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Abstract

Anthropogenic alterations to the Missouri River have placed the Pallid Sturgeon (*Scaphirhynchus albus)* population in jeopardy and contributed to their listing as an endangered species. Pallid sturgeon were always less common than the sympatric Shovelnose Sturgeon (*S. platorynchus);* however, Pallid Sturgeon seemed to be more affected by river alterations as the river sturgeon ratio has become more skewed towards Shovelnose Sturgeon. Shortly after listing, population augmentation with hatchery produced Pallid Sturgeon began to supplement the diminishing wild population. Therefore, the objective of this study was to present the current population status of the Pallid Sturgeon in the Missouri River along Nebraska's border. Moving upstream along Nebraska's eastern border the population of wild Pallid Sturgeon declines and appears very minimal to non-existent upstream of Gavins Point Dam. The wild Pallid Sturgeon population below Gavins Point Dam appears unchanged over the past decade. Hatchery supplementation has stocked almost 12,000 hatchery-reared Pallid Sturgeon above Gavins Point Dam and over 135,000 below, these hatchery-reared fish are surviving and contributing to the overall population throughout all reaches as the capture frequency has increased annually. Currently, the Pallid Sturgeon population consists primarily of stock (66%) and quality-sized (22%) fish, most of which are of hatchery origin. Mean relative condition of quality and preferred-size Pallid Sturgeon varied spatially and temporally. As the Pallid Sturgeon population increases several population recruitment obstacles still exist. Until the bottleneck preventing natural recruitment is lessened, continued listing of the Pallid Sturgeon as an endangered species is critical to drive river management and restoration efforts which are likely to influence species recovery.

Key words: Endangered, Fish, Missouri River, Pallid Sturgeon, *Scaphirhynchus*, Status

Introduction

Sturgeon populations continue to diminish worldwide, with most species listed as federally endangered, threatened, or vulnerable (Pikitch *et al.* 2005, Rosenthal, Pourkazemi and Bruch 2006). Anthropogenic activities along the Missouri River have been detrimental to sturgeon populations by blocking fish migrations, removing or fragmenting spawning sites, reducing drift distance for larvae, and depleting available prey (Dryer and Sandvol 1993, Hesse, Mestl and Robinson 1993, Keenlyne 1997, Secor *et al.* 2002). Additionally, abiotic factors such as the hydrograph, water temperature, and turbidity (Hesse and Mestl 1993, Pegg, Pierce and Roy 2003), which historically cued spawning migrations and events, have been altered.

Three sturgeon species inhabit the Missouri River along Nebraska's border. Pallid Sturgeon (*Scaphirhynchus albus,* Figure 1) are rare and were listed as federally endangered in 1990 (55 FR 36641-36647, U.S. Fish and Wildlife Service 1990) and consequently became listed as a state endangered species under the Nebraska Nongame and Endangered Species Conservation Act. Commercial harvest for sturgeon was eliminated in Nebraska in 1956 (Zuerlein 1988) but the potential for incidental take of Pallid Sturgeon from recreational fishing continues in the channelized reach. Shovelnose sturgeon (*S. platorynchus)* are the most common sturgeon species. However, numbers are low in the reach between Fort Randal and Gavins Point Dams (Shuman and Klumb 2012) but are more common in the unchannelized reach downstream of Gavins Point Dam (Stukel, Kral and Loecker 2013). In both reaches, Shovelnose Sturgeon are protected from commercial and recreational fishing. Shovelnose sturgeon are common in the channelized section (Huenemann and Steffensen 2013, Steffensen and Huenemann 2013) and are open to recreational fishing downstream of the confluence of the Big Sioux River, Iowa (rkm 1,181.3). Lake Sturgeon (*Acipenser fulvescens)* are the third sturgeon species present in the Missouri River in Nebraska, and are considered rare and are listed as a state threatened species in Nebraska.

The historic abundance of Pallid Sturgeon in the Missouri River is unknown since differentiation between Shovelnose and Pallid Sturgeon did not occur until 1905 (Forbes and Richardson 1905) by which time most sturgeon populations in North America had already been overfished. The earliest record of a Pallid Sturgeon in Nebraska was from an article in the Omaha Bee which described the fish display at the 1896 State Fair. The Bee reported, "The two largest sturgeons ever exhibited in Nebraska are to be seen. Each measure about four feet four inches in length and weigh twenty-five pounds.

Figure 1. Pallid Sturgeon. Image copyright of Joseph R. Tomelleri.

They are of the shovelnose variety of sturgeon and were caught in the Platte River". Since 1905, there have only been a few Pallid Sturgeon observations in the scientific literature or commercial fishing reports. Forbes and Richardson (1905) reported that Pallid Sturgeon composed 20% of the river sturgeon (e.g. Shovelnose and Pallid Sturgeon) captured in the lower Missouri River (i.e., Gavins Point Dam to the confluence of the Mississippi and Missouri rivers. However, by 1952 only 5% of the sturgeon species captured in South Dakota were Pallid Sturgeon (Bailey and Cross 1954). Following the closure of Gavins Point Dam in 1955, the South Dakota Department of Game, Fish and Parks collected two (2) Pallid Sturgeon from Lewis and Clark Lake; comparatively, 127 Shovelnose Sturgeon were collected (Sprague 1960). Schmulbach, Gould and Groen (1975) classified Pallid Sturgeon as rare in the Missouri River from Gavins Point Dame to Rulo, NE when only one Pallid Sturgeon was captured. Carlson *et al.* (1985) sampled six sites in the lower Missouri River, including one site near Brownsville, NE (rkm 859.4), where two Pallid Sturgeon were captured compared to 481 Shovelnose Sturgeon. Overall, Pallid Sturgeon composed only 0.3% of the river sturgeon captured during the Carlson *et al.* (1985) study.

Since the listing of the Pallid Sturgeon as an endangered species in 1990 and prior to the Pallid Sturgeon Population Assessment (PSPA) Project beginning in 2003, twelve (12) Pallid Sturgeon were captured by Nebraska Game and Parks Commission (NGPC) between 1992 and 2002 (Table 1). However, neither the Mississippi Interstate Cooperative Resource Association (MICRA) Sturgeon Study (Grady *et al.* 2001) nor the Benthic Fish Study (Berry, Wildhaber and Galat 2004) which intensively sampled the benthic fish community collected any Pallid Sturgeon from the Missouri River along the Nebraska border.

Historic records of Pallid Sturgeon from tributaries in Nebraska are also rare. A single Pallid Sturgeon was collected in 1979 in the Platte River approximately 30 rkm upstream from the confluence with the Missouri River (Kallemeyn 1983). Additionally, a Pallid Sturgeon was reported from the Niobrara River via the photo archives at Nebraska Game and Parks. A photograph of a Pallid Sturgeon captured in the Niobrara River from the 1950's confirms this rare collection (G. Mestl, Nebraska Game and Parks Commission, Pers. Comm.).

In the original Pallid Sturgeon recovery plan, six recovery priority management areas (RPMA) were identified, covering the known range of Pallid Sturgeon (Dryer and Sandvol 1993). The Missouri River reach downstream of Fort Randall Dam to the headwaters of Lewis and Clark Lake was included in RPMA #3. The reach downstream of Gavins Point Dam to the confluence of the Missouri and Mississippi rivers was included in RPMA #4. Early management and stocking decisions were based on these management areas.

To supplement the diminishing population of wild Pallid Sturgeon, artificial propagation was initiated by the Missouri Department of Conservation in 1992 and continues at multiple hatcheries (Huenemann 2013). Artificial propagation was considered critical to avoid extinction and stabilize the populations. All propagation efforts are conducted under the authorization of the Pallid Sturgeon Range-Wide Stocking and Augmentation Plan (USFWS 2008a). In addition, these efforts follow approved parental mating (E. Heist, Southern Illinois University-Carbondale, Pers. Comm.) and tagging (Jaeger *et al.* 2007, Steffensen, Klumb and Doyle 2009) protocols. Since 1994, 15 year classes have been stocked throughout the Missouri River adjacent to Nebraska.

All Pallid Sturgeon stocked into RPMA #3 were from broodfish collected from the Yellowstone and upper Missouri rivers, in eastern Montana and western North Dakota. Initially, fish stocked into RPMA #4 were from broodfish collected from the Mississippi River (1992 and 1997 year classes, Huenemann 2013). Stockings from 1999-2007 in RPMA #4 relied on surplus production from upper Missouri River broodfish. In 2007, genetic research identified three distinctive population stocks within the Pallid Sturgeon range (Schrey and Heist 2007). In response to this new information the Pallid Sturgeon Recovery Team placed a moratorium on stocking upper basin hatchery-reared progeny into RPMA #4 due to concerns about immigration into the Mississippi River (Steffensen and Huenemann 2013). Therefore since 2007, progeny stocked into RPMA #4 were only

Table 1. Historic Pallid Sturgeon captures by the Nebraska Game and Parks Commission in the Missouri River prior to the initiation of the PSPA Project in 2003.

Origin	Location	Date	Length	Weight
Wild	Brownville	4/14/1992	843	1750
Wild	Goose Island	5/17/2000	1162	
Wild	Upper Plattsmouth Bend	3/28/2001	922	2766
Hatchery	Mouth of Niobrara River	8/8/2001	576	524
Hatchery	Upper Plattsmouth Bend	5/29/2002	195	15
Hatchery	Upper Plattsmouth Bend	6/11/2002	243	44
Hatchery	Upper Plattsmouth Bend	6/11/2002	223	36
Wild	Upper Plattsmouth Bend	7/1/2002	700	1200
Wild	Upper Plattsmouth Bend	8/26/2002	950	3400
Hatchery	Ponca Creek Reach	10/22/2002	589	566
Hatchery	Upper Plattsmouth Bend	11/5/2002	576	542
Hatchery	Upper Plattsmouth Bend	11/5/2002	415	204

from local broodfish. In response to this new genetic information and other supporting evidence, in 2008 the management units for Pallid Sturgeon recovery were redefined (USFWS 2008a). The Missouri River along the entire state of Nebraska is located in the Central Lowlands Management Unit (CLMU) which begins at Fort Randall Dam and continues downstream to the confluence of the Missouri and Grand rivers.

Recent studies have documented that hatchery-reared Pallid Sturgeon are: surviving at rates similar to other sturgeon species (Hadley and Rotella 2009, Steffensen, Powell and Koch 2010): reaching sexual maturity (Steffensen, Pegg and Mestl 2013): and successfully spawning (DeLonay *et al.* 2010, DeLonay *et al.* 2012). However, no age-0 Pallid Sturgeon and very limited numbers of potentially wild juveniles have been documented in the lower Missouri River along Nebraska's border since PSPA Project sampling began in 2003 (Steffensen, Pegg and Mestl 2013). The objective of this paper is to present the current population status of wild and hatchery-reared Pallid Sturgeon in the Missouri River along Nebraska's border.

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). However as Pallid Sturgeon are a riverine species, no sampling occurred in the reservoir reach. 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

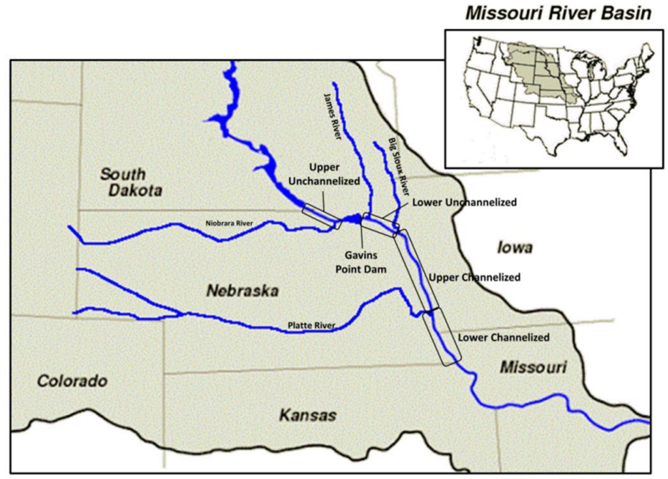

Figure 2. Map of the Missouri River basin. The four study reaches along Nebraska's eastern border are indicated within the ovals.

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.

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 with simple channel morphology and limited in-channel habitats. 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 turbidity, 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. 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) are 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.

Pallid Sturgeon were collected following the standard operating procedures developed for the PSPA Project using a variety of gears that captures the entire size range of Pallid Sturgeon (Welker and Drobish 2012a, Welker and Drobish 2012b). Sampling gears used (annually) to monitor the Pallid Sturgeon population trends included: gill nets, otter trawls, and trammel nets. Trot lines were then added to the sampling regime in 2009. Benthic static gill nets and trot lines were fished overnight for a maximum set time of 24 hours. Catch per unit effort (CPUE) for gill nets were measure by fish per net night and fish per 20 hook nights for trot lines. Benthic 4.9 m otter trawls were actively towed downstream while 1.0″ mesh trammel nets were drifted in the river's current. Catch per unit effort for otter trawls were measured by fish per 100 m trawled and fish per 100 m drifted for trammel nets. Additionally, static set lines and rod and reel fishing targeted specific habitats of known Pallid Sturgeon aggregations to increase recapture success. Beginning in 2008, NGPC conducted an additional intensive annual effort from an 80.5 rkm reach below the confluence of the Platte River to collect local reproductively mature broodfish for the propagation program. See Welker and Drobish (2012a, 2012b) for sampling gear specifics.

All Pallid Sturgeon sampled were collected and handled according to the Biological Procedures and Protocols for Researchers and Managers Handling Pallid Sturgeon (USFWS 2008b). All fish were measured to the nearest millimeter fork length, weighed to the nearest gram and checked for any tags or marks. Starting in 2005, fin clips were taken for genetic analysis from all unmarked Pallid Sturgeon and were sent to Southern Illinois University (Carbondale, IL) or US Fish and Wildlife Service's Lamar Fish Technology Center (Lamar, PA) for origin validation. Pallid Sturgeon were then classified as wild or hatchery-reared based on the presence of hatchery marks (i.e., scute removed, elastomer mark, passive integrated transponder, code wire tag, dangler tag, or various combination) or genetic analysis (Schrey *et al.* 2007); however, the origins of several fish remained unknown. Fish were determined to be wild when their genetic results did not match any known parental crosses used in the propagation program. However, the parental genetic archive is missing a few records, meaning some wild fish maybe classified incorrectly. Fish were determined to be of hatchery origin when hatchery tags were present or genetic results matched a known parental cross. Unknown-origin fish were those recaptured with an assumed hatchery tag (i.e., PIT tag); therefore, a genetic sample was not collected. However, a stocking or capture history could not be determined using the tag data.

Catch per unit effort was calculated for each gear deployment instead of overall catch per overall effort to get a measure of variance. These individual CPUEs were then averaged to get a total CPUE for an individual gear type, reach and year. Annual CPUE's for the standard sampling gears (i.e., gill nets, trot lines, otter trawls, and trammel nets) were used to assign a gear trend (i.e., increasing, decreasing, not changing or rare) by origin (i.e., wild and hatchery-reared). Population trends were then based on annual catch rate change amongst the suite of gears but also accounted for recruitment and the size distribution within each reach. The population's size structure was compared spatially and temporally using the incremental proportional size distribution (PSD) indices developed for Pallid Sturgeon (Guy *et al.* 2007, Shuman, Willis and Krentz 2006). Similarly, relative condition (K_n) was compared using the formula provided by Shuman *et al.* (2011). Length-at-maturity was 788-mm as described in Steffensen, Pegg and Mestl (2013). Finally, the ratio of Pallid Sturgeon to Shovelnose Sturgeon was calculated to compare to historical abundance information.

Results

Over the past 10 years, 3,445 Pallid Sturgeon were collected from the Missouri River along Nebraska's eastern border. Of those, 3,104 (90%) were hatchery-reared, 255 were wild, and 86 remain of unknown origin. Wild Pallid Sturgeon were most frequently captured in the lower channelized reach (N = 191) followed by the upper channelized reach (N = 56, Figure 3). Wild Pallid Sturgeon are infrequently collected in both unchannelized reaches (N = 8) and are considered rare (Table 2, Figure 3). Whereas, the catch rates of wild Pallid Sturgeon in the channelized reach appear consistent. Catch rates for hatchery-reared Pallid Sturgeon have increased throughout all reaches (Table 3). In the upper unchannelized reach, catch rates of hatchery-reared Pallid Sturgeon peaked in 2009 and have since declined. The remaining reaches have been more variable but catch rates with gill nets, which capture the most hatchery-reared Pallid Sturgeon, have been increasing annually. These increased catch rates are attributed to the artificial propagation and stocking program.

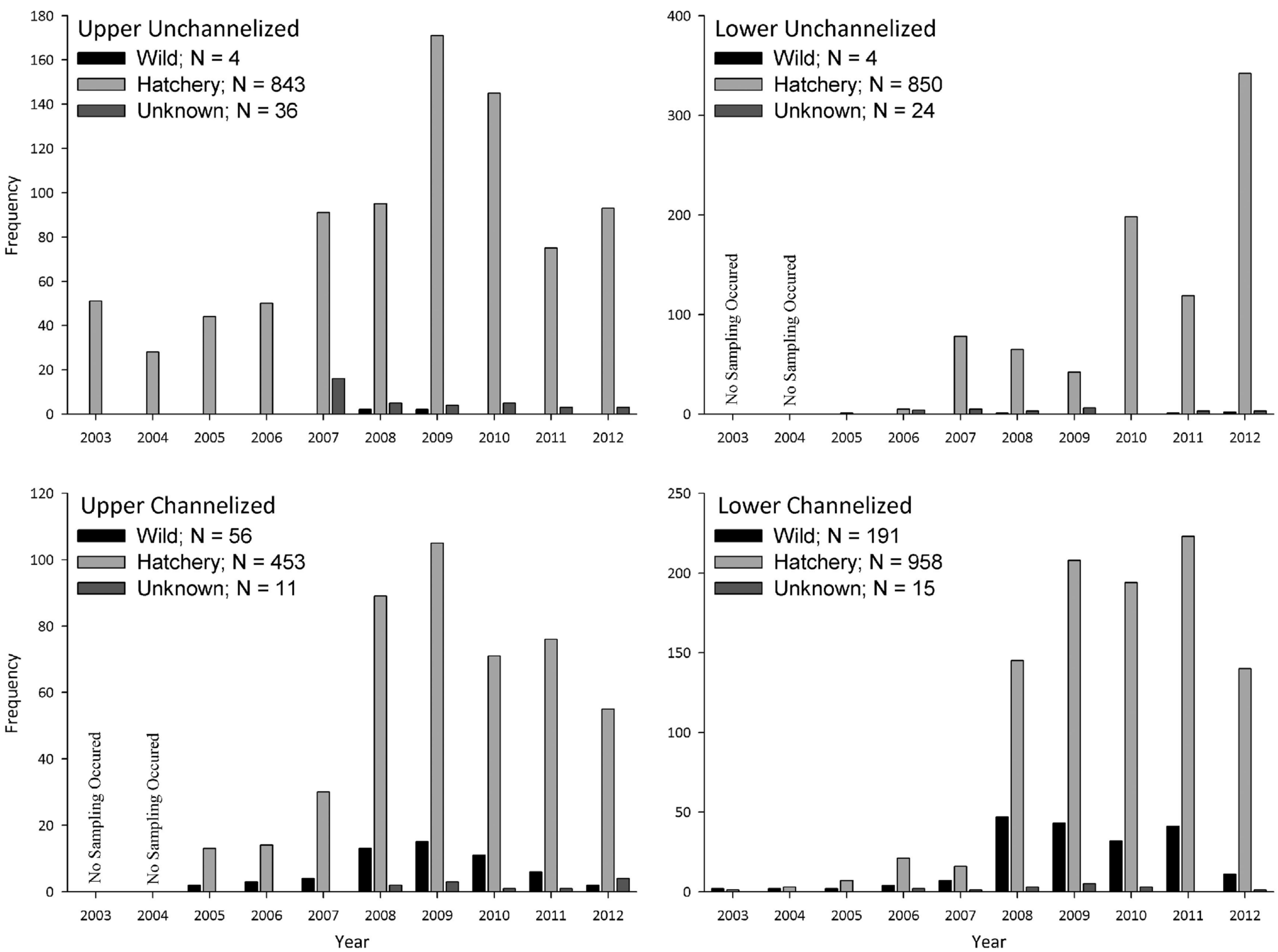

Figure 3. Annual capture history for Pallid Sturgeon by origin collected by reach in the Missouri River from 2003-2012. Figure includes all Pallid Sturgeon captured. Genetic records for hatchery progeny are incomplete. Thus, fish classiffied as wild should be considered "potentially wild," meaning these fish did not match a known parental cross. Pallid sturgeon of unknown origin did not have a genetic sample taken when capture; therefore, an origin could not be assisgned. Note that the y-axis scales are different for each graph.

Table 2. Mean catch per unit effort (±2 SE) and overall reach population status (I = Increasing, U = Unchanged, D = Decreasing, R = Rare) for wild Pallid Sturgeon collected by reach in the Missouri River from 2003-2012. n/s indicates no sampling occurred.

Reach	Gear	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	Status
Upper Unchannelized	GN	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	R
	TN	0.000	0.000	0.000	0.000	0.000	0.003 (0.006)	0.000	0.000	n/s[A]	0.000	
	OT	n/s	n/s	0.000	0.000	0.000	0.000	0.000	0.000	n/s[A]	0.000	
	TL	n/s	n/s	n/s	n/s	n/s	n/s	0.000	0.000	0.000	0.000	
Lower Unchannelized	GN	n/s	n/s	0.000	0.009 (0.004)	0.000	0.000	0.000	0.000	n/s[A]	0.000	R
	TN	n/s	n/s	0.000	0.000	0.000	0.003 (0.019)	0.000	0.000	n/s[A]	0.003 (0.006)	
	OT	n/s	n/s	0.000	0.000	0.000	0.000	0.000	0.000	n/s[A]	0.000	
	TL	n/s	n/s	n/s	n/s	n/s	n/s	0.000	0.000	0.000	0.003 (0.005)	
Upper channelized												
	GN	n/s	n/s	0.009 (0.011)	0.009 (0.009)	0.003 (0.005)	0.007 (0.009)	0.020 (0.016)	0.010 (0.009)	0.007 (0.009)	0.000	U
	TN	n/s	n/s	0.000	0.000	0.002 (0.002)	0.011 (0.010)	0.000	0.000	n/s[A]	0.000	
	OT	n/s	n/s	0.000	0.000	0.000	0.000	0.000	0.000	n/s[A]	0.000	
	TL	n/s	n/s	n/s	n/s	n/s	n/s	0.055 (0.045)	0.034 (0.018)	0.013 (0.015)	0.000	
Lower channelized	GN	0.000	0.000	0.000	0.007 (0.009)	0.009 (0.013)	0.017 (0.019)	0.012 (0.015)	0.009 (0.014)	0.027 (0.021)	0.006 (0.013)	U
	TN	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	n/s[A]	0.000	
	OT	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.000	n/s[A]	0.000	
	TL	n/s	n/s	n/s	n/s	n/s	n/s	0.035 (0.034)	0.021 (0.015)	0.000	0.038 (0.018)	

A: Incomplete sampling due to flooding conditions
GN: Gill nets, TN: Trammel nets, OT: Otter trawls, TL: Trot lines

A total of 11,589 hatchery-reared Pallid Sturgeon have been stocked in the upper unchannelized reach (Table 4). Early stocking events were mainly ≥age-2 fish from the 1997, 1998, and 1999 year classes. Later stockings featured mostly age-1 fish (64%, N = 7,436), with the exception being 3,400 age-0 and 26 ≥ age-2 fish. Numbers of fish varied by year class and ranged from 98 fish for the 1998 year class to 4,047 fish from the 2008 year class. The majority (N = 3,410) of the 2008 year class were stocked at age-0. In addition to hatchery supplementation, 12 adults were translocated from the upper Missouri River and Lake Sharpe.

Supplementation levels below Gavins Point Dam have occurred at higher levels with over 135,000 hatchery-reared Pallid Sturgeon released (Table 4). This includes the entire lower Missouri River, not just along Nebraska's eastern border. The majority (N = 71,236) were stocked at age-1 followed by age-0 (N = 59,734). The number of fish stocked was dependent upon the number of broodfish captured and the subsequent numbers of offspring that survived to a stock size fish. Numbers stocked varied from 532 from the 1999 year class to nearly 40,000 fish from the 2004 year class.

Lengths of wild Pallid Sturgeon varied from 330 to 1,108 mm with an overall mean length of 860 mm (Figure 4). The majority (N = 207, 76%) were greater than the minimum length-of-maturity (788 mm) while only five fish were less than 500-mm. Comparatively, only 5% of the hatchery-reared Pallid Sturgeon collected were greater than the minimum length-of-maturity (Table 5). Hatchery-reared fish lengths varied from 111–1,125 mm with an overall mean length of 534 mm.

Using the PSD terminology of Guy et al. (2007), stock-sized fish (330-629 mm, N = 2,284) were the most common size group captured throughout all reaches and across all years (Table 5) followed by quality-sized (630-839 mm, N = 743) and preferred-sized (840-1039 mm, N = 241) fish. Overall, 71% of Pallid Sturgeon captured in the upper unchannelized reach were stock-sized whereas 83% were stock sized fish in the lower unchannelized and 72% were stock-sized in the upper channelized. Conversely, only 55% of fish in the lower channelized reach were stock-sized. All sub-stock (≤ 329 mm) fishes were of hatchery-origin while large (i.e., memorable [1040-1269 mm] and trophy sized [≥ 1270 mm]) adults are rare captures. No sub-stock and only 22 stock-sized wild Pallid Sturgeon were collected.

Differences in mean relative condition (K_n) for stock-sized Pallid Sturgeon were minimal between reaches; whereas, quality-sized and preferred-sized fish were

Table 3. Mean catch per unit effort (±2 SE) and overall reach population status (I = Increasing, U = Unchanged, D = Decreasing, R = Rare) for hatchery-reared Pallid Sturgeon collected by reach in the Missouri River from 2003-2012. N/S indicates no sampling occurred.

Reach	Gear	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	Status
Upper Unchannelized	GN	0.023 (0.045)	0.050 (0.057)	0.032 (0.028)	0.037 (0.027)	0.087 (0.046)	0.090 (0.050)	0.215 (0.093)	0.060 (0.034)	0.066 (0.037)	0.210 (0.141)	I
	TN	0.005 (0.006)	0.019 (0.016)	0.045 (0.027)	0.016 (0.011)	0.070 (0.047)	0.073 (0.039)	0.075 (0.041)	0.059 (0.032)	n/s^A	0.050 (0.027)	
	OT	n/s	n/s	0.011 (0.010)	0.006 (0.007)	0.029 (0.024)	0.036 (0.020)	0.035 (0.027)	0.024 (0.017)	n/s^A	0.017 (0.013)	
	TL	n/s	n/s	n/s	n/s	n/s	n/s	0.818	0.988 (0.374)	0.667 (0.253)	0.325 (0.220)	
Lower Unchannelized	GN	n/s	n/s	0.000	0.004 (0.008)	0.004 (0.009)	0.021 (0.018)	0.008 (0.011)	0.023 (0.023)	n/s^A	0.047 (0.030)	I
	TN	n/s	n/s	0.003 (0.006)	0.010 (0.008)	0.077 (0.033)	0.025 (0.021)	0.035 (0.027)	0.039 (0.037)	n/s^A	0.018 (0.011)	
	OT	n/s	n/s	0.000	0.003 (0.006)	0.010 (0.008)	0.021 (0.017)	0.010 (0.008)	0.005 (0.005)	n/s^A	0.008 (0.011)	
	TL	n/s	n/s	n/s	n/s	n/s	n/s	0.067 (0.050)	0.100 (0.036)	0.143 (0.057)	0.142 (0.063)	
Upper channelized	GN	n/s	n/s	0.004 (0.008)	0.014 (0.012)	0.011 (0.010)	0.065 (0.029)	0.050 (0.029)	0.037 (0.027)	0.081 (0.036)	0.054 (0.027)	I
	TN	n/s	n/s	0.019 (0.010)	0.000	0.031 (0.014)	0.026 (0.019)	0.020 (0.020)	0.050 (0.049)	n/s^A	0.012 (0.046)	
	OT	n/s	n/s	0.012 (0.014)	0.008 (0.007)	0.025 (0.020)	0.015 (0.013)	0.034 (0.022)	0.003 (0.005)	n/s^A	0.019 (0.024)	
	TL	n/s	n/s	n/s	n/s	n/s	n/s	0.258 (0.109)	0.202 (0.059)	0.211 (0.067)	0.088 (0.039)	
Lower channelized	GN	0.013 (0.025)	0.010 (0.020)	0.000	0.017 (0.014)	0.028 (0.022)	0.074 (0.042)	0.058 (0.034)	0.064 (0.029)	0.105 (0.081)	0.106 (0.058)	I
	TN	0.000	0.000	0.015 (0.017)	0.027 (0.017)	0.027 (0.019)	0.016 (0.015)	0.011 (0.035)	0.000	n/s^A	0.028 (0.037)	
	OT	0.000	0.006 (0.012)	0.004 (0.007)	0.009 (0.010)	0.004 (0.008)	0.020 (0.020)	0.013 (0.018)	0.012 (0.017)	n/s^A	0.010 (0.017)	
	TL	n/s	n/s	n/s	n/s	n/s	n/s	0.251 (0.087)	0.198 (0.062)	0.116 (0.054)	0.222 (0.067)	

A Incomplete sampling due to flooding conditions
GN: Gill nets, TN: Trammel nets, OT: Otter trawls, TL: Trot lines

Table 4. Number of hatchery-reared Pallid Sturgeon stocked by age class (age-0, age-1, and ≥ age-2) above and below Gavins Point Dam. Numbers stocked below Gavins Point Dam includes all fish stocked in the lower Missouri River, not just along Nebraska's border.

Age Class	Year Class															
	1992	1997	1998	1999	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
	Upper Unchannelized (RPMA #3)															
Age-0												3,410				
Age-1					558	601	515	868	1,005	600	1,169	637	848	635		
≥ Age-2		438	98	181				26								
Total		438	98	181	558	601	515	894	1,005	600	1,169	4,047	848	635		
	Missouri River below Gavins Point Dam (RPMA #4)															
Age-0		2,015					5,364	30,628			2,000	4,466	3,981	3,673	7,607	
Age-1					7,384	9,241	4,743	8,508	3,654	3,642	1,336	2,197	10,611	5,907	14,013	
≥ Age-2	2,533	35		532				15			1,094					
Total	2,533	2,050		532	7,384	9,241	10,107	39,151	3,654	3,642	4,430	6,663	14,592	9,580	21,620	

variable spatially and temporally (Figure 5). Overall K_n for quality-size fish was higher in the channelized reaches (upper channelized, K_n = 0.93, lower channelized, K_n = 0.93) compared to the unchannelized reaches (upper unchannelized, K_n = 0.88, lower unchannelized, K_n = 0.88). Preferred-size fish followed the similar trend.

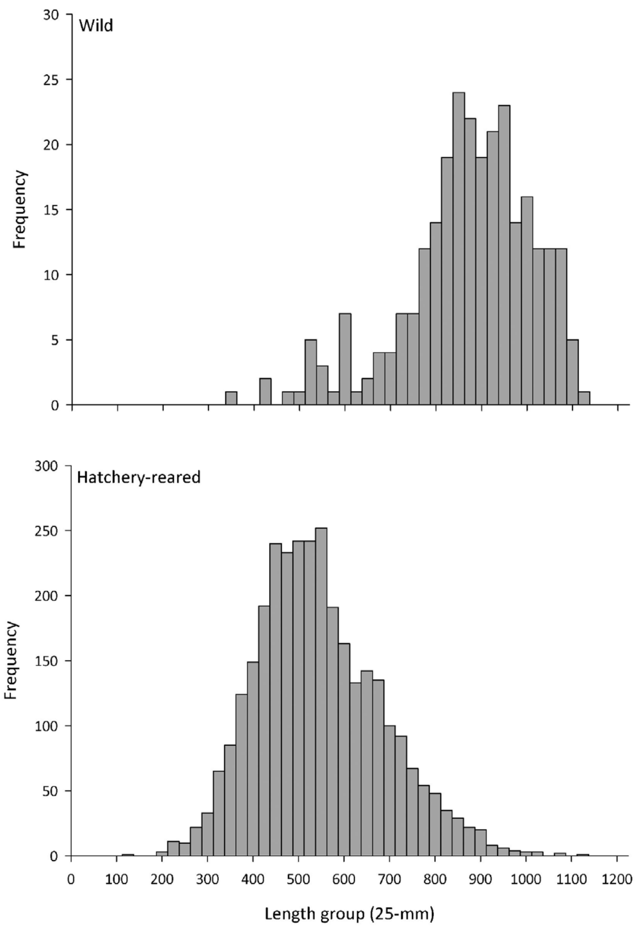

Figure 4. Length-frequency of all wild and hatchery-reared Pallid Sturgeon captured in the Missouri River from 2003-2012. Length at maturity is 788 mm as described by Steffensen, Pegg and Mestl (2013). Note that the y-axis scales are different for each graph.

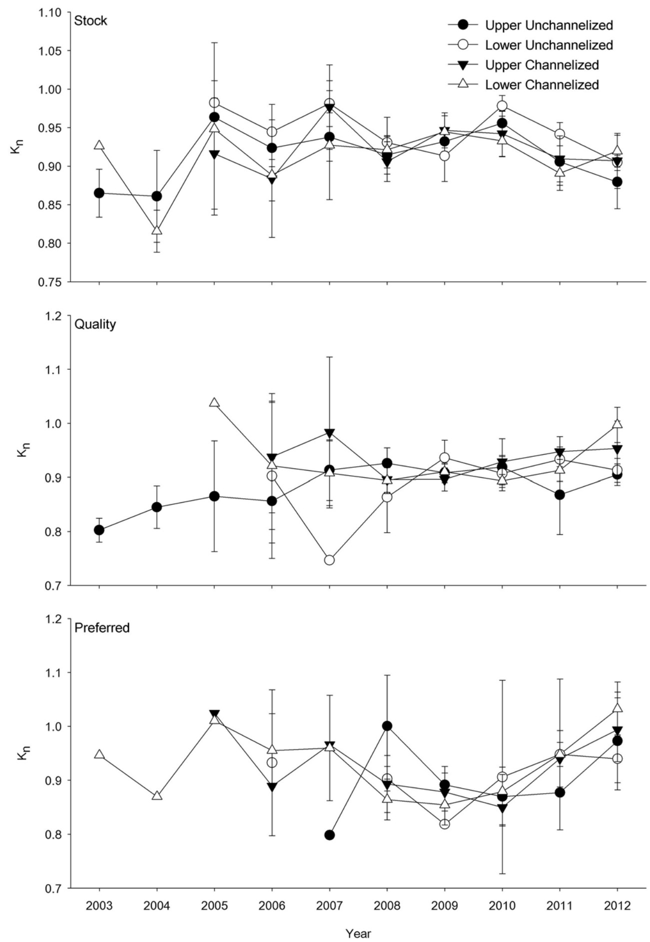

Figure 5. Relative condition factor (K_n) for stock-sized, quality-sized and preferred-sized Pallid Sturgeon by reach in the Missouri River from 2003-2012. Figure includes all Pallid Sturgeon captured. K_n was calculated using the equation in Shuman *et al.* (2011). Note that the y-axis scales are different for each graph.

Finally, relative condition for quality-sized and preferred-sized fish has been steadily increasing the past four years.

Overall, 2% of all sturgeon captured in 2003 were Pallid Sturgeon (Table 6). The relative frequency of Pallid Sturgeon collections have increased annually, except for 2011 when flooding conditions limited sampling efforts, and now Pallid Sturgeon are approximately 8% of all sturgeon captured. However, this is highly skewed by the influx of hatchery-reared Pallid Sturgeon, the use of trot lines, and targeted sampling efforts. The upper unchannelized reach has the highest density of Pallid Sturgeon where capture rates indicate 28% of the sturgeon population is represented by Pallid Sturgeon. Comparatively, the upper channelized has the lowest density (2.7%) of Pallid Sturgeon in the sturgeon population. Wild Pallid Sturgeon only account for 0.3% of all Pallid Sturgeon collected across all reaches. Even in the lower channelized reach where wild Pallid Sturgeon are more frequently collected, wild Pallid Sturgeon only contribute to 0.4% of the entire sturgeon population.

Discussion

The population of wild Pallid Sturgeon in the upper unchannelized reach is rare or nearly extirpated as only four wild Pallid Sturgeon have been collected in 10 years of sampling. Similarly, wild Pallid Sturgeon are rarely captured in the lower unchannelized reach. In the channelized reaches, the wild Pallid Sturgeon population seems unchanged and perhaps increasing in the lower unchannelized reach. However, the age of these fish combined with the lack of observed natural reproduction and recruitment suggests this population maybe approaching senescence over the next several decades. A few juvenile Pallid Sturgeon were collected

Table 5. Percent incremental proportional size distribution (PSD) for all (wild and hatchery-reared) Pallid Sturgeon collected by reach in the Missouri River from 2003-2012.

Reach	Year	Stock (330-629 mm)	Quality (630-839 mm)	Preferred (840-1039 mm)	Memorable (1040-1269 mm)	Trophy (≥ 1270 mm)
Upper Unchannelized	2003	49	49	0	0	2
	2004	67	33	0	0	0
	2005	91	9	0	0	0
	2006	83	17	0	0	0
	2007	86	11	1	0	2
	2008	73	21	5	0	0
	2009	75	18	6	1	0
	2010	85	12	3	0	0
	2011	82	16	1	0	0
	2012	45	46	6	2	0
Lower Unchannelized	2005	100	0	0	0	0
	2006	50	25	25	0	0
	2007	98	2	0	0	0
	2008	87	10	3	0	0
	2009	80	17	2	0	0
	2010	90	9	1	0	0
	2011	85	14	2	0	0
	2012	81	16	3	0	0
Upper Channelized	2005	80	0	10	10	0
	2006	73	20	7	0	0
	2007	89	7	4	0	0
	2008	69	24	6	1	0
	2009	70	22	6	3	0
	2010	72	20	5	3	0
	2011	73	17	9	1	0
	2012	60	32	7	2	0
Lower Channelized	2003	33	0	33	33	0
	2004	50	0	25	25	0
	2005	63	13	13	13	0
	2006	75	15	10	0	0
	2007	67	17	17	0	0
	2008	51	31	17	2	0
	2009	43	45	10	2	0
	2010	49	40	10	1	0
	2011	62	20	18	1	0
	2012	59	19	19	2	0

Table 6. Ratio of wild and all Pallid Sturgeon (PDSG) to Shovelnose Sturgeon by reach in the Missouri River from 2003-2012. n/s indicates no sampling occurred in that reach.

Year	Upper Unchannelized		Lower Unchannelized		Upper Channelized		Lower Channelized	
	Wild PDSG	All PDSG	Wild PDSG	All PDSG	Wild PDSG	All PDSG	Wild PDSG	All PDSG
2003		1 : 4.2	n/s	n/s	n/s	n/s	1 : 1196.0	1 : 797.3
2004		1 : 3.4	n/s	n/s	n/s	n/s	1 : 436.6	1 : 436.6
2005		1 : 5.4		1 : 536.0	1 : 601.5	1 : 80.2	1 : 974.0	1 : 324.7
2006		1 : 5.9	1 : 1910.0	1 : 126.9	1 : 549.7	1 : 97.0	1 : 577.8	1 : 107.0
2007		1 : 4.0		1 : 22.6	1 : 701.5	1 : 82.5	1 : 304.4	1 : 101.5
2008	1 : 148.0	1 : 2.9		1 : 27.7	1 : 249.6	1 : 31.2	1 : 89.8	1 : 23.5
2009	1 : 149.5	1 : 1.7	1 : 631.0	1 : 37.4	1 : 158.3	1 : 19.3	1 : 104.0	1 : 21.1
2010		1 : 1.3	1 : 1437.0	1 : 7.0	1 : 391.0	1 : 33.0	1 : 200.1	1 : 30.6
2011		1 : 0.9		1 : 5.1	1 : 352.5	1 : 25.5	1 : 126.5	1 : 23.5
2012		1 : 1.3		1 : 4.1		1 : 36.7	1 : 816.6	1 : 26.9

and classified as wild because genetic analysis did not match any known hatchery parental cross. This information needs to be used cautiously as the parental genetic archive is missing some records, meaning that they may have actually been of hatchery origin. Regardless, natural recruitment of Pallid Sturgeon is rare to non-existent.

The rarity of wild Pallid Sturgeon is evident when comparing the relative proportion to Shovelnose Sturgeon. Range-wide, the relative proportion of wild pallid to Shovelnose Sturgeon is substantially less compared to when the species was described a century ago (Forbes and Richardson 1905) and even since Gavins Point Dam was constructed (Bailey and Cross 1952). However, the relative proportion has not changed the past 3 decades (Carlson *et al.* 1985). Although this information is comparable for historic abundance estimates, it needs to be used with caution as gear selection can highly influence the size and species captured. Hatchery supplementation has bolstered the overall Pallid Sturgeon population and greatly changed the Pallid Sturgeon to Shovelnose Sturgeon ratio as has the integration of trot lines into the PSPA Project sampling regime. The current Pallid Sturgeon population is primarily fish of hatchery origin. As hatchery supplementation continues and fish recruit to our gears their relative abundance is increasing in all reaches.

Survival estimates for stocked hatchery-reared Pallid Sturgeon has been estimated by Hadley and Rotella (2009) for the upper unchannelized reach and by Steffensen, Powell and Koch (2010) for the lower Missouri River in Nebraska. These estimates suggest hatchery-reared Pallid Sturgeon are surviving at rates similar to other sturgeon supplementation programs (Irelands *et al.* 2002, Irvine, Schmidt and Hildebrand 2007) and the juveniles are recruiting to the adult population. Steffensen, Pegg and Mestl (2013), describing the Pallid Sturgeon population characteristics in the lower Missouri River, determined that hatchery-reared fish are maturing by age-9 for females and age-7 for males, earlier than previously noted by Keenlyne and Jenkins (1993). Steffensen, Pegg and Mestl (2013) also noted the minimum length-at-maturity was 788 mm which means minimal number of hatchery-reared Pallid Sturgeon have recruited to reproductive size. As these fish continue to grow the number of reproductively ready fish will continue to increase and hopefully this increase will result in natural reproduction.

Hatchery-reared fish have been documented spawning at several sites downstream of Gavins Point Dam (DeLonay *et al.* 2012). Spawning has occurred in the unchannelized and channelized reaches of the lower Missouri River and in at least two tributaries (i.e., Platte River and James River, DeLonay *et al. In Review*). However, larval Pallid Sturgeon have not been captured during other larval fish sampling efforts in Nebraska waters (Reade 2000, G. Mestl, NGPC, Pers. Comm.).

Post hatch, larval Pallid Sturgeon drift downstream for 11-17 days or an estimated 245 to 530 km, when water velocities ranged between 0.43 – 0.56 m/s, before gaining the ability to initiate their benthic life stage (Braaten *et al.* 2008). Therefore, if Pallid Sturgeon successfully spawn in the upper unchannelized reach the larva would drift into the headwaters of Lewis and Clark Lake, greatly decreasing the probability of survival, or possibly remain in the drift and entrain through Gavins Point Dam and potentially, contributing to the Missouri River population downstream of Gavins Point Dam. Therefore, the likelihood that the Pallid Sturgeon population will become self-sustaining in the upper unchannelized reach is minimal. This theory is fortified by the lack of juvenile *Scaphirhynchus* species collected over the past 10 years (Shuman and Klumb 2012). If Pallid Sturgeon would successfully spawn below Gavins Point Dam, progeny would likely need a longer drift distance than suggested by Braaten *et al.* (2008) as the water velocities are much higher in the channelized Missouri River compared to the unaltered upper Missouri River in eastern Montana and western North Dakota. A larval Pallid Sturgeon produced in the vicinity of Gavins Point Dam may settle out of the drift near the Platte River, but would be more likely to continue on beyond the Nebraska border.

The population status presented in this paper is based on the standard sampling regime and gears (Tables 2 and 3, i.e. gill nets, trammel nets and otter trawls) used in the PSPA Project. However, NGPC initiated an additional effort in 2008 (in the lower channelized reach) to collect reproductively mature adult Pallid Sturgeon. Furthermore, the PSPA Project implemented the use of trot lines prior to the 2009 sampling season, which greatly increased the number of Pallid Sturgeon collected. Additionally in the lower unchannelized reach, Stukel, Kral and Loecker (2013) discovered a concentration of Pallid Sturgeon in the confluence of the James River and started a targeted effort in 2007. Because these targeted efforts greatly increase our capture probability; the abundance of Pallid Sturgeon may be higher than observed from the standardized sampling. Also, the reach below Gavins Point is an open population; therefore, Pallid Sturgeon can immigrate and emigrate freely from the Missouri River along Nebraska's border. These movements may affect local abundance estimates. Conversely, the upper unchannelized reach only provides emigration through Gavins Point Dam. Steffensen and Huenemann (2013) recently quantified this entrainment rate. Eighty-three hatchery-reared Pallid Sturgeon, originally stocked in the upper unchannelized reach, have been recaptured downstream of Gavins Point Dam throughout the lower Missouri River. Thus 0.7% of hatchery-reared Pallid Sturgeon, that were originally stocked in the upper channelized reach, survived entrainment and are now part of the lower river's population. Finally, habitat complexity and catchability may skew comparisons between reaches. The diversity of habitats in the unchannelized reaches is much greater than the more simplistic channelized river.

A population estimate has not been determined for the entire Missouri River along Nebraska's border; however, Steffensen, Powell and Pegg (2012) estimated the populations from an 80.5 rkm reach below the confluence with the Platte River. From 2008-2010, the population of hatchery-reared Pallid Sturgeon increased while the wild Pallid Sturgeon population declined from 2008 to 2009 but were similar between 2009 and 2010. This reach below the confluence of the Platte River may have the highest density of wild Pallid Sturgeon in the lower Missouri River due to the attraction of the Platte and repeated stocking events.

Pallid sturgeon have been collected in several tributaries to the main-stem Missouri River. In the upper unchannelized reach, Wanner *et al.* (2010) collected three hatchery-reared Pallid Sturgeon in the lower Niobrara River, just upstream of its confluence with the Missouri River. In the lower channelized reach, M. Hamel (University of Nebraska-Lincoln, pers. comm.) collected 137 Pallid Sturgeon throughout the lower Platte River, including 8 potentially wild Pallid Sturgeon and 15 fish that remain of unknown origin. As sampling progresses farther up the Platte River so does the apparent range of the Pallid Sturgeon. Angler reports from the Elkhorn River and Salt Creek, tributaries to the Platte River, suggest use by Pallid Sturgeon. In South Dakota, anglers reported the capture of Pallid Sturgeon in the James and Vermillion rivers. It appears tributaries may play a previously unknown role in sturgeon reproduction, as telemetered reproductively mature female Pallid Sturgeon have successfully spawned in the lower James River and Platte River (DeLonay *et al., In Review*). Additionally, non-reproductive Pallid Sturgeon were also located with telemetry in the Big Sioux River, Iowa (B. Neely, Kansas Department of Wildlife, Parks and Tourism, pers. comm.).

With the reproductive characteristics of Pallid Sturgeon (i.e., late-maturing and intermittent spawning) recovery will take a minimum of several decades. Currently, the Pallid Sturgeon population in the Missouri River along Nebraska's border is not in any immediate danger of extirpation as hatchery augmentation has increased the population for the near-term. As the number of reproductively mature adults increase, the likelihood of successful spawning increases but larval development and recruitment is as yet unknown. Ultimately, these are the critical components to Pallid Sturgeon sustainability and recovery.

Management Recommendation

Pallid Sturgeon may be considered for down listing or delisting when the adult population (N = 5,000 per management unit) is genetically diverse and self-sustaining for two generations (USFWS 2013). Therefore, we recommend the continued listing of Pallid Sturgeon as an endangered species as natural reproduction and recruitment is minimal to non-existent through the Nebraska reach of the Missouri River. Maintaining a long-term monitoring project (i.e. PSPA Project) is necessary to monitor and document changes to the current population of wild and hatchery-reared Pallid Sturgeon and to detect any successful recruitment that may occur. Continuation of the hatchery supplementation program is warranted until adequate recruitment and natural reproduction occurs.

We recommend continuing with no sturgeon harvest in the unchannelized reaches of the river as Pallid Sturgeon are readily captured on hook and line, especially at the confluence of the James River in the lower unchannelized reach and downstream of the Niobrara and Missouri river confluence in the upper unchannelized reach. We recommend considering a ban on recreational Shovelnose Sturgeon harvest in the channelized reach as several studies have demonstrated that fishermen (i.e., commercial and recreational) struggle to distinguish between *Scaphirhynchus* species (Killgore *et al.* 2007, Bettoli *et al.* 2009). However, Peters and Parham (2008) reported sturgeon anglers around the Missouri and Platte rivers confluence were able to differentiate *Scaphirhynchus* species 87% of the time, but generalized anglers only identify the correct species 66% of the time. Because of this similarity of appearance, in 2010 the USFWS listed Shovelnose Sturgeon as a threatened species in areas where *Scaphirhynchus* species coexist (U.S. Fish and Wildlife Service 2010). This ruling did not affect Nebraska's fishing regulations but demonstrates the concern with range-wide species identification.

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