Vol. 52: 225–230, 2023
https://doi.org/10.3354/esr01275

ENDANGERED SPECIES RESEARCH
Endang Species Res

Published November 16

NOTE

Post-stocking condition of endangered pallid sturgeon released at age 0

Nathan J. C. Gosch[1,*], Todd R. Gemeinhardt[1], Jerrod R. Hall[2], Kasey W. Whiteman[3], Tim L. Welker[4], Joseph L. Bonneau[4]

[1]US Army Corps of Engineers, Kansas City, MO 64106, USA
[2]Nebraska Game and Parks Commission, Lincoln, NE 68503, USA
[3]Missouri Department of Conservation, St. Joseph, MO 64507, USA
[4]US Army Corps of Engineers, Yankton, SD 57078, USA

ABSTRACT: Condition indices are commonly used to assess fish population status and are well suited for endangered species given that length and weight data collection is noninvasive. In the Missouri River, endangered age-0 pallid sturgeon *Scaphirhynchus albus* are typically released during autumn, but 2 experimental summer stockings of 53–56 or 41–42 day-old individuals occurred during consecutive weeks in July 2018. Captures during subsequent field seasons provided a rare opportunity to assess condition of known-age individuals that spent most of their lives in the wild. By the end of 2022, 115 unique pallid sturgeon were captured at age 1 or older, which is a high capture rate (1.35%) compared to autumn age-0 stockings. Most individuals yielded condition values in the normal category with median values for both stockings near 1. Despite different mean fork lengths at stocking (118 or 80 mm), condition values of captured individuals were not significantly different between stockings. Additionally, the percentage of individuals in low, normal, and robust condition were not significantly different compared to published long-term datasets from the lower and upper Missouri River basins. We conclude that pallid sturgeon captured from these experimental stockings have fared well in the wild, which highlights the potential benefits of stocking relatively young individuals during summer. Similar experimental stockings in the future would provide additional data for evaluating a potential shift in age-0 stocking strategy.

KEY WORDS: Endangered · Pallid sturgeon · Condition · Age 0 · Stocking · *Scaphirhynchus albus*

1. INTRODUCTION

Assessments of body condition have been broadly utilized in fisheries management for decades (e.g. Le Cren 1951) because this tool can provide valuable information regarding the status of a population, including overall health as well as responses to management efforts and environmental conditions (Pope & Kruse 2007). Condition indices have a long history in fish management and are still common given their ease of use and the noninvasive collection of length and weight information (Pope & Kruse 2007). Noninvasive methods are particularly well suited for endangered species due to the reduced mortality risk from excessive handling and to meet potential legal requirements (Pauli et al. 2010).

The pallid sturgeon *Scaphirhynchus albus* was listed as federally endangered in 1990 (US Fish and

*Corresponding author: nathan.j.gosch@usace.army.mil

Publisher: Inter-Research · www.int-res.com

Wildlife Service 1990), and recovery efforts in the Missouri River basin, USA, have been ongoing since the early 1990s (Randall et al. 2017). Using data from 2003–2015, Steffensen et al. (2017) observed a decline in pallid sturgeon condition in certain areas of the species range, especially the middle Missouri River, which was defined as Fort Randall Dam (river km 1416.2) to the Grand River confluence (river km 402.3). Given the potential negative effects of poor condition on reproduction (e.g. reduced fecundity, reduced egg viability, reduced egg size, and longer time between spawning events), their work prompted increased interest in understanding the factors that may affect pallid sturgeon condition and defining condition categories (i.e. low, normal, and robust) for this species using a large, long-term dataset of over 12000 individuals (Randall et al. 2017).

Having defined condition categories provides valuable context when making potential comparisons (e.g. among populations or years) as well as evaluating how particular stocking events are faring in the wild. In the Missouri River, age-0 pallid sturgeon are typically stocked during autumn. During 2018, however, 2 unique summer stockings of relatively young age-0 pallid sturgeon (mean fork length [FL] at time of stocking was 118 or 80 mm) occurred near Sioux City, Iowa, during consecutive weeks in July. Earlier results from these experimental stockings provided important information regarding pallid sturgeon dispersal (Gemeinhardt et al. 2021) and growth (Gosch et al. 2022). For this study, we measured condition values of captured individuals to provide important insight into the potential success of these stockings of relatively young fish, which had spent most of their lives (greater than 80%) in the Missouri River. As such, we evaluated the condition of captured individuals from these experimental stockings using the categories developed by Randall et al. (2017). We also made comparisons with lower and upper Missouri River basin condition data from Randall et al. (2017) to provide context regarding this unique summer stocking.

2. MATERIALS AND METHODS

During May of 2018, pallid sturgeon were propagated at Gavins Point National Fish Hatchery (Yankton, South Dakota, USA) using 8 crosses of wild individuals (8 males and 6 females) that were captured from the Missouri River below Gavins Point Dam during routine monitoring efforts (Gemeinhardt et al. 2021, Gosch et al. 2022). Progeny for the first week of stocking (Stocking 1 hereafter) were raised for 53–56 d and marked with a blue visual implant elastomer (VIE) tag. Progeny for the second week of stocking (Stocking 2) were raised for 41–42 d and marked with a yellow VIE tag. The parental crosses for Stocking 1 were distinct from Stocking 2, and a small number of individuals from each stocking were retained in the hatchery for release at age 1 with a passive integrated transponder (PIT) tag and a scute removed. Given these factors, individuals experiencing VIE tag loss could still be identified to Stocking 1 or Stocking 2 using genetic parentage analysis. Stocking 1 occurred from July 9–12 with a total of 4861 fish (mean FL = 118 mm). Stocking 2 occurred from July 18–19 with a total of 3634 fish (mean FL = 80 mm).

Field crews captured pallid sturgeon from this experimental stocking during standard annual collection efforts using trotlines and benthic otter trawls. Before field collection, we received federal and state sampling permits. Upon capture, all pallid sturgeon were handled according to federal protocols (US Fish and Wildlife Service 2012). Weight (g) and FL (mm) were recorded and used to calculate an individual's condition factor (K_n). If an individual was captured more than once, the most recent length and weight data were used for condition calculations if possible. Randall et al. (2017) developed a condition equation ($\log_{10}$ [weight] = −5.9205 + 3.1574 × $\log_{10}$ [FL]) using data from the Missouri River Recovery Program Pallid Sturgeon Population Assessment Project and Habitat Assessment and Monitoring Program. Due to 'substantial differences in size structure' between the upper Missouri River basin (the Missouri River above Lake Sakakawea, including the Yellowstone River) and the lower basin (below Fort Randall Dam), Randall et al. (2017) developed the equation using only individuals measuring 200 to 1200 mm, which decreased bias from large upper Missouri River basin females. They also used a statistical approach to develop condition categories where individuals with K_n values ±1 SD from the mean would be considered 'normal' condition, K_n values <1 SD from the mean would be considered 'low' condition and K_n values >1 SD from the mean would be considered 'robust' condition.

Similar to Gosch et al. (2022), we restricted analyses to individuals that had spent over 80% of their post-hatch life in the river at the time of capture to minimize the potential hatchery effects on K_n. We divided the number of unique individuals captured at age 1 or older by the total number released during each stocking to determine the percentage of individuals captured at age 1 or older from both stockings; then a chi-square test of homogeneity was used to assess potential differences between stockings. These capture percentages represent the minimum level of recruitment to age 1 because we are likely only sampling a small fraction of the individuals that survived to age 1. To compare K_n values between stockings, we constructed boxplots for each stocking and conducted a rank sum test (due to a lack of normality). The thresholds for each condition category (low, normal, and robust) were overlaid on the boxplots to provide a visual comparison with the results of Randall et al. (2017). We also calculated the percentage of individuals in each condition category and used a chi-square test of homogeneity to assess potential differences between stockings. Then we used data from Randall et al. (2017) to compute the percentage of individuals in each condition category for the upper and lower Missouri River basins to provide further context regarding condition of the 2018 stockings. We only used data for the 200 to 600 mm FL categories based on the lengths observed during this study. Bar charts were constructed, and a chi-square test of homogeneity was used for statistical comparisons. To assess potential annual differences in K_n, we constructed boxplots by year and a Kruskal-Wallis non-parametric ANOVA was used for statistical analysis.

3. RESULTS

Between April 2019 and December 2022, we captured 115 unique age-1+ pallid sturgeon, or 1.35% of the total released fish, from the July 2018 experimental stockings. Recaptures were rare as only 4 of these individuals were captured twice. The percentage of individuals captured at age 1 or older did not differ significantly by stocking (1.17% and 1.60% of fish captured from Stocking 1 and Stocking 2, respectively; $\chi^2 = 2.8$, df = 1, p = 0.09). Four of the captured individuals did not have a weight recorded because capture occurred when a scale was not onboard, leaving 111 individuals for condition assessment (56 from Stocking 1 and 55 from Stocking 2). Median K_n values were near 1 for both stockings and 70% of individuals were in the normal category (Fig. 1). Overall, there was considerable overlap among box plots, and K_n values were not significantly different between stockings (Fig. 1). When comparing the percentages of individuals among the Randall et al. (2017) condition categories, both stockings yielded nearly identical percentages in the robust category, while some disparity existed in the normal and low categories (Fig. 2). Overall, this disparity between stockings was not statistically significant regarding the percentage of fish found within each condition category (Fig. 2), so the 2 stockings were pooled for subsequent analyses.

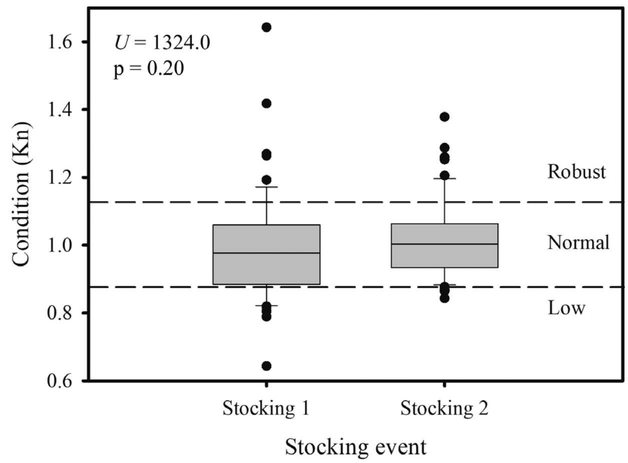

Fig. 1. Boxplots of condition by stocking event for age-0 pallid sturgeon released during July of 2018 and subsequently captured from the Missouri River. Condition formula and categories were developed by Randall et al. (2017). Median: horizontal line in each box; 25th and 75th percentiles represented by the box dimensions; 10th and 90th percentiles represented by the whiskers; outliers: black dots

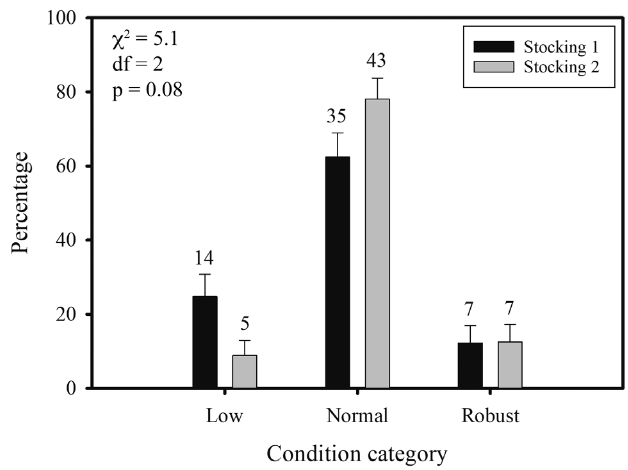

Fig. 2. Percentage of pallid sturgeon by condition category (Randall et al. 2017) from each stocking event. Number of individuals captured provided above each bar

The Randall et al. (2017) lower basin dataset included over 3903 individuals in the 200 to 600 mm FL categories. Compared to our pooled dataset from Stocking 1 and Stocking 2, there was no significant difference in the percentage of individuals distributed among condition categories (Fig. 3). The upper basin dataset included over 5700 pallid sturgeon in

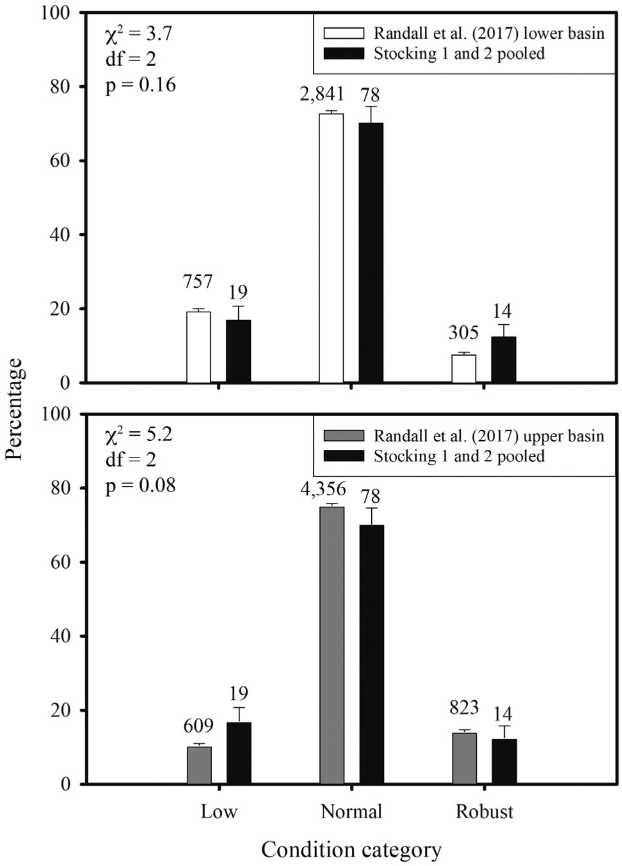

Fig. 3. Percentage of pallid sturgeon by condition category for the lower Missouri River basin (below Fort Randall Dam; upper panel) and the upper Missouri River basin (above Lake Sakakawea, including the Yellowstone River; lower panel) from Randall et al. (2017) as well as Stocking 1 and Stocking 2 pooled. Number of individuals captured provided above each bar

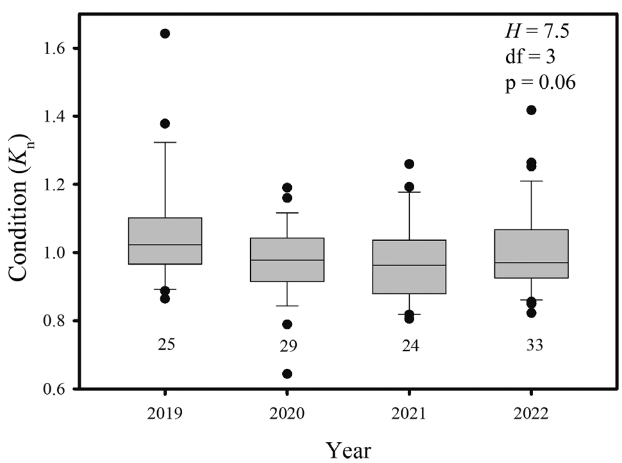

Fig. 4. Boxplots of condition by year for Stocking 1 and Stocking 2 pooled. Number of pallid sturgeon captured provided below each boxplot. Median: horizontal line in each box; 25th and 75th percentiles represented by the box dimensions; 10th and 90th percentiles represented by the whiskers; outliers: black dots

the 200 to 600 mm FL categories, and our pooled dataset was not significantly different when comparing the percentage of individuals distributed among condition categories (Fig. 3).

When comparing condition among years, the highest median K_n value was observed during 2019 (Fig. 4). However, there was still considerable overlap among the box plots, especially compared to 2022. Statistically, there was no significant overall difference in K_n values among years (Fig. 4).

4. DISCUSSION

The stocking of age-0 pallid sturgeon into the Missouri River below Gavins Point Dam usually occurs during autumn; however, experimental summer stockings of younger individuals during July of 2018 yielded important insight regarding dispersal (Gemeinhardt et al. 2021) and growth (Gosch et al. 2022) of this endangered species in the wild during early life stages. This study builds on those previous efforts by providing valuable context regarding post-stocking condition as new captures from this stocking effort continued in the Missouri River below Gavins Point Dam. In general, both stockings appear to be faring well in the wild, as most individuals had K_n values in the normal category and the median value for both stockings were near 1. Comparisons with long-term datasets from the lower and upper Missouri River basins were also consistent with this conclusion, as the percentage of individuals in each of the Randall et al. (2017) condition categories were similar to the percentages from this study. The similarity with the upper basin dataset was particularly informative, as pallid sturgeon condition has been a lesser concern in this area of the river. Randall et al. (2017) found that condition values were relatively high in the upper basin, which may be a function of more natural river habitat features when compared to the lower basin habitat features (Steffensen et al. 2017). While these comparisons provide important context regarding the condition of individuals from both stockings, Randall et al. (2017) also highlighted the lack of a documented, quantitative connection between K_n values and factors potentially affecting pallid sturgeon population dynamics (e.g. a threshold K_n value needed for reproductive cycling). Future research assessing potential quantitative relationships between K_n values and biologically important processes or metrics, such as fecundity, reproductive cycling, spawning, and mortality would provide critical insight regarding how condition affects this endangered species. This information would also be helpful for prioritizing pallid sturgeon recovery efforts in the Missouri River basin.

Assessing how pallid sturgeon condition changes over time was also important for understanding status and trends of these experimental stockings. For example, variability in K_n values over time is not necessarily cause for concern given that resource availability and river conditions can be dynamic, but steadily declining or consistently low K_n values over many years could indicate the needs of these individuals are not being fully met in the wild. This was not the case during this study based on our assessment of K_n values among years. Specifically, K_n values were only marginally higher in 2019 despite high water and widespread, persistent floodplain connectivity (Gosch et al. 2021), and there was not a significant decrease in condition in subsequent years. Furthermore, 2022 yielded the most comparable K_n values with 2019, which provides additional support that condition does not appear to be consistently decreasing since stocking. This finding may be particularly relevant, as these stocked individuals transition to piscivory. Previous research reported that pallid sturgeon began shifting to piscivory around 600 mm FL, which corresponded to ages 5 to 7 (Grohs et al. 2009). Fish stocked in July of 2018 are starting to reach this potential prey shift as some of the more recently captured individuals exceeded 600 mm. Gosch et al. (2022) reported that individuals from these experimental stockings appear to be growing well in the wild relative to pallid sturgeon reared exclusively in a hatchery, and this study provides additional support for that finding, as some individuals have reached the transition-to-piscivory size of 600 mm before age 5. Being able to survive and recruit to age 1 and beyond was an important benchmark for individuals stocked during July of 2018 (Gosch et al. 2022), and continued condition assessment of these individuals during and after the transition to piscivory would be a valuable next step for evaluating these experimental stockings of age-0 pallid sturgeon.

Although the use of VIE tags was an important tool for learning from this stocking, tag loss is likely to increase going forward. Jaeger et al. (2007) reported that VIE tag retention in hatchery-reared pallid sturgeon was 6 to 8 yr, and it appears that tag loss may be increasing for individuals stocked during the summer of 2018. As time from stocking increased, field crews have noted that tags are becoming more difficult to see. Currently, there have been a total of 9 individuals from these experimental stockings that were not identifiable by VIE tag, starting with 2 individuals captured during November of 2021 and an additional 7 individuals captured in November–December of 2022. While other studies have already demonstrated the value of VIE tags for easily identifying individuals from Stocking 1 and Stocking 2 (Gemeinhardt et al. 2021, Gosch et al. 2022), this study also demonstrated the value of a secondary method of identification (i.e. using distinct genetic crosses coupled with PIT tag implantation and scute removal of siblings that were stocked at age 1).

Overall, these stockings coupled with routine monitoring have provided valuable information on dispersal (Gemeinhardt et al. 2021), growth (Gosch et al. 2022), and now condition of pallid sturgeon stocked during the critical age-0 life stage. These stockings have established that age-0 pallid sturgeon stocked during summer at mean FL of 80 and 118 mm can survive well relative to other age-0 stocking events. For example, Gosch et al. (2022) reported that 0.90 % of this experimental stocking was captured at age 1 or older, which was nearly 3 times the average from a long-term age-0 pallid sturgeon stocking dataset consisting primarily of autumn-stocked, older individuals (Steffensen et al. 2019). The additional captures documented during this study demonstrate that a minimum of 1.35 % of the individuals stocked in July 2018 recruited to at least age 1. When comparing the percentage of individuals captured at age 1 or older, Stocking 2 was observationally higher than Stocking 1 (1.60 vs. 1.17 %); however, this difference was not significant despite the difference in mean size at stocking of nearly 40 mm. Furthermore, the percentage for both stockings were relatively high compared to the long-term average capture rate of 0.34 % reported for age-0 stockings consisting primarily of autumn-stocked, older individuals (Steffensen et al. 2019).

To continue building on this work, additional experimental stockings will be important. For example, free embryo stockings of genetically distinct 1 d post-hatch (dph) and 5 dph individuals were implemented during 2019 in the Missouri River below Gavins Point Dam. These annual stockings will provide survival information for the youngest life stages (i.e. the free embryo drift period), which is a current knowledge gap for pallid sturgeon population modeling efforts (M. Colvin, US Geological Survey, pers. comm.). Relative to this study, it may take more years of monitoring to evaluate these 1 and 5 dph stockings due to a variety of potential factors including relatively higher mortality, annual variability in survival, and fluctuations in the number of free embryos stocked annually due to variability in brood stock availability. These free embryo stockings efforts will also be critical for prioritizing recovery efforts, evaluating management actions, and assessing hypotheses regarding potential pallid sturgeon limiting factors. During this study, we found that summer stocking of relatively young individuals could be a potentially viable stocking strategy in the Missouri River below Gavins Point Dam; however, it is currently unknown how summer stocking will consistently perform relative to autumn stocking. For example, the environmental conditions and/or parental crosses available during 2018 may have contributed to unusually high post-stocking survival (Gosch et al. 2022). As such, additional experimental stockings of 40 to 60 dph individuals would provide important data regarding a potential shift from autumn to summer stocking of age-0 pallid sturgeon.

Acknowledgements. Funding was provided by the US Army Corps of Engineers, Kansas City and Omaha Districts. We thank the Nebraska Game and Parks Commission, Missouri Department of Conservation and US Army Corps of Engineers field crews for fish collection. Any use of trade, firm, or product names is for descriptive purposes only and does not imply endorsement by the US Government. All product names and trademarks cited are property of their respective owners. This report is not to be construed as an official Department of Army position unless so designated by other authorized documents.

LITERATURE CITED

Gemeinhardt TR, Gosch NJC, Hall JR, Whiteman KW, Welker TL, Bonneau JL (2021) Assessing large-scale movement of an endangered fish: dispersal of stocked age-0 pallid sturgeon in the lower Missouri River. Aquat Conserv 31:3326–3333

Gosch NJC, Hall JR, Civiello AP, Haas JD, Gemeinhardt TR, Bonneau JL (2021) Floodplain connectivity and age-0 sturgeon prey consumption in the lower Missouri River. River Res Appl 37:1243–1253

Gosch NJC, Gemeinhardt TR, Hall JR, Whiteman KW, Welker TL, Bonneau JL (2022) Using age-0 stocking to assess growth and recruitment of endangered pallid sturgeon *Scaphirhynchus albus.* Fishes 7:50

Grohs KL, Klumb RA, Chipps SR, Wanner GA (2009) Ontogenetic patterns in prey use by pallid sturgeon in the Missouri River, South Dakota and Nebraska. J Appl Ichthyol 25:48–53

Jaeger M, Bollig H, Gardner B, Holm R and others (2007) Protocols for tagging and marking hatchery reared pallid sturgeon in Recovery Priority Management Areas 1, 2, and 3. Upper Basin Pallid Sturgeon Workgroup Tagging Committee. http://pallidsturgeon.org/wp-content/uploads/2018/01/UB6-Upper-Basin-Workgroup-Protocols-for-tagging-and-marking-hatchery-reared-pallid-sturgeon-2007.pdf

Le Cren ED (1951) The length–weight relationship and seasonal cycle in gonad weight and condition in the perch (*Perca fluviatilis*). J Anim Ecol 20:201–219

Pauli JN, Whiteman JP, Riley MD, Middleton AD (2010) Defining noninvasive approaches for sampling of vertebrates. Conserv Biol 24:349–352

Pope KL, Kruse CG (2007) Condition. In: Guy CS, Brown ML (eds) Analysis and interpretation of freshwater fisheries data. American Fisheries Society, Bethesda, MD, p 423–471

Randall MT, Colvin ME, Steffensen KD, Welker TL, Pierce LL, Jacobson RB (2017) Assessment of adult pallid sturgeon fish condition, Lower Missouri River — application of new information to the Missouri River Recovery Program. US Geol Surv Open-File Rep 2017–1121

Steffensen KD, Mestl GE, Phelps QE (2017) Range-wide assessment of pallid sturgeon *Scaphirhynchus albus* (Forbes & Richardson, 1905) relative condition. J Appl Ichthyol 33:13–21

Steffensen KD, Hamel MJ, Spurgeon JJ (2019) Post-stocking pallid sturgeon *Scaphirhynchus albus* growth, dispersal, and survival in the lower Missouri River. J Appl Ichthyol 35:117–127

US Fish and Wildlife Service (1990) Endangered and threatened wildlife and plants: determination of endangered status for the pallid sturgeon. Fed Regist 55:36641–36647

US Fish and Wildlife Service (2012) Biological procedures and protocols for researchers and managers handling pallid sturgeon: US Fish and Wildlife Service, Billings, MT. www.pallidsturgeon.org/wp-content/uploads/2012/11/pallid-sturgeon-handling-protocols-2012-update-signed-.pdf#:~:text=The%20following%20protocols%20will.%20be%20followed%20to%20ensure,loss%20of%20pallid%20sturgeon%20associated%20with%20permitted%20activities

Editorial responsibility: Eduardo Martins, Vancouver, British Columbia, Canada
Reviewed by: M. Randall and 2 anonymous referees

Submitted: June 29, 2023
Accepted: September 13, 2023
Proofs received from author(s): November 13, 2023