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ARTICLE

Incidence, Types, and Shedding and Ingestion Times of Metallic Fishing Tackle in the Digestive Systems of White Sturgeon

James A. Lamansky Jr. and Kevin A. Meyer*
Idaho Department of Fish and Game, 1414 East Locust Lane, Nampa, Idaho 83686, USA

Brett J. Bowersox and Joe M. DuPont
Idaho Department of Fish and Game, 3316 16th Street, Lewiston, Idaho 83501, USA

Brandon Bentz and Ken B. Lepla
Idaho Power Company, 1221 West Idaho Street, Boise, Idaho 83702, USA

Abstract
Over the last decade, fishing tackle has been documented in the digestive tracts of White Sturgeon *Acipenser transmontanus* in several fisheries in the Columbia River basin, raising concerns about the prevalence and types of tackle being consumed and the ability of these long-lived fish to shed such metal in a timely manner. We scanned 2,077 White Sturgeon with a metal detector and X-rayed (with a portable X-ray system) 443 fish in the Hells Canyon reach of the Snake River to characterize the incidence, quantity, and type of hooks and other metal fishing tackle that had been ingested. We also estimated the amount of time for fish to eliminate ingested metal and to ingest new metal. For the fish we captured, which averaged 118 cm and ranged from 47 to 287 cm (fork length), 21% contained metal in their digestive tract, with smaller fish (<100 cm) less likely to contain metal (10%) than larger fish (>100 cm; 36%). Much of the metal in the digestive systems of White Sturgeon was fishing tackle that was not gear targeting White Sturgeon and included large and small hooks, jigs, swivels, and pieces of broken metal. White Sturgeon with metal in their digestive systems, on average, weighed slightly less than fish without metal, suggesting that metal may slightly hinder food consumption or assimilation, though this affect was apparently short lived. White Sturgeon X-rayed at least twice over the course of the study were able to pass ingested metal on average in 492 d, but one piece of metal was retained for at least 1,266 d. White Sturgeon ingested new metal on average every 575 d. In summary, our results suggest that White Sturgeon effectively process the metal they ingest, and that most if not all their metal passage is by oxidation through the digestive system.

The White Sturgeon *Acipenser transmontanus* is the largest freshwater fish species in North America and is native to large river systems along the west coast of the continent. While still widely distributed, most populations of White Sturgeon have experienced considerable declines in abundance over the last century caused by overfishing, habitat alteration, and dam construction and operation that has fragmented formerly connected populations (reviewed in Hildebrand et al. 2016). In response to population declines, regulations have been imposed to curtail commercial and sport harvest fisheries since the early 1900s, and many White Sturgeon fisheries are now managed with catch-and-release regulations.

Despite the strict regulations, angling for White Sturgeon remains popular, and managers remain concerned that angling may be negatively impacting White Sturgeon populations, even in catch-and-release fisheries. For example, Kozfkay and Dillon (2010) documented that

*Corresponding author: kevin.meyer@idfg.idaho.gov
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individual White Sturgeon in a heavily fished reach of the Snake River in Idaho were caught an average of 7.7 times in a 1-year period. Nearly all White Sturgeon are landed using bait, and compared to other terminal tackle, bait fishing for most species results in higher rates of deep hooking and, consequently, hooking mortality (reviewed in Muoneke and Childress 1994). Fortunately, deep hooking in White Sturgeon bait fisheries appears to be rare, as evidenced by a recent study documenting a 0.6% deep hooking rate (Lamansky et al. 2018a). Nevertheless, White Sturgeon in various populations in the Columbia River basin are known to have metal fishing tackle in their digestive systems (Idaho Power Company 2015; Bowersox et al. 2016; Halvorson et al. 2018). The apparent lack of deep hooking in White Sturgeon fisheries coupled with the knowledge that metal ingestion is relatively common suggests that the ingestion does not stem directly from angling but rather indirectly, with White Sturgeon presumably ingesting baited hooks that have broken off on the river bottom (Lamansky et al. 2018a). Regardless of the method of ingestion, there is concern about the ability of White Sturgeon to pass such angling tackle.

Corrosion and shedding rates of hooks lodged in the digestive tract of fish have been monitored previously but usually as ancillary information in studies focused on deep hooking or the benefits of cutting the line on deeply hooked fish (e.g., Mason and Hunt 1967; Hulbert and Engstrom-Heg 1980; Schill 1996; Broadhurst et al. 2007; Butcher et al. 2007). When fish were examined in many of these studies, the sections of hooks exposed to the digestive system were often corroded or missing, whereas the intact and uncorroded parts of hooks were often embedded in tissue outside the digestive tract. Such findings led to the recommendation that when a fish being caught and released is deeply hooked, leaving the hook inside the fish by cutting the line generally results in less internal organ damage and lower postrelease mortality (Mason and Hunt 1967; Schill 1996; Tsuboi et al. 2006; Butcher et al. 2007; Fobert et al. 2009); fish can then digest or egest the hook from the body at a later date. However, formal investigations of hook passage times are generally lacking, especially for hooks with heavy wire diameter such as is typically used for White Sturgeon. When soaked for 399 d in laboratory beakers that simulated acidic White Sturgeon stomach conditions, sturgeon-sized hooks (with 2.0-mm-diameter wire) lost 34% of their initial weight and 70% of their initial compression strength (Lamansky et al. 2018b), but the applicability of these findings to wild White Sturgeon hook passage time remains uncertain. There is also uncertainty regarding potential chronic impacts that hooks in the digestive tract may have on fish, such as reduced food consumption, digestion, assimilation, and, ultimately, individual growth or body condition. Using metal detectors and X-rays on captured and recaptured fish, we investigated the following: (1) the occurrence, amount, and type of hooks and metal ingested by White Sturgeon, (2) the relative condition of White Sturgeon with and without metal, to assess potential growth or fitness impacts from metal ingestion, and (3) the rates of ingestion and passage of metal angling tackle by White Sturgeon.

METHODS

The study took place in the Snake River, which is the largest tributary to the Columbia River. The study reach included 172 km of the Snake River, extending from the confluence of the Clearwater River upstream to Hells Canyon Dam, and also included the lower 51 km of the Salmon River, which joins the Snake River near the midpoint of the study reach. For most of the study reach, the Snake River flows through Hells Canyon, the deepest gorge in North America. While very remote, this section of the river is popular among whitewater rafters and jet boaters, many of whom angle for White Sturgeon during their trip. White Sturgeon habitat in this section of the Snake River may represent the most natural habitat that remains in the entire Columbia River basin (Hildebrand et al. 2016), and the White Sturgeon population is consequently relatively robust (Idaho Power Company 2015). Nevertheless, in its entirety the main stem of the Snake River has been highly altered by dozens of dams for hydropower and irrigation purposes; most lack ladders and thus severely restrict the movement of fish, including White Sturgeon.

White Sturgeon were sampled by angling or using set lines from 2010 through 2014, generally during the months of June–October. Set lines consisted of a 30-m main line of nylon rope sunk to the river bottom, with six Mustad tuna circle hooks (sizes 12/0 to 16/0) spaced evenly along the main line and baited with cut bait. Set lines were retrieved and reset each morning of sampling. Once all set lines were retrieved and reset each day, field crews bait fished for White Sturgeon using standard sturgeon angling methods as described in Lamansky et al. (2018a).

Upon capture, White Sturgeon were placed upside down in a vinyl sling with fiberglass poles and were hoisted onboard the boat. Water was pumped from the river through a hose to irrigate the gills during handling. Fish were scanned for a passive integrated transponder (PIT) tag in the dorsal musculature from previous capture events, and in the absence of a PIT tag one was inserted in this location. Fork length (cm) and pectoral girth (cm; measured immediately posterior to the pectoral fin) were measured for all captured fish, and weight (to the nearest 0.1 kg) was measured using a digital hanging scale (TCI

Scales, model LPC-4-HS; accuracy ±1%). Relative weight was calculated for each fish using the standard weight equation for White Sturgeon developed by Beamesderfer (1993). Fish were then scanned with a hand-held metal detector (Garrett Pro-pointer or White's Matrix 100), designed to detect iron-based metals, to identify the presence or absence of metal inside the fish. Fish were scanned along the entire ventral side of the body from mouth to anus to search for ingested metal.

A portable X-ray system (Sound-Eklin TruDR lx portable digital radiography system coupled with a MinXray HF100+ portable X-ray generator) was used to capture lateral X-ray images from a subsample of fish. All fish ≥130 cm were X-rayed regardless of whether the metal detector detected metal inside the fish; for fish <130 cm, only those fish with metal (based on the metal detector scan) were X-rayed. Images were immediately reviewed with a laptop computer, and generator settings were adjusted until clear X-ray images were obtained, usually at about 95 kVp and 2.0 mAs but varying slightly depending on the girth of the fish. Multiple X-ray images were produced for each fish in order to scan the entire digestive tract of the fish. Field crews followed all safety procedures necessary to minimize X-ray exposures. A portable aluminum stand with adjustable mounting brackets was constructed to hold the X-ray generator and plate in proper alignment and with consistent separation (about 75 cm); it also allowed operators to stay behind the X-ray generator to further minimize X-ray exposure.

A sturgeon-sized hook (Gamakatsu octopus J hook, size 8/0) was placed on the ventral side of X-rayed fish to serve as a reference hook size in images. Because all images were captured at the same scale, this was only done at the beginning of the study to establish a reference, which was used to categorize hook size throughout the study. Individual pieces of metal in all X-ray images were classified as follows: (1) sturgeon-sized hooks (generally 6/0 or larger; wire diameter generally 2.0 mm or larger); (2) smaller bait hooks, such as would be used for salmon, trout, or catfish (generally 5/0 or smaller; wire diameter generally 1.0 mm or smaller; (3) jigs (hooks with weighted heads; wire diameter generally about 1.0 mm), which are typically used for Smallmouth Bass *Micropterus dolomieu* in this reach of the river; (4) swivels; and (5) metal fragments (i.e., broken hooks, broken swivels, and other unidentifiable metal). For fish captured and X-rayed multiple times, images were compared through time to track the shedding of individual pieces of metal (whole pieces and fragments) as well as the arrival of new metal.

Data analyses.— We used logistic regression to evaluate whether pectoral girth (as the independent variable) was related to the ability of the metal detector to accurately detect the presence of metal observed in X-ray images. For the response variable, a dummy value of 0 was used for inaccurate detections and a value of 1 was used for accurate detections. We assumed that all metal was observed in the X-ray images.

We tested whether the prevalence of ingested metal (based on metal detector observations) differed by fish size using analysis of variance. Fish were binned into 50-cm size-groups, and Tukey's multiple comparison procedure was used to determine which size-groups differed from each other. Based on X-ray images, a chi-square test was used to test whether the types of ingested metal differed between these same size-groups.

To evaluate whether the presence of metal in the digestive system of White Sturgeon affected fish condition, length–weight relationships for fish with and without metal (based on metal detectors) were compared using a general linear model. A categorical independent variable for metal (present or absent) was not included in the model because it was biologically nonsensical to evaluate whether the *y*-intercept of the length–weight relationships (i.e., the weight of fish at 0 cm in length) differed for fish with and without metal. Instead, independent variables included fork length and a metal × fork length interaction term that tested whether metal affected fish growth. The relationship was linearized with $\log_{10}$ transformations of both length and weight data prior to model construction. Residuals were evaluated to ensure that normality and heteroscedasticity assumptions were met. We also tested for a difference in mean relative weight for fish with and without metal using a *t*-test.

Fish X-rayed more than once provided information on how long it took for White Sturgeon to pass existing metal or ingest new metal. For this analysis, individual pieces of metal were treated as the experimental unit because individual pieces could be visually tracked with very little ambiguity. Logistic regression was used to relate metal shedding to the number of days between X-rays, using a binary response variable for shedding of an existing piece of metal (0 = not shed, 1 = shed). Consequently, a probability of metal shedding equal to 0.5 can be interpreted as the time required to shed an existing piece of metal. A shortcoming of this approach is that it assumes each piece of metal was ingested at the time of the first X-ray. This result is an underestimate of metal shedding time because the metal was already present at the time of the first X-ray and had been corroding inside the fish for an unknown amount of time. In fact, the bias in this estimate is equal to the mean length of time that such metal had already been ingested, which can be estimated using data from fish X-rayed three or more times, where a piece of metal was absent in the first X-ray, present in the second X-ray, and absent again in the third X-ray; the correction equals one half of the mean time between the first two X-rays. We therefore interpreted the summation of the underestimate and the correction as the best

approximation of shedding time for individual pieces of metal. Fork length was included in the logistic regression model to evaluate whether the length of time required to shed metal was related to fish size. Metal type was also tested for an effect on shedding time; because sturgeon hook wire diameter is much thicker (about 2.0 mm) than all other metal that was observed (about 1.0 mm), only two categories were included for metal type (i.e., sturgeon and other).

A similar logistic regression model was developed to assess how long it took White Sturgeon to ingest new metal, with a binary response variable for new metal ingestion (0 = no new metal ingested, 1 = new metal ingested); fish length was also included in the full model. This analysis was not subject to the shortcoming noted above for the hook passage model; therefore, standard 95% confidence intervals were calculated for new metal ingestion. Analyses were conducted using the SAS statistical software package (SAS 2010) with an α value of 0.05.

RESULTS

A total of 2,077 White Sturgeon were sampled and scanned with a metal detector, ranging in fork length from 47 to 287 cm (mean = 118 cm). Twenty-one percent of these fish scanned positive for metal. In comparison, a total of 443 fish were X-rayed, including 238 that contained metal (according to X-ray images) and 205 that did not. While there was strong agreement between the metal detector and X-ray images, the metal detector produced false negatives 14% of the time that metal was observed in fish X-ray images, and produced false positives 4% of the time that fish were X-rayed and no metal was observed in the images (Table 1). The ability of the metal detectors to detect the presence of metal observed with X-ray images was not reduced for fish with larger girth (Wald $\chi^2 = 3.03$, $P = 0.08$).

Of the X-rayed White Sturgeon that contained metal, 48% contained one piece of metal, 20% contained two pieces, 12% contained three pieces, and 20% contained four or more pieces of metal (Figure 1). The most individual pieces of metal identified in X-ray images of a single fish was 14 pieces. Of all the pieces of metal observed in X-ray images, 41% were large hooks typically used for sturgeon angling, 11% were smaller bait hooks typically used for smaller target species (such as Smallmouth Bass, salmonids, or catfish), 14% were jigs, 15% were swivels, and 19% were either broken fragments of fishing hooks or swivels or other unidentifiable metal fragments, some of which appeared to include fence staples, pieces of wire, and perhaps metallic foil.

The percent of White Sturgeon that contained metal varied by length-group ($F = 46.95$, $P < 0.001$; Figure 2). Tukey's multiple comparison procedure revealed that fish in the smallest size-group (50–99 cm) were the least likely to contain metal (10%) and differed significantly from all but the largest size-group (>249 cm). Fish 150–199 cm in length were most likely to contain metal (46%) but differed significantly only from the two smallest size-groups. The types of metal ingested by fish did not differ between size-groups ($\chi^2 = 20.05$, $P = 0.07$; Figure 3).

Fish with metal gained weight at a slightly reduced rate compared with fish without metal (Figure 4), as indicated by the significant fork length × metal interaction term ($t = 3.43$, $P < 0.001$) in the length–weight general linear model. Based on this relationship, a fish that grew from 200 to 220 cm would have gained 22.6 kg in weight if it contained metal compared with 23.3 kg if it had no ingested metal. Moreover, the mean relative weight of fish with metal (0.86) was slightly lower than for fish without metal (0.88), and this difference was statistically significant ($t = 4.58$, $P < 0.001$).

A total of 65 individual White Sturgeon were X-rayed more than once, of which 57 were X-rayed twice, 5 were X-rayed three times, and 2 were X-rayed four times. The time interval between X-rays of the same fish ranged from 8 to 1,594 d (mean = 605 d). Some fish never had metal in any X-ray, some had metal in multiple X-rays, and

TABLE 1. The number of White Sturgeon sampled in the Hells Canyon reach of the Snake River with and without metal according to a metal detector compared with the presence of metal observed in X-ray images of the same fish.

	Metal with X-ray	
Metal with detector	Yes	No
Yes	204	9
No	34	196

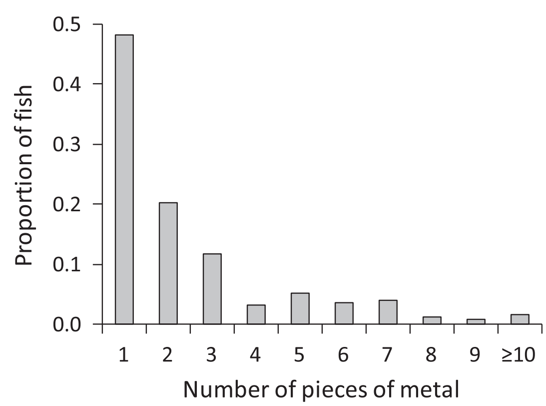

FIGURE 1. The proportion of X-rayed White Sturgeon captured in the Hells Canyon reach of the Snake River, Idaho, that contained various amounts of metal in their digestive tracts.

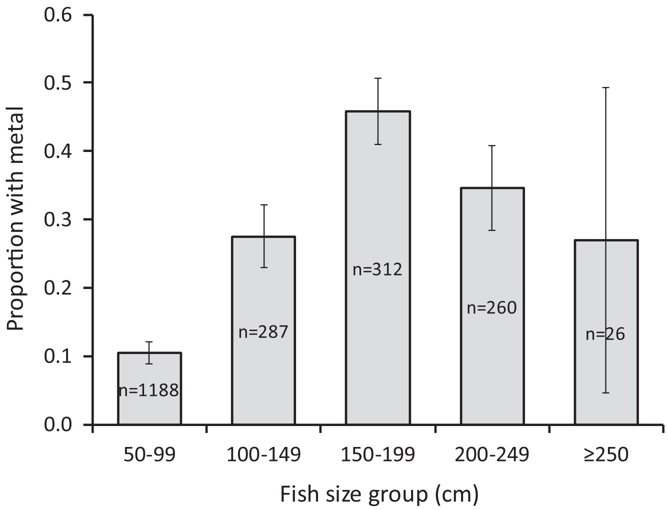

FIGURE 2. The proportion of X-rayed White Sturgeon captured in the Hells Canyon reach of the Snake River, Idaho, that contained at least one piece of metal by size-group. Error bars are 95% confidence intervals.

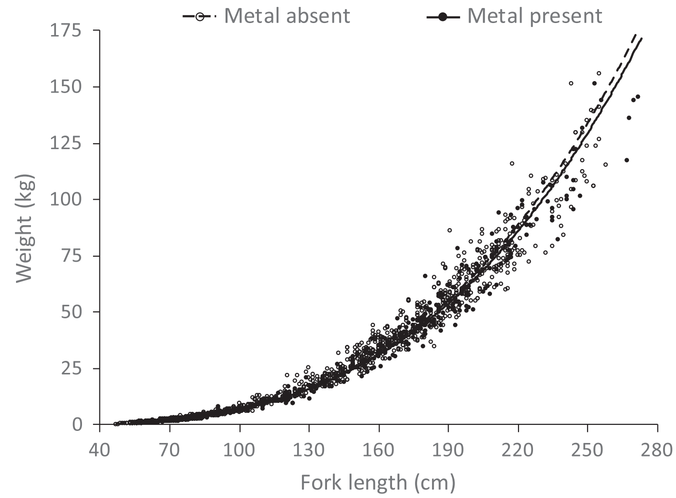

FIGURE 4. Comparisons of fork length to weight of White Sturgeon that contained metal (solid circles, solid line) and those that did not (open circles, dashed line) sampled from the Hells Canyon reach of the Snake River, Idaho. Lines fitted to the data are power functions, but data analyses fit linear relationships to log-transformed lengths and weights.

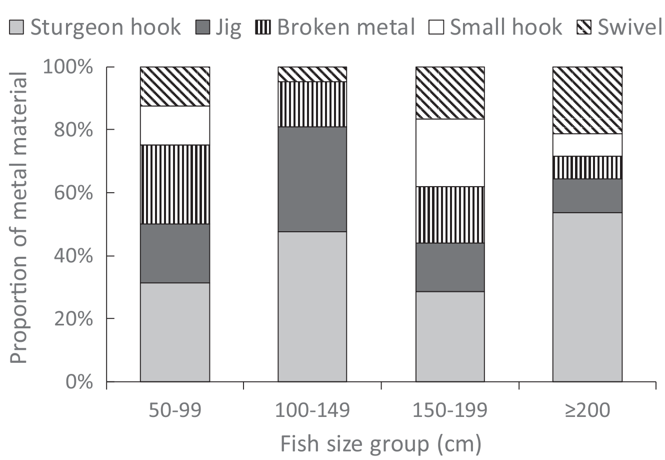

FIGURE 3. Types of metal observed in the digestive tracts of X-rayed White Sturgeon captured in the Hells Canyon reach of the Snake River, Idaho, by size-group.

some changed from having metal to not having metal and vice versa. Fish X-rayed more than once captured the shedding of 65 existing pieces of metal but also the retention of 41 existing metal pieces and the ingestion of 52 new metal pieces between X-rays. The fastest observation of an existing piece of metal being shed was 279 d, although there were no repeat X-rays between 42 and 270 d from the first X-ray; the longest interval the same piece of metal was observed in a fish was 1,266 d.

Logistic regression analyses revealed that the number of days between X-rays was related to the probability of shedding existing metal (Wald $\chi^2 = 15.74$, $P < 0.001$) and ingesting new metal (Wald $\chi^2 = 24.37$, $P < 0.001$). Fish length was not related to shedding existing metal (Wald $\chi^2 = 3.19$, $P = 0.07$) or ingesting new metal (Wald $\chi^2 = 0.01$, $P = 0.91$). Metal shedding also was not related to whether the metal was a thicker diameter sturgeon-sized hook or other metal material (Wald $\chi^2 = 1.24$, $P = 0.26$). Based on the metal shedding logistic regression results, and the shortcoming and correction of this shortcoming (as described in the Methods), we estimated that on average White Sturgeon were able to pass metal through their digestive system in approximately 492 d. Based on the metal ingestion logistic regression results, we estimated that on average White Sturgeon ingested new metal every 575 d (95% confidence interval = 458–699 d).

DISCUSSION

Most White Sturgeon that were captured in this study had no metal in their digestive systems, and the fish that did generally had only one or two pieces of metal. Nevertheless, this study and previous investigations (Idaho Power Company 2015) suggest that 15–20% of the Hells Canyon population of White Sturgeon have metal in their digestive tracts. In most recreational fisheries, such elevated levels of angling terminal tackle in the digestive tracts of fish would be the result of deep hooking; hooks would be lodged deeply because fish swallowed the hook and the line either broke during fighting or was cut loose by anglers in order to avoid internal organ damage during hook removal (Schill 1996; Schisler and Bergersen 1996; Taylor et al. 2001; Aalbers et al. 2004). However, for White Sturgeon in the Snake River, a companion

investigation to this study found that only 0.6% of landed White Sturgeon were hooked deeply (Lamansky et al. 2018a). As previously mentioned, such a low deep-hooking rate in a White Sturgeon population with a considerable amount of metal in their digestive tracts suggests that the most likely source of ingested metal in this population is from White Sturgeon ingesting tackle lost by anglers on the river bottom (also see Hildebrand et al. 2016). Such a conclusion is further supported by the fact that much of the metal observed inside White Sturgeon consisted of terminal tackle not targeting (and rarely if ever hooking) White Sturgeon, such as bass, salmon, trout, and catfish bait hooks and jigs.

The X-ray images of White Sturgeon captured and X-rayed more than once clearly documented the ingestion of new metal and the shedding of existing metal. For fish X-rayed three or four times, images sometimes captured hook oxidation and breakage prior to eventual hook passage. While data limitations prevented us from estimating unambiguous metal shedding times, the approximations we developed suggest that White Sturgeon on average shed ingested metal in about 16 months and ingest new metal every 19 months. Our results contrast most previous studies that have demonstrated much faster (<6 months) hook shedding times on a variety of freshwater and saltwater species (e.g., Mason and Hunt 1967; Schill 1996; Tsuboi et al. 2006; Broadhurst et al. 2007; Weltersbach et al. 2016). The protracted hook shedding time for White Sturgeon was not surprising considering the following factors. First, as previously mentioned, hook ingestion in most fisheries is associated with deep hooking, but often this may be no deeper than the gills or esophagus (Nuhfer and Alexander 1992; Dubois et al. 1994; Weltersbach et al. 2016); as long as serious injury does not occur, these shallower hooking locations (relative to the stomach) may lend themselves more readily to regurgitation, which would be faster than digesting (i.e., corroding and breaking) and then passing the hook through the digestive system. For White Sturgeon, as pointed out above, hook ingestion is more likely associated with ingesting food that is loose on the river bottom and that unknowingly (to White Sturgeon) is attached to a metal hook; swallowing such a hook is not likely to result in shallow hook lodging. Also, White Sturgeon have a unique digestive system morphologically, including a forestomach and gizzard. Most of the metal observed in this study, and a companion hatchery White Sturgeon study on hook shedding (J. A. Lamansky Jr., unpublished data), appeared to be located in the gizzard, past the stomach–gizzard sphincter and perhaps too deep to be shed orally. Once metal reaches the gizzard, passing the metal through the entire digestive system may be (morphologically) the only option for White Sturgeon.

The bell-shaped relationship between White Sturgeon length and the presence of metal suggests that fish length influenced the vulnerability of fish to metal ingestion or their ability to shed metal once it was ingested, but we tested whether length affected hook passage time and found no effect (although the effect was nearly significant); we infer from this that small fish (<100 cm) were perhaps less vulnerable to hook consumption. Small White Sturgeon may forage more cautiously or target their foraging efforts in areas where they are less prone to encountering broken-off gear on the river bottom. It seems unlikely that mouth morphology explains the reduced incidence of ingested metal in smaller fish since the type of gear ingested did not differ from that of larger fish. The apparent lack of a fish size effect on hook passage in the present study contrasts previous studies that have found positive relationships between fish length and hook shedding rates for European Eel *Anguilla anguilla* (Weltersbach et al. 2016) and Yellowfin Bream *Acanthopagrus australis* (McGrath et al. 2011). The latter authors argued that fish may need to rotate the hook in the digestive system to facilitate hook shedding, which would presumably be easier for larger fish. However, in the present study no particular pattern of hook orientation was evident in the digestive tract from one X-ray to the next for hooks that were shed compared with hooks that were not shed.

The results of this study indicate that White Sturgeon that have ingested metal in their digestive systems have a slightly reduced body condition compared with those without metal. Most studies that have investigated fish growth after hook ingestion have been of short duration (i.e., a few months or less), some of which have shown reduced growth (e.g., Aalbers et al. 2004) but most of which have not (e.g., Broadhurst et al. 2007; Fobert et al. 2009; Stein et al. 2012). A longer duration study conducted on Largemouth Bass *Micropterus salmoides* that were intentionally deeply hooked showed no reduction in survival or growth (compared with control fish) up to 11 months after they were caught, regardless of whether the hook was removed or not (DeBoom et al. 2010). A confounding factor in all of these studies is that the hooks were ingested (and either left in place or removed) because the fish was hooked deeply during angling, thus any reduction in growth could have been caused by internal organ damage from deep hooking, the presence of the metal itself, or both. Results from the present study indicate that even in the absence of internal organ damage from deep hooking, the presence of metal in the digestive tracts of White Sturgeon may reduce their food conversion efficiency, nutrient uptake, and perhaps even foraging frequency if angling gear is impeding the passage of food through their digestive system. However, it should be noted that of the 57 fish captured more than once, over one-third had metal for one capture event but not the other. This highlights how often metal is ingested and passed and suggests that any reduction in

body condition from metal ingestion is likely short term. Indeed, considering how often White Sturgeon ingest and pass metal, a statistical difference in the length–weight relationship and mean relative weight between fish with and without metal would only materialize if fish that consumed metal on average exhibited reduced weight gain while those that shed metal on average exhibited improved weight gain. White Sturgeon readily consume many food items with hard shells or bones (e.g., mussels, crayfish, fish) that once ground by their gizzard may form sharp edges; thus, they are likely well adapted to pass hard, sharp items through their digestive tract.

In summary, the results of this study suggest that most White Sturgeon in the Hells Canyon reach of the Snake River have no metal in their digestive system, and for those that do (1) much of the metal is angling tackle targeting other species of fish, (2) consumed metal will pass through their digestive tract on average in 492 d, which is faster than new metal is ingested, and (3) metal consumption causes a slight reduction (at least temporarily) in body condition. These findings suggest that White Sturgeon population-level impacts from metal consumption are minor, though conducting population simulations may help better contextualize these impacts relative to other potential limiting factors (Jager et al. 2002). Considering that much of the metal inside White Sturgeon was not terminal tackle targeting White Sturgeon, efforts should be made to educate the general angling public (not just sturgeon anglers) on ways to limit the amount of baited or scented tackle lost on river bottoms. While the use of portable X-ray machines illuminates the types of metal in fish digestive tracks, metal detectors rarely misidentify the presence or absence of metal inside these fish. Regardless of which metal detection device is used, better knowledge of the types and quantity of metal in other White Sturgeon populations would help clarify how widespread angling tackle consumption is.

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