

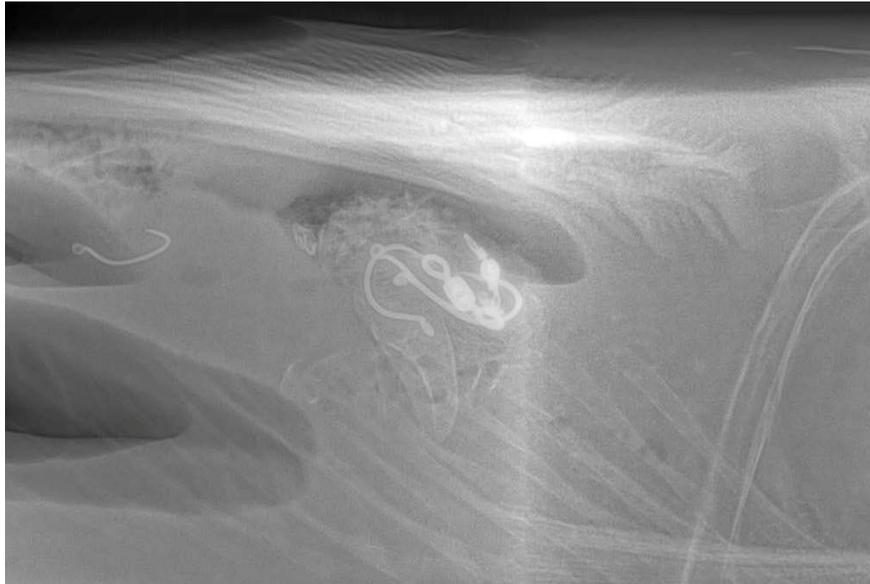
FISHERY RESEARCH



PROJECT 5—WHITE STURGEON RESEARCH

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Report Period July 1, 2011 to June 30, 2012



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Project 5—White Sturgeon Research

**Subproject 1: White Sturgeon Investigations: Hatchery White
Sturgeon**

Subproject 2: Hook Investigations: Hook Corrosion

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**ANNUAL PERFORMANCE REPORT
SUBPROJECT 1: WARMWATER FISHERIES INVESTIGATIONS**

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ABSTRACT

Angling for white sturgeon *Acipenser transmontanus* is popular in Idaho, causing managers to consider the effects angling pressure or ingested fishing tackle may have on populations. We implanted circle and J hooks in offset and inline configurations at three levels (1 hook, 5 hooks, and 5 hooks with a monofilament leader and a swivel) into the stomachs of 118 white sturgeon to assess the effects of ingesting hooks on growth and stress response. In the first five months of the experiment, we have found no differences in the fork length, vent length, girth, or hematocrit levels of fish with the different treatments. X-ray examination has also shown that implanted hooks remain in the gizzard five months after implantation. Although no difference is currently apparent, the study is not yet completed.

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INTRODUCTION

Sturgeon populations have been declining worldwide for decades (Rochard et al. 1990; Birstein et al. 1997). Reasons include habitat alterations from dam and irrigation diversion construction (Parsley et al. 1993; Beamesderfer and Farr 1997), overharvest, and the desirability of eggs for caviar (Boreman 1997). Five of the eight sturgeon species in the United States are currently listed as threatened or endangered under the Endangered Species Act (Williams et al. 1989; Secor et al. 2002). Sturgeon are a long-lived species with the ability to live more than 100 years (Semakula and Larkin 1968), usually spawning for the first time between 15 and 30 years of age, and oftentimes going 10 years between spawning events (Semakula and Larkin 1968). Because sturgeon are long lived and spawn infrequently, populations are vulnerable to decline via overfishing or mortality from the associated effects of angling (Rieman and Beamesderfer 1990; Boreman 1997).

In Idaho, populations of white sturgeon *Acipenser transmontanus* have been in decline due to over harvest and habitat fragmentation from dam construction for at least 100 years (Cochnauer et al. 1985). Although under strict catch-and-release and barbless hook regulations since 1971, sport fisheries for white sturgeon still exist in Idaho (Idaho Department of Fish and Game 2008). Due to the popularity of sturgeon fisheries, and the potential sensitivity to increased mortality rates, managers are concerned about the effects on populations from angling pressure and ingested fishing tackle. More specifically, fishery managers are concerned that the terminal tackle used to catch white sturgeon may be reducing reproductive success or increasing mortality rates due to chronic stress from 1) deep-hooking injury; 2) the retention of hooks that were broken off or left in the fish intentionally; or 3) the consumption of “ghost gear” (tackle that was lost to the river and subsequently eaten). For example, Kozfkay and Dillon (2010) documented that individual white sturgeon were caught an average of 7.7 times in a one-year period for a population that lives below C J Strike Dam in southern Idaho. Likewise, sampling has identified that approximately 30% of white sturgeon in the Hell’s Canyon reach of the Snake River have metal hooks or other metal terminal tackle in their digestive systems (J. Dupont, IDFG, personal communication; K. Lepla, Idaho Power Company, personal communication). Anecdotal reports are also increasing that anglers are finding white sturgeon with hooks or fishing line protruding from the body.

The digestive system of white sturgeon is similar to other chondrosteans (Buddington and Christofferson 1985). The alimentary canal length (ACL) is short, ranging from 70-100% of fork length. The alimentary canal consists of the esophagus (5% ACL); the stomach, composed of two regions (40-50% ACL); the intestine (20-25% ACL); the spiral valve (20-25% ACL); and a short rectum (2-3% ACL). The two regions of the stomach form a loop, and consist of an anterior fore-stomach and a muscular pyloric region, often referred to as a gizzard. The fore-stomach is capable of distending 3-5 times the empty state when food is present. The muscle wall of the gizzard is hypertrophic and is designed to aid in grinding up hard food items, such as fish bones or shells, for further digestion (Buddington and Christofferson 1985).

Considering that white sturgeon in Idaho are caught almost exclusively using bait, and in some reaches are caught multiple times per year, a reduction in deep hooking rates could benefit populations. Recent studies suggest that using circle hooks reduces deep hooking injury in many fish species (Cooke et al. 2003a, 2003b; Cooke and Suski 2004; Fobert et al. 2009) and reduces the mortality of caught and released fish compared to conventional J hooks (Prince et al. 2002; Aalbers et al. 2004; Graves and Horodysky 2008; Serafy et al. 2008). However, the majority of these studies were conducted on marine fish in commercial long-line fisheries. Several studies also suggest that when a fish is deeply hooked, cutting the line and releasing

the fish results in lower post-hooking mortality (Schill et al. 1986; Tsuboi et al. 2006; Fobert et al. 2009). However, few studies have examined longer term effects on mortality rates, reproductive fitness, or body condition when hooks are left in fish, and those that do focus on deep hooked fish (see Mason and Hunt 1967; Marnell 1969; Hulbert and Engstrom-Heg 1980; Broadhurst et al. 2007; Butcher et al. 2007). To our knowledge, no published studies exist that identify the length of time hooks eaten by fish persist in the digestive system or the effects that hooks have on mortality, growth rates, or reproductive success of any fish species.

Circle and J hooks differ in design and function. J hooks are designed with the point parallel to the shank (Figure 1A), whereas circle hooks are designed with the point perpendicular to the shank (Figure 1B). The design of a circle hook prevents the point from piercing tissue in the esophagus, gills, or inside the mouth until the hook is pulled through the mouth opening, whereby the point pierces the lip and encircles the mandible (Huse and Fernö 1990; ASMFC 2003; Cooke and Suski 2004). Manufacturers recommend that anglers using circle hooks not set the hook, but apply slow, steady pressure while reeling after a fish strikes to allow the circle hook to function and reduce deep-hooking (e.g., Montrey 1999; see ASMFC 2003). However, a study by Sullivan et al. (2013) suggests this may not be the case. J hooks are designed with the point exposed to penetrate tissue immediately when pressure is applied through the line, which likely increases deep hooking. Correspondingly, hooks may be designed with an inline or offset point. Inline hooks are constructed with the front of the hook in the same plane as the shank (Figure 2A), whereas offset hooks have the front bent at angle compared to the shank (Figure 2B). The amount of offset often ranges between 4-18 degrees from the line of the shank and can vary greatly between manufacturers. A hook with an offset point is designed to penetrate more quickly, and when circle hooks are designed with an offset point, the benefits of reduced deep hooking may be reduced (Aalbers et al. 2004; Graves and Horodysky 2008).

The objectives of our study were to determine the effects of common hook types used for sturgeon angling and the number of hooks within the digestive system on the growth and stress response of white sturgeon after hooks reach the stomach. We assessed the length of time hooks persist in the digestive system, the breakdown of the hook material, and whether hooks were dissolved, isolated inside the body, or passed through the digestive tract. We also measured growth parameters and the production of stress hormones to assess whether the presence of hooks affected white sturgeon fitness.

OBJECTIVES

1. To assess the disposition (dissolved, regurgitated, passed through the digestive system, etc.) of inline and offset circle and J hooks after implantation into white sturgeon stomachs.
2. To assess the effects of inline and offset circle and J hooks on the growth and stress response of white sturgeon after one hook, five hooks, and five hooks with monofilament leader and swivel are implanted into stomachs.

METHODS

We acquired 118 white sturgeon from a commercial hatchery operator from the Hagerman Valley, Idaho to conduct our study. The white sturgeon were 6-9 years old and ranged in length from 1.0-1.5 m and weighed from 15-60 kg. The study fish resided in a single

concrete raceway (25 X 4 m) with a constant flow of 0.042 m³/s at a temperature of 12°C with slight seasonal variations. Study fish were fed volitionally with Rangen 450/sinking, 8 mm pellets, throughout the study period. All study fish were tagged with a passive integrated transponder (PIT) tag to allow identification of individual fish during subsequent handling.

We implanted hooks with different shapes (circle/J hooks) and sets (inline/offset) at three treatment levels (1 hook, 5 hooks, and 5 hooks with 480 mm of 60# test monofilament and a size 1 brass barrel snap swivel; Table 1) into the stomachs of study fish on 15 September 2011. The hooks were similar to those commonly used by sturgeon anglers in Idaho and were constructed from high-carbon steel with similar wire diameter, dimensions, and finish. The model of hooks used were Gamakatsu Octopus circle hooks (size 7/0, black nickel finish, model # 208417) and Gamakatsu Octopus J hooks (size 7/0, black nickel finish, model # 02149), in both inline and offset configurations. To simulate current Idaho sturgeon fishing regulations, hooks were debarbed before implantation by pinching the barb down with pliers. Each hook type and treatment level (Table 1) was implanted into nine white sturgeon. We also used ten fish as a control group that were treated as study fish, but without hooks. The hooks were implanted into white sturgeon stomachs using a flexible vinyl tube. Hooks were imbedded into a small piece of fish flesh and placed into the end of the tube. The tube was inserted into the mouth and gently pushed down the esophagus (approximately 120 mm) into the stomach. Using a plunger, the hooks were pushed out of the tube into the stomach, and the tube was removed.

Growth parameters were measured and the hooks in the digestive tract were monitored using a portable X-ray machine (Sound-Eklin tru/DRLX System). At the time of hook insertion (9 September 2011), we initially measured fork length (mm), the distance between the tip of the nose and anal vent (vent length; mm), and girth (mm) directly posterior to the pectoral girdle. Measurements were repeated every four weeks following hook insertion. Immediately following hook insertion, placement of the hooks was viewed using a portable X-ray machine. The X-ray system consisted of an X-ray generator and a plate that receives the X-ray beam, compiles the received information, and sends a digital image to a computer. The protocol settings on the X-ray generator were consistently set at 96 kilovolts (kVp) and 2.00-second exposure (mAs) to produce an acceptable image. We constructed a custom, wheeled rack with adjustable brackets on which to mount the X-ray generator and plate to aid alignment with the study fish. Using the rack also allowed workers to stay a minimum of 2 m away from the X-ray generator during use, the safe distance required to avoid X-ray scatter. During X-rays, study fish were placed in a sling and suspended on sawhorses between the X-ray generator and the plate. Study fish were X-rayed every four weeks after hook insertion to assess the passage and breakdown of hook material.

We measured two common stress response parameters, blood plasma cortisol, and hematocrit levels, to determine whether the presence of hooks in the alimentary tract caused a stress response in our study fish. Blood was collected as quickly as possible after fish were removed from the raceway for measurement and was collected every four weeks after hook insertion during measurement and X-ray procedures. Whole blood was sampled from the caudal vein, directly posterior to the anal fin, using a 38 mm, 22-gauge hypodermic needle and a heparinized, 3 cc syringe. A small amount of whole blood was placed into a hematocrit tube and centrifuged until the plasma and hemoglobin stratified (1-2 min), after which the percent hemoglobin was recorded. The remaining whole blood was placed into two, 1.5 ml microcentrifuge tubes, and centrifuged until the plasma and hemoglobin were separated (1-2 min). The plasma was pipetted into CryoVials, frozen in liquid nitrogen, and stored in a -80°C freezer until further analysis. As a preliminary evaluation of cortisol levels (cortisol µg/ml), we analyzed blood samples from individual fish for two of the harsher treatments (n = 10; 5MOC

and 5MOJ), two lighter treatments ($n = 5$; 1OC and 1OJ), and the control group ($n = 10$) taken during the sampling event when hooks were inserted (15 September 2011) and again on 12 October 2011. We calculated the difference in cortisol level between the two sampling times and compared the means. Cortisol assays were performed by the Oregon State University Fish Co-Operative Laboratory, Corvallis, Oregon using a double antibody radioimmunoassay.

We analyzed data by comparing the effects of hook shape (circle/J hooks), set (inline/offset), and number (1 hook, 5 hooks, and 5 hooks with 480 mm of 60# test monofilament and a size 1 brass barrel snap swivel) on the percent change of growth and hematocrit measurements. The sampling unit was an individual fish with a particular hook type and treatment. The response variables were the proportional difference between the initial (15 September 2011) growth, hematocrit, and cortisol measurements and the measurements taken most recently (9 February 2012). The proportional differences between the initial and subsequent measurements of fork length, vent length, girth, and hematocrit were tested with analysis of variance (ANOVA; $\alpha = 0.1$) with Tukey pairwise comparisons to determine differences between groups (Minitab 2010).

RESULTS

To date, all fish have increased in fork length (Figure 3) and vent length (Figure 4) and no effect from the shape ($F = 0.87$, $df = 1$, $p = 0.35$), set ($F = 2.19$, $df = 1$, $p = 0.14$), or number of hooks ($F = 1.52$, $df = 2$, $p = 0.22$) is apparent. Girth also increased for all fish (Figure 5) with no effect from shape ($F = 0.28$, $df = 1$, $p = 0.6$), or set ($F = 0.12$, $df = 1$, $p = 0.74$). However, the number of hooks had an effect on the girth of study fish ($F = 3.88$, $df = 2$, $p = 0.02$). The increase in girth was less than half for fish with five hooks, monofilament, and a swivel than those that received one or five hooks (Figure 5). Likewise, hematocrit levels were not different for shape ($F = 0.47$, $df = 1$, $p = 0.49$), or set ($F = 0.31$, $df = 1$, $p = 0.59$), but an effect was apparent for hematocrit level due to the number of hooks ($F = 3.27$, $df = 2$, $p = 0.04$). Hematocrit levels in fish with five hooks, monofilament, and a swivel decreased over 7% from the initial measurements, whereas hematocrit levels in fish with one or five hooks have increased slightly (Figure 6). We did not detect differences in any first order interactions between shape, set, and number of hooks. Similarly, accounting for all combinations of shape, set and number of hooks (second order interactions), no effects were apparent on the growth or hematocrit parameters measured. Fork length was not different ($F = 0.85$, $df = 12$, $p = 0.6$; Figure 7), vent length was not different ($F = 1.39$, $df = 12$, $p = 0.18$; Figure 8), girth was not different ($F = 1.31$, $df = 12$, $p = 0.23$; Figure 9), and hematocrit levels were not different ($F = 1.06$, $df = 12$, $p = 0.41$; Figure 10). Cortisol levels were highly variable among individual sturgeon and no differences were apparent between the groups tested (Figure 11).

According to X-rays immediately following hook insertion, hooks were located in the fore-stomach as intended (Figure 12). In all following X-ray events, the hooks were located in the gizzard (Figure 13). A swivel was identified in the intestine, posterior to the pyloric sphincter, of only three fish (Figure 14). One fish had passed a swivel through the vent on 15 December 2011, and was attached with monofilament to the hook that resided in the gizzard.

DISCUSSION

The presence of five hooks with monofilament and a swivel attached inside white sturgeon digestive systems appears to have an effect on the growth and health of the study fish

with the most dramatic hook treatment (five hooks with monofilament and a swivel attached), whereas the presence of hooks at the other levels appears to have no effect on hatchery sturgeon. The decrease in hematocrit levels in fish with five hooks, monofilament, and a swivel (Figure 6) suggests that the tackle may be having deleterious effects on the fish. Low hematocrit levels indicate the possibility of internal bleeding or other internal injury (Hoar et al. 1992). Ingested hooks could pierce the gut wall at any point along the alimentary canal and possibly lacerate other internal organs (Borucinska et al. 2002). Furthermore, the presence of monofilament and a swivel may increase the likelihood of having hooks pierce the stomach wall. The peristaltic action of passing the swivel could orient the hook so the gap faces posteriorly and any pressure applied to the swivel or line could cause the hook to penetrate surrounding tissue. According to our X-rays, one fish passed a swivel through the intestine and out of the body, yet the swivel remained attached to the hook. The X-rays provide evidence this is happening; however, we plan to dissect several study fish later in the experiment to verify tissue damage.

Although the girth for all study fish increased, the girth of study fish with five hooks, monofilament, and a swivel increased only half as much over the same time interval (Figure 5). The slower increase in girth may be evidence that either the fish are not eating as much or the tackle is interfering with normal digestion. In 2012, 34% of sturgeon mortalities on the trash rack at Swan Falls Dam (Snake River, Idaho) contained large amounts of fishing tackle, and oftentimes hooks and line appeared to block the pyloric sphincter, reducing or eliminating the passage of food into the intestines (P. Bates, Idaho Power Company, personal communication).

After five months with hooks in their digestive systems, according to the X-rays, the hooks remain in the gizzards of all study fish (Figure 6). We suspect the hooks are too large to pass through the pyloric sphincter. We expect hooks to remain in the gizzard until sufficiently corroded or weakened to a point the muscular, grinding action of the gizzard can break the hooks into smaller pieces allowing passage into the intestine. We are unsure what the final disposition of the hooks will be. Broadhurst et al. (2007) reported a small number of yellow bream *Acanthopagrus australis* passed hooks through the anus in 12 d or less. Four other yellow bream contained hooks after 105 d; all were found in the stomach wall and had lost only 4.5% of their weight to corrosion. Likewise, Borucinska et al. (2002) reported 6 of 211 blue sharks *Prionace glauca* retained hooks that were sampled after being caught and released by recreational fishermen. Of those, three were embedded in the esophagus and only lightly corroded; three were in the anterior stomach and were heavily corroded. Two hooks in the stomach had pierced the gut wall and lacerated the liver. However, the hooks in these studies were not ingested freely from the environment (i.e., ghost gear), but were introduced into the fish through angling and fish were deep-hooked. Consequently, most hooks were lodged in esophageal or stomach tissue and not available for chemical digestion in the digestive system. We could find no studies where hooks were ingested or implanted into the digestive system of fish to study the mechanisms fish employ to pass hooks, or the effects ingested hooks would have on fish health.

Overall, regardless of differences in growth and stress parameters reported on at present, these results are preliminary and the final outcomes may be entirely different. Also, comparing results from hatchery sturgeon may not be applicable to fish in the wild because of diet and the vagaries of nature. We are currently X-raying white sturgeon captured from the wild to identify the movement and elimination of fishing tackle through the digestive tract. X-rays will be compared as wild fish are recaptured over time and changes in the amount and types of tackle evaluated to determine a relative time for passage. The outcomes of these studies should

provide information that will allow improved estimation of mortality due to the ingestion of fishing tackle and help ascertain whether associated mortality is having population level effects.

RECOMMENDATIONS

1. Finish the current study to determine the disposition of implanted hooks and the time required for white sturgeon to break down and eliminate hooks from the digestive system.
2. Compare hatchery white sturgeon results with hook passage of wild white sturgeon by X-raying a minimum of ten sturgeon containing metal after a one-year period.

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Table 1. Nomenclature of the 13 different hook configurations implanted into white sturgeon stomachs, including the number of hooks, set (inline/offset), hook shape (circle/J), the presence of monofilament and a swivel, and number of fish.

Treatment	# Hooks	Set	Shape	Monofilament	# Fish
1IC	1	Inline	Circle	none	9
1IJ	1	Inline	J	none	9
1OC	1	Offset	Circle	none	9
1OJ	1	Offset	J	none	9
5IC	5	Inline	Circle	none	9
5IJ	5	Inline	J	none	9
5OC	5	Offset	Circle	none	9
5OJ	5	Offset	J	none	9
5MIC	5	Inline	Circle	Mono	9
5MIJ	5	Inline	J	Mono	9
5MOC	5	Offset	Circle	Mono	9
5MOJ	5	Offset	J	Mono	9
CONTROL	none	none	none	none	10

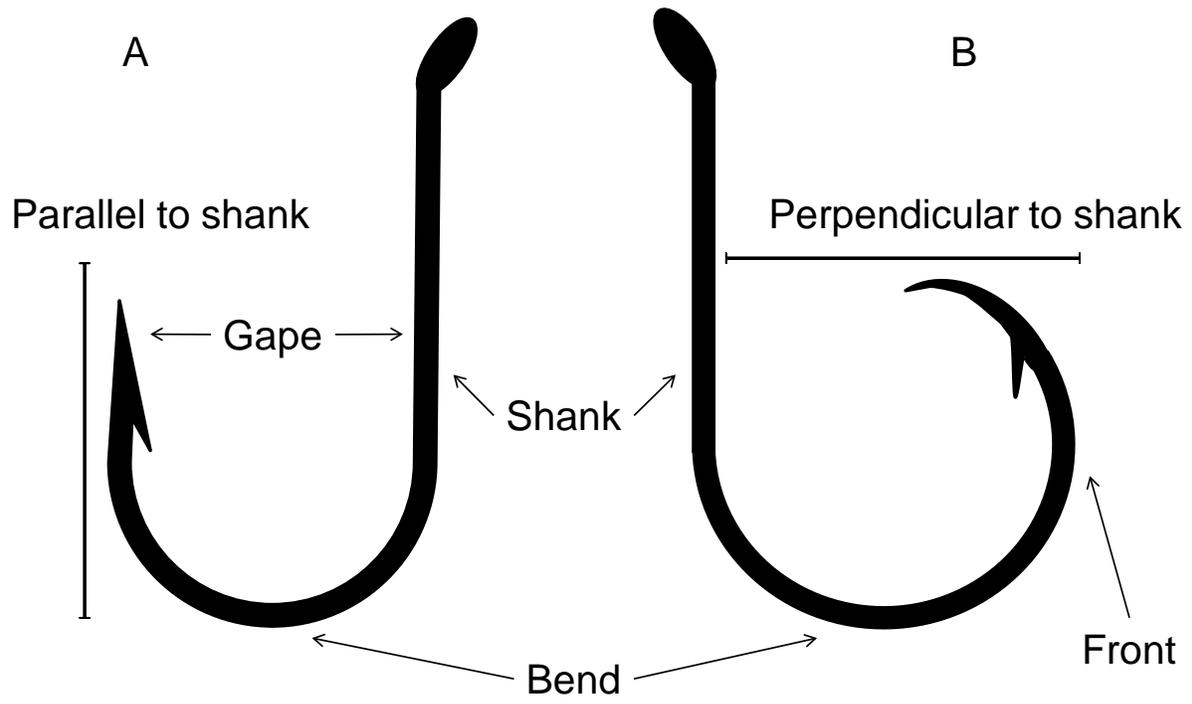


Figure 1. Example of a J hook (A) and a Circle hook (B) with the different parts labeled.

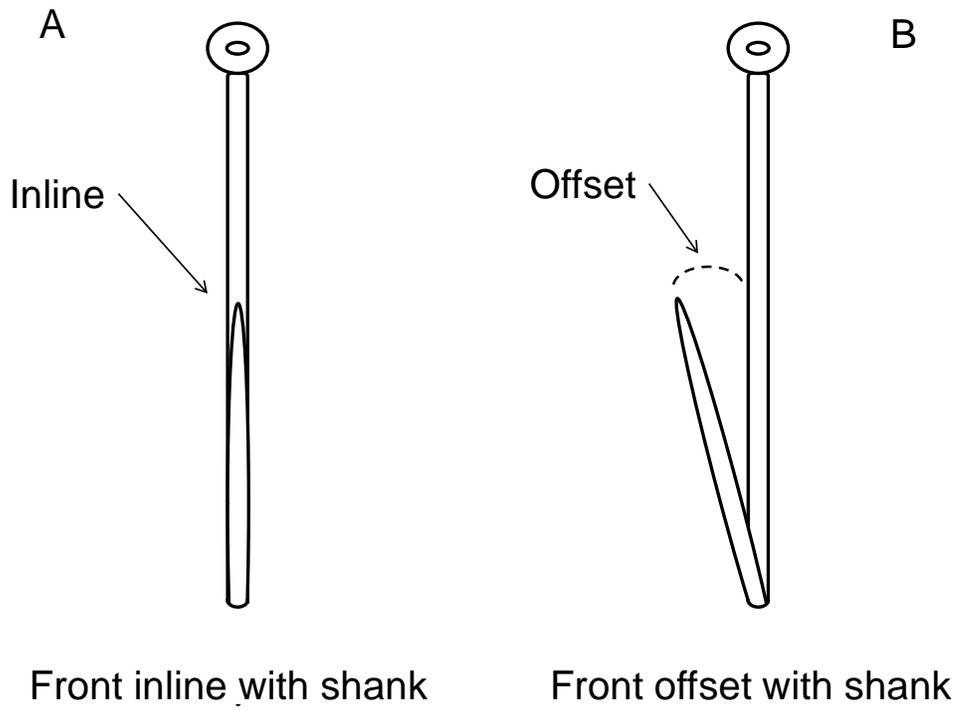


Figure 2. Example of an inline hook (A) and an offset hook (B).

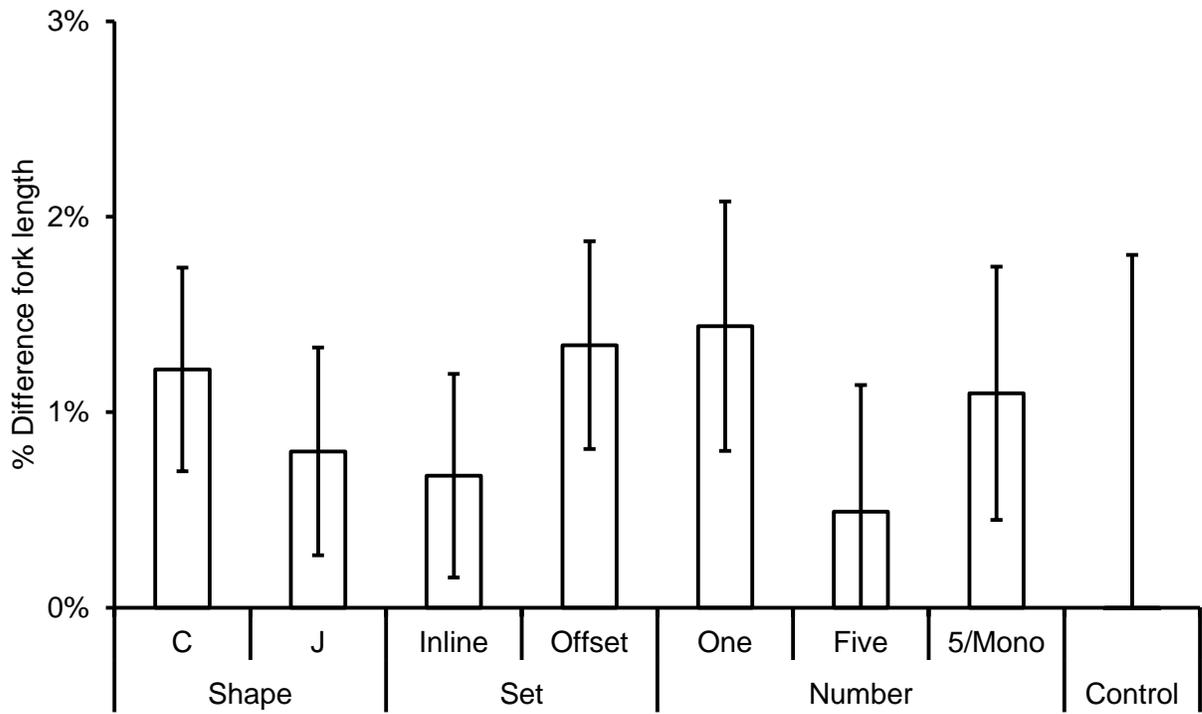


Figure 3. The mean percent difference in white sturgeon fork length for the three hook variables (shape, set, number) between the initial (15 September 2011) and most recent measurements (9 February 2012). Error bars are 90% confidence intervals.

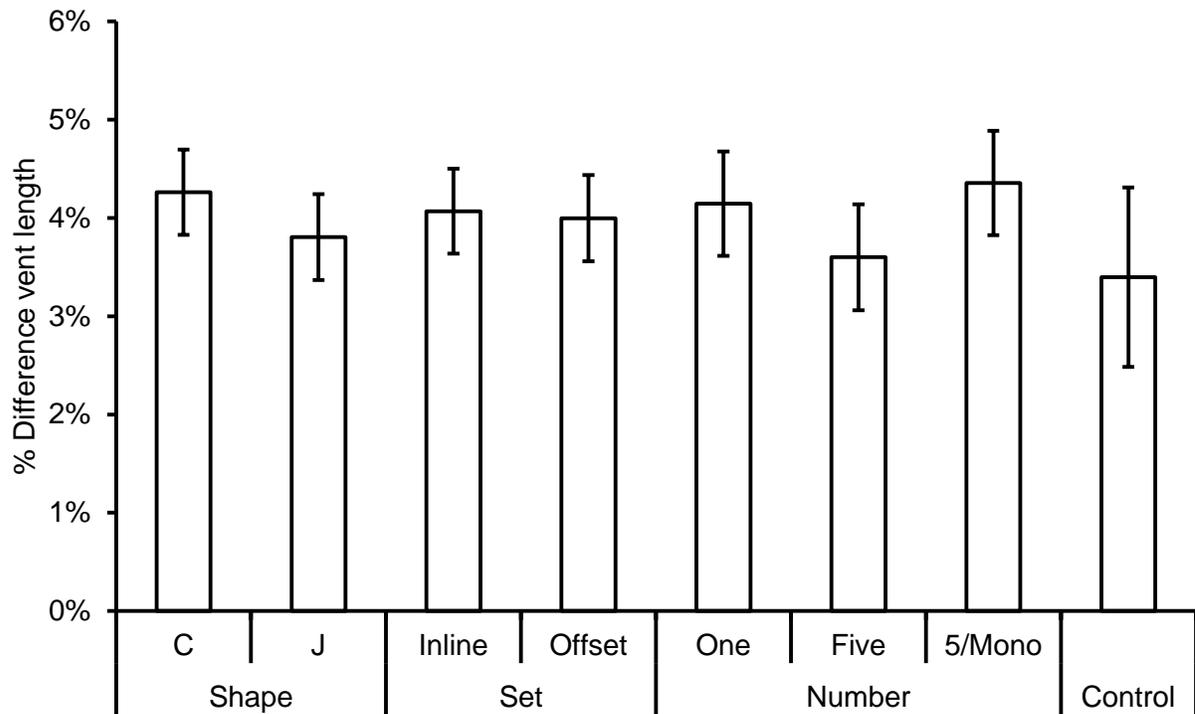


Figure 4. The mean percent difference in white sturgeon vent length for the three hook variables (shape, set, number) between the initial (15 September 2011) and most recent measurements (9 February 2012). Error bars are 90% confidence intervals.

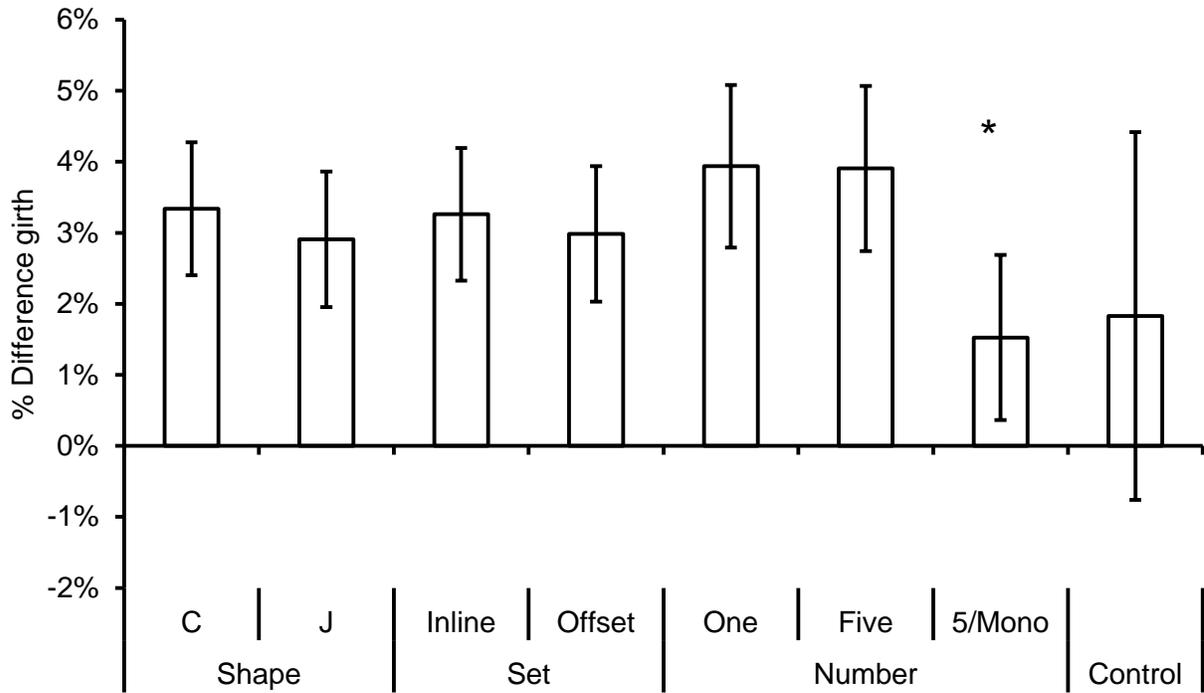


Figure 5. The mean percent difference in white sturgeon girth length for the three hook variables (shape, set, number) between the initial (15 September 2011) and most recent measurements (9 February 2012). Error bars are 90% confidence intervals. Variables with a * are significantly different.

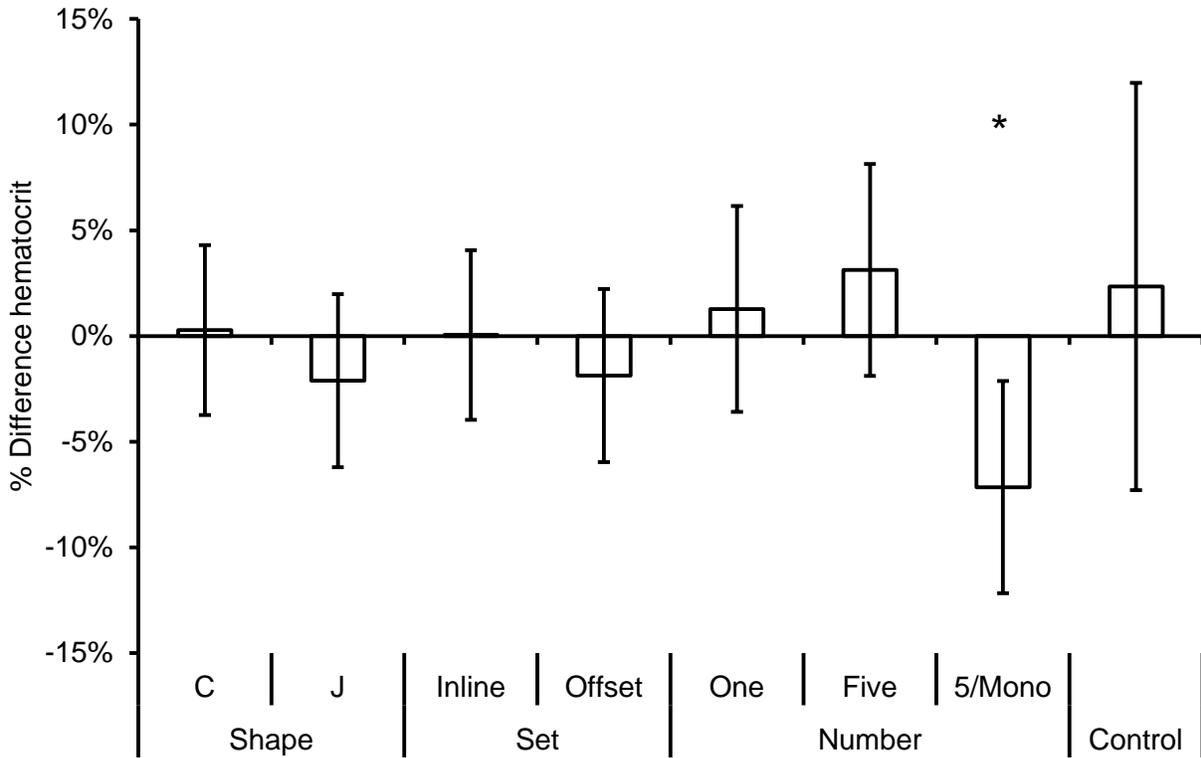


Figure 6. The mean percent difference in white sturgeon hematocrit level for the three hook variables (shape, set, number) between the initial (15 September 2011) and most recent measurements (9 February 2012). Error bars are 90% confidence intervals. Variables with a * are significantly different.

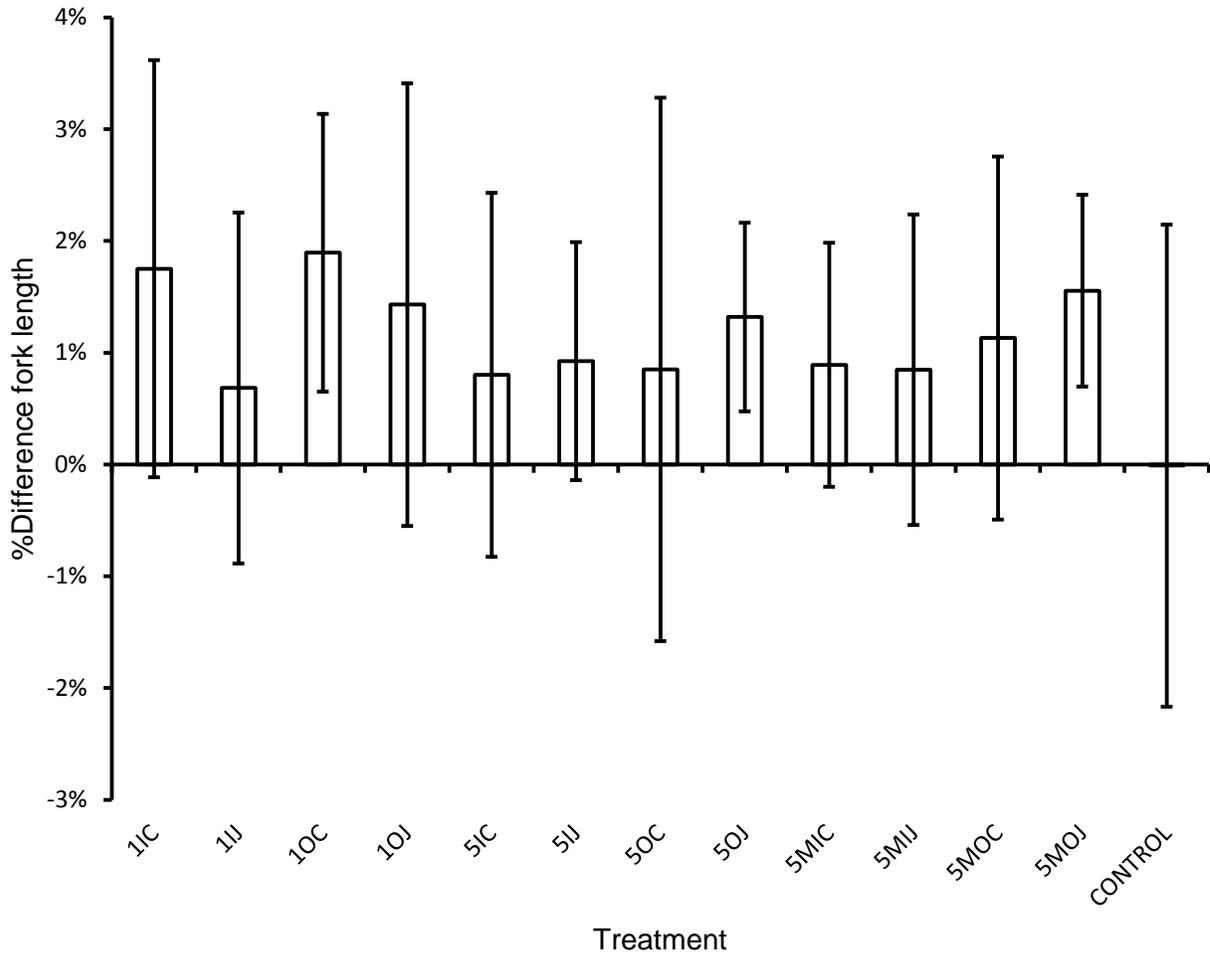


Figure 7. The mean percent difference in white sturgeon fork length for the different combinations of hook variables between the initial (15 September 2011) and most recent measurements (9 February 2012). Error bars are 90% confidence intervals.

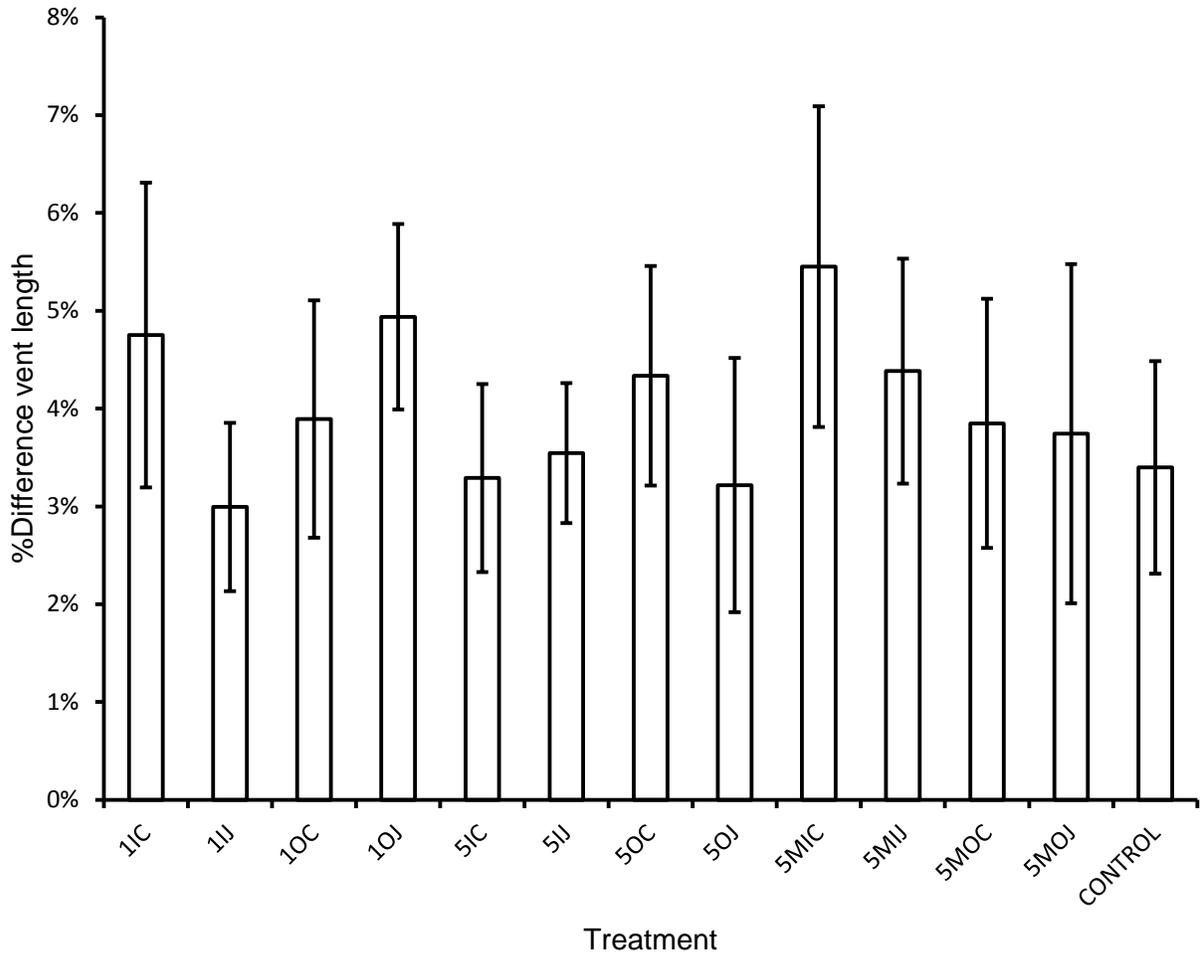


Figure 8. The mean percent difference in white sturgeon vent length for the different combinations of hook variables between the initial (15 September 2011) and most recent measurements (9 February 2012). Error bars are 90% confidence intervals.

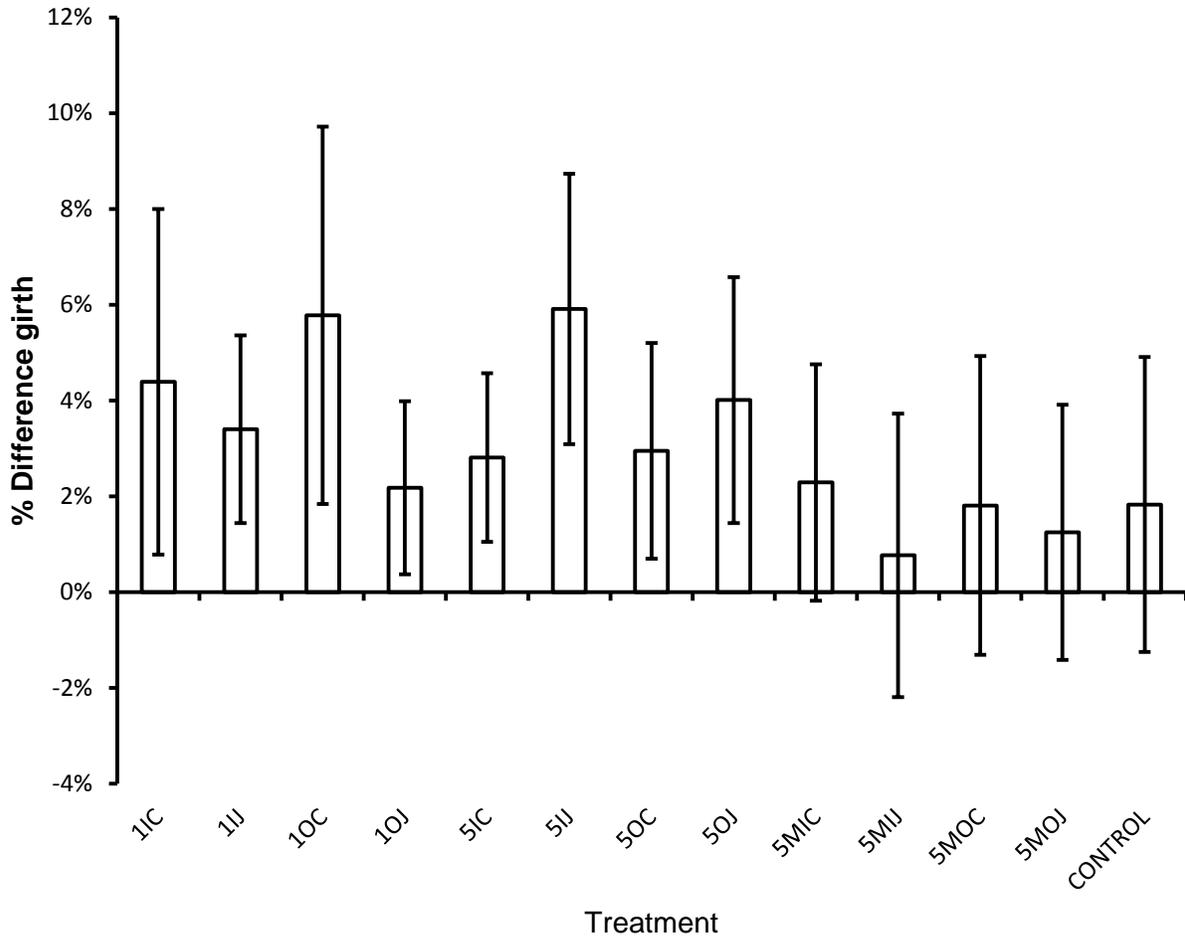


Figure 9. The mean percent difference in white sturgeon girth for the different combinations of hook variables between the initial (15 September 2011) and most recent measurements (9 February 2012). Error bars are 90% confidence intervals.

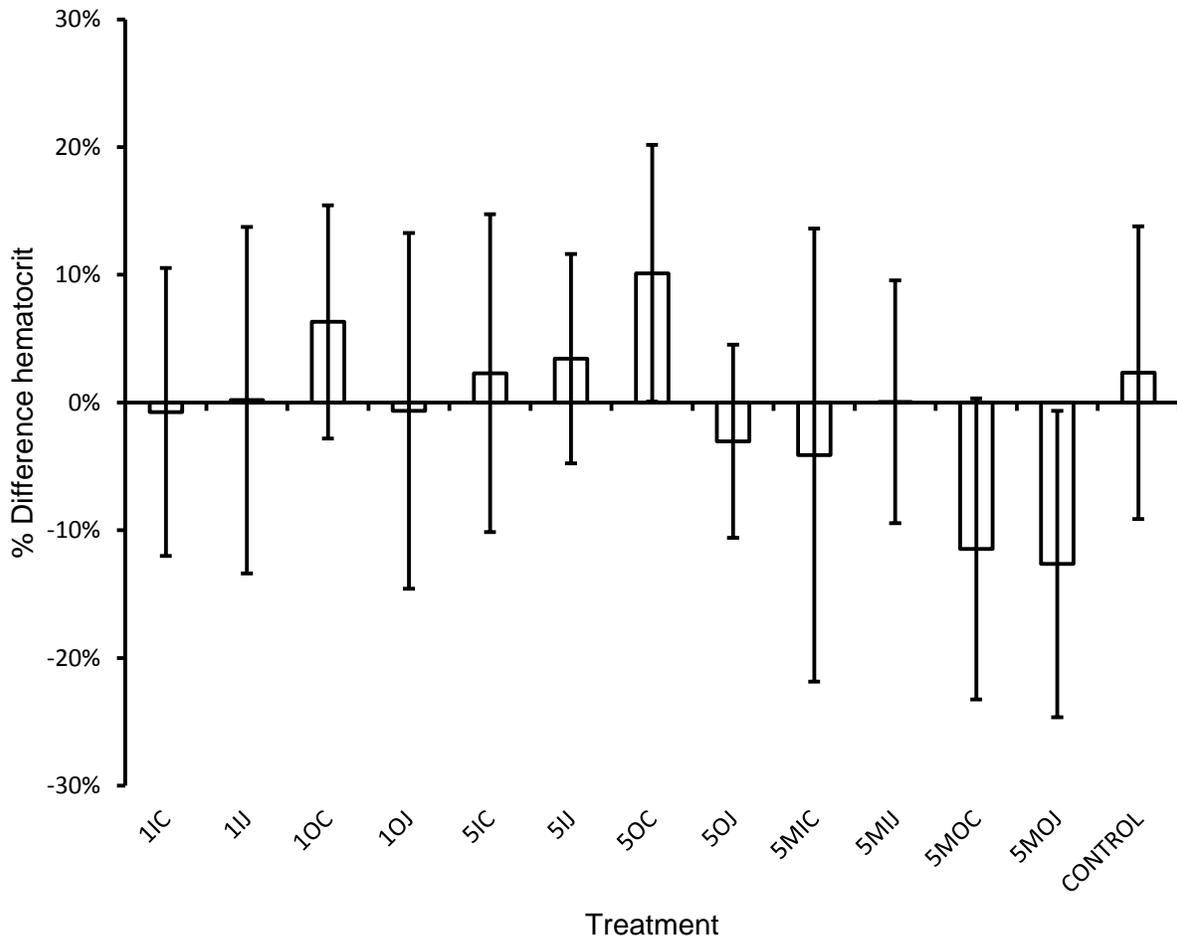


Figure 10. The mean percent difference in white sturgeon hematocrit levels for the different combinations of hook variables between the initial (15 September 2011) and most recent measurements (9 February 2012). Error bars are 90% confidence intervals.

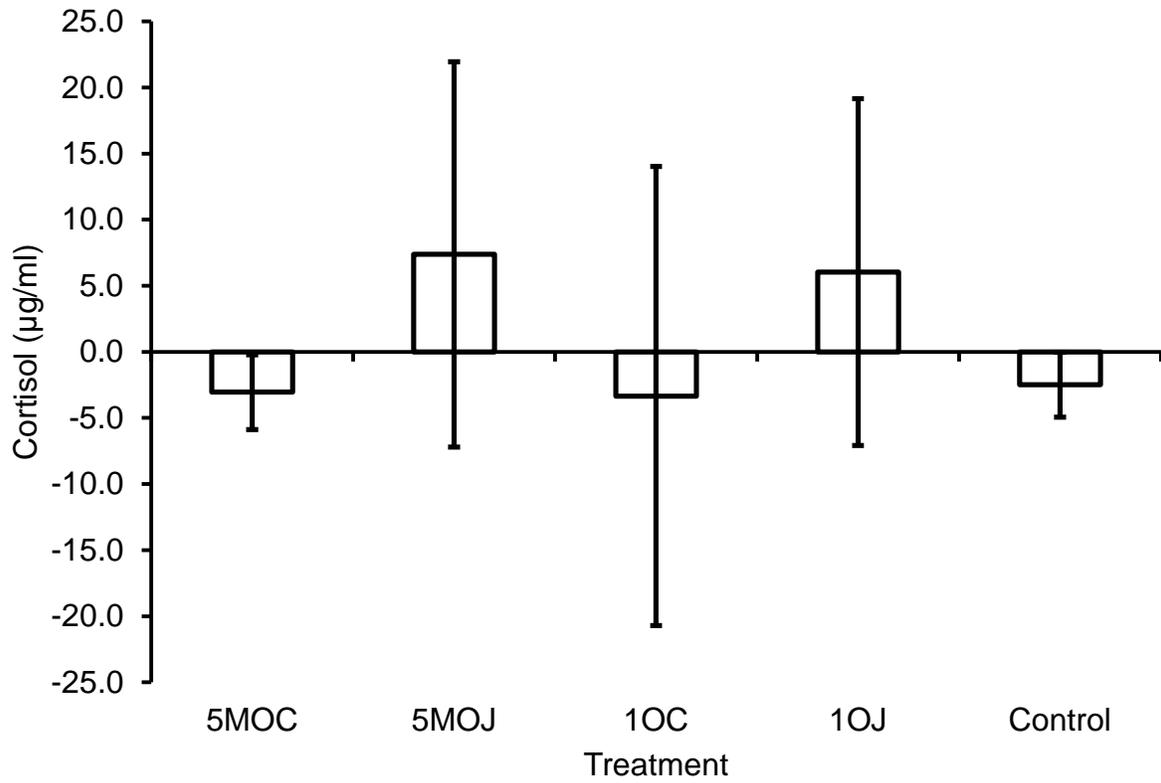


Figure 11. The mean difference in white sturgeon cortisol levels for the different combinations of hook variables between the initial measurements (15 September 2011) and one month later (10 October 2011). Error bars are 90% confidence intervals.

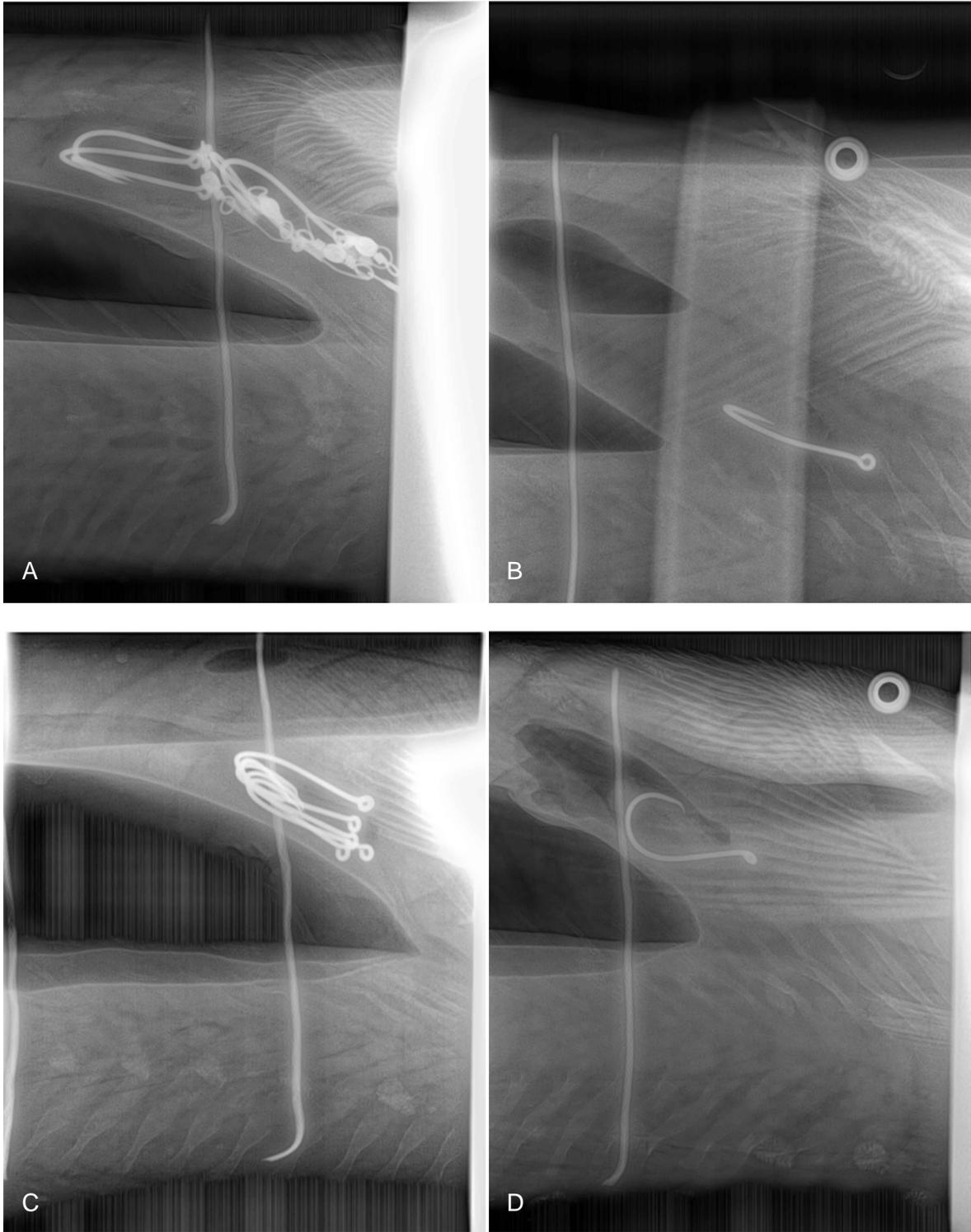


Figure 12. Example of X-rays of white sturgeon with five hooks, monofilament and a swivel (A), a single J hook (B), five J hooks (C), and a single circle hook (D) immediately after insertion on 9 September 2011. All hooks are in the alimentary canal in the fore-stomach.

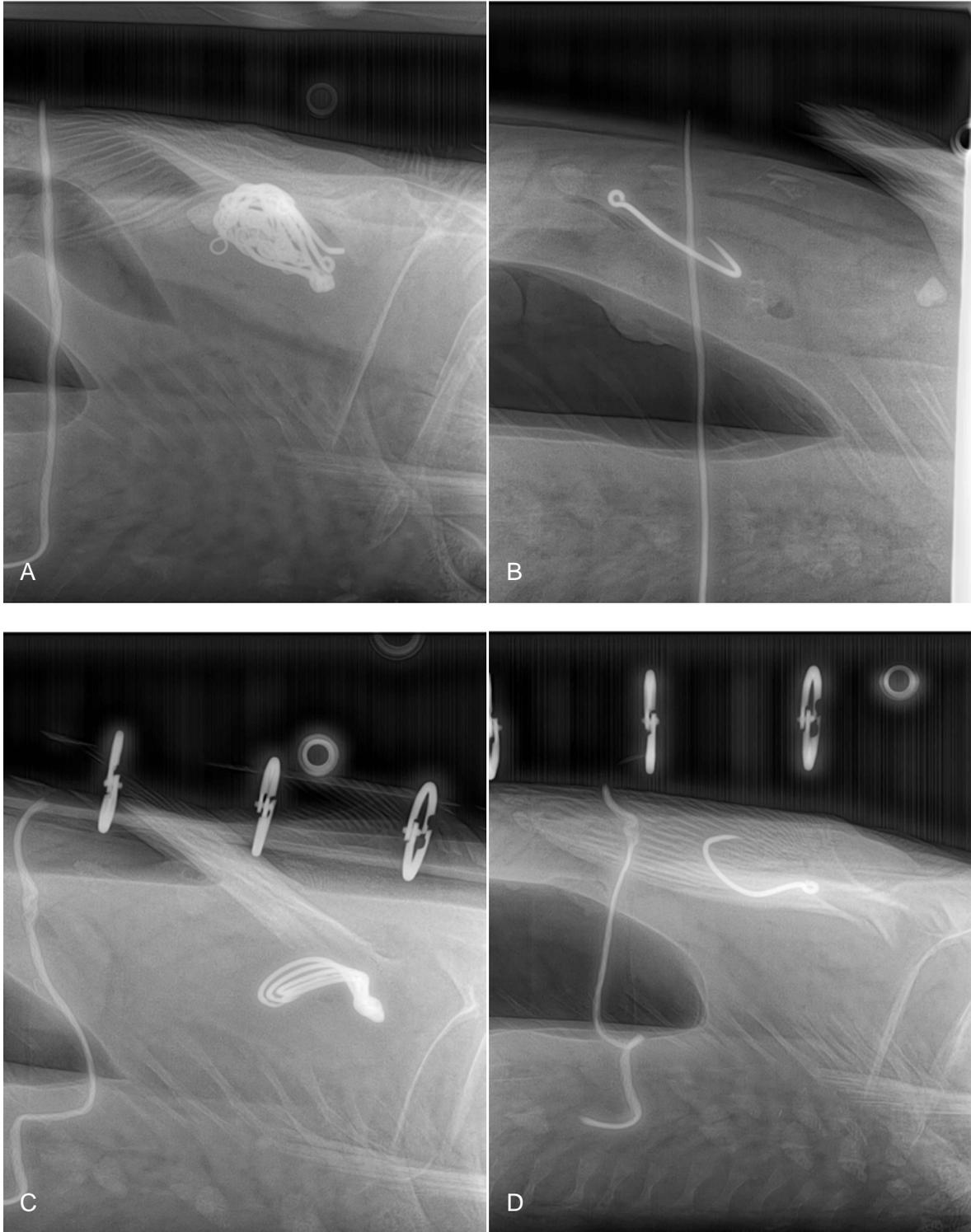


Figure 13. Example of X-rays of white sturgeon with five hooks, monofilament and a swivel (A), a single J hook (B), five J hooks (C), and a single circle hook (D) four weeks after insertion on 15 October 2011. All hooks are in the gizzard.

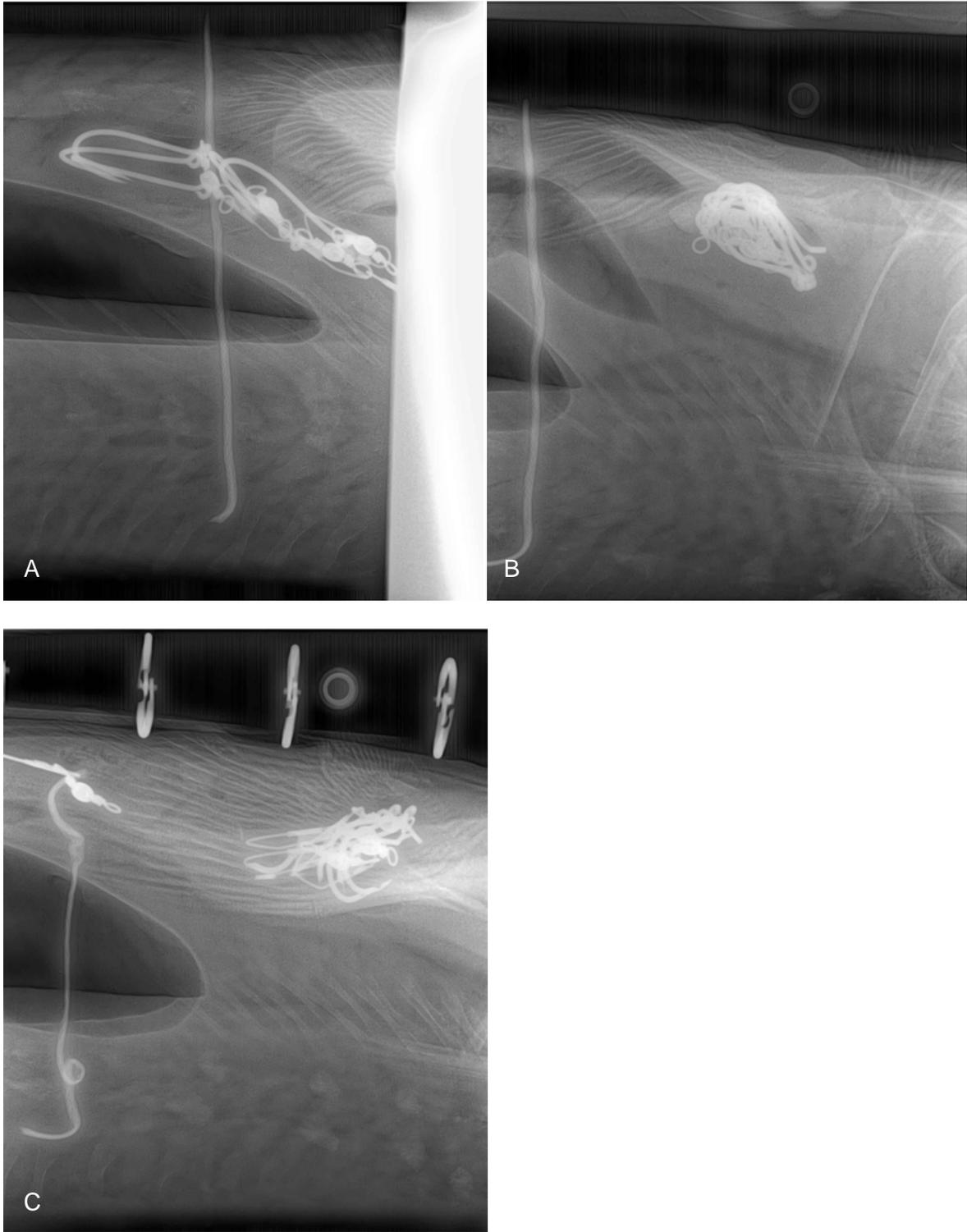


Figure 14. X-rays of fish 5MOJ #48 (5 hooks with monofilament and a swivel) immediately after hook insertion on 15 September 2011, hooks are in the fore-stomach (A), after four weeks on 15 October 2011, hooks are in the gizzard (B), and after 20 weeks on 9 February 2012, one swivel has passed through the pyloric sphincter and is in the intestines, the remaining swivels and hooks are in the gizzard (C).

**ANNUAL PERFORMANCE REPORT
SUBPROJECT 2: WARMWATER FISHERIES INVESTIGATIONS**

State of: Idaho Grant No.: F-73-R-33 Fishery Research
Project No.: 5 Title: White Sturgeon Research
Subproject #2: Hook Investigations:
Hook Corrosion
Contract Period: July 1, 2011 to June 30, 2012

ABSTRACT

Over the last decade, field reports indicate many white sturgeon *Acipenser transmontanus* have apparently ingested and retained hooks and other fishing tackle in their digestive systems. The effect of ingested fishing tackle on the health, growth, and reproduction of white sturgeon is unknown. The length of time fishing tackle persists in the digestive system is also unknown. We conducted a lab study to estimate the length of time sturgeon-sized hooks could persist in the digestive system of white sturgeon using a simple, buffered acid solution to simulate stomach conditions during digestion. We determined that fishing hooks with different finishes corrode at different rates. Hooks with a bronze finish lost the most weight overall (71.6%). Hooks with silver nickel (14.2%) and black nickel (7.5%) finishes lost less weight, and hooks with a red lacquer finish lost only 3.7% of their weight after 70 d. We estimated the bronze hooks would dissolve completely in approximately 90 d, silver nickel hooks in 340 d, black nickel in 490-780 d, and red lacquered hooks in 960 to over 2100 d. Presuming our simulated stomach conditions mimic actual conditions, our study suggests that hooks with different finishes could persist inside a white sturgeon for long periods of time.

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INTRODUCTION

A common piece of advice given to anglers is that if a fish is hooked deeply (i.e., the hook is lodged where removal with fingers or pliers is difficult or impossible) the line should be cut close to the body and the fish released. Many studies suggest that compared to forcefully removing the hook when a fish is hooked deeply, fish survive better when the line is cut and the fish released with the hook remaining embedded (Tsuboi et al. 2006; Fobert et al. 2009). The assumption is that hooks will cause less tissue damage by not removing them and the hook will quickly deteriorate or pass out of the body, yet few studies report the length of time required for hooks to corrode (see Kitano et al. 1990; Edappazham et al. 2010, McGrath et al. 2011). The same is true of studies evaluating the physical properties of fishing hooks (Varghese et al. 1997; Edappazham et al. 2007). Furthermore, the studies on hook corrosion used a salt spray test approved by the American Society for Testing and Materials (ASTM E 352-93 2000) as a standard test. The salt spray test evaluates corrosion resistance as a measure of longevity and functionality of hooks in a marine environment, not how hooks react in a biologically digestive environment. Likewise, few studies evaluated the time hooks persist when left in bodies of fish, and those were of short duration and not the primary focus of the studies (e.g., Mason and Hunt 1967; Hulbert and Engstrom-Heg 1980; Schill 1986; Broadhurst et al. 2007; Butcher et al. 2007). Little information exists concerning the length of time hooks will persist inside a fish's body, and we could find no studies that examined how long hooks are present in the digestive system of fishes when hooks are accidentally or eaten voluntarily.

Throughout human history, different materials have been used to catch and hook fish, from simple carved wooden or stone hooks to highly engineered metals and coatings (Edappazham 2010). Manufacturers today offer hooks with high strength and durability that resist corrosion in many conditions from freshwater to marine environments. Most hooks today are made using high carbon steel wire for strength, protected by metallic plating or lacquers to prevent the steel core from corroding. Some hooks are made from metals that are naturally resistant to corrosion including stainless steel or brass (Edappazham 2010). Manufacturers have developed hooks that are strong and resist corrosion under normal use. However, hooks with those properties will probably resist breaking down as quickly inside a fish.

In Idaho, reports of hooks and other fishing tackle ingested by white sturgeon *Acipenser transmontanus* have increased over the last decade. However, preliminary studies demonstrate that deep hooking of white sturgeon and line break-off rates of hooked fish are low (<5%; J. Dupont, IDFG, personal communication) suggesting this is not the mechanism for ingesting tackle. The likely cause is that white sturgeon eat fishing tackle left in rivers after terminal tackle becomes snagged on the river bottom and anglers break their line, losing the gear. Gear lost includes hooks, sinkers, swivels, jigs, and lures. Idaho fishing regulations require that anglers use a sliding leader/weight combination when fishing for white sturgeon (IDFG 2012). The purpose of the regulation is to prevent the sinker from remaining attached to the hook if the line is broken. Nevertheless, the bait oftentimes remains on the hook and can subsequently be found and eaten by white sturgeon. Approximately 55% of the white sturgeon sampled in the reach of the Snake River below C J Strike Reservoir have metal of some type in their bodies (K. Lepla, Idaho Power Company, personal communication), and 35% of the white sturgeon sampled in the Snake River below Hells Canyon Dam contain fishing gear (J. Dupont, IDFG, personal communication). The effect of ingested fishing tackle on white sturgeon health, growth, and reproduction is unknown, as is the length of time fishing tackle persists in the digestion systems of white sturgeon.

Because of the difficulty of using live sturgeon, we conducted a lab study to estimate the length of time for hooks to corrode and deteriorate using a simple, buffered acid solution to simulate stomach conditions during digestion. During digestion in a stomach, hydrochloric acid (HCl) is secreted along with enzymes to hydrolyze food for absorption (Bond 1979). After food enters the stomach, the pH decreases (becomes acidic) as HCl is secreted, then returns to a neutral state (approximate pH 7) after the food passes into the intestines (Bond 1979; Moyle and Cech 1988). The pH in a sturgeon stomach can range between 1-4 (Bond 1979; Moyle and Cech 1988), and can vary considerably depending on the food consumed. We created an HCl solution buffered with potassium chloride (KCl) at pH 2 to simulate stomach conditions. Our objective was to measure the time necessary for hooks with different finishes to dissolve in simulated stomach conditions and estimate the time required for hooks to corrode or break up to a point where a fish could possibly pass the hook material through the digestive tract.

OBJECTIVES

1. To determine the time required for fishing hooks to dissolve in simulated stomach conditions of a fish.

METHODS

We selected hooks to conduct our experiment in sizes and finishes commonly used for white sturgeon angling in Idaho, and that were most widely available in local stores. We chose Gamakatsu Octopus hooks in size 7/0 (model # 02149) finished with black nickel, silver nickel, and red lacquer, and Mustad 4/0 hooks (model # 92671) with a bronze finish (Figure 1). We prepared 20 total hooks of each finish, divided into two treatments. For the first treatment, the finish on 10 hooks was left intact (whole), and for the second treatment, we abraded (scratched) a 10 mm section along the bottom of the shank. The finish was compromised by twice dragging the hook across a file. We scratched the hooks to simulate the abrasive action of rocks contacting hooks on the stream bottom that could potentially hasten the dissolving of a hook by removing the protective barrier.

We prepared a solution of HCl buffered with KCl to simulate the conditions inside a stomach during digestion. The solution was buffered to keep the pH consistent throughout the experiment. We began by dissolving 149.1 g KCl in 1000 ml of deionized water to make a 2 M KCl solution. We then mixed 324 ml of 2 M HCl and deionized water to a volume of 3000 ml. Finally, we combined the 1000 ml KCl solution with 3000 ml of HCl solution to achieve a 4000 ml, 2 M HCl/KCl stock solution. Before use, we mixed 275 ml of the stock solution with 750 ml of deionized water (1:3 ratio) to achieve a 0.5 M HCl/KCl solution with a pH 2. We confirmed the pH with litmus strips to ensure the correct pH was achieved. Individual hooks were placed in 100 ml glass beakers and covered with 50-60 ml of the buffered acid solution. Beakers were sealed with Parafilm® to prevent evaporation and protect against spills.

Hooks were weighed periodically to quantify the amount of metal lost to the reaction in the acid solution. Hooks were initially weighed before placing in the acid solution then were removed weekly, rinsed, dried, and weighed using a jewelers scale (± 0.002 mg). We followed a strict protocol during weighing to prevent spills and ensure proper drying of the hooks. Using four 1 L flasks, we filled one with a solution of tap water and approximately 250 g of baking soda. The second was filled with tap water. The third was filled with deionized water, and the fourth with raw baking soda for neutralizing used solution and emergency spills. We removed

the hooks from the acid solution with non-reactive forceps and dipped the hook into the first beaker with the baking soda and water solution for up to 30 s or until the visible reaction ceased. The hook was then dipped into the plain tap water, and finally in the deionized water. After rinsing, the hooks were placed on absorbent paper towels to air dry thoroughly. After several minutes, the dry hooks were weighed and placed back into their original acid solution beakers. The pH of the acid solution in each beaker was checked with litmus paper and replaced if the pH was above 3. Overall, replacing the acid solution was required approximately every three weeks. We measured the corrosion of the hooks by dividing the weekly weight of a hook by the previous weight and subtracting from one to calculate the percent of weight lost during weekly intervals. We also calculated the total amount of weight lost as a percent by dividing the final weight by the initial weight and subtracting from one. We analyzed the effect of finish and treatment (whole and scratched) on the total percent weight lost over the entire period with analysis of variance ($\alpha = 0.05$) and Tukey pairwise comparisons to determine where differences exist. The weekly intervals were analyzed with linear regression to forecast the time required for the hooks to disappear entirely. We present results obtained to date, although the experiment is ongoing.

RESULTS

Fishing hooks with different finishes corroded at different rates. After 10 weeks in the acid solution, the effect of finish and treatment was significant ($F = 13.24$, $p < 0.01$). The effect of finish was highly significant ($F = 1741.39$, $p < 0.001$) and was responsible for 98.5% of the variation in the model. The effect of treatment, although significant, only explained $< 0.01\%$ of the variation in the model. Tukey comparisons suggested that hooks with each finish were significantly different from each other (Figure 15). Hooks with the bronze finish lost the most weight overall (71.6%), hooks with the silver nickel finish (14.2%) and black nickel (7.5%) lost less weight, and hooks with the red lacquer finish lost 3.7% of their weight in 10 weeks (Figure 15). Regressing the weekly interval for lost weight, provided the weekly loss in weight remains consistent, the bronze hooks should disappear completely in approximately 90 d, whereas the silver nickel hooks should disappear in approximately 340 d. Hooks with the black nickel finish should last between 490-780 d. We estimate the red lacquer finished hooks will last from 960 to over 2100 d (Table 2).

DISCUSSION

The advice given to anglers that hooks will corrode away quickly if left inside a fish may be incorrect, at least in the case of sturgeon-size hooks. Depending on the hook finish, we estimate it would take between three months (bronze finish) to almost six years (red finish) for a hook of the size we tested to completely dissolve. To some, 90 d is relatively fast for a hook to disappear, but clearly almost six years is a long time. Broadhurst et al. (2007) reported that, at the completion of their study (105 d), hooks inside yellow bream retained over 95% of their original weight.

We realize our lab experiment does not account for other factors that could affect the length of time a hook could persist in the digestive system of a fish. Factors such as abrasion of the hook from other tackle (swivels or sinkers), from other hard food items (crayfish or clams) probably accelerate the breakdown of hook material. We have plans to evaluate the breakdown of other terminal tackle to include swivels, sinkers, and monofilament in simulated stomach conditions. Regardless, a hook ingested by a fish would not likely dissolve completely, but

would break into pieces after the material weakened sufficiently from digestion; subsequently, the pieces would be able to pass through the intestine and out of the body. However, we designed the study to be on the severe end of digestive environments by keeping a relatively constant pH of 2 for 24 h/d at ambient room temperature (18-21°C). When a fish ingests food, the pH inside the stomach becomes acidic only when food is present, probably only several hours/d, and water temperatures are oftentimes cooler depending on environmental conditions, which would slow digestion rates. Increased temperatures accelerate the rates that chemical reactions occur (Pauling 1970). Therefore, our estimates for the length of time a hook would take to dissolve inside a fish stomach are likely underestimated. However, hooks are probably not required to completely dissolve inside the digestive tract because, in the case of white sturgeon, the peristaltic action of the gizzard likely breaks the hook apart after the metal is weakened, allowing passage of the smaller pieces. Further research should evaluate the tensile or compression strength required to break hooks after exposure to stomach conditions.

In summary, our results suggest that hooks commonly used for sturgeon fishing may require up to a year or more to dissolve adequately to pass through the digestive system of a white sturgeon (also see previous chapter). The amount of time for hooks to digest increases the likelihood that stress or physical injury may lead to increased mortality in populations of white sturgeon or other fish species that ingest such material.

RECOMMENDATIONS

1. Finish the current study to determine the length of time for hooks to dissolve in simulated stomach conditions and whether rates increase, decrease, or remain constant as hooks dissolve over time.
2. Introduce other fishing gear (i.e., swivels, sinkers, smaller hooks, monofilament, etc.) into the simulated stomach solution to evaluate the time required for those materials to dissolve.
3. Evaluate the tensile strength of hooks at regular intervals during submersion in the simulated stomach conditions to approximate the time required for hooks to break apart inside the digestive system of a white sturgeon.

ACKNOWLEDGEMENTS

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Table 2. The estimated number of days hooks with different finishes and treatments will take to dissolve completely in the simulated stomach solution and the R² value for the regression line used to make the estimates. Hooks were in the solution for 70 d.

Hook Finish	Treatment	R²	# of days
Bronze	Scratched	0.96	73
	Whole	0.96	100
Silver Nickel	Scratched	0.98	340
	Whole	0.94	341
Black Nickel	Scratched	0.95	490
	Whole	0.96	774
Red Lacquer	Scratched	0.95	961
	Whole	0.95	2115

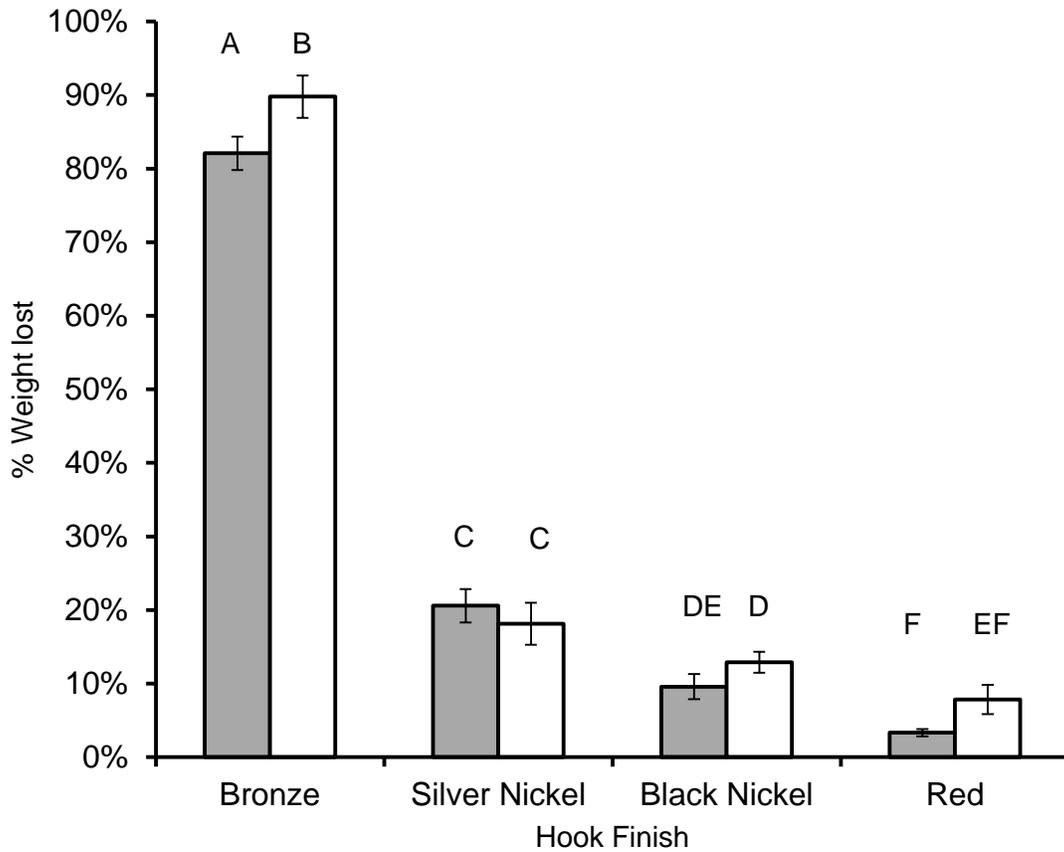


Figure 15. The percent weight lost of whole (gray) and scratched (white) hooks with four finishes after 70 d in the simulated stomach solution. Bars that do not share a letter are significantly different. Error bars are 95% confidence intervals.

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