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Influence of hook type and live bait on the hooking performance of inline spinners in the context of catch-and-release brook trout *Salvelinus fontinalis* fishing in lakes

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ABSTRACT

The objective of catch-and-release angling is for the fish to survive with minimal fitness consequences. However, fish survival can be compromised by a number of factors, especially anatomical hooking location. To evaluate whether hook type or bait influence hooking outcomes, we tested different combinations of hook (treble or single siwash hooks) and bait (hook tipped with worm or no worm) while angling for brook trout (*Salvelinus fontinalis*) with inline spinner-style fishing lures. The study was conducted at spring water temperatures (~20 °C) in small lakes stocked with trout in southwestern Quebec, Canada. Incidences of hooking in the interior of the mouth (i.e. internal hooking) were uncommon (19%), did not differ significantly between hook types or bait treatments, and occurred independently of fish size. Reflex impairments after hook removal were not related to hook or bait treatment. Short-term mortality was quantified with 24 h holding in net pens and was determined to be infrequent for all treatment groups (treble/worm: 6%; treble/no worm: 5%; single/worm: 2%; single/no worm: 0%). Although no fish were hooked in the gills, esophagus, stomach, odds of mortality increased by 14.21 when fish were hooked internally, which is consistent with the position that hook placement is an important predictor of the fate of fish released by anglers. However, our finding that neither hook nor bait type significantly increased the odds of internal hooking, bleeding, reflex impairment, or mortality in this study suggests that restrictions imposed on the use of baited lures or certain hook types attached to lures when fishing may have little influence on short-term catch-and-release mortality of brook trout at these temperatures.

1. Introduction

Recreational angling is popular throughout the world (Arlinghaus et al., 2015) with many anglers practicing catch-and-release (C&R) voluntarily or to comply with fishing regulations (Cooke and Cowx, 2004). However, the fate of released fish is often unknown, making it unclear if releasing fish is an effective management or conservation strategy (Cooke and Schramm, 2007). By quantifying C&R mortality as well as potential sublethal consequences (e.g., injury, stress, reflex impairment), it is possible to determine the sustainability of angling practices and refine them such that mortality and fitness impairment among released fish is suitably low (Arlinghaus et al., 2007; Cooke et al., 2013a).

Angling gear, fishing or handling techniques (i.e., active or passive angling, handling time, internal hook removal), and environmental conditions (i.e., capture depth, water temperatures) are all important factors that can contribute to mortality in C&R fisheries (Arlinghaus et al., 2007; Bartholomew and Bohnsack, 2005; Cooke and Suski, 2005). The proximate factor most linked to fish mortality is hooking in critical anatomical locations, including the gill arches, eyes, esophagus, and highly vascularized regions of the mouth interior (Bartholomew and Bohnsack, 2005; Fobert et al., 2009; Muoneke and Childress, 1994; Nuhfer and Alexander, 1992; Pauley and Thomas, 1993; Schisler and Bergersen, 1996). Although

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hooking in critical locations may not cause immediate mortality, it can exacerbate the physiological stress response and/or hinder recovery resulting from angling and handling stresses. The physiological stress response to angling is a significant consideration in C&R (Cooke et al., 2013b; Wedemeyer and Wydoski, 2008), the effects of which can be approximated by conducting reflex impairment tests that provide an index of fish vitality. Reflex impairment tests such as reflex action mortality predictors (RAMP) can be calibrated for individual species to predict survival from fisheries encounters (Davis and Ottmar, 2006; Raby et al., 2012). Understanding how gear types influence hooking location and resulting impairments in fishes can contribute to informed guidelines for regulations imposed on recreational fisheries (Arlinghaus et al., 2007).

Recreational anglers target salmonid fishes across the world. Given the economic value of salmonids and their variable conservation status, there has been extensive research on the effects of C&R, particularly for freshwater trout in lotic environments (e.g. Nuhfer and Alexander, 1993; Pauley and Thomas, 1993; Schill, 1996; Schisler and Bergersen, 1996). However, trout also inhabit lakes, which have unique hydrographic conditions that can affect fish ecophysiology, behaviour, feeding, and by extension recreational fishing (Higham et al., In Press). Brook trout (*Salvelinus fontinalis*) inhabit lakes and ponds throughout Eastern North America and have been introduced around the world (MacCrimmon and Campbell, 1969). Despite their distribution and abundance having drastically declined due to habitat loss, atmospheric changes, and overexploitation, brook trout remain a recreationally important species exposed to a relatively high degree of C&R (Detar et al., 2014; Hudy et al., 2008). Knowing the extent to which C&R results in mortality of fish is important for population modeling and thereby for fisheries management (Risley and Zydlewski, 2010); however, Hühn and Arlinghaus (2011) suggested that gear-specific research is lacking for this species. To examine the extent to which actively fished inline spinner-type lures (a common lure style for catching trout) contribute to short-term injury, impairment, and mortality of brook trout in such C&R settings, we fished for brook trout with spinners fitted with either treble or single hooks that were either baited or unbaited. Treble hooks are larger and presumably cannot be ingested as deeply as single hooks, but have more points of contact with the fish than single hooks, potentially increasing the likelihood of injury. Therefore, we predicted that fish captured by single hooks would have more instances of internal hooking than treble hooks but less instances of bleeding. Given that other C&R studies generally show that natural bait is ingested more deeply than artificial lures (e.g., Arlinghaus et al., 2008), we expected that trout captured by unbaited hooks would exhibit less internal hooking and bleeding. Finally, we expected reflex impairment and mortality to increase with injury and that treble hooks and baited hooks would result in more frequent reflex impairment and mortality relative to other treatments.

2. Methods

2.1. Study site

Angling was conducted at the Kenauk Nature Reserve near Montebello, Quebec, Canada in Lakes Jackson, L'Orignal, Collins, and de la Montagne (approximate coordinates: 45.7°N, 74.9°W). All lakes were stocked with brook trout from fish hatcheries near Mont-Tremblant, Quebec. Brook trout were angled from rowboats across the entire lake. Data collection took place on eight different days in June 2015 at surface water temperatures of 20.0 ± 1.5 °C (mean ± SD, range = 17.8–23.0 °C).

2.2. Equipment

Two hook types were fished with and without bait to test the influence of gear on hooking location. Hooks were either a treble or a single siwash-style hook on an inline spinner lure. All hooks were barbed, which reflected the common practice of recreational anglers in the region. For the baited treatments, hooks were bare or baited with ~2 cm of live earthworm. Medium-light action spinning rods were fished with 2.7 kg break strength monofilament fishing line. All anglers used either size 2 Blue Fox Vibrax (Rapala VMC Corporation, Helsinki, Finland), size 3 Panther Martin (Harrison-Hoge Industries Inc., Port Jefferson, New York, USA), or Mepps (Sheldons', Inc., Antigo, Wisconsin, USA) spinner lures in a variety of colours with no additional weight. The lures were of similar dimensions and of the same hook size (i.e., size 6 for treble and Siwash hooks).

2.3. Angling procedures

To capture brook trout, anglers either trolled the lures behind slowly moving rowboats or actively casted. Actual speed of movement of the lures through the water was similar between both fishing techniques. When a fish struck the lure, anglers set the hook using a sweeping lateral movement of the rod. Trout were landed in a knotless mesh net and transferred to a cooler filled with water to minimize air exposure (<10 s). We recorded fight time (s), total length (mm) and hooking location during transfer to the cooler. Anglers removed hooks with haemostats or pliers. Hook wounds were inspected and any bleeding was noted. After hook removal, RAMP was assessed (Davis and Ottmar 2006; Raby et al., 2012). The components of the RAMP test that were used were tail grab, body flex, and orientation (i.e. righting reflex), because these are often the best indicators of fish vitality in C&R scenarios (Brownscombe et al., 2013; Lennox et al., 2015a). The trout were then tagged with individually numbered plastic t-bar anchor tags and transferred into $0.9 \times 0.9 \times 0.9$ m floating net pens that held up to 15 fish or $1.2 \times 1.2 \times 1.2$ m net pens that held up to 30 fish (maximum fish density of 1 fish per 0.06 m^3) for 24 h to observe short-term mortality (hereafter referred to as mortality). Fish from both treatments were mixed in the net pens. After 24 h, tags were removed from surviving fish before they were released back into the lake.

2.4. Analyses

Analyses were conducted using R (R Core Team, 2014) statistical software. Multiple logistic regression was used to analyze the effects of hook type, bait, fish length and fight duration on the occurrence of internal hooking, bleeding and mortality as well as the degree of reflex impairment. Although fight duration can increase with body size, we found that fight duration and fish length were not collinear ($R^2 = 0.07$), therefore both variables were included in the analysis of bleeding, reflex impairment and mortality.

Hooking location data from 44 trout were missing because the hook was shaken out by the fish upon capture, therefore these individuals were excluded from statistical analyses. Hooking locations were categorized as either internal (tongue, eye, nare, gullet, inner roof of mouth, and gills) or superficial (upper, lower, and side of jaw). Hooking in the jaw is generally held to be non-invasive, easy to remove, and an area of limited vascularization compared to the internal buccal cavity where highly vascular muscle and tissue as well as organs can be pierced by hooks, prolonging unhooking time and increasing tissue damage and injury. Given small sample sizes of fish with multiple impaired reflexes, reflex impairment scores were divided into groups of fish that were unimpaired (RAMP = 0) and impaired (RAMP = 1–3) upon capture. Finally, hooking mortality estimates were generated for all brook trout captured. Fourteen trout disappeared from the net pens overnight; they may have