Spring 6-30-2015

The Status of Fishes in the Missouri River, Nebraska: Emerald Shiner (*Notropis atherinoides*), Red Shiner (*Cyprinella lutrensis*), River Shiner (*N. blennius*), Sand Shiner *N. stramineus*), Spotfin Shiner (*C. spiloptera*)

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Abstract
Despite major anthropogenic modification to the Missouri River system, relative abundance of five shiner species within Nebraska's reach of the Missouri River has increased since the 1940's. The combined abundance of five species: Red Shiner *Cyprinella lutrensis*, Spotfin Shiner *C. spilopterus*, Emerald Shiner *Notropis atherinoides,* River Shiner *N. blennius*, Sand Shiner *N. stramineus,* represented > 50% of the small fish community in the Missouri River over the past ten years (2003-2012). More than 3,600 mini-fyke nets were deployed, resulting in over 158,600 shiners collected from the Missouri River along Nebraska's eastern border between 2003 and 2012. Past literature has documented population declines of several native chub and minnow species; however, limited information exists about the magnitude of change in relative abundance and species composition amongst the fish community. A review of the population status for five shiner species and a discussion of population trends among four reaches along the borders of Nebraska are presented.

Keywords: *Cyprinella,* Missouri River, *Notropis,* shiner, status

Introduction

Several studies have investigated the small bodied fish community within the Nebraska reach of the Missouri River (Meek 1894, Evermann and Cox 1896, Johnson 1942, Hesse 1994, Berry et al. 2004). Early studies indicate that native minnow species (i.e., Emerald Shiner *Notropis atherinoides,* Red Shiner *Cyprinella lutrensis*, River Shiner *N. blennius,* Sand Shiner *N. stramineus, and* Spotfin Shiner *C. spilopterus*) comprised a small portion of the small fish community (Johnson 1942, Bailey and Allum 1962). Since anthropogenic modifications altered the Missouri River, these native minnow species have increased as much as 28% in relative abundance (Pflieger and Grace 1987, Berry et al. 2004). Modifications to the river, which include fragmentation and channelization, have altered the natural hydrograph and temperature regime, reduced turbidity, and changed the sediment transport that historically created the dynamic habitat elements necessary for native fauna and flora survival (Hesse et al. 1993). Hesse (1994) quantified the reduction of several native *Cyprinidae* species and made several recommendations to aid in recovery; however, his paper did not include the native shiner species. As there is evidence showing continued population declines for all native chub and selected native minnow species (Steffensen et al. 2014), the importantance to assess the population trends of the other native shiner species in the Missouri River was evident. Therefore, our objectives are to present (1) historic status of five native shiner species, and (2) recent population trends and status of these shiners from two different time periods; 1983 to 1994 and 2003 to 2012 in the Missouri River along Nebraska's border.

Emerald Shiner *Notropis atherinoides*

The Emerald Shiner is characterized by its large eyes in proportion to its elongated and silvery slender body (Pflieger 1997, Figure 1). The dorsal fin is set well behind the origin of the pelvic fins and its body has a distinct silver lateral band, an emerald green back, and a white belly. Emerald Shiners do not exhibit breeding colors and barbels are absent. Adults commonly range between 64 and 90 mm, with a maximum length of 114 mm, have a life span of three to five years, and are sexually mature at age-1 (Pflieger 1997). Spawning occurs from May to July in shallow waters over a bottom of sand or firm mud (Flittner 1964). Their growth is rapid; reaching 55% of their adult size in the first growing season (Fuchs 1967). Emerald Shiners aggregate in large schools within open pelagic areas of large bodies of water (both lakes and rivers). They tolerate a wide range of turbidity and sediment types and can be found where swift currents exist. Diets consist mainly of invertebrates, foraging on both terrestrial and aquatic insects near the surface of the water (Hrabik et al. *In Press*).

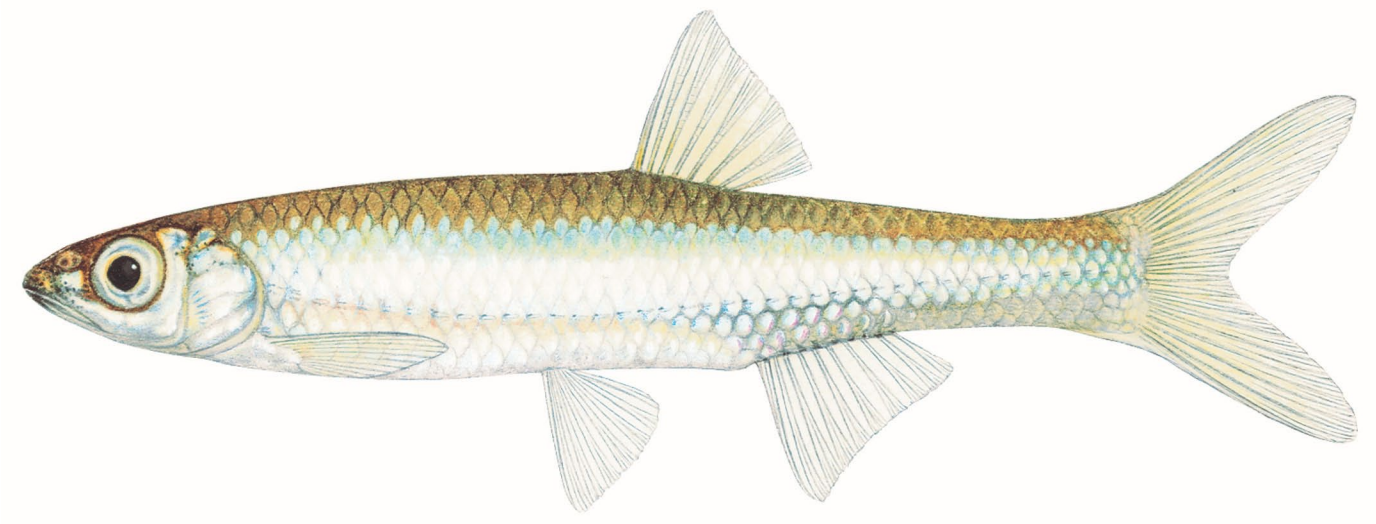

Figure 1. Emerald Shiner. Image copyright of Joseph R. Tomelleri.

Distribution and historic status

Emerald Shiners are found throughout the Missouri and Mississippi River Basins into the Great Lakes region and north to southern Canada (Lee et al. 1980). In 1892, Meek (1892) documented their presence in the Missouri River near Sioux City; however, Johnson (1942) describes the Emerald Shiner as a rare fish in Nebraska, having only collected three fish from the Platte River near Columbus. More recently Emerald Shiner has become one of the most abundant minnows in the Missouri and Mississippi rivers (Pflieger 1997). Between 1996 and 1998, Berry and Young (2004) found that Emerald Shiners comprised 26% of fish collected from the Missouri River along Nebraska's north eastern border. No Emerald Shiners were captured from the interior rivers and streams in Nebraska from 2004 to 2008 during Nebraska Department of Environmental Quality's (NDEQ) Stream Biological Monitoring Program (Bazata 2011); however during 2000-2003, Peters and Parham (2008) commonly collected Emerald Shiners in the lower Platte River in seines and trawls. Additionally, Peters and others in 2006 reported Emerald Shiners captured in the following Nebraska river basins; Elkhorn, Little Blue, Loup, Nemaha, Niobrara, Platte, and Republican from 2003 to 2005.

Red Shiner *Cyprinella lutrensis*

The Red Shiner is a small, deep-bodied fish that commonly grows to 50 to 75 mm in length with a maximum length of 90 mm (Pflieger 1997, Figure 2). Their eyes are smaller in proportion to their body size than an Emerald Shiner, with a terminal mouth. Breeding males are a vibrant metallic blue on the top of their head and dorsal fin and display bright red across all other fins (Pflieger 1997). Red Shiners feed primarily on small insects, but will opportunistically seize any available food items within the appropriate size range (Hale 1963, Stasiak 1987). They become sexually mature in their second or third summer and spawning occurs over an extended period from late May to early September in most mid-western waters (Pflieger 1997). A variety of spawning habitats are used for depositing eggs, from vegetation or woody debris in mid-water column or at the surface to depositing eggs over nests of other sunfishes in sand or gravel on the river-bottom (Cross and Collins 1995, Pflieger 1997). With its adaptable characteristics, Red Shiners reside in a variety of habitats from pools and backwaters to streams and large turbid rivers. These adaptable characteristics suggest that Red Shiners are tolerant of unstable environments and a wide range of conditions.

Distribution and historic status

The Red Shiner is native in the Mississippi and Gulf drainages from South Dakota to Illinois and through northern Mexico (Lee et al. 1980). They have been introduced throughout the Colorado River Basin and into the northeastern United States (Lee et al. 1980). Locally, Red Shiners are one of the most common fishes in large rivers throughout Nebraska (Stasiak 1987). Johnson (1942) reported high abundances in the Nemaha River basin and small tributaries adjacent to the Platte River. Johnson (1942) also recorded its presence in the Missouri River; however, there was no mention of their abundance. Peters and others in 2006 reported Red Shiners captured in every Nebraska drainage basin except the White River / Hat Creek drainage from 2003 to 2005. Additionally, assessments by NDEQ reported Red Shiners representing 22% of all fish collected from inland rivers and streams (Bazata 2011). While Red Shiners comprised just over 70%

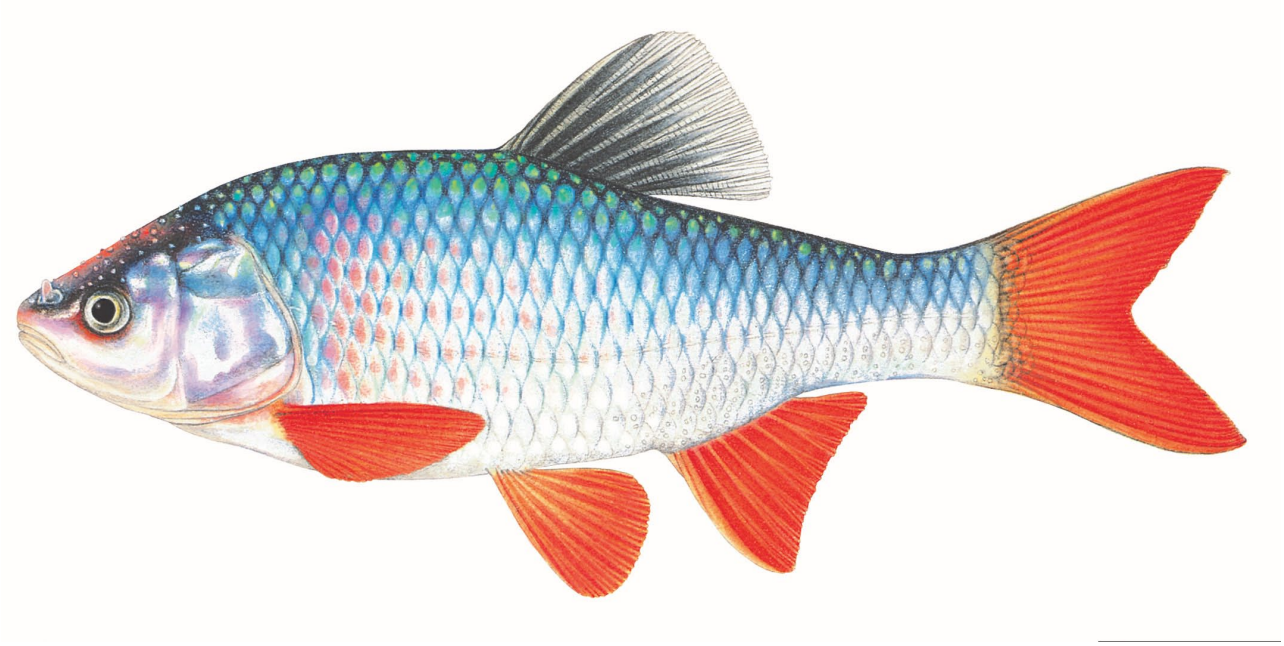

Figure 2. Red Shiner. Image copyright of Joseph R. Tomelleri.

Figure 3. River Shiner. Image courtesy of Konrad Schmidt

of the total fish collected in seine hauls from the lower Platte River during 2000-2003 (Peters and Parham 2008).

River Shiner *Notropis blennius*

The River Shiner is a more robust fish with smaller eyes in proportion to their body in comparison to the Emerald Shiner (Pflieger 1997, Figure 3). The dorsal fin is set about even with the origin of the pelvic fin base, is silver in color and there is sometimes a faint dusky stripe along the midline of the fish. A dorsal midline stripe, of uniform thickness, is present and not expanded anterior or the dorsal fin. Adults range between 50 and 90 mm with a potential maximum length of 100 mm (Pflieger 1997). Males mature at age-2, females at age-3, and with a life-span of 4 to 5 years (Becker 1983). Breeding males are without special colors but do develop small tubercles along the rays of the pectoral fins (Becker 1983). Spawning is reported to occur during late spring through mid-summer (Harlan et al. 1987). Their food consists primarily of small aquatic insects but occasionally include some plant matter (Hrabik

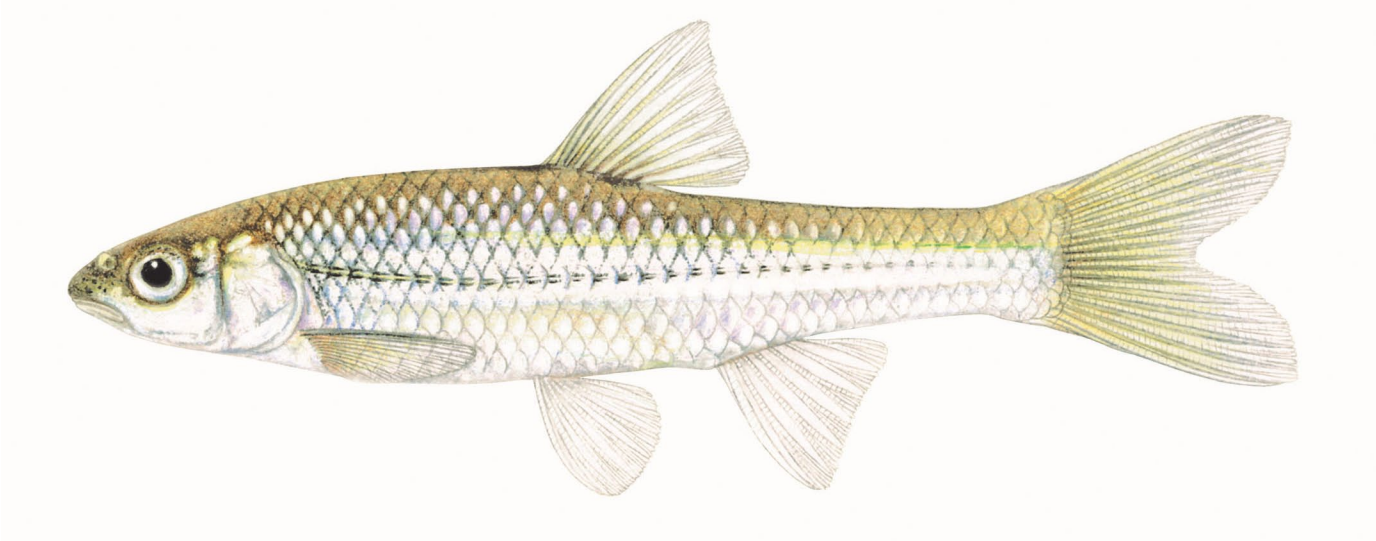

Figure 4. Sand Shiner. Image copyright of Joseph R. Tomelleri.

et al. *In Press*). River Shiners are a schooling species that inhabit the large open channels within large rivers with swift currents, over a variety of substrates in turbid water (Hrabik et al. *In Press*).

Distribution and historic status

The River Shiner occurs almost exclusively in the Missouri and Mississippi rivers, occasionally ascending into some of their tributaries (Pflieger 1997). In Canada, scattered populations are disbursed throughout the Hudson Bay drainages from Alberta to Manitoba (Lee et al. 1980). During the 1940s, River Shiners were documented from the Missouri, Platte, Loup, Elkhorn, lower Niobrara and Republican rivers in Nebraska (Johnson 1942). Pflieger and Grace (1987) reported that River Shiners comprised of less than 0.1% of the fish community in the 1940's, but had increased to 7.7% by the 1980's in the Missouri River within the state of Missouri. A Missouri River survey in the late 1990's observed that River Shiners were present from the upper unchannelized reach downstream through the lower channelized portion of the Missouri River, but comprised less than 0.1 % of all fish collected (Berry et al. 2004). Additionally, Peters and others in 2006 reported River Shiners captured at multiple sites across 11 Nebraska river basins which included; Elkhorn, Little Blue, Loup, Nemaha, Niobrara, Platte, and Republican from 2003 to 2005. More recently, NDEQ's Stream Biological Monitoring Program did not capture any River Shiners from the interior Nebraska waters (Bazata 2011); however, River Shiners consisted of nearly 7% of the total catch in seine hauls during 2000-2003 from the lower Platte River (Peters and Parham 2008).

Sand Shiner *Notropis stramineus*

The Sand Shiner has a slender silvery body with large eyes and a small oblique mouth (Harlan et al. 1987, Figure 4). The lateral line is made up of a band of small black dashes ("mouse tracks") which is unique from other shiner species. The dorsal fin is set even with the origin of the pelvic fin bases (Hrabik et al. *In Press*) and has a thin black stripe that expands into a wedge-shape spot at the anterior base of the fin. Adult Sand Shiners range from 43 to 66 mm with a maximum length of about 70 mm (Pflieger 1997). Sand Shiners reach sexual maturity at age-2 to 3 and have a maximum life span of three years (Tanyolac 1973). Spawning occurs from late April until the end of August (Pflieger 1997). Their generalized food habits consist of detritus, small benthic insects and small crustaceans (Harlan et al. 1987). The Sand Shiner lives in schools and thrives over substrates consisting primarily of shifting sand. It occurs in streams and rivers of all sizes, but is more abundant in rivers that have permanent flow (Pflieger 1997). Their generalized food habits consist of detritus, small benthic insects and small crustaceans (Harlan et al. 1987). The Sand Shiner lives in schools and thrives over substrates consisting primarily of shifting sand. It occurs in streams and rivers of all sizes, but is more abundant in rivers that have permanent flow (Pflieger 1997).

Distribution and historic status

The Sand Shiner is common throughout the Midwestern United States from Pennsylvania to the eastern Great Plains and from Texas to southern Canada (Lee et al. 1980). It occurs in small rivers and streams through-

Figure 5. Spotfin Shiner. Image copyright of Joseph R. Tomelleri.

out the Missouri River Basin but is less common in the main stem Missouri River. In Nebraska, it is one of the most common fishes found in the sand-bottom interior streams (Stasiak 1987, Hrabik et al. *In Press*). A survey in the 1940's observed this species in every river basin in the state and concluded that the fish was increasing in abundance (Johnson 1942). From 1996 to 1998 Sand Shiners comprised only 0.01% of fish collected from the Missouri River reaches between Nebraska and South Dakota borders (Berry et al. 2004). An Interior stream assessment by NDEQ reported Sand Shiners represented 22% of fish collected (Bazata 2011). Additionally, Peters and others (2006) sampled Sand Shiners at 114 sites across 12 river basins which included; Elkhorn, Little Blue, Loup, Nemaha, Niobrara, Platte, and Republican from 2003 to 2005. Specifically, in the lower Platte River, Sand Shiners represented 3.5% of the total catch in seine hauls during 2000-2003 (Peters and Parham 2008). In spite of their wide distribution throughout most of Nebraska's rivers and streams, Sand Shiner abundance is relatively low within the main stem Missouri River.

Spotfin Shiner *Cyprinella spilopterus*

The Spotfin Shiner is commonly identified by its dark spot between the last few rays of the dorsal fin (Becker 1983, Figure 5). The body is moderately slender with flattened-sides, small eyes, a moderately oblique mouth and barbels are absent (Pflieger 1997). Similar to the Red Shiner, the Spotfin Shiner has silvery sides and blue reflections which become more prevalent in breeding males (Hrabik et al. in press). Maximum size is reported to be 122 mm for adults, but is commonly within the range of 63 to 114 mm (Pflieger 1997). Spotfin Shiners have similar life spans to other shiner species, reaching maturity after two years and longevity of five years. Spawning occurs from May to August in areas that have swift water flowing over sand flats (Harlan 1987). Their generalized food habits consist mostly of aquatic and terrestrial insects (Pflieger 1997). Spotfin Shiners occur in moderate to large streams and rivers of moderate to high turbidity, with bottom of sand, gravel or rubble (Lee et al. 1980).

Distribution and historic status

The Spotfin Shiner is widely distributed throughout the upper Mississippi River basin from northern Minnesota south to northeastern Oklahoma and east to northern Alabama (Lee et al. 1980, Pflieger 1997). Pflieger (1997) reported that in the state of Missouri, Spotfin Shiners were rarely collected in the lower Missouri River between 1945 and 1995. In Nebraska, nonnative Spotfin Shiner was introduced as a forage fish in various bodies of water (Schainost 1987). Recent assessments by the Nebraska DEQ did not capture any Spotfin Shiners in Nebraska's interior river systems (Bazata 2011). However, another survey in the late 1990s did document their presence in the Missouri River in Nebraska (Berry et al. 2004). Additionally, Peters and others (2006) captured Spotfin Shiners in Bazile creek a major tributary to the Missouri River.

Materials and methods

Study area

For this analysis, the Missouri River along Nebraska's border was divided into 5 reaches, four riverine reaches

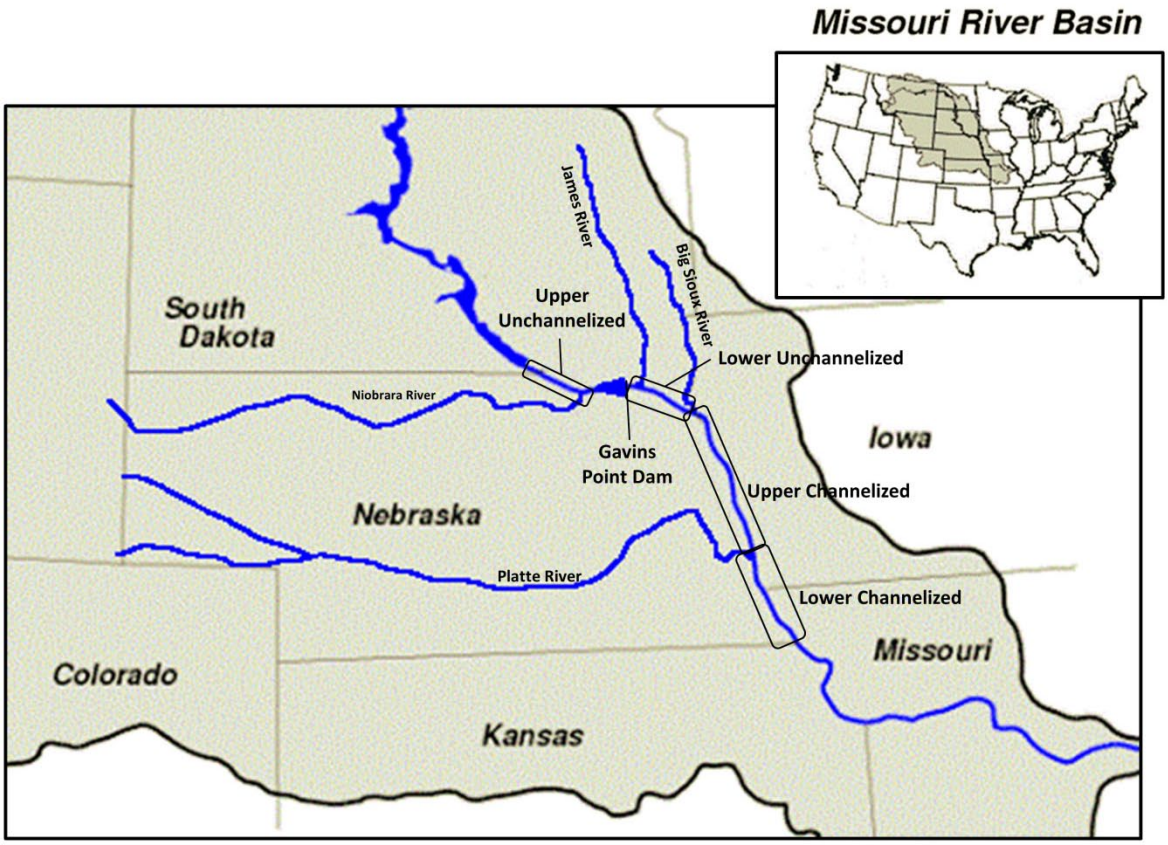

Figure 6. Map of the Missouri River basin. The four study reaches along Nebraska's eastern border are indicated within the boxes.

and one reservoir, based on physical and morphological characteristics (Figure 6). No data were included in any analysis or in the results section from Lewis and Clark Reservoir reach, because annual sampling within this reach was variable and non-standardized for any comparison with other reaches. The upper unchannelized reach begins at the Nebraska / South Dakota border (rkm 1,411.0) and continues downstream to the headwaters of Lewis and Clark Lake (rkm 1,331.7). Fort Randall Dam is 5.0 rkm upstream of the state border between South Dakota and Nebraska and highly influences this reach through hypolimnetic and power peaking discharges (Hesse and Mestl 1993). Water management practices have altered the natural hydrograph and temperature regime, reduced turbidity, and degraded the channel upstream of the Niobrara River. The Niobrara and Missouri River confluence is located at rkm 1,358.0. Resembling the unaltered river, the Missouri River downstream of the Niobrara River confluence has formed a large braided delta extending into the former headwaters of Lewis and Clark Lake. The effects of hypolimnetic releases and channel degredation caused by discharge from Fort Randall are reduced by Niobrara River outflows, with increased water temperature, turbidity and bed load.

Gavins Point Dam (rkm 1,305.2) impounds the Missouri River forming Lewis and Clark Lake which is the smallest and most downstream main-stem Missouri River reservoir. The main purpose of Gavins Point Dam is to stabilize the irregular discharges from Fort Randall Dam to support navigation on the lower Missouri River (Hesse and Mestl 1993). The lower unchannelized reach begins at Gavins Point Dam and continues downstream to approximately Ponca, NE (rkm 1,211.8) where channelization begins. Like the upper unchannelized reach, this reach also experiences channel bed degradation, hydrograph alterations, and reduced turbidity levels; however, water temperatures are less affected.

The channelized portion of the Missouri River starts upstream of Sioux City, IA (rkm 1,182.4) where channelization begins by "training" the river through a series of bends and dike structures and continues to the confluence with the Mississippi River (rkm 0.0) and includes 394.0 rkm along Nebraska's eastern border. Along the Nebraska border, this channelized section was divided into two reaches by the Platte River (rkm 957.6); the upper channelized reach (Ponca, NE to the Platte River confluence) and lower channelized reach (Platte River confluence to the Nebraska / Kansas state line [rkm 788.4]).

Channel morphology in the channelized reaches consists of a series of dike structures on the inside bends and revetment on the outside bends and is limited to a few habitats types. The upper channelized reach has a highly degraded channel; however, tributary (i.e., Big Sioux River and Little Sioux River) discharges increase turbidity levels. The lower channelized river is less impacted by the degrading channel due to bedload discharge from the Platte River and more frequent flooding. Seasonally, the Platte River influences the temperature and hydrograph on the lower channelized reach.

Data collection

Data were acquired from a historic seine survey conducted by Nebraska Game and Parks Commission (NGPC) and current sampling by the Pallid Sturgeon Population Assessment (PSPA) crews. The historic dataset consisted of data collected during 1983 to 1994 and was acquired from the historical database produced by NGPC, funded by the Federal aid in fish restoration Dingell-Johnson Project F-75-R-11. Standard quarter arc seine samples were conducted and reported as the number of fish per seine haul. Measurements of the bag seine used for sampling were 15.24 by 1.83 m with a mesh size of 6.13 mm. Annual sampling effort was inconsistent among sampled reaches and years.

Current data were acquired from three field offices associated with the U.S. Army Corps of Engineers (USACE) funded PSPA Project. USACE formed a long-term monitoring and assessment project in response to the 2000 Missouri River Biological Opinion (Bi-Op, USFWS 2000) and 2003 Amendment (USFWS 2003). Sampling was initiated in 2003 in the upper unchannelized and lower channelized reaches with full implementation along Nebraska's eastern border in 2005. The U.S. Fish and Wildlife Service (USFWS) Great Plains Fish and Wildlife Conservation Office sampled the upper unchannelized reach while South Dakota Department of Game, Fish and Parks (SDGFP) sampled the lower unchannelized reach. NGPC sampled the two channelized reaches. The PSPA Project operates under a stratified random design in which the river reaches are the strata and the experimental unit (i.e., river bends) are randomly selected annually (Welker and Drobish 2011a). Twenty-five percent of the river bends per strata were randomly selected and sampled with a suite of standard gears. Standard gears were deployed annually throughout all reaches in the available habitats. Sampling was limited throughout all reaches in 2011 due to the record inflows in the upper Missouri River basin which subsequently resulted in record discharges from the Missouri River main stem dams.

Fish were collected following the standard operating procedures developed for the PSPA Project using a variety of gears (Welker and Drobish 2011a; Welker and Drobish 2011b). Data from mini-fyke net catches were used to monitor *Cyprinidae* population trends. Mini-fyke net catch per unit effort (CPUE) was reported as the number of fish per net night. For the current dataset CPUE for mini-fyke nets was calculated for each gear deployment instead of overall catch per overall effort to get a measure of variance (±2 SE). These individual CPUEs were then averaged and weighted based on annual effort to get a total CPUE for an individual reach and year. For the historic dataset CPUE's were calculated as total fish divided by total effort to get number of fish per seine haul for each reach and year. An accurate variance could not be calculated due to inconsistency in the recorded data per site. All fish sampled were measured to the nearest millimeter. See Welker and Drobish (2011a; 2011b) for sampling gear and method specifics.

Results

Historic results (1983-1994)

Historic sampling effort resulted in over 35,600 fish collected from 1,601 seine deployments in the unchannelized and channelized reaches of the Missouri River that border Nebraska (Table 1). Target species comprised 69% (N = 24,433) of the total catch collected across the four reaches (Table 2). The highest overall CPUE for target species was 27.9 (2SE = 13.6) fish per seine haul from the lower unchannelized reach followed by the upper channelized reach (CPUE = 21.1, 2SE = 9.1), the upper unchannelized reach (CPUE = 14.4, 2SE = 9.9) and lower channelized reach (CPUE = 13.1, 2SE = 8.0; Table 1). Annual catch rates of target species were highly variable and ranged from 0.0 (upper unchannelized in 1992) to 61.8 fish per seine haul (upper unchannelized in 1988) with a combined overall mean of 19.1 (2SE = 5.72) target species per seine haul. However, no discernable trends among years and reaches were detected.

Current results (2003 to 2012)

Current sampling efforts resulted in over 290,000 fish collected from 2,931 mini-fyke net deployments from the four reaches of the Missouri River along Nebraska's eastern border between 2003 to 2012 (Table 3). The five target shiner species represented 55% (N = 158,666) of the total catch in mini-fyke nets across all reaches and years (Table 3 and 4). Mean catch per unit effort of the targeted shiner species increased in a downstream trend with the highest overall CPUE (81.0 fish per net night, 2SE = 8.3) in the lower channelized reach followed by the upper channelized reach (CPUE = 60.8, 2SE = 6.1), the lower unchannelized reach (CPUE = 47.3, 2SE = 8.1) and upper unchannelized reach (CPUE = 20.4, 2SE = 4.6; Table 3). The percent composition of target species by reach ranged from 45% in the upper unchannelized reach to 67% in the lower

Table 1. Number of deployments (effort), total number of fish collected, mean annual catch per unit of effort of all species collected and CPUE (2SE) for the target species (i.e., Emerald Shiner., Red S., River S., Sand S., and Spotfin S.) while seining the Missouri River from 1983-1994.

Year	Effort	Total Fish	Overall CPUE	Target Spp CPUE	Effort	Total Fish	Overall CPUE	Target Spp CPUE
	Upper Unchannelized				Lower Unchannelized			
1983[a]	107	1,847	17.3	15.4	60	1,499	25.0	17.9
1984[a]	155	2,185	14.1	9.1	86	845	9.8	3.5
1985[a]	214	2,821	13.2	9.0	127	2,175	17.1	12.8
1986[a]	93	712	7.7	3.6	106	3,437	32.4	25.2
1987	46	793	17.2	16.6	65	2,283	35.1	30.1
1988	12	1,145	95.4	61.8	23	214	9.3	2.6
1989	9	106	11.8	5.1	16	1,014	63.4	50.7
1990	15	495	33.0	10.3	11	816	74.2	60.8
1991[a]	12	481	40.1	31.9				
1992[a]	2	2	1.0	0.0				
1993[a]	11	117	10.6	4.8	8	293	36.6	17.3
1994	34	365	10.7	5.3	17	1,185	69.7	57.8
Total	710	11,069	22.7 (14.6)	14.4 (9.9)	519	13,761	37.3 (15.2)	27.9 (13.6)
	Upper Channelized				Lower Channelized			
1983[a]								
1984[a]								
1985[a]								
1986[a]	29	466	16.1	8.1				
1987	64	1,951	30.5	21.5	45	517	11.5	6.8
1988	33	543	16.5	15.0	7	51	7.3	3.1
1989	13	864	66.5	47.1	7	131	18.7	8.6
1990	13	436	33.5	26.1	10	197	19.7	9.7
1991[a]	20	809	40.5	12.0	7	800	114.3	28.1
1992[a]								
1993[a]	35	922	26.3	10.6				
1994	33	1,248	37.8	28.3	56	1,887	33.7	22.3
Total	240	7,239	33.5 (11.4)	21.1 (9.1)	132	3,583	34.2 (32.9)	13.1 (8.0)

a. Denotes seine hauls were not deployed throughout all reaches.

channelized reach. Total annual CPUE for the five target species ranged from 5.3 (SE = 1.1, lower channelized in 2003) to 266.8 fish per net night (SE = 51.8, lower channelized in 2008). There were no discernable annual trends for any of the four reaches in total CPUE of the five target species.

Emerald Shiner

From the historic dataset, Emerald Shiners were the most abundant (N = 17,913) of the five target species collected across four reaches of the Missouri River from 1983 to 1994 (Table 2). Annual seine haul catch rates ranged from 0.0 (1992 upper unchannelized) to 43.4 fish per haul (1989 lower unchannelized). The lower unchannelized reach had the highest overall mean CPUE of 17.6 fish per haul from 1983 to 1994. Percent composition decreased moving downstream, with Emerald Shiner representing 58.3% of fish collected in the upper unchannelized reach, while only 35.3% in the lower channelized reach.

From the current dataset, Emerald Shiners were also the most abundant target species collected (N = 52,960) from 2003 to 2012 and comprised 18.2% of the mini-fyke net catch (Table 4). Emerald Shiners were sampled annually from every reach and ranged from 1.0 to over 90.5 fish per net night with each reach producing a year or two substantially higher than the overall mean. For example, in the upper channelized reach the CPUE in 2005 was 50.4 (2SE = 39.8) fish per net night compared to the overall mean of 10.3 (2SE = 11.8) fish per net night. These peaks actually occurred in different years within the different reaches; 2005 in the upper unchannelized, 2005 and 2009 in the lower unchannelized, 2006 in the upper channelized and 2006 and 2008 in the lower channelized. Catch rates for Emerald Shiners by reach were not statistically similar due to large standard error values (upper unchan-

Table 2. Total number of target shiners collected (N), mean annual catch per unit effort (CPUE) with two standard error (2SE) and percent composition of five target species collected by seining from 1983 to 1994 by Nebraska bordered reaches of the Missouri River.

Species	Reach	N	1983[a]	1984[a]	1985[a]	1986[a]	1987	1988	1989	1990	1991[a]	1992[a]	1993[a]	1994	Overall CPUE (2SE)	% Composition
Emerald	U. Unchannelized	6,458	15.0	6.9	8.2	2.9	16.1	43.0	5.0	7.7	21.7	0.0	3.8	1.5	11.0 (6.9)	58.3
	L. Unchannelized	7,295	9.8	1.4	11.6	17.6	25.9	1.1	43.4	29.5			10.9	24.8	17.6 (8.5)	53.0
	U. Channelized	2,896				3.8	16.2	10.2	26.5	14.6	7.0		3.6	18.6	12.6 (5.6)	40.0
	L. Channelized	1,264					3.9	1.9	6.0	4.8	18.9			15.2	8.4 (5.6)	35.3
Red	U. Unchannelized	570	0.1	1.9	0.5	0.5	0.2	1.0	0.0	1.3	4.9	0.0	0.5	0.1	0.9 (0.8)	5.1
	L. Unchannelized	529	0.4	0.4	0.2	3.6	0.5	0.0	0.1	1.3			0.0	0.8	0.7 (0.7)	3.8
	U. Channelized	588				2.2	1.0	1.0	5.9	4.2	2.1		4.2	3.2	3.0 (1.2)	8.1
	L. Channelized	335					1.3	0.9	1.3	0.8	3.1			4.1	1.9 (1.1)	9.3
River	U. Unchannelized	62	0.1	0.0	0.1	0.0	0.0	0.0	0.0	0.1	1.2	0.0	0.4	0.0	0.2 (0.2)	0.6
	L. Unchannelized	148	0.5	0.0	0.3	0.1	0.1	0.0	1.3	3.5			0.8	0.0	0.7 (0.7)	1.1
	U. Channelized	380				0.7	0.4	0.8	12.0	3.2	2.9		0.5	1.1	2.7 (2.8)	5.2
	L. Channelized	242					0.7	0.4	1.1	3.9	5.9			2.1	2.4 (1.7)	6.8
Sand	U. Unchannelized	187	0.2	0.2	0.2	0.0	0.2	0.0	0.1	0.6	4.2	0.0	0.2	0.4	0.5 (0.7)	1.7
	L. Unchannelized	1,865	7.2	1.6	0.7	2.2	2.6	0.3	0.9	20.7			5.5	29.5	7.1 (6.3)	13.6
	U. Channelized	354				0.4	1.3	1.1	1.8	2.5	0.1		1.5	3.6	1.5 (0.8)	4.9
	L. Channelized	68					0.5	0.0	0.0	0.1	0.3			0.8	0.3 (0.3)	1.9
Spotfin	U. Unchannelized	350	0.0	0.0	0.0	0.1	0.1	17.8	0.0	0.6	0.0	0.0	0.0	3.4	1.8 (2.9)	3.2
	L. Unchannelized	443	0.0	0.0	0.0	1.6	0.9	1.2	4.9	5.7			0.1	2.7	1.7 (1.3)	3.2
	U. Channelized	379				0.9	2.6	2.0	0.8	1.6	0.0		0.9	1.8	1.3 (0.6)	5.2
	L. Channelized	20					0.4	0.0	0.1	0.1	0.0			0.0	0.1 (0.1)	0.6

a. Denotes seine hauls were not deployed throughout all reaches.

Table 3. Number of deployments (effort), total number of fish collected, mean annual catch per unit of effort (CPUE; fish per net night) with two standard error (2SE) of all species collected and CPUE for the target species (i.e., Emerald S., Red S., River S., Sand S., and Spotfin Shiner) while mini-fyke netting the Missouri River from 2003-2012.

Year	Effort	Total Fish	Overall CPUE	Target Spp CPUE	Effort	Total Fish	Overall CPUE	Target Spp CPUE
	Upper Unchannelized				Lower Unchannelized			
2003[a]								
2004[a]	87	2,045	23.5 (12.4)	11.7 (2.1)				
2005	80	12,151	151.9 (100.1)	59.9 (19.5)	104	8,147	79.8 (26.6)	59.6 (11.9)
2006	80	2,005	25.1 (13.7)	10.6 (3.2)	107	7,288	69.4 (20.4)	53.2 (7.2)
2007	80	3,046	38.1 (14.7)	21.4 (7.3)	102	11,366	112.5 (31.5)	30.6 (3.6)
2008	80	1,819	22.7 (7.7)	12.7 (2.3)	96	8,846	92.1 (36.8)	52.5 (10.2)
2009	81	1,989	24.6 (11.1)	10.9 (2.8)	96	7,555	78.7 (60.5)	44.0 (13.4)
2010	80	2,217	27.7 (7.5)	13.0 (3.4)	96	3,058	32.2 (8.2)	12.2 (2.9)
2011[a]								
2012	80	4,016	50.2 (14.3)	24.2 (5.6)	96	12,403	134.8 (43.9)	79.6 (26.4)
Total	648	29,288	45.5 (31.1)	20.4 (4.6)	697	58,663	85.7 (24.6)	47.3 (8.1)
	Upper Channelized				Lower Channelized			
2003[a]					50	717	14.3 (3.4)	5.3 (1.1)
2004[a]					40	774	19.4 (9.5)	12.8 (1.7)
2005	136	2,604	20.0 (4.5)	9.6 (1.0)	88	1,809	22.9 (7.7)	15.6 (3.2)
2006	144	31,979	223.6 (138.7)	210.4 (30.2)	111	14,869	133.9 (67.7)	116.7 (21.2)
2007	121	12,400	103.3 (30.4)	63.5 (14.2)	72	7,386	102.6 (63.3)	69.6 (16.8)
2008	120	15,666	138.6 (76.4)	65.1 (14.7)	72	35,836	504.7 (239.6)	266.8 (51.8)
2009	120	3,928	33.3 (7.5)	20.7 (2.6)	96	3,975	41.8 (14.8)	23.5 (4.4)
2010	120	46,318	406.3 (340.8)	24.2 (2.9)	96	3,543	38.5 (10.4)	19.2 (3.7)
2011[a]								
2012	120	4,418	39.8 (18.3)	32.1 (7.1)	80	16,112	214.8 (116.7)	199.3 (32.2)
Total	881	117,313	137.9 (104.7)	60.8 (6.1)	705	85,021	121.4 (105.7)	81.0 (8.3)

[a] Denotes mini-fyke nets were not deployed throughout all reaches.

nelized, CPUE = 10.3 [2SE = 11.8] fish per net night, lower unchannelized, CPUE = 22.5 [2SE = 17.2], upper channelized, CPUE = 16.5 [2SE = 24.7], and lower channelized, CPUE = 19.7 [2SE = 14.2]).

Red Shiner

For the historical dataset, 2,022 Red Shiners were collected throughout the four reaches from 1983 to 1994 and were the third most dominate shiner species collected. Relative abundance was lower and less variable compared to Emerald Shiners with catch rates ranging from 0.0 to 5.9 fish per seine haul (Table 2). Across the four reaches, Red Shiners were most represented in the channelized reaches where they comprised 9.3% in the lower channelized reach and 8.1% in the upper channelized reach.

Red Shiners were the second most abundant (N = 47,228) target species collected throughout all reaches between 2003 and 2012 and comprised 16.2% of the overall total mini-fyke net catch. Over 18,500 Red Shiners were collected in the lower channelized reach, while only 143 fish were captured in the upper unchannelized reach (Table 4). Red Shiner catch rates increased moving downstream from the upper unchannelized reach (CPUE = 0.2) to the lower channelized reach (CPUE = 26.5). Mini-fyke net catch rates across years within river reaches were variable with no discernable trends (Table 4). There were four years with a CPUE of 0.1 (2SE < 0.1) fish per net night and all were observed in the upper unchannelized reach. The largest CPUE across reaches and years was 79.9 (2SE = 69.3) fish per net night in lower channelized reach in 2008.

River Shiner

For the historical dataset, River Shiners were the least frequently collected shiner species. Only 832 River Shiners were collected during the historical time period across the four reaches (Table 2). River Shiner catch rates ranged from 0.0 in multiple years to 12.0 fish per seine haul (1989 upper channelized). Seventy-five percent of the River Shiner total catch were collected within the channelized reaches of the Missouri River. Percent composition increased moving downstream where River Shiners comprised 0.6% of the total catch in the upper unchannelized reach compared to 6.8% of the total catch in the lower unchannelized reach.

Table 4. Total number of target shiners collected (N), catch per unit effort (CPUE) with two standard error (SE) and percent composition of five target species collected in mini-fyke nets from 2003 to 2012 by Nebraska bordered reaches of the Missouri River.

Species	Reach	N	2003[a]	2004[a]	2005	2006	2007	2008	2009	2010	2011[a]	2012	Overall CPUE (2SE)	% Composition
Emerald	U. Unchannelized	6,677		4.8	50.4	1.6	1.0	3.8	3.5	4.1		13.9	10.3 (11.8)	22.8
	L. Unchannelized	15,086			19.0	13.7	4.4	8.4	35.5	7.9		68.5	22.5 (17.2)	25.7
	U. Channelized	15,809			1.3	90.5	5.4	7.1	4.6	2.5		3.8	16.5 (24.7)	13.5
	L. Channelized	15,388	1.8	5.2	7.7	62.4	12.0	31.3	2.7	10.3		43.5	19.7 (14.2)	18.1
Red	U. Unchannelized	143		0.2	0.1	0.1	0.6	0.2	0.1	0.3		0.1	0.2 (0.1)	0.5
	L. Unchannelized	10,191			31.0	22.1	9.8	28.2	2.3	2.3		6.2	14.5 (9.3)	17.4
	U. Channelized	18,377			3.7	61.9	40.7	16.0	8.8	10.5		1.2	20.4 (17.0)	15.7
	L. Channelized	18,517	2.9	2.8	6.1	26.0	46.6	79.9	9.4	5.4		59.7	26.5 (19.2)	21.8
River	U. Unchannelized	8			0.1		< 0.1		< 0.1				< 0.1 (< 0.1)	< 0.1
	L. Unchannelized	5			< 0.1	< 0.1						< 0.1	< 0.1 (< 0.1)	< 0.1
	U. Channelized	11,729			1.8	31.1	10.2	40.3	2.8	4.3		4.0	13.5 (11.8)	10.0
	L. Channelized	14,618	0.4	3.2	1.3	16.9	7.8	141.8	10.5	2.6		8.3	21.4 (30.3)	17.2
Sand	U. Unchannelized	627		1.8	0.3	0.5	0.9	2.7	0.1	0.1		1.3	1.0 (0.7)	19.8
	L. Unchannelized	4,629			9.6	8.5	9.3	14.2	3.3	0.3		1.1	6.6 (3.9)	4.4
	U. Channelized	4,487			0.7	19.3	3.4	1.4	3.4	3.3		2.6	4.9 (4.9)	4.0
	L. Channelized	2,673	0.1	1.4	0.5	11.2	2.2	13.6	0.9	0.8		0.5	3.5 (3.4)	7.8
Spotfin	U. Unchannelized	5,786		4.9	9.0	8.4	18.9	6.0	7.2	8.6		8.9	9.0 (3.0)	2.1
	L. Unchannelized	2,597				8.9	7.2	1.7	2.8	1.7		3.8	3.7 (2.4)	7.9
	U. Channelized	4,658			2.2	7.6	3.8	0.4	1.0	3.6		20.4	5.6 (5.2)	3.8
	L. Channelized	6,661	0.1	0.2	< 0.1	0.3	1.0	< 0.1				87.2	9.9 (19.3)	3.1

a. Denotes seine hauls were not deployed throughout all reaches.

Table 5. Percent composition of five target species mini-fyke netted from 2003 to 2012 by reach of the Missouri River.

Species	Upper Missouri River[a]	NE Upper Unchannelized	NE Lower Unchannelized	NE Channelized Reaches	Lower Channelized Missouri River[b]		
					West	Central	Eastern
Emerald Shiner	70.3	22.8	25.7	15.4	16.3	10.7	16.0
Red Shiner	[c]	0.5	17.4	18.2	25.5	47.2	30.5
River Shiner	[c]	< 0.1	< 0.1	13.0	1.4	0.3	1.2
Sand Shiner	1.6	2.1	7.9	3.5	0.3	0.2	0.4
Spotfin Shiner	[c]	19.8	4.4	5.6	0.0	0.0	< 0.1

a. Denotes Fort Peck Dam (rkm 2,851.0) to headwater of Lake Sakakawea (rkm 2,523.5). Data acquired from: Wilson *et al*. 2006, Haddix *et al*. 2007ab, Wilson 2007, Haddix *et al*. 2008ab, Wilson 2008, Haddix *et al*. 2009ab, Wilson 2009, Haddix *et al*. 2010ab, Wilson 2010, Haddix *et al*. 2011ab, Wilson 2011, Haddix *et al*. 2012ab, Wilson 2012, Haddix *et al*. 2013, Hunziker *et al*. 2013 and Wilson 2013.

b. Nebraska / Kansas state line (rkm 788.4) to the confluence of the Mississippi River (rkm 0.0); West (rkm 591.4 to 402.3), Central (rkm 402.3 to 209.2), Eastern (rkm 209.2 to 0). Data acquired from: Kennedy *et al*. 2006, Utrup *et al*. 2006ab, Caton *et al*. 2007, Plauck *et al*. 2007, Utrup *et al*. 2007, Niswonger *et al*. 2008, Plauck *et al*. 2008, Utrup *et al*. 2008, Herman *et al*. 2009, Niswonger *et al*. 2009, Plauck *et al*. 2009, Herman *et al*. 2010, Horner *et al*. 2010, Plauck *et al*. 2010, Niswonger *et al*. 2011, Ridenour *et al*. 2011ab, Meyer *et al*. 2012, Niswonger *et al*. 2012, Ridenour *et al*. 2012, Meyer *et al*. 2013, Niswonger *et al*. 2013 and Wrasse *et al*. 2013.

c. Species do not occur in that reach of the river.

River Shiners were collected much more frequently (N = 26,360) in the Missouri River along the borders of Nebraska during the current time period. However, River Shiners were rarely collected in the unchannelized river (N = 13) reaches as 99% came from the channelized reaches (Table 4). Also, River Shiner catch rates increased moving downstream from the unchannelized reaches through the lower channelized reach. Within the channelized reaches, catch rates varied across years ranging from 0.4 (2SE = 0.2) fish per net night in 2003 to 141.8 (2SE = 110.1) fish per net night in 2008. Catch rates peaked for both channelized reaches in 2008 and were substantially higher than the overall mean CPUE for each reach.

Sand Shiner

From the historic dataset, Sand Shiners were the second most abundant shiner species collected with 2,474 captured among the four reaches of the Missouri River (Table 2). The majority (N = 1,865; 75%) of the Sand Shiners were collected from the lower unchannelized reach. The highest annual catch rate also came from the lower unchannelized reach with 29.5 fish per seine haul in 1994. Below Gavins Point Dam, both catch rates and percent composition for Sand Shiners decreased by reach as the lower channelized had an overall mean catch rate of 0.3 fish per seine haul and represented only 1.9% of the catch.

Sand Shiner abundance was far less in comparison to previous species discussed from the current time period with 12,416 fish collected across the four sampled reaches. The Sand Shiner was collected within the four reaches every year they were sampled (Table 4). Sand Shiner catch rates ranged from multiple occasions with a CPUE of 0.1 among several years to 19.3 (2SE = 10.9) fish per net night in the upper channelized reach in 2006. Sand Shiner catch rates were variable across years and reaches; nonetheless, most were captured below Gavins Point Dam (lower unchannelized [N = 4,629], upper channelized [N = 4,487], and l. channelized [N = 2,673], Table 4).

Spotfin Shiner

The nonnative Spotfin Shiner were first collected in Nebraska bordered waters of the Missouri River in 1986, and from then on was collected annually across the reaches except for 1991 and 1992 (Table 2). From the historic dataset, 1,192 Spotfin Shiners were collected among the four reaches. The highest annual catch rate for Spotfin Shiners occurred in 1988 (17.8 fish per seine haul) in the upper unchannelized reach. The overall mean CPUE decreased from 1.8 fish per seine haul in the upper unchannelized downstream to 0.1 fish per seine haul in the lower channelized reach.

From the current dataset Spotfin Shiners were present throughout all four reaches, with a total abundance of 19,701 fish collected between 2003 and 2012 (Table 4). Spotfin Shiner catch rates were greatest in the upper unchannelized (CPUE = 9.0 [2SE = 3.0] fish per net night) and lower channelized reaches (CPUE = 9.9 [2SE = 19.3]; Table 4). Mean annual catch rates by reach ranged from zero on several occasions (i.e., lower unchannelized 2005, lower channelized 2009 – 2010) to 87.2 (2SE = 103.4) fish per net night in the lower channelized reach in 2012.

Missouri River Basin Percent Composition Comparison

The highest percent composition (70.3%) for Emerald Shiners was in the upper Missouri River from Fort Peck Dam (rkm 2,850.0) to the headwaters of Lake Sakakawea (rkm 2,523.5; Table 5) and declined through the unchannelized reaches. Percent composition was simi-

lar throughout the channelized reaches to the confluence with the Mississippi River (rkm 0.0). Conversely, Red Shiner percent composition continued to increase as one moved farther downstream into the lower Missouri River (i.e., Nebraska / Kansas state line [rkm 788.4] to the confluence with the Mississippi River). The percent compositions for River Shiners, Sand Shiners and Spotfin Shiners were greatest in the reaches that bordered Nebraska and rarely sampled in the other reaches of the Missouri River.

Discussion

Effects to the Missouri River (i.e., river impoundment, floodplain connectivity, altered hydrograph) are apparent as small native fish assemblages have been altered over the last few decades (Fuchs 1967, Pflieger and Grace 1987, Hesse et al. 1993, Hesse 1994, Steffensen et al. 2014). The five target shiner species presented in this paper comprised 55% of all small fish species collected in mini-fyke nets from the Missouri River along Nebraska's eastern border between 2003 and 2012. However, prior to impoundments to the river, *Macrhybopsis* and *Hybognathus* species were in greater abundance and were the dominant small bodied fish. Pflieger and Grace 1987 reported that Flathead Chubs *Hybopsis gracilis* and Plains Minnows *Hybognathus placitus* comprised 87% of the small species collected using bag seines during 1940-1944 in the Missouri River. The five targeted shiner species were observed in the 1940's but represented only 3.7% of the total fish sampled. Additionally, Pflieger and Grace 1987 documented substantial increases in shiners (i.e., Emerald Shiners, River Shiners, Red Shiners, and Sand Shiners) from the time periods 1940-45 and 1978-83. However from 1978 to 1983, the combined percent composition of the four species was less than 50%. Therefore, percent compositions of shiners species have increased from < 10% in the 1940's upwards to 20% in the 1960's and increased further throughout this study (Pflieger and Grace 1987, Hesse 1994, Berry and Young 2004).

In the last 20 to 30 years the relative abundance of these shiner species has increased when compared to previous surveys (i.e., pre-1983). Statistical comparisons cannot be made between the historic and current datasets due to different sampling gears and methods, although Kennedy et al. (Missouri Department of Conservation, Pers. Comm.) determined that bag seines and mini-fyke nets sampled similar species composition. Furthermore, percent composition for the targeted shiner species presented in this paper were similar between gears. Therefore, general observations can be discussed. For example, Figures 7 and 8 present annual catch rates of the five shiner species in the unchannelized river reaches. Generally the historic catch rates in the unchannelized reaches had fluctuations of greater frequency, magnitude, and duration when compared to the current catch rates. These catch rates may be influenced by gear type and deployment since most shiners species are schooling fish that congregate in certain habitats. However in the channelized reaches between time periods, the annual variations were greater in recent catch rates when compared to historical catch rates, with Emerald Shiners being the exception (Figures 9 and 10). In general, the channelized reaches had greater relative abundance of the target species compared to the unchannelized reaches. We speculate the channelized reaches are less affected by the mainstem dams (i.e., altered hydrograph, reduced turbidity) and benefit from inputs from other large tributaries. Fluctuations in annual catch rates from seining and mini-fyke nets are expected when dealing with short life span cyprinid species and other additional factors (i.e., hydrograph, water clarity, and habitat availability for gear deployments; Hesse 1994). Overall fish numbers from the current dataset were lower in the unchannelized reaches compared to the channelized reaches, suggesting that Fort Randall and Gavins Point dams have a strong influence on catch rates within these reaches. Hesse (1994) discussed how river conditions below dams have negatively affected *Macrhybopsis* and *Hybognathus* species, which may explain the current dataset's lower catch rates of targeted species in the unchannelized reaches. However, these differences could partly be habitat complexity and gear catchability issues as well. The channelized reach, narrower in river width with fewer habitat types, may force higher concentrations of small fish into areas where mini-fyke nets are deployed, thus increase their susceptibility to sampling gears. Even though mini-fyke nets were standardized across the sampled area; catchability based on available habitat is varied across reaches, thus helping to explaining differences in fish numbers for targeted species between reaches.

The current status of the small fish assemblages of the Missouri River have shifted to a shiner species dominated community, while other species (i.e. *Hybognathus* species) have declined (Steffensen et al. 2014). Nonetheless, shiner populations are highly cyclic and catch rates showed no overall trend to suggest an increase or decrease in abundance across the four reaches within the time period of 2003 to 2012. Results indicate that catch rates for target species frequently fluctuate by species, year and within a river reach. Despite year to year and within reach variability, target species were persistently captured throughout the Missouri River. From the current dataset, mean CPUE by year and reach of all five target species resulted in an average of 53.2 (2SE = 22.6) fish per net night across the four reaches. Spatially, mean target species CPUE increased in a downstream trend from the upper unchannelized to the lower channelized reach.

River alterations and management decisions have resulted in a negative response by several cyprinids (chubs and *Hybognathus* species) while species composition has

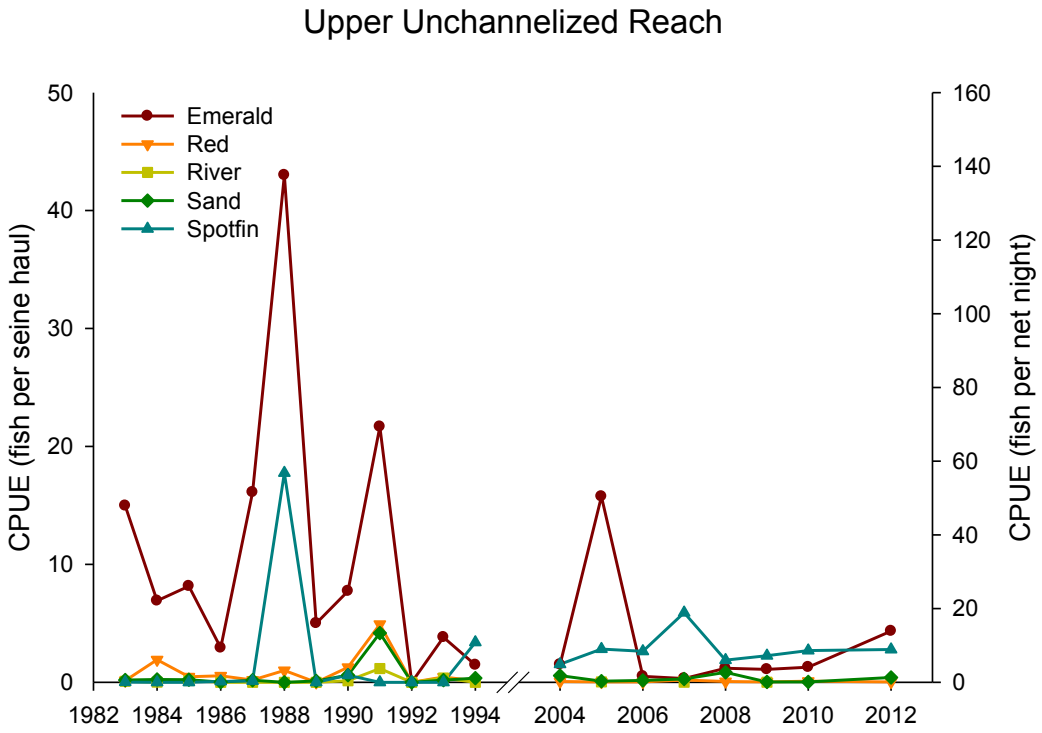

Figure 7. Annual catch rates of five target species from 1983 to 2012 in the upper unchannelized reach of the Missouri River.

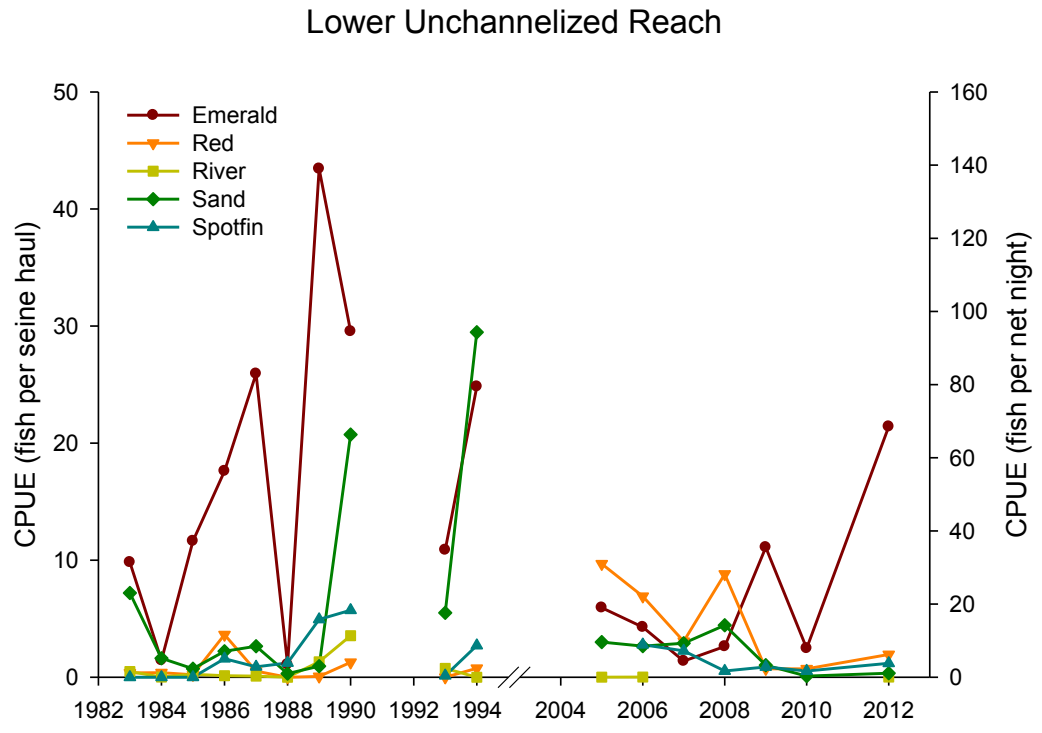

Figure 8. Annual catch rates of five target species from 1983 to 2012 in the lower unchannelized reach of the Missouri River.

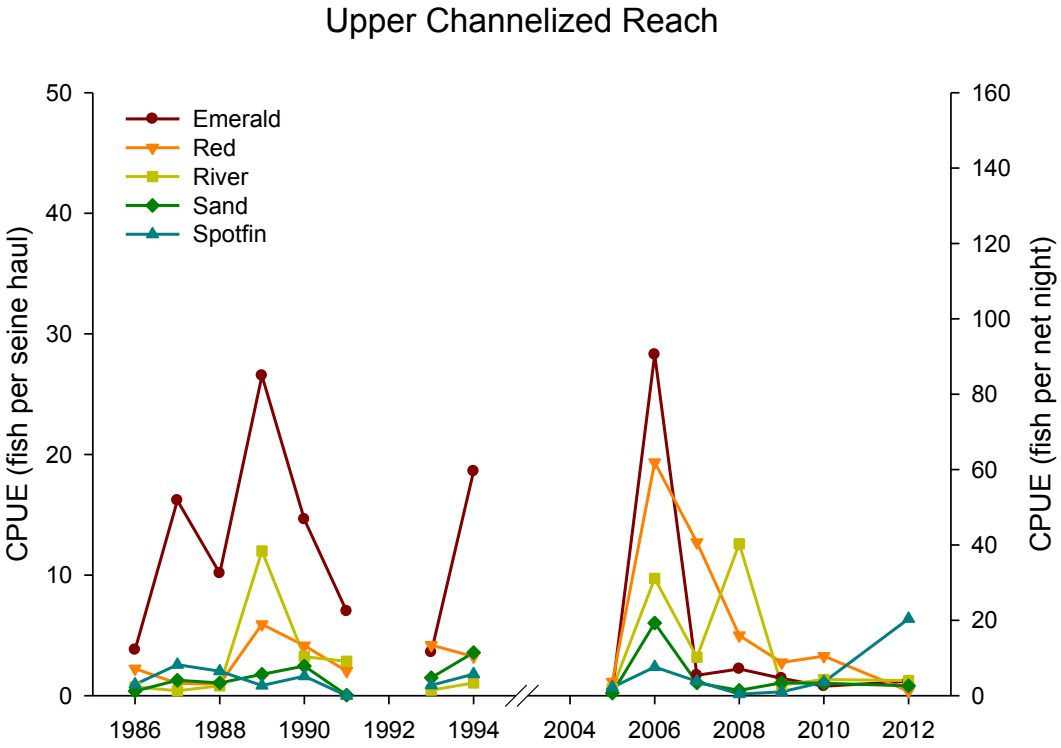

Figure 9. Annual catch rates of five target species from 1983 to 2012 in the upper channelized reach of the Missouri River.

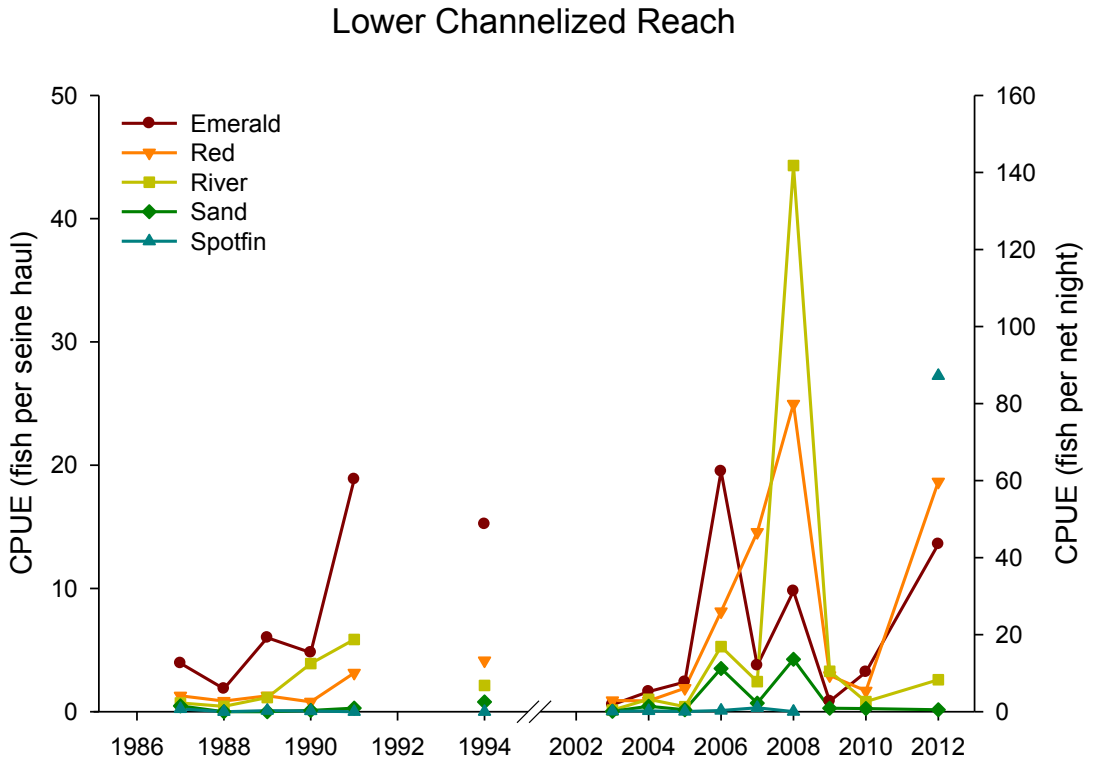

Figure 10. Annual catch rates of five target species from 1983 to 2012 in the lower channelized reach of the Missouri River.

shifted to more shiner species in the Missouri River (Steffensen et al. 2014). These shiner species are equipped to be more tolerant to changes in the river as decreased turbidity and modifications in flow regimes from dam construction have resulted in a shift of species in the fish community. The target species have not only become more abundant in the Missouri River over time, they are also common within Nebraska's tributaries (Peters et al. 2006, Bazata 2011). As a result, this change in the small bodied fish community has the potential to affect other species of higher trophic status (e.g., sauger, catfishes), and especially benthic feeding predator species (e.g., sturgeon).

The current Missouri River management and conditions have provided suitable habitat for the shiner species as their percent composition continues to increase over the past decades. Sampling methods have not been consistent between the historic and current sampling regimes; therefore, we cannot determine if the abundance of shiners are statistically increasing or just relative to the other small bodied fishes. As standardized sampling continues under the guidance of the Pallid Sturgeon Population Assessment protocols monitoring and assessment of these small bodied and short lived species will be continually studied. We theorize these target species will continue to persist in the Missouri River unless dramatic management decisions significantly alter the system.

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