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MANAGEMENT BRIEF

Determining the Presence of Hooks Inside White Sturgeon Using Metal Detector and Portable X-Ray Technology

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Abstract
We examined the feasibility of using handheld metal detectors and portable X-ray technology to assess the occurrence and type of hooks ingested by White Sturgeon *Acipenser transmontanus* in the Hell's Canyon reach of the Snake River, Idaho. Three hundred and fifty-two White Sturgeon were collected in the Hell's Canyon reach using angling and setline techniques from 2009 to 2011. Thirty-one percent scanned positive for the presence of hooks inside them. We found the handheld metal detector accurately determined hook presence in White Sturgeon 97% of the time when verified with X-ray. Larger size-classes of fish had a higher occurrence of hooks inside them (>50%) than did smaller size-classes. Occurrence of hooks within White Sturgeon across the entire study area was similar from year to year, ranging from 25% to 33%. We estimated that 64% of hooks observed with X-ray images were consistent with gear used for White Sturgeon angling and 36% were consistent with gear used for Smallmouth Bass *Micropterus dolomieu* and steelhead *Oncorhynchus mykiss* angling. Five White Sturgeon previously captured with hooks inside them did not scan positive for hooks upon recapture, indicating that they had passed hooks through the digestive tract or out the abdominal cavity. Hook ingestion is relatively common within this population; however, additional investigations on deep-hooking, hook processing, and potential effects on fish health need to be conducted before drawing conclusions about effects on the population.

White Sturgeon *Acipenser transmontanus* provide a unique and valuable recreational fishing opportunity in a number of locations throughout their range (Dillon and Grunder 2008). White Sturgeon fisheries are popular given the species's ability to commonly reach sizes >2 m (Simpson and Wallace 1982; Bates et al. 2014). Large sizes are attained by being a long-lived and late-maturing species (Simpson and Wallace 1982; Bates et al. 2014). Given these unique life history and population dynamics, fishery managers often use more protective management approaches for White Sturgeon populations than for fish species capable of withstanding higher exploitation (Rieman and Beamesderfer 1990).

The White Sturgeon population in the Hell's Canyon reach is one of the more robust White Sturgeon populations within the Snake River, Idaho, and provides a valuable recreational fishery (Dillon and Grunder 2008). This fishery has been managed using catch and release rules since 1971 after research showed that harvest was significantly affecting the size structure of the population (Dillon and Grunder 2008). Although the size structure has responded positively to the catch and release rules (Lukens 1984; Dillon and Grunder 2008), managers recognize that some level of indirect mortality will continue as a result of hooking, landing, and releasing fish (Barnhart 1989). Therefore, additional regulations have been put in place to further reduce incidental mortality. For

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example, the Idaho Department of Fish and Game (IDFG) 2016–2018 regulations require the use of barbless hooks when fishing for White Sturgeon and prohibit the removal of White Sturgeon from the water.

White Sturgeon may live up to 100 years (Brown 2001). In Hell's Canyon, they are slow growing, averaging 2–4 cm per year for fish <100 cm and >140 cm total length (TL), and 4–8 cm per year for fish 100–140 cm TL (Bates et al. 2014). Age of sexual maturity is as late as 35–40 years in this population (Lepla et al. 2001; Bates et al. 2014). In addition, White Sturgeon do not reproduce every year, with reproductive periodicities being reported of 2 to 11 years (Simpson and Wallace 1982; Cochnauer 1983; Chapman et al. 1996). Recent evidence suggests the spawning periodicity of female White Sturgeon in Hell's Canyon exceeds 11 years (K. B. Lepla, Idaho Power Company, personal communication). These life history characteristics suggest that population levels may be affected by small increases in mortality (Lepla et al. 2001; Bates et al. 2014). Idaho Department of Fish and Game personnel have typically necropsied two or three White Sturgeon each year that were found dead within the Hell's Canyon reach of the Snake River. Some necropsied individuals contained hooks within their body cavity, the majority of hooks being contained within the digestive tract. These observations elevated the desire to develop a method to estimate the proportion of White Sturgeon that have hooks in their body cavity and, if present, estimate the number of hooks contained within individuals. Previous studies have used metal detectors to determine the presence of hooks in fish (Schill 1996; DuBois and Pleski 2007). On the basis of these studies, we wanted to test whether external scanning with a metal detector would be a viable method of estimating the presence of ingested hooks and other terminal tackle in Hell's Canyon White Sturgeon.

The White Sturgeon fishery in Hell's Canyon is only one of several fisheries within this reach of the Snake River. High-effort fisheries for steelhead *Oncorhynchus mykiss* and Smallmouth Bass *Micropterus dolomieu* also overlap the White Sturgeon fishery. The variety of terminal tackle recovered during initial White Sturgeon necropsies indicated hook ingestion was not strictly associated with the White Sturgeon fishery, as smaller size hooks were also observed. From the tackle recovered in necropsies, we hypothesized that baited hooks became available for ingestion in two ways: swallowed hooks could be broken off when actively fighting a White Sturgeon, and hooks could be broken off on the bottom while fishing for White Sturgeon or other species and subsequently ingested. Testing our hypothesis required that we develop a technique to determine not only whether a hook was present within a fish but also what type (intended for White Sturgeon angling or not) and quantity of hooks were present within the fish. We evaluated the use of portable X-ray technology as a technique for identifying the ingested gear. Laboratory X-ray has been used to examine hooks in Yellowfin Bream *Acanthopagrus australis* (Broadhurst et al. 2007) and Kemp's Ridley sea turtle *Lepidochelys kempii* and European Pond turtle *Emys orbicularis* digestive tracts (Nemoz et al. 2004; Rudloe and Rudloe 2005).

The specific objectives of this study were to determine whether metal detectors and X-ray could accurately detect and identify the type of hooks within the body cavity of White Sturgeon and determine whether ingested hooks were accumulating in White Sturgeon between captures.

STUDY AREA

The Hell's Canyon Reach of the Snake River borders Idaho, Washington, and Oregon (Figure 1). This reach is free flowing for approximately 172 river kilometers from Hell's Canyon Dam to slack water at the upstream end of Lower Granite Reservoir near the town of Lewiston, Idaho. Operations of Hell's Canyon Dam influence river discharge of the Snake River within the study reach. The Salmon, Grande Ronde, and Imnaha rivers are unregulated river sys-

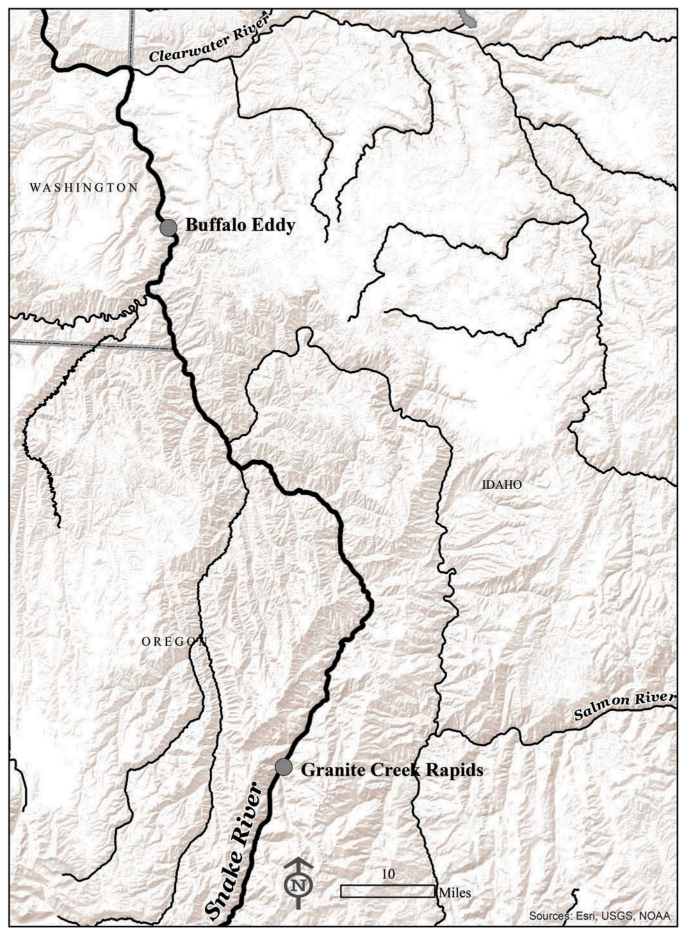

FIGURE 1. The study area from Buffalo Eddy to Granite Creek Rapids within the Hell's Canyon reach of the Snake River where White Sturgeon were caught and assessed for the presence of hooks from 2009 through 2011.

tems that also enter the main-stem Snake River within the study reach. White Sturgeon sampling for this study was confined to the main-stem Snake River between Buffalo Eddy and Granite Rapids (Figure 1).

METHODS

White Sturgeon sampling.—White Sturgeon were collected during the 2009–2011 field seasons (April–November) using hook-and-line angling. Anglers used rods, reels, and terminal tackle commonly used in the White Sturgeon fishery. Fishing gear consisted of a 27.2-kg test mainline attached to a 36.3-kg test leader. Sinker weight was varied according to fishing conditions. Gamakatsu Octopus 8/0 circle and Gamakatsu Octopus 9/0 J hooks were used in the study. White Sturgeon anglers fished from a boat and cast or dropped baited hooks and weights into White Sturgeon holding areas. Rods were tended or set in a rod holder. The river kilometer at each location fished was recorded.

In addition to angling, some White Sturgeon in the 2009 and 2010 field seasons were captured using setlines. Each setline consisted of a 30-m mainline (0.79-cm double-braid nylon rope) rigged with six evenly spaced hooks. A steel spring clip and swivel with a 600-lb. test gangen line connected each hook to the mainline. The setline was attached to shore on one end and held to the streambed by heavy pieces of galvanized chain (10 kg). Floats were attached to the shore end of the mainline in case the setline was pulled into the water. Setlines were left unchecked for a maximum of 12 h.

Sampling effort was not stratified spatially or temporally. Sampling efforts were dispersed throughout the entire study reach, but effort was focused in areas believed to hold White Sturgeon so that we could maximize the number of fish examined with the handheld metal detector and X-ray techniques.

We measured and recorded TL and pectoral girth (measured directly behind the pectoral fins) for all captured White Sturgeon. We examined for and recorded hook scars, previous PIT tags if detected, and any wounds or visible signs of injury or previous marks. Fish were scanned for PIT tags using Destron Fearing FS-2001 International Organization for Standardization (ISO) readers. All readers were ISO-upgraded to allow for detection of 400-, 125-, and 134.2-kHz tags. Any fish not previously PIT-tagged was marked by inserting a new PIT tag at the base of the dorsal fin. First-time captured fish were also marked externally by removing the second lateral scute (counting back from the gill arch) on the left side.

Hook detection and X-ray.—Fish were scanned for hooks along the entire ventral side of the body from mouth to anus by pressing a Garrett Pro-pointer or White's Matrix 100 handheld metal detector against the abdomen. Before scanning each fish, metal detectors were verified to be working by using a known metal object. Metal detectors were moved from the anterior to the posterior of the fish using short lateral motions to attempt to detect hooks. A hook was determined to be present when the metal detector produced a constant beep in the same location on the fish. When a hook was detected, the area was rescanned to make sure a false positive did not occur.

To verify the accuracy of metal detectors in determining the presence of hooks in White Sturgeon, we also examined some of the fish by using X-ray on selective trips during 2010 and 2011. To X-ray samples in the field, we used a Sound-Eklin Tour eSeries 1008G portable digital radiography system coupled to a Min X-ray high-frequency XDT-F80 X-ray generator. In 2010, we examined all fish captured using X-ray techniques when the portable unit was present. In 2011, we X-rayed only fish that tested positive for hooks by the handheld metal detector. Sampling trips that included X-ray verification of the metal detector were distributed across the study area. All X-rayed White Sturgeon were placed upside-down in a vinyl sling, suspended between the rails of a jet boat with a 2.5-m beam. Water was pumped in their mouths and over the gills to ensure fish were respiring. The personnel conducting radiography were equipped with recommended safety equipment, including leaded gloves and leaded apron. Multiple radiographic views were taken along the entire digestive tract of the individual. In addition to lateral–lateral radiographic projections obtained on all White Sturgeon sampled (Figure 2), orthogonal projections were obtained on the smaller White Sturgeon when the body size allowed for diagnostic ventro-dorsal projections (Figure 3). The orthogonal view provided the precise location of a hook within the digestive tract. An 8/0 White Sturgeon hook was placed on the surface of the abdomen of all X-rayed White Sturgeon to serve as an external marker in radiographic images (Figure 2). Radiographic parameters varied between 50 and 120 kVp at 1.0–2.0 mAs, depending on the girth of the individual White Sturgeon, using common radiographic settings based on previous pilot studies. After the X-raying was complete, fish were held in the water until they swam away under their own power.

Radiographic images produced by X-ray were downloaded on a field computer and later observed on a monitor screen. The total number of hooks by type (White Sturgeon, steelhead, bass, etc.) and swivels were recorded for each individual White Sturgeon X-rayed. Hook location within the body cavity of each fish was also recorded. Using this information, we compared the frequency with which hooks were found in different size-classes of White Sturgeon. Since sampling proceeded over multiple years, recaptured individuals were included in hook presence estimates.

Because this study covered 3 years, we were able to track hook disposition changes (hook present to not present and vice versa) for several recaptured individuals. In most cases, this ability was limited to fish that had been scanned with the metal detector at least twice, but one fish that was X-rayed on two occasions provided additional detail.

FIGURE 2. One of several lateral-lateral radiographic images taken of a White Sturgeon captured in 2010 from the Hell's Canyon reach of the Snake River to evaluate it for the presence of hooks. The top hook is an 8/0 reference sturgeon hook placed on the fish, and the lower hook was ingested by the sturgeon.

RESULTS

Hook Detection and X-ray

A total of 352 White Sturgeon were captured during the study. Total length of fish captured ranged from 31 to 290 cm with a mean length of 140 cm (Figure 4). Of these, 341 were examined for the presence of hooks using metal detectors. We observed that 25, 33, and 29% of fish scanned positive for hooks in 2009, 2010, and 2011, respectively.

Hook ingestion by size-class was similar across years, so data from 2009 through 2011 were combined. The two smaller size-classes of White Sturgeon had the lowest occurrence of hook ingestion, 11% and 26%, respectively (Figure 5). Hooks were observed in more than 45% of captured White Sturgeon within the three largest size-classes (>150 cm; Figure 5).

A total of 135 White Sturgeon were X-rayed during the 2010 and 2011 field seasons to verify the accuracy of the metal detector and evaluate the number and the type of hooks within their body cavity. X-ray verification showed that the metal detector was 97.1% accurate at confirming the presence or absence of hooks in White Sturgeon. The metal detector recorded three false positives and one false negative for hooks.

The number of hooks found within an individual fish ranged from 0 to 12 (Figure 6). Of the fish containing hooks, 75% contained one or two hooks (Figure 6). Approximately 7% of the fish sampled contained five or more hooks (Figure 6).

A total of 131 hooks were observed in White Sturgeon through X-ray during the 2010 and 2011 field seasons. Overall, 64% of the observed hooks were sturgeon hooks and 36% were nonsturgeon hooks (Figure 7). Sturgeon hooks were more common than nonsturgeon hooks in all size-classes sampled (Table 1). Of the sturgeon hooks identified to type, the most common design was the j-hook (86%); the remaining were circle hooks (14%; Figure 7). Eight sturgeon hooks were degraded or positioned in a manner where type was unable to be identified.

Hook Processing

We recaptured 42 White Sturgeon during the study. Seventy percent of the fish were recaptured once. Seven fish were

FIGURE 3. A radiographic image using an orthogonal projection (ventro-dorsal view) to evaluate hook ingestion by White Sturgeon captured from the Hell's Canyon reach of the Snake River.

recaptured twice, and one individual was recaptured four times. Average duration between recapture events was 223 d (range, 2–650 d). Of the recaptured fish, 70% tested the same for the presence of hooks (hook or no hook both captures) and 30% had a change in hook occurrence (hook to no hook, or no hook to hook) from capture to recapture. Of the 12 fish that had a change in hook occurrence, 58% gained hooks from capture to recapture and 42% had lost hooks from capture to recapture. The average time at large from capture to recapture for fish that lost hooks was 204 d (range, 2–393 d). One individual X-rayed in 2010 was recaptured and X-rayed in 2011. This individual had 12 hooks within the digestive tract in 2010 and 5 in 2011.

DISCUSSION

This study found that the use of handheld metal detectors is a valid and accurate technique to evaluate whether White Sturgeon are ingesting fishing hooks. Metal detectors have been used to estimate tackle loss in fisheries (Duerr and DeStefano 1999) and to examine hook ingestion in sea turtles (Rudloe and Rudloe 2005), but limited work has been done to examine the efficacy of using metal detectors to detect hooks inside fish. Studies cited earlier (Schill 1996; DuBois and Pleski 2007) have used metal detectors in raceway studies with smaller study subjects, but no metal detector work has been verified with X-ray. We believe that metal detectors may provide a valuable and economical tool for assessing terminal

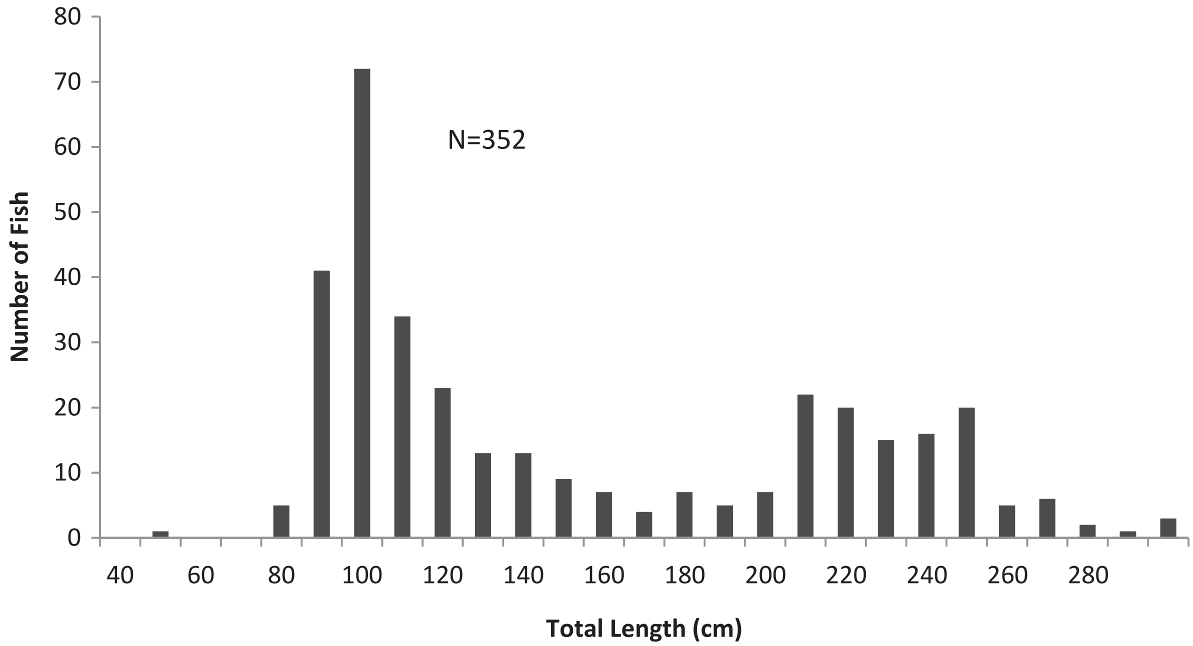

FIGURE 4. Size distribution of White Sturgeon sampled in Hell's Canyon during the 2009–2011 field seasons.

fishing gear ingestion in recreational fisheries. Since this technology was tested on a large fish such as White Sturgeon and was able to detect smaller-sized hooks in this large fish species, it should also work with smaller species. Caution should be taken when interpreting handheld metal detector results for hook ingestion, however, since a positive detection does not necessarily indicate a hook. Other types of metal may be present in fish such as other terminal tackle and a variety of tags (e.g., PIT tags and radio tags).

Field X-ray was also verified as a valid technique for determining the presence, type, and location of hooks found inside White Sturgeon. Study species that are small and numerous can be sacrificed and X-rayed in laboratory settings. White Sturgeon are too large to transport easily and are a species of conservation need within Idaho; therefore, they could not be sacrificed for the study (IDFG 2005). Future hook ingestion studies evaluating the type and location of hooks or terminal tackle ingested should consider field X-ray to collect the data without the need to sacrifice or transport fish from the field.

This study suggests that the majority of hooks found inside White Sturgeon occurred because they were ingesting hooks (likely baited) broken off on the bottom by anglers. We observed (either through X-ray, metal detector, or personal observation)

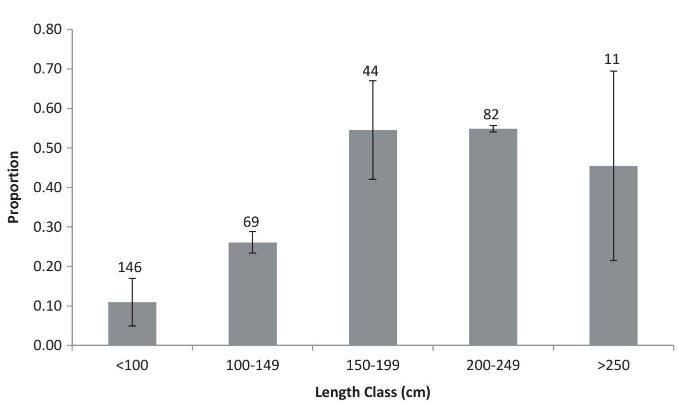

FIGURE 5. Proportion of White Sturgeon by size-class that contained hooks as determined by handheld metal detectors and X-ray within the Hell's Canyon reach of the Snake River during the 2009–2011 field seasons. Sample size per length class displayed above 90% confidence bars.

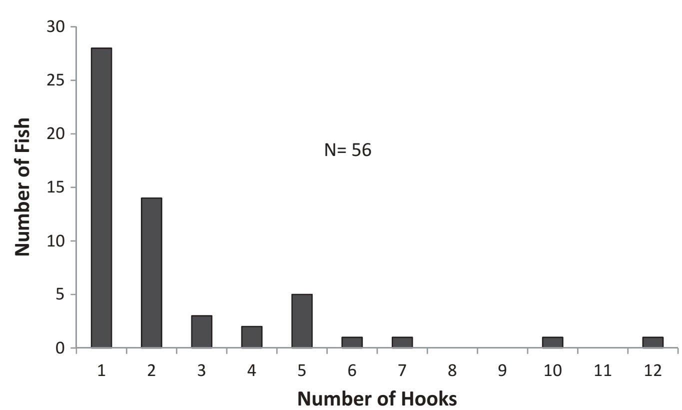

FIGURE 6. A hook frequency histogram showing the number of hooks found in White Sturgeon, as determined by X-ray, that were caught throughout the study area within the Hell's Canyon reach of the Snake River during the 2010 and 2011 field seasons.

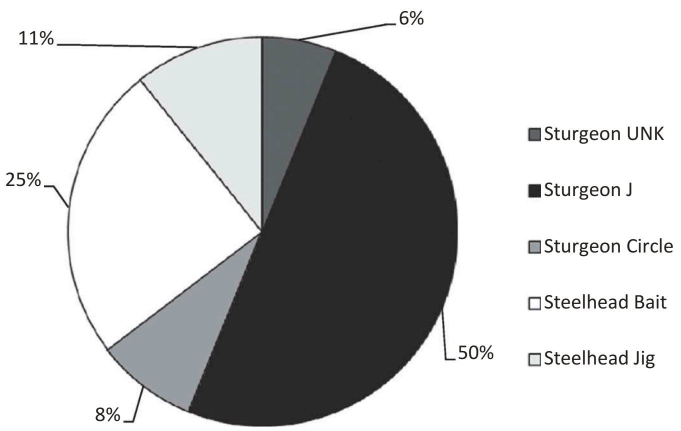

FIGURE 7. The percentage of different hook types observed in White Sturgeon by X-ray that were caught in the Hell's Canyon reach of the Snake River during the 2010 and 2011 field seasons (n = 131).

only one hook imbedded in the mouth or esophagus during this study. If angler breakoffs were a significant reason for finding hooks in White Sturgeon, we should have observed them imbedded in the mouth or esophagus more frequently. In addition, 36% of the hooks found within White Sturgeon appeared to be from other fisheries. High break-off rates occur in drift fisheries typically associated with salmon and steelhead angling in the area. Our results indicate that White Sturgeon are ingesting broken-off baited hooks from these fisheries as well.

Recaptures of multiple fish over the course of the study indicated that some White Sturgeon passed hooks between capture events. In addition, of the White Sturgeon containing hooks inside them, most had one or two within their body cavity, providing evidence that hooks are not accumulating over time. Other studies have found that fish expel hooks considered to be deep hooked (Schill 1996; Tsuboi et al. 2006; Broadhurst et al. 2007; DuBois and Pleski 2007). Schill (1996) during a 2-month study found that 74% of deep-hooked Rainbow Trout did in fact shed their hooks. Tsuboi et al. (2006) estimated 53.3 ± 36.3 d (average ± SD) till hooks were evacuated out of Whitespotted Char *Salvelinus leucomaenis* that had been deep hooked and had the fishing line cut. However, work conducted by Dubois and Pleski (2007) found that only 20% of surviving fish had shed their hooks after 6 weeks. In all cases, the work was conducted on nonanadromous salmonids, which are much smaller than White Sturgeon. We do not believe that hook ingestion is caused by deep-hooking in this study. This research suggests that large fish such as White Sturgeon can pass fish hooks successfully through the digestive tract or out the abdominal cavity. Observations during this study indicate that White Sturgeon can rid their body of hooks both ways. On multiple occasions we captured fish with fishing line or hooks or both coming out their anus, and occasionally we observed hooks protruding out the body wall.

Based on initial findings from this study, statewide White Sturgeon fishing rules in Idaho were changed in 2010 to require the use of a sliding sinker attached to a test line of lesser pound strength. This rule was created to reduce the number of hooks broken off and left in the river. With this rule, when an angler snags a weight on the bottom, the weight can be broken off, allowing retrieval of the hook. We expect this rule will reduce the number of sturgeon hooks ingested by White Sturgeon. Ingestion of hooks by White Sturgeon in Hell's Canyon is relatively common; however, assessing the effects of this on individuals or the population was outside the scope of this study. A variety of studies have documented differing effects that deep-hooking, handling time, and removing hooks can have on postrelease survival of fishes (Warner 1979; Muoneke and Childress 1994; Bettoli and Osborne 1998; Butcher et al. 2007). Further research specific to angling methods, deep-hooking, and potential impacts on fish health specific to the White Sturgeon population in Hell's Canyon is needed before any conclusions can be drawn regarding the effect of hook ingestion on this population.

TABLE 1. Number and percent of White Sturgeon and bass or steelhead hooks (other) present within different size-classes of White Sturgeon X-rayed in 2010–2011 within the Hell's Canyon reach of the Snake River.

	Hook type		% Hook type	
Length class (cm)	White Sturgeon	Other	White Sturgeon	Other
<100	5	1	83	17
100–149	11	6	65	35
150–199	27	10	73	27
200–250	35	26	57	43
250+	6	4	60	40
Total	84	47	64	36

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Most importantly, we remember Larry Barrett, an author on this paper, as the true Sturgeon General for his participation at the inception of this study and unending passion for White Sturgeon in Hell's Canyon. Special thanks to the many volunteers and Idaho Department of Fish and Game staff who participated in data collection for this study. Finally, we thank Ed Schriever, Jim Fredericks, Kevin Meyer, Jeff Dillon, and three anonymous reviewers for their constructive comments and edits, which greatly improved the manuscript.

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