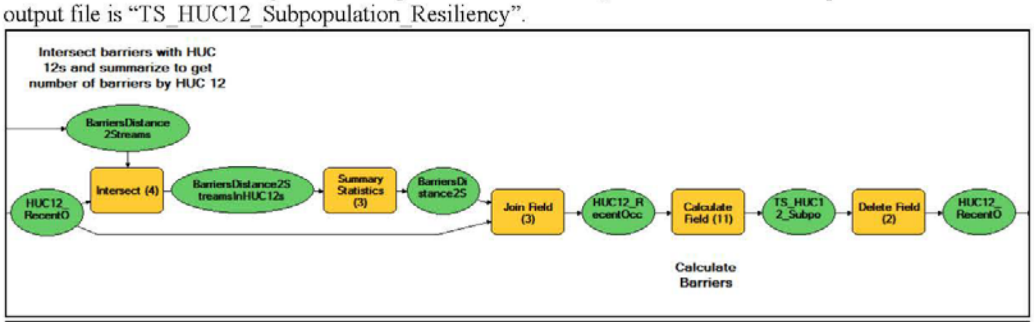


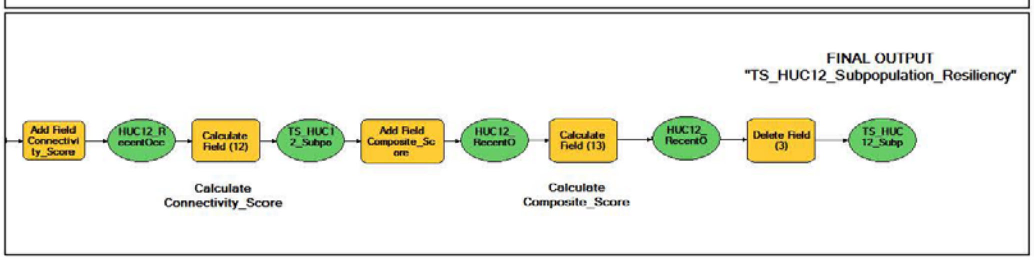
Calculate the sinuosity score, and intersect road lines with streams to get stream crossings. Summarize the crossing points by HUC 12 to count the number of crossings in each HUC. Calculate crossing density and crossing density median value.





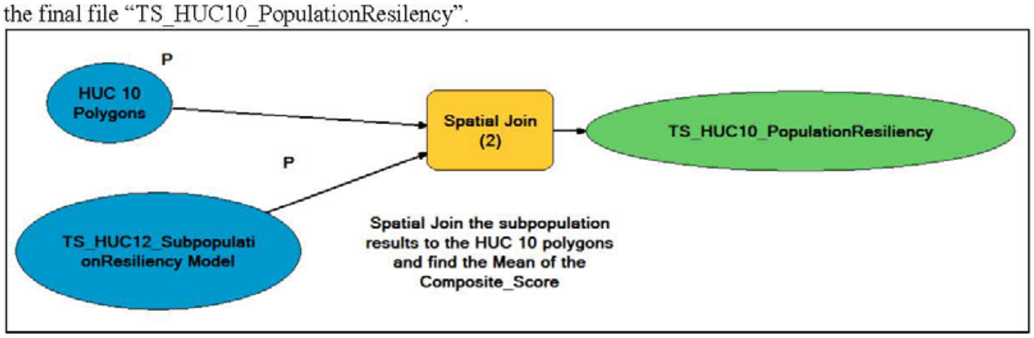
Intersect barrier points with HUC 12 polygons to get barrier points in each HUC. Summarize number of barriers in each HUC, and join this to the HUC 12 polygons. Calculate the number of barriers in each HUC, and calculate the connectivity score. Using all calculated scores, calculate the final composite score. The output file is "TS_HUC12_Subpopulation_Resiliency".





8.2 Topeka Shiner Resiliency Population Model Tools

Find the mean of the composite score for HUC 12s that reside within an individual HUC 10 and write this to the final file "TS_HUC10_PopulationResilency".



9 Population Model Metadata

9.1 Watershed Boundary Dataset, HUC 10

WBDHU10

Watershed Boundary Dataset, Sub-region, 10-digit, Region, Sub-basin, US, United States, 8-digit, 2-digit, Hydrologic Units, WBD, 6-digit, 4-digit, Basin, Hydrologic Unit Code, HUC, Watershed

The intent of defining Hydrologic Units (HU) within the Watershed Boundary Dataset is to establish a base-line drainage boundary framework, accounting for all land and surface areas. Hydrologic units are intended to be used as a tool for water-resource management and planning activities particularly for site-specific and localized studies requiring a level of detail provided by large-scale map information. The WBD complements the National Hydrography Dataset (NHD) and supports numerous programmatic missions and activities including: watershed management, rehabilitation, and enhancement, aquatic species conservation strategies, flood plain management and flood prevention, water-quality initiatives and programs, dam safety programs, fire assessment and management, resource inventory and assessment, water data analysis and water census.

The Watershed Boundary Dataset (WBD) is a comprehensive aggregated collection of hydrologic unit data consistent with the national criteria for delineation and resolution. It defines the areal extent of surface water drainage to a point except in coastal or lake front areas where there could be multiple outlets as stated by the Federal Standards and Procedures for the National Watershed Boundary Dataset (WBD), herein after referred to as the "Standard" (http://pubs.usgs.gov/tm/11/a3). Watershed boundaries are determined solely upon science-based hydrologic principles, not favoring any administrative boundaries or special projects, nor particular program or agency. This dataset represents the hydrologic unit boundaries to the 12-digit (6th level) for the entire United States. Some areas may also include additional subdivisions representing the 14- and 16-digit hydrologic unit (HU). At a minimum, the HU's are delineated at 1:24,000-scale in the conterminous United States, 1:25,000-scale in Hawaii and the Caribbean, and 1:63,360-scale in Alaska, meeting the National Map Accuracy Standards (NMAS) Higher resolution boundaries are being developed where partners and data exist and will be incorporated back into the WBD. WBD data are delivered as a dataset of polygons and corresponding lines that define the boundary of the polygon. WBD polygons attributes include hydrologic unit codes (HUC), size (in the form of acres and square kilometers), name, downstream hydrologic unit code, type of watershed, non-contributing areas, and flow modifications. The HUC describes where the unit is in the country and the level of the unit. WBD line attributes contain the highest level of hydrologic unit for each boundary, line source information and flow modifications. WBDHU10 represents the 10-digit hydrologic unit boundaries (previously referred to as Watersheds). Only the attribution is editable at the 10-digit hydrologic unit by the WBD In-State Steward. Within the United States, approximately 18,075 10-digit hydrologic units (Watersheds) are in the WBD, and

Funding for the Watershed Boundary Dataset (WBD) was provided by the USDA-NRCS, USGS and EPA along with other federal, state and local agenies. Representatives from many agencies contributed a substantial amount of time and salary towards quality review and updating of the dataset in order to meet the WBD Standards. See dataset specific metadata for further information

The distributor shall not be held liable for improper or incorrect use of this data, based on the description of appropriate/inappropriate uses described in this metadata document. It is strongly recommended that this data is directly acquired from the distributor and not indirectly through other sources which may have changed the data in some way. These data should not be used at scales greater than 1:24,000 for the purpose of identifying hydrographic watershed boundary feature locations in the United States. The Watershed Boundary Dataset is public information and may be interpreted by all organizations, agencies, units of government, or others based on needs; however, they are responsible for the appropriate application of the data. Photographic or digital enlargement of these maps to scales greater than that at which they were originally delineated can result in misrepresentation of the data. If enlarged, the maps will not include the fine detail that would be appropriate for mapping at the small scale. Digital data files are periodically updated and users are responsible for obtaining the latest version of the data from the source distributor. Acknowledgment of the origination agencies would be appreciated in products derived from these data.

-179.229655	179.856675
71.439573	-14.424695

Topics and Keywords ▼►

Place keywords US, United States

Thesaurus ▼►

Title U.S. Department of Commerce, 1977, Countries, dependencies, areas of special sovereignty, and their principal administrative divisions (Federal Information Processing Standards 10-3): Washington, D.C., National Institute of Standards and Technology.

Theme keywords Watershed Boundary Dataset, Sub-region, 10-digit, Region, Sub-basin, 8-digit, 2-digit, Hydrologic Units, WBD, 6-digit, 4-digit, Basin, Hydrologic Unit Code, HUC, Watershed

Citation ▼►

Title WBDHU10
Publication date 2015-12-16

Presentation formats digital map
FGDC geospatial presentation format Vector Digital Data Set (Polygon)

Hide Citation ▲

Citation Contacts ▼►

Responsible party
Organization's name U.S. Environmental Protection Agency (EPA)
Contact's role originator

Responsible party
Organization's name Other Federal, State, and local partners (see dataset specific metadata for details)
Contact's role originator

Responsible party
Organization's name U.S. Geological Survey (USGS)
Contact's role originator

Responsible party
Organization's name U.S. Department of Agriculture - Natural Resource Conservation Service (NRCS)
Contact's role originator

Resource Details ▼►

Dataset languages English (UNITED STATES)

Status completed
Spatial representation type vector

Processing environment Microsoft Windows 7 Version 6.1 (Build 7601) Service Pack 1; Esri ArcGIS 10.3.0.4322

Credits

Funding for the Watershed Boundary Dataset (WBD) was provided by the USDA-NRCS, USGS and EPA along with other federal, state and local agenies. Representatives from many agencies contributed a substantial amount of time and salary towards quality review and updating of the dataset in order to meet the WBD Standards. See dataset specific metadata for further information

Extents ▼ ▶

Extent
Geographic extent
Bounding rectangle
West longitude -179.229655487
East longitude 179.856674735
South latitude -14.4246950943
North latitude 71.4395725902

Extent
Description

publication date

Temporal extent
Beginning date 1980-01-01
Ending date 2015-01-01

Extent
Geographic extent
Bounding rectangle
Extent type Extent used for searching
West longitude -179.229655
East longitude 179.856675
North latitude 71.439573
South latitude -14.424695
Extent contains the resource Yes

Hide Extents ▲

Resource Points of Contact ▼ ▶

Point of contact
Organization's name U.S. Geological Survey
Contact's role point of contact

Contact information ▼ ▶
Phone
Voice 1-877-275-8747

Address
Type postal
Delivery point U.S. Geological Survey, National Geospatial Technical Operations Center, P.O. Box 25046
City Denver
Administrative area CO
Postal code 80225

e-mail address mailto:bpgeo@usgs.gov?subject=WBDHU10

10 Sub-population Model Metadata

10.1 Watershed Boundary Dataset, HUC 12 and HUC 10

HUC12s_HUC10s

Watershed Boundary Dataset, Sub-region, 12-digit, 10-digit, Region, US, United States, Subbasin, 8-digit, 2-digit, Subwatershed, WBD, Hydrologic Unit, 6-digit, 4-digit, Basin, Hydrologic Unit Code, Watershed

The intent of defining Hydrologic Units (HU) within the Watershed Boundary Dataset is to establish a base-line drainage boundary framework, accounting for all land and surface areas. Hydrologic units are intended to be used as a tool for water-resource management and planning activities particularly for site-specific and localized studies requiring a level of detail provided by large-scale map information. The WBD complements the National Hydrography Dataset (NHD) and supports numerous programmatic missions and activities including: watershed management, rehabilitation, and enhancement, aquatic species conservation strategies, flood plain management and flood prevention, water-quality initiatives and programs, dam safety programs, fire assessment and management, resource inventory and assessment, water data analysis and water census.

The Watershed Boundary Dataset (WBD) is a comprehensive aggregated collection of hydrologic unit data consistent with the national criteria for delineation and resolution. It defines the areal extent of surface water drainage to a point except in coastal or lake front areas where there could be multiple outlets as stated by the Federal Standards and Procedures for the National Watershed Boundary Dataset (WBD), herein after referred to as the "Standard" (http://pubs.usgs.gov/tm/11/a3). Watershed boundaries are determined solely upon science-based hydrologic principles, not favoring any administrative boundaries or special projects, nor particular program or agency. This dataset represents the hydrologic unit boundaries to the 12-digit (6th level) for the entire United States. Some areas may also include additional subdivisions representing the 14- and 16-digit hydrologic unit (HU). At a minimum, the HU's are delineated at 1:24,000-scale in the conterminous United States, 1:25,000-scale in Hawaii and the Caribbean, and 1:63,360-scale in Alaska, meeting the National Map Accuracy Standards (NMAS) Higher resolution boundaries are being developed where partners and data exist and will be incorporated back into the WBD. WBD data are delivered as a dataset of polygons and corresponding lines that define the boundary of the polygon. WBD polygons attributes include hydrologic unit codes (HUC), size (in the form of acres and square kilometers), name, downstream hydrologic unit code, type of watershed, non-contributing areas, and flow modifications. The HUC describes where the unit is in the country and the level of the unit. WBD line attributes contain the highest level of hydrologic unit for each boundary, line source information and flow modifications. WBDHU12 represents the 12-digit hydrologic unit boundaries (previously referred to as Subwatersheds). Within the United States, approximately 98,363 12-digit hydrologic units are in the WBD,

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-179.229655	179.856675
71.439573	-14.424695

There is no scale range for this item.

Topics and Keywords ▼▶

Place keywords US, United States

Thesaurus ▼▶

Title U.S. Department of Commerce, 1977, Countries, dependencies, areas of special sovereignty, and their principal administrative divisions (Federal Information Processing Standards 10-3): Washington, D.C., National Institute of Standards and Technology.

Hide Thesaurus ▲

Theme keywords Watershed Boundary Dataset, Sub-region, 12-digit, 10-digit, Region, Subbasin, 8-digit, 2-digit, Subwatershed, WBD, Hydrologic Unit, 6-digit, 4-digit, Basin, Hydrologic Unit Code, Watershed

Hide Topics and Keywords ▲

Citation ▼▶

Title HUC12s_HUC10s
Publication date 2015-12-16

Presentation formats digital map
FGDC geospatial presentation format Vector Digital Data Set (Polygon)

Hide Citation ▲

Citation Contacts ▼▶

Responsible party
Organization's name U.S. Environmental Protection Agency (EPA)
Contact's role originator

Responsible party
Organization's name Other Federal, State, and local partners (see dataset specific metadata for details)
Contact's role originator

Responsible party
Organization's name U.S. Geological Survey (USGS)
Contact's role originator

Responsible party
Organization's name U.S. Department of Agriculture - Natural Resource Conservation Service (NRCS)
Contact's role originator

Hide Citation Contacts ▲

Resource Details ▼▶

Dataset languages English (UNITED STATES)

Status completed
Spatial representation type vector

Processing environment Microsoft Windows 7 Version 6.1 (Build 7601) Service Pack 1; Esri ArcGIS 10.3.0.4322

Credits

Funding for the Watershed Boundary Dataset (WBD) was provided by the USDA-NRCS, USGS and EPA along with other federal, state and local agenies. Representatives from many agencies contributed a substantial amount of time and salary towards quality review and updating of the dataset in order to meet the WBD Standards. See dataset specific metadata for further information

Hide Resource Details ▲

Extents ▼▶

Extent
Geographic extent
Bounding rectangle
West longitude -179.229655487
East longitude 179.856674735
South latitude -14.4246950943
North latitude 71.4395725902

Extent
Description

publication date

Temporal extent
Beginning date 1980-01-01
Ending date 2015-01-01

Extent
Geographic extent
Bounding rectangle
Extent type Extent used for searching
West longitude -179.229655
East longitude 179.856675
North latitude 71.439573
South latitude -14.424695
Extent contains the resource Yes

Hide Extents ▲

Resource Points of Contact ▼▶

Point of contact
Organization's name U.S. Geological Survey

Contact's role point of contact

Contact information ▼►
Phone
Voice 1-877-275-8747

Address
Type postal
Delivery point U.S. Geological Survey, National Geospatial Technical Operations Center, P.O. Box 25046
City Denver
Administrative area CO
Postal code 80225
e-mail address mailto:bpgeo@usgs.gov?subject=HUC12s_HUC10s

10.1 Tiger Roads, 2016

TIGER Roads 2016

2016, TIGER, Roads

2016 TIGER roads line file clipped to Topeka shiner range for use in the Topeka shiner resiliency model.

2016 TIGER roads line file clipped to Topeka shiner range for use in the Topeka shiner resiliency model.

U.S. Census Bureau

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-108.149315	-82.420001
48.231474	33.177646

There is no scale range for this item.

Citation ▼►
Title TIGER Roads 2016

Presentation formats digital map

Hide Citation ▲

Resource Details ▼ ►

Dataset languages English (UNITED STATES)

Spatial representation type vector

Processing environment Microsoft Windows 7 Version 6.1 (Build 7601) Service Pack 1; Esri ArcGIS 10.3.0.4322

Credits
U.S. Census Bureau

Hide Resource Details ▲

Extents ▼ ►

Extent
Geographic extent
Bounding rectangle
Extent type Extent used for searching
West longitude -108.149315
East longitude -82.420001
North latitude 48.231474
South latitude 33.177646
Extent contains the resource Yes

Hide Extents ▲

Resource Constraints ▼ ►

Constraints
Limitations of use

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10.2 Topeka Shiner Stream Flowlines

Topeka Shiner Streams 2017 SSA

Topeka Shiner, Streams, 2017, SSA

These streams were compiled from the NHD flowlines data set using outlet locations for streams where Topeka shiners had be observed during the period 1999 to 2016. The are attributed with the date of the most recent Topeka shiner observation.

These streams were compiled from the NHD flowlines data set using outlet locations for streams where Topeka shiners had be observed during the period 1999 to 2016. The are attributed with the date of the most recent Topeka shiner observation.

USFWS

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-105.241218	-88.065696
46.945933	34.829822

There is no scale range for this item.

Citation ▼ ▶

Title Topeka Shiner Streams 2017 SSA

Presentation formats digital map

Hide Citation ▲

Resource Details ▼ ▶

Dataset languages English (UNITED STATES)

Spatial representation type vector

Processing environment Microsoft Windows 7 Version 6.1 (Build 7601) Service Pack 1; Esri ArcGIS 10.3.0.4322

Credits
USFWS

Hide Resource Details ▲

Extents ▼ ▶

Extent
Vertical extent
Minimum value 0.000000
Maximum value 0.000000

Extent
Geographic extent
Bounding rectangle
Extent type Extent used for searching
West longitude -105.241218
East longitude -88.065696
North latitude 46.945933
South latitude 34.829822
Extent contains the resource Yes

Hide Extents ▲

Resource Constraints ▼ ▶

Constraints
Limitations of use

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system at the USFWS, no warranty expressed or implied is made regarding the accuracy or utility of the data and information on any other system or for general or scientific purposes, nor shall the act of distribution constitute any such warranty. This disclaimer applies both to individual use of the data, and information, and aggregate use with other data and information. It is also strongly recommended that careful attention be paid to the contents of the metadata file associated with these data and information. The USFWS shall not be held liable for improper or incorrect use of the data and information described and/or contained herein.

10.3 Barriers

Stream Barriers 03/09/2017

Stream Barriers, ECOS, GeoFIN

Export of stream barriers from ECOS GeoFIN. Provided 03/09/2017 for use in V.2 of the Topeka shiner resiliency model.

Export of stream barriers from ECOS GeoFIN. Provided 03/09/2017 for use in V.2 of the Topeka shiner resiliency model.

ECOS GeoFIN

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-176.683800	-65.672000
71.295541	17.978330

There is no scale range for this item.

Citation ▼ ►

Title Stream Barriers 03/09/2017

Presentation formats digital map

Hide Citation ▲

Resource Details ▼ ►

Dataset languages English (UNITED STATES)

Spatial representation type vector

Processing environment Microsoft Windows 7 Version 6.1 (Build 7601) Service Pack 1; Esri ArcGIS 10.3.0.4322

Credits
ECOS GeoFIN

Hide Resource Details ▲

Extents ▼ ►

Extent
Geographic extent
Bounding rectangle
Extent type Extent used for searching
West longitude -176.683800
East longitude -65.672000
North latitude 71.295541
South latitude 17.978330
Extent contains the resource Yes

Hide Extents ▲

Resource Constraints ▼ ►

Constraints
Limitations of use

Although these data and information have been processed successfully on a computer system at the USFWS, no warranty expressed or implied is made regarding the accuracy or utility of the data and information on any other system or for general or scientific purposes, nor shall the act of distribution constitute any such warranty. This disclaimer applies both to individual use of the data, and information, and aggregate use with other data and information. It is also strongly recommended that careful attention be paid to the contents of the metadata file associated with these data and information. The USFWS shall not be held liable for improper or incorrect use of the data and information described and/or contained herein.

10.4 Observations

Observations from V.1 TS Resiliency Model (1999-2014) merged with collected 2015/2016 observations

Observations, Topeka Shiner, 1999 through 2016

These Topeka shiner observation points were collected from the states of IA, KS, NE, MN, MN, and SD for the purpose of input into the Topeka shiner resiliency model. They include a Year date, which is required for scoring in the model.

These Topeka shiner observation points were collected from the states of IA, KS, NE, MN, MN, and SD for the purpose of input into the Topeka shiner resiliency model. They include a Year date, which is required for scoring in the model. Data compiled for version one of the model (1999 – 2014) included sources that didn't explicitly state Topeka shiner capture. These locations were confirmed, and the model assumes presence for Topeka shiner.

Coordinates have been removed from these points at the request of the state agencies who provided the data.

Compiled by the USFWS.

Although these data and information have been processed successfully on a computer system at the USFWS, no warranty expressed or implied is made regarding the accuracy or utility of the data and information on any other system or for general or scientific purposes, nor shall the act of distribution constitute any such warranty. This disclaimer applies both to individual use of the data, and information, and aggregate use with other data and information. It is also strongly recommended that careful attention be paid to the contents of the metadata file associated with these data and information. The USFWS shall not be held liable for improper or incorrect use of the data and information described and/or contained herein.

-102.546792	-91.977496
45.847248	37.900920

There is no scale range for this item.

Citation ▼ ▶

Title Observations from V.1 TS Resiliency Model (1999-2014) merged with collected 2015/2016 observations

Presentation formats digital map

Hide Citation ▲

Resource Details ▼ ▶

Dataset languages English (UNITED STATES)

Spatial representation type vector

Processing environment Microsoft Windows 7 Version 6.1 (Build 7601) Service Pack 1; Esri ArcGIS 10.4.1.5686

Credits

Compiled by the USFWS.

Hide Resource Details ▲

Extents ▼ ▶

Extent
Geographic extent
Bounding rectangle
Extent type Extent used for searching
West longitude -102.546792
East longitude -91.977496
North latitude 45.847248
South latitude 37.900920
Extent contains the resource Yes

Hide Extents ▲

Resource Constraints ▼ ▶

Constraints
Limitations of use

Although these data and information have been processed successfully on a computer system at the USFWS, no warranty expressed or implied is made regarding the accuracy or utility of the data and information on any other system or for general or scientific purposes, nor shall the act of distribution constitute any such warranty. This disclaimer applies both to individual use of the data, and information, and aggregate use with other data and information. It is also strongly recommended that careful attention be paid to the contents of the metadata file associated with these data and information. The USFWS shall not be held liable for improper or incorrect use of the data and information described and/or contained herein.