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Short communication

Injury and immediate mortality associated with recreational troll capture of bull trout (*Salvelinus confluentus*) in a reservoir in the Kootenay-Rocky Mountain region of British Columbia

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ABSTRACT

We evaluated hooking injury and immediate mortality arising from capture of troll-caught adult bull trout (*Salvelinus confluentus*) in a reservoir in the Kootenay-Rocky Mountain region of British Columbia in the spring (water temperature 2–15 °C) where regulations enabled anglers to use both barbed and barbless hooks. We captured 126 bull trout on lures and only a single mortality occurred (0.79% immediate mortality rate). Most bull trout maintained equilibrium and those that lost equilibrium were fought for significantly more time ($p = 0.03$). Overall, approximately 79% of fish were hooked in the mouth. Nearly 16% of fish were foul hooked, which was independent of the number of hooks ($p = 0.76$) and troll speed ($p = 0.08$). Although not statistically related to troll speed, foul hooking occurred in nearly 90% of those captured at faster speeds (i.e., ≥5.3 kph). The depth that hooks swallowed was not influenced by trolling speed or the number of hooks ($p > 0.05$ in all cases). Incidences of bleeding were lowest among single barbless hooks (10%) but did not significantly differ from the other hook configurations (∼18%). To our knowledge, this is the first study that examines such hook type issues in freshwater troll fisheries and the first published estimate of hooking mortality for bull trout, a species that is considered imperilled throughout much of its range. Although immediate mortality was very low, the high incidence of bleeding and foul hooking warrant further investigation into the impacts of different recreational fishing practices on short-term and delayed mortality of bull trout, especially for imperilled populations.

1. Introduction

Bull trout (*Salvelinus confluentus*) are a popular recreational sportfish endemic to the western United States and Canada (Cavender, 1978; Goetz, 1989). However, the species is imperilled throughout much of its range and both it and its habitats are afforded a variety of protection by state, provincial and federal legislation (Rieman et al., 1997; Federal Register, 1998; Lohr et al., 2000; Post and Johnston, 2002). There are a number of threats to bull trout populations including habitat alteration and introduced species (Bond, 1992; Rieman and McIntyre, 1993; McPhail and Baxter, 1996), but one of the least studied threats is recreational fisheries exploitation. In many recreational fisheries harvest regulations intended to reduce angling exploitation requires that some or all bull trout are released (Post et al., 2003). In addition, many anglers retain a strong conservation ethic and routinely practice catch-and-release (Arlinghaus et al., 2007). A key assumption of both mandatory and voluntary catch-and-release is that the majority of the fish survive with minimal negative consequences arising from the angling event (Wydoski, 1977; Cooke and Schramm, 2007).

While hooking induced mortality is routinely considered as a potential threat to the recovery of depleted bull trout populations (Post and Johnston, 2002; Paul et al., 2003), there are no peer reviewed studies that quantify hooking injury and immediate mortality for adult bull trout. Some consulting reports have attempted to estimate angling related mortality, but this was not the primary purpose of the research activity and there is little information upon which to judge the credibility of the estimates. For example, Clayton (1998) estimated hooking mortality of bull trout in a Montana river to be 5%. Alarmingly, modeling exercises have revealed that even low hooking mortality rates (i.e., ≤10%) would be sufficient to cause local extirpation of bull trout populations (Post and Paul, 2000). Knowledge of real hooking induced injury and morality for bull trout would be useful for determining the risk of different levels of angling effort.

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There are a number of factors that have the potential to influence the fate (e.g., long-term injury, growth depression, or death) of fish following an angling event including hooking location and depth, duration of air exposure and water temperatures [reviewed in Bartholomew and Bohnsack (2005) and Cooke and Suski (2005)]. To address deep hooking issues, managers have used gear regulations that restrict the use of organic baits, limiting anglers to artificial flies or lures. In addition, other gear restrictions such as the use of barbless single hooks are common. Although barbless hooks often reduce injury and handling time, there is little evidence of a direct reduction in hooking mortality from their use (Taylor and White, 1992; Schill and Scarpella, 1997). Moreover, most of the studies that have led to the broad application of barbless single hooks have focused on small salmonids (see Taylor and White, 1992), often in hatchery or stream environments where fish are targeted by actively casting. While casting is a popular activity for larger lentic-dwelling populations of salmonids (e.g., Holtby et al., 1992), it is also common to troll using artificial lures. Furthermore, there have been relatively few studies that have examined different hook type (i.e., barbed vs. barbless, single vs. multiple hooks) issues in freshwater trolling-based fisheries (see Dedual, 1996).

We evaluated hooking injury and immediate mortality arising from capture of troll-caught adult bull trout in a reservoir in the Kootenay-Rocky Mountain region of British Columbia. Gear regulations in this area are somewhat unique because they enable anglers to use both barbed and barbless hooks and up to two single or treble hooks. Currently only streams are restricted to the use of single barbless hooks in British Columbia, whereas elsewhere it is typical to find bull trout fisheries that restrict anglers to single barbless hooks, particularly in lotic systems. We focused on injury and immediate mortality because the methods needed to generate delayed mortality estimates [e.g., external telemetry tags (Donaldson et al., 2008) or net pens (Pollock and Pine, 2007)] for wild adult bull trout were logistically difficult, and obtaining control fish using other capture methods was not possible. Assessing injury and immediate mortality is important, however, since these metrics provide the first clear indications of the possible long-term consequences of catch-and-release and post-release mortality, e.g., pulsatile blood flow (Arlinghaus et al., 2007). Here we provide the first estimate of hooking mortality for bull trout and examine whether the type of hooks, the number of hooks, trolling speed, hooking depth, and fight duration had any effects on bleeding, foul hooking, hooking depth, and equilibrium. Collectively, data emanating from this study have the potential to inform management of these popular but imperilled sportfish and to provide anglers with strategies for reducing injury and mortality, thus improving the welfare status of angled fish (Cooke and Sneddon, 2007).

2. Methods

All bull trout used in this study were captured from Kinbasket Reservoir (52° 8′ N, -118° 28′ W) in the north Kootenay-Mountain region of British Columbia. Kinbasket Reservoir is a large glacial and snowmelt fed impoundment of the Canoe and Columbia Rivers of British Columbia. Most of the land area was logged prior to flooding; however, stumps and scattered stands of timber still remain in the confluence and in many of the larger tributaries. The resultant habitat, including larger permanent tributaries and the deep pelagic zone, are suitable for several species of salmonids, including: bull trout, rainbow trout (*Oncorhynchus mykiss*), and kokanee (*Oncorhynchus nerka*). The mean depth of the reservoir varies seasonally as a result of the large drawdown which can change the reservoir elevation by as much as 47 m (RL & L 2001). Surface water temperatures recorded at the Mica Dam on Kinbasket Reservoir were typical of the post ice-out period and ranged from approximately 2 °C in early April to 15 °C by the end of May.

We used angling practices that reflect common techniques used during a spring salmonid troll fishery in this region. A spring sampling season was chosen because trolling capture rates are known to be highest at this time of year when fish are generally found near the surface and thus easily targeted (J. Tippe, local guide, personal communication). To capture bull trout, three similarly skilled anglers monitored three lines that were trolled during daylight hours between April 11 and May 25, 2010. Trolling speeds were consistent between a relatively slow (<5.3 kph) and fast troll (≥5.3 kph). Bull trout were targeted sub-surface to 10 m using rods equipped with 15 lb monofilament line, clip-type trolling weights that ranged from one to six oz., 8–13 cm minnow-shaped hard plug lures (e.g., Lyman plugs), fitted with one or two # 4/0 single hook(s).

Hooked bull trout were brought to the boat, landed in a rubber net, and placed into a 100 L cooler filled with fresh lake water. The fight duration from the moment a bull trout was hooked to time it was placed in the cooler was recorded for each fish. Since higher trolling speed might result in more foul hooking events (J. Tippe, local guide, personal communication), we also recorded the trolling speed at the time of hooking. Foul hooking was defined as hook entry through the exterior of any part of the body. Bleeding status at the hooking site was noted as absent, present (i.e., minimal bleeding), or pulsatile (i.e., heavy bleeding). We then removed the hook(s) and checked whether the fish could maintain equilibrium (denoted as yes/no). Bull trout were anesthetised (40 mg of clove oil/L, emulsified with 9 parts ethanol to 1 part clove oil), at which time hooking depth (mm), hooking location, and total length (mm) were measured. Hooking depth was recorded as the distance from the anterior aspect of the lower lip to the furthest point the hook was swallowed. Anatomical hooking location was categorized as upper jaw, lower jaw, corner jaw or other (e.g., eye, operculum, head, or body). Surviving fish were eventually released following full recovery from the aesthetic.

To assess the role of hook type on bull trout injury and mortality, we trolled lures (Lyman Lures, Kelowna, BC) with different hook types (barbless or barbed) and number (one hook or two hooks) including single barbless, double barbless, single barbed, and double barbed. It is worth noting that not each hook type/combination was fished equally so we were unable to evaluate the capture efficiency of different hook types. Hooking depth could not be measured in one case because the wound could not be found in a reasonable amount of time.

2.1. Data analysis

To test if the type of bleeding (absent/minimal/pulsatile) could be predicted by the hook type and hook number, we used a Generalized Linear Model with a multinomial distribution. We also used a GLM with a binomial distribution to test if troll speed [slow (<5.3 kph) or fast (≥5.3 kph)] and hook number (one/two) could be used to predict whether foul hooking would occur. Since we believed hooking depth could be affected by the speed of retrieval and deep hooking in the mouth could lead to gill damage and eventual mortality, we also evaluated the effects of trolling speed and hook number on arcsine square-root transformed length-corrected hooking depth (hooking depth/total length; Dunmall et al., 2001) with a two-way Anova. This analysis did not include foul hooked fish. Finally, a GLM with a binomial distribution was used to test whether longer fight times and the occurrence of foul hooking could predict whether fish lost equilibrium. All tests were computed using the software package Statistica© v8.0 (StatSoft. Inc., Tulsa, OK). Tests were considered significant at $p < 0.05$. All values are presented as means ± 1 standard error unless otherwise indicated and references to sample size are denoted as *n*.

3. Results and discussion

We captured 126 bull trout in 21 days of trolling in Kinbasket Reservoir. Fight times averaged 128 ± 4.8 s and total lengths ranged from 434 to 881 mm with a mean of 620 ± 7.36 mm. Only one fish died, which was likely due to massive blood loss from a hooking injury to the gills. One death yielded an immediate mortality estimate of only 0.79%. Although this is too low an estimate to warrant further evaluation, these results still reflect the existing catch-and-release literature, where mortality or a reduction in the likelihood of survival was often associated with a hooking injury to the gill and the resultant blood loss (e.g., Pelzman, 1978; reviewed in Bartholomew and Bohnsack, 2005). Although we attempted to revive the fish, it failed to recover from anaesthesia and surgery. In this study, all fish were subject to anaesthesia and intracoelomic implantation of telemetry transmitters which represents a series of additional stressors on top of the capture and handling components of catch-and-release. As such, the immediate mortality estimate that we derive should be considered as liberal. Interestingly, a mortality rate of <1% represents one of the lowest mortality rates observed for any freshwater fish (Reviewed in Muoneke and Childress, 1994; Bartholomew and Bohnsack, 2005; Arlinghaus et al., 2007), and particularly low for salmonids (Taylor and White, 1992). One of the only other studies to evaluate immediate hooking mortality for lentic salmonids captured while trolling revealed that mortality rates ranged between 0 and 11.5% for four different trolling methods targeting rainbow trout in Lake Taupo, New Zealand (Dedual, 1996). Although none of the techniques are directly comparable to those used in the present study, they emphasize that subtle differences in technique can alter mortality estimates. In the Dedual (1996) study, the variation in mortality among techniques was attributed primarily to barotraumas, with fish captured using harling (i.e., trolled flies) techniques on the surface having no mortality and those captured at depths exceeding 35 m via downrigger experienced 12.5% immediate mortality. Fish in the present study were captured at depths of 10 m or less which is on the shallow side of the depth ranges used in the Dedual (1996) study.

We were only able to locate one other estimate of hooking mortality for bull trout and that value emanated from a non-peer reviewed study from Alberta where lotic fish were captured by angling and then radio tracked to evaluate survival (Clayton, 1998). In that study, mortality was estimated to be approximately 5%, or 5 times higher than the estimate in this study. However, because our sampling was conducted in the spring, the water temperatures could be considered low to moderate for bull trout (Selong et al., 2001). As such, it is reasonable to expect that in other systems where temperatures were warmer, or during other seasons in this system, mortality may be higher (Cooke and Suski, 2005). It is probably reasonable to assume that hooking mortality estimates generated for bull trout captured while trolling on lures are unlikely to be representative of hooking mortality estimates generated for bull trout captured via casting in lotic systems given the typical difference in lure size and configuration (i.e., casting typically would use smaller lures). Indeed, it may be more appropriate to rely on values from congenerics or confamilials [(brook charr (*Salvelinus fontinalis*; Nuhfer and Alexander, 1992), white-spotted charr (*Salvelinus leucomaenis*; Tsuboi et al., 2006) and lake charr (*Salvelinus namaycush*; Lee and Bergersen, 1996) or the confamilial rainbow trout (*Oncorhynchus mykiss* Klein, 1965) and cutthroat trout (*Oncorhynchus clarkii*; Hunsaker et al., 1970)] when seeking hooking mortality estimates for bull trout in streams.

Immediate post-capture bleeding (overall 32% of fish bled) in this study exceeded that typically observed in other studies (reviewed in Muoneke and Childress, 1994; Bartholomew and Bohnsack, 2005). Bleeding is often associated with hook type,

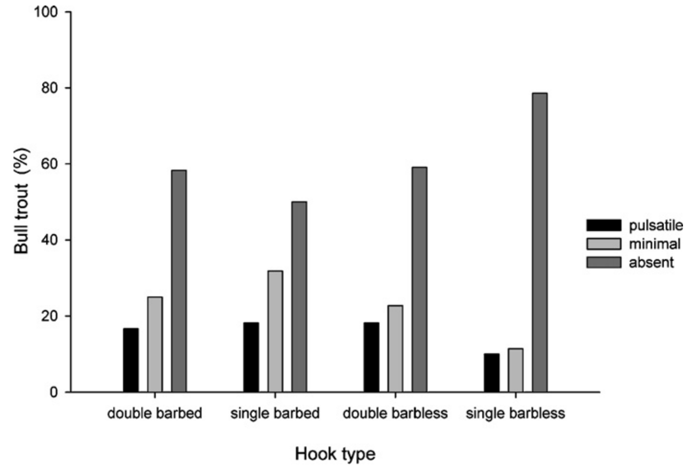

Fig. 1. The percentage of bull trout that exhibited pulsatile bleeding, minimal bleeding or did not bleed according to hook type for the spring bull trout troll fishery in Kinbasket Reservoir, April to May, 2010.

where the use of barbed hooks typically results in more bleeding than barbless hooks (reviewed in Taylor and White, 1992). However, in the current study bleeding was not affected by either hook number (*Wald* = 1.1, $p = 0.58$) or hook type (*Wald* = 2.4, $p = 0.31$) with no significant interaction (*Wald* = 1.6, $p = 0.56$). The lack of a clear statistical relationship was at least partially attributable to small sample sizes for some treatments. Over half of the bull trout catch was made using baits rigged with single barbless hooks (56%), followed by single barbed (17%), double barbless (17%), and double barbed (10%). Bleeding occurred in 47% of all bull trout captured using barbed hooks and 26% of those captured using barbless hooks. Of all the fish caught by baits with two hooks, 42% experienced some bleeding while 28% of fish bled when captured by one hook. A pulsatile bleeding injury was less common (13% of all fish) and was observed in 10% of bull trout caught by single barbless hooks and approximately 18% of those caught on other hook types (Fig. 1). Pulsatile blood flow only lasted for several minutes, in most cases, however it is unclear whether blood loss led to anaemia and subsequent delayed mortality or sublethal impairment.

Overall, we found hooks to be embedded in the upper jaw ($n = 49$), lower jaw ($n = 29$), corner jaw ($n = 18$), operculum ($n = 7$), eye ($n = 7$), body ($n = 5$), tongue ($n = 5$), head ($n = 3$), gill arch ($n = 2$), and unknown ($n = 1$). Previous research has revealed that the number of hooks often influences hooking location (Muoneke and Childress, 1994). However in our study, mean length-corrected hooking depth did not differ between lures carrying one or two hooks ($F = 0.87$, $p = 0.35$; Fig. 2) or if lures were trolled at slow or fast speeds ($F = 0.23$, $p = 0.63$). Of the 126 bull trout captured, 16 were foul hooked by single hooked lures and four were foul hooked by multi-hook lures with no significant difference among the frequency of foul hooking relative to hook number (*Wald* = 0.09, $p = 0.76$) or trolling speed (*Wald* = 3.01, $p = 0.08$) with no significant interaction (*Wald* = 1.22, $p = 0.27$). Although the relationship between trolling speed and the occurrence of foul hooking is not statistically significant, it is worth noting that only two of the 18 fish captured at the highest trolling speed (≥5.3 kph) were hooked in the mouth. Foul hooking has been studied in casting fisheries. For example, Bettoli et al. (2000) reported a 42% foul hook rate in sauger (*Stizostedion canadense*), however, rarely has foul hooking been studied in the context of catch-and-release troll fisheries and the incidence observed here with bull trout may be some of the highest observed to date (reviewed in Muoneke and Childress, 1994).

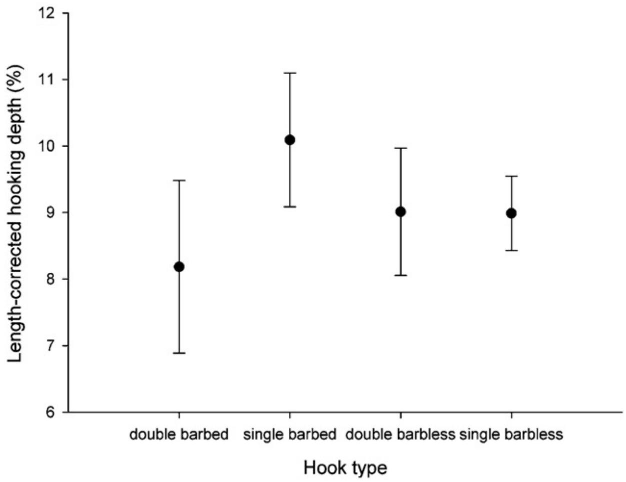

Fig. 2. Mean length-corrected hooking depth (%) in bull trout captured by trolling different hook types in Kinbasket Reservoir, April–May, 2010.

After landing, 93% of bull trout maintained equilibrium while in the holding tank, and of those without equilibrium (i.e., 9 of 126), six experienced bleeding. Fish that lost equilibrium were fought for significantly more time (mean of 168 ± 18 s) than those that maintained equilibrium (mean of 126 ± 5 s, $Wald = 4.73$, $p = 0.03$) while foul hooking had no effect on equilibrium ($Wald = 0.62$, $p = 0.43$). Longer fights tend to result in depletion of tissue energy stores which require time to recover (Kieffer, 2000). Loss of equilibrium is a highly relevant metric for evaluating catch-and-release fishing as it is a reflex impairment indicator (Davis, 2007). Loss of equilibrium could make fish more susceptible to predation after release. In our study, we assessed reflex impairment upon landing the fish and prior to fish being exposed to anaesthesia. Before release, fish had to regain equilibrium loss from anaesthesia and be able to actively swim away from human stimulation of the caudal peduncle. The requirement of demonstrating recovery from the combined stresses of capture and anaesthesia is atypical of normal catch-and-release events. Although we did not evaluate post release mortality in this study, one fish (post anaesthesia and surgery) was taken by a bald eagle at the time of release, thus lending credibility to the notion that post-release predation may be an issue even for large bull trout.

Collectively, these data suggest that for recreational troll fisheries targeting bull trout at low water temperatures, immediate hooking mortality is low, fight duration has an effect on equilibrium, and injury through foul hooking or bleeding is common. In the present study fish were captured at relatively shallow depths and no evidence of barotrauma was observed. By contrast, the only other freshwater trolling that involved anglers targeting salmonids recorded barotrauma in fish caught from greater depths (Dedual, 1996). Fish that fought for longer periods were more likely to lose equilibrium upon landing, but those also tended to be the largest fish. As such, there may be merit in using heavier gear to reduce fight duration, or alternatively, spending more time recovering exhausted fish. In the present study we failed to expose fish to air, a common occurrence among recreational anglers when photographing their catches. Air exposure has the potential to exacerbate physiological disturbances (Ferguson and Tufts, 1992; Cooke et al., 2001) and elevate mortality (Ferguson and Tufts, 1992; Gingerich et al., 2007). In addition, fish were angled at water temperatures that are regarded as relatively benign for this species (Selong et al., 2001). As such, it is worth noting that the hooking mortality estimate derived here may represent the lower bound of mortality, even though we exposed fish to the additional challenge of anaesthesia and surgery. When fish are exposed to lengthier handling (e.g., during photos and measurements) or warmer water temperatures (e.g., under thermally stratified conditions), it is reasonable to expect that mortality may be higher. Most fishing effort for bull trout in Kinbasket Reservoir is during the spring when the system is isothermal and surface water temperatures are generally cold (J. Tippe, local guide, personal communication); angling at warmer water temperatures may not be as relevant, particularly for this system. By angling in cool water temperatures we revealed that immediate mortality was negligible. Although the effect of hook configuration on bleeding was inconclusive, the incidence of bleeding was high compared to other studies. Given that even low levels of hooking mortality could make recreational fisheries for bull trout unsustainable (Post et al., 2003), additional efforts should be made to quantify hooking mortality (immediate, short-term and delayed) relative to a broader range of environmental conditions, gear types, and angler behaviours.

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