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Evaluating different hook removal gear for in-water dehooking of jaw-hooked fish captured with barbed or barbless hooks

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ABSTRACT

Dehooking tools are often touted as a means to remove hooks from fish caught in recreational fisheries, especially for fish intended for release. We used Bluegill as a model species to test the efficacy of five dehooking tools as well as bare hands, for both barbed and barbless hooks. Bare hands took the longest to dehook fish, and there was little difference in dehooking times among the dehooking tools used. Tissue tearing, however, tended to be more extensive for fish dehooked with tools compared to bare hands. For all dehooking tools and bare hands, barbed hooks took significantly longer to remove than barbless hooks, and there was a 65% increase in tissue tear size for fish caught on barbed hooks. Those fish scored as difficult for hook removal were caught on barbed hooks. Overall, larger fish took longer to dehook than smaller fish, but tearing was not size-dependent. Incidence of bleeding was low and not significantly different among treatments. The only fish that experienced reflex impairment were those caught on barbed hooks that also had the longest dehooking times. Overall, for Bluegill hooked in the upper jaw, our study showed that using barbless hooks is a more important than which purpose-built dehooking tool is used. Given the diversity of species caught in recreational fisheries across a wide range of locations and scenarios, we recommend more studies of this kind be conducted, as well as for tackle manufactures to work closely with fisheries scientists to design dehooking tools that minimize physical injury.

1. Introduction

Recreational angling is a popular activity around the globe with billions of fish captured on an annual basis. Release rates of fish are highly variable, but it is estimated that approximately two thirds of fish that are captured are released which equates to ~ 30 billion fish (Cooke and Cowx, 2004). There has been extensive research focused on quantifying release mortality and understanding the factors that contribute to mortality (reviewed in Muoneke and Childress, 1994; Bartholomew and Bohnsack, 2005; Arlinghaus et al., 2007). Anglers, fisheries managers, and the broader angling community alike (i.e., industry, NGOs) are interested in the development of best practices that enable the capture, handling, and release of fish in ways that promote positive welfare outcomes (e.g., minimal injury and stress with high levels of survival; Cooke et al., 2017; Brownscombe et al., 2017). Moreover, best practices continue to evolve with new science as well as new innovations arising from the recreational fishing community itself (Cooke et al., 2021a, 2021b).

One area where such innovations are common is related to the design of hook removal gears intended to facilitate the release of fish. Removing hooks by hand can be challenging, therefore various gears ranging from gripping devices (e.g., hemostats, pliers) and disgorgers have been developed. Previous research has revealed that some hook removal gears can cause catastrophic damage to fish when they are used to remove hooks from fish that are deeply hooked (Cooke and Danylchuk, 2020), however, such devices may be useful for hook removal in shallowly hooked fish. A study that involved the efficacy of different dehooking gears for removal of barbed hooks from the jaw region of smallmouth bass while held by hand in air revealed that there was no evidence of conservation benefit arising from use of dehooking tools

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(Cooke et al., 2021a, 2021b). Yet, for fish that are to be released, the most desirable scenario may be to dehook a fish without touching it at all (e.g., by reaching over the side of a boat or from shore) and not exposing it to air. Air exposure is one of the most stressful aspects of catch-and-release (Cooke et al., 2015), while handling can result in dermal injuries (Skomal, 2007; Colotelo and Cooke, 2011; Foster et al., 2020). Prolonged handling of species in areas with high predator burden can also intensify predation risk (Lennox et al., 2017). Efforts to release fish in as little time as possible, without having to touch the fish, would represent a meaningful improvement to fish welfare in recreational fisheries.

We are unaware of any studies that have tested different dehooking gears for releasing fish with not having to hold them or remove them from the water. Given that barbs on hooks are known to influence dehooking time (Schaeffer and Hoffman, 2002; Alós et al., 2008), it would be useful to understand the extent to which barbed hooks (relative to barbless hooks) influence dehooking gear performance. There are a remarkable number of products marketed as being useful for the "touchless" removal of fish hooks, yet such claims are largely untested. Here, we report on a study where we tested five different dehooking tools (including bare hands) with both barbed and barbless hooks to understand how those factors influenced aspects of handling and fish condition. We restricted our study to fish captured in the jaw region and kept fish in the water for hook removal. Bluegill (*Lepomis macrochirus*) were used as a model given that they are often encountered as bycatch and thus release rates tend to be high. Moreover, bluegill have been used as a model in many previous catch-and-release studies given the ability to obtain relatively large sample sizes.

2. Methods

2.1. Field sampling

All research was conducted under the auspices of a Scientific Collection Permit from the Ontario Ministry of Natural Resources and Forestry and an Animal Care Certificate from Carleton University (2020-Cooke-CRU). This study was conducted between 2 June and 6 June of 2021 on Big Rideau Lake, Ontario, Canada (Latitude: 44.750. Longitude: −76.233). Research was conducted during the COVID-19 pandemic, and thus we operated under the Cooke Lab Research Resumption Plan approved by Carleton University with all field work conducted by the Cooke family household bubble. Surface water temperature during the study was stable at ~24 °C.

Angling was conducted from a shallow-water fishing boat and bluegill were captured on medium action spinning rods and reels with 3.6 kg (6 lb) line. All fish were captured using size 6, non-offset baitholder hooks rigged with 1 cm of dew worm. Barbed hooks were purchased for the study, and a subset made barbless by crushing the barb with a pair of pliers. Fight times were standardized to 15 s. Fish were landed and immediately placed in a 20 L cooler filled with ambient lake water. Water was changed every 10 min to maintain good water quality. Air exposure was limited to < 5 s to simulate a fish being handled while kept in water (e.g., over the side of the boat). Use of a cooler was necessary to collect information on the hook removal process and the state of the fish. Fish were processed immediately upon capture by a single researcher (SJC). Fish were visually assessed to ensure that the hook was located in the upper jaw. Any fish that were hooked in other anatomical locations were released. Similarly, any fish that fell off prior to handling were excluded from the study.

For shallow hooked fish, six treatments (see Fig. 1 for image of all gears except hands) and hook types were alternated randomly to remove the hook while the fish was in the water. For a maximum of 60 s, the handler did not touch the fish and restricted physical contact to the hook using the hook removal gear or hand. We considered 60 s to be the maximum time before an angler would give up on best practice dehooking (i.e., no handling) and likely try to hold the fish or remove it

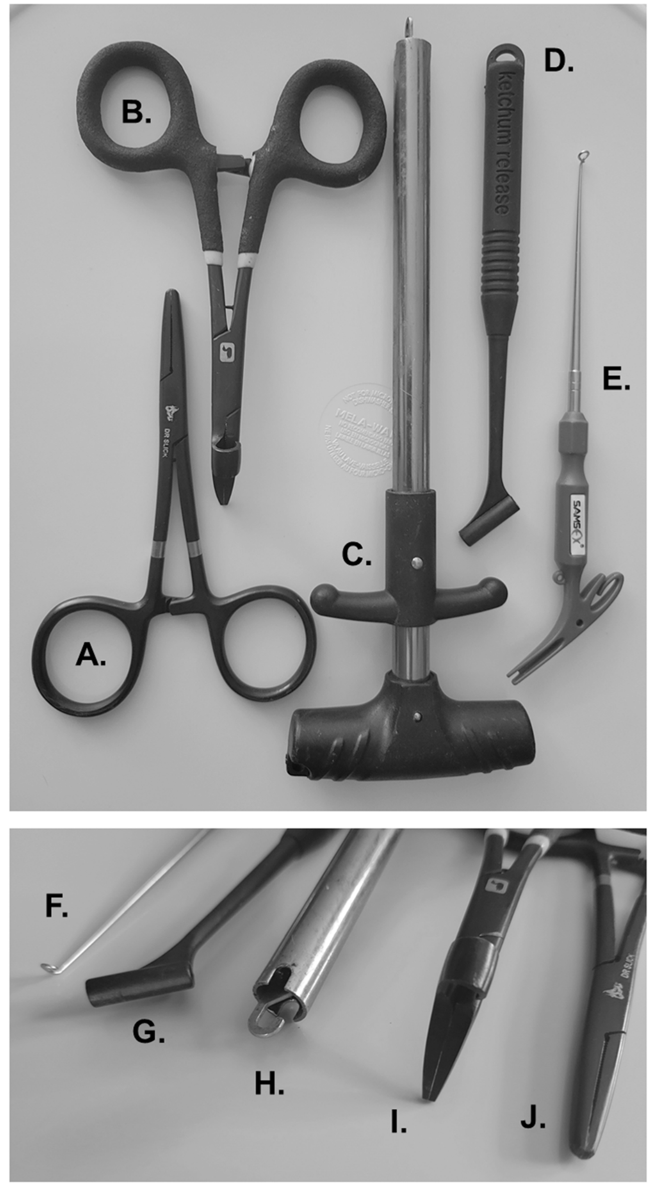

Fig. 1. Dehooking gear used in study (details in methods section). A. Hemostats. B. Loon dehooking forceps. C. Mechanical hook remover. D. Ketchum Release. E. Loop dehooker. F. Close-up of the Loop dehooker. G. Close-up of Ketchum Release tool. H. Close-up of the Mechanical hook remover. I. Close-up of Loon dehooking forceps. J. Close-up of Hemostats.

from water to remove the hook. For fish that reached a dehooking time of 60 s, the fish were gripped around the body to enable hook removal. All other fish remained submerged for the entirety of the hook removal period.

The "hand" treatment involved using only the thumb and fingers to remove the hook. All dehooking tools used in our study were those either commonly promoted by segments of the angling community and/or easily available on the internet through Amazon. The hemostat (Fig. 1; Dr. Slick Stainless Steel Hemostats, 14.0 cm, Dr. Slick, Belgrade, MT, USA) treatment involved gripping the shank of the hook and used wrist movement and leverage to apply force until the hook was extracted from the jaw. Following manufacturer guidelines, the mechanical dehooking device (Fig. 1; Easy Reach Fish Hook Remover Squeeze-Out Fish Hook Separator, 21.0 cm) involved gripping the hook at the bend of the shank, depressing the plunger and using wrist movements to apply force to remove the hook. The Loon (Fig. 1; Rogue Hook Removal Forceps with

Jaw Tool, 14.0 cm, Loon Outdoors, Boise, ID, USA), Ketchum Release (Fig. 1; Ketchum Release Tool Original, 20.3 cm, Waterworks-Lamson, Hailey, ID, USA) and loop (Fig. 1; SAMSFX Fishing Loop Hook Remover Tool, 17.0 cm) methods involved introducing the line into the device and then slipping the tool down the line and over the shank of the hook and applying pressure in an attempt to pop out the hook (as per manufacturer recommendations). The handler (SJC) practiced using each hook removal approach at least 20 times before initiating the study.

For all treatments, the time to remove the hook was recorded (to the nearest second). The timer began when the dehooking gear (or fingers for the hand treatment) first contacted the hook and was stopped when the hook was removed. The ease of hook removal was assessed by scoring the force needed to remove the hook, the relative torque applied, and the overall ease/difficulty, each from a low of 1 (easy or minimal) to a high of 3 (difficult/excessive). These three values were summed to create a composite measure of overall difficulty. The researcher then recorded the depth of hook penetration (measured from the tip of the snout to the nearest mm; as per Cooke et al., 2001), measured the length of tissue tear (as per DuBois and Dubielzig, 2004; e.g., tearing of the buccal membrane), and noted any evidence of bleeding. Fish were then transferred to a water filled trough to where they were measured (total length) to the nearest mm. All fish were then tagged with a T-bar anchor tag (Floy Manufacturing) to ensure that they were not reused in the study.

While fish were being released, they were assessed for reflex impairment while being held in water alongside the boat (Davis, 2010). Fish were held upside down to determine if they could right themselves within 3 s. Next, the tail of the fish was grabbed to determine if they responded by bursting away. These two reflexes, when absent, have previously been documented as being indicative of post-release mortality (in salmonids, Raby et al., 2012).

2.2. Data analysis

We were interested in the effects of hook removal treatment, hook barb, and fish length on the incidences of bleeding, flesh tearing, unhooking difficulty, and hook removal time. Four separate linear models were established to test these main effects on the outcomes.

The first model that tested bleeding was a generalized linear model with a binomial response (blood present or absence) that was run with the *glm* function in R. The second model was a generalized linear model with a negative binomial response for tearing, which was measured in millimeters based on the wound gape following unhooking. Negative binomial was selected based on overdispersion of the poisson glm and run with the *glm.nb* function in the MASS package (Venables and Ripley). Unhooking difficulty was a composite score of three values: force, torque, and ease, which were each scored 1–3 and then summed such that easy unhooking = 3 (1 +1 +1) and very difficult unhooking = 9 (3 +3 +3). Unhooking difficulty had a poisson error family run with the *glm* function in R. Finally, unhooking time was modeled as a negative binomial response based on the number of seconds extra time needed to unhook the fish by each method.

Incidence rate ratios, which is an expression of effect size in percentage change relative to the intercept, were determined by exponentiation of the negative binomial regression coefficients (Hilbe, 2011). Each of the three models had the same fixed effects: total length, hook barb (present or absent), and unhooking treatment. For each model, it was determined whether to include an interaction between treatment and barb by comparing an interactive model with a fully fixed model by AIC, with the model having smaller AIC presented. Where appropriate, multiple comparisons of the treatment factor levels were performed using a Tukey Test with the *pairs* function in the R package emmeand (Lenth, 2020).

3. Results

Three hundred and twenty-one bluegill were captured, handled, and dehooked for this study. Bluegill ranged from 115 to 215 mm in total length (mean = 146 mm).

Dehooking times ranged from 0 s to 60 s, with a median of 5 s (Fig. 2). The model without a treatment:barb interaction was determined to be the better model (ΔAIC = 4). Barbed hooks (median = 8 s) took significantly longer to dehook ($z = 11.35$, $p < 0.01$) compared to barbless (median = 3 s). Dehooking by hand took the longest (median = 7.5 s) and Tukey multiple comparisons revealed that this was significantly longer than when using the mechanical dehooking tool ($z = -4.16$, $p < 0.01$) and the loop tool ($z = -3.54$, $p < 0.01$). The mechanical dehooking tool was also significantly faster (median = 5 s) than the Loon tool (median = 4 s, $z = -3.32$, $p = 0.01$). Longer fish also took significantly longer to dehook ($z = 3.78$, $p < 0.01$).

Most bluegill were easy to dehook with a score 3 (force = 1, torque = 1, ease = 1; 56%; Fig. 3). The model without an interaction between treatment and barb was the better model (ΔAIC = 7). Only 30 fish were extremely difficult (force = 3, torque = 3, ease = 3; 9%). All fish that scored 9 were captured on barbed hooks and the median score for barbed hooks was 6 compared to 3 (the minimum) for barbless hooks ($z = 9.00$, $p < 0.01$). All treatments had a median score of 3 except for hands, for which the median was 4; however, no comparisons were significant according to the Tukey multiple comparisons. Longer fish were more difficult to dehook ($z = 2.73$, $p < 0.01$).

Most fish (41%) experienced no tearing (Fig. 4) and the median level of tearing was 1 mm (Fig. 5). According to AIC, the model with the interaction between dehooking treatment and hook barb was better than the fully fixed model (ΔAIC = 8). Only one fish each experienced level seven or nine tearing (0.03%). Median tearing was 2 for barbed hooks and 0 for barbless hooks ($z = 2.15$, $p = 0.03$) and the incidence risk rate was 1.65, indicative of a 65% increase in the tear length for barbed hooks relative to barbless. Median tearing was 2 for the mechanical and the Loon dehooking device, 1 for hemostats and Ketchum Release, 0.5 for hands, and 0 for the loop tool (Fig. 5). Correspondingly, the mechanical dehooker resulted in tearing severity significantly larger than the loop tool, hemostats, and hands (all $z > 3.15$, all $p < 0.02$). Tearing was not affected by fish length ($z = 1.84$, $p = 0.07$). There was a significant interaction between hook barb and dehooking gear affecting tear length. Median tear length was 2 for all treatments with barbed hooks, and zero for all dehooking treatments with barbless hooks except for mechanical and Loon dehookers (median = 1; Fig. 5). According to multiple comparisons, 28 of 66 treatment:barb interactions were significant; notable comparisons that were not significant were the mechanical dehooker without barb not different from all six treatments with barb (all $z > -2.43$, all $p > 0.39$) and Loon with barbless hook not significantly different from hands, hemostats, or Loon dehooking tool with barb (all $z > 3.18$, all $p > 0.06$).

Only 30 fish in the study (9%) were bleeding. The model without an interaction between treatment and hook barb was the better model (ΔAIC = 4). Fish hooked with barbed hooks bled more (14%) than fish hooked with barbless hooks (5%; $z = 2.53$, $p = 0.01$; Fig. 6). Although the Loon dehooking tool had a high (15%) incidence of bleeding compared to the others (all < 8%), no dehooking treatment had significantly higher rates of bleeding. Total length did not affect Bluegill bleeding ($z = 1.61$, $p = 0.11$).

Only six fish suffered from reflex impairment (all had lost equilibrium and did not burst) negating any formal quantitative analysis. All of those fish were captured on barbed hooks and had among the longest handling times (i.e., loop, 44 s; hand, 29 s; Ketchum Release, 60 + s; Loon, 2 fish at 60 + s and 1 at 22 s).

4. Discussion

We tested six different methods of dehooking Bluegill that were

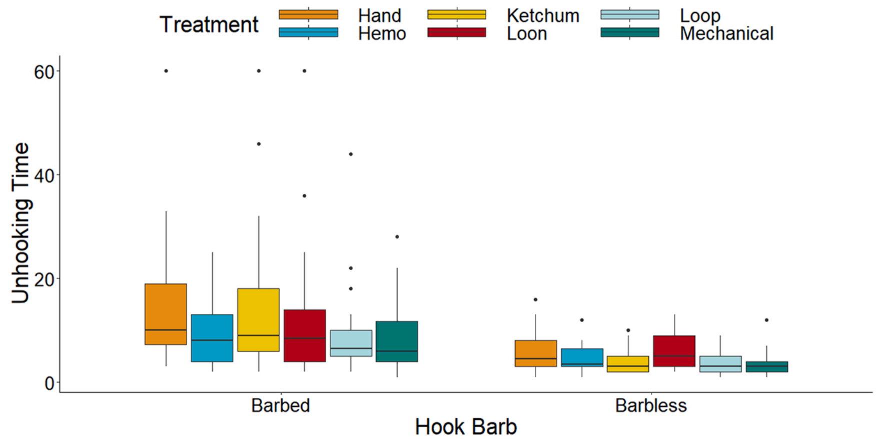

Fig. 2. Distributions of unhooking times in seconds for each dehooking device and hook type (barbed or barbless) illustrated by boxplots.

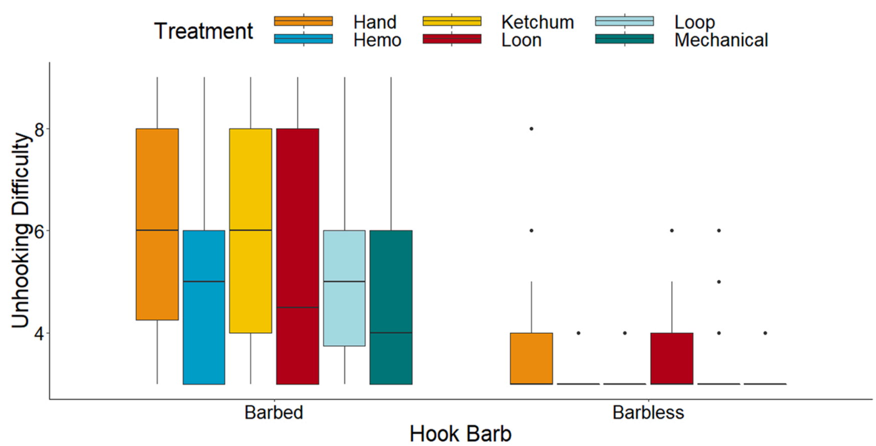

Fig. 3. Distributions of unhooking difficulty for each dehooking device and hook type (barbed or barbless) illustrated by boxplots. Difficulty was scored from the sum of three variable scores (each 1–3): force, torque, and overall difficulty.

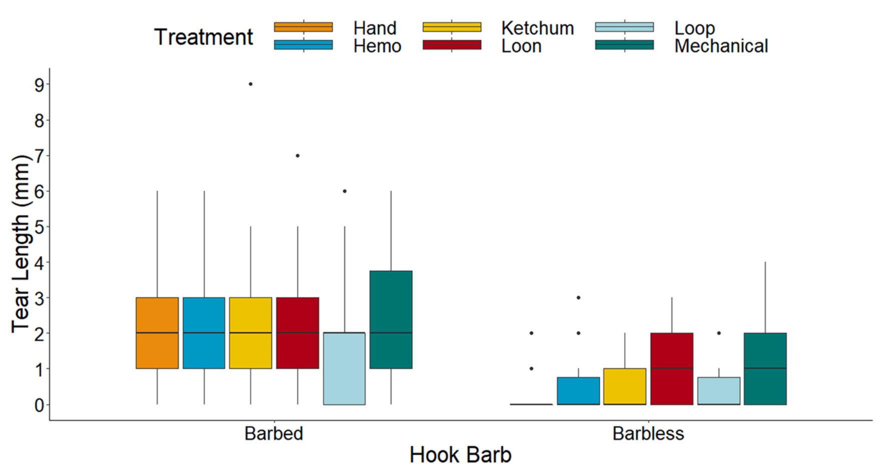

Fig. 4. Distributions of tear length (in mm from jaw) for each dehooking device and hook type (barbed or barbless) illustrated by boxplots.

hooked in the jaw region without removing the fish from the water or gripping the fish by hand. The most prominent finding was that barbless hooks were significantly faster and easier to remove than barbed hooks irrespective of which hook removal device was used. That finding is not entirely surprising given that barbless hooks are widely regarded as being faster and easier to remove based on research on a wide range of freshwater and marine fish. Effect sizes are somewhat variable but in general, use of barbless hooks tends to reduce handing time by half (e.g., Cooke et al., 2001; Schaeffer and Hoffman, 2002; Alós et al., 2008; Trahan et al., 2021). Yet, when we assessed the influence of different dehooking devices on hook removal time, there was little evidence that gear type was influential. The most notable pattern was that hand gripping of the hook to enable removal of the hook took longer than any of the dehooking devices. There were minor differences in hook removal

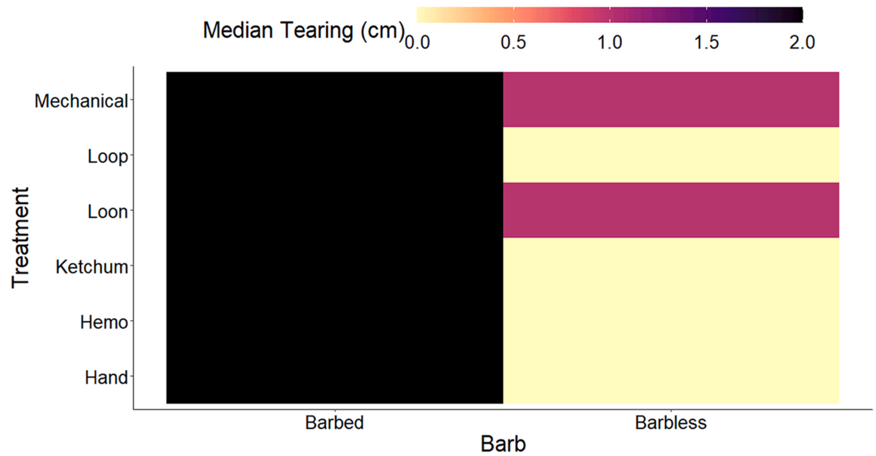

Fig. 5. Median values of tear length (in cm from jaw) for each dehooking device and hook type (barbed or barbless) illustrated by heat mapping.

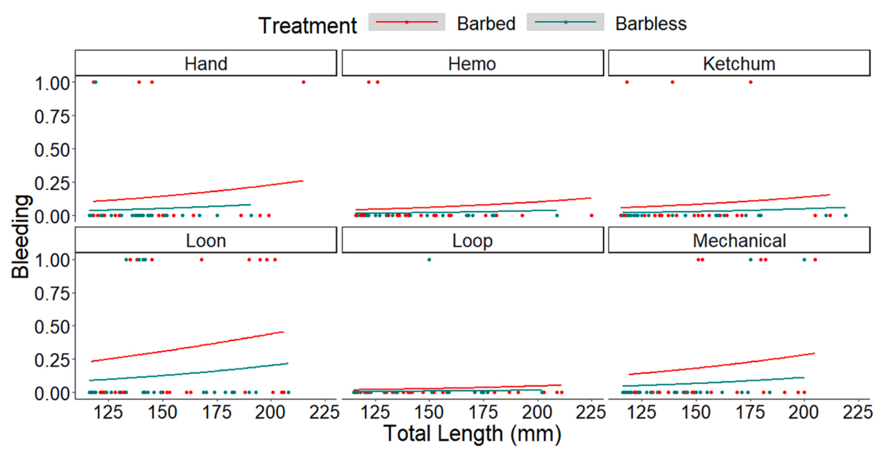

Fig. 6. Logistic regression for bleeding incidence for each dehooking device and hook type (barbed or barbless) including regression lines.

time among gears for a given hook type but on the order of a few seconds so it is unlikely that the level of variation in handling time observed here would be biologically meaningful. The measures of hook removal ease as assessed by a composite score of force, torque, and ease tended to mirror patterns in hook removal time.

If handling occurs in air, the reduction in hook removal time associated with using barbless hooks would translate to reductions in air exposure. In this study, fish were dehooked while submerged in water which may account for the fact that fish were unlikely to exhibit reflex impairment indicative of physiological impairment often associated with exhaustion of anaerobic pathways when fish are forced to power muscles without oxygen (Cooke et al., 2015). Only six fish exhibited reflex impairment and all were captured on barbed hooks. All those fish tended to take several seconds longer than average to be dehooked. Although the fish were in water, holding the hook and attempting removal may have impeded respiration, which could have led to hypoxic conditions for the fish, similar to what happens when fish are captured in gillnets (Hopkins and Cech, 1992; Farrell et al., 2001). Moreover, fish often struggled during hook removal, so longer periods of hook removal presumably translated to higher levels of physiological exhaustion (Kieffer, 2000). What is clear from our work and supported by other studies (e.g., Cooke et al., 2021a, 2021b; Trahan et al., 2021) is that barbless hooks are removed more rapidly than barbed hooks, which can reduce reflex impairment indicative of stress.

Tearing was a reasonably common outcome for fish in this study. For example, tearing tended to be more extensive for fish dehooked using the mechanical dehooking tool and the Loon forceps, intermediate for the hemostats and Ketchum Release device, and least for hands and the loop tool. Cooke et al. (2021a), (2021b) also observed tearing in fish where dehooking gears were used on fish held by hand in air. The extent of tearing was also influenced by barbed hooks relative to barbless hooks. Specifically, there was a 65% increase in the tear length for barbed hooks relative to barbless. This is not unsurprising given that the purpose of barbs is to make it more difficult for fish to get off a hook (Larson, 2007) with requisite need for force and/or tearing to get a barbed hook out of most tissues (e.g., Warner, 1979; Kaimmer, 1994). We observed little bleeding associated with hook removal although there was a significant effect of barbs. Barbed hooks tended to have higher incidences of bleeding than barbless hooks as has been documented elsewhere (DuBois and Pleski, 2007; Alós et al., 2008; Reeves and Staples, 2011).

Collectively, our findings reveal that although some hook removal gears have the potential to yield slightly faster dehooking times, they also yield greater levels of injury to the fish. What is remarkable is the extent to which the presence of the barb influenced the performance of the dehooking gears. For all dehooking gears, the barbless hooks were removed approximately twice as fast as barbed hooks. Moreover, the barbless hooks yielded less tissue damage and less frequent bleeding. The combination of those findings reveals that for fish hooked in the jaw, there is more benefit derived from encouraging use of barbless hooks than use of dehooking gears. Indeed, use of simple hemostats was similarly effective to purpose-built tools intended to facilitate hook removal. Even bare hands performed reasonably well, especially for barbless hooks which does not require any financial investment. It is important to note that Bluegill are reasonably small so for larger fish with more robust mouth tissues, dehooking gears may be more useful. This would also extend to fish with dentition (e.g. *Esox* spp.) for which use of hands could lead to injuries to the handler or in instances where lures have multiple hooks or treble hooks (see Trahan et al., 2021).

The idea of being able to release fish without physically restraining them or removing them from the water is laudable and highly relevant to sensitive fish species (see Cooke et al., 2016) or conditions that push fish to their limits (e.g., warm water temperatures that are becoming more common due to climate change; Townhill et al., 2019; Jeanson et al., 2021). Indeed, there have been recent innovations in hook types such as short bite designs that are another means of enabling rapid release with minimal handling (Harris et al., 2021). The fact that none of the purpose-built dehooking gears had excellent performance suggests that there is room for more innovation in dehooking gears. Such gears should be tested to ensure that they facilitate dehooking and do so without causing significant injury. Investigations should consider species-specific traits such as size, mouth morphology, likelihood of jaw hooking, and dentition because there is unlikely to be a tool that is universally successful for all species or contexts. In fact, we observed a significant effect of body size on outcomes in this study which is surprising given the relatively narrow size range studied here. As such, exploring the effectiveness of hook removal tools across a wider range of fish body sizes would be useful to better understand the generality of our findings. Moreover, evaluating use of dehooking gears with lures that have treble hooks or more than one hook would be worthwhile. In the interim, we encourage the use of barbless hooks for catch-and-release fishing. We also advocate for anglers to keep dehooking gears at the ready for difficult dehooking (especially deep hooking) but note that simple hemostats or pliers are likely sufficient for jaw hooking which was the focus of this study.

CRediT authorship contribution statement

Steven J. Cooke: Conceptualization, Methodology, Investigation, Data curation, Writing – original draft. **Benjamin W.C. Cooke:** Conceptualization, Methodology, Investigation. **Joshua T.H. Cooke:** Conceptualization, Methodology, Investigation. **Cameron J.A. Cooke:** Conceptualization, Methodology, Investigation. **Luc LaRochelle:** Writing – review & editing. **Andy J. Danylchuk:** Conceptualization, Writing - review & editing. **Sascha Clark Danylchuk:** Conceptualization, Writing – review & editing. **Robert J. Lennox:** Formal analysis, Writing – review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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