Status of Native Stream Fishes within Selected Protected Areas of the Niobrara River in Western Nebraska

Jonathan J. Spurgeon, Richard H. Stasiak, George R. Cunningham,
Kevin L. Pope, and Mark A. Pegg

ABSTRACT—Lotic systems within the Great Plains are characterized by highly fluctuating conditions through both space and time. Fishes inhabiting these systems have adopted specific life-history strategies to survive in such environments; however, anthropogenic disturbance to prairie streams has resulted in declines and extirpation of many native stream fishes. Terrestrial protected areas (i.e., parks and reserves) are designated to support native flora and fauna and, it is assumed, to provide protection to native fishes. We assessed the presence and relative abundance of stream fish populations within protected areas along the Niobrara River in western Nebraska based on data collected during 1979, 1989, 2008, and 2011. The spatial extent of protection, landscape changes resulting in degraded physiochemical parameters, and introduced species may reduce the effectiveness of these terrestrial protected areas in protecting native fishes in Great Plains stream environments.

Key Words: prairie, streams, protected areas, non-native, diversity

Introduction

Prairie streams and rivers by their very nature are extreme environments characterized by seasonal and annual fluctuating conditions (Matthews 1988; Dodds et al. 2004). For instance, seasonality in rainfall and evapotranspiration results in potentially extreme intra-annual variability of a stream's flow regime. High flows and flooding, resulting from melting snowpack and spring rains, are often followed by periods of extreme low flows and desiccation. Seasonal climate patterns also produce large fluctuations in water temperatures. However, extremes in the physicochemical environment of prairie streams are often predictable over annual cycles, and stream biota have adapted to variation in climate driven variability (Matthews 1988).

Fishes inhabiting stream environments have evolved specific strategies to live in such dynamic conditions (Matthews et al. 1988). Modes of adaptation can be summarized by behavioral, physical, and life-history changes (Lytle and Poff 2004). Behavioral strategies of stream fishes include the ability to adjust to changing flow conditions and to seek refuge in low-flow areas during floods and in permanent pools during droughts (Magoulick and Kobza 2003). In addition to behavioral changes, fishes must possess the physiological tolerance to handle extremes in abiotic conditions including temperature and oxygen (Matthews et al. 1988). Finally, some stream fishes have evolved life-history strategies to maximize recruitment of young through broadcast spawning, thereby allowing larvae to drift to suitable habitats downstream (Perkin and Gido 2011).

Long-term stability of stream fish assemblages results from a combination of predictability of environmental variability and the adaptability to deal with this variability. However, anthropogenic disturbance has altered the long-term predictability of prairie stream and river environments, reducing both the resistance and resilience of resident fish communities. For instance, water withdrawals exacerbate stream drying, thus eliminating potential refuge environments, and dams and diversions decrease connectivity and limit the potential

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for recolonization (Dodds et al. 2004; Falke et al. 2011). Introduced species have further impacted prairie fishes through predation and competition (Gido et al. 2004). As a result of these stressors, prairie stream fishes are in decline (Gido et al. 2010).

Conservation of prairie habitats and the subsequent protection of the streams and rivers flowing through them will become increasingly important as future changes in climate occur and demand for water and energy resources increases (Dodds et al. 2004). Protected areas may have the ability to maintain native species diversity and curb the impacts of anthropogenic alteration on freshwater habitats (Saunders et al. 2002; Abell et al. 2007; Lawrence et al. 2011). Freshwater environments, including streams, are presumed protected because they are included within a terrestrial protected area (Saunders et al. 2002). However, aquatic environments may need additional protection at larger spatial scales than current terrestrial reserves permit (Herbert et al. 2010). Little is known concerning the extent to which prairie streams and their native fish communities are protected through inclusion by terrestrial reserve networks.

The Niobrara River flows across the Great Plains, extending 692 km from its headwaters in Wyoming to its confluence with the Missouri River. The Niobrara River flows through several protected areas in western Nebraska, including the Agate Fossil Beds National Monument, The Nature Conservancy's Cherry Ranch, and the Prairie Plains Resource Institute's Guadalcanal Memorial Prairie and Ranch. These protected areas were established to conserve historic artifacts and native flora and fauna. Due to the lack of large-scale anthropogenic alteration (e.g., impoundments and channelization), native fish communities within these areas are expected also to be afforded some level of protection. However, native fish populations in the Niobrara River in and around these protected areas may be susceptible to decline due to the increased demand for water resources and the threat of invasion by non-native fishes (e.g., rainbow trout [*Onchorhynchus mykiss*], brown trout [*Salmo trutta*], largemouth bass [*Micropterus salmoides*], bluegill [*Lepomis macrochirus*], and northern pike [*Esox lucius*]) from both upstream and downstream locations similar to many Great Plains rivers (Dodds et al. 2004). The purpose of this paper is to highlight potential areas in need of active management as well as areas where native fish communities require continued protection. Therefore, we assessed the presence and relative abundance of stream fish populations within protected areas along the Niobrara River in western Nebraska based on data collected during distinct sampling periods in 1979, 1989, 2008, and 2011.

Methods

Fish Community

We used fish data collected from 1979 and 1989 (Stasiak 1990), 2008 (Pegg and Pope 2008), and 2011 (Stasiak et al. 2011) to assess long-term changes in fish community structure within Agate Fossil Beds National Monument (AGFO) and at the two upstream protected areas: The Nature Conservancy's Cherry Ranch (TNC-CR) (n = 3 sites) and the Prairie Plains Resource Institute's Guadalcanal Memorial Prairie and Ranch (GMPR) (n = 1 site) (Fig. 1). Sample sites in June 2008 and 2011 were primarily identified based on Stasiak (1990) to assist in documenting site-specific changes in species presence over time. The sample sites also corresponded closely with the National Park Service's Heartland Inventory and Monitoring Network sites within AGFO. During the 1979, 1989, and 2011 sampling years at least 100 m long reaches were seined (2.5 × 1.5 m straight seine and 4 × 1.5 m bag seine; both with 6 mm bar mesh) at approximately the same locations (with the addition of four sampling locations in June 2011). Collections continued at each site until at least five successive hauls did not reveal new species. In June 2008 an additional survey was conducted at AGFO using backpack electrofishing (Smith-Root-Model 15, pulsed-DC, 300 V output voltage, 70 Hz ["J" setting on control], and 4 ms pulses). A minimum of 150 m were sampled across the 10 sampling sites at AGFO, where sampling was conducted moving upstream, exposing the shoreline and underwater structures to the electrical field generated by the electrofisher when engaged. While sampling, at least two netters were used in addition to the person carrying the electrofisher; block-nets were not used. Collected fishes were held in aerated buckets before processing. Across all survey periods, fishes were identified to species using both sight identification and reference material (Pflieger 1997), counted, and released.

Physical Stream Characteristics

We summarized physiochemical measurements obtained in 2008 (Pegg and Pope 2008) and 2011 (Stasiak et al. 2011). Single static physiochemical characteristics

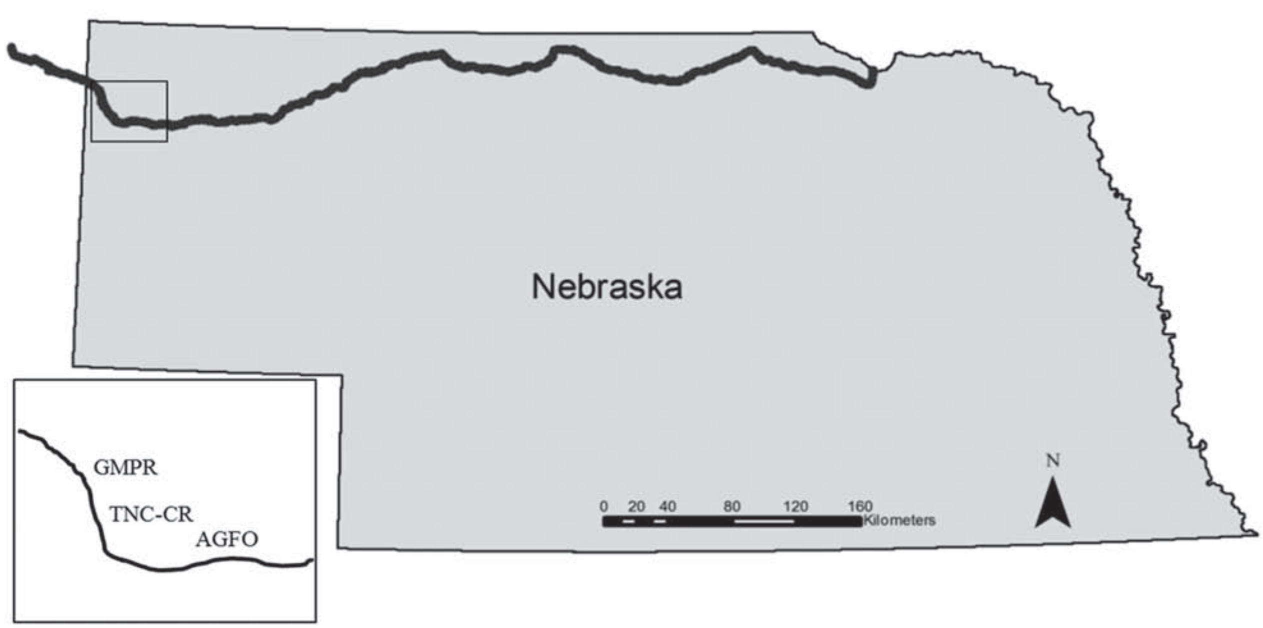

FIGURE 1. Approximate location of sample sites including Agate Fossil Beds National Monument (AGFO), The Nature Conservancy's Cherry Ranch (TNC-CR), and Guadalcanal Memorial Prairie and Ranch (GMPR) along the Niobrara River in northwestern Nebraska, USA.

of each site were measured, georeferenced, and recorded at the time of fish collections, which occurred throughout the day. Parameters included location, stream width (m), water depth (m), water velocity (m/s), water conductivity (μS/cm), turbidity (NTU), and dissolved oxygen (DO) concentration (mg/l). Water velocities were measured at the thalweg (0.6 × total depth) and reflect maximum velocity at a sample site. In 2008, stream width was measured with a measuring tape, depth was measured using a wading rod, and water quality was taken using a YSI-85 and a Hach turbidimeter. In 2011, temperature, pH, and total dissolved solids (TDS) were measured using a Yellow Springs Instruments #55 oxygen meter; current velocity was measured using a Global Water FP101 Global Flow velocity meter. Depth and stream width were estimated in 2011. Habitat assessment methods followed stream sampling procedures outlined in Bain and Stevenson (1999).

Results

Fish Community

A total of nine species representing five families were surveyed at AGFO in 1979 (n = 7 species) and 1989 (n = 8 species). In June 2008, electrofishing surveys documented a 77% decline in species richness, with only two species, native white sucker (*Catostomus commersoni*) and non-native northern pike, being collected. Similar to 2008, the June 2011 survey also showed a similar decline in species richness, with only three species being collected. In addition to white sucker and northern pike, green sunfish (*Lepomis cyanellus)* was collected in 2011 (Table 1). At TNC-CR, 10 unique native species, including both Tier I and II species classified by the Natural Heritage Program of the Nebraska Game and Parks Commission, were collected in June 2011 (Table 2). In comparison, only three species were collected at GMPR; however, this may be a consequence of only one site being sampled at this location (Table 2).

Physical Stream Characteristics

In June 2008 DO concentrations were <5.0 mg/l (Table 3) and were often below concentrations required by species native to the Niobrara River within AGFO (Table 4). Additional samples of DO at sunrise and sunset were collected by Pegg and Pope (2008) within and outside AGFO, and similarly low levels were recorded over a large spatial extent ranging from the Wyoming-Nebraska state line to locations downstream of AGFO; sunset samples were higher than sunrise samples. Subsequent samples in October 2008 indicated DO levels had improved (>10 mg/l). Low DO levels were again recorded in June 2011, which were similar to those in June

TABLE 1. Counts of individual fish species collected from the Niobrara River at Agate Fossil Beds National Monument

Species	1979[a]	1989	2008	2011
Brassy minnow (*Hybognathus hankinsoni*)	44 (37%)	29 (4.7%)	0	0
Central stoneroller (*Campostoma anomalum*)	6 (5.5%)	25 (4.0%)	0	0
Creek chub (*Semotilus atromaculatus*)	36 (33.3%)	273 (44.2%)	0	0
Fathead minnow (*Pimephales promelas*)	10 (9.3%)	128 (20.7%)	0	0
Longnose dace (*Rhinichthys cataractae*)	0	4 (0.6%)	0	0
White sucker (*Catostomus commersoni*)	9 (8.3%)	153 (24.8%)	6 (50%)	37 (54.4%)
Iowa darter (*Etheostoma exile*)	1 (0.9%)	0	0	0
Plains topminnow (*Fundulus sciadicus*)	0	3 (0.4%)	0	0
Brown trout (*Salmo trutta*)[b]	2 (1.8%)	4 (0.6%)	0	0
Northern pike (*Esox lucius*)[b]	0	0	6 (50%)	29 (42.6%)
Green sunfish (*Lepomis cyanellus*)	0	0	0	2 (2.9%)

Notes: Count data were collected in 1979 and 1989 by Stasiak (1990), during 2008 by Pegg and Pope (2008), and in 2011 by Stasiak et al. (2011). Parentheses beside count data in the year columns indicate percentages of total catch for each species.
[a]Only two sites were collected in 1979.
[b]Species not native to the upper Niobrara River drainage.

TABLE 2. Presence of individual species collected from Niobrara River upstream of Agate Fossil Beds National Monument at The Nature Conservancy's Cherry Ranch and the Prairie Plains Resource Institute's Guadalcanal Memorial Prairie and Ranch in 2011

Species	Cherry Ranch	Guadalcanal Memorial Prairie
Creek chub (*Semotilus atromaculatus*)	x	x
Fathead minnow (*Pimephales promelas*)	x	
Finescale dace (*Chrosomus neogaeus*)*	x	x
Northern pearl dace (*Margariscus nachtriebi*)	x	
Chrosomus hybrid (*C. neogaeus* × *C. eos*)	x	
Central stoneroller (*Campostoma anomalum*)	x	
Longnose dace (*Rhinichthys cataractae*)	x	
Brassy minnow (*Hybognathus hankinsoni*)	x	
White sucker (*Catostomus commersonii*)	x	x
Plains topminnow (*Fundulus sciadicus*)	x	

*Nebraska Game and Parks Commission Heritage Program Tier I or II species

2008, suggesting a temporal pattern to low DO levels during summer months. During fish collections in June 2008 turbidity ranged from 1.14 to 10.4 NTU, conductivity ranged from 373 to 402 μS/cm, velocity ranged from 0.03 to 0.36 m/s, depth ranged from 41 to 71 cm, and channel width ranged from 1.8 to 4.3 m. During fish collections in June 2011, pH ranged from 7.50 to 8.50, TDS ranged from 174 to 1300 ppm, and velocity ranged from near 0 to 0.65 m/s.

Discussion

The native fish community has markedly declined in the Niobrara River within AGFO. An array of factors may be attributed to this decline. The introduction of non-native species for recreational purposes has a long and extensive history within the Niobrara River. A total of 387,923 northern pike were stocked in Box Butte Reservoir, downstream of AGFO, between 1949 and 1985

TABLE 3. Static temperature and dissolved oxygen readings for selected sampling sites in the Niobrara River within and near Agate Fossil Beds National Monument

Site	Latitude (°)	Longitude (°)	Temperature (°C)	Dissolved oxygen (mg/l)
2008				
1	42.42560	−103.72848	20.6	4.7
2	42.42282	−103.72901	18.1	3.4
3	42.41840	−103.74488	17.7	3.2
4	42.41923	−103.74521	18.0	2.8
5	42.41903	−103.75473	18.7	3.1
6	42.41546	−103.75548	21.3	5.4
7	42.41504	−103.75791	21.3	5.7
8	42.41545	−103.75872	20.4	5.1
9	42.41550	−103.76038	19.1	4.3
10	42.42097	−103.79077	21.8	6.7
11	42.42054	−103.77918	21.1	9.5
2011				
1	42.42921	−103.71545	21.4	4.79
2	42.42831	−103.72576	24.3	6.78
3	42.42749	−103.72972	20.3	3.37
4	42.42467	−103.72972	19.8	3.63
5	42.42167	−103.74612	19.7	3.11
6	42.42093	−103.75540	24.4	4.88
7	42.41713	−103.75869	19.9	5.58
8	42.42443	−103.78679	21.0	3.61
9	42.42326	−103.79116	18.3	6.80
10	42.42737	−103.80298	27.0	7.95
11	42.45125	−103.83430	25.8	8.13
12	42.45467	−103.83510	26.0	7.36

Note: Sampling measurements were recorded by Pegg and Pope (2008) and Stasiak et al. (2011).

(Nebraska Game and Parks Commission, unpublished data). Upstream dispersal to other portions of the Niobrara River has likely occurred and may be the source of fishes within AGFO. Biotic interactions between introduced and native fishes may explain the decline in species within AGFO. For instance, the establishment of northern pike, a non-native predator, may have contributed to the observed declines in the native fish community. Northern pike are known to reduce and even eliminate species when they are introduced and become established (He and Kitchell 1990). Compared to AGFO, a relatively diverse native fish community was observed within the Niobrara River at TNC-CR. Unlike the AGFO segment of the Niobrara River, non-native predators were absent from both the TNC-CR and GMPR segments, presumably from a large low-head control structure preventing upstream migration. Although diversity of fishes at GMPR was similar to AGFO ($n = 3$ species), all these species were native as compared to the presence of non-native species at AGFO. Additionally, more sampling effort (i.e., more than the one sample that was done in this study) in this reach is needed and may reveal a greater diversity in species. The lack of non-native predators within these river segments may explain the greater abundance and diversity of native fishes compared to AGFO.

Physicochemical stressors also may partly explain the observed declines in native fishes in the Niobrara

TABLE 4. Minimum dissolved oxygen (DO) concentrations for each species historically and currently found in the Niobrara River at Agate Fossil Beds National Monument

Species common name	**Species scientific name**	**Lower lethal limit (mg/l)**	**Source**
Brassy minnow	*Hybognathus hankinsoni*	2.1*	Ostrand and Wilde 2001
Brown trout	*Salmo trutta*	3.0	Doudoroff and Shumway 1970
Central stoneroller	*Campostoma anomalum*	2.3	Hlohowskyj and Chagnon 1991
Creek chub	*Semotilus atromaculatus*	2.4	Starrett 1950
Fathead minnow	*Pimephales promelas*	1.0	Bennett et al. 1995
Iowa darter	*Etheostoma exile*	1.7*	Hancock and Sublette 1958
Northern pike	*Esox lucius*	1.5	Casselman 1978
Plains topminnow	*Fundulus sciadicus*	<1.6	Smale and Rabeni 1995
White sucker	*Catastomus commersoni*	2.4	Dence 1948

Note: The lower lethal limit is the published DO concentration at which each species cannot survive for an indefinite period of time.

*Information from species in same genus.

River. Although concentrations of DO below minimum thresholds that cause stress (<5 mg/l) and mortality (<3 mg/l) were observed during summer months, our physiochemical dataset is limited in both spatial and temporal scale (Stickney and Kohler 1990). However, Boyles et al. (2013) found a shift to more tolerant invertebrate taxa (e.g., Chironomidae and Amphipoda) and a decline in more sensitive invertebrate families (e.g., Ephemeroptera, Plecoptera, and Trichoptera). Increases in physiochemical parameters including temperature and sediment and decreases in stream flow and dissolved oxygen were reported as potential contributors to changes in the invertebrate community in the Niobrara River within AGFO (Boyles et al. 2013). Although native stream fishes have evolved in highly variable environments characterized by fluctuating diel temperature and DO concentrations (Dodds et al. 2004), these fluctuations typically do not exceed stress and mortality limits in unaltered systems. Dense vegetation was observed along the shoreline throughout much of AGFO as well as at other sites where water quality was measured. Oxygen demands associated with decomposition of plant material from this vegetation may explain the low DO levels throughout the study area, which could influence species diversity (Pollock et al. 2007). However, species diversity remained consistent in areas outside AGFO that had heavy vegetation cover but lacked northern pike (e.g., TNC-CR). Northern pike are more tolerant of low DO levels (Casselman 1978) and may be well suited to withstand potentially degraded conditions compared to the native fish community, further exacerbating the combined impact of both physiochemical and biotic perturbation. Additionally, the presence of both in-stream and riparian vegetation may contribute to greater survival of northern pike at multiple life stages. Northern pike is a phytophillic spawner, and the dense in-stream vegetation provides abundant habitat for egg laying and protection to young. Similarly, dense stands of riparian vegetation may provide cover for adults and reduce predation from avian and mammalian predators. Therefore, a synergistic relationship between dense vegetation stands and non-native predators may exist in the Niobrara River within AGFO. A greater understanding of the temporal and spatial extent of habitat quality (i.e., the combination of biological and physiochemical parameters) is needed to target potential locations precluding immigration of fishes from source populations that may limit reestablishment of species within the Niobrara River. For instance, within AGFO, the high abundance of northern pike and periods of low water quality may prevent reestablishment of the native fish community.

Within AGFO, stream restoration and protection of the native fish community may still be possible. For instance, Stasiak et al. (2011) proposed a method for rehabilitating the river segment within AGFO through removal of non-native fishes and subsequent translocation of native fishes. Translocation of freshwater fishes is increasingly used to redistribute species across their historical range, and in some cases this approach has been successful (Mueller and Wydoski 2004), albeit the success can be limited (Minckley 1995). For example, hatchery-reared individuals often do poorly compared with wild stock (George et al. 2009), and inadequate removal of non-native species prior to translocation has been cited as a primary reason for failure to reestablish native fish populations (Harig et al. 2000). The native species diversity in the Niobrara River within TNC-CR may serve as an important source population for both natural dispersal and potential translocation efforts to areas of this river having lower diversity. Continued protection of TNC-CR to ensure an intact fish community is present, and non-native species control within the AGFO reach is needed.

Prairie stream fishes depend on multiple spatial scales to carry out their life-history strategies and recover in the highly dynamic environments where they live (Falke and Fausch 2010; Falke et al. 2012; Perkin and Gido 2012). As a result, management focusing on discrete locations within a riverscape may be inadequate because processes are occurring over larger spatial scales (Fausch et al. 2002; Lowe et al. 2006). Therefore, individual reserves may not adequately conserve species diversity within the Niobrara River. Rather, protection at larger spatial scales (e.g., regional networks of reserves) may be needed, as well as protection of watersheds beyond reserve boundaries and upstream reaches (Long et al. 2012). Enhancement of the size and distribution of protected areas throughout the Great Plains region is needed to increase redundancy of protected area and the associated fish fauna (Herbert et al. 2010). At a national scale, protected areas within the National Park Service may protect a substantial proportion of native freshwater fish biodiversity (Lawrence et al. 2011; Long et al. 2012). However, at a smaller scale within the Great Plains, the paucity of protected areas, with the intention of protecting freshwater resources, may leave stream fishes unprotected from urban and agricultural development as well as from the spread of invasive species. Future assessments of the fish community within the upper Niobrara River should include temporal and spatial aspects of the biotic community as well as abiotic factors that may influence species distributions and population dynamics. Successful collaboration among stakeholders across the prairie landscape will be necessary to facilitate future conservation and rehabilitation efforts (Miller et al. 2012).

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Jonathan J. Spurgeon, School of Natural Resources, University of Nebraska–Lincoln, Lincoln NE 68583, Jonathan.Spurgeon@huskers.unl.edu

Richard H. Stasiak, Department of Biology, University of Nebraska at Omaha, Omaha NE 66182

George R. Cunningham, Department of Biology, University of Nebraska at Omaha, Omaha NE 66182

Kevin L. Pope, US Geological Survey–Nebraska Cooperative Fish and Wildlife Research Unit, and School of Natural Resources, University of Nebraska–Lincoln, Lincoln NE 68583

Mark A. Pegg, School of Natural Resources, University of Nebraska–Lincoln, Lincoln NE 68583

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