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Abstract

Early fisheries investigation of the Missouri River fish community indicated that Sauger were common throughout Nebraska, including all major Missouri River tributaries. However due to many factors, their current range is restricted to the Missouri River and the lower reaches of a few tributaries. Hesse (1994) recommended listing Sauger as a state endangered species but this recommendation was never implemented. Therefore, the objective of this paper is to reevaluate the current population status of Sauger in the Missouri River along Nebraska's border. Over 2,100 Sauger have been captured from the Missouri River along Nebraska's eastern border since 2003. Sauger were most frequently captured in the riverine reach above Gavins Point Dam where they comprised 10% to 14% of the adult fish community captured. Sauger populations appear to be relatively stable throughout this reach over the past decade. Sauger were infrequently captured below Gavins Point Dam, representing less than two percent of the adult fish community. The Sauger population below Gavins Point Dam is highly variable making any long-term trends difficult to determine. The Sauger population reacted positively to the extreme flood conditions throughout the Missouri River in 2011, especially below Gavins Point Dam. As river management has not changed over the past half century, Sauger are just one of several native fish species experiencing greatly diminished population levels and rage contraction due to major river modifications.

Keywords: Missouri River, *Sander*, Sauger, Status, Trend

Introduction

Sauger (*Sander canadensis*) are native throughout central North America and inhabit rivers, reservoirs and lakes. Early ichthyological studies of the Missouri River fishes of Nebraska indicated that Sauger were common throughout Nebraska (Evermann and Cox 1896, Johnson 1942, Jones 1963). Historic Sauger distribution in Nebraska included the Missouri River and its major tributaries (Jones 1963). Sauger were collected throughout the Platte (to the Wyoming border), Blue, Loup, Elkhorn and Niobrara rivers; however, their current range is restricted to the lower reaches of these tributaries. Population declines appeared to be correlated with habitat fragmentation and degradation, as well as over exploitation by anglers (Hesse 1994, Pegg *et al*. 1996, Pegg *et al*. 1997, McMahon and Gardner 2001). Dams, which impede Sauger migrations and serve as concentration points that increase their vulnerability to angling, also affect connectivity to spawning areas, as well as disrupting the natural hydrograph, turbidity and temperature regimes necessary for species persistence. McMahon (1999) stated that Sauger is the most sensitive percid species to the aforementioned habitat alterations.

In response to system-wide population declines, hatchery supplementation has occurred throughout the Missouri River basin, especially in the main-stem reservoirs. Limited numbers of Sauger were stocked in Lewis and Clark Lake and the Nebraska reach of the Missouri River (Hesse *et al*. 1989). However, Hesse (1983) reported these hatchery reared fish did not survive; therefore, population supplementation has not continued in either Lewis and Clark Lake or the Nebraska reach of the Missouri River.

Identification and habitat preferences

Though generally smaller, Sauger are close relatives of Walleye (*Sander vitreus*) with a similar long and slender body morphology. Sauger collected in the Nebraska reaches of the Missouri River seldom exceed 610 mm (24 inches) or 2.0 kg (4.4 lbs.); whereas, Walleye attain lengths up to 750 mm (30 inches) and weights to 4.8 kg (10.5 lbs., K. Steffensen, unpublished data or present study). Sauger are distinguished from Walleye by the presences of dark spots on the webbing of the spinous dorsal fin and the lack of markings near the base of the last few spines (Pfieger 1997, Hesse 1994, Figure 1). Sauger coloration is bronze or brown with dark patterns extending below the lateral line. Additionally, Sauger lack the large white mark on the lower lobe of the caudal fin which is a distinguishing characteristic of the Walleye.

Sauger inhabit main channel habitats within larger rivers that are characterized by high turbidity and deep water (Hesse 1994, Pegg *et al*. 1997). Kallemeyn and Novotny (1977) captured Sauger in most habitats in the unchannelized and channelized reaches of the Missouri River. Sauger are a highly migratory species, moving hundreds of kilometers in open systems (Pegg *et al*. 1997, Jaeger *et al*. 2005). Sauger aggregate near spawning

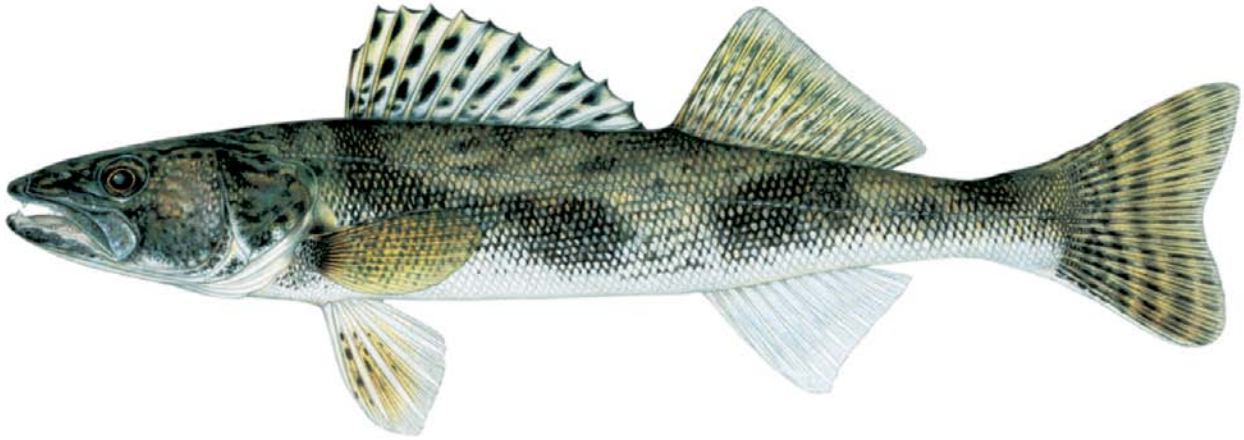

Figure 1. Sauger. Image copyright Joseph R. Tomelleri.

habitats in late winter and generally spawn in April when water temperatures are between 7.2 - 10.0ºC (Morris *et al*. 1974). Males arrive at the spawning areas before the females (Nelson 1968) and spawning occurs at night with several males fertilizing the eggs of a single female. Spawning substrates include coarse sand, gravel, cobble and pebbles (Hesse 1994) and spawning depth ranges from 0.3 – 1.8 m (Nelson 1968). Post hatch, larvae drift in the water column for 10 – 12 days with an estimated drift distance of 115 miles (McMahon 1999). Post absorption of the yolk sac, Sauger begin feeding on zooplankton but quickly change their diet to macroinvertebrate larvae and pupae (Nelson 1968). Sauger become piscivorous at approximately 70 to 110 mm (Nelson 1968, Priegal 1969). Females generally grow quicker than males and attain a larger maximum size (Pfieger 1997) and both genders reach sexual maturity at two years.

Hesse (1994) previously reported on the status of Sauger in Nebraska and noted that "Sauger is in desperate need of help" and may be approaching extirpation in Nebraska. Hesse documented that since river alterations (i.e., channelization and impoundment), the Sauger population has been reduced by 98%; therefore, recommended the species be immediately listed as an endangered species in Nebraska. To date, Sauger have not been listed as either a state endangered or threatened species. Thus, the objective of this paper is to re-evaluate the current population status of Sauger in the Missouri River along Nebraska's border using recently collected data.

Materials and methods

Study area

For this analysis, the Missouri River along Nebraska's border was divided into 5 reaches, four riverine reaches and one reservoir, based on physical and morphological characteristics (Figure 2). 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 the hypolimnetic releases from Fort Randall are reduced by Niobrara River outflows, with increased water temperature, turbidity and bed load.

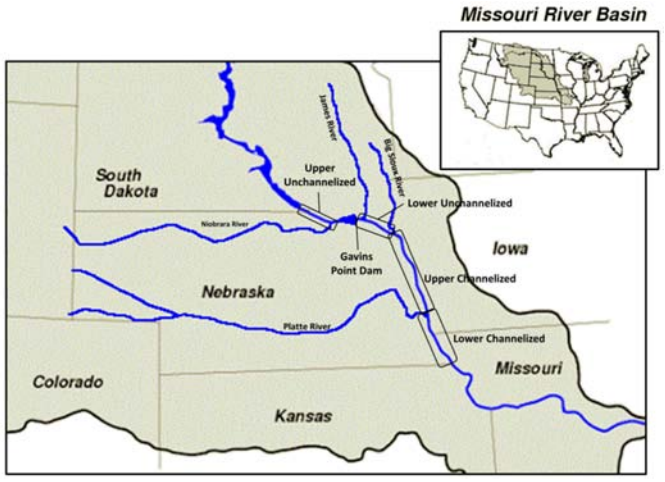

Figure 2. Map of the Missouri River basin. The four study reaches along Nebraska's eastern border are indicated within the ovals.

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.

Downstream of the lower unchannelized reach is a 29.5 rkm reach where channelization begins by "training" the river through a series of bends and dike structures. This reach more closely resembles the channelized reach; therefore, capture data is included with the upper channelized reach. The channelized portion of the Missouri River starts upstream of Sioux City, IA (rkm 1,182.4) 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]). The upper channelized reach has a highly degraded channel; however, tributary (i.e., Big Sioux River and Little Sioux River) impacts increase turbidity levels. The lower channelized river has an aggrading channel due to the influence of the Platte River and floods more frequently. Seasonally, the Platte River can highly influence the temperature and hydrograph on the lower channelized reach. 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.

Data collection

Data were acquired from three Field Offices associated with the U.S. Army Corps of Engineers (USACE) funded Pallid Sturgeon Population Assessment (PSPA) Project. The USACE formed a long-term monitoring and assessment project in response to the 2000 Missouri River Biological Opinion (Bi-Op, USFWS 2000) and the 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. Nebraska Game and Parks Commission (NGPC) sampled the two channelized reaches. The PSPA Project operates under a stratified random design in which the reaches are the strata and the experimental unit (i.e., river bends) were annually randomly selected (Welker and Drobish 2012a). Twenty-five percent of the bends per segment were randomly selected and sampled with a suite of standard gears. Standard gears were deployed annually throughout all reaches in the available habitats. Sampling efforts began in late-February into early-March when ice flows subside and continue through late-November. 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.

Sauger were collected following the standard operating procedures developed for the PSPA Project using a variety of gears (Welker and Drobish 2012a, Welker and Drobish 2012b). Gears used (annually) to monitor the Sauger populations included: gill nets, otter trawls, trammel nets and mini-fyke nets. Benthic static gill nets and mini-fyke nets were fished overnight for a maximum set time of 24 hours and catch per unit effort (CPUE) was calculated as the number of fish per net night. Benthic 4.9 m otter trawls were actively towed downstream while 1.0" trammel nets were drifted in the current. Catch per unit effort for otter trawls and trammel nets was calculated as number of fish collected per 100 m sampled. All Sauger were measured to the nearest millimeter and weighed to the nearest gram. See Welker and Drobish (2012a, 2012b) for more complete sampling gear specifications.

Catch per unit effort was calculated for each gear deployment then averaged by year to get an annual CPUE and a measure of variance. Annual CPUE's (annual number of Sauger captured/annual effort) were calculated for the standard gears (i.e., gill nets, otter trawls, trammel nets and mini-fyke nets) used in the PSPA Project and a gear trend (i.e., increasing, decreasing or stable) was based if the slope of a linear regression (PROC REG in SAS 9.2) line and if the slope was significantly different ($\alpha = 0.05$) than a zero slope. Population trends were then based on annual catch rate change amongst the suite of gear but also accounted for recruitment, the size distribution and rate of hybridization within each reach. Length frequency distributions were compared using the Kolmogorov-Smirnov test (PROC NPAR-1WAY in SAS 9.2) between reaches. The population's size structure was compared spatially and temporally using the incremental proportional size distribution (PSD) indices (Gabelhouse 1984) and the condition factor of relative weight (W_r; C.S. Guy, Kansas State University, unpublished data). Overall mean W_r was tested between reaches (PROC GLM in SAS 9.2).

Results

Over 2,100 Sauger were captured from the four riverine reaches of Missouri River along Nebraska's eastern border from 2003 through 2012. Sauger were most frequently captured in the upper unchannelized reach (N = 1,178) followed by the upper channelized (N = 590) and lower channelized reaches (N = 253, Table 1). Sauger were most infrequently captured in the lower unchannelized reach (N = 102). River wide, gill nets (N = 971) collected the most Sauger followed by trammel nets (N = 621), otter trawls (N = 388) and mini-fyke nets (N = 143). All gears displayed a similar trend in catch rates by reach, with the upper unchannelized reach having the highest catch rates followed by the upper channelized, lower channelized and finally the lower unchannelized reaches (Figure 3). The only exception was

Table 1. Number of deployments (effort), total number of fish collected, mean CPUE (fish per 100 m trawled) of all species collected and total number and CPUE for Sauger from 2003-2012 by reach.

Gear	Effort	Total Fish	Overall CPUE	Total Sauger	Sauger CPUE	Percent Composition	Effort	Total Fish	Overall CPUE	Total Sauger	Sauger CPUE	Percent Composition
	Upper Unchannelized						Lower Unchannelized					
GN	1708	4,271	2.50	417	0.24	9.8%	1599	8,778	5.50	41	0.03	0.5%
TN	2005	3,399	0.81	485	0.12	14.3%	2402	7,535	2.93	31	0.01	0.4%
OT	1391	4,338	1.08	226	0.06	5.2%	2041	5,106	1.73	19	< 0.01	0.4%
MF	648	29,288	45.2	50	0.08	0.2%	687	58,663	85.4	11	0.02	0.0%
	Upper Channelized						Lower Channelized					
GN	1224	16,430	8.11	331	0.14	2.0%	945	14,865	8.11	182	0.10	1.2%
TN	2121	7,913	4.06	82	0.04	1.0%	1622	6,090	4.49	23	0.02	0.4%
OT	2078	18,441	7.90	109	0.05	0.6%	1513	17,158	9.28	34	0.02	0.2%
MF	849	117,313	138.2	68	0.08	0.1%	685	85,021	124.1	14	0.02	0.0%

GN: Gill nets, TN: Trammel nets, OT: Otter trawls, MF: Mini-fyke nets

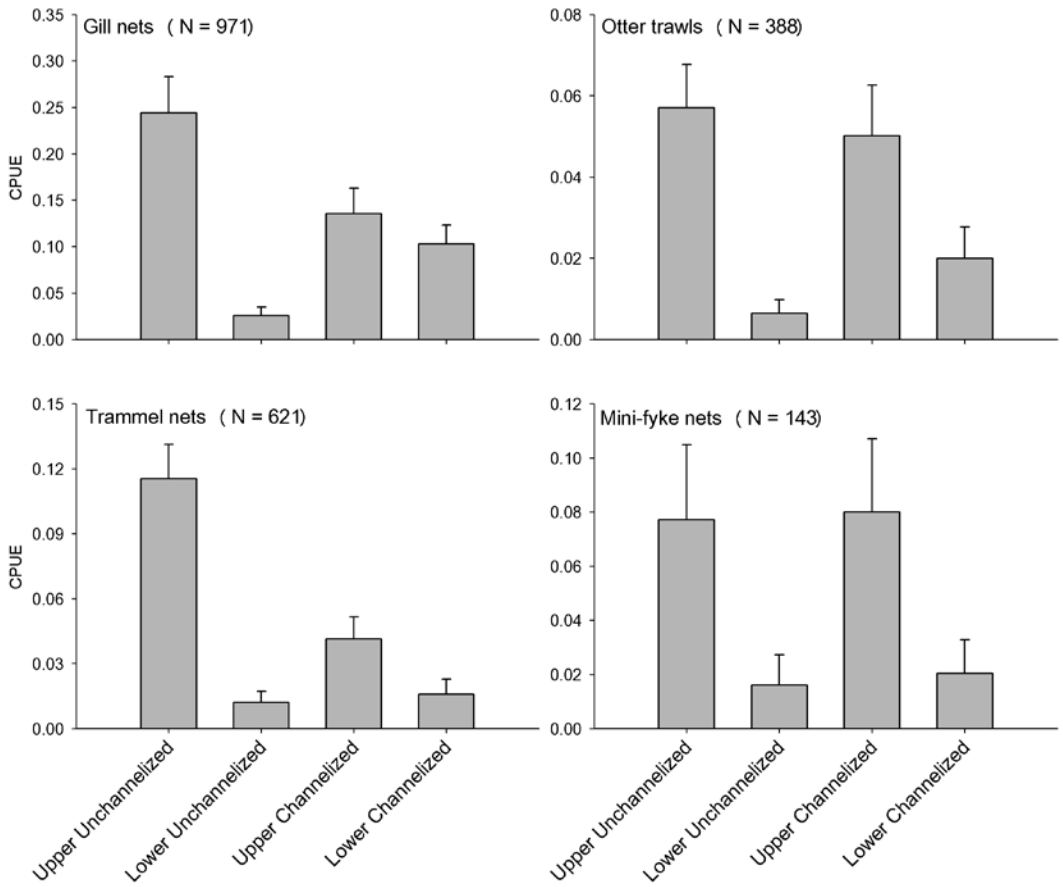

Figure 3. Mean catch per unit effort (± 2 SE) of Sauger by gear type and reach in the Missouri River along Nebraska's eastern border from 2003-2012. Note that the y-axis scales are different for each graph.

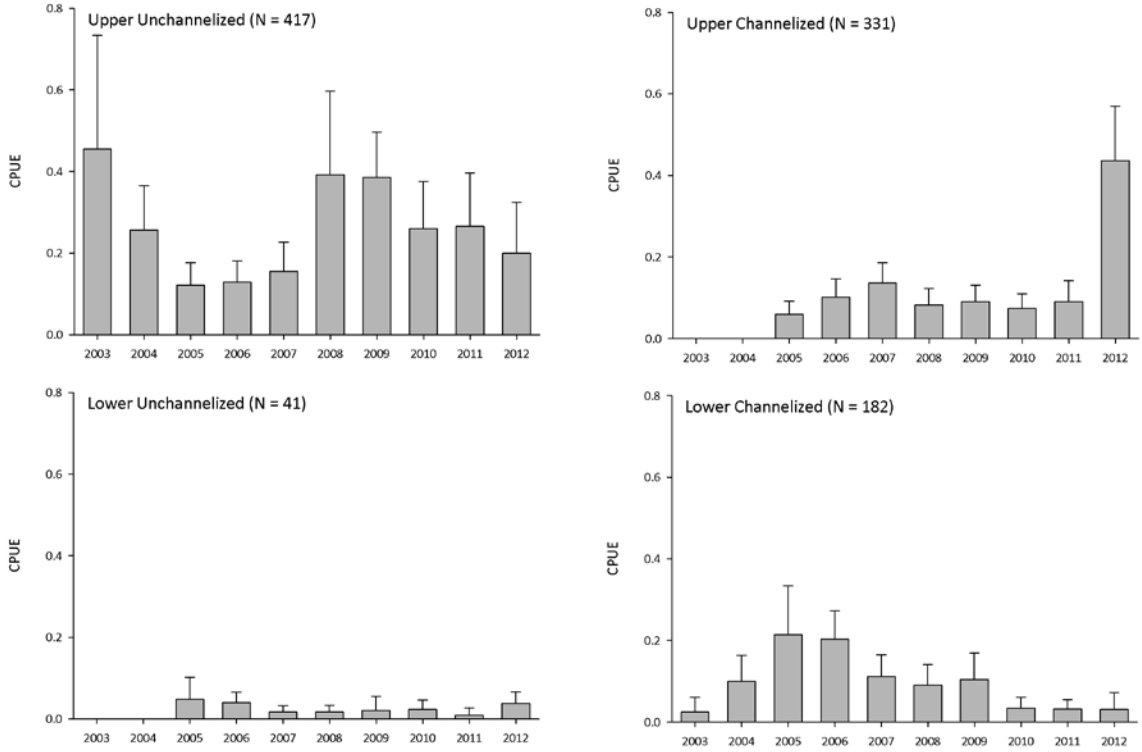

Figure 4. Mean gill net catch per unit effort (± 2 SE) for Sauger by reach in the Missouri River along Nebraska's eastern border from 2003-2012. Note that the y-axis scales are different for each graph.

catch rates with mini-fyke nets from the upper channelized were slightly higher than the upper unchannelized. Sauger catch rates with gill nets (CPUE = 0.24 fish per net night) and trammel nets (CPUE = 0.12 fish per 100 m drifted) in the upper unchannelized reach were at least twice as high as observed in the lower three reaches. Otter trawl and mini-fyke net catch rates were similar between the upper unchannelized and lower channelized reaches but three to six times higher than the lower unchannelized and lower channelized reaches.

Sauger represented a large percentage of the fish community in the upper unchannelized reach. Sauger comprised 14.3% of the adult fish community captured in trammel nets followed by 9.8% in gill nets and 5.2% in otter trawls (Table 1). In the lower three reaches, Sauger represented less than two percent of the relative abundance. Overall, Sauger represented a very small fraction (< 0.05 %) of the fish captured in mini-fyke nets across all reaches.

In the upper unchannelized reach, Sauger were most frequently captured in gill nets (N = 417) and trammel nets (N = 485) resulting in an overall CPUE of 0.24 fish per net night and 0.12 fish per 100 m drift, respectively (Figures 4 and 5). Catch rates with gill nets displayed a bimodal trend when CPUE's peaked in 2003 (CPUE = 0.46 fish per net night) and 2008 (CPUE = 0.39) and subsequently decreased the following years. Trammel net catch rates were more variable and did not display any discernible trend, but also peaked in 2008 (CPUE = 0.25 fish per 100 m drifted) at over twice the long-term mean CPUE. Reproduction and recruitment occurred annually in this reach. Age-0 Sauger captures peaked in 2008 when 19 fish were collected in otter trawls and mini-fyke nets followed by 2012 (N = 14) and 2009 (N = 12). Overall, no gears in the upper unchannelized reach showed either a significant change in the population size or trend.

In the lower unchannelized reach, Sauger were not frequently captured from 2005 to 2012. Sauger catch rates peaked with all gears in 2005 (Figures 4-7) and have declined since. No significant change in the population has occurred; however, the population size appears to be lower compared to the upper unchannelized and upper channelized reaches. During post flood sampling in 2012, Sauger CPUE's were the second highest recorded with all gears and was only the third time age-0 Sauger were captured in this reach.

In the upper channelized reach, catch rates with gill nets were relatively stable from 2005 through 2011 (Figure 4). However, catch rates in 2012 (CPUE = 0.436 fish per net night) was over four times greater than the long-term mean (CPUE = 0.009). Additionally, catch rates

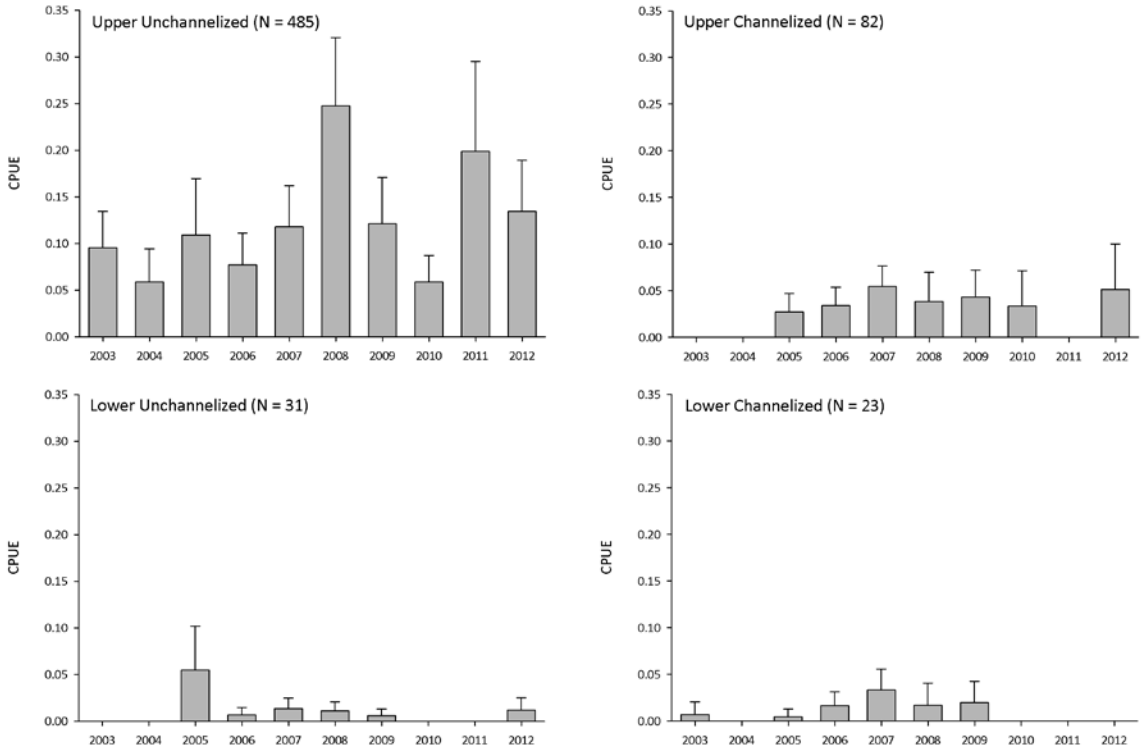

Figure 5. Mean trammel net catch per unit effort (± 2 SE) for Sauger by reach in the Missouri River along Nebraska's eastern border from 2003-2012. Note that the y-axis scales are different for each graph.

in 2012 were amongst the highest recorded with otter trawls (CPUE = 0.08 fish per 100 m trawled) and trammel nets (CPUE = 0.05 fish per 100 m drifted, Figures 5 and 6). Age-0 Sauger are captured annually with mini-fyke nets but catch rates are highly variable (Figure 7). The highest catch rate occurred in 2009 (CPUE = 0.28 fish per net night) and was four times higher than the long-term mean (Figure 7). However, no significant change in overall population size has occurred.

Lastly in the lower channelized reach, gill nets (N = 182) collected the majority of Sauger with infrequent captures using trammel nets, otter trawls and mini-fyke nets (Figures 4-7). Gill net CPUE peaked in 2005 and has steadily decreased; whereas, catch rates in otter trawls peaked in 2006. Age-0 Sauger were most frequently collected in 2006 (N = 35). Since 2006, age-0 Sauger have only been capture three times in the lower channelized reach in mini-fyke nets. However, no significant change in the population has occurred from 2003 to 2012.

The PSPA Project utilized a suite of gears that sampled the entire Sauger community. Gill nets ($\bar{X}$ = 421 mm, SD = 66) and trammel nets ($\bar{X}$ = 376 mm, SD = 68) mainly sampled the adult Sauger community; whereas, otter trawls ($\bar{X}$ = 252 mm, SD = 121) sample the entire population. Finally, mini-fyke nets target the small fish community, including age-0 fish, and rarely collected Sauger over 150 mm. The mean length of Sauger sampled ranged from 315 mm in the lower unchannelized reach to 354 mm in the lower channelized reach for all gears. The length frequency distribution of Sauger in the upper unchannelized reach was significantly different than the lower unchannelized (KS_a = 2.19, P = 0.0001) and the lower channelized (KS_a = 1.50, P = 0.0218; Figure 8). There were no other statistical differences in length frequency distributions between the other reaches. The difference between the upper unchannelized reach compared to the lower unchannelized and lower channelized reaches is the capture of age-0 Sauger captured in otter trawls and mini-fyke nets. Mini-fyke net catch rates for age-0 Sauger were approximately five time high in the upper unchannelized reach (CPUE = 0.055 fish per net night, N = 40) compared to the lower unchannelized reach (CPUE = 0.011, N = 8) and lower channelized reach (CPUE = 0.011, N = 8). Conversely, otter trawl catch rates was slightly higher in the lower channelized reach (CPUE = 0.012 fish per 100 m trawled, N = 20) compared to the upper unchannelized reach (CPUE = 0.007, N = 30). No age-0 Sauger were captured in the lower unchannelized reach with otter trawls.

Preferred-sized Sauger (380-510 mm, 52%) were the most common size group captured throughout all reaches and across all years (Table 2), followed by

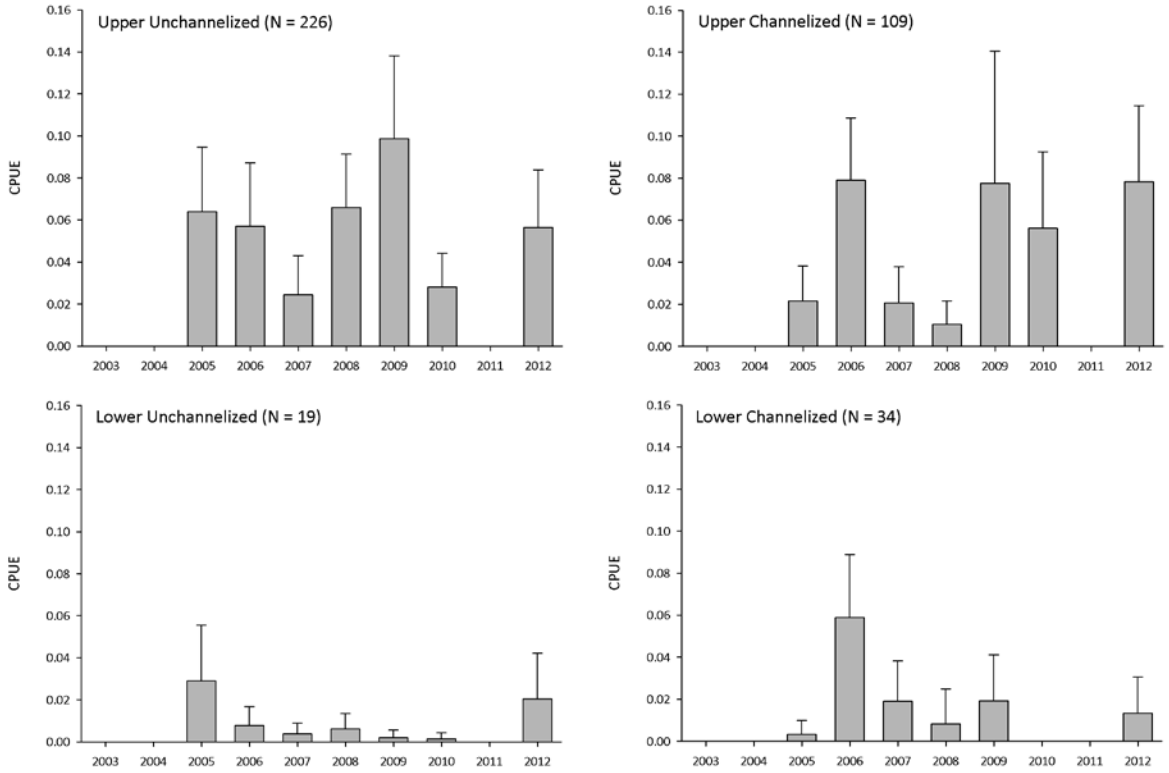

Figure 6. Mean otter trawl catch per unit effort (± 2 SE) for Sauger by reach in the Missouri River along Nebraska's eastern border from 2003-2012. Note that the y-axis scales are different for each graph.

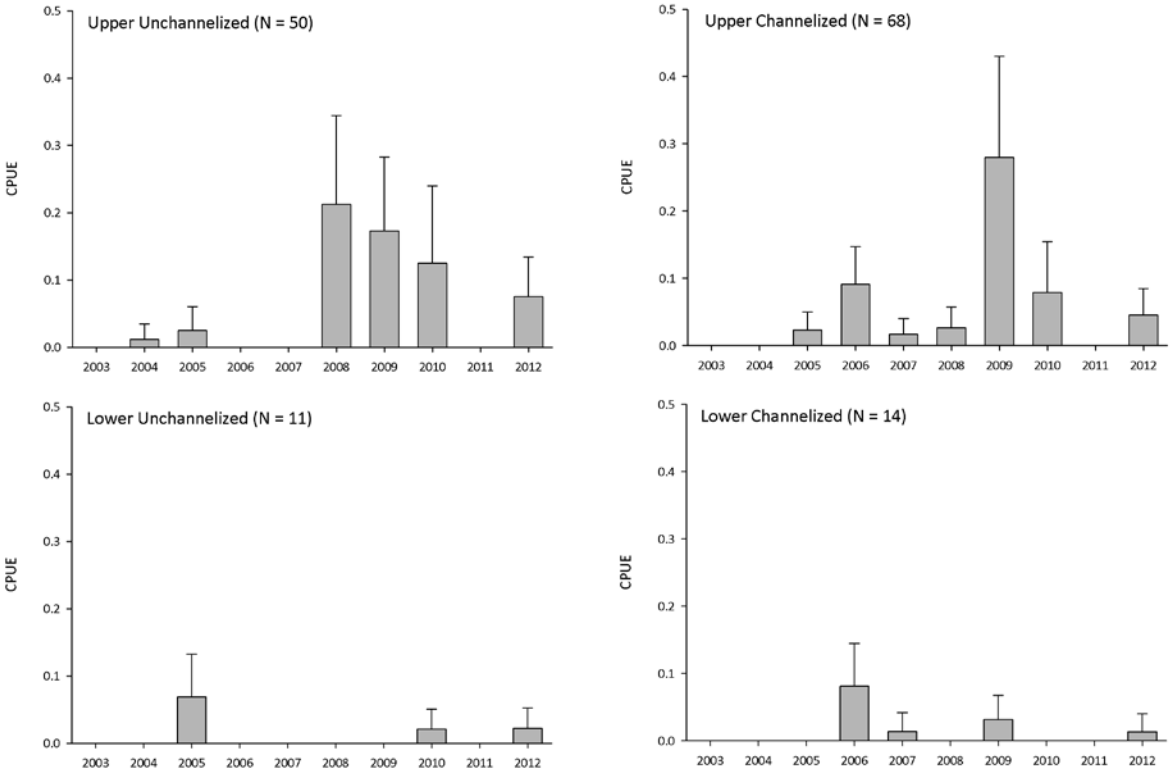

Figure 7. Mean mini-fyke net catch per unit effort (± 2 SE) for Sauger by reach in the Missouri River along Nebraska's eastern border from 2003-2012. Note that the y-axis scales are different for each graph.

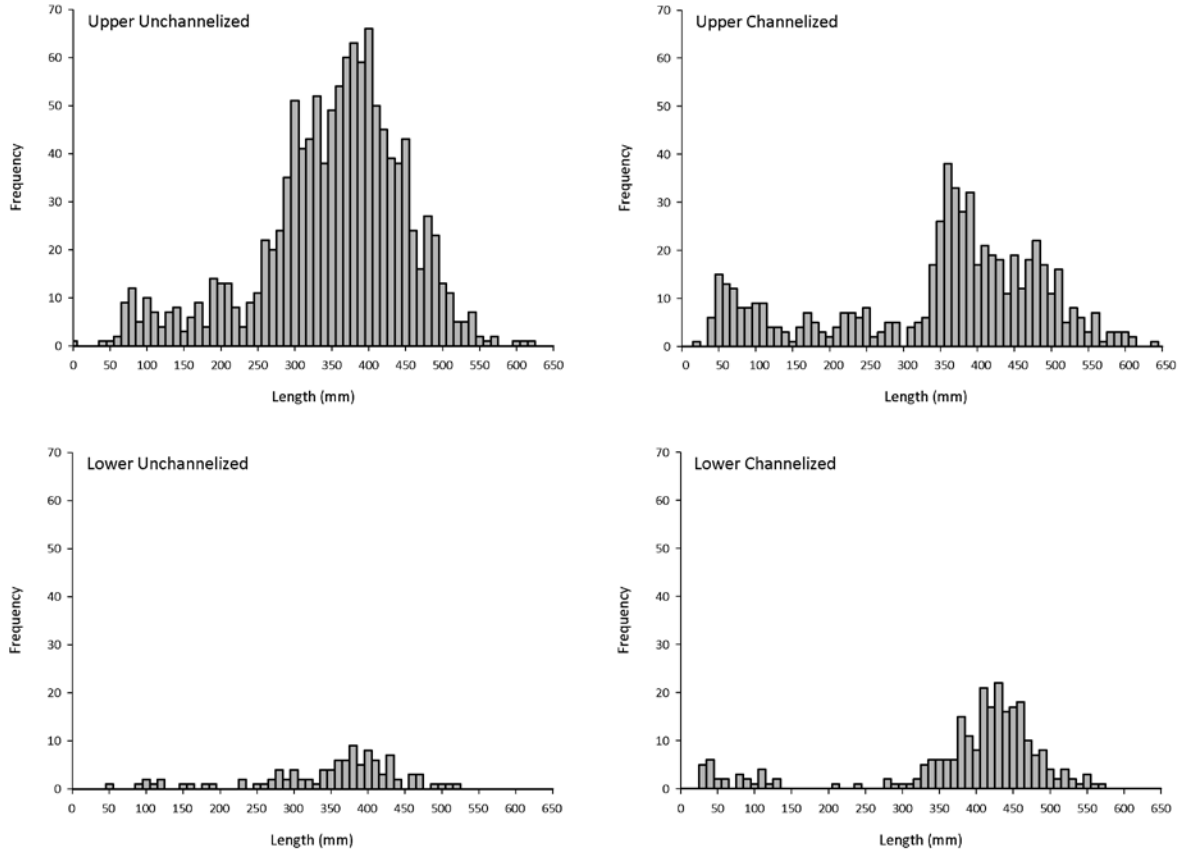

Figure 8. Length-frequency of Sauger captured in the Missouri River along Nebraska's eastern border from 2003-2012 by reach.

quality-sized (300-380 mm, 30%) and stock-sized (200-300 mm, 12%) fish. An additional, 253 sub-stock sized Sauger (< 199 mm) were collected. Memorable and trophy-sized fish are rarely collected throughout this study area but collected most frequently in the upper channelized reach. The PSD distributions were similar for the unchannelized reaches and the upper channelized reach but different from the lower channelized reach. Preferred sized fish were more abundant in the lower channelized reach compared to the upstream reaches and the percent of stock and quality sized fish was lower.

Overall annual mean relative weight (W_r) for stock-sized Sauger was similar and ranged from 76 to 82 (Figure 9). Quality-sized Sauger were highly variable temporally but spatially the mean W_r in the unchannelized reaches ($W_r = 79 \pm 1.9$) was significantly lower than the channelized reaches ($W_r = 93 \pm 1.8$, $P < 0.0001$). Preferred-sized Sauger were not as temporally variable as quality-sized Sauger but displayed similar reach trends. Relative weight was significantly higher in the channelized reaches ($W_r = 93 \pm 0.8$), $P < 0.0001$) compared to the unchannelized reaches ($Wr = 82 \pm 0.6$).

Hesse (1994) reported the gill net CPUE for Sauger from 1983 through 1991 in the upper unchannelized reach. Hesse's gill nets were similar to those used by the PSPA program but were three times longer (91.4 m); therefore, CPUE data were adjusted to the PSPA standard 30.5 m gill net. Catch rates peaked in 1983 with

Table 2. Number Sauger captured and mean percent incremental proportional size density (PSD) for Sauger collected by reach in the Missouri River from 2003-2012.

Reach	N	Stock (200 - 300 mm)	Quality (300 - 380 mm)	Preferred (380 - 510 mm)	Memorable (510 - 630 mm)	Trophy (≥ 630 mm)
Upper Unchannelized	1076	15	35	47	3	0
Lower Unchannelized	91	13	32	53	2	0
Upper Channelized	478	10	27	51	12	0
Lower Channelized	225	2	15	77	6	0
Total Captured	1,870	223	570	966	109	2

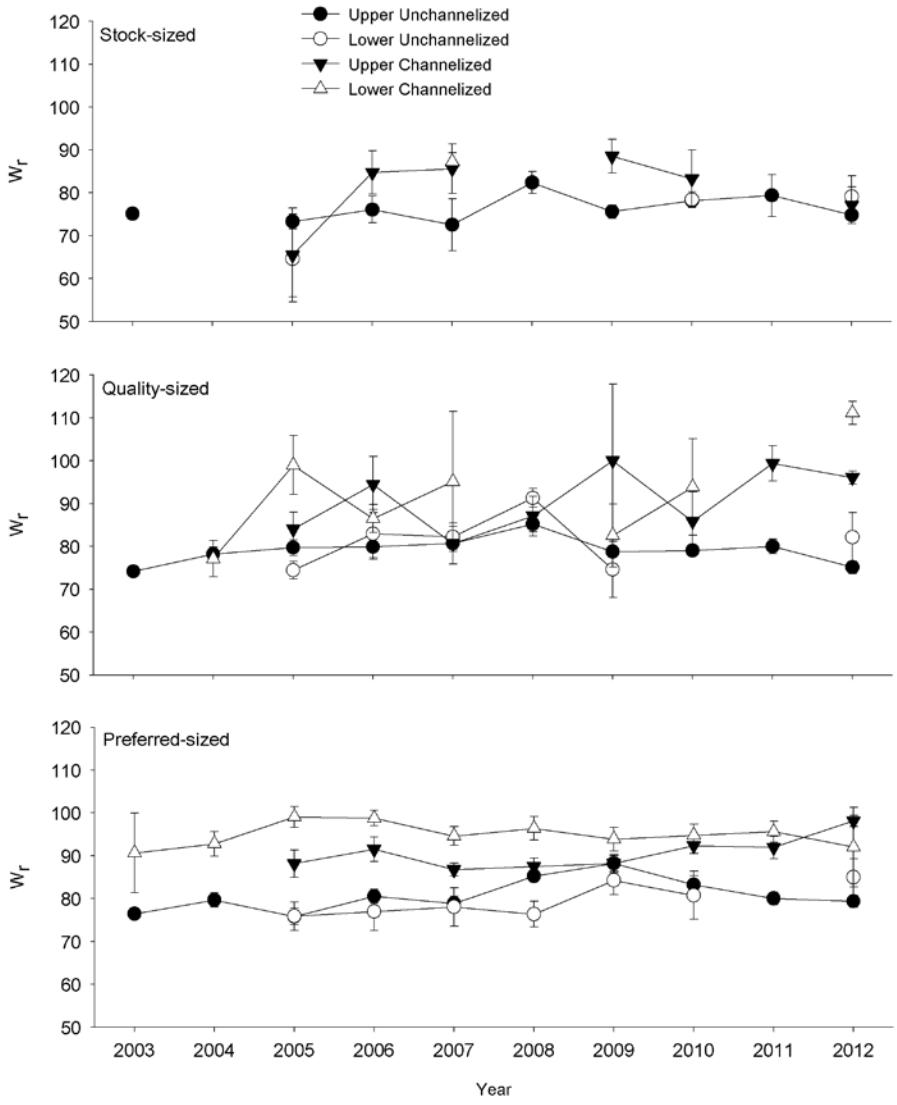

Figure 9. Relative weight (W_r) for stock-sized, quality-sized and preferred-sized Sauger by reach in the Missouri River along Nebraska's eastern border from 2003-2012.

1.5 fish per net night and steadily deceased until Sauger (≤ 0.1 fish per net night) were rarely collected from 1988 through 1991 (Figure 10). Gill net sampling in this reach resumed in 2003 and catch rates have returned to the levels observed in the mid-1980's. However, Sauger abundance has increased compared to the 1988 to 1991 time period (P = 0.0039).

Discussion

Sauger populations are greatly diminished compared to historic levels when Sauger comprised 10 to 65% of the main channel big-river fish group (Hesse 1994). In the upper unchannelized reach, the fish community is represented by 10 to 14% Sauger and the Sauger population appears to be relatively stable over the past decade. The population in the river below Gavins Point Dam is highly variable and it is difficult to determine any trend; however, Sauger now represents a minimal part of the large fish community. The Sauger population in the lower unchannelized reach has been the most affected by river alteration and fragmentation. This reach is impacted by the clear water released from Gavins Point Dam, which are not favorable conditions for Sauger. In comparison, that portion of the upper unchannelized reach below the mouth of the Niobrara has higher turbidity levels and supports a healthier Sauger population. In the upper unchannelized reach, Graeb *et al*. (2009) found that Sauger spawning locations shifted from the clear, cold water habitats downstream of Fort Randall Dam to the warmer, more turbid waters of the Niobrara River confluence. Sauger do not fare well in low turbidity conditions and generally Walleye become more abundant in these conditions (Nelson and Walburg 1977).

Furthermore in the unchannelized reaches, Sauger are a popular sport fish. Currently, a 381-mm (15") minimum length limit restricts Sauger harvest in the upper unchannelized reach but no length limit regulations exist below

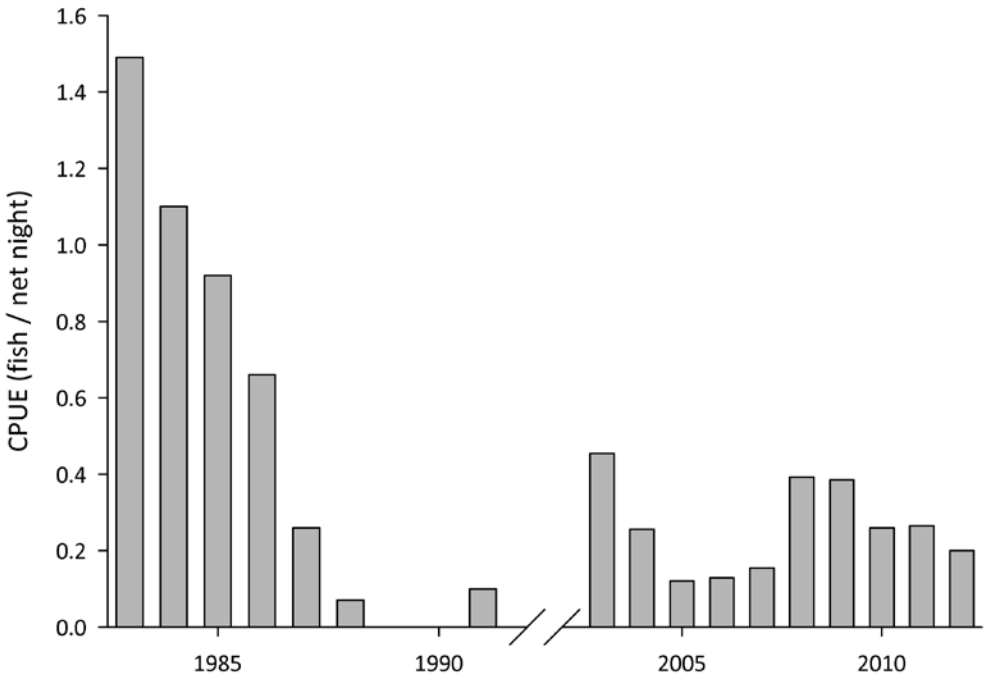

Figure 10. Long-term mean gill net catch per unit effort for Sauger for the upper unchannelized reach. Data from 1983-1991 was acquired from Hesse (1994) and standardized to 2003-2012 data set.

Gavins Point Dam. The lack of protection of small fish may account for the suppressed Sauger population levels in the lower unchannelized as small sized fish are regularly harvested (Mestl *et al*. 2001). Comparatively, Sauger are rarely targeted by anglers in the upper unchannelized reach and our data suggest that 45% of the sampled population are greater than the minimum length limit.

In the channelized reaches, the reduced Sauger populations are in part due to river channelization which eliminated critical backwater habitats and food availability. The effects of channelization are evident throughout the lower Missouri River as Sauger abundance downstream of the Nebraska/Kansas border is comparable to the channelized reaches throughout Nebraska. Annual catch rates varied annually but were generally between 0.03-0.20 fish per net night (Meyer *et al*. 2013, Niswonger *et al*. 2013, Wrasse *et al*. 2013). Sauger are most readily collected in the channelized river during winter gill netting when Sauger aggregate in deep pools behind wing dikes.

Sauger were once common in most tributaries throughout Nebraska; however, recent use of tributaries by Sauger in the state has not been well studied. Wanner *et al*. (2010) collected 125 Sauger while trammel netting in the Niobrara River from Spencer Dam to the confluence with the Missouri River in 2008 and 2009. Sauger consisted of 8% of the total trammel net catch in 2008 and 13% in 2009. However, larval Sauger comprised less than 0.01% of the larval fish collected. Hamel and others sampled the lower Platte River (below the confluence with the Loup River to the confluence with the Missouri River) from 2009-2012 and rarely captured Sauger (MJ Hamel, University of Nebraska-Lincoln, personal communication). Only 84 Sauger were captured in almost 3,200 trammel net deployments. How tributaries contribute to the Missouri River Sauger population is not completely understood, but relative abundance in the lower Niobrara and Platte Rivers appears to be similar to that found in the adjacent river reach.

Hybridization with Walleye is another factor affecting the Sauger populations, especially in the lower unchannelized reach. In the lower unchannelized reach, only 102 Sauger were collected the past decade and over 400 Walleye and 526 Sauger x Walleye hybrids (aka, Saugeyes) during this same period. The hybridization rate throughout this reach is approximately one hybrid for every pure Sauger or Walleye. Hybridization in the upper unchannelized reach is less common (N = 88, 1:13) but is more frequent than the channelized reaches (upper; N = 8, 1:74 and lower; N = 7, 1:36). Graeb (2006) noted frequent hybridization between Walleye and Sauger in Lewis and Clark Lake, as 21% of fish examined were identified as hybrids, occurring in multiple year classes. The increase in hybridization in unchannelized reaches is hypothesized to be an artifact of interrupted spawning migration by dams. Gavins Point Dam and Fort Randall Dam impede upstream fish movement and cause the species to aggregate in similar areas when spawning.

Age at sexual maturity of Missouri River Sauger was estimated based on the work of Preigel (1969). In a study on Lake Winnebago, WI in the early 1960's determined

that 50% of the male and female populations were sexually mature at a mean length of 249 and 285 mm, respectively, and that all males and females ≤ 229 mm were sexually immature. Based on these criteria and the populations sampled, 88% of the Sauger in the upper unchannelized, 87% in the lower unchannelized, 78% in the upper channelized, and 89% in the lower channelized populations are mature sized fish. This suggests that the Sauger population is heavily skewed towards mature sized fish in the Missouri River with limited reproduction and recruitment or the standard gears used for this study do not thoroughly sample the Sauger population (Figure 8).

Sauger reacted positively to the extreme flooding conditions throughout the Missouri River in 2011, especially in the lower unchannelized and upper channelized reaches. Similarly, Hesse (1994) reported large numbers of age-0 Sauger during the 1993 Missouri River flood while Van Zee (1996) found that age-0 Sauger abundance in Lewis and Clark Lake was positively associated with discharge from Fort Randall and Gavins Point Dams. As the Missouri River continues to be managed for navigation flows rather than a natural hydrograph, which cue Sauger migration and spawning, Sauger populations will likely continue to decline and require artificial supplementation.

To recover the Sauger population, Heese (1994) recommended "cessation of harvest, recovery of the natural hydrograph, recovery of sediment transport, recovery of snags and organic matter dynamics, and re-connection of cut-off side channel morphology". Essentially, except for creation of new side channels in the channelized reaches, these management recommendations have not been implemented. Sauger are just one of several native Missouri River fish species whose populations have been greatly diminished.

Management Recommendation

Hesse (1994) recommended listing Sauger as a state endangered species due to their precipitous declines throughout the Nebraska reaches of the Missouri River. Based on our sampling over the past decade, we do not feel endangered species listing is warranted, although increased management is needed. Continued monitoring of the Sauger population abundance is necessary to track population trends. Additionally, we recommend the development of a standard electrofishing survey to more accurately compare historic Sauger abundances to present conditions and a genetic fitness survey to monitor hybridization of Sauger and Walleye. Finally, a creel survey in the tail waters of Gavins Point Dam and Fort Randall Dam would document exploitation rates and determine the size structure of harvested Sauger, especially below Gavins Point no minimum size limit exist.

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