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RESEARCH ARTICLE

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CATCH-AND-RELEASE FISHING OF TUCUNARÉ (*Cichla kelberi*) AND PIRAPITINGA (*Piaractus brachypomus*): HOOK TYPE vs POST-CATCH FISH HEALTH

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ABSTRACT

The growing popularity of catch-and-release fishing and consequent injuries to fish need to be studied to develop species-specific techniques that limit damage. Therefore, we tested the hypothesis that the hook type used in catch-and-release fishing affects fish health. Specifically, we evaluated the catch-and-release of *Cichla kelberi* (tucunaré) and *Piaractus brachypomus* (pirapitinga) with different types of hooks (barbed J-hook, barbed circle hook, barbed wide gap hook and barbless J-hook) and their influence on several parameters: fight time, perforation and bleeding type (location), hook removal time and healing (post release). After catching and releasing 284 fish (n = 107 *C. kelberi* and n = 177 *P. brachypomus*), we found that the barbed circle hook for *C. kelberi* and the barbless J hook for *P. brachypomus* reduced the damage caused by catch-and-release fishing. Removal of these hooks from the animals took less time (i.e. was easier), caused less perforation damage and bleeding and resulted in faster healing. Thus, we confirmed our hypothesis that hook type plays a significant role in fish health and survival in catch-and-release tanks and may contribute to the conservation and sustainable use of this resource.

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INTRODUCTION

Catch and release (CandR) fishing is growing in popularity worldwide and can provide a strategy for the conservation and sustainable use of fishing resources (Cooke *et al.,* 2018). Nevertheless, success requires fishers to acquire awareness, knowledge and less-harmful techniques and an understanding of species-specific responses to catch-and-release fishing (Cooke and Schramm, 2007). Depending on fish species, catch-and-release fishing may cause high rates of post-release mortality or a variety of nonlethal effects that can affect short and long-term health and survival (Muoneke and Childress, 1994, Arlinghaus *et al.,* 2007). One consequence of CandR fishing is fish stress, which can cause physiological and behavioral changes (Gargan *et al.,* 2015) that can affect foraging skills (Thompson *et al.,* 2018) and reduce anti-predatory and competitive defensive responses (Danylchuk *et al.,* 2014). This stress can also be enhanced by the pain caused by fishers and their equipment, which include significant injuries (Cooke and Sneddon, 2007) exposure to ambient air and water with higher temperatures (Gingerich *et al.,* 2007). These situations can also cause immunological suppression (Lennox *et al.,* 2015), which can increase susceptibility to infections from various parasites (Varandas *et al.,* 2013) and may result in death. Other important factors affecting fish health after CandR include the locations of hook perforations and the type of equipment used. Hook type, for example, is a significantpredictor of mortality and non-lethal injuries, the severity of which varies by species (Cooke and Suski, 2005, Czarkowski and Kapusta, 2019). Studies by Bartholomew and Bohnsack (2005) and Muoneke and Childress (1994) provide good examples of how improper CandR practices can affect fish. Therefore, studies are needed to develop and propose CandR protocols and to evaluate the harm or benefit from using different types of equipment (Cooke and Suski, 2005, Brownscombe *et al.,* 2017). For example, fishing with circle hooks reduces mortality rates in some species (Pacheco *et al.,* 2011, Cooke *et al.,* 2012, Wilson and Diaz, 2012) while barbless hooks can be removed more easily and quickly in *Oncorhynchus tshawytscha* (Gjernes, Kronlund and Mulligan 1993), *Oncorhynchus kisutch* (Gjernes, Kronlund and Mulligan 1993), *Diplectrum formosum* (Schaeffer and Hoffman, 2002) and *Oncorhynchus mykiss* (Meka, 2004). Nevertheless, the results of these studies cannot be extrapolated to all CandR species, especially considering differences in morpho-physiology and behavior. Brazil is home to 14% of the world's fish species, with 3467 freshwater species and 1227 marine species (Froese and Pauly, 2015). Brazilian sport fishing has attracted an increasing number of practitioners and encompassed a wide variety of species (Freire *et al.*, 2016). However, unlike other countries where this type of fishing is better studied (Cooke and Cowx, 2004), in Brazil there is a substantial lack of technical information on post-release fish survival and which species are best suited to sport fishing. This information could be useful not only for the conservation and management of native species of ecological and commercial value, but also for the organizations responsible for the planning and management of fisheries (Cooke and Cowx, 2004). Therefore, our goal was to determine whether the type of hook used in CandR fishing could affect the health of two fish species that are native to Brazil and frequently fished by sport fishers: *Cichla kelberi*, chosen as a representative carnivorous species and *Piaractus brachypomus*, as an omnivorous and generalist species. To achieve this, we evaluated different aspects that can put the survival of post-release animals at risk and foment debate on how this sport can contribute to the conservation and sustainable management of fisheries. Given the morpho-physiological differences between *C. kelberi* and *P. brachypomus*, we hypothesized that hook type would have a significant impact on the health of these fishespost release.

MATERIAL AND METHODS

Study site and animals: The study was conducted at the experimental fish farm of the Pisciculture department at the Federal Goiano Institute - Urutaí Campus (Urutaí, Goiás state, Brazil). The fish farm covers 1,250 m^2, with an average depth of 1.4 m and sufficient flow to maintain water levels. Adult *Cichlakelberi* and *Piaractusbrachypomus* were acquired from commercial fish farms, introduced into the experimental fish farm and left to acclimatize for at least 30 days before commencement of the study. During this period, *P. brachypomus*was fed twice daily with commercial feed (ad libitum), while the carnivorous *C. kelberi* (Zaret, 1980) preyed on juvenile Nile tilapia (*Oreochromis niloticus*) and small Characiformes fishes (*Astyanax spp.*) that had been previously introduced into the experimental farm. The fish were fasted for 48 hours before conducting the CandR experiments.

Fishing procedures and assessment of stress biomarkers: Seven volunteer fishers were invited to participate and instructed on study objectives and equipment use. The fish were caught using braided multifilament line (Power pro®), rapala tournament rods (5̕6 ”10-20 lb) and shimano® reels (syncopate, 2500FG). Live bait (*Astyanax sp*., 5 -10 cm long) were used to catch *C. kelberi*while pieces of beef heart, sausage, fruit (acerola and guava), cheese and sweetened wheat dough were used for *P. brachypomus*. The volunteers were free to choose the type of bait and when they would use it. Fishing took place over 45 days, occurring once a week between 7:00 am and 11:00 am. In order to simulate authentic CandR practices, the volunteers included both experienced and inexperienced fishers who were free to adopt individual fishing tactics. However, they were restricted to the following types of hooks: barbless “J” (JS) (Gamakatsu®, size 4.0), barbed “J” (JC) (Pinnacle®, size 4.0), barbed wide gap (WG) (Pinnacle®, 4.0) and barbed circlehook (CC) (Kenzaki®, size 4.0). The average number of fishers per day was 6.2 ± 0.9, with an average effort of 3.5 ± 0.4 hours/day, totaling 157 hours of fishing.

The following parameters were recorded whenever a fish was caught: fight time (time from when the fish was hooked until its removal from the water), hook location, occurrence and type of bleeding and the time needed to remove the hook from the fish. Hook location was categorized as: (i) buccal or mandibular surface; (ii) intermediate perforation in the gills, operculum or eyes or (iii) deep perforation in the pharynx, esophagus or intestine (Cooke et al., 2003). Bleeding was classified as “no bleeding” (no evidence of bleeding), “moderate bleeding” (less than 0.1 mL of blood) and “chronic bleeding” (more than 0.1 mL of blood) (Fobert et al., 2009). Hook removal time was ranked as “easy” (lasting less than 10seconds), “average” (11s ≤ x ≤ 20s, where x is the removal time) or “difficult” (lasting more than 20seconds). Hook removal was carefully carried out using a hook-removal pliers. Afterwards, the fish were placed in a net cage that had a similar fish density (0.5 to 1.0 fish/m^3)to that of the fish farm (0.6 fish/m^3) and then reassessed 7 days later to categorize wound healing as: i) fully healed (no indication of hook injury), ii) partially healed (wound smaller than the initial perforation); iii) unhealed (injury greater than or equal to the initial perforation).

The physical-chemical parameters of the water (e.g. temperature, oxygen concentration and ammonia) were evaluated weekly (using a thermometer and commercial kits) to guarantee that conditions in both the fish farm and the net cage were within appropriate limits for breeding tropical fish (Vogel *et al.,* 2019). All caught fish were identified by combinations of one or two colored beads that were attached to the anal fin by a flexible synthetic thread (nylon, 0.20 mm in diameter) (Faria et al., 2003). The ends of the thread were tied in a loop so that the fish could move unhindered. In cases of swallowed hooks, the lines were cut such that the fish was released with the hook (Weltersbach et al., 2016). Finally, the fish in the net cage were fed daily with a commercial fish food (ad libitum) and by smaller fish that could pass through the net and serve as food for *C. kelberi*.

Statistical analysis: The frequency data for each hook were arranged in double-entry contingency tables and separated by species. Fisher's exact test for independent samples (5% significance) was used to analyze associations among hook type and classifications of hook removal, perforation, location, bleeding and healing for each species. These analyses were performed using the ca package (Nenadic and Greenacre, 2007) in the R software package.

Ethics: All procedures were approved by the Ethics Committee on Animal Use at the Instituto Federal Goiano (no. 06/2015).

RESULTS AND DISCUSSION

Two hundred and eighty-four fish were caught (107 *C. kelberi* (37.67%) and 177 *P. brachypomus* (62.33%)). The mean body biomass of *C. kelberi* was 0.81 ± 0.43 kg (mean ± SD), while that of *P. brachypomus* was 2.83 ± 0.53 kg. Fight times ranged from 5s to180 s (mean: 28.06 ± 25.40s) for *C. kelberi*and 74s to 975s (mean: 202.62 ± 92.26s) for *P. brachypomus*. Longer fight times for *P. brachypomus*are probably due to their greater size and biomass (Heberer *et al.,* 2010). We did not observe any effect of hook type on the wound site for these fish species (p> 0.05) (Figure 1A-B), although other studies have shown that circle hooks cause more superficial perforations than J-hooks (Pacheco *et al.,* 2011, Lennox *et al.,* 2015). We also found that 7.47% (n=8) of the wounds were classified as deep in *C. kelberi*, which yielded the only fish death in the experiment, while 1.12% (n=2) were classified as deep for *P. brachypomus*.

Unlike the current study, Lennox et al. (2015) found a greater frequency of deep wounds in *L. macrochirus*using J-hooks than with circle hooks. This result was attributed to the circular shape of the hook which tends to lodge in the in the mouth or jaw and prevents penetration of the esophagus, throat, gills or other deep tissue.The large mouth opening and strike voracity of *C. kelberi*may explain why hook type did not affect perforation location (Gomiero and Braga, 2003; Holley *et al.*, 2008; Barroco, Freitas and Lima, 2018), while oral morphology and the presence of molariform teeth may explain similar findings for *P. brachypomus* (Cooke *et al.,* 2003). Previous studies have shown that circle hooks cause less frequent deep perforations in certain fish species, such as *Hemirammphus brasiliensis* (Prince, Ortiz and Venizelos, 2002), *Thunnus thynnus* (Skomal *et al.,* 2007), *Thunnus obesus* and *Thunnus albacares* (Pacheco *et al.,* 2011) and *Lepomis macrochirus* (Lennox *et al.,* 2015). However, circle hooks did not prove advantageous for individuals of *Lepomis macrochirus* and *Lepomis gibbosus* (Cooke *et*

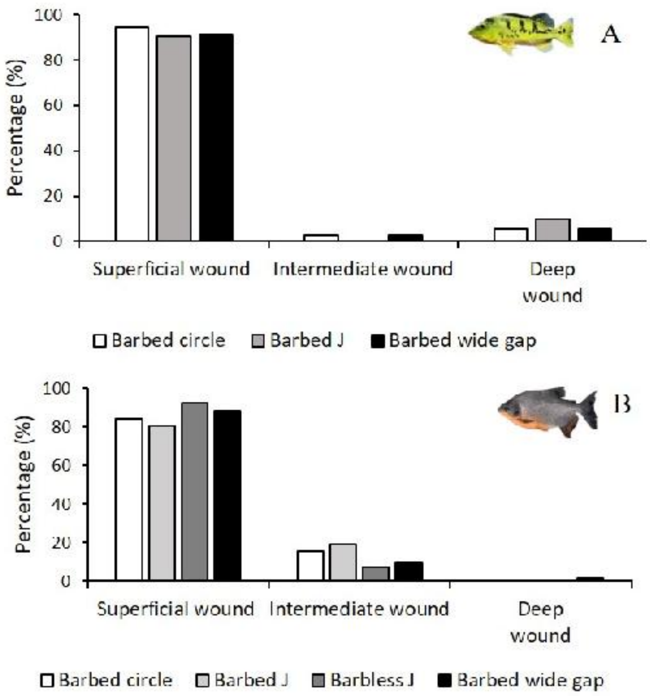

Figure 1. Wound classification (superficial, intermediate and deep) and percent occurrence for barbed circle hooks, barbed J-hooks, barbless J-hooks and barbed wide gap hooks for (A) *Cichla kelberi* and (B) *Piaractus brachypomus*. Results for the barbless J-hook were not shown in A since this hook was not evaluated for *C. kelberi*. The bars represent the percentage of each injury category in the animals (n = 107, *C. kelberi* and n = 177, *P. brachypomus*). The data were compared by Fisher's Exact test at 5% probability.

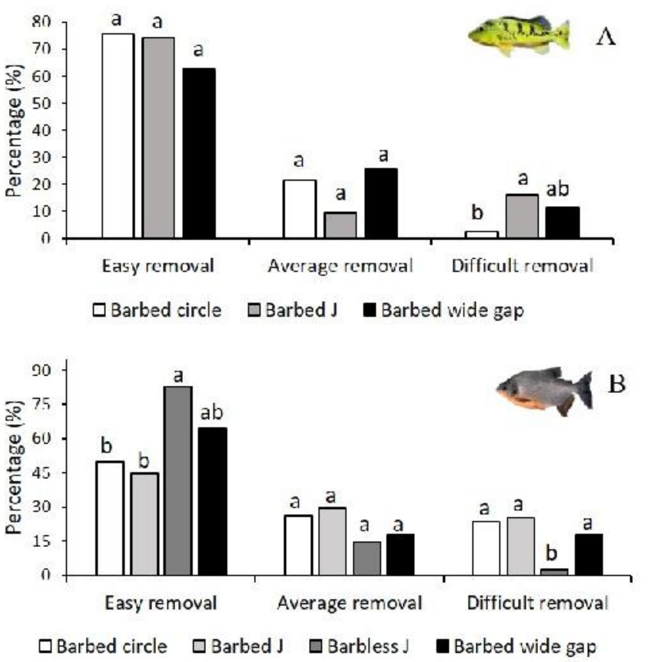

Figure 2. Hook removal (easy, average and difficult) and percentage of occurrence with barbed circle hooks, barbed J-hooks, barbless J-hooks and barbed wide gap hooks for (A) *Cichla kelberi* and (B) *Piaractus brachypomus*. Results for the barbless J-hook were not shown in "A" since this hook was not evaluated for *C. kelberi*. The bars represent the percentage of each injury category in the animals (n = 107, *C. kelberi* and n = 177, *P. brachypomus*). Distinct lowercase letters indicate significant differences between the "easy", "average" and "difficult" categories, as shown by Fisher's Exact test at 5% probability.

al., 2003). The results of these studies and those of the current one show that hook effects may differ by fish species, especially due to differences in anatomy-morphology and dentition that directly influence eating habits. Therefore, different catch-and-release guidelines are needed for different fish species. Hook type had no effect onhook removal time in the "easy" ($p \geq 0.30$) and "average"($p \geq 0.11$) categories for *C. kelberi* (Figure 2A).

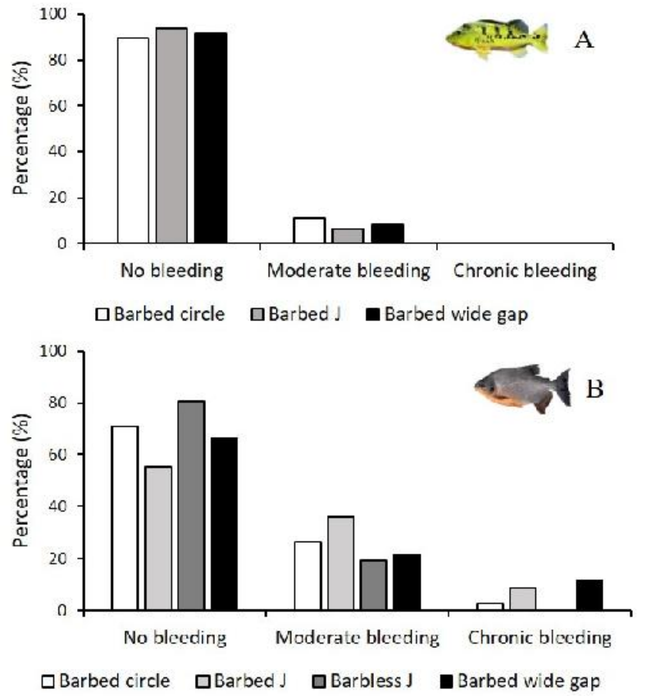

Figure 3. Bleeding type (no bleeding, moderate bleeding and chronic bleeding) and percent occurrence with barbed circle hooks, barbed J-hooks, barbless J-hooks and barbed wide gap hooks for (A) *Cichla kelberi* and (B) *Piaractus brachypomus.* Results for the barbless J-hook were not shown in "A" since this hook was not evaluated for *C. kelberi*. The bars represent the percentage of each wound category in the animals (n = 107, *C. kelberi* and n = 177, *P. brachypomus*). The data were compared by Fisher's Exact test at 5% probability.

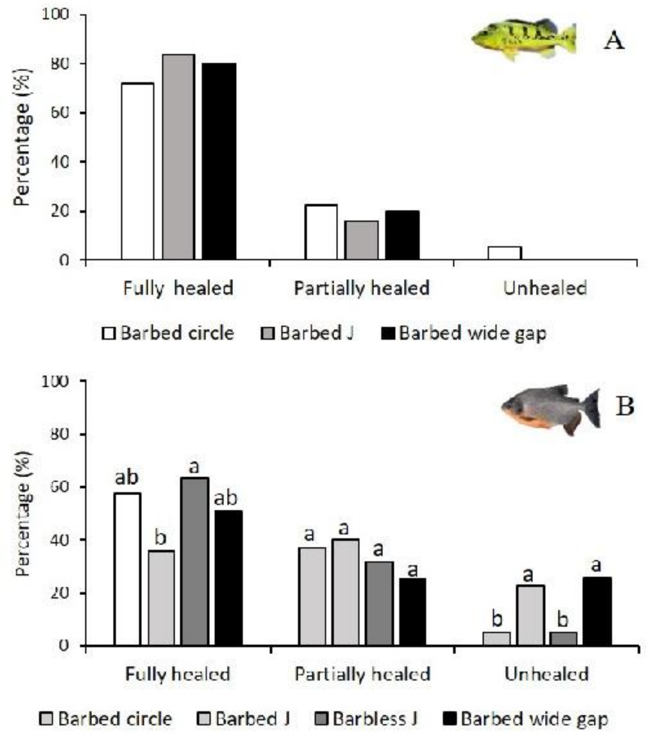

Figure 4. Healing (fully healed, partially healed and unhealed) and percent occurrence from barbed circle hooks, barbed J-hooks, barbless J-hooks and barbed wide gap hooks for (A) *Cichla kelberi* and (B) *Piaractus brachypomus*. The bars represent the percentage of each would category in the fish (n=107, *C. kelberi* and n=177, *P. brachypomus*). Distinct lowercase letters indicate significant differences within between the "fully healed", "partially healed" or "unhealed" categories, as shown by Fisher's Exact test, at 5% probability.

However, barbed J-hooks were more frequent in the "difficult" category than were barbed circle hooks for *C. kelberi* ($p = 0.02$)

(Figure 2A). Cooke *et al.* (2003) also found that difficult withdrawals were more common with J-hooks than with circle hooks for *Micropterus salmoides.*

For *P. brachypomus*, the barbless J-hook showed a greater frequency in the "easy" removal category (p = 0.003) than in the "difficult" category (p = 0.003) (Figure 2). Our findings weresimilar to those of Dubois and Dubielzig (2004) who found that barbless hooks took less time to remove from *Oncorhynchus mykiss*, *Salmo trutta* and *Salvelinus fontinalis* than did barbed hooks, and that thisdifference could reduce fish mortality. Hook withdrawal time is positively correlated with nonlethal harm in some fish species (Thorstad et al., 2004; Cooke and Suski, 2005) and is considered an important mortality predictor (Ferguson and Tufts, 1992; Cooke and Suski, 2005).Thus, quick hook removal reduces handling and air exposure times, which in turn increasessurvival chances (Brownscombe *et al.*, 2017).

Hook type also had no effect on bleeding type (no bleeding, moderate bleeding and chronic bleeding) in both species (Figure 3). There were no instances of chronic bleeding in *C. Kelberi.* This may be explained by the mostly cartilaginous oral structure of Cichlidae, which bleeds very little or not at all (Kullander and Nijssen, 1989). Eleven cases (6.21%) of chronic bleeding were found for *P. brachypomus*, which can be explained by its well vascularized mouth morphology. Nevertheless, the barbless J-hook did not cause any chronic bleeding for *P. brachypomus*, which shows that this hook type decreases tissue damage and consequently reduces the risk of chronic bleeding (Dubois and Dubielzig, 2004). Cooke *et al.*, (2003) also found little bleeding (2.7% for J hooks and 5.1% for circle hooks) for *L. macrochirus* and *L. gibbosu*. Thus, both wound location and bleeding significantly affect tfish caught using CandR (Reeves and Bruesewitz, 2007; Gargan *et al.*, 2015). Hook type also had no effect on healing (fully healed ($p \geq 0.25$), partially healed ($p \geq 0.54$) or unhealed ($p \geq 0.49$) for *C. kelberi.* However, for *P. brachypomus*, barbed circle hooks and barbless J-hooks showed a lower frequency of unhealed wounds, while the barbless J-hook showed a higher frequency of fully healed wounds ($p \leq 0.03$) than did the barbed J-hook. Furthermore, the barbed J-hook showed a lower frequency of fully healed wounds (p=0.01) and a greater frequency of unhealed wounds (p = 0.01). These results can be explained by the fact that barbless hooks are easier to remove and therefore cause less tissue damage and result in faster medicinal (Weltersbach and Strehlow, 2013). Fish with unhealed wounds may be susceptible to parasitic infections, which can lead to weakness or even death (Weltersbach and Strehlow, 2013).

CONCLUSION

Our data confirmed the hypothesis that hook type has a significant effect on the health of *C. kelberi* and *P. brachypomus* in CandR fishing. For *C. kelberi*, the barbed circle hook was the easiest to remove and reduced the occurrence of tissue damage. However, for *P. brachypomus*, the barbless J-hook was easiest to remove and resulted in better healing. The mortality rate of both species was low. Furthermore, the use of specific hooks and general CandR guidelines can reduce damage and contribute to species survival and conservation. Nevertheless, other possible types of damage from CandR fishing (physiological, behavioral and immunological), which were not considered in the present study, could be evaluated in future research.

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