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Effects of Retention Gear on the Injury and Short-Term Mortality of Adult Smallmouth Bass

STEVEN J. COOKE*[1]

Department of Biology, University of Waterloo, Waterloo, Ontario N2L 3G1, Canada

W. JAMES HOGLE

Department of Environment and Resource Studies, University of Waterloo, Waterloo, Ontario N2L 3G1, Canada

Abstract.—Little is known about the effects of the different types of fish retention gear commonly used by recreational anglers, such as stringers, fish baskets, and keep nets. The injury and short-term mortality of 313 adult smallmouth bass *Micropterus dolomieu* were studied at Lake Erie over a range of water temperatures (10.6–21.8°C). Lure-caught fish were retained by one of the following six gear types or methods for 3–5 h: metal stringer through lip, metal stringer through gill arch, cord through lip, cord through gill arch, wire fish basket, and nylon keep net. Fish were then transferred to a holding pen and their survival estimated relative to control fish over a 48-h period. Control fish exhibited very little mortality (3%) and had negligible physical injury across all sampling periods. Most retained fish (95%) experienced some form of injury or mortality. In general, increased injury and mortality coincided with higher water temperatures, particularly when water temperatures reached 21.8°C. Survival and injury varied among retention gears, but gill damage or fungal lesions associated with abrasion, along with the cumulative stress of angling and retention, appeared to be the precursors to most deaths. These results suggest that even at low water temperatures, significant injury can occur from retention gear; at higher temperatures, this injury seems to manifest itself in death. For this reason, these gears should only be used with fish that are to be harvested, not those that are to be temporarily retained before release.

Competitive and recreational angling for black bass *Micropterus* spp. commonly involves the retention of fish over a period of time (usually hours) before release. Professional anglers often hold fish in aerated live wells, whereas recreational anglers commonly use more affordable, readily available, and convenient methods, including stringers, fish baskets, and keep nets. The increasing popularity of competitive angling (Schramm et al. 1991a) and concern about its biological effects (Schramm et al. 1991b) has spurred research into the effects of retaining black bass in live wells (Plumb et al. 1988; Hartley and Moring 1993; Steeger et al. 1994) as well as into the effects of other procedural factors that may alter survival (Weathers and Newman 1997).

Although participation in competitive events is common, many anglers fish solely recreationally and practice strict catch and release or some degree of selective harvest (Quinn 1996). There are several reasons why anglers may retain fish and later release them. These include the desires to cull fish of certain sizes for harvest, to determine if enough fish can be caught to merit harvest, and to photograph fish or show them to others. Fish are retained by various types of gear, including stringers, fish baskets, and keep nets. Some management agencies have limited the use of retention gear, and most professional competitive angling organizers have prohibited their use, requiring anglers to use aerated live wells instead. Previous research has investigated the effects of keep net retention on the growth, survival (Raat et al. 1997), and stress response and recovery (Pottinger 1997, 1998) of various cyprinid species. Additional research has also focused on the changes in water quality in keep nets during retention (Pottinger 1997). However, little information exists on the effects of fish retention gear (other than live wells) on the injury and survival of game fish.

Our purpose was to determine the effect of various types of retention gear on the injury and short-term mortality of smallmouth bass *Micropterus dolomieu* that were angled and held at several different water temperatures. We tested the hypothesis that mortality and fish injury rates were not influenced by type of gear retention, including

* Corresponding author: scooke@uiuc.edu

[1] Present address: Program in Natural Resource Ecology and Conservation Biology, Department of Natural Resources and Environmental Sciences, University of Illinois, and Center for Aquatic Ecology, Illinois Natural History Survey, 607 East Peabody Drive, Champaign, Illinois 61820, USA.

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TABLE 1.—Descriptions of the different retention gear treatments that were compared to assess the injury and mortality rates across a range of water temperatures (10.6–21.8°C). Smallmouth bass captured in Lake Erie were allocated to one of six treatments or to a control group that was only angled.

Treatment	Description
Cord–lip	Solid-braid nylon cord (175 cm) with a stainless steel spike (9 cm). Spike pushed through the crease in the ventral surface of the mouth floor, entering the mouth in the connective tissue between the lingual and mandibular teeth.
Cord–gill	Solid-braid nylon cord (120 cm) with a stainless steel spike (9 cm). Spike inserted anteriorly between the operculum and the first gill arch, exiting through the mouth.
Metal–lip	Stainless steel sliding-sleeve snap hooks (9 cm) on chain (100 cm). Open snap pushed through the crease in the ventral surface of the mouth floor, entering the mouth in the connective tissue between the lingual and mandibular teeth. Snap then closed.
Metal–gill	Stainless steel sliding-sleeve snap hooks (9 cm) on chain (100 cm). Snap inserted anteriorly between the operculum and the first gill arch, exiting through the mouth prior to closing.
Wire basket	Metal-wire-mesh (3 cm) collapsible fish basket (32 cm in diameter, 42 cm high) with spring-loaded access gates at the top and bottom. Fish placed into and removed from the basket via the top gate.
Nylon keep net	Nylon-mesh (3 cm) keep net (34 cm in diameter, 46 cm high) with drawstring opening at top. Fish placed into and removed from the keep net via the opening.

metal and cord stringers through the lip and gills, wire fish baskets, and nylon keep nets.

Methods

Study site.—All fish used for this study were captured in the forebay of the Nanticoke Thermal Generating Station on the north shore of Lake Erie (42°48N, 80°04W). The forebay, which has an abundant population of smallmouth bass and provides a secure site for holding fish, is monitored continuously for temperature. The retention site had a continuous influx of fresh water from Lake Erie, although the water currents did not create a substantial flow for the fish to swim against. Additional site descriptions are included in Wiancko (1981).

Retention gear.—We chose six different types of retention gear or methods that are commonly used by anglers in southern Ontario (Table 1). The gears that we deployed can generally be divided into two categories: stringers and holding baskets. The retention gear used in this study was readily available from local tackle shops and large retail stores.

Experimental approach.—Smallmouth bass were angled using 3/8-oz jig heads with a 1/0 barbed Gamakatsu hook with 4-in plastic Yamamoto salted twister tail grubs. Once hooked, each fish was brought directly to the angler within 20 s. After hook removal, fish were placed in a 60-L cooler continuously supplied with lake water for several minutes before being randomly assigned to one of the retention gear types (Table 1). The retaining gear was anchored randomly along a cement structural wall, with the fish suspended at a depth of 1 m below the surface of the water to reflect recreational angling practices. Fish were held by each retention gear in groups ranging from two to four individuals. Although we had four units of each type of gear available, we were unable to deploy all of them every day because of differences in the number of fish captured. Fish captured during the experiment were held under treatment conditions for 3–5 h. Following the allotted retention period, each fish was individually removed from the treatment, externally anchor-tagged near the posterior aspect of the spiny dorsal fin, and measured for total length. The fish were also examined for injury (Table 2), and initial mortality was recorded. Fish were removed from the water for a minimum of 30 s and a maximum of 120 s for this observation and processing. Following this procedure, fish were placed in a single 7.06-m^3 holding pen suspended from the same structure as the retention gear for 48 h. After 48 h, surviving fish were removed from the holding pen and observed for injuries (Table 2) before being released in the intake forebay. Delayed mortalities were also recorded.

Control fish were angled and treated similarly to the treatment fish. That is, controls were anchor-tagged and measured before being placed in the holding pen at the same time as treatment fish were placed in their respective treatments. During the study period, water temperatures on the date of angling ranged from 10.6°C to 21.8°C and during the subsequent retention period from 8.6°C to 22.7°C (see Table 3).

Statistics and data analysis.—One-way analysis of variance (ANOVA) was used to test for differences in the size of fish across sampling dates and among the six treatments and controls. The ANOVA was also used to test for differences in the

TABLE 2.—Injury and mortality classifications used to assess the effects of different retention methods on smallmouth bass in Lake Erie. Fish were examined for injuries immediately after they were removed from the retention gear and again after they had been in a holding pen for 48 h. Classifications are listed from the least to the most injurious.

Injury classification code	Description
1. Undetectable injury	No detectable injury to fish. Fins, scales, and gill area undamaged.
2. Slight injury	No obvious injury to fish. Slight fraying of fins, loss of scales, minor abrasion of gill or tissue.
3. Moderate injury	Injury to fish visible. Fins frayed, moderate scale loss, moderate abrasion of gill or tissue.
4. Extreme injury	Injury to fish obvious. Fins badly frayed, major scale loss, and major abrasions with lesions. Gill and tissue trauma, including hemorrhaging or loss of perfusion.
5. Delayed mortality	Fish death between 5 and 48 h after capture.
6. Initial mortality	Fish death during the first 5 h after capture. During this time fish were either held as controls in a cage or were in a treatment.

size of fish that were classified as having no detectable injury or as having experienced initial or delayed mortality (excluding control fish). The effects of retention gear and water temperature on injury and mortality were examined by performing analysis of covariance (ANCOVA) using the mixed procedure (Littell et al. 1996). Injury and mortality rates (ranked from 1 to 6; Table 2) were the dependent variables, and type of retention gear and water temperature on the angling and retention dates were the class variables. Data were analyzed for normality by means of probability plots, residual plots, and the Wilks−Shapiro test. Because data were deemed to be normal, no transformations were required. The ANOVA was conducted with SYSTAT and the assessment of normality and ANCOVA procedures with SAS. All tests were considered significant at $\alpha = 0.05$.

Results

We caught 313 smallmouth bass on five different sampling days between 5 June 1998 and 4 August 1998. The mean total length of fish did not differ significantly between sampling periods ($F_{4,308} = 0.64$, $P = 0.792$) or across treatments when all sampling periods were combined ($F_{6,306} = 0.42$, $P = 0.868$). Control fish exhibited very little total mortality (3%) and had negligible physical injury (0%) across all sampling periods, which was in contrast to the high levels of injury noted for fish in other treatments.

The total mortality of fish in the control group was negligible for all water temperatures; the total mortality of treated fish increased with water temperature (reaching a high of 61% at 21.8°C). Treated fish exhibited no initial mortality, except in the final treatment period when initial mortality was 42%. Control fish experienced delayed mortality only on the second experimental date (6%, two fish); delayed mortality was noted for fish retained on gear on all but the first experimental date, the number rising on a seasonal or temperature-influenced basis. The maximum delayed mortality for the treated fish was 19% on the last sampling date. Size of fish did not vary significantly among those having no detectable injury, initial mortality, or delayed mortality ($F_{2,49} = 1.54$, $P = 0.224$).

Water temperature did not influence the mortality rates of control fish, but it did affect the mortality rates of fish held in other treatments (Figure 1). The influence of water temperature on injury rates only became significant at 21.8°C ($F_{4,64} = 29.67$, $P < 0.001$). At this temperature, injury and mortality rates were significantly higher than at all other water temperatures (10.6°C: $t = -8.44$, $P < 0.001$; 14.8°C: $t = -9.85$, $P < 0.001$; 18.7°C:

TABLE 3.—Smallmouth bass angled in Lake Erie were assigned to one of six treatments or to a control group on five study dates. The fish were divided into from one to four treatment replicates, each with two to four fish. The total number of fish in each treatment on each date is given in parentheses.

Date	Water temperature (°C)	Controls (N)	Number of replicates per treatment (total number of fish per treatment)					
			Cord–lip	Cord–gill	Metal–lip	Metal–gill	Nylon	Wire
5 Jun	10.6	6	2 (5)	2 (6)	2 (4)	2 (6)	2 (5)	2 (5)
18 Jun	14.8	33	4 (16)	4 (16)	3 (12)	4 (14)	4 (13)	4 (16)
12 Jul	19.7	3	1 (3)	1 (4)	1 (3)	1 (3)	1 (3)	1 (4)
17 Jul	18.7	13	2 (8)	2 (8)	3 (8)	3 (9)	3 (9)	3 (9)
4 Aug	21.8	11	3 (9)	3 (10)	3 (10)	3 (12)	2 (8)	3 (9)

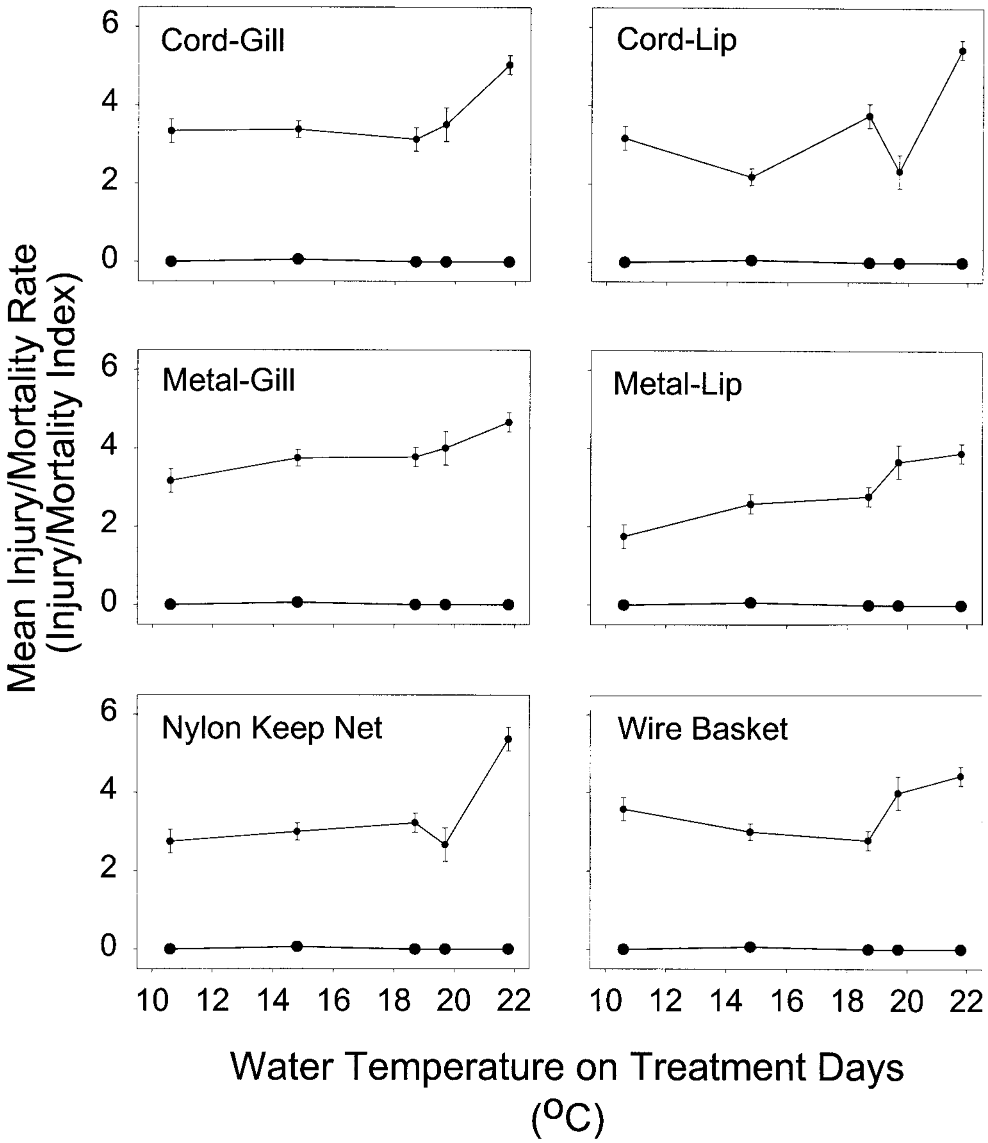

FIGURE 1.—Injury and mortality rates of fish held in various treatment groups. The injury and mortality rates of control fish are also plotted at the bottom of each panel for reference. Detailed descriptions of the treatments are presented in Table 1 and the injury and mortality classifications are described in Table 2. Corresponding water temperatures for each of the five sampling periods are available in Table 3.

t = −7.77, P < 0.001; 19.7°C: t = −5.22, P < 0.001).

Differences were also observed in the levels of injury and mortality of fish held on different retention gears ($F_{5,64}$ = 4.64, P = 0.001). The metal−lip treatment was significantly less injurious than the other retention gears (cord−gill: t = 3.69, P < 0.001; cord−lip: t = 2.35, P = 0.022; metal−gill: t = 4.50, P < 0.001; nylon: t = −2.67, P = 0.010; wire: t = −2.54, P = 0.014). The metal−gill treatment was marginally more injurious than the cord−lip (t = 2.10, P = 0.040) and the wire basket (t = 2.01, P = 0.049). No other differences in injury or mortality rates were noted.

Discussion

Hooking and Handling Mortality

We observed no mortality during the first 5 min following capture. Furthermore, the initial and delayed mortality of control fish was negligible, even at the highest water temperatures. These temperatures remained within the tolerable range for this species and did not approach the thermal maximum (Armour 1993). Fish used for this study were all captured on jig heads with twister tails, a lure that tends to hook fish in the premaxilla, resulting in minimal injury and rapid hook removal (K. Dumall, University of Waterloo, unpublished data). Other researchers have reported low hooking-mortality rates for smallmouth bass captured on artificial lures (Clapp and Clark 1989; Green et al. 1989). The limited angling mortality that we observed may also be attributed to the careful handling procedure prior to placing fish in the holding pen. Angling stress was equivalent among treatments.

Effects of Stress

We observed relatively high mortality rates for fish held on retention gears, especially at higher temperatures. Recent research suggests that the cardiac output and heart rate of smallmouth bass increase with temperature, although recovery time from strenuous exercise (simulated angling) is not influenced by temperature (J. Schreer, University of Waterloo, unpublished data). Following strenuous exercise, fish acclimated to higher water temperatures have less metabolic scope available because they are already performing at a higher metabolic rate. The prolonged disturbance associated with retaining fish on different gears, in addition to the angling-induced stress at warmer temperatures, may have been sufficient to cause death (Wood et al. 1983).

In a series of studies related to handling and hauling, Carmichael et al. (1983) suggested that smallmouth bass may be more sensitive to stress than previously thought, as evidenced by prolonged plasma glucose and electrolyte level disturbances. Stress resulting from excessive fish handling or crowding, such as the conditions experienced in our retaining treatments, may also lower the disease resistance of fish (Wedemeyer 1970). Fish were also exposed to air during this experiment, which affects survival (Ferguson and Tufts 1992) and prolongs cardiac disturbance (S. Cooke, University of Illinois, unpublished data). We attempted to minimize air exposure for all individuals and to maintain consistency among treatments. The cord stringers sometimes became tangled, causing longer delays in returning the fish to the water; in these cases, however, exposure to air was still less than 2 minutes. Although the control fish were only handled once before being placed in the holding pen, it is unlikely that the additional exposure of treated fish to air would have caused differences in mortality.

Fish may also experience increased physiological disturbance because of decreased levels of dissolved oxygen caused by a localized high density of fish or the physical impairment of ventilation by some retention gears. The use of stringers involves inserting a metal clamp or pin through the gill area or the snout region, thus restricting the swimming and ventilatory activity of the fish. Generally, the number of clamps on a metal stringer limits the number of fish that can be held, whereas the number of fish that can be kept on cord stringers depends on the length of the cord. Keep nets vary in composition but are generally made of nylon or metal mesh. Unlike some stringers, keep nets and fish baskets do not have a preset maximum for the number of fish held. Consequently, most keep nets can be expected to have a high density of fish within a small area. Such a density is known to decrease the level of dissolved oxygen within the keep net and the surrounding area (Pottinger 1997). In our study, the constant flow of water probably minimized localized oxygen depletion, but the impairment of ventilation by the stringers may have prevented adequate movement of oxygenated water over the gill surface.

Retention Gear Injury and Mortality

The two most obvious and potentially lethal mechanical injuries that we observed were abrasion of the scales and fins and damage to the gills and gill arches. Although abrasion, loss of scales, and frayed fins do not immediately kill fish, such injuries may lead to delayed fungal infections and possibly to death (e.g., Cooke et al. 1998). This type of injury was most common in fish held in the wire baskets and nylon keep nets, where individual fish were especially prone to rub against one another, although fish held in other treatments also suffered damage of this type. The least injurious type of retention gear was the metal stringer through the lip. This was probably because the fish were not abrading against netting (as they were in the baskets and keep nets) and were not experiencing major gill trauma (which would be expected in the stringer−gill treatments). Furthermore, the metal stringer did not tangle as much as the cord stringer. In our study, the number of fish held by each replicated treatment gear varied between two and four. Our sample size was insufficient to permit examination of the effect of the number of fish held on injury and mortality rates. This potential source of variation may merit future investigation, although our results clearly show that retaining fish by any of the methods that we used results in injury and mortality rates consistently higher than in control fish.

The increased mortality associated with higher water temperatures that we observed may be directly related to improved growth conditions for water mold at warmer temperatures. Infections caused by *Saprolegnia* are usually associated with wounds and lesions that are exacerbated by excessive handling and other epidermal trauma (Wolke 1975; Richards 1978). Abrasion, such as that observed in the basket and keep net treatments, may predispose fish to infection by disrupting the mucous covering on their surface that serves as a barrier and possesses some antifungal properties (Tiffney 1939). Raat et al. (1997) also reported loss of scales and a secretion of mucus associated with abrasion from fish held in keep nets; however, they do not attribute any mortality to such injuries.

Damage to the gills was the other common injury observed in this study. Abrasion and other physical damage to the gill filaments and lamellae were prominent in many fish that were held on either the metal stringer through the gill or the cord stringer through the gill. Gills are the primary respiratory exchange organ and are very delicate (Hughes 1984). Those fish with gill injuries that survived the 48-h monitoring period had large mucus concentrations on the gill filaments in the area where abrasion occurred, and the gill filaments and lamellae in the damaged area were much lighter than those in undamaged areas. This indicated that the damaged gill tissue was no longer perfused with blood and therefore was not functioning, a development that leads to a decrease in usable gill surface area. We did not determine whether this gill damage further degraded or improved following release.

Conclusions and Management Implications

In our study, retaining captured fish caused higher injury and mortality rates than releasing them immediately after capture. Survival and injury varied among retention methods, but gill damage and fungal lesions associated with abrasion appeared to be the precursors to most of the delayed deaths. Our results suggest that significant injury can occur as a result of using retention gear, even at low temperatures. At higher temperatures, injury often leads to death. We suggest that management agencies limit the use of retention gear to situations in which retained fish will be harvested.

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