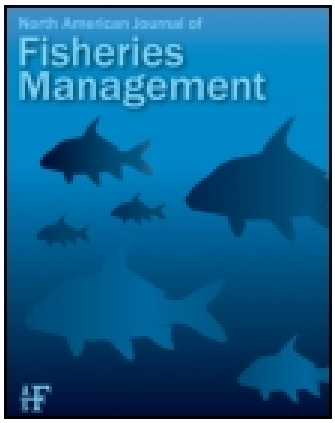

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Hooking Mortality of Saugers in the Tennessee River

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Abstract.—We assessed hooking mortality of saugers *Stizostedion canadense* in two Tennessee reservoirs by holding fish overnight in a net-pen. We also attached radio tags equipped with a mortality switch to 19 saugers to document survival. Rates of gas bladder overinflation and foul-hooking using common terminal gear were estimated. The mortality rate for saugers observed in the net-pen was only 4% (3 of 74). Seventeen of 19 radio-tagged saugers were located and 15 were alive 12 d later (12% mortality). Although we could not detect a statistical relation between mortality and gas bladder overinflation, depth of capture was weakly related to the occurrence of gas bladder overinflation. When we caught saugers using the terminal gear most common in these fisheries (a bucktail jig tipped with a minnow and equipped with a trailing treble hook), equal numbers of fish were caught by the jig hook and stinger hook. Despite the fact that 42% of all the saugers we caught were foul-hooked, blood flowed from the primary hook wound in only 21% of all the fish we caught. Concerns that using a stinger hook increases rates of foul-hooking and mortality were unfounded; most (70%) saugers were hooked ''fairly'' (i.e., in the jaws or mouth) when the stinger hook was responsible for the hook-up, and the jig hook was responsible for twice as many foul-hookings as the stinger hook. Based on these findings, we recommend that the minimum length limit remain in effect for saugers in Tennessee waters. We also conclude that prohibiting the use of stinger hooks is unwarranted.

Fishing for saugers *Stizostedion canadense* is an important seasonal activity in reservoirs on the Tennessee River. Anglers target saugers during the winter and early spring when saugers migrate upstream in search of suitable spawning shoals. Although saugers can pass through the locks at some dams (Maceina et al. 1996; Pegg et al. 1997), passage rates are low and the dams serve to concentrate saugers for several months, during which they are susceptible to high rates of exploitation (Pegg et al. 1996). Saugers remain concentrated in dam tailraces until the urge to find suitable spawning shoals results in rapid downstream dispersal, usually in late March or early April (St. John 1990; Pegg et al. 1997). By late spring, saugers have dispersed into downstream reservoirs, where they are only incidentally caught for the remainder of the year.

In response to concerns that sauger populations were on the verge of collapse in several main-stem Tennessee River reservoirs in the early 1990s, the Tennessee Wildlife Resources Agency reduced the daily creel limit (walleyes *Stizostedion vitreum* and saugers combined) from 30 fish to 10 fish and imposed minimum length limits in 1992. The minimum size limit in Kentucky Reservoir, on the lower Tennessee River, was 356 mm total length; the size limit was set at 381 mm in all other waterbodies.

Minimum length limits will be counter-productive if released fish suffer high mortality (e.g., Bettoli and Osborne 1998); thus, we initiated this study of sauger hooking mortality. Biologists with the Tennessee Wildlife Resources Agency (TWRA) were also concerned that the use of ''stinger hooks'' (a treble hook attached to the jig hook by a piece of monofilament) was increasing mortality through foul-hooking. Although hooking mortality studies have increased in recent years and much is already known (see review by Mouneke and Childress 1994), we found no published reports on rates of hooking mortality of saugers or rates of foul-hooking for any percids. Hoffman et al. (1996) described mortality rates for saugers and walleyes at a live-release tournament, but those data would not apply to fish released immediately. Low rates of hooking mortality of walleyes have been reported (1.1%, Fletcher 1987; 5–16%, Payer et al. 1989; 0.8%, Schaefer 1989). One factor linked to high rates of hooking mortality is gas bladder expansion. Angler complaints lodged with TWRA staff that many saugers returned to the water were unable to repressurize their air bladders (i.e., they floated upon release) were an additional reason to conduct this study. Keniry et al. (1996) studied the phenomenon of gas bladder expansion on yellow perch *Perca flavescens* and concluded that bladder expansion negatively affected survival and that puncturing over-inflated bladders im-

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proved survival. Collins et al. (1999) also noted that gas bladder inflation negatively affected survival of reef fishes, and that deflation improved survival.

The primary objectives of this study were to estimate short-term (overnight) and long-term (12-d) hooking mortality of saugers in the Tennessee River and to examine factors that may contribute to hooking mortality. We also collected information on rates of foul-hooking and injury with the use of different terminal gears and the occurrence of gas bladder expansion.

Methods

Saugers were caught with conventional fishing gear below Pickwick Dam (the headwaters of Kentucky Lake) and Ft. Loudoun Dam (the headwaters of Watts Bar Reservoir) between 14 January 1999 and 26 March 1999. All angling was performed by the authors, who were occasionally accompanied by fisheries graduate students. A 1998 survey of sauger anglers below Pickwick Dam revealed that most anglers fished with bucktail jigs tipped with a live minnow, and most anglers (450 of 510) always or sometimes used a stinger hook when jigging (Bettoli 1998). The stinger hook is either impaled into the tail of the minnow, or allowed to dangle. Another popular fishing method was to jig a blade lure, which was usually equipped with a pair of double or treble hooks. Thus, we always fished either a minnow-tipped bucktail jig (1/0 size hook) with an attached stinger hook (size 4) or a blade lure.

Once a sauger was hooked, water depth was recorded using an electronic fish finder. Saugers are demersal and the baits were always jigged within 1 m of the bottom; thus, we assumed that the depth at hook-up was known within 1 m. Hook location was recorded, and for fish caught with jigs, we also noted the primary hook responsible for capture (i.e., jig hook or stinger hook). The severity of bleeding at the point of hook penetration was coded as either 0 (none or slight), or 1 (blood dripping or flowing from wound). The degree of gas bladder overinflation was scored as 0 (no expansion visible), 1 (expansion visible at rear of buccal cavity), or 2 (stomach or esophagus clearly distended into buccal cavity). Air temperature, water temperature, and total length (mm) were recorded, as well as handling time (elapsed time between the fish coming out of the water and, after being unhooked and processed, being placed in an 145-L cooler filled with aerated lake water). Individually numbered T-bar anchor tags were attached to the saugers, which were held for no more than 45 min then transported to a large pen (1.5 m $\times$ 1.5 m $\times$ 11 m) that rested on the river bottom and extended to the surface. Thus, saugers could assume a demersal existence while confined. The net-pen was slowly raised the following day and the status of saugers was checked; saugers were held overnight (16–22 h), and we assumed that our mortality rates represented conventional 24-h mortality rates. We also assumed that observed mortality rates would be liberal, because saugers were not released immediately into the net-pen.

As a follow-up to the overnight net-pen observations, we attached small (3.3-g) radio transmitters (30.090–30.280 mHz) to 19 saugers that we caught 25–26 March 1999. The weight of the smallest radio-tagged sauger (270 mm), predicted from a log-weight: log-length regression model for Tennessee River saugers (N = 3,309; author's unpublished data) was 163 g. Thus, the radio tags weighed no more than 2.1% of the body weight of any fish we tagged; they weighed about 0.9% of the weight of the average sauger we tagged. Three saugers were radio-tagged and held overnight in the net-pen; the remaining 16 saugers were tagged and released immediately at their point of capture, 7 km downstream of the dam. We pooled the data from all 19 fish to describe long-term (> 24 h) survival of released fish.

The transmitters had a guaranteed life of 16 d. Absorbable suture material was attached to the transmitters and passed through the dorsal musculature anterior to the dorsal fin. Fish were held in a foam-lined cooler that was filled with lake water, and the procedure usually took less than 90 s. The transmitters were equipped with a mortality switch that would double the normal pulse rate (55 pulses/min) in the event the tag did not move for 8 h. The upper 18 km of the tailwater was traversed to locate radio-tagged saugers on 31 March 1999. The upper 34 km of the tailwater was traversed on 6 April 1999, and the location and status (dead or alive) of the fish, as indicated by the pulse rate, was recorded.

We used multiple logistic regression (SAS Institute 1995) to model the probability of gas bladder overinflation as a function of water temperature, depth of capture, and total length of each fish; the null hypothesis that each predictor variable had no effect on the binary response variable (no overinflation = 0; modest or severe overinflation = 1) was tested with the chi square statistic. We used 2 $\times$ 2 contingency tables and the chi square statistic to compare proportions of fish foul-hooked

TABLE 1.—Classification of primary hook location, amount of bleeding from the hook wound, and the severity of gas bladder overinflations for 113 saugers experimentally angled using two types of terminal gear in the Tennessee River, January–March 1999. Parenthetical values are percents.

Classification	Jig-and-stinger (N = 93)	Blade lure (N = 20)	Total (N = 113)
Primary hook location			
Foul hooked in head	12	0	12 (10.6)
Foul hooked in gular region (throat)	22	2	24 (21.2)
Foul hooked in body or fins	9	3	12 (10.6)
Jaws	44	13	57 (50.4)
Anterior mouth cavity	6	2	8 (7.1)
Posterior mouth cavity[a]	0	0	0
Pharynx	0	0	0
Amount of bleeding			
None or slight	74	15	89 (78.8)
Flowing	19	5	24 (21.2)
Gas bladder overinflation			
None	58	12	70 (62.0)
Modest	24	7	31 (27.4)
Severe	11	1	12 (10.6)

[a] At or posterior to first gill arch.

by the jig hook and the stinger hook and the proportions of radio-tagged and net-pen saugers that died (SAS Institute 1990; Elliott 1993). The Wilcoxin two-sample test and the Z-statistic were used to compare mean depth of capture and total lengths of radio-tagged and pen-held saugers (SAS Institute 1990). Statistical significance was declared at $P \leq 0.05$.

Results

We experimentally caught 113 saugers during this study; 74 fish were held in the net-pen on four dates to estimate overnight mortality, 19 fish were affixed with radio tags and released to estimate long-term mortality, and the remainder (N = 20) provided data on hook locations, bleeding, and gas bladder overinflation. Saugers ranged in total length from 220 to 475 mm (mean = 346; SE = 4.5). Depth at capture ranged from 5 to 18 m (mean = 9.1; SE = 0.6). Water temperatures averaged 10.0°C and ranged from 7°C to 12°C during the study; air temperatures averaged 9.2°C and ranged from 1°C to 14°C.

Ninety-three saugers were caught with bucktail jigs tipped with a minnow and equipped with a stinger hook (Table 1); equal numbers were caught by the stinger hook (N = 47) and the jig hook (N = 46). Forty-two percent of all the saugers we caught were foul-hooked by the primary hook in the head, throat, body or fins; 58% bit the hook, but none were hooked past the first gill arch or in the esophagus (Table 1). The foul-hooking rates for saugers caught using bladebaits (5 of 20) and bucktail jigs (43 of 93) did not differ (chi square = 3.038; df = 1; P = 0.081). Despite the high-rates of foul-hooking, almost 80% of the saugers (89 of 113) displayed little or no bleeding from the hook wound.

Contrary to expectations, use of a stinger hook when jigging did not increase rates of foul-hooking, as most saugers (33 of 47) were hooked in the jaws or mouth when the stinger hook was the primary hook. Saugers were also more than twice as likely to be foul-hooked by the jig hook (29 of 43) than the stinger hook (14 of 43; chi square = 10.343; df = 1; P = 0.001).

Only three of 74 saugers (4%) held overnight in the net-pen died. They averaged 341 mm in total length (SE = 5.4; range: 220–410 mm), and their mean depth at capture was 8.2 m (SE = 0.5; range: 5.2–15.8 m). Given such a low mortality rate, no attempt was made to model the factors responsible for mortality.

Gas bladder overinflation was evident in 38% of all saugers caught (Table 1); about 11% exhibited severe overinflation (i.e., the stomach was clearly distend into the buccal cavity). Gas bladder overinflation was not related to hooking mortality, as only one of three saugers that died in the net-pen exhibited any gas bladder overinflation. Overinflation was influenced by depth of capture (logistic regression; chi square = 9.19; df = 1; P = 0.0024), but not water temperature (chi square = 1.94; df = 1; P = 0.1636) or total length (chi square = 1.22; df = 1; P 0.2697). Although depth at capture was a significant predictor of gas bladder

overinflation, most of the variation remained unexplained ($r^2 = 0.14$).

The 19 radio-tagged saugers were similar in mean total length (350 mm) to the saugers held in the net-pen (341 mm; $Z = 0.838$; df = 91; $P = 0.4017$), but their average capture depth was deeper (12.1 m versus 8.2 m; $Z = 5.475$; df = 91; $P = 0.0001$). Five days after release, 15 of the 19 tagged saugers were located within 18 km of the dam; 2 of the 15 fish were dead. Seven days later, tagged fish were located within 27 km of the dam. Two of the four missing saugers were located and were alive, and the 15 saugers located the previous week were all relocated and their status (dead or alive) did not change. Thus, the long-term (12-d) mortality rate for the radio-tagged saugers was 12% (2 dead of 17 located). This mortality rate did not differ from the 4% overnight mortality rate calculated for net-pen fish (chi square = 1.583; df = 1; $P = 0.208$); however, expected frequencies in two cells of the 2×2 contingency table were less than 5, and this comparison may not be statistically valid (Elliott 1993).

Discussion

Although the two radio-tagged saugers that could not be located following release were scored as suffering from extreme gas bladder overinflation, for the following reasons, we do not assume that they both died. Nine of the 15 radio-tagged saugers that survived suffered from some overinflation; two were judged to be severely overinflated, yet they lived. The two missing fish were both foul-hooked, but so were four survivors. Also, saugers placed into the net-pen that were judged to be suffering from severe overinflation ($N = 5$) all lived. We have no compelling evidence to suggest that the two radio-tagged saugers that were never located had died; thus, we believe that the 12% mortality rate for radio-tagged saugers was not biased low.

The low (4–12%) hooking mortality of saugers in the Tennessee River was similar to low rates of hooking mortality reported for walleyes in other water bodies (Fletcher 1987; Payer et al. 1989; Schaefer 1989), which suggests that catch-and-release regulations can benefit many walleye and sauger fisheries. Even if hooking mortality rates for Tennessee River saugers were as high as 12%, the minimum length limits currently in effect are probably desirable for the following reason. Sauger anglers interviewed during a creel survey at Kentucky Lake on the Tennessee River took advantage of a regulation in 1997 that allowed them to harvest three fish each day under the minimum length limit. Nearly half of 1,711 saugers creeled in 1997 were under the size limit (that exception to the minimum length was subsequently eliminated), and 60% of anglers ranked ''catching fish to eat'' as the most important of six possible reasons for them to fish for saugers (Bettoli 1998). Thus, many anglers were motivated to harvest every fish they caught. Forcing anglers to return all under-sized saugers, even if a small percentage subsequently died, would probably have the desired effect of reducing exploitation and conserving stock abundance. Also, the effects of elevated water and air temperatures, which exacerbates hooking mortality for some species (e.g., striped bass *Morone saxatilis,* Bettoli and Osborne 1998; rainbow trout *Oncorhynchus mykiss,* Schisler and Bergersen 1996), are of minor concern because the sauger fisheries throughout the Tennessee River occur predominantly in winter and spring, when air and water temperatures are cool.

Our findings demonstrated that using a stinger hook did not increase the incidence of foul-hooking. Twice as many saugers were fair hooked by the stinger hook than by the jig hook, and the jig hook was most responsible for foul-hooking. Although we did not examine rates of foul-hooking by the jig hook when no stinger hook was attached, few saugers (8 of 93) were hooked by both the stinger and main jig hook, and in all but one of those instances, the jig hook was responsible for capture (i.e., only one sauger bit the stinger hook and was subsequently foul-hooked by the jig hook). In the absence of any other compelling information, the use of stinger hooks should not be restricted.

Although we detected no relationship between mortality and gas bladder overinflation, we did detect a relationship between depth of capture and overinflation, as others have reported (e.g., Keniry et al. 1996). We do not consider gas bladder overinflation a serious problem affecting survival of released sauger in Tennessee reservoirs; however, the public's negative perception of this issue warrants further examination. If gas bladder overinflation occurs slowly in saugers, as we suspect, fish retrieved and released quickly would stand a better chance of regaining depth and repressurizing, as has been noted for largemouth bass *Micropterus salmoides* and burbot *Lota lota* (Feathers and Knable 1983; Lee 1992; Bruesewitz et al. 1993). Research that controlled for the amount of time it took to bring saugers to the surface and then return them to the water might reveal how

these two components of the angling experience affect gas bladder overinflation.

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