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Kevin L. Pope
University of Nebraska-Lincoln, kpope2@unl.edu

Gene R. Wilde
Texas Tech University

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Kevin L. Pope
U.S. Geological Survey – Nebraska Cooperative Fish and Wildlife Reserach Unit
School of Natural Resources, University of Nebraska–Lincoln
Lincoln, Nebraska 68583 USA
E-mail: kpope2@unl.edu
and
Gene R. Wilde
Department of Biological Sciences, Texas Tech University
Lubbock, Texas 79409 USA

ABSTRACT

We conducted a field experiment to determine the survival rate of foul-hooked (hooked external to the oral cavity) largemouth bass (*Micropterus salmoides*) caught and released by recreational anglers. Of 42 largemouth bass caught with hard-plastic baits containing three treble hooks, 15 were hooked only within the mouth and 27 had at least one hook penetrating the external surface of the fish (i.e., foul-hooked). There was no difference in survival of mouth-hooked (100%), foul-hooked (100%), or control (100%) largemouth bass.

INTRODUCTION

In many fisheries, a substantial portion of the fish population may be caught and released by anglers (Schill et al. 1986, Nuhfer and Alexander 1992, Davis 2002). However, not all fish survive catch and release, and the variability in survival ranges from 0 to 100% depending on species, water temperature, and tackle used (Muoneke and Childress 1994).

It appears that the most important factor influencing survival of fish caught and released by anglers is the anatomical site of hooking—whether a fish is hooked in the mouth, gills, esophagus, or elsewhere (Pelzman 1978, Weidlein 1987, Muoneke and Childress 1994, Bartholomew and Bohnsack 2005, Butcher et al. 2007). Earlier, we investigated the relationships between water temperature and anatomical site of hooking with survival of largemouth bass (*Micropterus salmoides*) to develop a predictive model (Wilde and Pope 2008). We found that survival was unrelated to water temperature, from 7 to 27 °C, and that survival was 98.3% for fish hooked in the mouth and 55.0% for fish hooked in the esophagus. However, we did not assess the potential hazard associated with foul-hooking, which causes hooking wounds external to the oral cavity (Davie and Kopf 2006). The rate of foul-hooking may exceed 10% in some fisheries (e.g., Bettoli et al. 2000, Falterman and Graves 2002, Prince et al. 2002), and survival of fish that are foul-hooked may be considerably less than survival of fish hooked within the mouth (e.g., Taylor et al. 2001).

No previous study has assessed survival of largemouth bass that are foul-hooked and released, although largemouth bass commonly are foul-hooked when caught on artificial lures and the incidence of foul-hooking appears to be correlated with the number of hooks on the lure (e.g., Wilde et al. 2003). Survival might be reduced in foul-hooked fish if hooks penetrate the external musculature and damage internal organs such as the heart or liver (e.g., Hulbert and Engstrom-Heg 1980, Diggles and Ernst 1997, Aalbers et al. 2004). Therefore, we conducted a field experiment to measure survival of foul-hooked largemouth bass caught and released by anglers. This experiment was specifically designed to test the null hypothesis that there is no difference in survival between largemouth bass hooked within the mouth and largemouth bass that are foul-hooked.

METHODS AND MATERIALS

We conducted the experiment on 17-20 July 2006 at the 04 Ranch, McLean, Texas on a 4-ha, spring-fed impoundment, with a shoreline development index of 1.32, a mean depth of 1.7 m, and 73% vegetation coverage (Shavlik 2000) that contained largemouth bass and bluegill (*Lepomis macrochirus*; Wilde et al. 2003). During the study, water temperature at a depth of 0.5 m ranged from 28.6 to 29.9 °C, dissolved oxygen ranged from 10.0 to 10.8 mg $\cdot$ l^{-1}, and conductivity was 344 µS $\cdot$ cm^{-1}.

Four anglers each used a 2.0-m medium-action rod, 3.6-kg test line, and hard-plastic crank-baits and top-water lures manufactured with three barbed treble hooks. We used lures with three treble hooks because previously a high rate of foul-hooking was observed on lures with three treble hooks compared to lures with only two treble hooks (Wilde et al. 2003).

Once a fish was landed, we recorded the anatomical location(s) of hooking and the numbers of points on each treble hook penetrating the fish. We then removed hooks from the fish and marked (fin punch) the fish to denote its treatment (mouth-hooked or foul-hooked). The fish was then placed into one of twenty five 132-L holding pens constructed from plastic containers. Each pen (84 cm X 51 cm X 50 cm) had rounded corners and a solid lid, and water circulation was facilitated by a series of 3-cm holes in the sides (N = 12 and 9 on each long and short side, respectively) and 4-cm holes in the bottom (N = 8). The pens were slightly buoyant and floated just at the surface of the impoundment. Two or three pens were towed behind the boat during angling so that captured fish could be placed directly into pens. Once fish captured by angling were secure in a pen, that pen was towed to and anchored in the deepest area of the impoundment.

Control fish were captured immediately after angling ceased; control fish were collected last to prevent disturbance of fish in the impoundment so as to maximize catch by anglers. Control fish were captured using a boat electrofisher (pulsed DC) and temporarily held in the boat's livewell until transferred to the pens already containing fish captured via angling. The protocol called for one fish from each treatment (mouth-hooked, foul-hooked, and control) to be placed in each pen. However, some pens contained only two fish because only 15 of the angled fish were mouth-hooked.

Survival of captured largemouth bass was expected to exceed 90% (Pelzman, 1978, Wilde and Pope, 2008). Thus, we chose a target sample size of 25 largemouth bass ≥200-mm total length (TL) for each treatment. The first 25 fish caught that were eligible for each treatment were included in the study. This target sample size was selected as a compromise between the trade-off of logistically capturing fish via angling ($N = 25$ required successfully capturing at least 50 largemouth bass ≥200-mm TL within a single day) and resolution available to estimate survival ($N = 25$ provided divisions of 4% for survival estimates). Reasonable statistical power would be achieved because, given the design employed for this study, individual fish were independent observations. Further, this experiment was conducted during summer when mortality was expected to be the greatest (e.g., Wilde 1998).

Holding pens were checked daily over three days, a common observation period for survival studies (Nelson 1998, Dunmall et al. 2001, Edwards et al. 2004, Stunz and McKee 2006) and a period that is appropriate for largemouth bass (Wilde and Pope 2008). After three days, surviving largemouth bass were released back into the impoundment.

RESULTS AND DISCUSSION

Of 42 angler-caught largemouth bass, 15 were hooked only within the mouth and 27 had at least one hook penetrating the external surface of the fish (i.e., foul-hooked). Thirty-four largemouth bass were larger than the minimum size (200-mm TL) specified in our protocol, producing actual sample sizes of nine mouth-hooked fish and 25 foul-hooked fish; these fish ranged in TL from 255 mm to 439 mm. Evidently, most largemouth bass are foul-hooked when captured with commonly used lures containing three treble hooks.

Largemouth bass were hooked in a variety of locations, including the mouth (36 of 42 fish), the face (16), the side of the body (9), the isthmus (3), the belly (3), the eye (2), and the gills (1). The sum of these exceeds 42 because several fish were hooked in multiple locations. The middle treble hook resulted in the greatest number of hook penetrations (mean number of hook penetrations per fish = 0.9), followed by the rear hook (mean = 0.6) and the front hook (mean = 0.5). The average number of hook penetrations per fish caught was 2.0. The rear treble hook was most responsible for foul-hooking (18 of 26 fish), followed by the middle treble hook (11) and then the front treble hook (4); the sum exceeds sample size because some fish were foul-hooked by two hooks.

All control fish (N = 25), which ranged in TL from 279 to 445 mm, survived the 3-d holding period. Likewise, all angler-caught fish survived the 3-d holding period. As such, survival (100%) did not differ among treatments (i.e., mouth-hooked, foul-hooked, control). The use of small holding pens ensured that individual fish were independent observations and thus, truly represented experimental units needed to allow estimation of sampling error, if necessary, based on the number of fish caught. The largemouth bass held in the pens showed no ill effects due to confinement; survival was 100%, and video showed that the fish were calm and showed no obvious stress-related behaviors.

Relatively few studies have assessed survival of foul-hooked fish that were released by anglers. Survival of foul-hooked common snook (*Centropomus undecimalis*) was 93%, which was intermediate to survival rates of common snook hooked in the mouth (99%) and esophagus/stomach (84%, Taylor et al. 2001). Survival of foul-hooked spotted seatrout (*Cynoscion nebulosus*) was 92%, which was similar to the survival rate of spotted seatrout hooked in the mouth (90%) and greater than survival rates of spotted seatrout hooked in the gills (25%) and esophagus (5%, James et al. 2007). Survival of foul-hooked sand flathead (*Platycephalus bassensis*) was 100%, which was similar to survival rate of sand flathead hooked in the mouth (99.6%) and greater than the survival rate of sand flathead hooked in the esophagus and stomach (64%, Lyle et al. 2007). We found that survival of foul-hooked largemouth bass was 100% (this study), which was similar to the survival rate of largemouth bass hooked in the mouth (98.3%, Wilde and Pope 2008; 100%, this study) and greater than the survival rate of esophagus-hooked largemouth bass (55%, Wilde and Pope 2008). Thus, results from the limited number of studies suggest that survival rates for foul-hooked fish vary among species and that survival associated with hooking fish external to the oral cavity is greater than survival of fish hooked in the esophagus and stomach. No study has assessed sublethal effects (e.g., reduction in growth or reproductive output) of foul-hooking, but negative effects are possible. For example, damage to eyes (e.g., Pope and Wilde 2004) and the mouth (e.g., Meka 2004) may permanently influence the ability and competitiveness of released fish to feed (Davie and Kopf 2006) and avoid predators.

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