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Short communication

Injury rates, hooking efficiency and mortality potential of largemouth bass (*Micropterus salmoides*) captured on circle hooks and octopus hooks

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Abstract

We compared the injury rates, hooking efficiency, and mortality potential of circle hooks and the more conventional octopus hooks for largemouth bass (*Micropterus salmoides*) captured on minnows in central Illinois. Fish captured on circle hooks ($N = 125$) were hooked less deeply, exhibited less bleeding, and were more easily removed from the hook than were those captured on octopus hooks ($N = 134$). The majority of fish captured using both hook types were hooked in the upper lip. Mortality rates were uniformly low for both hook types (circle, 5.1%; octopus, 6.6%). Fish that were identified as potential mortalities were typically hooked deeply in a vital organ or tissue (i.e., heart, gullet, gill arch), exhibited substantial bleeding, and were difficult to remove from the hook. No size-selective trends were noted among hook types, nor were there any differences in total length among mortalities and survivors. Capture efficiency for circle hooks was half that of octopus hooks. Our results suggest that circle hooks do provide some minimal conservation benefits relative to conventional octopus hooks despite having similar mortality rates.

Keywords: Hook type; Catch-and-release; Injury rates; Capture efficiency; Recreational angling; Largemouth bass

1. Introduction

Advances in hook technology, driven by desires to increase hooking efficiency while decreasing injury and mortality in recreational catch-and-release fisheries, have resulted in the development and recent widespread marketing of circle hooks. Circle hooks differ from more conventional "J" shaped hooks in that the point of the hook bends back perpendicularly towards the shank of the hook (Soucie, 1994). Circle hooks use the force of the line to rotate the hook around such that they hook on the jaw region, and hence do not require a forceful pull to set the hook unlike many other hook types. Because the hook is oriented inwards, there is an apparent reduced risk of gullet hooking or lethal injury caused by damage to other tissues (Montrey, 1999).

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Originally used by commercial fishers for trotlines and long-lines (McEachron et al., 1985; Ott and Storey, 1991; Woll et al., 2001), circle hooks have been identified as a potential conservation tool for minimizing injury and mortality rates in freshwater and particularly marine recreational fisheries (e.g., Lukacovic, 2000; Grover et al., 2002; Prince et al., 2002; Skomal et al., 2002). In general, data across studies suggest that circle hooks are effective at minimizing deep hooking, thus reducing potential injury to vital organs. In marine fish species, circle hooks have also been shown to have similar hooking efficiency to more conventional "J" type hooks (e.g., Skomal et al., 2002). Recent circle hook marketing efforts and conservation articles in the popular press have targeted freshwater anglers based on the assumption that circle hooks may provide similar benefits (e.g., Stange, 1999). The only studies that have tested circle hooks in fresh water found that circle hooks performed similarly to three other hook types (i.e., wide gap, aberdeen and baitholder) for bluegill (*Lepomis macrochirus*) and pumpkinseed (*L. gibbosus*) in terms of efficiency, injury and short term mortality. Interestingly, however, circle hooks had an increased propensity to hook bluegill in the eye relative to other hook types (Cooke, Unpublished data). For rock bass (*Ambloplites rupestris*), circle hooks were less injurious than other hook types but had reduced hooking efficiency (Cooke et al., 2003).

Based upon the need to further examine the effectiveness of circle hooks for use in freshwater catch-and-release fisheries, we conducted a study in central Illinois to compare the hooking efficiency, injury, and mortality risk of circle hooks and more conventional octopus hooks. Our objective was to provide management agencies, outdoor media, and tackle manufacturers with credible data to make informed decisions regarding the use of circle hooks in freshwater systems. We used largemouth bass (*Micropterus salmoides*) as a test species based upon their importance as recreational sport-fish in North America and because they are frequently released following capture (e.g., Ostrand et al., 1999). Largemouth bass were also a desirable species for this study in that their gape size is relatively large compared to other freshwater species used in circle hook research to date, giving them a heightened risk for deep hooking.

2. Methods

2.1. Field site and animals

All angling experiments were conducted in experimental ponds (ranging in size from 0.137 to 0.4 ha surface area) at the Sam Parr Biological Station near Kinmundy, IL. The ponds contained natural invertebrate forage and were stocked regularly with fathead minnows (*Pimephales notatus*). Largemouth bass were the dominant predator in the experimental ponds used for this study. Angling was conducted from shore or 3 m docks that extended out in the ponds to a depth of at least 1 m. Experiments were conducted on five separate dates between April 7 and April 19, 2002. During this period, water temperatures ranged from 14 to 23 °C. Previous studies examining the effects of hook type on injury and mortality across a range of water temperatures revealed that water temperature did not significantly influence injury or mortality rates for warm-water fishes (Muoneke and Childress, 1994; Cooke, Unpublished data). Exploratory analysis of our data suggested that this was also the case in our study, so we grouped fish across temperatures.

2.2. Apparatus

For this study, we used two commercially available hook types that are frequently used by anglers to target largemouth bass: circle (size 4, black/chrome, ringed eye, curved in point, model 208408, Gamakatsu Inc.),[1] and octopus (size 2, black/chrome, ringed eye, model 02409, Gamakatsu Inc.) (Fig. 1). By using a size 4 circle hook and a size 2 octopus hook, the overall dimensions of the hooks were matched almost identically as circle hook sizes are categorized differently than conventional hooks. All anglers used small fathead minnows ranging in size from 35 to 55 mm in total length hooked through the lip or the tail. No sinkers or bobbers were used in this study. Anglers used medium action spinning rods and 6 lb test line. Anglers rotated hook regularly to ensure that all participants angled using both hook types.

[1] Mention of trade names does not imply government endorsement.

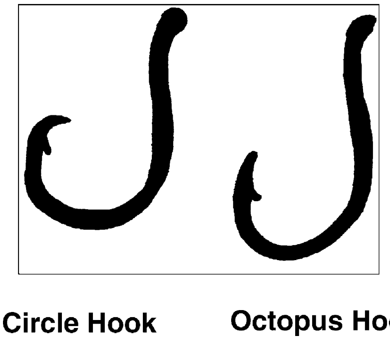

Fig. 1. Line drawings of the two different hook types used in this study. Detailed descriptions of the hook types are included in the text.

2.3. Experimental procedures and meristics

Anglers were instructed to cast the bait into the pond and let the minnow sink for several seconds prior to reeling the bait in slowly. Upon detecting a strike, anglers fishing with octopus hooks were instructed to set the hook whereas those fishing with circle hooks were told to reel in any slack and to apply constant pressure to the line. We standardized the duration of time that the fish was hooked to 15–30 s. This interval was sufficient to ensure that all fish could be easily landed without creating undue exhaustion.

Upon capture, the anatomical location of the hook (upper jaw, lower jaw, side jaw, roof, eye, and gullet) was noted. The location of hook penetration was measured from the anterior aspect of the (lower) lip to the deepest (i.e., most posterior) point of hook penetration (Dunmall et al., 2001). Ease of hook removal was categorized using the slight modifications to the criteria proposed by Cooke et al. (2001). If hemostats were required to remove the hook, the fish was categorized as "difficult". If the removal of the hook was not possible using hemostats without causing substantial injury, the line was cut and the fish were categorized as "not possible". Hooks that were removed by hand with little effort were categorized as "easy". After assessing ease of hook removal, the recorder looked for the presence of blood and recorded responses as either "none" or "some". The fish were also measured for total length (mm). We used total length to size correct the depth of hook penetration, permitting a comparison of hook penetration depth among fish of different sizes (Dunmall et al., 2001). Anglers were queried as to the number of missed strikes or fish that escaped prior to successfully landing the most recent fish. Fish were sufficiently abundant and easy to catch such that patchiness or angler ability were not considered to be important.

Most mortalities resulting from different gear types are immediate and result from hooking in vital organs and/or excessive bleeding (Muoneke and Childress, 1994). For this reason, we did not hold fish to assess short-term or delayed mortality. Instead, using our experience in conducting hooking injury and mortality studies, we assessed the potential mortality risk faced by each fish. Those fish not hooked in a potentially lethal location and that had little or no bleeding were assumed to survive and classified as such. Those that were hooked in a vital organ or bled excessively were considered to be potential mortalities. Following enumeration, all fish except those that died immediately were released into the ponds.

2.4. Analysis

Continuous data were not transformed because they were determined to be normally distributed with homogeneous variances. Homogeneity of variance assumptions were assessed using Levenes test and normality was verified using normal probability plots and the Shapiro Wilks test statistic. Differences in total length, depth of hook penetration, and relative hooking success index values among different hook types were assessed using two-sample *t*-tests.

Categorical data were analyzed with contingency table analysis. For each categorical (dependent) variable of bleeding, anatomical hooking location, and ease of hook removal, the factors included as independent variables in the analysis were hook type. *t*-Tests were used for exploring differences in the sizes and hook penetration depth (continuous variables) of fish that were suspected mortalities versus those that survived. Chi-square analysis was used to test for differences in the distribution of hooking locations, incidences of bleeding, and ease of hook removal (categorical variables) between fish that died versus those that survived. All analyses were conducted using JMP 4.0 (SAS Institute, Inc.). All values reported are means ±

S.E., and the level of significance (∝) for all tests was 0.05.

3. Results

In total we angled 259 largemouth bass ranging in size from 118 to 335 mm. Total lengths of the fish captured by circle hooks ($N = 125$, 205 ± 2.6 mm) were similar to those captured on octopus hooks ($N = 134$, 201 ± 1.9 mm) ($t = 1.220$, $P = 0.224$).

Octopus hooks (0.40 ± 0.079 missed fish) were more efficient at hooking fish than were circle hooks (0.80 ± 0.094 missed fish) ($t = 3.326$, $P = 0.001$) (Fig. 2A). The depth of hook penetration varied among

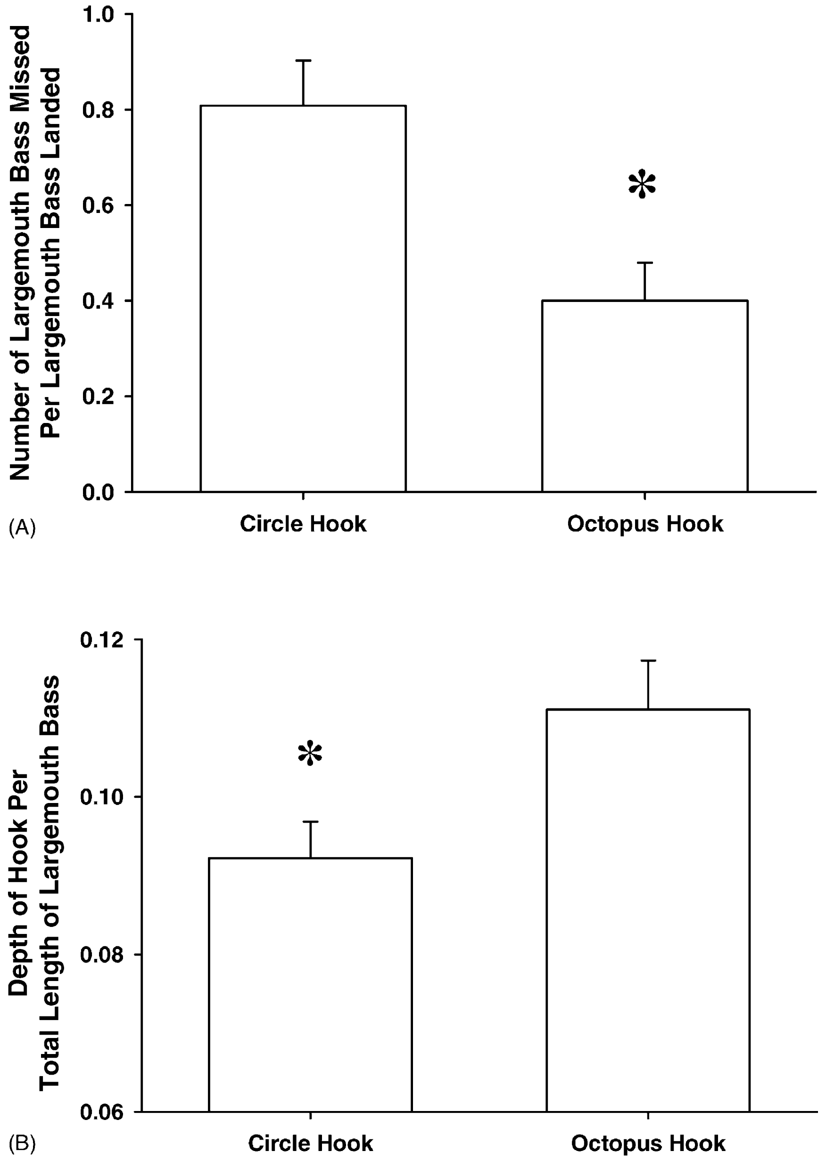

Fig. 2. (A) Number of largemouth bass hooked per largemouth bass missed using circle and octopus hooks. (B) Depth of hook insertion per total length for largemouth bass caught using circle hooks and octopus hooks. The asterisk (∗) indicates significant difference (t-test, $P < 0.05$) between groups.

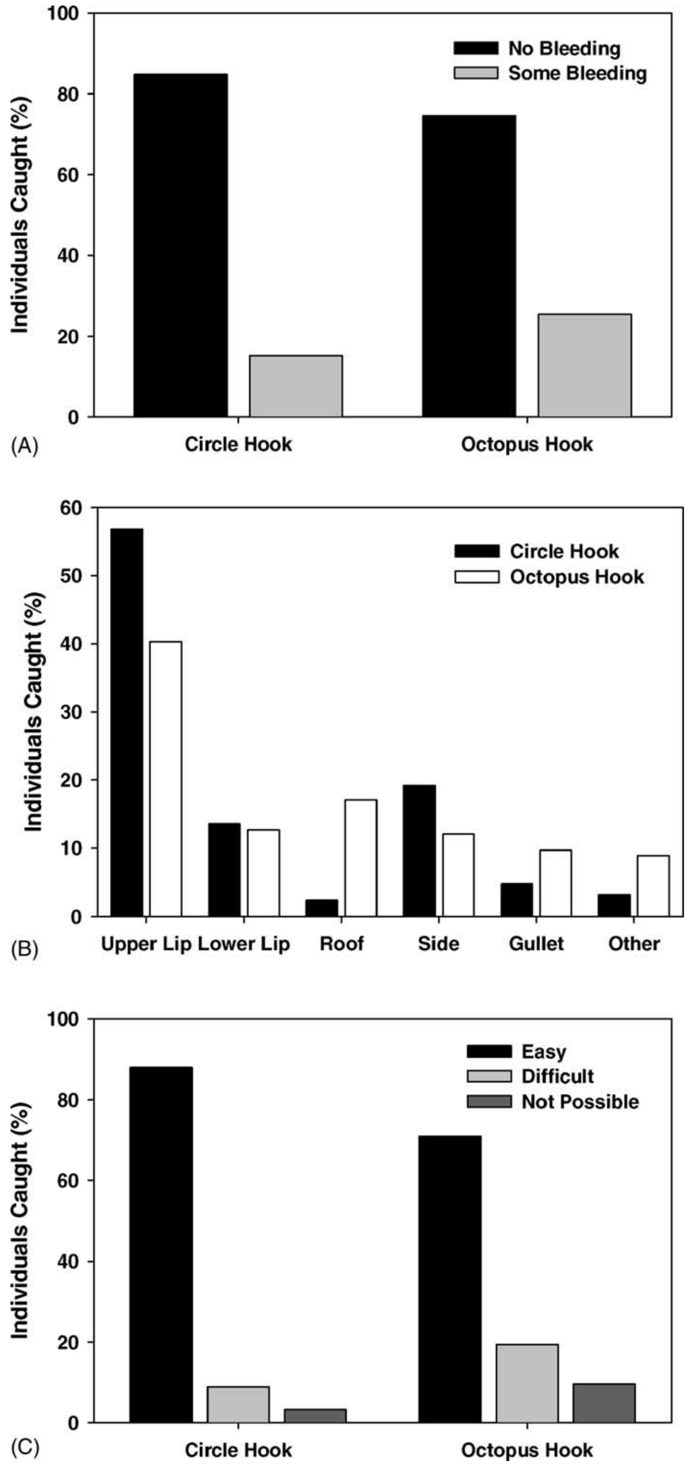

Fig. 3. (A) Comparison of bleeding levels among largemouth bass caught on circle hooks and octopus hooks. (B) Location of hook insertion for 125 largemouth bass caught on circle hook and 134 largemouth bass caught using octopus hooks. (C) Comparison of ease of hook removal for largemouth bass caught on circle hooks and octopus hooks.

hook types with fish captured on circle hooks being hooked less deeply (0.092 ± 0.005) than those captured on octopus hooks (0.111 ± 0.006) ($t = 2.405$, $P = 0.017$) (Fig. 2B).

Incidences of bleeding varied by hook type with those captured on circle hooks bleeding less frequently (15.2% bleeding) than those captured on octopus hooks (25.4% bleeding) ($X^2 = 4.166$, $P = 0.041$) (Fig. 3A). Hooking location was also influenced by hook type ($X^2 = 28.376$, $P < 0.001$) (Fig. 3B). In general, fish were hooked most frequently in the upper jaw (56.8% for circle hooks and 40.3% for octopus hooks). Very few fish captured on circle hooks were captured in the roof of the mouth (2.4%) whereas roof-hooked fish constituted a substantial portion of hooking locations for those captured on octopus hooks (17.2%). Octopus hooks yielded nearly twice as many gullet-hooked fish (9.7%) than circle hooks (4.8%). Ease of hook removal varied significantly with hook type ($X^2 = 11.850$, $P = 0.003$) (Fig. 3C).

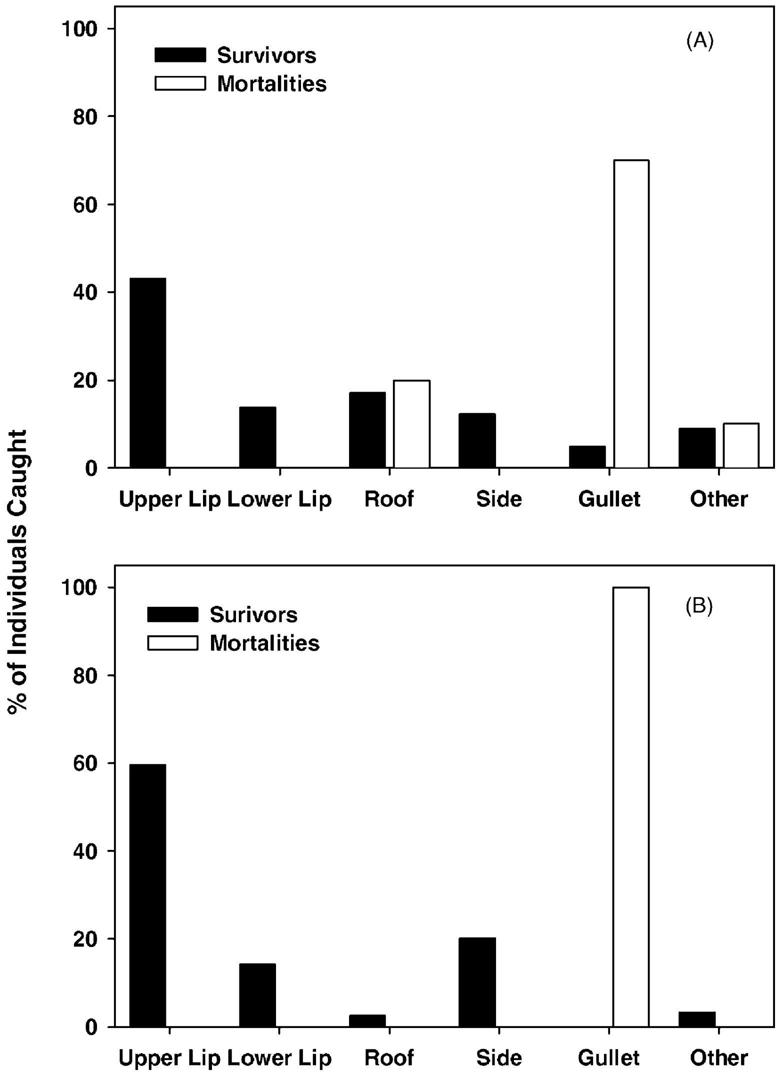

Fig. 4. Differences in hook location for largemouth bass that died and largemouth bass that survived capture using circle (A) and octopus hooks (B).

For both hook types, the majority of hooks were easy to remove (circle, 87.9%; octopus, 70.9%). However, octopus hooks (19.4%) were determined to be difficult to remove more than twice as frequently as circle hooks (8.9%). Similarly, octopus hooks (9.7%) were determined to be not possible to remove three times as frequently as circle hooks (3.2%).

Mortality rates were generally low and did not differ by hook type ($X^2 = 0.819$, $P = 0.365$). Our assessment of mortality risk indicated that 5.1% of fish captured on circle hooks and 6.6% of fish caught on octopus hooks were likely to die. For both hook types, the total lengths of fish that we classified as mortalities did not differ from those classed as survivors ($t_{\text{circle hook}} = 0.344$, $P_{\text{circle hook}} = 0.737$, $\text{TL}_{\text{survivors}} = 205 \pm 2.7$ mm, $\text{TL}_{\text{mortalities}} = 201 \pm 1.92$ mm; $t_{\text{octopus hook}} = 1.296$, $P_{\text{octopus hook}} = 0.197$, $\text{TL}_{\text{survivors}} = 201 \pm 1.8$ mm, $\text{TL}_{\text{mortalities}} = 210 \pm 11.5$ mm). Depth of hooking differed among those fish that died and those that survived for both hook types ($t_{\text{circle hook}} = 10.265$, $P_{\text{circle hook}} < 0.001$, $\text{Depth}_{\text{survivors}} = 0.084 \pm 0.004$,

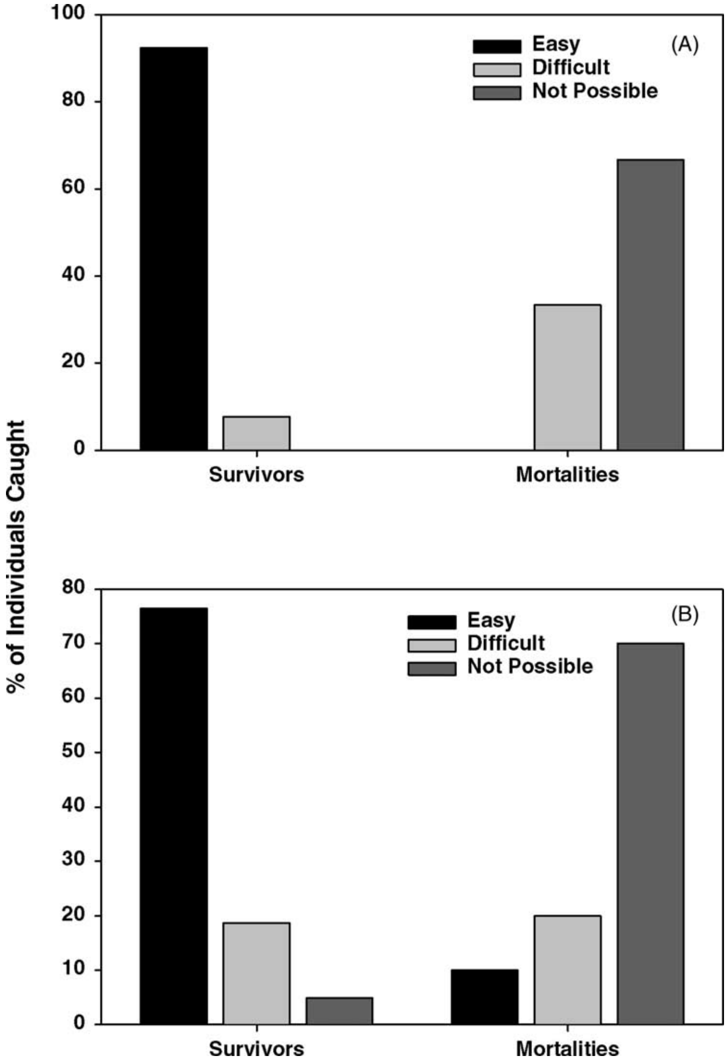

Fig. 5. Differences in ease of hook removal for largemouth bass that died and largemouth bass that survived capture using circle (A) and octopus hooks (B).

$Depth_{mortalities} = 0.248 \pm 0.015$; $t_{octopus\ hook} = 6.432$, $P_{octopus\ hook} < 0.001$, $Depth_{survivors} = 0.101 \pm 0.006$, $Depth_{mortalities} = 0.235 \pm 0.017$). Bleeding was more prevalent in fish that subsequently died (circle = 66.7%, octopus = 100%) than those that survived (circle = 12.6%, octopus = 19.5%) for both hook types ($X^2_{circle} = 8.746$, $P = 0.003$; $X^2_{octopus} = 29.790$, $P < 0.001$). Hooking locations varied significantly among those classified as survivors and mortalities for both hook types ($X^2_{circle} = 48.146$, $P < 0.001$; $X^2_{octopus} = 32.565$, $P < 0.001$) (Fig. 4A and B). Similarly, the ease of hook removal differed significantly among those that were classified as survivors and mortalities for both hook types ($X^2_{circle} = 37.616$, $P < 0.001$; $X^2_{octopus} = 28.003$, $P < 0.001$) (Fig. 5A and B).

4. Discussion

In our study, largemouth bass angled using circle hooks were consistently injured to a lesser extent than largemouth bass captured using more conventional octopus hooks. These results largely reflect the anatomical hooking locations where circle hooks penetrated. Circle hooks rarely penetrated the gullet, the roof of the mouth or other locations such as gill arches and the eyes compared to octopus hooks. The upper lip, lower lip, and side of the lip/cheek (which do not result in substantial bleeding or life-threatening injury when hooked) comprised more than 80% of all hooking locations for circle hooks, but only 65% of hooking locations for octopus hooks. Even higher rates of jaw hooking with circle hooks have been observed in striped bass (*Morone saxatilis*) (Lukacovic, 2000).

The disparity in hooking locations among hook types observed in our study is also reflected in the differences in relative hooking depth. The relative hooking depths noted here for largemouth bass using both hook types (circle, ∼0.09; octopus, ∼0.11) are substantially deeper than values reported for pumpkinseed and bluegill for four hook types including circle hooks (∼0.04 to 0.06) (Cooke, Unpublished data). The interspecific variation in mouth morphology and feeding modes, and resultant variation in hooking depth highlights the difficulty in broadly applying the results observed with one species to others.

Although apparently more difficult to gullet-hook fish with circle hooks, it did occur six times. Octopus hooks resulted in 13 gullet-hooked fish, nearly twice that of the circle hooks. When hooked in the gullet, it was usually not possible to remove the hook. Pelzman (1978) noted that 56% of largemouth bass hooked in the esophageal region using a "J" hook died, most from hemoraging in the pericardial cavity. Skomal et al. (2002) observed that Atlantic bluefin tuna (*Thunnus thynnus*) hooked in the esophageal region often died due to excessive bleeding resulting from cardiac puncture. Fish that were hooked deeply in our study lead us to sever the line and release the fish. Attempts to remove gullet-hooked circle hooks is nearly impossible, and in our opinion, more difficult than the removal of "J" style hooks. Thus, when circle hooks do become gullet-hooked, their removal has the potential to create substantial tissue damage, potentially to vital organs.

Although we did not monitor mortality directly, we did assess mortality risk based upon the methods employed by other circle hook researchers (e.g., Skomal et al., 2002). Overall, mortality of largemouth bass in our study was quite low for both hook types (circle, 5.1%; octopus, 6.6%). These mortality rates are also low relative to other studies of largemouth bass hooking mortality (excluding tournament captured fish) where values have ranged from 0 to 76.9% (May, 1973; Rutledge and Pritchard, 1977; Pelzman, 1978). Most of the circle hook studies in marine systems have observed greater disparity in mortality rates between circle hooks (generally lower) and "J" type hooks (generally higher) (e.g., Caruso (2000), striped bass, circle, 3%, "J", 15.5%; Lukacovic (2000), striped bass, circle, 0.8%, "J", 9.1%; Skomal et al. (2002), Atlantic bluefin tuna, circle, 4%, "J", 28%; Grover et al. (2002), chinook salmon, (*Oncorhynchus tshawytscha*) circle, 31%, "J", 46%). Conversely, the only other freshwater assessment of circle hooks (Cooke, Unpublished data) noted that bluegill and pumpkinseed exhibited negligible mortality on four hook types including circle hooks across a broad range of water temperatures. All of the fish captured on octopus hooks that bled were classified as mortalities where as only 2/3rds of those captured on circle hooks that bled were classified as mortalities. Anecdotally, we observed more tissue damage when we removed circle hooks, even for those classified as easy to remove. However, because circle hooked fish were hooked in non-vital locations, the bleeding was relatively minor.

Of paramount interest to most anglers is the ability to successfully hook and land fish. Because circle hooks differ substantially in design from “J” type hooks, we felt it essential to test the hooking efficiency of these two hook styles. Our results indicate that for every fish landed successfully on a circle hook, ∼0.8 fish would be missed or escape prior to landing. Conversely, octopus hooks would result in ∼50% fewer fish being lost than circle hooks (i.e., ∼0.4 fish lost for every fish landed). Capture efficiencies reported by other researchers are variable among species. Consistent with our results, Orsi et al. (1993) reported that chinook salmon were hooked and landed less frequently with circle hooks than other hook types. However, for striped bass and Atlantic bluefin tuna, capture efficiencies were similar among circle hooks and “J” type hooks (Caruso, 2000; Skomal et al., 2002). In freshwater fisheries, capture efficiencies for bluegill were highly variable among hook types (Cooke, Unpublished data), however, for pumpkinseed (Cooke, Unpublished data) and rock bass (Cooke et al., 2003), circle hooks generally had lower capture efficiencies than other hook types.

Collectively, our results suggest that circle hooks do provide some conservation benefit for largemouth bass. Although mortality rates were similar among hook types, circle hooks resulted in comparatively less injury. Furthermore, the reduced hooking depth minimizes the chance that fish will be hooked in vital organs and may facilitate hook removal. Interestingly, use of circle hooks reduced the number of fish hooked and landed by 50% compared to octopus hooks. Therefore, anglers using circle hooks would catch fewer fish than those using octopus hooks. Because the mortality results were similar among hook types, we cannot provide strong support for adopting the use of circle hooks preferentially over octopus hooks. Because mortality rates did not differ, management agencies must decide if the injury levels are of sufficient concern to advocate the use of circle hooks. Similarly, anglers must weight the minimal conservation benefit of using circle hooks with the reduced number of fish that they will capture when using that hook style.

Our research is somewhat contradictory to the growing body of marine literature that shows immense benefit from using circle hooks (Lukacovic, 2000; Prince et al., 2002; Skomal et al., 2002). Our research presented here, coupled with other freshwater research on circle hooks (Cooke et al., 2003; Cooke, Unpublished data) suggests that circle hooks may not be the panacea suggested by many tackle manufacturers and outdoor media outlets. Indeed, interspecific variation may also play an important role in determining the effectiveness of different hook types. We advocate continued research into different hook designs and urge comparative studies of different hook types prior to widespread adoption of untested terminal tackle.

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