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ARTICLE

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Influence of four hook types across four hook removal tools, including bare hands, on the effectiveness of hook removal and reflex impairment of Bluegill (*Lepomis macrochirus*) captured from a lake in Eastern Ontario

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Abstract

Hook removal devices have been developed to enable rapid release of angled fish, yet little research has evaluated their effectiveness and potential for injury among hook types. We compared the performance of hook removal tools and bare hands with four hook types on freshwater *Lepomid* sunfish. Dehooking performance was assessed using hook removal time, unhooking difficulty, degree of tissue damage at the hooking location, and immediate reflex impairment. Unhooking difficulty was positively related to hooking depth. Unhooking difficulty was lowest for hemostats and the mechanical dehooking device; however, the mechanical dehooking device caused the largest tearing of mouth tissue. Unhooking difficulty was the main driver for hook removal time, tissue tear length, and overall reflex impairment. Hooks that were harder to remove caused higher reflex impairment. Hook type had little influence on the effectiveness of hook removal tools, although circle hooks were more difficult to remove and caused greater injury when using tools. Although use of hook removal tools can be beneficial for fish that are released, more research is needed on more species targeted by recreational anglers, and more hook removal tools. We suggest that hemostats should be used to remove hooks from fish to reduce unhooking difficulty, tissue tears, long air exposure, and thereby to increase the welfare of the fish.

KEYWORDS
catch-and-release, dehooking, hooks, injury, recreational fishing, tools

1 | INTRODUCTION

Catch-and-release (C&R) recreational fishing is a popular activity with fish released because of angler conservation ethic or to comply with regulations (Arlinghaus et al., 2007). Understanding how anglers and their gear interact with fish has become increasingly important in developing effective management strategies that consider fish welfare and population-level consequences of mortality (reviewed in Arlinghaus et al., 2007; Bartholomew & Bohnsack, 2005; Muoneke & Childress, 1994). Risk of injury, degree of physiological stress, and post-release mortality in C&R recreational fisheries depend on complexities associated with how fish are captured and handled (reviewed in Brownscombe et al., 2017). Systematic evaluations have identified practices to reduce sub-lethal effects and minimize mortality in C&R fisheries (Brownscombe et al., 2017), which, in turn, form the basis of science-based best practices to promote animal welfare and increase overall benefits of releasing fish.

Hook removal is an essential component of a C&R angling event because the duration and difficulty to unhook fish could cause a suite of impacts, including physical injuries, long air exposure, and prolonged handling (Cook et al., 2015). For deeply hooked fish, cutting the line and leaving the hook in place may be less impactful (Cooke & Danylchuk, 2020). However, for freshwater fish species that are not deeply hooked, hook removal is the norm. Given the potential challenges to remove hooks, a wide variety of hook removal devices have been developed by the tackle industry to make the process easier, more efficient (i.e., reduce injury and air exposure duration), and potentially safer for anglers. Nonetheless, effectiveness of these products has rarely been evaluated among hook types (but see Cooke et al., 2021). The effectiveness and potential injury caused by these hook-removing devices among hook types (i.e., single point or treble hooks) and with lures that have multiple hooks on them is unknown. For example, hook removal time was influenced by hooks, lures, and species, but hook removal tools were not evaluated (Trahan et al., 2021). Removing hooks by hand can be challenging or dangerous, depending on the species of fish and anatomical hooking location. Hook removal tools were designed to increase grip strength on the hook, increase reach to grasp the hook, and increase precession of hook grasping. Challenges of using hands to remove hooks from fish range from a lack of grip on the hook, potential injury (i.e., fish with teeth), and lack of precession when grasping hooks (fish with small jaws). Although various tools are thought to "aid" with hook removal, death occurs regardless of tool type used to remove hooks from fish that are deeply hooked (i.e., in the gullet, Cooke & Danylchuk, 2020), so the line (or hook) should be cut instead of removing the hook (Fobert et al., 2009). However, when fish are not deeply hooked (i.e., hooked in the jaw), use of a simple hook removal tool, such as pliers or hemostats, can reduce hook removal time relative to bare hands (Cooke et al., 2021, 2022). Even though hook removal tools minimize handling and air exposure times, these products can cause greater injury (i.e., tissue tearing and bleeding) relative to fish for which hooks were removed by hand (Cooke et al., 2022). Barbed hooks also take longer to remove, even with the aid of a hook removal tool, compared to barbless hooks (Alós et al., 2008; Cooke et al., 2022; Schaffer & Hoffman, 2002). Furthermore, the diversity of hook styles used by anglers rivals the diversity of fish they target, so the efficacy of removal tools will vary among hook types and species.

Our objective was to determine whether hook type influenced the effectiveness, injury, and reflex impairment levels of a small, bodied freshwater fish when combined with different hook removal tools, including bare hands. Most studies of hook removal focused on either hook type or hook removal tool, rather than both hook removal tools and hook types. To test the effectiveness of hook removal tools, Bluegill (*Lepomis macrochirus*), a popular species for bait-fishing anglers in North America, were captured with four different commercially available hook types, and hook removal time, tear length (tissue tear in the mouth at the hook site), unhooking difficulty, and immediate reflex impairment levels were compared among commercially available hook removal tools (hemostats, mechanical dehooker, and Ketchum Release Tool) and bare hands.

2 | METHODS

2.1 | Fish capture

Bluegill were captured from shallow water (<3 m) during June 2–24, 2021, on Big Rideau Lake, Ontario, Canada (44°44′59.9 N, 76°13′60.0 W), when surface water temperature ranged from 24°C to 26°C. The Bluegill is a small-bodied fish species with a small mouth. Fish were caught using medium action spinning rods with 3.6 kg line from a small fishing boat, under a Scientific Collection Permit from the Ontario Ministry of Natural Resources and Forestry and an Animal Care Certificate provided by Carleton University. Angling-induced fight times were standardized to 15 s to ensure accuracy of response variables.

Following capture, fish were placed in a cooler filled with lake water for hook removal treatments. Water in the cooler was replaced every 10 min to maintain water quality. A cooler was needed to ensure overall health and for an equilibrium test. Only fish hooked in the upper jaw were used, and all other accidental catches were released immediately following capture. Different hook types are prone to different hooking locations (e.g., Cooke et al., 2003), so we sought to directly compare hook types. Although we did not record the incidence of hook locations not in the jaw, ~10% of fish were not included in the study, usually because they fell off prior to hook removal or were deep hooked in the gullet, which led us to cut the line as recommended by Fobert et al. (2009).

Four hook removal devices were tested: bare hands, hemostat, Ketchum Release Tool, and mechanical dehooking device (Figure 1). The three removal devices were chosen because they were readily available in most tackle stores and were popular with recreational anglers. Bare-hand release consisted of using the thumb and fingers to grip the shank of the hook to remove from the jaw. Bare hands, the mechanical dehooking tool, and Ketchum Tool are rather unique, while hemostats are often considered "pliers" which is a broader design type when considering hook removal tools. The hemostat (Dr. Slick Stainless Steel Hemostats, 14.0 cm, Dr. Slick, Belgrade, MT, USA) was used to grip the shank of the hook, while using wrist movements to leverage the hook until removed from the fish's mouth. The Ketchum Release Tool (Ketchum Release Tool Original, 20.3 cm, Waterworks-Lamson, Hailey, ID, USA) was operated by inserting the line into the tool, running the tool down the line until it reached the shank of the hook, and applying pressure to pop the hook loose. The mechanical dehooking device (Easy Reach Fish Hook Remover

Squeeze-Out Fish Hook Separator, 21.0cm) was used to grip the hook at the bend in the shank, initiating the devices plunger, and moving the wrist to remove the hook.

Each hook removal device was tested with four different hook types (Figure 2): circle (Eagle Claw Circle Sea, non-offset, Model L702), octopus (Mustad, Model 92553), Aberdeen (Eagle Claw Light Panfish, Model 202EL), and baitholder (Mustad, Model 92641). These hooks and the specific hook manufacturer were chosen based on their similarity across other manufacturers that produce hooks of the same style. For the purpose of this study, we chose to keep the hook types rather basic to single-pointed hooks that can be used for live bait fishing. All hooks were size 6 and baited with a 3-mm segment of dew worm, a logical hook size and dew worm segment for catching Bluegill with live bait. Treatments were assigned randomly to avoid bias. Following capture, the removal process was timed from when the hook removal device or hand was placed on the hook until the hook was removed. Fish remained in the water, and aside from the bare-hand hook removal, fish were not touched during the dehooking process to simulate a fish being released over the side of a boat. Fish were supported by water during the dehooking process. If dehooking exceeded 60s, a hand was placed on the fish and additional time was recorded to prevent unnecessary prolonged stress to the fish. Hook removal difficulty was recorded as a composite sum of scores for the force and torque required to remove the hook,

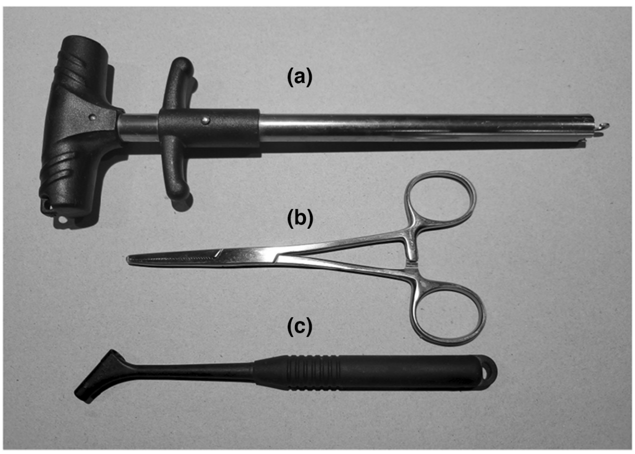


FIGURE 1 Mechanical dehooking tool (a), hemostat (b), and Ketchum release tool (c) used to remove various size 6 barbed hooks from Bluegills (*Lepomis macrochirus*) on Big Rideau Lake, Ontario, Canada during June 2–24, 2021.

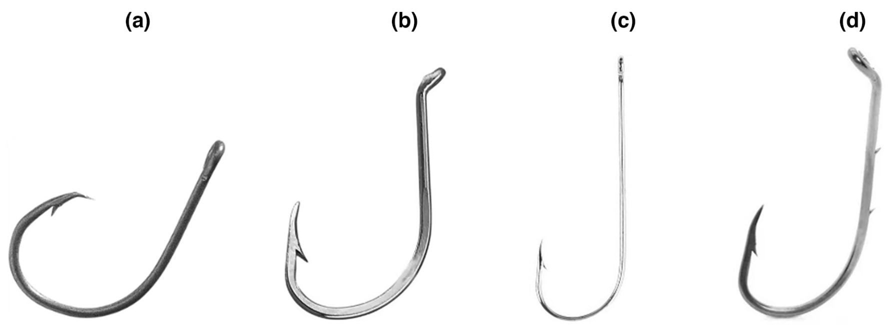
and ease of removing the hook. A score between 0 and 2 was assigned for torque, force, and ease: 0 = easily removed with little force or torque; and 2 = more difficult to remove or required more force and torque. The findings of this study must remain in the context of the hook removal tools used here and only for small single-pointed hooks on small-bodied fish. The results from this study cannot be broadly applied to all fish species, hook types, and tool types.

Following hook removal, hooking depth and tissue tear length (if present) were recorded to the nearest mm (beyond the 1-mm hook puncture), and presence of blood was assessed. Prior to release, captured fish were tested for equilibrium response, and the presence of a burst response to generate a reflex indicator score as an indication of overall health and survival ability of fish once released. An equilibrium response was tested by holding the fish upside down in the cooler and recording if the fish could right itself within 3s. Similarly, the burst response was tested by holding the tail of the fish and recording if the fish could burst away from being held. Equilibrium and burst responses were recorded as "yes or no." Finally, fish were placed in a water-filled trough to record total body length (mm) and fitted with T-bar anchor tags to ensure no fish were recaptured during the study.

2.1.1 | Data analysis

Data analyses used R (3.6.2) via R Studio (version 1.2.5033). One-way ANOVA was used to test for differences in fish length between hook and tool types, followed by Tukey HSD multiple comparisons ($p \leq 0.05$). General linear models using the *glm* function were used to assess the effect of explanatory variables on hooking depth, unhooking difficulty, time to hook removal, mouth tissue tear length, and reflex impairment score. Hooking depth was fit with hook type and fish length as explanatory variables. Unhooking difficulty was fit with the hook-type × tool-type interaction, hooking depth, and fish length as explanatory variables. Hook removal time was fit with the hook-type × tool-type interaction, unhooking difficulty, hook depth, and fish length as explanatory variables. Tear length was fit with the hook-type × tool-type interaction, unhooking difficulty, hooking depth, and fish length as explanatory variables. Reflex score was fit with the hook-type × tool-type interaction, hook removal time, unhooking difficulty, hooking depth, tissue tear length, and fish length as explanatory variables. Tukey HSD multiple comparisons were

FIGURE 2 Size 6 barbed hooks (a = Eagle Claw Circle Sea, non-offset, Model L702; b = Mustad octopus, Model 92553; c = Eagle Claw Light Panfish Aberdeen, Model 202EL; and d = Mustad baitholder, Model 92641) used to capture Bluegill (*Lepomis macrochirus*) on Big Rideau Lake, Ontario, Canada, during June 2–24, 2021.



used to test significance of differences among hook and tool types for all models ($p \leq 0.05$). Backwards elimination was used to select final models with the lowest AIC.

3 | RESULTS

Total length of 419 Bluegill averaged 137 mm (SD = 23 mm) and ranged 115–215 mm. Fish length differed among hook types (Table 1; $F_{414,3} = 11.590$, $p < 0.001$) but not among tool types ($F_{414,3} = 1.667$, $p = 0.174$). Total length of Bluegill was positively related to hooking depth ($F_{413,1} = 176.967$, $p < 0.001$). Hooking depth was influenced by the hook type ($F_{414,1} = 4.709$, $p = 0.003$); however, post-hoc results failed to identify significant difference in hooking depths among hook types.

Unhooking difficulty was related to tool type, hook type, and hooking depth (ΔAIC = 5). Unhooking difficulty significantly increased with hooking depth ($F_{410,1} = 66.152$, $p < 0.001$). Both hook type ($F_{411,1} = 7.333$, $p < 0.001$) and hook removal tool ($F_{414,1} = 27.924$, $p < 0.001$) had an influence on the unhooking difficulty. Hook removal was more difficult by hand compared to when the mechanical dehooking tool (Figure 3.1; $z_3 = -7.691$, $p < 0.001$) or hemostats ($z_3 = -5.626$, $p < 0.001$) were used. In contrast, hook removal was more difficult with the Ketchum Release Tool than the mechanical dehooking tool ($z_3 = 6.793$, $p < 0.001$) or hemostats ($z_3 = 4.730$, $p < 0.001$). Unhooking difficulty did not differ between the Ketchum Release Tool and hooks removed by hand ($z_3 = -0.943$, $p = 0.782$), or between hooks removed with hemostats and the mechanical dehooking tool ($z_3 = 2.035$, $p = 0.175$). Octopus hooks were less difficult to remove than Aberdeen hooks (Figure 3.2; $z_3 = -3.539$, $p = 0.003$) and circle hooks ($z_3 = -5.211$, $p < 0.001$). Circle hooks were more difficult to remove than baitholder hooks ($z_3 = 4.138$, $p < 0.001$) but not Aberdeen hooks ($z_3 = 1.690$, $p = 0.329$). Unhooking difficulty did not differ

TABLE 1 TukeyHSD post-hoc comparisons of differences in mean total length of Bluegill (*Lepomis macrochirus*) between different hook types used on Big Rideau Lake, Ontario, Canada during June 2–24, 2021.

Hook type comparison	Mean difference (mm)	Lower bound (95% CI)	Upper bound (95% CI)	p value
Baitholder—Aberdeen	17	9	25	*<0.001*
Circle—Aberdeen	2	−7	10	0.959
Octopus—Aberdeen	4	−5	12	0.666
Circle—Baitholder	−15	−23	−7	*<0.001*
Octopus—Baitholder	−13	−21	−5	*0.003*
Octopus—Circle	2	−6	10	0.917

Note: Significant differences in total length between hook types are indicated in italics.

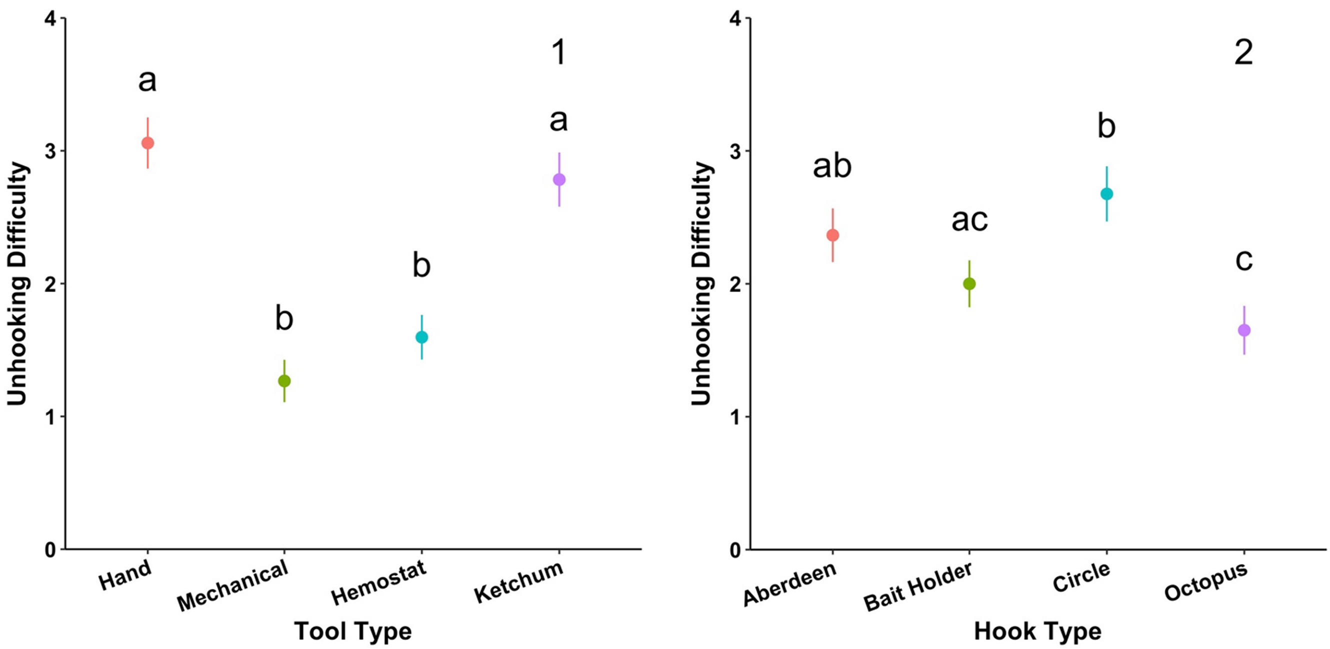


FIGURE 3 Mean (error bars = standard deviation) of unhooking difficulty four different tools or methods (1) and four different hook types (2) used to catch Bluegill (*Lepomis macrochirus*) by angling on Big Rideau Lake, Ontario, Canada, during June 2–24, 2021. Unhooking difficulty is a composite score of the force, torque, and ease to remove the hook. Dissimilar letters represent significant differences among tool or hook types.

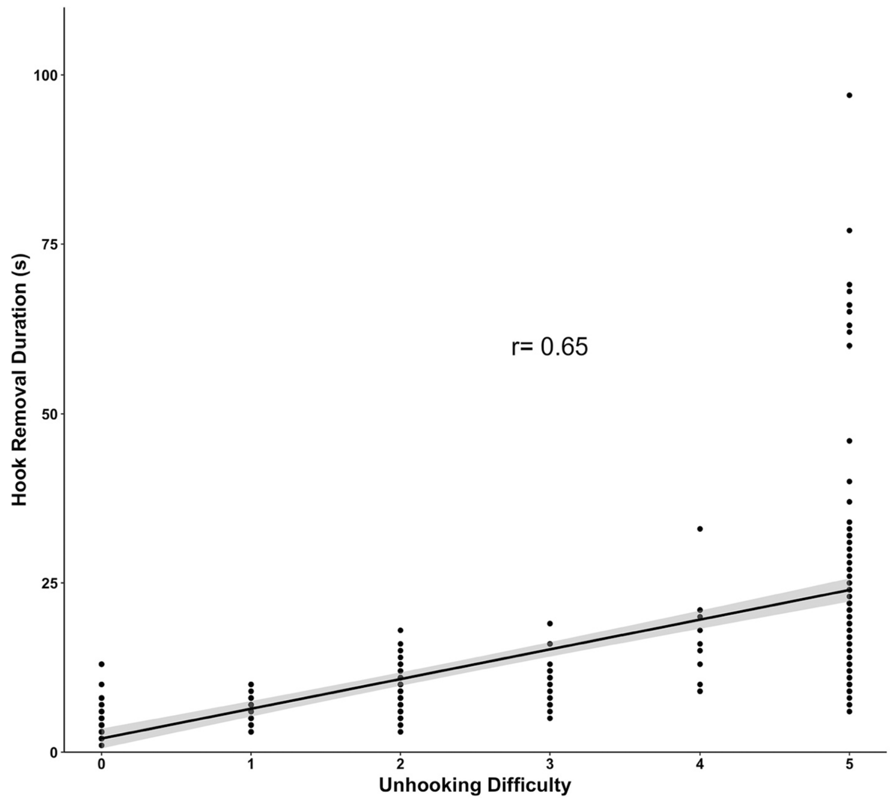


FIGURE 4 Correlation ($y = 2.016 + 4.391$, $p < 0.001$) between hook removal time and unhooking difficulty for Bluegill (*Lepomis macrochirus*) caught by angling on Big Rideau Lake, Ontario, Canada, during June 2–24, 2021. Unhooking difficulty is a composite score of the force, torque, and ease it took to remove hooks. Gray shaded area represents the 95% confidence interval.

significantly between octopus and baitholder hooks ($z_3 = -1.092$, $p = 0.694$), or between circle and Aberdeen hooks ($z_3 = 1.690$, $p = 0.329$).

Hook removal time was related to tool type, hooking depth, and unhooking difficulty (ΔAIC = 8). Hook removal time was influenced by the tool type used ($F_{414,1} = 28.092$, $p < 0.001$); however, the post-hoc test failed to identify significant difference among tool types. Hooking depth increased the time it took to remove hooks ($F_{412,1} = 3.762$, $p = 0.053$). Hook removal time increased significantly with unhooking difficulty (Figure 4; $F_{413,1} = 233.266$, $p < 0.001$).

Mouth tissue tear length was related to unhooking difficulty, tool type, and hook type (ΔAIC = 7). Hook type ($F_{411,1} = 22.165$, $p < 0.001$) and tool type ($F_{414,1} = 8.627$, $p < 0.001$) had an influence on the mouth tissue tear length. Tear length increased with unhooking difficulty ($F_{410,1} = 99.155$, $p < 0.001$). The mechanical dehooking tool resulted in larger tissue tears than hooks removed by hand (Figure 5; $z_3 = 5.972$, $p < 0.001$), hemostats ($z_3 = 5.516$, $p < 0.001$), and the Ketchum Release Tool ($z_3 = 4.065$, $p < 0.001$). Tissue tear length did not differ between hooks removed with the Ketchum Release Tool and hemostats ($z_3 = 1.273$, $p = 0.580$) or hand removal ($z_3 = 2.116$, $p = 0.148$). Tear length did not differ between hooks removed by hemostats or by hand ($z_3 = 0.770$, $p = 0.864$). Circle hooks caused larger tissue tears during hook removal than Aberdeen hooks ($z_3 = 4.584$, $p < 0.001$), baitholder ($z_3 = 5.578$, $p < 0.001$) and octopus hooks ($z_3 = 4.983$, $p < 0.001$). Tissue tear length did not differ between Aberdeen and baitholder hooks ($z_3 = -1.013$, $p = 0.742$), octopus and Aberdeen hooks ($z_3 = -0.495$, $p = 0.960$), and finally between octopus and baitholder hooks ($z_3 = 0.511$, $p = 0.957$).

Reflex impairment was related to the hook-type × tool-type interaction, unhooking difficulty, mouth tissue tear length, and hooking depth. Reflex impairment levels increased with increasing tear length ($F_{409,1} = 3.897$, $p = 0.049$) and unhooking difficulty ($F_{410,1} = 25.520$, $p < 0.001$). However, reflex impairment was not influenced by hooking depth ($F_{408,1} = 1.333$, $p = 0.249$). Hook type ($F_{414,1} = 7.964$, $p < 0.001$) and tool type ($F_{414,1} = 6.231$, $p < 0.001$) influenced the reflex impairment level of Bluegill. Furthermore, the interaction between the tool type and hook type influenced the immediate reflex impairment ($F_{399,1} = 2.404$, $p = 0.012$). Reflex impairment levels were the highest when circle hooks were removed with the Ketchum Release Tool ($t_{399,1} = 2.099$, $p = 0.036$).

4 | DISCUSSION

We found that choice of hook removal tool affected hook removal difficulty, hook removal time and increased with hook removal difficulty, which generally confirmed that hook removal time can be reduced by using hook removal devices (e.g., Cooke et al., 2022). Reducing hook removal time is important because air exposure negatively impacts fish welfare because fish are not able to obtain oxygen when removed from water (Cook et al., 2015). Air exposure duration also influences the ability of fish to obtain oxygen once returned to water due to gill lamella collapsing and adhering to one another (Ferguson & Tufts, 1992).

We found that the mechanical dehooking tool caused larger tears during unhooking than hand removal, hemostats, and the Ketchum Release Tool, which was consistent with earlier research (Cooke et al., 2022). Presumably, the mechanical dehooking tool caused

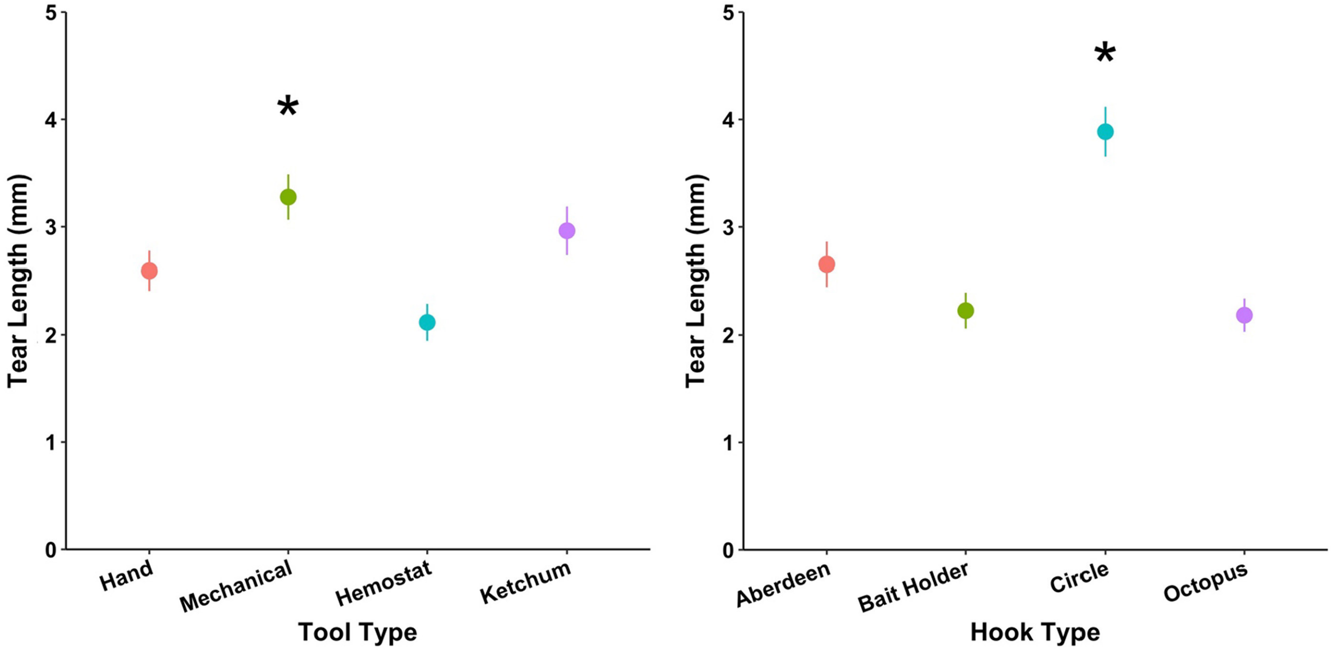


FIGURE 5 Mean (error bars = standard deviation) of mouth tissue tear length of four hook removal tools (left panel) and four hook types (right panel) for Bluegill (*Lepomis macrochirus*) caught by angling on Big Rideau Lake, Ontario, Canada, during June 2–24, 2021. Asterisks represent hook or tool types that differed significantly from the rest.

larger tears during unhooking because of the tight grip around the hook that reduces hook flex on jaw tissue and thereby causes more extensive tear damage. Tears in mouth tissue of angled fish cause immediate physical damage to captured fish, so tear length can impact feeding by some fish species (Thompson et al., 2018). Our study also suggests that greater tear lengths resulting from greater unhooking difficulties cause higher reflex impairment levels, which is not surprising given that tear lengths are a form of physical injury that can have an influence on the animal as a whole.

Furthermore, we found that circle hooks caused longer tears in mouth tissue than other hook types, which was consistent with circle hooks causing more severe injuries than other conventional hook types when targeting Bluegill (Cooke & Suski, 2004). This finding is not that surprising given the inverted hook point that circle hooks possess. However, circle hooks generally reduce rates and extent of angling-related injuries to other species of captured fish (Davie & Kopf, 2006). A reduced rate of gut hooking by circle hooks likely reduces post-release mortality because gut hooking often damages the stomach or other internal organs that leads to extensive bleeding (Lyle et al., 2007). In addition, post-release survival increased 2%–5% when using circle hooks for sand flatheads, a benthic-dwelling marine fish species, which was generally associated with reduced gut hooking (Lyle et al., 2007). Furthermore, our study also suggests that greater tear lengths resulting from greater unhooking difficulties cause higher reflex impairment levels, which is not surprising given that tear lengths are a form of physical injury that can have an influence on the animal as a whole, evident from the reflex scores.

Although our results indicated little connection between hook types and effectiveness of hook removal devices, use of hook removal tools can facilitate hook removal, regardless of hook type, by decreasing handling time and air exposure. However, use of these tools can cause greater tear length of mouth tissue than when hooks are removed by hand. More effective removal devices are needed for situations when bare hands are the primary tool for hook removal. Many anglers use up-to-date practices when catch-and-release angling, such as minimizing handling time and using proper dehooking tools. We suggest that anglers use hemostats to remove hooks from Bluegill, or other fishes with small mouths, to reduce air exposure, injury, reflex impairment, and thereby to increase fish welfare and survival.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

ETHICS STATEMENT

The study was approved by an Institutional Animal Care and Use Committee (110558).

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