Management and Ecological Note

Effects of hook type on injury and capture efficiency of rock bass, *Ambloplites rupestris,* angled in south-eastern Ontario

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The injury rates, hooking efficiency, and mortality in rock bass, *Ambloplites rupestris* Rafinesque, angled using circle hooks and three conventional hook types were compared. Circle hooks have only recently been introduced to recreational fisheries and differ substantially from other hook designs. Unlike conventional hooks, the point of a circle hook bends back towards the shank of the hook such that the point is perpendicular to the shank. Circle hooks have been touted by angling media, conservation organizations and tackle manufacturers as effective tools for minimizing injury and mortality of fish while maintaining capture efficiency (Montrey 1999; Stange 1999). The basic premise behind circle hook use is that the orientation of the hook point will prevent deep hooking, yielding high jaw hooking rates consistent with minimal injury and mortality. Empirical assessments of this premise are lacking, especially in freshwater systems (Cooke, Suski, Barthel, Ostrand, Tufts & Philipp, in press). Because of the interspecific variation in feeding mode, mouth morphology, gape size and angling techniques, it is necessary to examine the performance of circle hooks relative to other hook types to determine if the use of circle hooks should be advocated as a conservation measure. In this study, rock bass were used because of their frequency of capture in recreational fisheries, coupled with their high rates of release as a result of low food value (Cooke, Philipp, Dunmall & Schreer 2001).

All fish were angled from Lake Opinicon, Ontario, between 18 May and 15 June 2001. During that time, water temperatures ranged from 18 to 26 °C, but previous studies examining the effects of hook type on injury and mortality in some confamilial species (bluegill *Lepomis macrochirus* Rafinesque and pumpkin seed *L. gibbosus* L.) revealed that water temperature did not significantly influence injury or mortality rates across the range of water temperatures examined (Cooke *et al.* in press). For this reason, the influence of temperature on injury rates was not examined. Four commercially available hook types that are frequently used by anglers to target rock bass were used: baitholder hook (size 6, bronze, offset, down eye, model 3181UK, Eagle Claw Inc.), Aberdeen hook (size 6, gold, light wire, ringed eye, model 3202UK, Eagle Claw Inc.), circle hook (size 6, black/chrome, curved in point, mutu light, model 5114–051, Owner Inc.), wide bend (size 6, bronze, plain shank, offset, ringed eye, model L042, Eagle Claw Inc.). All anglers used the same organic bait (Crappie Nibbles, silver glitter, Berkley Inc.), and all anglers fished for equal lengths of time using all different hook types. The duration of time the fish was angled was standardized to 15–30 s.

Upon capture, several different response variables were recorded. 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 penet-

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ration (Dunmall, Cooke, Schreer & McKinley 2001). Ease of hook removal was categorized using slight modifications to the criteria proposed by Cooke *et al.* (2001), and was categorized as either easy or difficult. After assessing ease of hook removal, the recorder examined the fish for the presence of blood (categorized as either none or some) and recorded the fish's total length in millimetres. Anglers then recorded the number of casts required before a fish was successfully hooked. This was termed the relative hooking difficulty index, and relative hooking difficulty values indicate that a particular hook is catching more fish relative to the number of losses. The index was reset to zero when the angler successfully landed a fish.

Most mortalities resulting from different gear types are immediate and result from hooking in vital organs and/or excessive bleeding (Muoneke & Childress 1994). For this reason, fish were not held to assess short-term or delayed mortality. Instead, using past experience in conducting hooking injury and mortality studies, the potential mortality risk faced by each fish was assessed. Those that were hooked in a vital organ or bled excessively were considered to be potential mortalities.

Differences in total length, depth of hook penetration, and relative hooking difficulty values among different hook types were compared using a one-way analysis of variance (ANOVA) followed by a Tukey *post hoc* test. Categorical data were analysed with contingency table analysis. For each categorical (dependent) variable of bleeding, anatomical hooking location, and ease of hook removal, the independent variable in the contingency analysis was hook type. All analyses were conducted using JMP 4.0 (SAS Institute, Inc.) and the level of significance (α) for all tests was 0.05.

Ninety-one rock bass ranging in size from 93 to 271 mm (mean among all groups = 193.7 ± 4.6 mm SE) were caught (Table 1), and the mean total length of rock bass captured using the different hook types was not statistically different (ANOVA, $F = 0.759$, d.f. = 87, $P = 0.520$). Conversely, the relative hooking difficulty was influenced by hook type (ANOVA, $F = 7.711$, d.f. = 87, $P < 0.001$). Fish captured on circle hooks were nearly twice as difficult to hook than all other hook types (Tukey, $P < 0.05$).

Anatomical hooking location varied by hook type ($\chi^2 = 17.110$, d.f. = 87, $P = 0.047$). Circle hooks were hooked in the jaw 76% of the time, higher than all other hook types. However, for all hook types, the jaw was the most common hooking location. Among all hook types, the second most commonly hooked location was the roof of the mouth. Only the circle hook and wide gap hook never hooked fish in vital organs, the eye or the gullet. Despite variation in anatomical hooking location, incidences of bleeding were uniformly low among hook types ($\chi^2 = 6.692$, d.f. = 87, $P = 0.082$). No bleeding was observed for any fish captured on widegap and circle hooks, whereas, 13% of fish captured on Aberdeen hooks and 5% of fish captured on baitholder hooks exhibited bleeding. Bleeding was usually associated with gullet hooking and eye hooking.

Relative hooking depth varied among hook types (ANOVA, $F = 3.676$, d.f. = 87, $P = 0.015$). Baitholder hooks were hooked more deeply than circle hooks (Tukey, $P < 0.05$). Consistent with variation in hooking depth, ease of hook removal also varied by hook type ($\chi^2 = 7.922$, d.f. = 87, $P = 0.048$). Circle hooks were deemed to be the easiest to remove, and were only categorized as difficult in one instance. Other hook types were categorized as difficult to remove 14% (wide gap) and 29% (Aberdeen and baitholder) of the time. The assessment of mortality potential for fish captured using different hook types did not identify any fish with sufficient injuries that would likely manifest themselves in death (i.e. no major bleeding as a result of cardiac puncture or rupture of gill arches). The fish hooked in the gullet were not characterized as potential mortalities because the hook was always oriented upwards and away from the pericardial cavity. The hook was not removed from all gullet hooked fish, as has been suggested elsewhere. For example, Cooke *et al.* (2001) did not remove gullet hooked jigs from four rock bass and did not observe mortality in any of these fish over a 72-h retention period.

Circle hooks have been identified as a potential conservation tool for minimizing injury and mortality rates in freshwater and particularly marine recreational fisheries. Results from this study suggest that there are clear conservation benefits from angling rock bass using circle hooks, similar to Atlantic bluefin tuna, *Thunnus thynnus* L. (Skomal, Chase & Prince 2002), striped bass, *Morone saxatilis* Walbaum (Caruso 2000), and chinook salmon, *Oncorhynchus tshawytscha* Walbaum (Grover, Palmer-Zwahlen & Mohr 2002) fisheries. The only other study on circle hooks in freshwater systems (Cooke *et al.* in press) determined that there were no benefits from using circle hooks for bluegill and pumpkinseed. Those authors suggested that the size of the circle hook (same as used in this study, no. 6) may have been too large to function properly for those species. The mouths of rock bass are larger than those of bluegill and pumpkinseed, which may explain the performance of circle hooks in this study. Circle hooks were found to be the easiest to remove due to shallow hooking depth and frequent jaw hooking. Since the time for cardiac parameters to recover from angling disturbance is correlated positively

Table 1. Characteristics of rock bass captured using four different hook types. Total length, relative hooking depth and relative hooking difficulty are presented as means ($\pm$ SE) and dissimilar symbols indicate significant differences. Incidences of bleeding, ease of hook removal, and anatomical hooking location are presented as frequency of occurrence in percentage

Parameter	Aberdeen hooks	Baitholder hooks	Circle hooks	Wide Gap hooks
n	24	21	25	21
Total length (mm)	195* (9)	182* (10)	197* (9)	201* (10)
Relative hooking depth	0.048*,† (0.010)	0.084† (0.011)	0.036* (0.010)	0.059*,† (0.011)
Relative hooking difficulty	1.5* (0.3)	1.1* (0.3)	3.0† (0.3)	1.1* (0.3)
Incidence of bleeding (%)	None, 87	None, 95	None, 100	None, 100
	Some, 13	Some, 5	Some, 0	Some, 0
Ease of hook removal (%)	Easy, 71	Easy, 71	Easy, 96	Easy, 86
	Difficult, 29	Difficult, 29	Difficult, 4	Difficult, 14
Anatomical hooking location (%)	Jaw, 71	Jaw, 71	Jaw, 76	Jaw, 52
	Roof, 21	Roof, 10	Roof, 24	Roof, 48
	Eye, 4	Eye, 5	Eye, 0	Eye, 0
	Gullet, 4	Gullet, 14	Gullet, 0	Gullet, 0

with air exposure duration during hook removal (Cooke *et al.* 2001), the reduced handling time that results from the use of circle hooks would facilitate recovery in rock bass. Mortality was negligible for rock bass angled across a range of water temperatures (18–26 °C) using four hooks types, as was also observed by Cooke *et al.* (2001) for rock bass captured on barbed and barbless, plastic jigs and worms at 16 °C. However, because circle hooks resulted in significantly higher hooking difficulty (roughly twice as high as other hook types) relative to other hook types, it is unlikely that most anglers would voluntarily adopt the use of circle hooks for this or other similar species. Thus, consistent with other marine studies, circle hooks do have the potential to minimize injury and thus potential mortality for rock bass, however, the reduced capture efficiency will likely make these hooks less desirable to anglers.

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