ECOLOGY OF GLACIAL RELICT FISHES IN SOUTH DAKOTA'S SANDHILLS REGION

BY ELI FELTS

A thesis submitted in partial fulfillment of the requirements for the

Master of Science

Major in Wildlife and Fisheries Sciences

Specialization in Fisheries Science

South Dakota State University

2013

ECOLOGY OF GLACIAL RELICT FISHES IN SOUTH DAKOTA'S SANDHILLS REGION

This thesis is approved as a credible and independent investigation by a candidate for the Master of Science in Wildlife and Fisheries Science degree and is acceptable for meeting the thesis requirements for this degree. Acceptance of this thesis does not imply that the conclusions reached by the candidate are necessarily the conclusions of the major department.

4/2/13

Katie Bertrand, Ph.D.
Major Advisor — Date

4-2-13

David Willis, Ph.D.
Head, Department of
Natural Resource Management — Date

18-APR-2013

Dean, Graduate School — Date

ACKNOWLEDGMENTS

I thank my parents, Craig and Jackie Felts, for their unwavering support through all of my life's endeavors. Special thanks to my brother Jake Felts, and his wife, Jeni Felts, for providing friendship and much needed comic relief. I would also like to thank all of my other incredibly supportive family members. Your encouragement and kind words are very much appreciated.

I wish to thank my advisor, Dr. Katie Bertrand, for her patience and dedication, and for holding me to a high standard of excellence. In addition to serving as an outstanding advisor, Katie has greatly increased my appreciation for the importance and staggering complexity of stream ecosystems. I must also thank my other committee members, Dr. Brian Graeb and Dr. David Willis, for their support and unique perspectives on stream fish.

I would like to thank the many graduate students who have offered friendship, guidance and countless hours of fish talk during my time in Brookings. I am thankful for all of the good times and interesting conversations this group has provided. One of the reasons I was drawn to this field was because it seemed to attract loyal, intelligent, hardworking people, and my peers at SDSU have proved me right on that account.

I am deeply thankful for the help of Ranger Matt Tucker of the Rosebud Sioux Tribe Game, Fish and Parks; without his assistance I would have only sampled a small fraction of the streams described in this thesis. I am grateful to all the landowners who allowed me to access their land. Additional field and laboratory assistance was provided by Megan Leonard, Jacob Krause, Jason Breeggemann, Craig Felts and Jess Stover. Feedback on research ideas and presentations was provided by past and present members of the "Bertrand-Graeb" lab. I also wish to express my appreciation for the support staff (Terri Symens, Di Drake, Kate Tvedt, and Dawn VanBallegooyen) in the Department of Natural Resource Management. Funding for this research was provided by South Dakota State Wildlife Grant T2-8-R-1, the South Dakota Agricultural Experiment Station at South Dakota State University, and the South Dakota Department of Game, Fish and Parks.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ABSTRACT

ECOLOGY OF GLACIAL RELICT FISHES IN SOUTH DAKOTA'S SANDHILLS REGION

ELI FELTS

2013

Native stream fish zoogeography has changed substantially across North America during the last century as habitat degradation, stream fragmentation and introductions of nonnative species have led to numerous extinctions, extirpations and altered distributions. Insufficient information regarding imperiled species often results in reactive, rather than proactive, management, and knowledge of species status and ecology is critical in identifying conservation priorities. South Dakota populations of three dace species (northern redbelly dace *Chrosomus eos*, finescale dace *Chrosomus neogaeus*, and pearl dace *Margariscus margarita*) are relict of Pleistocene Glaciation and are isolated from the northern core of their distribution, but little information exists regarding their distribution or abundance in South Dakota. We used previous and current fish collection records along with a current habitat assessment to assess the status and co-occurrence of these three dace species and to assess the status of two other state listed species (blacknose shiner *Notropis heterolepis*, plains topminnow *Fundulus sciadicus*). We also quantitatively described fish assemblage patterns throughout southwestern South Dakota. Finally, we investigated regional variability of pearl dace population characteristics. We sampled fish and habitat in 42 stream reaches within the White, Little White, and Keya Paha river basins during 2010-2012 and compiled previous collections from South Dakota and Nebraska. Additionally, we re-sampled four pearl dace populations in order to estimate ages and quantify population demographics. We detected four of five target species and found that each target species was limited to two Major Land Resource Areas in South Dakota, both of which contain springfed streams that are not present in neighboring drainages. Fish assemblages were primarily structured by stream size and habitats that support relict dace species tended to have higher species richness and diversity than other sample reaches. We documented regional variation in pearl dace growth and condition. This study updates the distribution and status of conservation listed species, identifies landscape level habitat filters, and provides insight into fish assemblage patterns in springfed Great Plains streams. Furthermore, our results were used to identify specific tributary streams as conservation priorities and as candidates for continued research efforts.

Chapter 1: Conservation status of five headwater specialists in southwestern South Dakota

This chapter is in preparation for submission to the journal the American Midland Naturalist and was co-authored by Katie Bertrand. It is formatted following the American Midland Naturalist guidelines.

Abstract

Native stream fish zoogeography has changed substantially across North America during the last century as habitat degradation, stream fragmentation and introductions of nonnative species have led to numerous extinctions, extirpations and altered distributions. Insufficient information regarding imperiled species often results in reactive, rather than proactive, management, and knowledge of species status and ecology is critical in identifying conservation priorities. We used previous and current fish collection records along with a current habitat assessment to assess the status of five targeted conservation listed fishes in southwestern South Dakota (northern redbelly dace *Chrosomus eos*, finescale dace *Chrosomus neogaeus*, pearl dace *Margariscus margarita*, blacknose shiner *Notropis heterolepis*, and plains topminnow *Fundulus sciadicus*). We compiled records from previous collections within the White, Little White and Keya Paha River Basins in South Dakota as well as adjoining and neighboring drainage basins in Nebraska, and sampled fish and habitat at 42 stream reaches within the White, Little White, and Keya Paha river basins during 2010-2012, focusing on tributary streams. We detected four of five target species. All species preferred tributary streams over larger rivers (third order or greater). All target species except blacknose shiner exhibited patchy distributions and abundance patterns, normally occurring at low relative abundance but occasionally

exhibiting moderate to high relative abundance. Each target species was limited to two Major Land Resource Areas (MLRA) in South Dakota, both of which contain perennial, spring fed streams that are not present in neighboring drainages. This study updates the distribution of conservation listed species, identifies landscape level habitat filters, and offers guidance for conservation and research efforts.

Introduction

Freshwater fish zoogeography results from hierarchical environmental filters, ranging from continental to local scales. North American freshwater fish zoogeography was primarily shaped by glaciation and reinvasion (Hocutt and Wiley, 1986) but during the last century anthropogenic influences such as changing land use (Waters, 1995), dam construction (Mammoliti, 2002; Falke and Gido, 2006), and introductions of nonnative species (Moyle, 1986) have increased. These stressors contributed to range reductions and declines in local abundance for many North American native freshwater fishes (Miller *et al.*, 1989; Williams *et al.*, 1989; Jelks *et al*., 2008). Current North American freshwater fish zoogeography is a product of glacial history as well as altered physical habitat (Gorman and Karr, 1978) and negative interactions between native and introduced species (Rahel, 2002), and it is important to identify the drivers of local persistence and abundance to stem anthropogenic extirpations.

Disjunct and peripheral populations tend to be smaller and more susceptible to extirpation by stochastic events (Sheldon, 1988; Moyle and Williams, 1990; Lesica and Allendorf, 1995) and are generally recognized as conservation priorities. In the South Dakota Comprehensive Wildlife Action plan if a species is either rare, if South Dakota represents a substantial portion of the species' overall range, or if the species relies on declining or unique habitat in South Dakota, then that species is a greater priority for research and management (SDGFP, 2006). Seven species listed as species of greatest conservation need by the South Dakota Department of Game, Fish and Parks (SDGFP, 2006) occur in the Little White and Keya Paha rivers and their tributary networks, five of which (plains topminnow *Fundulus sciadicus*, northern redbelly dace *Chrosomus eos*, finescale dace *Chrosomus neogaeus*, pearl dace *Margariscus margarita*, and blacknose shiner *Notropis heterolepis*) prefer small, springfed headwater tributaries and are represented by disjunct or peripheral populations in South Dakota (Pflieger, 1997; Rahel and Thel, 2004; Cunningham, 2006; Stasiak, 2006; Stasiak and Cunningham, 2006). The three dace species are relict of Pleistocene glaciation (Cross, 1970; Cross *et al.*, 1986; Pflieger, 1997) and are represented in South Dakota and Nebraska by disjunct populations. Southwestern South Dakota represents the northern periphery of plains topminnow distribution. Blacknose shiner has declined or been extirpated from much of its previous distribution (Bernstein *et al*., 2000; Roberts and Burr, 2006; Hoagstrom *et al*., 2007), and remaining populations in South Dakota and Nebraska are now on the periphery of the blacknose shiner distribution. Little is known about the distribution or abundance of these species in South Dakota.

Temporal trends in fish species status are best identified with long-term data sets collected using standardized methods. However, surveys are often designed and executed not to examine long-term trends but to answer specific questions, which results in irregular survey frequency and methodology, and presence/absence data (Patton *et al*., 1998). Qualitative measures (*i.e*,. presence/absence) are insensitive to meaningful changes, detecting only substatntial declines or extirpations (Miller *et al*., 1989; Williams *et al*., 1989; Reinthal and Stiassny, 1991; Patton *et al*., 1998). Accordingly, conservation practices often are not implemented until populations have declined substantially, resulting in few successful recoveries (Orians, 1980; Rohlf, 1991). Available records of the five listed headwater specialists in the Little White and Keya Paha river basins of South Dakota document only species presence/absence (Cunningham *et al*., 1995), so the current distribution and abundance trends of these species are unknown.

The status of these five headwater specialist species in southwestern South Dakota needs to be updated to understand current status and to identify factors that limit their distributions. Baseline abundance data will allow for more meaningful temporal comparisons in the future, and an evaluation of potential threats to these species will help managers develop conservation priorities. Our objectives were to: (1) update species distributions for five headwater specialists in southwestern South Dakota, (2) provide baseline abundance data for these species, and (3) identify preferred habitat and factors limiting distributions of these five species in southwestern South Dakota.

Study Area

The White River is a fifth order tributary to the Missouri River and drains much of southwestern South Dakota. The Little White and Keya Paha rivers are both third order streams. Tributaries to these rivers have unique physical, hydrological and biological characteristics when compared with other Great Plains tributaries. In general, tributaries in this region can be described as perennial flashy streams, whereas those in neighboring drainages would be classified as intermittent runoff streams (*sensu* Poff and Ward, 1989). Perennial flashy streams are maintained by subsurface flow, providing more stable temperature and discharge regimes than intermittent runoff streams, which are characterized by long periods of zero discharge and low predictability (Keech and Bentall, 1971; Matthews, 1988; Poff and Ward, 1989; Fausch and Bramblett, 1991; Dodds *et al*., 2004). Despite the buffering effects provided by cool groundwater inputs, all streams in this region are exposed to highly variable precipitation and temperature patterns (Poff and Ward, 1989; Fausch and Bramblett, 1991; Dodds *et al*., 2004).

The White River originates in Sioux County in northwestern Nebraska, and drains 26,418 km^2 as it flows through southwestern South Dakota before reaching its confluence with the Missouri River in Lyman County, South Dakota (Fryda, 2001). Discharge typically peaks during spring and early summer and decreases through late summer, fall and winter (Fryda, 2001). The majority of the White River basin is characterized by silt and clay soils resulting in streams that are fed primarily by runoff and carry extremely high sediment loads (Fryda, 2001). However, in southwestern South Dakota tributaries originate from the northern extent of the Nebraska Sandhills Major Land Resource Area (MLRA) and run through the Mixed Sandy and Silty Tablelands and Badlands (USDA, 2006), where a permeable sand geology has formed springfed perennial tributary streams. The Little White River basin drains the majority of these MLRAs within the White River basin, but a small number of direct tributaries in Shannon and Mellette counties also originate from the sandy landscape. We sampled tributaries in southern Shannon County because they originate in the Nebraska Sandhills. Southern Shannon County landscape includes sandhills formations and sandy plains, and cattle grazing is the primary land use (USDA, 2006).

The Little White River lies entirely within South Dakota, draining 4,105 km^2 in Bennett, Todd and Mellette counties before entering the White River. Discharge typically peaks in spring (March-April) and decreases throughout the year (Bleed and Flowerday, 1989). The southern portion of the Little White River basin is in the Nebraska Sandhills MLRA, resulting in springfed perennial tributary streams, whereas tributaries lower in the catchment flow over the Dakota-Nebraska Eroded Tablelands and also the Mixed Sandy and Silty Tablelands and Badlands. Streams in the Dakota-Nebraska Eroded Tablelands are similar to those in the Nebraska Sandhills, whereas streams in the Mixed Sandy and Silty Tablelands and Badlands and are fed primarily by runoff and carry high sediment loads (USDA, 2006). The landscape varies from sandhills formations in southern Bennett County to areas of interspersed mixed forest and sandy plains in Todd and Mellette counties. Cattle grazing is the primary land use, although row crop agriculture also occurs on a limited basis (USDA, 2006).

The Keya Paha River drains 3,319 km^2 in Todd and Tripp counties, South Dakota. The river also drains parts of Keya Paha and Boyd counties in Nebraska before reaching its confluence with the Niobrara River. High discharge is observed during the spring (March-April) and normally decreases through September, although another peak often occurs during late fall (October-November) (Harland, 2003). The Keya Paha river basin is within the Dakota-Nebraska Eroded Tablelands, where permeable surface material and topography lead to well-defined stream channels and perennial springfed streams (USDA, 2006). The landscape consists of sandy plains, mixed prairie range and interspersed cropland. Primary land uses are row-crop agriculture and cattle grazing (Harland, 2003).

Methods

To update species distributions and quantify relative abundance we collected fish at 42 reaches in the White, Little White, and Keya Paha River basins from 2010 through 2012 (Table 1-1, Figure 1-1). We also compiled all previous fish collection records from our study area and adjoining and neighboring drainages in Nebraska to characterize distributions. Previous fish collections in these river basins were conducted by many different agencies and universities including the University of Michigan (Bailey and Allum, 1962), University of Nebraska-Omaha (Cunningham *et al*., 1995), United States Fish and Wildlife Service (USFWS, 1997), South Dakota State University (Harland, 2003), the United States Geological Survey (USGS, 2002, 2003, 2004, 2008, 2009), and the Nebraska Game and Parks Commission (NGPC, Personal Communication). The majority of these records offer only species presence/absence records and qualitative habitat descriptions. A variety of gears (dip netting, seine hauls, backpack electrofishing) were used, and reach length was variable. Harland (2003) collected fish with seine nets in a number of sample reaches in the White and Keya Paha river basins (Table 1-1, Figure 1-1) and recorded relative abundance and habitat features, which were used in our analysis.

For our collections, we designated a sample reach as a stream segment 35 times the mean wetted width with a minimum reach length of 100 meters (Lyons, 1992). We first selected those streams with records of species of greatest conservation need (N = 13), and to increase sample size we randomly selected an additional 16 tributary streams. Sample reach location within streams depended upon accessibility and landowner consent. Sample reaches were electrofished in an upstream direction (ETS ABP-3-300), and all fish were identified to species. Two individuals of each species within a sample reach were preserved as voucher specimens, and all other individuals were released. We quantified catch per unit effort as the number of fish captured per square meter.

We quantified a number of reach scale variables to assess habitat preferences and limiting factors for target species. We measured wetted width at 10 equally spaced points throughout the sample reach to calculate mean wetted width. We measured velocity (m/s) and depth (m) across the stream channel at three evenly spaced transects throughout each sample reach. We measured depth (m) with a topset wading rod and velocity (m/s) using a flow meter (Flowmate Model 2000) mounted on the topset wading rod. These measurements were taken at five equally spaced points across transects. We measured temperature and conductivity (µs/cm) with a multiparameter water quality sonde (Hydrolab MS5), and transparency (cm) using a turbiditube. Similar measurements were taken by Harland (2003).

We calculated landscape level variables for all reaches including those sampled by Harland (2003). We quantified watershed area (m^2) for each reach and for entire drainage basins using a 30 meter digital elevation model from the National Elevation Dataset (Gesch, 2007) in conjunction with the Arc Hydro tools in ESRI® ArcGIS 9.3 (ESRI, 2010). We quantified landcover type within watersheds of individual reaches and for entire drainage basins using the National Land Cover Database (Fry et al. 2011) in conjunction with Arc Hydro tools in ESRI® ArcGIS 9.3 (ESRI, 2010). We used ESRI® ArcGIS (ESRI, 2010) to assign a Major Land Resource Area (MLRA) to each reach.

We summarized the range of each habitat variable across all sample reaches to assess the gradient of those variables within our study area. Additionally, habitat variable ranges were summarized individually for all sample/study reaches at which each target species was collected. We modeled relative abundance at sample reaches as a function of habitat characteristics for species with greater than seven encounters (plains topminnow and pearl dace). The relationships between MLRAs and species distributions were investigated by imposing updated target species distributions on MLRA boundaries within our study area.

Results

All five target species preferred tributary streams, but varied in distribution extent and abundance. All distributions were limited to two MLRA's, the Nebraska Sandhills and Dakota-Nebraska Eroded Tablelands (Figure 1-2). All target species have been documented in the Keya Paha River basin, located within the Dakota-Nebraska Eroded Tablelands, and their distributions were more extensive in this watershed than in any others examined. Relative abundance tended to be low for all target species (<0.2 fish/m^2), but all except blacknose shiner were collected at moderate to high local abundance at one or more reaches (Figure 1-3).

Two target species (pearl dace and plains topminnow) have been collected in the White River basin. During the current study we visited three tributary reaches within this division and detected one target species, plains topminnow. Plains topminnow and pearl dace also have been encountered within the Little White River basin. All five target species have been documented in the Keya Paha River basin. During the current study, we detected four target species in the Keya Paha River basin including northern redbelly dace, pearl dace, blacknose shiner, and plains topminnow.

Plains topminnow was the most widespread of any conservation listed species in our study area, collected from any major river drainages in South Dakota and Nebraska with at least some part of their watershed on the Nebraska Sandhills or the Dakota-Nebraska Eroded Tablelands MLRA (Figure 1-2). This species occurred at greater than half of our sample reaches in all three river basins. Plains topminnow was encountered more frequently in tributaries (89 % of collections) than mainstems. Relative abundance was generally less than 0.2 fish/m^2 but we did record relative abundance as high as 0.5 fish/m^2 (Figure 1-3). Conductivity, watershed area and velocity all tended to be low at reaches with plains topminnow present (Table 1-2, Figure 1-4).

Pearl dace was collected in the Little White and Keya Paha river basins during both current and previous studies, and previous research also reported this species in the White River basin. All collections occurred within the Nebraska Sandhills and Dakota-Nebraska Eroded Tablelands MLRAs (Figure 1-2). A majority of pearl dace records came from tributary streams (95.1 %). Pearl dace relative abundance was generally less than 0.2 fish/m^2 but in reaches within both the Little White and Keya Paha river basins we documented relative abundance exceeding 2 fish/m^2 (Figure 1-3). Pearl dace was present only in sample reaches with conductivity less than 600 µs/cm and watershed area less than 200 km^2 (Table 1-2, Figure 1-4).

Records of northern redbelly dace, finescale dace, and a hybrid of those two species (*Chrosomus eos* X *neogaeus*) in South Dakota were confined to the Keya Paha River basin, which lies entirely within the Dakota-Nebraska Eroded Tablelands MLRA.

Neither *Chrosomus* species occurred in mainstems. We detected only northern redbelly dace during our sampling. The three sample reaches in which we found this species had narrow wetted width (< 2.3 m) and small watershed area (<120 km^2) (Figure 1-3). Relative abundance did not exceed 0.2 fish/m^2 at any sample reaches (Figure 1-3).

Blacknose shiner has been found only in the Keya Paha River basin in South Dakota. Unlike other conservation listed species, blacknose shiner has not been collected in neighboring drainages in the Nebraska Sandhills. During our sampling, we collected a single individual from Sand Creek; thus, we did not quantify habitat associations for this species.

Discussion

Plains topminnow, blacknose shiner, pearl dace, and northern redbelly dace in southwestern South Dakota occur only in streams that drain Nebraska Sandhills and Dakota-Nebraska Eroded Table Land MLRAs. Additionally, a hybrid of northern redbelly dace and finescale dace *Chrosomus eos* X *neogaeus* was previously reported from these waters (Cunningham *et al*., 1995; NGPC, Personal Communication). In these areas parent material is permeable, resulting in perennial headwater streams fed by clear, cool groundwater (USDA, 2006). Conductivity was much lower in these streams than in those draining neighboring MLRAs. None of our target species were present in streams with conductivity in excess of 600 µs/cm. Conductivity has a strong link with fish assemblage structure in the southern Great Plains (Echelle *et al*., 1972; Taylor *et al*., 1993; Higgins and Wilde, 2005), and also may influence fishes in our study area. Frequency of occurrence and relative abundance of all target species, excluding finescale dace which were never collected in this study, were higher in the Keya Paha River basin, which lies entirely on the Dakota-Nebraska Eroded Tableland. The most likely explanation for this observation is that topography in the Keya Paha River Basin has greater relief, and thus, stream channels are better defined than in the Nebraska Sandhills (Omernik, 1987; USDA, 2006). Target species occurred more patchily in the Nebraska Sandhills, wherever we found springfed streams with well-defined channels.

Overall, plains topminnow appears to be stable in southwestern South Dakota. This is one of the most common species in the region, occurring at high relative abundance in certain habitats. Recent studies have reported declining plains topminnow distribution throughout much of its range (Patton *et al*., 1998; Fischer and Paukert, 2008; Pasbrig *et al*., 2012). Negative biotic interactions have occurred in parts of the plains topminnow distribution (Fischer and Paukert, 2008), but are unlikely to limit plains topminnow in South Dakota as nonnative species are rare in this region, and most species identified by Fischer and Paukert (2008) as potential competitors were either absent or rare in our study area. Habitat fragmentation has been identified as a major threat throughout the plains topminnow range (Rahel and Thel, 2004; Pasbrig *et al*., 2012) and is more likely to influence plains topminnow occurrence in southwestern South Dakota. Relative abundance was typically less than 0.2 fish/m^2 but exceeded 0.5 fish/m^2 in some reaches, which may be preferred habitats for thriving source populations. Connectivity to these locations should be prioritized, and these are important populations to monitor intensively as indicators of long-term species persistence in the region. We observed the highest relative abundance of plains topminnow in reaches with low current velocity, pool development, and abundant aquatic vegetation, while we recorded only very low relative abundance in larger streams with high current velocity. These results are consistent with findings of other researchers (Propst and Carlson, 1986; Lynch and Roh, 1996; Rahel and Thel, 2004). Plains topminnow is tolerant of sustained harsh conditions such as high temperatures and low dissolved oxygen concentrations (Brinkman, 1994; Smale and Rabeni, 1995) which may explain why they were more common than other target species during this study.

Pearl dace was detected throughout the Little White and the Keya Paha watersheds in a wide range of habitats. In southwestern South Dakota, and in the Great Lakes region, pearl dace are most commonly collected in first and second order streams, and more rarely in third order streams (Scott and Crossman, 1973; Becker, 1983). This species prefers headwater streams that are smaller and cooler than streams that occur lower in a catchment (Scott and Crossman, 1973, Stauffer *et al*., 1984). Higher order streams also may be harsher (*e.g.*, high temperatures, turbidity) in South Dakota and Nebraska than similarly sized streams in the Great Lakes region. Pearl dace relative abundance exceeded 2 fish/m^2 in two reaches, which stood out from the population of sample reaches in terms of their small watershed area, greater degree of isolation from the watershed mainstem, more marked pool development, and slower current velocity. Pearl dace occurrence in South Dakota and Nebraska is relict of Pleistocene Glaciation, and persistence in this region is a result of suitable habitat persistence. In the northern core of their range (Cross *et al*., 1986), coolwater lakes and bogs provide abundant suitable habitat (McPhail and Lindsey, 1970; Scott and Crossman, 1973; Becker, 1983; Hatch *et al*., 2003), and in the study region, perennial springfed headwater stream pools maintain relict pearl dace populations. Although populations appear to be thriving where preferred habitat exists, the rarity of such habitat in South Dakota justifies state threatened status.

State threatened status also is appropriate for northern redbelly dace which occurs very rarely in South Dakota. Finescale dace were not encountered during this study, making their status unclear. Records of both northern redbelly dace and finescale dace in southwestern South Dakota have been confined to the Keya Paha River basin, although finescale dace collections have mainly occurred in the Nebraska portion of the catchment. These two species are considered syntopic (Stasiak, 2006; Stasiak and Cunningham, 2006); both are well adapted to cold water and prefer springfed first order streams (Brett, 1944; Tyler, 1966; McPhail and Lindsey, 1970). In the northern portion of their range, northern redbelly dace and finescale dace are commonly found in low velocity springfed streams, and are often associated with beaver *Castor canadensis* ponds (Stasiak, 1972; Eddy and Surber, 1974; Schlosser, 1995; Stasiak, 2006). Additionally, they are found in cool glacial lakes with abundant cover as well as in bog drainage networks (Greeley and Bishop, 1933; Hubbs and Cooper, 1936; Das, 1990). Overall, northern redbelly dace and finescale dace seem to have more specialized habitat requirements than pearl dace or plains topminnow, restricting their distribution in South Dakota and Nebraska.

Blacknose shiner is rare, occurring only in the Keya Paha River basin of Nebraska and South Dakota, and may soon be extirpated from South Dakota. We encountered one individual in the Keya Paha River basin in South Dakota, and this species had only been documented in four tributary streams in the Keya Paha River basin prior to this study. Blacknose shiner has been extirpated from much of its former distribution due to wetland loss, increased turbidity and siltation resulting from erosion and pollution (Cross and

Moss, 1987; Hoagstrom *et al*., 2006). Extirpations are most numerous in states with intensive row-crop agriculture including Iowa (Bernstein *et al*., 2000), Illinois (Roberts and Burr, 2006) and South Dakota (Hoagstrom *et al*., 2006). The factors that have commonly been attributed to declines (*e.g*,. siltation, wetland loss) are not currently occurring in the Keya Paha River basin, so it is possible that this species will persist on a limited basis in this watershed.

Four of the target species were characterized by low relative abundance in most sample reaches and high relative abundance in a few sample reaches. Road crossings, dams, and other causes of stream fragmentation in this region, may eliminate connections between suitable habitat patches (Warren and Pardew, 1998; Bouska and Paukert, 2010) and thus pose the greatest threats to the persistence of the target species. Where these influences already occur, remediation efforts may benefit species of greatest conservation need in the region. With the distribution and relative abundance presented in this study, as well as the relationships between environmental factors and occurrence and relative abundance, natural resource managers have a baseline against which to compare future conditions and a more complete understanding of the requirements of the targeted species. Continuous sampling from headwaters to mainstem confluences in streams where we documented high abundance of listed species may help to further identify local habitat preferences and dispersal patterns. This information would provide a more detailed understanding of individual species ecology and further our understanding of the factors which promote the regional persistence of these species.

Literature Cited

Bailey, R. M. AND M. O. Allum. 1962. Fishes of South Dakota. Miscellaneous publications, Museum of Zoology, University of Michigan, Ann Arbor. No. 119.

Becker, G. C. 1983. Fishes of Wisconsin. University of Wisconsin Press, Madison. 1052 p.

Bernstein, N. P., M. Getting, T. Kamp, S. Christian, R. Smith, J. Steele AND S. Steele. 2000. The status of blacknose shiner (*Notropis heterolepis*) in Iowa: a preliminary survey. *J. Iowa Acad. Sci*., **107**:16-20.

Bleed, A. AND C. Flowerday. 1989. An atlas of the sand hills. Resource Atlas No. 5a. Conservation Survey Division, University of Nebraska, Lincoln, NE.

Bouska, W.W. AND C.P. Paukert. 2010. Road crossing designs and their impact on fish assemblages of Great Plains streams. *Trans. Am. Fish. Soc*., **139**: 214-222.

Brett, J. R. 1944. Some lethal temperature relations of Algonquin Park fishes. Pub. Fish Res. Lab. No. 63, University of Toronto Biological Studies Series No. 52.

Brinkman, M. A. 1994. Observations of the plains topminnow in South Dakota. *Prair. Nat.*, **78**:126-154.

Cross, F. B. 1970. Fishes as indicators of Pleistocene and recent environments in the Great Plains, p. 241-257 *In:* W. Dort Jr. and J.K. June Jr.(eds.). Pleistocene and recent environments of the central Great Plains. University of Kansas Press, Lawrence. 433 p.

———, R. L. Mayden AND J. D. Stewart. 1986. Fishes in the western Mississippi basin (Missouri, Arkansas, and Red Rivers), p. 363-412 *In:* C. H. Hocutt and E. O.

Wiley (eds.). The zoogeography of North American freshwater fishes. John Wiley & Sons, New York. 866 p.

——— AND R. E. Moss. 1987. Historic changes in fish communities and aquatic habitat in plains streams of Kansas, p. 155-165 *In:* W. J. Matthews and D. C. Heins (eds.). Community and evolutionary ecology of North American stream fishes. University of Oklahoma Press, Norman. 310 p.

Cunningham, G. R., R. D. Olson AND S. M. Hickey. 1995. Fish surveys of the streams and rivers in south central South Dakota west of the Missouri River. *Proc. So. Dak. Acad. Sci.*,**74**:55-64.

Cunningham, G.R. 2006. Pearl dace (*Margariscus margarita*): a technical conservation assessment. USDA Forest Service, Rocky Mountain Region. 43 p.

Das, M. K. 1990. Spawning time and fecundity of northern redbelly dace, *Phoxinus eos*, and finescale dace, *Phoxinus neogaeus*, and their hybrids in Upper Pierre Grey Lake, Alberta. *Can. Field Nat.*, **104**:409-413.

Dodds, W. K., K. Gido, M. R. Whiles, K. M. Fritz AND W. J. Matthews. 2004. Life on the edge: the ecology of Great Plains prairie streams. *Bioscience,* **54**:205-216.

Echelle, A.A., A.F. Echelle, AND L.G. Hill. 1972. Interspecific interactions and limiting factors of abundance and distribution in the Red River pupfish, *Cyprinodon rubrofluvialitis*. *Am. Mid. Nat*., **88**: 109-130.

Eddy, S. AND T. Surber. 1974. Northern fishes. Third edition. University of Minnesota Press, Minneapolis, MN. 252 p.

ESRI (Environmental Systems Resource Institute). 2010. ArcMap 9.3. ESRI, Redlands, California.

Falke, J. A. AND K. B. Gido. 2006. Spatial effects of reservoirs on fish assemblages in Great Plains streams in Kansas, USA. *Riv. Res. Applic.*,**22**:55-68.

Fausch, K. D. AND R. G. Bramblett. 1991. Disturbance and fish communities in intermittent tributaries of a western Great Plains river. *Copeia*, **1991**:659-674.

Fry, J., G. Xian, S. Jin, J. Dewitz, C. Homer, L. Yang, C. Barnes, N. Herold AND J. Wickham. 2011. Completion of the 2006 National Land Cover Database for the conterminous United States. *Photgramm. Eng. Rem. Sens.*, **77**: 858-864.

Fryda, D.D. 2001. A survey of the fishes and habitat of the White River, South Dakota. M.Sc. Thesis. South Dakota State University Brookings.

Fischer, J. R. AND C. P. Paukert. 2008. Historical and current environmental influences on an endemic Great Plains fish. *Am. Midl. Nat.*, **159**:364-377.

Gesch, D.B. 2007. The National Elevation Dataset, p. 99-118 *In:* D. Maune (ed). Digital Elevation Model technologies and applications: The DEM Users Manual, 2nd Edition. American Society for Photogrammetery and Remote Sensing, Bethesda, Marlyand. 655 p.

Gorman, O. T. AND J. R. Karr. 1978. Habitat structure and stream fish communities. *Ecology*, **59**:507-515.

Greeley, J. R. AND S. C. Bishop. 1933. Fishes of the upper Hudson watershed with annotated list. Pages 61-101 *In*: A biological survey of the upper Hudson watershed. Supplement to 22nd Annual Report, New York State Coservation Department. 341 p.

Harland, B. C. 2003. Surveys of the fishes and habitat of western South Dakota streams. M.Sc. Thesis. South Dakota State University Brookings.

Hatch, J. T., K. P. Schmidt, D. P. Siems, J. C. Underhill, R. A. Bellig, AND R. A. Baker. 2003. A new distribuitonal checklist of Minnesota fishes, with comments on historical occurrence. *J. Minn. Acad. Sci.*, **67**:1-17.

Higgins, C.L. AND G.R. Wilde. 2005. The role of salinity in structuring fish assemblages in a prairie stream system. *Hydrobiologia*, **549**: 197-203.

Hoagstrom, C. W., C. A. Hayer, J. G. Kral, S. S. Wall AND C. R. Berry. 2006. Rare and declining fishes of South Dakota: a river drainage scale perspective. *Proc. So. Dak. Acad. Sci.*, **85**:171-211.

———, S. S. Wall, J. G. Kral, B. G. Blackwell AND C. R. Berry. 2007. Zoogeographic patterns and faunal change of South Dakota fishes. *West. N. Am. Nat.*, **67**:161-184.

Hocutt, C.H. AND E.O. Wiley. 1986. The zoogeography of North American freshwater fishes. John Wiley & Sons, New York. 866 p.

Hubbs, C. L. AND G. P. Cooper. 1936. Minnows of Michigan. Cranbrook Institute of Science Bulletin 8, 84 pp.

Jelks, H. L., S. J. Walsh, N. M. Burkhead, S. Contreras-Balderas, E. Diaz-Pardo, D. A. Hendrickson, J. Lyons, N. E. Mandrak, F. McCormick, J. S. Nelson, S. P. Platania, B. A. Porter, C. B. Renaud, J. J. Schmitter-Soto, E. B. Taylor AND M. L. Warren. 2008. Conservation status of imperiled North American freshwater and diadromous fishes. *Fisheries*, **33**:372-407.

Keech, C. F. AND R. Bentall. 1971. Dunes on the plains: The Sand Hills region of Nebraska: Resource Report Number 4. University of Nebraska Conservation and Survey Division, Lincoln.

Lesica, P. AND F. W. Allendorf. 1995. When are peripheral populations valuable for conservation?. *Conserv. Biol.,* **9**:753-760.

Lynch, J. D. AND B. R. Roh. 1996. An ichthyological survey of the forks of the Platte River in western Nebraska. *Trans. Neb. Acad. Sci.*, **23**:65-84.

Lyons, J. 1992. The length of stream to sample with a towed electrofishing unit when fish species richness is estimated. *N. Am. J. Fish. Manage.*, **12**:198-203.

Mammoliti, C. S. 2002. The effects of small watershed impoundments on native stream fishes: A focus on the topeka shiner and hornyhead chub. *Trans. Kansas Acad. Sci.*, **105**:219-231.

Matthews, W. J. 1988. North American prairie streams as systems for ecological study. *J. North Am. Benthol. Soc.*, **7**:387-409.

McPhail, J. D. AND C. C. Lindsey. 1970. Freshwater fishes of Northwestern Canada and Alaska. Fisheries Research Board Canada, Ottawa. 381 p.

Miller, R. R., J. D. Williams, AND J. E. Williams. 1989. Extinctions of North American fishes during the past century. *Fisheries*, **14**:22-38.

Moyle, P. B. 1986. Fish introductions into North America: patterns and ecological impact, p. 27-43 *In:* H. A. Mooney and J. A. Drake, (eds.). Ecology of biological invasions of North America and Hawaii. Springer-Verlag New York Inc., New York. 321 p.

——— AND J. E. Williams. 1990. Biodiversity loss in the temperate zone: decline of the native fish fauna of California. *Conserv. Biol.*, **4**:275-284.

Omernik, J.M. 1987. Ecoregions of the conterminous United States. *Ann. Assoc. Am. Geogr.*, **77**: 118-125.

Orians, G. H. 1980. Micro and macro in ecological theory. *Bioscience*, **30**:79.

Pasbrig, C. A., K. D. Koupal, S. Schainost AND W. W. Hoback. 2012. Changes in range-wide distribution of plains topminnow *Fundulus sciadicus*. *Endang. Spec. Res*., **16**:235-247.

Patton, T. M., F. J. Rahel AND W. A. Hubert. 1998. Using historical data to assess changes in Wyoming's fish fauna. *Conserv. Biol*., **12**:1120-1128.

Pflieger, W. L. 1997. The fishes of Missouri. Revised edition. Missouri Department of Conservation, Jefferson City. 372 p.

Poff, N.L. AND J.V. Ward. 1989. Implications of streamflow variability and predictability for lotic community structure: a regional analysis of streamflow patterns. *Can. J. Fish. Aquat. Sci*., **46**: 1805-1817.

Propst, D. L. AND C. A. Carlson. 1986. The distribution and status of warmwater fishes in the Platte River drainage, Colorado. *The Southw. Nat*., **31**: 149-167.

Rahel, F.J. 2002. Homogenization of freshwater fish fauna. *Ann. Rev. Ecol. Syst*., **33**: 291-315

——— AND L. A. Thel. 2004. Plains topminnow (*Fundulus sciadicus*): a technical conservation assessment. USDA Forest Service, Rocky Mountain Region. 44 p.

Reinthal, P. N. AND M. L. J. Stiassny. 1991. The Freshwater fishes of Madagascar: a study of an endangered fauna with recommendations for a conservation strategy. *Conserv. Biol*., **5**:231-242.

Roberts, M. E. AND B. M. Burr. 2006. Current conservation status of the blacknose shiner, *Notropis heterolepis*, in Illinois. *Trans. Ill. St. Acad. Sci*., **99**:75-86.

Rohlf, D. J. 1991. Six biological reasons why the endangered species act doesn't work- and what to do about it. *Conserv. Biol.*, **5**:273-282.

Schlosser, I. J. 1995. Dispersal, boundary processes, and trophic-level interactions in streams adjacent to beaver ponds. *Ecology*, **76**:908-925.

Scott, W. B. AND E. J. Crossman. 1973. Freshwater fishes of Canada. Fisheries Research Board of Canada, Ottawa, Ontario, Canada. 966 p.

SDGFP (South Dakota Department of Game, Fish, and Parks). 2006. South Dakota Comprehensive Wildlife Conservation Plan. SDGFP, Wildlife Division Report 2006-2008, Pierre.

Sheldon, A. L. 1988. Conservation of stream fishes: patterns of diversity, rarity, and risk. *Conserv. Biol.*, **2**:149-156.

Smale, M. A. AND C. F. Rabeni. 1995. Hypoxia and hyperthermia tolerances of headwater stream fishes. *Trans. Am. Fish. Soc.*, **124**:698-710.

Stasiak, R. H. 1972. The morphology and life history of the finescale dace, *Pfrille neogaea,* in Itasca State Park, Minnesota. Ph.D. dissertation. University of Minnesota, Minneapolis, MN.

———. 2006. Northern redbelly dace (*Phoxinus eos*): A technical conservation assessment. USDA Forest Service, Rocky Mountain Region. 42 p.

——— AND G. R. Cunningham. 2006. Finescale dace (*Phoxinus neogaeus*): A technical conservation assessment. USDA Forest Service, Rocky Mountain Region. 49 p.

Stauffer, J. R., D. R. Lispi AND C. H. Hocutt. 1984. The prefferrred temperatures of three *Semotilus* species. *Archiv fuer Hydrobiologie,* **101**:595-600.

Taylor, C.M., M.R. Winston, and W.J. Matthews. 1993. Fish species-environment and abundance relationships in a Great Plains river system. *Ecography*, **16**: 16-23.

Tyler, A. V. 1966. Some lethal temperature relations of two minnows of the genus *Chrosomus*. *Can. J. Zool*., **44**:349-364.

USDA (United States Department of Agriculture). 2006. Major land resource areas of the United States,the Caribbean, and the Pacific Basin. United States Department of Agriculture Handbook 296. United States Department of Agriculture, Natural Resource Conservation Service, Washington, D.C.

USFWS (United States Fish and Wildlife Service). 1997. Fishes of the Little White River, south central South Dakota. United States Fish and Wildlife Service FWMAO, Pierre, SD.

USGS (United States Geological Survey). 2002. Environmental monitoring and assesment program activities in South Dakota, annual progress report. U.S. Geological Survey, Rapid City, SD.

———. 2003. Environmental monitoring and assesment program activities in South Dakota, annual progress report. U.S. Geological Survey, Rapid City, SD.

———. 2004. Environmental monitoring and assesment program activities in South Dakota, annual progress report. U.S. Geological Survey, Rapid City, SD.

———. 2008. Environmental monitoring and assesment program activities in South Dakota, annual progress report. U.S. Geological Survey, Rapid City, SD.

———. 2009. Environmental monitoring and assesment program activities in South Dakota, annual progress report. U.S. Geological Survey, Rapid City, SD.

Warren, M.L. AND M.G. Pardew. 1998. Road crossings as barriers to small-stream fish movement. *Trans. Am. Fish. Soc.*, **127**: 637-644.

Waters, T. F. 1995. Sediment in streams: sources, biological effects, and control. American Fisheries Society, Bethesda, MD. 251 p.

Williams, J. E., J. E. Johnson, D. A. Hendrickson, S. Contreras-Balderas, J. D. Williams, M. Navarro-Mendoza, D. E. McAllister AND J. E. Deacon. 1989. Fishes of North America endangered, threatened, or of special concern. *Fisheries*, **14**:2-2

Table 1-1. — Coordinates and focal species occurrence at sample reaches. Reaches sampled by Harland (2003) indicated in bold. Coordinates are in North American Datum 1983 UTM Zone 14 (* denotes coordinates listed in Zone 13).

Waterbody name	Years sampled	X	Y	Plains topminnow	Pearl dace	Northern redbelly dace	Blacknose shiner
			White River Basin				
Wounded Knee Creek	2010	719081*	4769329				
Wolf Creek	2010	709474*	4765198	X			
Wolf Creek	2010	709026*	4765299	X			
Old Lodge Creek	2002	429026	4835097				
Dog Ear Creek	2002	419882	4836084				
Cottonwood Creek	2002	411577	4836553				
Oak Creek	2002	395163	4819666				
Oak Creek	2002	402170	4835654				
Pass Creek	2002	304549	4826617				
Blackpipe Creek	2002	322134	4819452				
Bear in the Lodge Creek	2002	271279	4840177				
Medicine Root Creek	2002	726861*	4815447				
Porcupine Creek	2002	708235*	4813409				
Wounded Knee Creek	2002	699117*	4810200				
			Little White River Basin				
Stinking Water Creek	2011	742211*	4776374				
Manbearpig Creek	2010 - 2012	286012	4770889	X			
Lake Creek Tributary	2010, 2011	285253	4772571	X	X		
Lake Creek	2010 - 2012	285693	4772805	X	X		
Lake Creek	2011	288524	4773464		X		
Elm Creek	2012	290023	4772358	X	X		
Elm Creek	2010, 2011	290015	4772406	X	X		
Elm Creek	2010	290418	4773094	X	X		
Cedar Creek	2011	317130	4773495	X	X		

Table 1-1. Cont'd.

Waterbody name	Years sampled	X	Y	Plains topminnow	Pearl dace	Northern redbelly dace	Blacknose shiner
Coffee Creek	2011	326745	4776030	X	X		
Coffee Creek Tributary	2011	328456	4775993				
Coffee Creek	2010, 2011	328322	4775897				
Spring Creek	2011	334122	4771882				
Omaha Creek	2011	340993	4783919				
Beads Creek	2011	337750	4785009	X			
South Ironwood Creek	2011	341110	4788197				
East Branch Rosebud Creek	2011	352865	4783876	X			
West Branch Rosebud Creek	2010, 2011	349012	4783494				
Rosebud Creek	2011	347452	4791323				
West Soldier Creek	2011	354429	4791761	X			
Upper Cutmeat Creek	2010, 2011	327582	4789564	X			
Gray Eagletail Creek	2011	339169	4807066				
Keya Paha River Basin							
Antelope Creek	2011	374234	4792873	X			
Rock Creek	2011	382412	4784070	X			
Rock Creek	2010	386187	4785781	X			
Keya Paha River	2010, 2011	389032	4785469	X			
Eagle Creek	2010	383225	4772962	X			
Eagle Creek	2011	391474	4773566	X	X		
Crazy Hole Creek	2011	398804	4782062	X			
Sand Creek	2011	403449	4766677	X			X
Sand Creek	2011	404549	4769929	X			
Shadley Creek	2011, 2012	412725	4767343		X	X	
Shadley Creek	2012	412338	4764414	X	X	X	

Table 1-1. Cont'd.

Waterbody name	Years sampled	X	Y	Plains topminnow	Pearl dace	Northern redbelly dace	Blacknose shiner
Willow Creek	2011, 2012	411576	4785166	X	X	X	
Willow Creek	2011	419970	4773624	X			
Lost Creek	2011	421115	4765079	X	X		
Cottonwood Creek	2011	427256	4765557				
Timber Creek	2011	432686	4763762				
Lute Creek	2011	452509	4761439				
Antelope Creek	2002	374917	4793007	X			
Antelope Creek	2002	387310	4787039	X			
Keya Paha River	2002	410169	4775627				
Keya Paha River	2002	420813	4771278				
Keya Paha River	2002	433595	4765215				
Rock Creek	2002	378731	4780632				
Rock Creek	2002	387310	4787039	X			
Sand Creek	2002	409874	4774390				
Eagle Creek	2002	396893	4779549				
Willow Creek	2002	420970	4771463	X			

Table 1-2. Range of habitat characteristics at all sampled reaches and at those where target species were detected. Mainstems include those reaches which are third order or greater.

	Reaches Considered					
Habitat characteristics	All tributaries	All mainstems	Plains topminnow present	Pearl dace present	Northern redbelly dace present	Blacknose shiner present
Number of reaches	61	6	30	12	3	1
Mean width (m)	0.78 - 7.02	2.88 - 28.81	0.78-5.97	1.70-6.36	1.86-2.30	2.84
Mean depth (m)	0.063 0.571	0.19 - 0.667	0.08-0.57	0.08-0.37	0.27-0.27	0.22
Mean velocity (m/s)	0.00 - 0.49	0.19 - 0.595	0.02-0.6	0.11-0.45	0.28-0.40	0.44
Temperature (°C)	10 - 30.2	19.3 - 29	15.5-26.3	13.0-22.1	13.0-20.4	26.3
Transparency (mm)	136 - 1200	126 - 528	126-1200	216-1200	527-662	171
Conductivity (µs/cm)	92 - 2510	400 - 955	92-559	92-559	445-465	448
Watershed area (km^2)	11 - 1193	387 - 3225	11-928	13-189	64-120	261

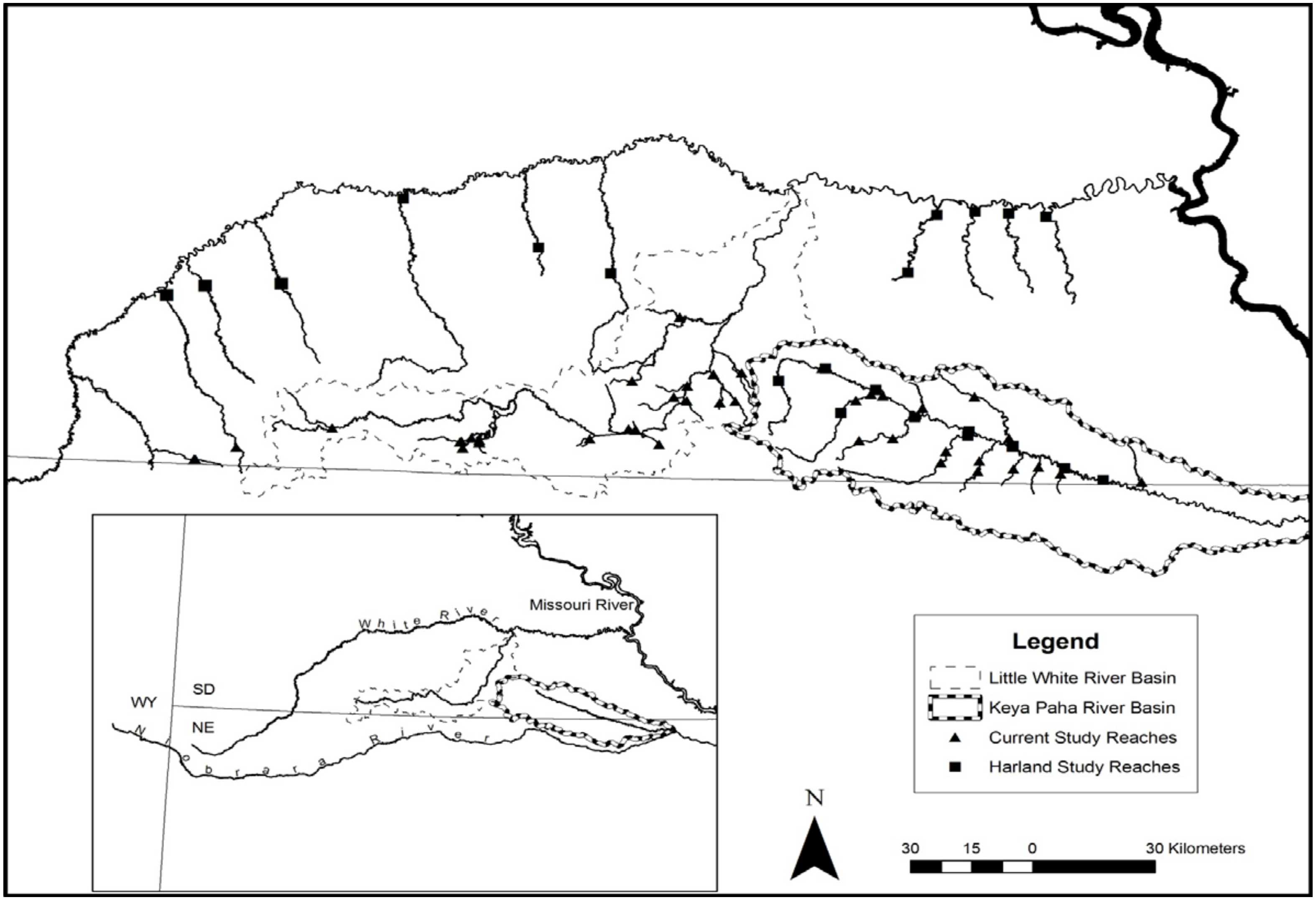

Fig. 1-1. Map of study area and sample reaches including those visited during the current study and by Harland (2003).

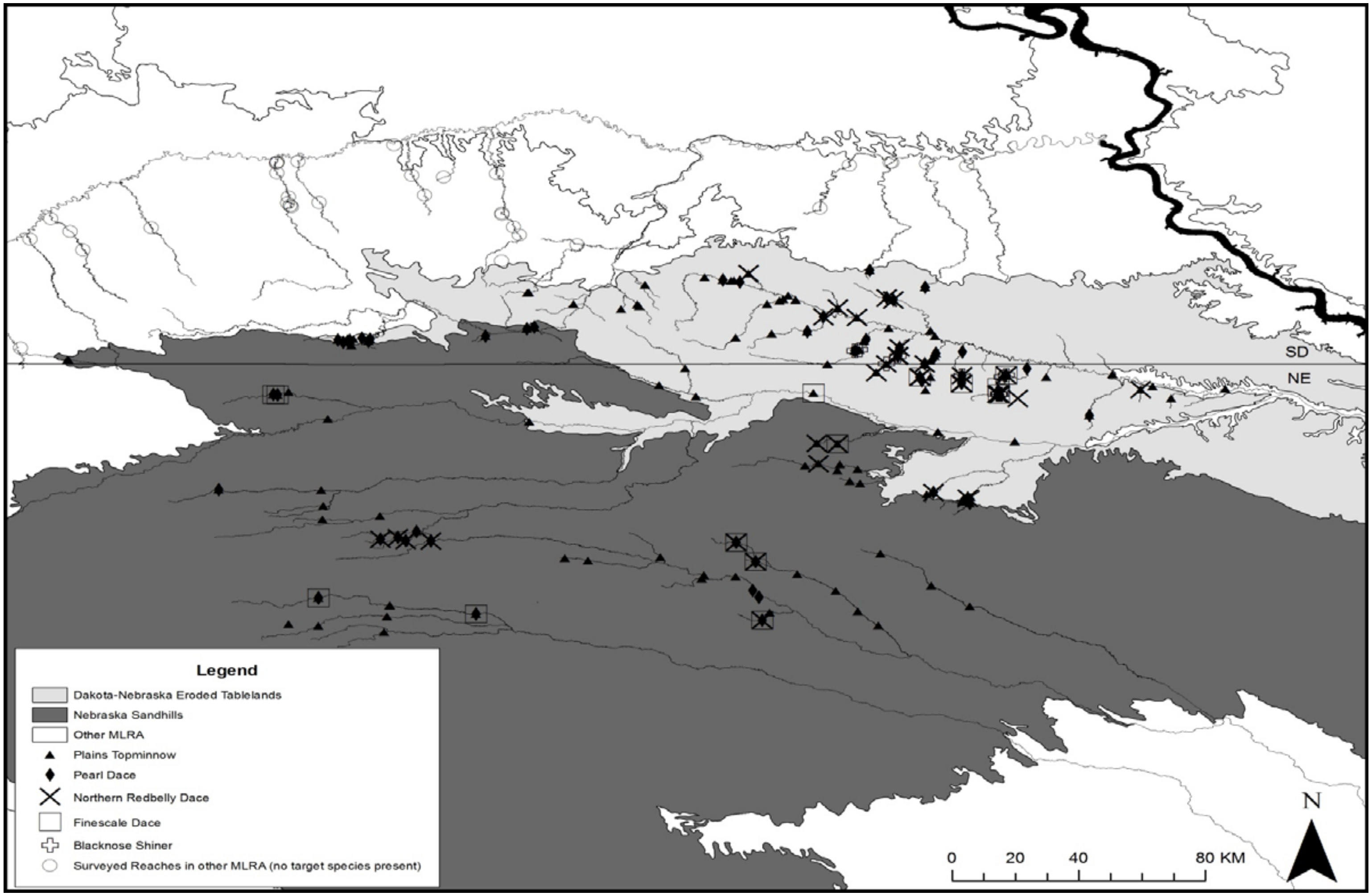

Fig. 1-2. Species of greatest conservation need distributions in relation to Major Land Resource Areas in northern Nebraska and southwestern South Dakota.

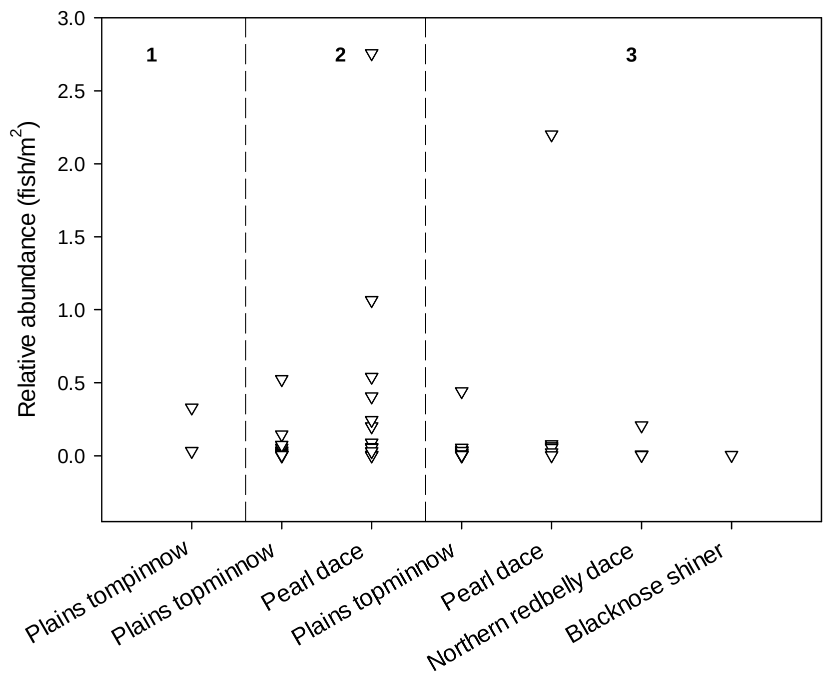

Fig. 1-3. Catch per unit effort (fish/m^2) distributions for target species during current study, separated by river basin: (1) White River, (2) Little White River, and (3) Keya Paha River.

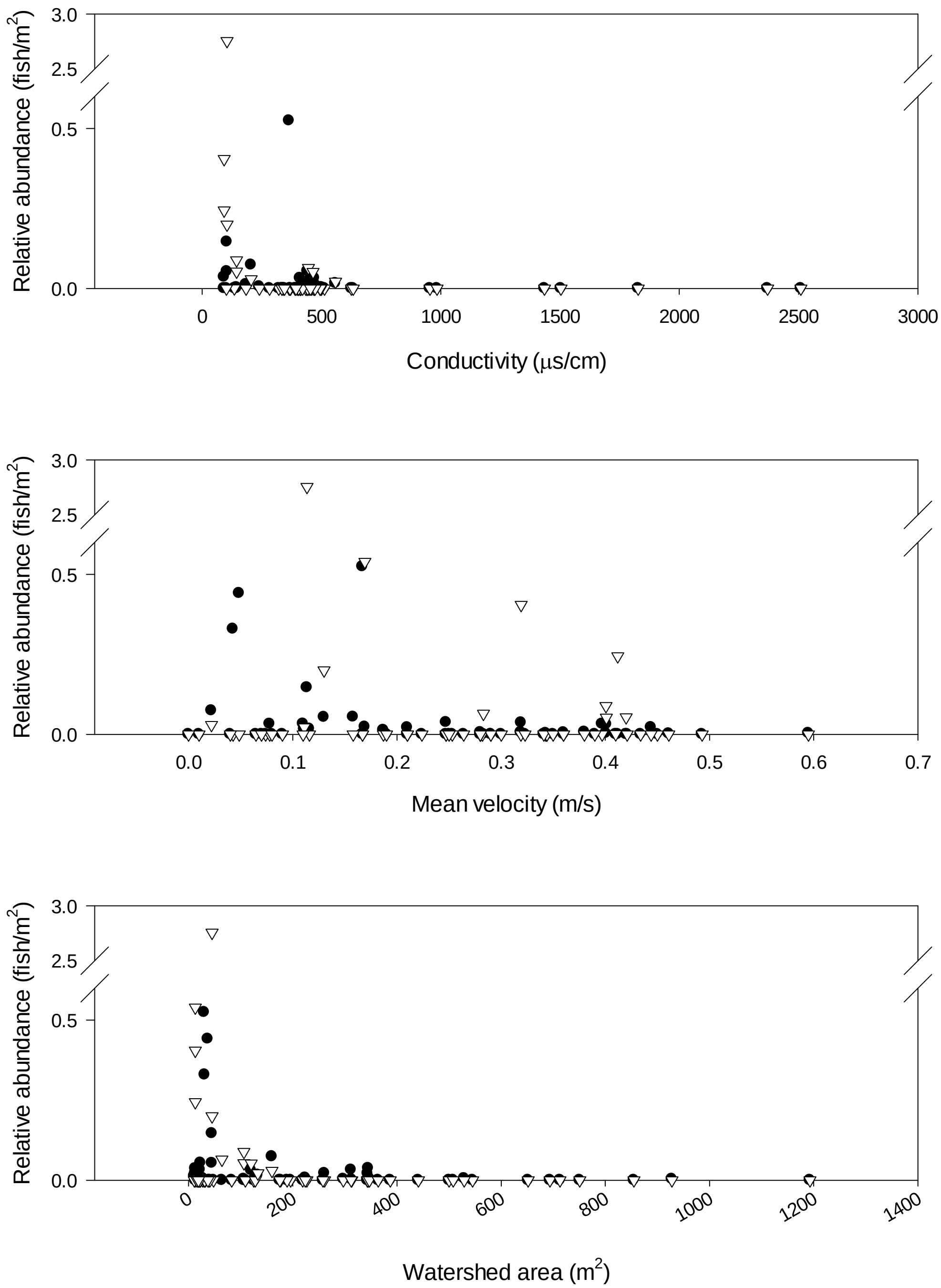

Fig. 1-4. Plains topminnow (filled circles) and pearl dace (open triangles) relative abundance (fish/m^2) as a function of conductivity, watershed area, and velocity. Data include reaches sampled by Harland (2003).

Chapter 2: Co-occurrence of glacial relict species and fish assemblage patterns in springfed South Dakota streams

Abstract

Stream fishes in the Great Plains region of North America often exist in harsh environments and are subject to high intrannual variability. Springfed streams are found sporadically throughout the region and provide stable conditions that often support unique fish species, and are important to fishes that are temporary inhabitants. In southwestern South Dakota, springfed streams support three glacial relict species (northern redbelly dace *Chrosomus eos*, finescale dace *Chrosomus neogaeus*, and pearl dace *Margariscus margarita*), which are isolated from the northern core of their distributions. These species display similar broad distributional patterns, but occurrence patterns within disjunct populations are unclear. We assessed co-occurrence among relict species and described assemblage patterns throughout their South Dakota distribution. We compiled records from previous collections within the White, Little White and Keya Paha river basins in South Dakota as well as adjoining and neighboring drainage basins in Nebraska, and sampled fishes at 42 sample reaches during 2010-2012. We did not document significant co-occurrence among any target species; pearl dace was encountered frequently, but both northern redbelly dace and finescale dace were quite rare, limiting the opportunity for co-occurrence. Relict species were documented most frequently in a group of neighboring tributaries in the Keya Paha River basin. Fish assemblages were primarily structured by stream size, but sample reaches with relict species did tend to exhibit high species richness and diversity relative to other reaches.

Our study identifies concentrations of glacial relict species in South Dakota and provides insight into fish assemblage patterns in springfed Great Plains streams.

Introduction

Over the past several million years, the Great Plains region has been subjected to extreme climatic shifts including both warm, dry periods and cool, wet periods (Cross 1970, Newbrey and Ashworth 2004, Hoagstrom and Berry 2006, Hoagstrom et al. 2011). Streams of the Great Plains region of North America are currently characterized by high intrannual variability, experiencing scouring floods and droughts and highly variable thermal regimes (Dodds et al. 2004). Springfed streams are found sporadically throughout the Great Plains, and are buffered against climatic changes, providing stable environments that oppose the generally harsh regional patterns (Chen et al. 2003). Springfed perennial streams serve as seasonal refuges (Power et al. 1999) and nursery areas for early life stages of fishes that are resident or temporary inhabitants (Vannote et al. 1980; Schlosser 1991; Fausch et al. 2002). These conditions often support the persistence of unique, isolated fish species, including both endemics (Hoagstrom et al. 2011) and relicts of recent environments (Cross 1970).

Isolated populations are important from a conservation standpoint as they often possess biologically significant differences from core populations (Hardie and Hutchings 2010), including greater stress adaptations (Parsons 1991; Hardie and Hutchings 2010) and increased risk of extirpation by stochastic events (Sheldon 1988; Lesica and Allendorf 1995). Vulnerability to these effects depends upon patch size and recolonization potential, factors which can be assessed by examining species geography (Abbitt et al. 2000). In a study of Sonoran Desert fishes, fragmentation was a better predictor of extinction risk than number of occurrences, underscoring the importance of spatial distribution to species persistence (Fagan et al. 2002). In western South Dakota, stream fishes have received modest amounts of study, resulting in many incomplete or out-of-date species distribution accounts and limiting the inferences that can be drawn from spatial patterns.

South Dakota populations of three dace species (northern redbelly dace *Chrosomus eos*, finescale dace *Chrosomus neogaeus*, and pearl dace *Margariscus margarita*) are relict of Pleistocene Glaciation (Cross 1970; Cross et al. 1986) and are isolated from the northern core of their distribution from the Great Lakes region into Canada. These species are federally secure (G5, Natureserve 2013), but are considered conservation priorities in three central Great Plains states (Nebraska, South Dakota, Wyoming). Springfed perennial headwaters provide rare habitat for endemic and glacial relict stream fishes to persist in the Great Plains, contain higher beta diversity, and thus contribute significantly to regional diversity (Meyer et al. 2007). Despite similar habitat requirements, differences in feeding ecology and dispersal capabilities may result in non-overlapping local distributions (Cochran et al. 1988; Schlosser et al. 1998; Mee and Rowe 2010).

The three dace species share similar native ranges, but existing reviews do not document occurrence patterns within disjunct subpopulations. Although these populations are all disjunct as a result of Pleistocene Glaciation, species may respond differently to local habitats. Our objectives were to: (1) characterize co-occurrence patterns of relict species and classify reaches in relation to relict species occurrence, (2) investigate geographical patterns of relict species occurrence, and (3) quantitatively describe fish assemblage patterns in southwestern South Dakota stream networks.

Study Area

The White River originates in Sioux County in northwestern Nebraska, and drains 26,418 km^2 as it flows through southwestern South Dakota before reaching its confluence with the Missouri River in Lyman County, South Dakota (Fryda 2001). The majority of the White River basin is characterized by silt and clay soils resulting in streams that are fed primarily by runoff and carry extremely high sediment loads (Fryda 2001). However, in southwestern South Dakota tributaries originate from the northern extent of the Nebraska Sandhills Major Land Resource Area (MLRA) and run through the Mixed Sandy and Silty Tablelands and Badlands (USDA 2006), where a permeable sand geology has formed spring fed, perennial tributary streams. The Little White River basin drains the majority of these MLRAs within the White River basin, but a small number of direct tributaries in Shannon and Mellette counties also originate from the sandy landscape.

The Keya Paha River drains 3,319 km^2 in Todd and Tripp counties, South Dakota. The river also drains parts of Keya Paha and Boyd counties in Nebraska before reaching its confluence with the Niobrara River. The Keya Paha River basin is within the Dakota-Nebraska Eroded Tablelands, where permeable surface material and topography lead to well defined stream channels and perennial, groundwater fed streams (USDA 2006).

Methods

Fish Occurrence Records.- We used literature and results from current collections to describe fish species occurrence in the White, Little White and Keya Paha river basins.

Assemblages were sorted into hydrologic divisions. The White, Little White and Keya Paha rivers were considered to be mainstem rivers. All of these rivers are third order or greater and contain different habitat than smaller streams. Specifically, mainstem rivers have greater wetted width, temperature, turbidity and discharge than their tributaries. We considered first and second order streams tributary streams, with the exception of Antelope and Rock creeks in the Keya Paha River basin, which are the headwaters of the Keya Paha River. Tributary networks were classified according to the mainstem into which they drain.

Questionable fish species records were verified, if possible, by examining voucher specimens in the Natural Heritage Fish Reference Collection for South Dakota in the Department of Natural Resource Management at South Dakota State University. We assessed records without voucher specimens using an approach similar to that described by Hoagstrom (2006) where questionable records were omitted unless we could independently verify the identification.

We sampled fish at 42 sample reaches from April through August during 2010-2012, and included 22 reaches sampled by Harland (2003) during 2002-2003 (Figure 2-1). For our collections we designated a sample reach as a stream segment 35 times the mean wetted width with a minimum reach length of 100 meters (Lyons 1992). We chose sample reaches by automatically selecting those with records of species of greatest conservation need, and selecting randomly from other tributary reaches. Reach location within streams depended upon accessibility and landowner consent. Reaches were electrofished in an upstream direction (ETS ABP-3-300), and all fish were identified to species. Two individuals of each species within a reach were collected as voucher specimens, and all other individuals were released.

Species were classified as native, out of state nonnative or in state nonnative based on interpretations of Hoagstrom et al. (2007). Native species are those that were likely present within a given river drainage when Europeans first settled in South Dakota. In state nonnatives are species native to some South Dakota river drainages but introduced to those considered for this study. Out of state nonnatives are nonnative wherever they occur in South Dakota.

Headwater specialist co-occurrence patterns.- We evaluated co-occurrence of relict species using a 2x2 contingency table analysis and one-tailed Fischer exact tests. We excluded collections from the White River basin because only pearl dace was found there. The Phi coefficient was used to measure the strength and direction of associations (Zar 1984). Pairwise contingency tables contained four categories: both species present, only species "A" present, only species "B" present and neither species present. We considered co-occurrence significant at α=0.05.

We compiled all available fish collection records in our study area to construct maps depicting presence and absence of listed species in our study area. We organized reaches with listed species into three tiers based on results of contingency analysis. Tier 1 reaches contained at least one of the two rarest relict species (northern redbelly dace, finescale dace), Tier 2 reaches contained pearl dace but none of the Tier 1 species, and all relict species were absent at Tier 3 reaches.

Assemblage Patterns.- We assessed patterns of fish faunal similarity among divisions using Sørenson's Index (Sørensen 1948) as our distance measure because it gives double weight to matches, which treats matches rather than mismatches as the most useful indicators of faunal similarity (Legendre and Legendre 1998; Hoagstrom et al. 2007). We quantified faunal disparity between tributaries and mainstem rivers by calculating unshared species richness, and also identified unshared species as native, in state nonnative or out of state nonnative. The White River basin was excluded from unshared species richness analysis as records from the mainstem and tributaries are much less complete than those available for other included hydrologic units. We compared species richness, Shannon diversity and Shannon evenness among tributary reaches with and without relict species, separated by river basin, using assemblage data collected during 2011.

We assessed faunal similarity among reaches using nonmetric multidimensional scaling (MDS). We used 2011 relative abundance data along with abundance data collected by Harland (2003) to compare assemblages in the mainstem and tributaries of the Keya Paha River basin. No abundance data were available for the mainstem Little White River, so only 2011 relative abundance data were used. We used Bray-Curtis dissimilarity as our distance measure, and relative abundance values were fourth root transformed prior to analysis. This analysis was conducted using package vegan in software R (Version 2.15.1).

Results

We found a significant positive association between northern redbelly dace and hybrid northern redbelly dace and finescale dace (Phi = 0.419, $P < 0.001$); no other significant relationships were detected. Pearl dace commonly occurred in the absence of Tier 1 species (32 % of pearl dace collections) but also co-occurred at 61 % of Tier 1 reaches. Tier 1 species were concentrated in a number of neighboring tributaries to the Keya Paha River (Figure 2-2). Pearl dace was relatively widespread in the Keya Paha River basin, but its distribution in the Little White River basin was patchy, and the greatest number of collections occurred in a group of closely neighboring streams on Lacreek National Wildlife Refuge in southern Bennett County.

Native species dominated all assemblages (Figure 2-3), but species composition, richness and unshared richness between tributaries and mainstem rivers differed across hydrologic divisions. Species richness was highest in the Keya Paha River and its tributaries, whereas the mainstem White River was the most species poor (Figure 2-3). Twenty species have been recorded in the mainstem White River, and 32 species have been collected in tributaries to the White River, excluding the Little White River basin (see Appendix 2-A for species list). In the Keya Paha River basin 31 species have been collected in the mainstem and 34 species have been collected in tributaries (see Appendix 2-B for species list). The Keya Paha River and its tributaries displayed the greatest similarity among hydrologic divisions (Table 2-1). Unshared richness was 29 %, and 18 % of unshared species were found only in tributaries (Figure 2-4). The Little White River and its tributaries were more similar to both Keya Paha River basin divisions than either White River basin division (Table 2-1). Unshared species richness in the Little White River basin was higher (50 %), and both the main stem and its tributaries contained nearly the same amount of unshared richness (24 % and 26 %, respectively) (Figure 2-4). The White River and its tributaries were the most distinct groups. Tier 2 reaches in the Little White River basin contained higher species richness, diversity and evenness when compared with Tier 3 reaches (Figure 2-5). Tier 1 and 2 reaches in the

Keya Paha River basin had similar species richness, diversity and evenness when compared with Tier 3 reaches (Figure 2-5).

Fish assemblages in the region primarily varied according to stream size and current velocity (Figure 2-6). Large river specialists characterized assemblages on the right side of MDS Axis 1, and these samples were collected from reaches draining the greatest watershed areas. The greatest sample scores along axis 1 were from mainstem reaches of the Keya Paha River. Lentic specialists characterized assemblages near the bottom of MDS axis 2, whereas lotic specialists were more typical near the top of axis 2. The greatest axis 2 sample scores were from shallow high velocity streams in the Little White River basin.

Discussion

Relict species co-occurrence and geographic patterns

Our analysis did not detect significant co-occurrence among relict species at the reach scale; however, geographic patterns seem to indicate similar stream preferences, particularly for Tier 1 species. Pearl dace were more widely distributed than other relict species, which likely influenced contingency analysis. This species was often present where other relict species were absent, likewise, when Tier 1 species were present, pearl dace was also commonly encountered. Unlike Tier 1 species, pearl dace occurred in mainstem reaches suggesting it may have a broader physiochemical tolerance or greater dispersal capability than other relict species, contributing to a broader distribution.

We detected significant co-occurrence between a hybrid and one of its parental species, northern redbelly dace, but did not find any association with its other parental species, finescale dace. This hybrid complex reproduces asexually via gynogenesis, requiring sperm from one of the parental species to stimulate embryo development (Goddard et al. 1989; Schlosser et al. 1998). In Ontario lakes, Mee and Rowe (2010) found a negative correlation between the presences of northern redbelly dace and finescale dace, and also noted that hybrids were not found in the absence of northern redbelly dace. Specialized feeding ecology and dispersal capabilities differentiate the parental species (Cochran et al. 1988; Schlosser et al. 1998; Mee and Rowe 2010), whereas their hybrids fill a generalist niche (Schlosser et al. 1998). Thus, when conditions favor one parental species (i.e., northern redbelly dace) hybrids will be more likely to occur than the other parental species (i.e., finescale dace).

Tier 1 and 2 species were concentrated in a network of neighboring tributary streams within the Keya Paha River basin, which suggests that habitat was more suitable in this catchment than in the Little White or White River basins. The close spatial proximity among patches may also contribute to long-term persistence by allowing for rescue effects following disturbances (*sensu* Brown and Kodrick-Brown 1977). Tier 2 species occurred at isolated patches in the Little White River basin and in direct tributaries to the White River, whereas Tier 1 species were absent from both of these catchments. The distance and stream environments (i.e., mainstem rivers) that separate Tier 2 patches probably prevent exchange of individuals among patches, indicating isolated populations. Populations in the White River basin are more vulnerable to extirpation by stochastic events.

Assemblage patterns

The mainstem and tributary fauna of the Little White and Keya Paha river basins were more similar to one another than to the White River mainstem and tributaries. Harsher physiochemical conditions in the White River basin (i.e., intermittency, broad temperature range, high conductivity) likely contribute to dissimilar fish fauna compared to the Little White and Keya Paha river basins (Fryda 2001; USDA 2006). Stream capture also may have contributed to the increased faunal similarity between the Little White and Keya Paha river basins (Swinehart et al. 1985; Mayden 1987). Faunal turnover between mainstems and tributaries was lower in the Keya Paha River basin than in the Little White River basin but tributaries in both basins contained similar levels of unshared richness. Inter-tributary movement may occur more frequently in the Keya Paha River basin because many tributary confluences with the mainstem are only separated by a short distance.

Little White River basin-wide diversity is reduced by hydrodynamic barriers and harsh physiochemical conditions which also reduces the occurrence of relict species. Exceptional reaches where relict species persist support relatively high species richness and diversity. In the Little White River basin, Tier 3 reaches displayed low diversity relative to Tier 2 reaches and scaled strongly along axis 2 of our MDS, indicating distinct assemblage types. The reaches that scored most negatively were directly downstream of impoundments and were dominated by a few centrarchid species; escapement from impoundments likely influenced the fish assemblages at those reaches (Martinez et al. 1994; Taylor et al. 2001). Reaches that scored positively along axis 2 were dominated by longnose dace *Rhinichthys cataractae*, which can pass stretches of shallow, high velocity water that acts as a hydrodynamic barrier to other species (Becker 1983; Pflieger 1997; Grossman et al. 2010). Species with high physiochemical tolerance (e.g.. fathead minnow *Pimephales promelas*, and plains topminnow *Fundulus sciadicus*) (Brinkman 1994; Smale and Rabeni 1995) characterized assemblages in low diversity reaches. Assemblage structure was principally influenced by stream size in the Keya Paha River basin, where richness, diversity and evenness were similar among tiers.

In southwestern South Dakota, headwater streams enhance regional diversity by supporting relict species that do not occur elsewhere in river networks (Paller 1994). Distributions varied among species, but more widespread species commonly co-occurred with rarer species. Spatial arrangement of habitat is important, as both Tier 1 and 2 reaches tended to occur in "neighborhoods" of tributary streams (Dunning et al. 1992). The presence of these species indicates environments that are buffered from the effects of harsh thermal and discharge regimes (Cross 1970; Stasiak 2006), and are centers of diversity. In the Little White River basin, Tier 2 reaches should be considered conservation priorities as they support conservation listed species and high diversity relative to the rest of the catchment. The abundance of Tier 1 and 2 reaches in the Keya Paha River basin identifies the entire watershed as a conservation priority. Much of the habitat in the Keya Paha River basin is possibly capable of supporting sink populations of relict species, but the presence or absence of such populations relies upon connectivity with source populations (Pulliam 1988). Thus, this catchment is also an excellent candidate for the study of stream fish source-sink dynamics.

Literature Cited

Abbitt, R. J. F., J. M. Scott, and D. S. Wilcove. 2000. The geography of vulnerability: incorporating species geography and human development patterns into conservation planing. Biological Conservation 96:169-175.

Becker, G. C. 1983. Fishes of Wisconsin. University of Wisconsin Press, Madison.

Brinkman, M. A. 1994. Observations of the plains topminnow in South Dakota. Prairie Naturalist 78:126-154.

Brown, J. H., and A. Kodric-Brown. 1977. Turnover rates in insular biogeography: effect of immigration on extinction. Ecology 58: 445-449.

Chen, X., X. Chen, C. Rowe, W. Hu, and M. Anderson. 2003. Geological and climatic controls on streamflows in the Nebraska Sandhills. Journal of the American Water Resources Association 39:217-228.

Cochran, P., D. Lodge, J. Hodgson, and P. Knapik. 1988. Diets of syntopic finescale dace, *Phoxinus neogaeus*, and northern redbelly dace, *Phoxinus eos*: a reflection of trophic morphology. Environmental Biology of Fishes 22:235-240.

Cross, F. B. 1970. Fishes as indicators of Pleistocene and recent environments in the Great Plains. Pages 241-257 *in* W. Dort Jr. and J.K. June Jr. editors. Pleistocene and recent environments of the cenral Great Plains. University of Kansas Press, Lawrence.

Cross, F. B., R. L. Mayden, and J. D. Stewart. 1986. Fishes in the western Mississippi basin (Missouri, Arkansas, and Red Rivers). Pages 363-412 *in* C. H. Hocutt and E. O. Wiley, editors. The Zoogeography of North American stream fishes. John Wiley & Sons, New York.

Dodds, W. K., K. Gido, M. R. Whiles, K. M. Fritz, and W. J. Matthews. 2004. Life on the edge: the ecology of Great Plains prairie streams. BioScience 54:205-216.

Dunning, J. B., B. J. Danielson, and H. R. Pulliam. 1992. Ecological processes that affect populations in complex landscapes. Oikos 65:169-175.

Fagan, W. F., P. J. Unmack, C. Burgess, and W. L. Minckley. 2002. Rarity, fragmentation, and extinction risk in desert fishes. Ecology 83:3250-3256.

Fausch, K. D., C. E. Torgersen, C. V. Baxter, and H. W. Li. 2002. Landscapes to riverscapes: bridging the gap between research and conservation of stream fishes. BioScience 52:483-498.

Fryda, D. D. 2001. A survey of the fishes and habitat of the White River, South Dakota. Master's thesis. South Dakota State University, Brookings.

Goddard, K. A., R. M. Dawley, and T. E. Dowling. 1989. Origin and genetic relationships of diploid, triploid, and diploid-triploid mosaic biotypes in the *Phoxinus eos-neogaeus* unisexual complex *in* R. M. Dawley and J. P. Bogart, editors. Evolution and ecology of unisexual vertebrates. New York Museum Bulletin 466, Albany, New York, USA.

Grossman, G. D., R. E. Ratajczak Jr., M. D. Farr, C. M. Wagner, and J. T. Petty. 2010. Why there are fewer fish upstream. American Fisheries Society Symposium 73:63-81.

Hardie, D. C. and J. A. Hutchings. 2010. Evolutionary ecology at the extremes of species' ranges. Environmental Reviews 18:1-20.

Harland, B. C. 2003. Surveys of the fishes and habitat of western South Dakota streams. Master's thesis. South Dakota State University, Brookings.

Hoagstrom, C. W. 2006. Fish community assembly in the Missouri River Basin. Doctoral disseration. South Dakota State University, Brookings.

Hoagstrom, C. W., J. E. Brooks, and S. R. Davenport. 2011. A large-scale conservation perspective considering endemic fishes of the North American plains. Biological Conservation 144:21-34.

Hoagstrom, C. W. and C. R. Berry Jr. 2006. Island biogeography of native fish faunas among Great Plains drainage basins: basin scale features influence composition. American Fisheries Society Symposium 48:221-264.

Hoagstrom, C. W., S. S. Wall, J. G. Kral, B. G. Blackwell, and C. R. Berry. 2007. Zoogeographic patterns and faunal change of South Dakota fishes. Western North American Naturalist 67:161-184.

Legendre, P. and L. Legendre. 1998. Numerical ecology, second English edition. Elsevier Science B.V., Amsterdam.

Lesica, P. and F. W. Allendorf. 1995. When are peripheral populations valuable for conservation?. Conservation Biology 9:753-760.

Lyons, J. 1992. The length of stream to sample with a towed electrofishing unit when fish species richness is estimated. North American Journal of Fisheries Management 12:198-203.

Martinez, P., T. Chart, M. Trammell, J. Wullschleger, and E. Bergersen. 1994. Fish species composition before and after construction of a main stem reservoir on the White River, Colorado. Environmental Biology of Fishes 40:227-239.

Mayden, R. L. 1987. Faunal exchange between the Niobrara and White river systems of the North American Great Plains. Prairie Naturalist 19:173-176.

Mee, J. A. and L. Rowe. 2010. Distribution of *Phoxinus eos*, *Phoxinus neogaeus*, and their asexually-reproducing hybrids (Pisces: Cyprinidae) in Algonquin Provincial Park, Ontario. PLoS ONE 5.

Meyer, J. L., D. L. Strayer, J. B. Wallace, S. L. Eggert, G. S. Helfman, and N. E. Leonard. 2007. The contribution of headwater streams to biodiversity in river networks. Journal of the American Water Resources Association 43:86-103.

NatureServe. 2012. NatureServe Explorer: An online enyclopedia of life [web application]. Version 7.1. NatureServe, Arlington, Virginia. Available http://www.natureserve.org/explorer. (Accessed Mar. 10, 2013).

Newbrey, M. G. and A. C. Ashworth. 2004. A fossil record of colonization and response of lacustrine fish populations to climate change. Canadian Journal of Fisheries and Aquatic Sciences 61:1807-1816.

Paller, M. H. 1994. Relationships between fish assemblage structure and stream order in South Carolina coastal plain streams. Transactions of the American Fisheries Society 123:150-161.

Parsons, P. A. 1991. Evolutionary rates: stress and species boundaries. Annual Review of Ecology and Systematics 22:1-18.

Pflieger, W. L. 1997. The Fishes of Missouri. Missouri Department of Conservation, Jefferson City.

Power, G., R. S. Brown, and J. G. Imhof. 1999. Groundwater and fish - insights from northern North America. Hydrological Processes 13:401-422.

Pulliam, H. R. 1988. Sources, sinks, and population regulation. The American Naturalist 132:652-661.

Schlosser, I. J. 1991. Stream fish ecology: a landscape perspective. BioScience 41:704-712.

Schlosser, I. J., M. R. Doeringsfeld, J. F. Elder, and L. F. Arzayus. 1998. Niche relationships of clonal and sexual fish in a heterogeneous landscape. Ecology 79:953-968.

Sheldon, A. L. 1988. Conservation of stream fishes: patterns of diversity, rarity, and risk. Conservation Biology 2:149-156.

Smale, M. A. and C. F. Rabeni. 1995. Hypoxia and hyperthermia tolerances of headwater stream fishes. Transactions of the American Fisheries Society 124:698-710.

Sørensen, T. 1948. A method of establishing groups of equal amplitude in plant sociology based on similarity of species content and its application to analyses of the vegetation on Danish commons. Det Kongelige Danske Videnskabernes Selskab, Biologiske Skrifter 5:1-34.

Stasiak, R. 2006. Northern redbelly dace (*Phoxinus eos*): A technical conservation assessment. USDA Forest Service, Rocky Mountain Region. 42 p.

Swinehart, J. B., V. L. Souders, H. M. DeGraw, and R. F. D. Jr. 1985. Cenozoic paloeography of western Nebraska *in* R. M. Flores and S. S. Kapla, editors. Cenozoic Paleographs of the West-Central United States. The Rocky Mountain Section, Society of Economic Paloentoligists and Mineralogists, Denver.

Taylor, C. A., J. H. Knouft, and T. M. Hiland. 2001. Consequences of stream impoundment on fish communities in a small North American drainage. Regulated Rivers: Research and Management 17:687-698.

USDA (United States Department of Agriculture). 2006. Major land resource areas of the United States, the Caribbean, and the Pacific Basin. United State Department of Agriculture Handbook 296. United States Department of Agriculture, Natural Resource Conservation Service, Washington D.C.

Vannote, R. L., G. W. Minshall, K. W. Cummins, J. R. Sedell, and C. E. Cushing. 1980. The river continuum concept. Canadian Journal of Fisheries and Aquatic Sciences 37:130-137.

Zar, J. H. 1984. Biostatistical analysis. Prentice Hall, New Jersey.

Table 2-1. Sørenson's faunal similarity coefficients for hydrologic divisions considered in current study. KP = Keya Paha River, W = White River, LW = Little White River.

	KP tributaries	KP main stem	W tributaries	W main stem	LW tributaries	LW main stem
KP tributaries	1	0.83	0.70	0.52	0.70	0.64
KP main stem		1	0.76	0.59	0.70	0.75
W tributaries			1	0.73	0.62	0.63
W main stem				1	0.42	0.62
LW tributaries					1	0.67
LW main stem						1

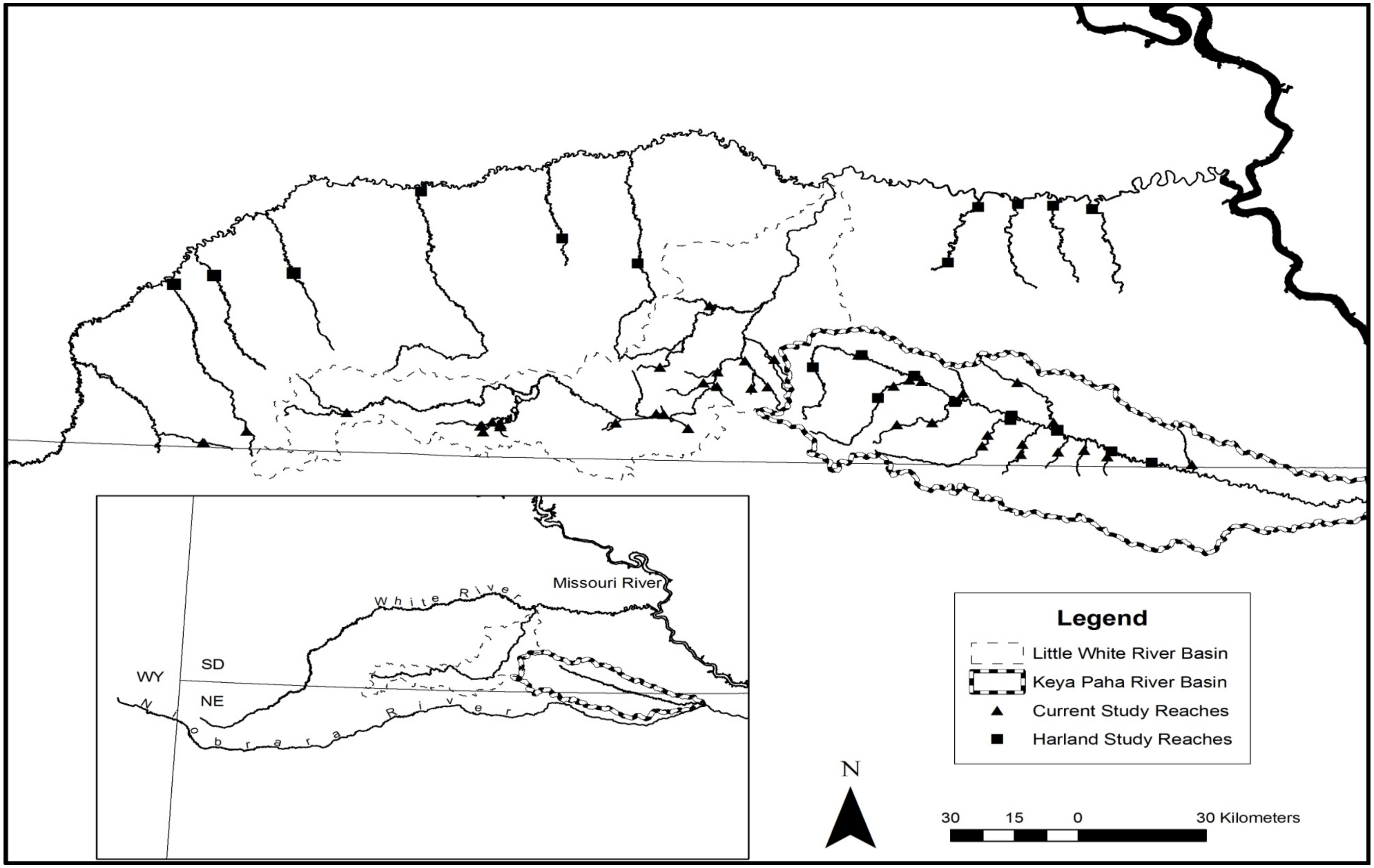

Fig. 2-1. Locations of sample reaches and hydrologic divisions in southwestern South Dakota including reaches sampled by Harland (2003) and during current study.

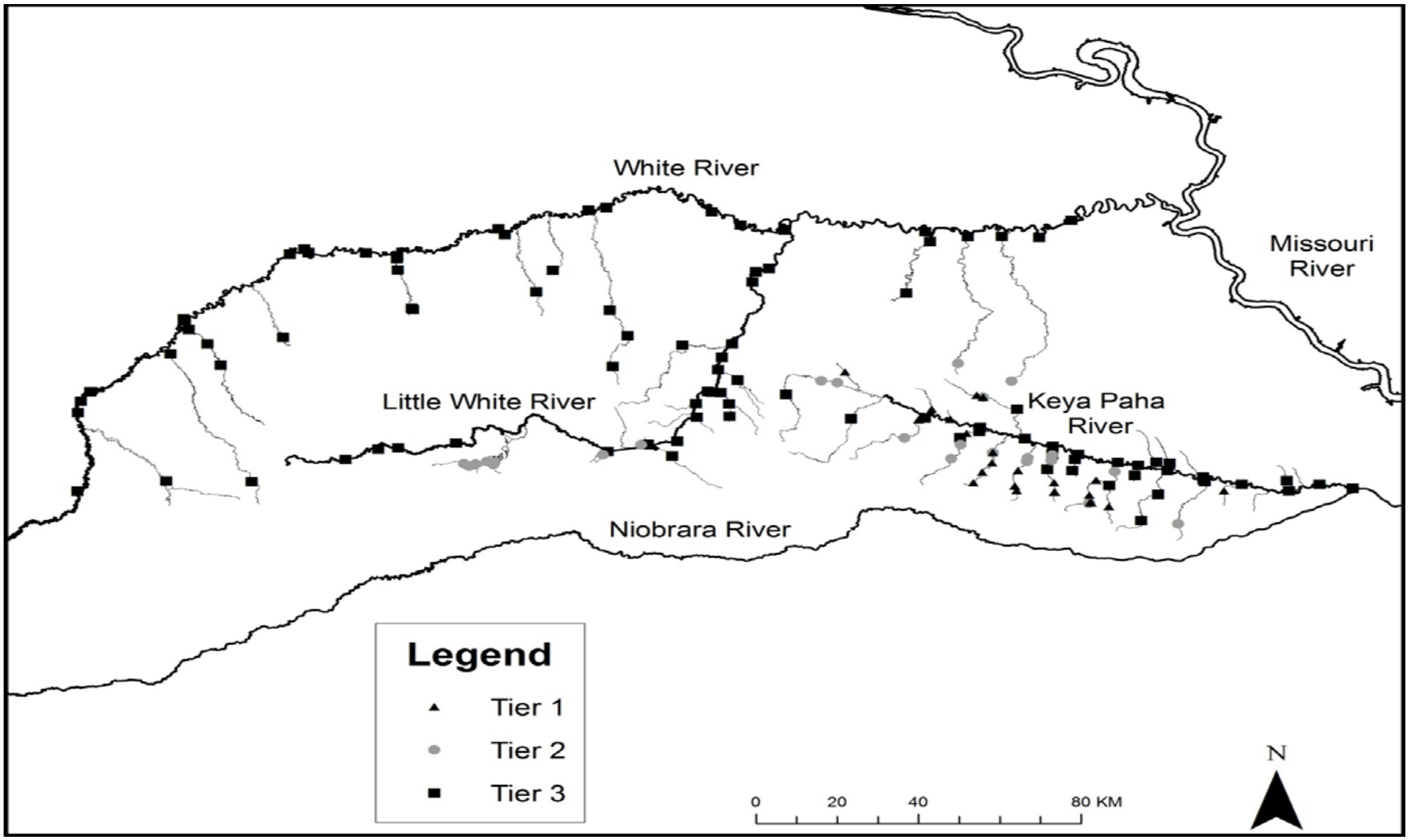

Figure 2-2. Species of greatest conservation need presence/absence within our study area and neighboring and adjoining watersheds in Nebraska. Tier 1 = Northern redbelly dace and/or finescale dace present. Tier 2 = Pearl dace present but no other relict species absent, Tier 3 = no relict species present.

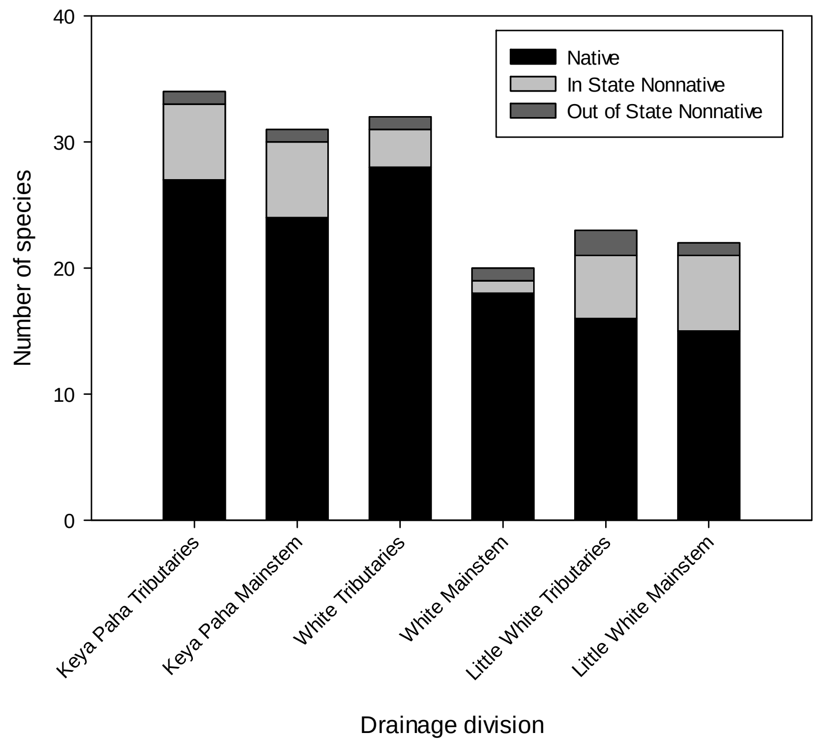

Figure 2-3. Native and nonnative species richness by hydrologic division. Nonnatives are divided into two groups: out of state nonnatives (introduced wherever present) and in state nonnatives (native to some South Dakota river drainages).

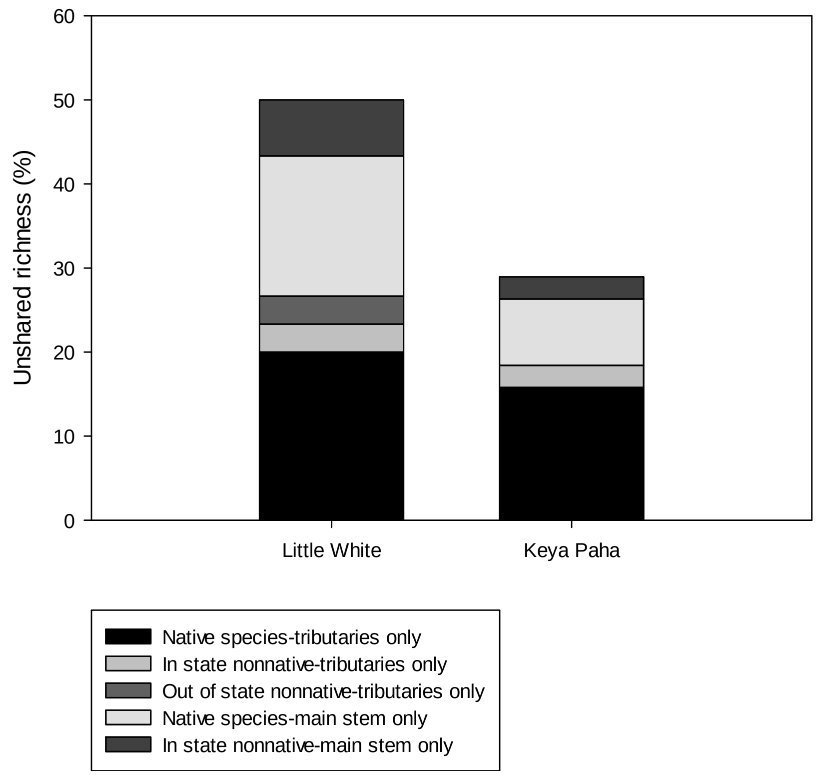

Figure 2-4. Unshared richness between mainstems and their tributary networks in the Little White and Keya Paha river basins.

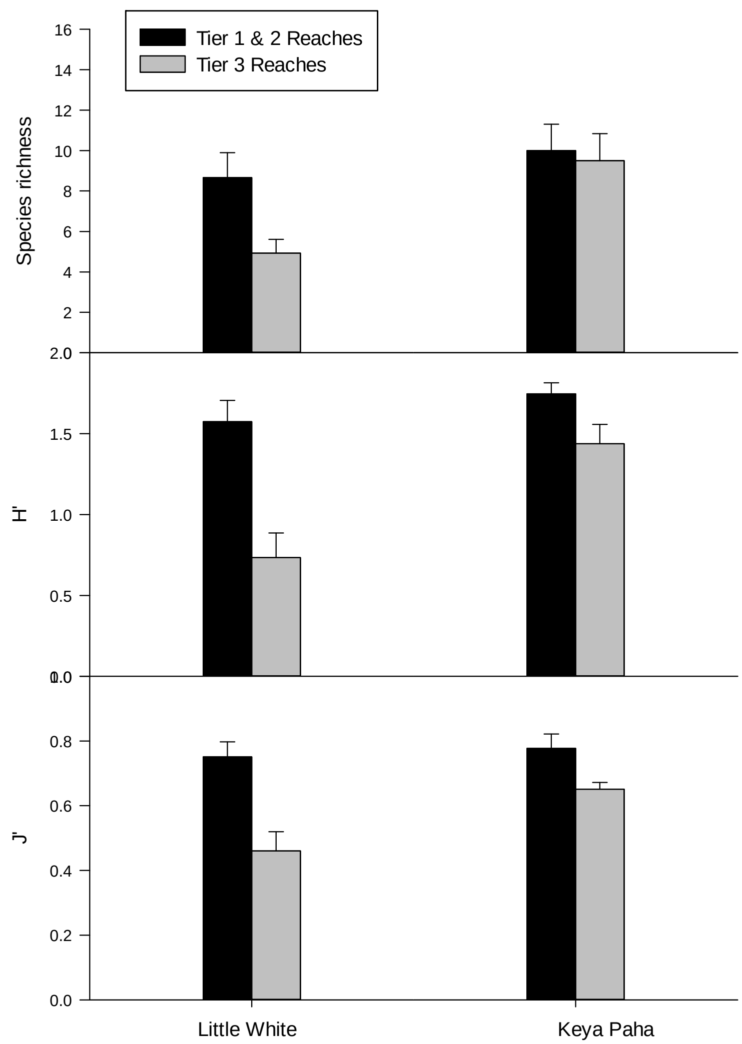

Figure 2-5. Mean species richness, Shannon's diversity (H'), and Shannon's evenness (J') at Tier 1 & 2 reaches versus Tier 3 reaches. Tier 1 = Northern redbelly dace and/or finescale dace present. Tier 2 = Pearl dace present but no other relict species absent, Tier 3 = no relict species present.

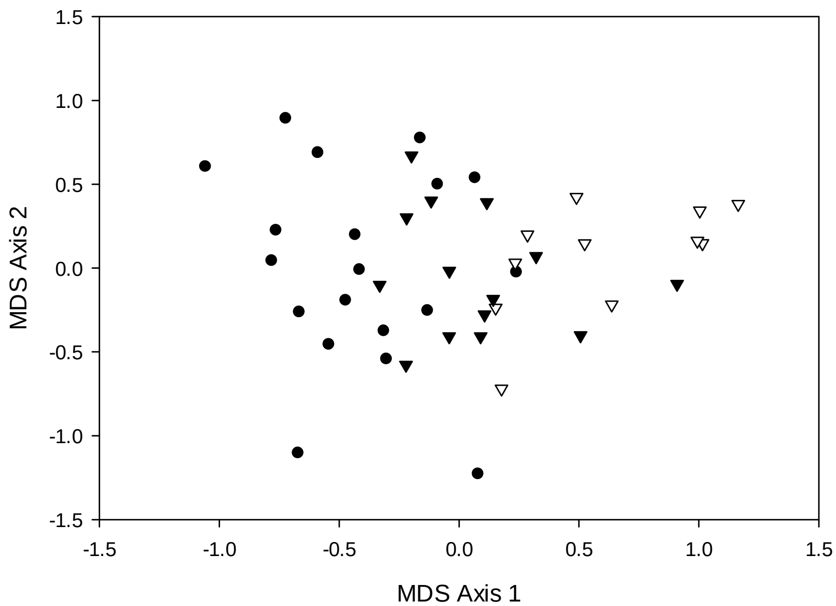

Figure 2-6. Nonmetric multidimensional scaling plot for Little White and Keya Paha river basin reaches. Filled circles indicate Little White River reaches (all tributaries), filled triangles indicate Keya Paha River tributaries, and open triangles indicate Keya Paha River mainstem.

Appendix 2-A. Fish species presence/absence and classifications in the White River, Little White River and their tributaries; n = native species, 1 = out of state nonnative, 2 = in state nonnative, **Bold** = species of greatest conservation need (SDGFP 2006).

	Historical Occurrence				
Family, Species	White River[a]	White River Tributaries[b]	Little White River[c]	Little White Tributaries[d]	% Occurrence (Current Study)
HIODONTIDAE					
Hiodon alosoides	n	n	-	-	-
CYPRINIDAE					
Campostoma anomalum	-	n	-	-	-
Cyprinella lutrensis	n	n	n	-	-
Cyprinus carpio	1	1	-	-	-
Hybognathus argyritis	n	n	n	-	-
Hybognathus hankinsoni	n	n	n	n	42.11
Hybognathus placitus	n	n	-	-	-
Luxilus cornutus	-	n	-	-	-
Macrhybopsis gelida	n	n	n	-	-
Margariscus margarita	-	n	-	n	31.58
Notemigonus crysoleucas	-	n	-	n	21.05
Notropis atherinoides	n	-	-	-	-
Notropis dorsalis	-	-	n	n	36.84
Notropis stramineus	n	n	n	n	21.05
Pimephales promelas	n	n	n	n	63.16
Platygobio gracilis	n	n	n	-	-
Rhinichthys cataractae	n	n	n	n	73.68
Semotilus atromaculatus	n	n	n	n	52.63
CATOSTOMIDAE					
Carpiodes carpio	n	n	-	-	-
Carpiodes cyprinus	-	n	-	-	-
Catostomus commersonii	n	n	n	n	15.79
Moxostoma macrolepidotum	n	n	n	-	-

Appendix 2-A. Continued….

Family, Species	Historical Occurrence				% Occurrence (Current Study)
	White River[a]	White River Tributaries[b]	Little White River[c]	Little White Tributaries[d]	
ICTALURIDAE					
Ameiurus melas	n	n	-	n	42.11
Ictalurus punctatus	n	n	n	n	-
Noturus flavus	n	n	n	n	21.05
Noturus gyrinus	-	n	-	-	-
ESOCIDAE					
Esox lucius	-	2	2	2	5.26
SALMONIDAE					
Oncorhynchus mykiss	-	-	-	1	5.26
Salmo trutta	-	-	1	1	-
FUNDULIDAE					
Fundulus sciadicus	-	n	-	n	52.63
GASTEROSTEIDAE					
Culaea inconstans	-	n	-	n	5.26
CENTRARCHIDAE					
Lepomis cyanellus	n	n	n	n	31.58
Lepomis gibbosus	-	-	-	2	10.53
Lepomis macrochirus	-	2	2	2	31.58
Micropterus salmoides	2	2	2	2	36.84
Pomoxis annularis	-	-	2	-	-
Pomoxis nigromaculatis	-	-	2	-	-
PERCIDAE					
Etheostoma exile	-	-	-	n	26.32
Perca flavescens	-	-	2	2	5.26
Sander canadensis	n	n	-	-	-
Sander vitreus	-	n	-	-	-

[a] Primary sources of fish assemblage data from the mainstem White River were Bailey and Allum (1962), Cunningham et al. (1995), Fryda (2001), and USGS (2002,2003,2008,2009).

[b] Primary sources of fish assemblage data from White River tributaries were Bailey and Allum (1962), Cunningham et al. (1995), Harland (2003), USGS (2002,2003,2004,2008), and the current study.

[c] Primary sources of fish assemblage data from the mainstem Little White River were Bailey and Allum (1962), Cunningham et al. (1995), USFWS (1997), and USGS (2002,2004,2009).

[d] Primary sources of fish assemblage data from Little White River tributaries were Bailey and Allum (1962), Cunningham et al. (1995), USGS (2003), and the current study.

Appendix 2-B. Fish species presence/absence and classifications in the Keya Paha River and its tributaries; n = native species, 1 = out of state nonnative, 2 = in state nonnative, * = records from Nebraska waters only, **Bold** = species of greatest conservation need (SDGFP 2006).

	Historic Occurrence		
Family, Species	Keya Paha River[a]	Keya Paha River Tributaries[b]	% Occurrence (Current Study)
HIODONTIDAE			
Hiodon alosoides	*	-	-
CYPRINIDAE			
Campostoma anomalum	n	n	53.33
Chrosomus eos	-	n	20.00
Chrosomus eos x neogaeus	-	n	-
Chrosomus neogaeus	-	n	-
Cyprinella lutrensis	n	n	20.00
Cyprinus carpio	1	1	33.33
Hybognathus argyritis	n	n	-
Hybognathus hankinsoni	n	n	73.33
Hybognathus placitus	*	-	
Luxilus cornutus	-	n	-
Macrhybopsis storeriana	n	-	-
Margariscus margarita	n	n	33.33
Notropis blennius	*	-	-
Notemigonus crysoleucas	n	n	13.33
Notropis dorsalis	n	n	66.67
Notropis heterolepis	-	n	6.67
Notropis stramineus	n	n	60.00
Pimephales promelas	n	n	80.00
Platygobio gracilis	n	n	6.67
Rhinichthys atratulus	n	n	13.33
Rhinichthys cataractae	n	n	40.00
Rhinichthys obtusus	-	*	
Semotilus atromaculatus	n	n	100.00
CATOSTOMIDAE			
Carpiodes carpio	n	n	-
Carpiodes cyprinus	n	-	13.33
Catostomus commersonii	n	-	66.67
Moxostoma macrolepidotum	n	-	6.67
ICTALURIDAE			
Ameiurus melas	n	n	40.00
Ameirus natalis	-	*	-
Ictalurus punctatus	n	n	26.67
Noturus flavus	n	n	26.67

Appendix 2-B. Continued….

	Historical Occurrence		
Family, Species	Keya Paha River[a]	Keya Paha River Tributaries[b]	% Occurrence (Current Study)
ESOCIDAE			
Esox lucius	2	2	6.67
FUNDULIDAE			
Fundulus sciadicus	n	n	73.33
GASTEROSTEIDAE			
Culaea inconstans	-	*	-
CENTRARCHIDAE			
Lepomis cyanellus	n	n	73.33
Lepomis gibbosus	-	2	-
Lepomis macrochirus	2	2	46.67
Micropterus salmoides	2	2	33.33
Pomoxis annularis	2	-	6.67
Pomoxis nigromaculatis	2	2	-
PERCIDAE			
Etheostoma exile	n	n	60.00
Etheostoma nigrum	-	n	-
Perca flavescens	2	2	13.33

[a] Primary sources of fish assemblage data for the mainstem Keya Paha River were Cunningham et al. (1995), Harland (2003), and the current study.

[b] Primary sources of fish assemblage data from Keya Paha River tributaries were Bailey and Allum (1962), NGPC(Personal Communication), Cunningham et al. (1995), Harland (2003), and the current study.

Chapter 3: Age-structured assessment of pearl dace *Margariscus margarita* in four southwestern South Dakota streams

Abstract

Environmental changes and altered biotic communities have contributed to extirpations and declines in local abundance of many native North American freshwater fishes during the last century. The mechanisms driving population declines can be tied to one of the three dynamic rate functions that regulate fish abundance and biomass (i.e., recruitment, growth, mortality). Research often focuses on distribution and abundance patterns of native non-game fishes, but investigations of population characteristics are relatively uncommon. We investigated how age structure and condition of pearl dace *Margariscus margarita* varied among four tributary streams in southwestern South Dakota and how age structure changed over time in these streams. Pearl dace populations were primarily composed of age-1 and age-2 individuals, and the oldest fish were estimated to be four years old. We found considerable differences in growth and condition between populations. Slow growth rates were associated with low condition, suggesting differences in food supply as the cause of variable growth rates among tributary streams. We documented synchrony in year-class strength, and also observed temporal change in age structure concurrent with local habitat changes. Our results indicated that beaver ponds may act as reproductive sources for pearl dace. Overall, our results indicated that pearl dace growth and condition varied between populations within southwestern South Dakota, mortality rates may be influenced by local habitat, and recruitment were affected by both broad and local processes. Thus, although relative abundance was similar among populations, our study revealed meaningful differences in

population rate functions, underscoring the importance of age structure analysis for conservation management.

Introduction

Habitat degradation, overexploitation, and negative interactions with introduced species have contributed to extirpations and declines of many North American freshwater fishes throughout their range during the last century (Miller et al. 1989; Williams et al. 1989; Jelks et al. 2008). Specifically, each of these factors negatively affects one or more of the dynamic rate functions (i.e., recruitment, growth, and mortality) that regulate fish abundance and biomass (Allen and Hightower 2010). In lotic environments, processes that operate on multiple spatial scales, such as hydrologic variability and spatial arrangement of habitats also influence fish populations (Vannote et al. 1980; Schlosser 1991; Fausch et al. 2002). Non-game research is often focused on species occurrence and abundance patterns, but understanding the variability of fish population dynamics within a riverscape is valuable for conservation managers as it elucidates the mechanisms underlying temporal trends in abundance, identifying undesirable environments and distinguishing source and sink populations (*sensu* Pulliam et al. 1988). For instance, Falke et al. (2010) studied variability of brassy minnow *Hybognathus hankinsoni* recruitment, growth and survival in different habitats of the Arikaree River, Colorado and used this information to forecast the effects of groundwater pumping and climate change on brassy minnow populations.

Pearl dace *Margariscus margarita* is federally secure (G5, Natureserve 2012), but receives protected status (S3, state threatened) in South Dakota (SDGFP 2006), where it is relict of Pleistocene Glaciation and is disjunct from the northern core of its distribution

(Cross 1970). Isolated populations are often considered conservation priorities, and may also exhibit biological differences when compared to core populations (Hardie and Hutchings 2010). A few studies documented presence/absence and abundance of pearl dace in South Dakota (Bailey and Allum 1962; Cunningham et al. 1995), but none of these studies investigated pearl dace age or growth in South Dakota. Some information has been published on pearl dace age and growth. Loch (1969) and Cunningham (1995) documented faster growth rates in Canada and Nebraska than Fava and Tsai (1974) observed in Maryland and Stasiak (1978) recorded in a different Nebraska stream, indicating range wide variation in pearl dace growth rates. However, each of these studies occurred at a single sample reach within a region and did not assess temporal trends. To our knowledge, neither intraregional variability nor temporal trends of pearl dace recruitment, growth and mortality have been investigated. Specific objectives of this study were to: (1) estimate and compare age structure, growth, and condition of pearl dace populations within and among river basins in southwestern South Dakota, and (2) use size structure as an index of age structure to assess temporal variation in pearl dace mortality and recruitment in South Dakota streams.

Study Area

We sampled five tributary streams within the Little White and Keya Paha river basins, South Dakota (Figure 3-1), in which we encountered pearl dace at high relative abundance during 2010 and 2011 surveys. In the Little White River basin we visited one sample reach on each of three streams: Elm Creek, Lake Creek and Lake Creek Tributary. In the Keya Paha River basin we visited one sample reach on each of two streams: Willow Creek and Shadley Creek. All sample streams were first or second order springfed perennial tributaries. Mean wetted width (1.8 – 4.1 m), depth (0.19 – 0.37 m), and water velocity (0.13 – 0.42 m/s) were similar among the five streams.

Methods

Fish collection.-Fishes were collected using a backpack electorifisher during a single pass in an upstream direction (ETS ABP-3-300). Two netters collected stunned fish with dip nets. During August 2010 and May through August 2011 all individuals were measured (mm TL) and released. During April 2012, we collected up to 50 individuals at four sample reaches (Lake, Elm, Shadley, and Willow) for age structure analysis. Fish were euthanized with an overdose of tricaine methane sulfonate (MS-222) and preserved in 95% ethanol.

Laboratory.- Fish were measured (mm total length; (TL), and weighed (0.1 g). We determined sex for each individual. Saggital otoliths were removed, dried and mounted in super glue. We polished mounted otoliths using wetted 1000 grit sandpaper. Two readers examined otoliths and independently estimated ages. Estimates were compared and disagreements were re-examined until a consensus was reached. All analysis was conducted using consensus ages.

Growth.- We calculated mean length-at-age separately for each reach during April 2012. We used an analysis of variance (ANOVA) to first test the null hypothesis that there were no differences in mean length-at-age between sexes within populations. Second, we used ANOVA to test the null hypothesis that there were no differences in mean length-at-age among populations; if we found differences between sexes within a population they were analyzed separately. If differences were detected, we used Tukey's honestly significant difference (HSD) test for multiple comparisons to assess differences among population means.

Condition.- We quantified condition using Fulton's condition factor (K) for each reach during April 2012. We tested for length-related trends within populations by performing an ANOVA among mean K for 25-mm length groups, starting at 45 mm, and considered comparisons significant at $\alpha = 0.05$. For populations with no significant length-related bias we used an ANOVA to test the null hypothesis of no differences in mean K between sexes. If we found no within population bias in K we used an ANOVA to test the null hypothesis of no significant differences in mean K among populations. We then used Tukey's HSD test to assess differences among population means.

Size structure.- We constructed relative length-frequency histograms (5 mm groups) across years for all sample reaches. Size structure was considered as an index of age structure, and we assigned age classes to length-frequency modes based on mean length-at-age estimates obtained from age structure analysis. This analysis was used to assess recruitment variability, mortality and age structure changes related to habitat dynamics.

Results

Growth and condition

Growth was similar between sexes but varied greatly among pearl dace populations. In Willow Creek age-2 males had significantly lower mean length (mean ± SE) than females ($F_{1,22} = 5.14$, $P = 0.03$); all other comparisons of mean length-at-age between sexes were nonsignificant at $\alpha = 0.05$. Growth was significantly different among populations at all ages (age-1 ANOVA: $F_{3,69} = 24.87$, $P < 0.0001$; age-2 ANOVA: $F_{4,78}$

= 49.08, $P < 0.0001$; age-3 ANOVA: $F_{2,21} = 5.27$. $P = 0.0139$). Based on Tukey's HSD, growth in Lake Creek and Willow Creek was faster than all other populations at all ages (Table 3-1, Figure 3-2). Growth was slower in Elm Creek when compared with Lake Creek and Willow Creek, and in Shadley Creek growth was the slowest among the four populations (Table 3-1, Figure 3-2).

Condition was similar among length groups and between sexes in all populations, and we concluded that there was no within population trends in condition. We found significant differences in condition among the four reaches sampled during April 2012 (ANOVA: $F_{3,\,180} = 16.63$, $P < 0.0001$). Based on Tukey's HSD tests, pearl dace condition (mean K ± SE) was higher in Lake Creek (0.819 ± 0.002) and Willow Creek (0.821 ± 0.002) than in Shadley Creek (0.705 ± 0.003) and Elm Creek (0.730 ± 0.014).

Age structure

All populations were primarily composed of two age groups, ages 1 and 2 (Figure 3-3). The oldest fish we collected were estimated to be 4 years old and maximum total length was 134 mm. The sex ratio was more even at ages 1 and 2 as compared to age 3, which was skewed towards females, and when compared with age-4 fish which were exclusively female (Figure 3-3). Age-2 individuals were most abundant in three of four sample reaches during 2012 (Figure 3-3). Age-1 individuals were encountered most frequently during 2011 surveys at the same three sample reaches (Figure 3-4).

Shadley Creek and Elm Creek samples displayed relatively truncated pearl dace age structures when compared to other sample reaches (Figure 3-4). Elm Creek samples contained a high proportion of age-1 individuals during both 2011 and 2012, although older individuals (> age 1) were more abundant during 2012. Shadley Creek pearl dace age structure was dominated by older fish (> age 1) during 2011 but contained almost exclusively age-1 fish during 2012 (Figure 3-4).

We observed temporal change in age structure at Lake Creek Tributary during a time when habitat changed due to beaver *Castor canadensis* pond succession (Figure 3-4). During 2010 beavers were still actively maintaining a pond within our sample reach and we observed relatively high frequency of four age classes (Figure 3-3). Beavers abandoned the pond by 2011 when we observed a relatively truncated size structure with few individuals larger than 100 mm. By April 2012 there was no remaining beaver pond habitat and we did not detect pearl dace at Lake Creek Tributary.

Discussion

Each of our sample populations displayed similar abundance patterns, but growth and condition varied significantly among populations. Our results suggest that pearl dace recruitment, growth and mortality varied among sample reaches and through time in southwestern South Dakota. Here, we highlight the implications of the observed variability and compare relict pearl dace populations to others described throughout their range.

Growth and condition

Pearl dace populations exhibited differences in growth and condition which may influence mortality rates. Populations in higher condition (i.e., Willow Creek and Lake Creek) also grew significantly faster than those in lower condition (i.e., Shadley Creek and Elm Creek). Similar relationships between growth and condition have been documented for largemouth bass *Micropterus salmoides* (Wege and Anderson 1978), northern pike *Esox lucius* (Willis and Scalet 1989), yellow perch *Perca flavescens* (Willis et al. 1991) and black crappie *Pomoxis nigromaculatus* (Guy and Willis 1995). Reduced condition indicates lower energy reserves (Goede and Barton 1990) and can be related to food supply (Marwitz and Hubert 1997), temperature (Cui and Wootton 1988), or changes in metabolism resulting from stress (Barton and Schreck 1987; Bergstedt and Bergersen 1997). We observed low variability in temperature among our study reaches and thus suspect that variation in food supply is the most likely explanation for differences in condition and growth among sample reaches.

Fish assemblage data from sample reaches suggest competition as a possible mechanism behind variable growth rates. We observed the highest overall relative abundance (all species pooled) and the highest creek chub *Semotilus atromaculatus* relative abundance at Shadley Creek (Figure 3-5). Pearl dace and creek chub feed on aquatic macroinvertebrates and zooplankton (McPhail and Lindesy 1970; Stasiak 1978; Tallman and Gee 1982, Pflieger 1997), creating the potential for diet overlap between these species. We also encountered large creek chubs (> 200 mm TL) which are commonly piscivorous (Pflieger 1997). Thus, creek chub predation at Shadley Creek may also contribute to the high pearl dace mortality.

Growth rates in our sample reaches appear to be fast for pearl dace. After the first year of growth, Fava and Tsai (1974) and Stasiak (1978) did not report any annual growth increments greater than 15 mm, whereas we observed annual growth of greater than 25 mm in both Lake Creek and Willow Creek. Cunningham (1995) reported intermediate growth rates (~ 17 mm during the second year of growth) in a Nebraska population of pearl dace. Scott and Crossman (1973) reported a maximum length of 155 mm from an Ontario population of pearl dace suggesting either faster growth rates or greater longevity. Our slowest growing populations were still comparable to other populations described throughout the pearl dace distribution, but variation in growth and condition may influence mortality rates.

In reaches with slower growth and lower condition, young age classes (ages 1 and 2) were most abundant, and we did not encounter any age-4 individuals. This result may indicate high mortality rates or size-specific segregation within riverscapes (Fausch et al. 2002). Our patterns are likely explained by variable mortality rates among older fish. For example, we observed a relatively high frequency of older age groups (> age-1) at Shadley Creek during 2011, but almost exclusively age-1 during 2012. Similarly, older age groups were present in Elm Creek, but individuals older than age 2 were quite rare (4 %) in our samples. Furthermore, we encountered fish from the entire range of observed ages at other sample reaches. Thus, there was little evidence of age-specific habitat segregation in our populations. Pearl dace is a small-bodied, brightly colored fish which is vulnerable to predation from a number of organisms; mortality rates may vary as a result of differential predation pressure.

Age structure

Modes in length-frequency histograms are often used to distinguish year classes, and this method tends to work best for the youngest two or three age classes (Isley and Grabowski 2007). In our length-frequency distributions for 2012, modes corresponded to mean length-at-age from age estimates. Thus, assuming growth was constant across years, size structure trends across years reflected age structure trends (Neumann and Allen 2007).

Sex ratio and age structure in our study area were similar to reports from other pearl dace populations (Fava and Tsai 1974; Stasiak 1978; Cunningham 1995). Age-1 and age-2 fish tend to dominate most populations and are composed equally of males and females (Fava and Tsai 1974; Stasiak 1978). The sex ratio of age-3 fish was skewed heavily toward females in Nebraska and Maryland (Fava and Tsai 1974; Stasiak 1978), and we observed a similar pattern in Lake Creek. We encountered very few age-3 individuals at other sample reaches. This pattern indicates that males experience higher mortality rates than females after age 2, although mortality is high for both sexes after age 2.

Year-class strength appeared to be synchronous among many of our streams as four of five streams displayed a large year class produced during 2010. Pearl dace spawning is cued by temperature and photoperiod and typically occurs during late April and early May in the Nebraska Sandhills (Langlois 1929, Fava and Tsai 1974, Cunningham 1995). Timing of spring water temperature rise varies annually depending on spring rainfall (Cunningham 1995; Cunningham 2006). High rainfall during early spring cues spawning by rapidly increasing water temperature, whereas years with reduced spring rainfall can result in little or no spawning activity (Cunningham 1995). March and April precipitation were well above long-term averages during 2010 and below long-term averages for the same months during 2011 (Figure 3-5), supporting the hypothesis that high spring rainfall increases pearl dace recruitment success.

Results from Lake Creek Tributary and the adjacent Lake Creek support Schlosser's (1995) suggestion that beaver ponds act as reproductive sources (*sensu* Pulliam 1988) for stream fishes. During 2010, Lake Creek Tributary contained a large, actively maintained beaver pond that supported a high abundance (> 2.5 fish/m^2) of pearl dace from a broad size range. By 2011, when beavers had apparently abandoned their dam, abundance decreased (< 1 fish/m^2) and size structure decreased. At the same time in nearby Lake Creek, we observed a high frequency (> 20 %) of small individuals (< 70 mm) and the size classes that had disappeared from Lake Creek Tributary. By 2012, the beaver pond had completely disappeared. We did not detect a single pearl dace in Lake Creek Tributary in Spring 2012, and the frequency of small individuals in Lake Creek had decreased (< 10 %). Although reproduction likely occurs in Lake Creek, the loss of nearby beaver pond habitat may have decreased year-class strength and subsequent abundance.

Pearl dace population demographics varied among streams within and among river basins in southwestern South Dakota. Pearl dace studies throughout their range indicate differences in size structure suggesting variable growth rates or longevity, but our results are the first to report intraregional variability in pearl dace growth and condition. Slow growth rates were associated with lower Fulton's condition factor, indicating that differences in food supply influenced growth rates, and may have contributed to increased mortality rates. Our results also suggest recruitment synchrony among pearl dace populations related to early spring rainfall. Furthermore, we provide evidence that beaver ponds act as reproductive sources for pearl dace. Source-sink dynamics may be important in maintaining pearl dace populations within riverscapes, so it is important to understand the spatial arrangement of pearl dace populations, and the variability of population dynamics within riverscapes.

Literature Cited

Allen, M. S. and J. E. Hightower. 2010. Fish population dynamics: mortality, growth, and recruitment.Pages 43-77 *in* W. A. Hubert and M. C. Quist, editors. Inland fisheries management in North America. American Fisheries Society, Bethesda.

Bailey, R. M. and M. O. Allum. 1962. Fishes of South Dakota. Museum of Zoology, University of Michigan, Ann Arbor.

Barton, B. A. and C. B. Schreck. 1987. Metabolic cost of acute physical stress in juvenile steelhead. Transactions of the American Fisheries Society 116:257-263.

Bergstedt, L. C. and E. P. Bergersen. 1997. Health and movements of fish in response to sediment sluicing in the Wind River, Wyoming. Canadian Journal of Fisheries & Aquatic Sciences 54:312-319.

Cross, F. B. 1970. Fishes as indicators of Pleistocene and recent environments in the Great Plains. Pages 241-257 *in* W. Dort Jr. and J.K. June Jr. editors. Pleistocene and recent environments of the cenral Great Plains. University of Kansas Press, Lawrence.

Cui, Y. and R. J. Wootton. 1988. Effects of ration, temperature and body size on the body composition, energy content and condition of the minnow, Phoxinus phoxinus (L.). Journal of Fish Biology 32:749-764.

Cunningham, G. R. 1995. Life history traits and reproductive ecology of the pearl dace, Margariscus margarita (Pisces: Cyprinidae) in the Sandhills of Nebraska. M.A. Thesis. The University of Nebraska-Omaha, Ohama, NE.

Cunningham, G. R., R. D. Olson, and S. M. Hickey. 1995. Fish surveys of the streams and rivers in south central South Dakota west of the Missouri River. Proceedings of the South Dakota Academy of Science 74:55-64.

Cunningham, G. R. 2006. Pearl dace (*Margariscus margarita*): A technical conservation assessment. USDA Forest Service, Rocky Mountain Region. 44 p.

Falke, J. A.,K. R. Bestgen, and K. D. Fausch. 2010. Streamflow reductions and habitat drying affect growth, survival, and recruitment of brassy minnow across a Great Plains riverscape. Transactions of the American Fisheries Society 139: 156-1583.

Fausch, K. D., C. E. Torgersen, C. V. Baxter, and H. W. Li. 2002. Landscapes to riverscapes: bridging the gap between research and conservation of stream fishes. BioScience 52:483-498.

Fava, J. A., Jr. and C. Tsai. 1974. The life history of the pearl dace, *Semotilus margarita*, in Maryland. Chesapeake Science 15:159-162.

Goede, R. W. and B. A. Barton. 1990. Organismic indices and an autopsy-based assessment as indicators of health and condition of fish. American Fisheries Society Symposium 8:93-108.

Guy, C. S. and D. W. Willis. 1995. Population characteristics of black crappies in South Dakota waters: a case for ecosystem specific management. North American Journal of Fisheries Management 15:754-765.

Hardie, D. C., and J. A. Hutchings. 2010. Evolutionary ecology at the extremes of species' ranges. Enrionmental Reviews 18: 1-20.

Isley, J. J., and T. B. Grabowski. Age and growth. Pages 187-228 *in* C.S. Guy and M.L. Brown, editors. Analysis and Interpretation of Freshwater Fisheries Data. American Fisheries Society, Bethesda

Jelks, H. L., S. J. Walsh, N. M. Burkhead, S. Contreras-Balderas, E. Diaz-Pardo, D. A. Hendrickson, J. Lyons, N. E. Mandrak, F. McCormick, J. S. Nelson, S. P. Platania, B. A. Porter, C. B. Renaud, J. J. Schmitter-Soto, E. B. Taylor, and M. L. Warren. 2008. Conservation status of imperiled North American freshwater and diadromous fishes. Fisheries 33:372-407.

Langlois, T. H. 1929. Breeding habits of the northern dace. Ecology 10: 161-163.

Loch, J. S. 1969. A description and general biology of the northern pearl dace, *Semotilus margarita nachtriebi* with an introductory discussion of taxonomic principles. Master's thesis. University of Toronto, Toronto, Ontario.

Marwitz, T. D., and W. A. Hubert. 1997. Trends in relative weight of walleye stocks in Wyoming reservoirs. North American Journal of Fisheries Management 17: 44-53.

McPhail, J. D., and C. C. Lindsey. 1970. Freshwater fishes of Northwestern Canada and Alaska. Bulletin 173, Fisheries Research Board Canada, Ottawa.

Miller, R. R., J. D. Williams, and J. E. Williams. 1989. Extinctions of North American fishes during the past century. Fisheries 14:22-38.

NatureServe. 2012. NatureServe Explorer: An online enyclopedia of life [web application]. Version 7.1. NatureServe, Arlington, Virginia. Available http://www.natureserve.org/explorer. (Accessed Mar. 10, 2013).

Neumann, R. M., and M. S. Allen. Size structure. Pages 375-421 *in* C.S. Guy and M.L. Brown, editors. Analysis and Interpretation of Freshwater Fisheries Data. American Fisheries Society, Bethesda.

Pflieger, W. L. 1997. The Fishes of Missouri. Missouri Department of Conservation, Jefferson City.

Pulliam, R. H. 1988. Sources, sinks, and population regulation. The American Naturalist. 5: 652-661.

Schlosser, I. J. 1991. Stream fish ecology: A landscape perspective. BioScience 41:704-712.

Schlosser, I. J. 1995. Dispersal, boundary processes, and trophic-level interactions in streams adjacent to beaver ponds. Ecology 76: 908-925.

Scott, W. B., and E. J. Crossman. 1973. Freshwater fishes of Canada. Fisheries Research Board of Canada, Ottawa, Ontario, Canada.

SDGFP (South Dakota Department of Game, Fish, and Parks). 2006. South Dakota Comprehensive Wildlife Conservation Plan. SDGFP, Wildlife Division Report 2006-2008, Pierre.

Stasiak, R. H. 1978. Food, Age and growth of the pearl dace, *Semotilus margarita*, in Nebraska. American Midland Naturalist 100:463-466.

Tallman, R. F., and J. H. Gee. 1982. Intraspecific resource partitioning in a headwaters stream fish, the pearl dace, *Semotilus margarita* (Cope). Environmental Biology of Fishes 7: 243-249.

Vannote, R. L., G. W. Minshall, K. W. Cummins, J. R. Sedell, and C. E. Cushing. 1980. The river continuum concept. Canadian Journal of Fisheries and Aquatic Sciences 37:130-137.

Wege, G. J. and R. O. Anderson. 1978. Relative weight (Wr): a new index of condition for largemouth bass. Pages 79-91 *in* G. D. Novinger and J. G. Dillard, editors. New approaches to the management of small impoundments. American Fisheries Society, Bethesda, Maryland.

Williams, J. E., J. E. Johnson, D. A. Hendrickson, S. Contreras-Balderas, J. D. Williams, M. Navarro-Mendoza, D. E. McAllister, and J. E. Deacon. 1989. Fishes of North America endangered, threatened, or of special concern: 1989. Fisheries 14:2-20.

Willis, D. W. and C. G. Scalet. 1989. Relation between proportional stock density and growth and condition of northern pike populations. North American Journal of Fisheries Management 9:488-492.

Willis, D. W., C. S. Guy, and B. R. Murphy. 1991. Development and evaluation of a standard weight (W_s) equation for yellow perch. North American Journal of Fisheries Management 11: 374-380.

Table 3-1. Mean length-at-age (TL mm) and annual growth increments among four South Dakota pearl dace populations in 2012.

	Lake Creek				Elm Creek			
	Male		Female		Male		Female	
Age	Mean TL (mm ± SE)	Increment (mm)	Mean TL (mm ± SE)	Increment (mm)	Mean TL (mm ± SE)	Increment (mm)	Mean TL (mm ± SE)	Increment (mm)
1	62.0 ± 1.6	62.0	60.2 ± 1.2	60.2	56.4 ± 0.9	56.4	59.1 ± 1.7	59.1
2	90.3 ± 2.7	28.3	95.2 ± 1.7	35.0	74.3 ± 2.1	17.9	72.0 ± 1.5	12.9
3	110.5 ± 4.5	20.2	112.1 ± 2.6	16.9	98.0 ± 2	23.7	81.0	9.0
4	---	---	128	15.9	---	---	---	---

	Willow Creek				Shadley Creek			
	Male		Female		Male		Female	
Age	Mean TL (mm ± SE)	Increment (mm)	Mean TL (mm ± SE)	Increment (mm)	Mean TL (mm ± SE)	Increment (mm)	Mean TL (mm ± SE)	Increment (mm)
1	63.0 ± 2.0	63.0	63.8 ± 1.5	63.8	53.5 ± 0.9	53.5	52.9 ± 0.9	52.9
2	91.3 ± 1.7	28.3	97.3 ± 1.7	33.5	60.5 ± 0.5	7.0	62.7 ± 1.9	9.8
3	107.0	15.7	109.0 ± 6.0	11.7	78	17.5	---	---
4	---	---	134.0	25	---	---	---	---

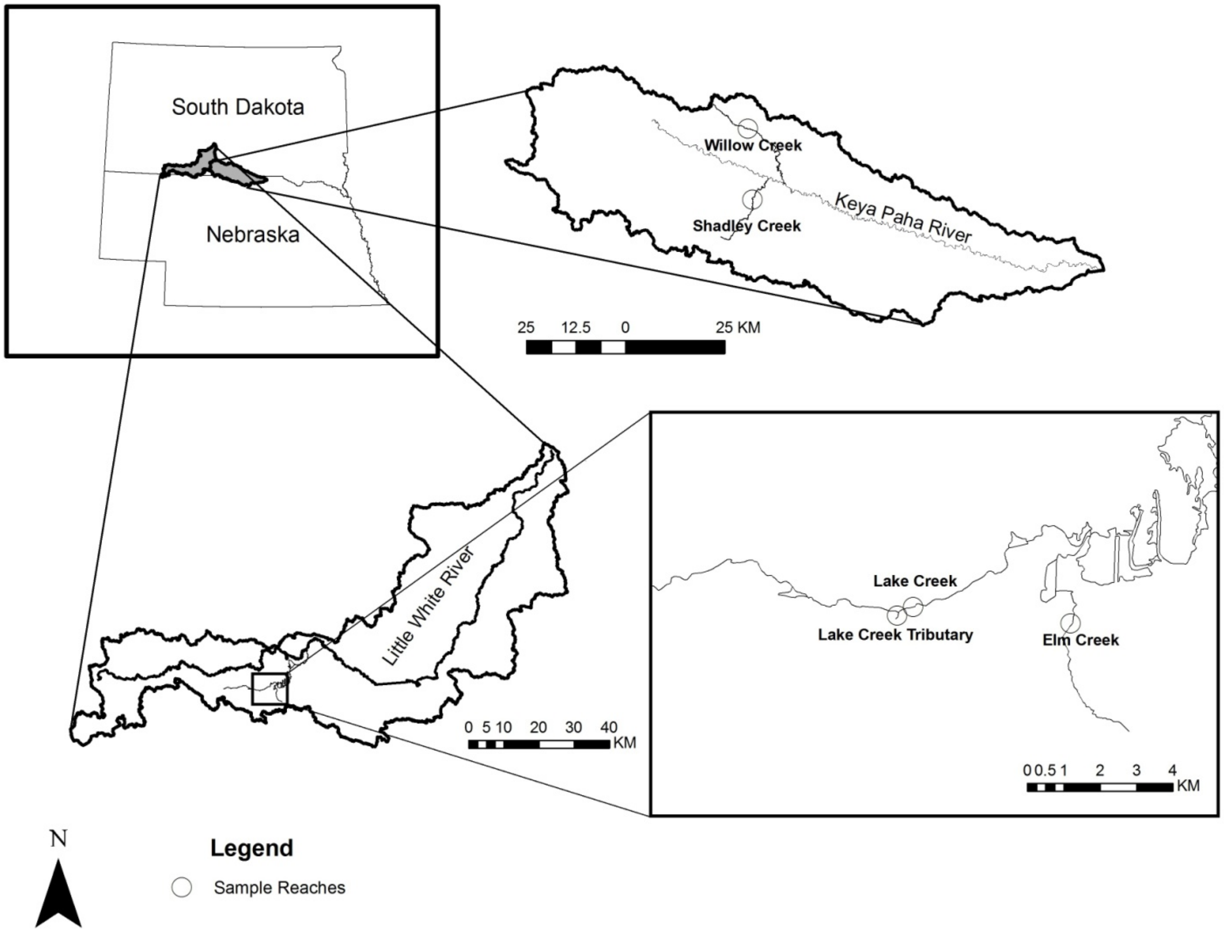

Figure 3-1. Map of study area and sample reaches in the Little White and Keya Paha river basins, visited 2010-2012.

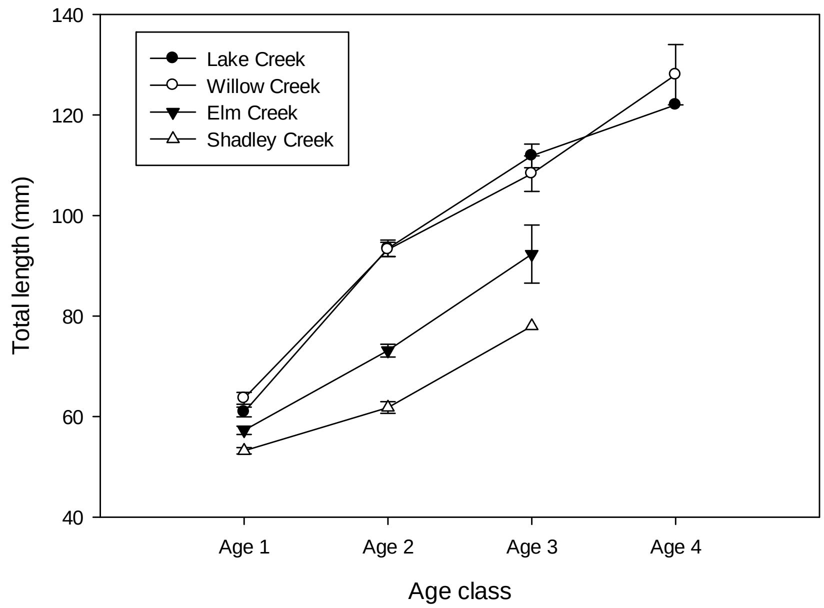

Figure 3-2. Mean length-at-age (± 1 SE) for pearl dace sampled from four South Dakota populations during 2012.

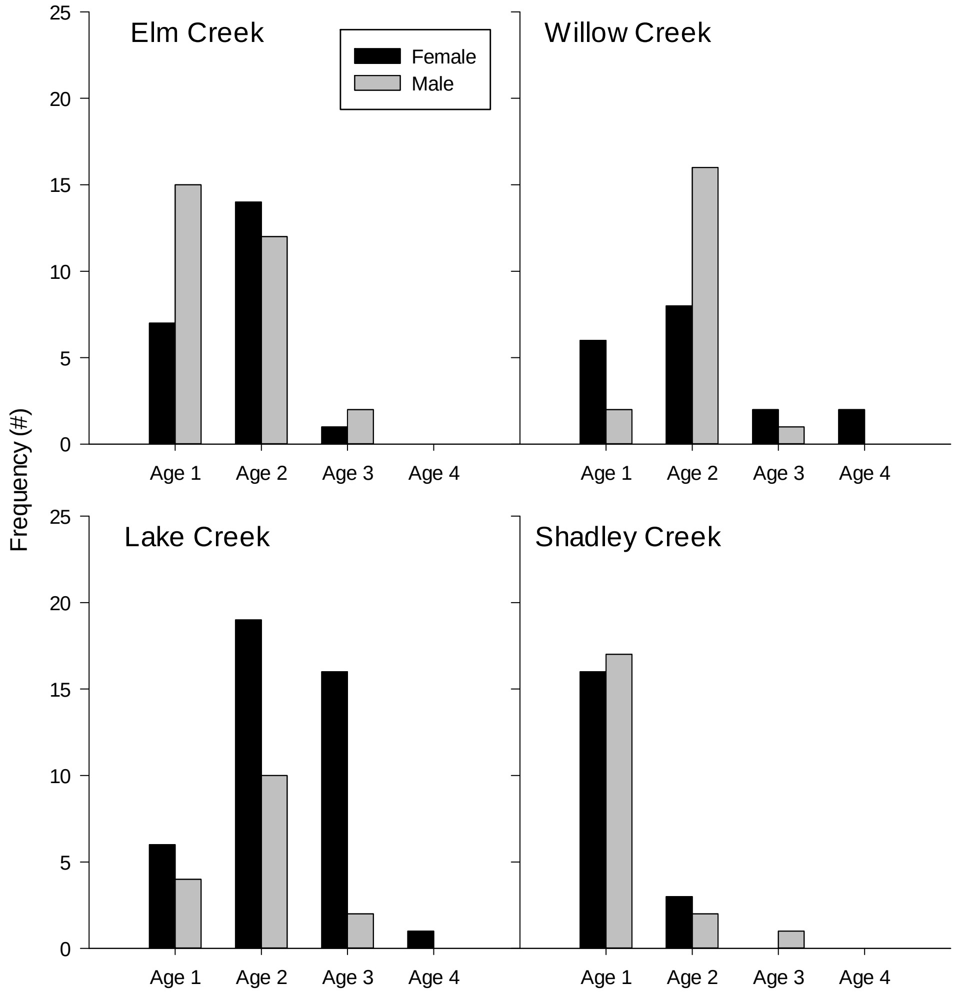

Figure 3-3. Sex ratio and age composition for four South Dakota pearl dace populations sampled during 2012.

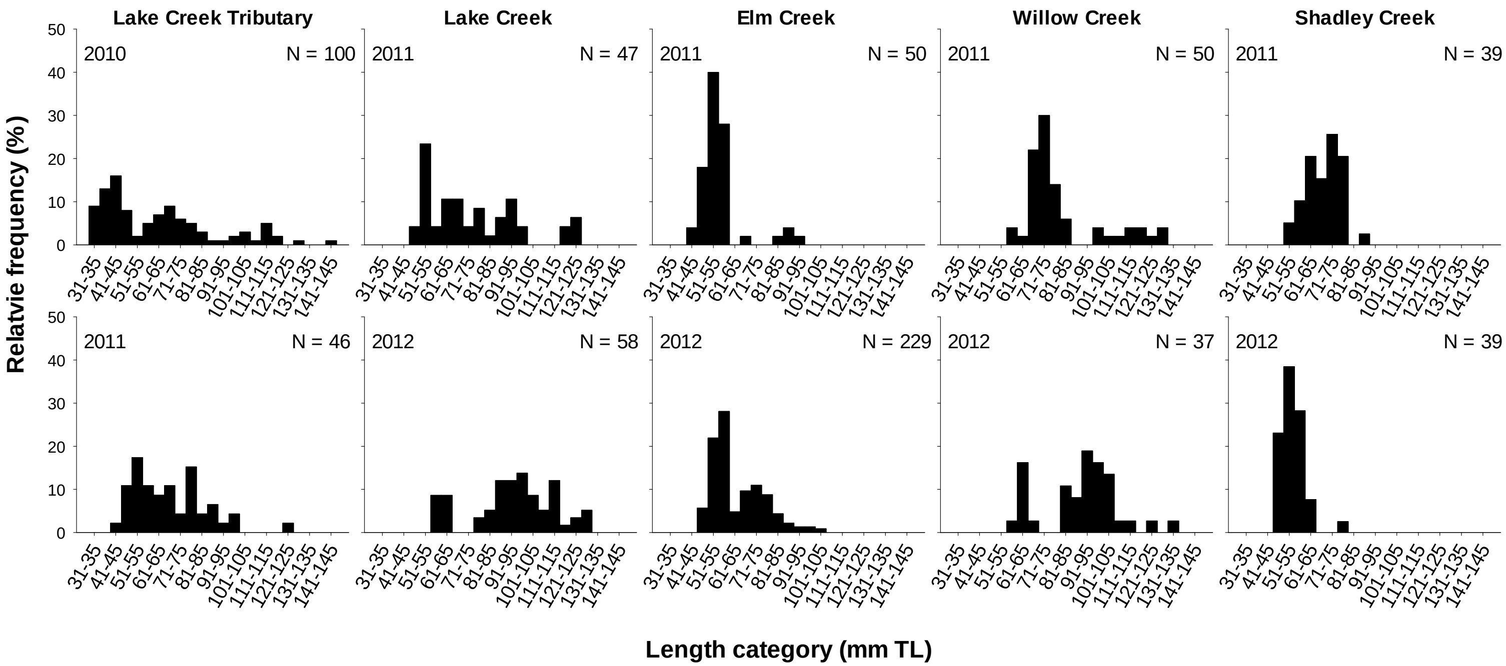

Figure 3-4. Size structure trends illustrated by relative length frequency histograms across time for pearl dace sampled in each of five reaches within the Little White and Keya Paha river basins sampled from 2010 to 2012. Rows represent years, and columns represent sample reaches.

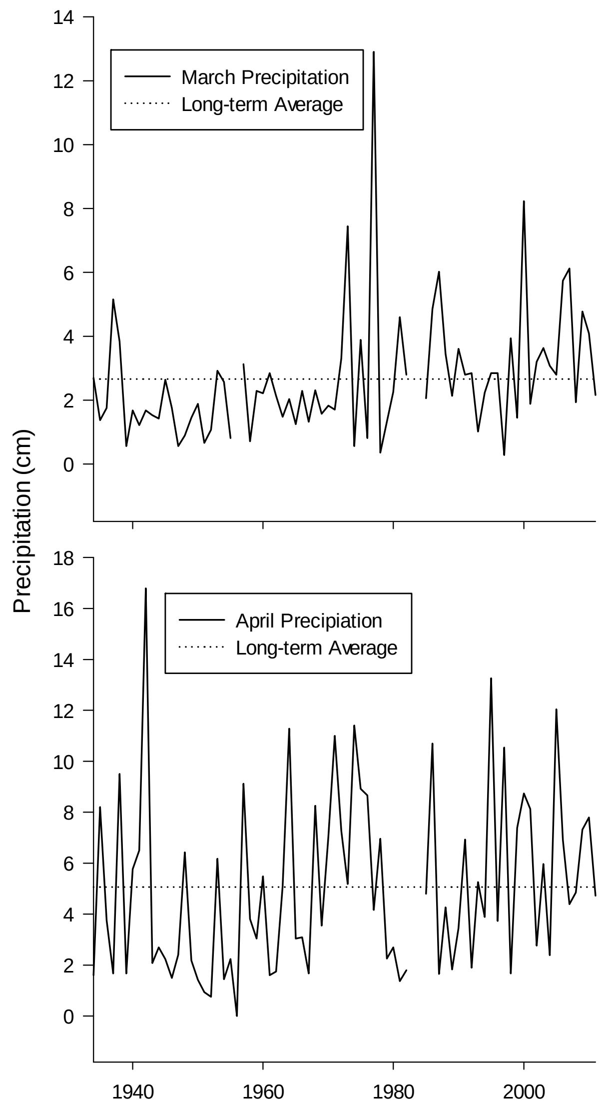

Figure 3-5. Monthly precipitation in Martin, South Dakota during March and April 1934-2011.

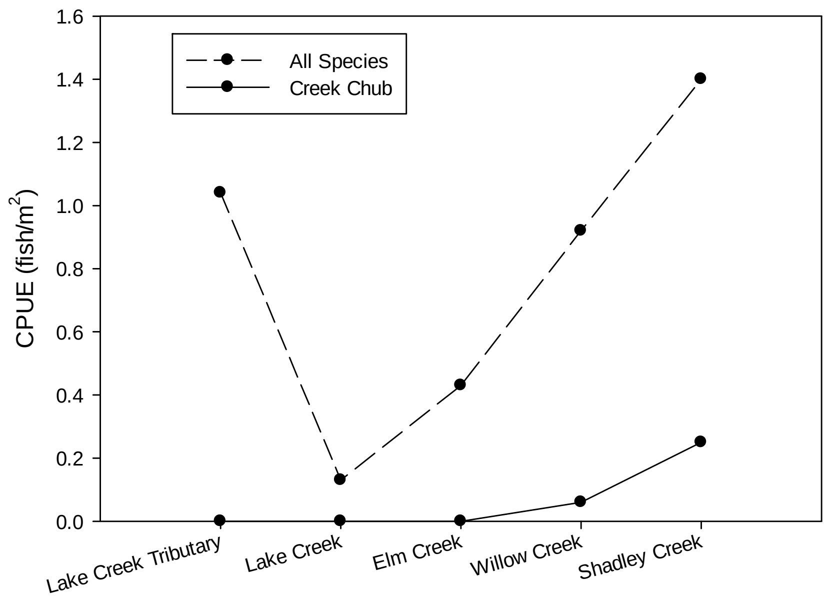

Figure 3-6. Catch per unit effort (fish/m^2) from 2011 surveys of all species (dashed line) and creek chub (solid line) at sample reaches considered in pearl dace age structure analysis.