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ARTICLE

Physiological Consequences of Different Fishing Tournament Culling Methods on Largemouth Bass

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Abstract

In live-release angling tournaments, fish are captured and typically held within onboard live-well systems, where they are subsequently "culled" (i.e., released) as larger fish are captured. Anglers often mark individual fish to easily identify them based on weight and to reduce handling time. However, there is limited information about the physiological consequences of using different culling apparatus on fish. This study examined the physiological consequences associated with using four different types of culling apparatus (i.e., metal stringer through the jaw, pincher on the jaw, lasso around the caudal peduncle, and zippered mesh bag) on Largemouth Bass *Micropterus salmoides* relative to controls during a 2-h live-well retention period. Blood samples were taken afterwards and were analyzed for blood glucose, blood lactate, plasma cortisol, and osmolality. Compared to the baseline control (i.e., fish that were captured, subjected to blood sampling, and immediately released), blood parameters (except osmolality) were significantly elevated in all treatments. The pincher and lasso treatments tended to yield higher physiological disturbances than the other treatments, including fish that were held in the live well without any culling apparatus. Moreover, the lasso culling apparatus appeared to cause noticeable injury relative to the other culling devices. Our research provides valuable information to help guide the selection of culling gear that maintains the welfare status of retained fish during tournaments.

Black bass *Micropterus* spp. are among the most popular sport fish in North America (Quinn and Paukert 2009). They are also frequently targeted in live-release competitive angling events (i.e., tournaments) that generate millions of dollars annually for local economies (Schramm et al. 1991). Estimates from more than two decades ago suggest that there were 120,000 such events in North America annually (Schramm et al. 1991). Although exact numbers are not known, it is estimated that there may be as many as 40,000 competitive bass fishing events

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held annually in just the southeastern United States, with a notable increase (124%) in the number of events occurring between 2002 and 2011 (Driscoll et al. 2012). Today, many bass fishing tournaments employ a live-release model, which requires that fish remain alive throughout the duration of the tournament until they are released post-weigh-in at a centralized site. Alternatively, some newer event formats use a catch–weigh–release strategy that eliminates the requirement to hold live fish on board (see Cooke et al. 2020). During typical tournaments, fish are confined to an onboard live-well system prior to weigh-in (Suski et al. 2004). Initial mortality rates of bass (judged during weigh-in) decreased from an average of 19.5% during the 1970s to 7.5% during the 1990s due to better angling practices and improved live-well design and function (Wilde 1998).

Although mortality in bass fishing tournaments is typically low (Kwak and Henry 1995; Wilde 1998; Edwards et al. 2004), fish do experience a variety of physiological disturbances. The fish are angled, requiring them to engage in high-intensity exercise that leads to a neuroendocrine stress response (i.e., catecholamine and cortisol secretion), depletes tissue energy stores, perturbs ion and acid–base status (i.e., accumulation of lactate), and increases metabolic rate (Wood 1991; Milligan 1996; Cooke et al. 2004; Suski et al. 2004). When retained in live wells, fish may begin to recover from the stress of capture if provided with adequate water quality and other environmental conditions (Suski et al. 2004). If live-well conditions are poor, fish may be exposed to hypoxia, hyperoxia, temperature changes, crowding, wave conditions, and accumulation of waste, which can cause increases in blood glucose, blood lactate, and plasma cortisol concentrations—indications of a generalized stress response (Suski et al. 2004). Furthermore, fish that are subjected to poor conditions may be unable to maintain position in currents, obtain food, or return to the capture site upon release (Cooke et al. 2002). Air exposure at the weigh-in can cause many of the same effects seen during live-well confinement in poor conditions, including increased blood lactate and plasma cortisol concentrations (Suski et al. 2004). However, with the development of water weigh-in systems that reduce or eliminate air exposure during the weigh-in procedure (see Tufts and Morlock 2004), the condition of fish during live-well retention is an important determinant of their ultimate welfare and fate.

An additional challenge that black bass face during live-well confinement is disturbance from anglers as they "cull" their catch, which involves replacing smaller individuals with larger ones. To aid in the culling process, it is common for anglers to weigh fish upon initial capture, record the fish mass, and identify the fish by using a colored culling device to enable individual identification. There are many different types of culling apparatus on the market, ranging from stringer-type or pincher-type clips that are placed in the mouth of fish to lassos that are placed around the caudal peduncle or even zippered, plasticized mesh bags into which individual fish are placed. Despite their widespread use, we are unaware of any published studies that have contrasted and evaluated the effects of different culling apparatus on bass condition.

The objective of this study was to evaluate how different culling apparatus typically used by tournament anglers influence the physiological status of wild Largemouth Bass *M. salmoides* during live-well retention. We predicted that the culling devices would lead to larger increases in blood glucose, blood lactate, and plasma cortisol concentrations than live-well confinement alone. To our knowledge, this is the first study to examine best culling practices, therefore our goal was to provide understanding for tournament anglers to reduce stress and improve the overall welfare of fish subjected to live-well retention during tournaments.

METHODS

Study area and species.— Largemouth Bass (367 ± 34 mm TL [mean $\pm$ SD]) were collected from shallow, vegetated bays of Warner Lake (South Frontenac, Ontario, Canada; 44°31'37.3"N, 76°22'50.2"W) between August 27 and September 9, 2019. Time of capture was limited to 0900–1700 hours because of fluctuation in diel patterns of basal and stress-induced cortisol secretion (Lankford et al. 2003; Cousineau et al. 2014). We used Largemouth Bass in this study because they are among the most popular tournament fish species (Schramm et al. 1991). All experimental practices were approved by the Carleton University Animal Care Committee under guidance from the Canadian Council on Animal Care.

Experimental protocol.— All fish were collected using rod and reel with a variety of plastic baits that are commonly used during angling tournaments. All fish were landed within 20 s, a typical fight duration in tournament bass studies given that tournament anglers rarely fight fish to exhaustion. Any fish that were bleeding or deeply hooked were excluded from the study and immediately released. For the culling apparatus and live-well control treatments, fish were landed, placed in a trough filled with fresh lake water, dehooked, and measured for TL. Fish less than 300 mm were released (consistent with the minimum slot size for black bass tournaments). Fish greater than 300 mm were scanned for the presence of a Biomark PIT tag using an HPR Lite hand-held reader to ensure that fish had not been previously exposed to a treatment. Selected fish were then assessed for impairment. Prior to attachment of the culling device, reflex indicators were assessed using the methods outlined by Davis (2010).

Reflex indicators provide a mechanism by which to visually assess common reflexes that may be compromised during a stress event, including orientation, startle response, vestibular–ocular response, and body flex during restraint out of water (Davis 2010). To reduce the bias of the observer, reflexes were scored as present (0) or not present (1), only when distinctly obvious. In this study, we assessed the following reflexes: (1) righting reflex, in which fish are flipped and the return to an upright position is then assessed; (2) startle response, in which fish are pinched on the caudal peduncle and rapid forward movement is assessed (Davis and Ottmar 2006); (3) body flex, in which the escape attempts of restrained fish are assessed; (4) operculum and mouth closure, in which the gulp response is assessed when the fish is held out of water; and finally (5) vestibular–ocular response, in which the eye moves in response to a body rotation around the anteroposterior axis (Davis 2007). Each fish was also observed for any preexisting body and fin injuries by using a scoring system before attachment of a culling apparatus. Body injuries were scored on a scale of 0 to 3, with 0 representing no injury, 1 (minor) representing faint bruising or scratching, 2 (moderate) representing bruising or scale damage, and 3 (severe) representing mucous or scale loss/peduncle strangulation and hemorrhaging. Tail injuries were also scored on a scale of 0 to 3, with 0 representing no injury, 1 (minor) representing minor fraying at the fin tips, 2 (moderate) representing moderate fraying or tearing, and 3 (severe) representing major fin tearing.

Next, a random number generator was used to randomly assign individual bass to one of five treatment groups: live-well control ($n = 13$), lasso ($n = 8$), metal stringer ($n = 9$), pincher ($n = 8$), or zipper bag ($n = 12$). The latter four treatments employed culling devices that are commonly used in a tournament setting (Figure 1). The stringer-style metal hook (Berkley Tournament Culling Kit) treatment involved piercing a metal clip through the membrane posterior to the fish's lower jaw; the pincher-style compression clip (Accu-Cull Elite E-Con Tags) treatment involved attaching a plastic clip to the fish's lower jaw. To make these two clip-style devices more comparable, the factory-provided plastic T-handle color marker on the Berkley stringer system was exchanged for the rubber tubing that is standard with the Accu-Cull pincher system. The lasso treatment (Zorro Baits) involved slipping a rubber lasso over the fish's tail, which was then secured in place against the body by sliding a clamp on the rubber tubing (near the caudal peduncle). The zipper bag treatment involved placing the fish into a zippered mesh sleeve that was plasticized (~50 cm in length; Glory Bag). Afterwards, individual fish were placed in black live wells (69 L; inside dimensions = 57.2 × 45.7 × 29.2 cm; temperature = 24.7 ± 0.8°C; dissolved oxygen [DO] = 8.0 ± 0.8 mg/L; DO saturation [DO_{sat}] = 98.2 ± 9.5%) that were

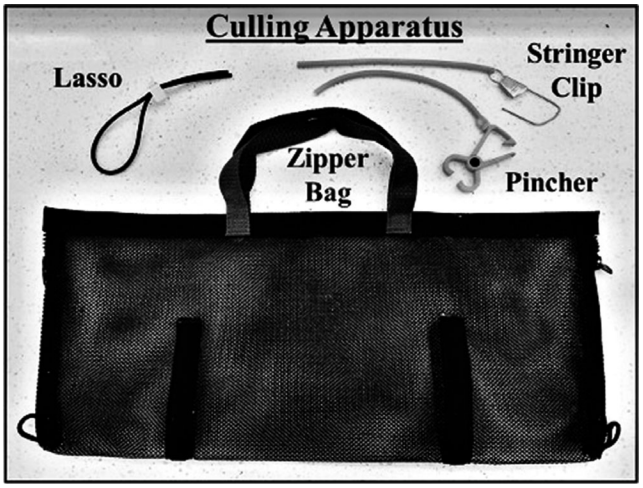

FIGURE 1. Culling apparatus used in the study of Largemouth Bass. The lasso was placed around the tail of the fish, the stringer clip pierced the membrane posterior to the lower jaw region, the pincher was clipped on the lower jaw, or the fish was placed within the zipper bag.

maintained using a flow-through system with lake water via a 0.1667-hp submersible utility pump. Fish were held individually in live wells to reduce confounding variables related to multiple retained fish (Cooke et al. 2002). To serve as a handling control for the experiment, the live-well control group was placed in the live wells without a culling apparatus.

The experimental series consisted of a simulation in which a fish was held in a live-well setting similar to what would be used in a tournament fishing boat (Suski et al. 2004; Keretz et al. 2018). The live-well treatment was 2 h in duration—a typical holding time during a tournament (Siepker et al. 2006, 2007). Indeed, in that context we were able to determine the extent to which the different culling gears impaired recovery, if at all; a similar approach was used by Suski et al. (2006) to assess the role of different live-well conditions on bass recovery. After confinement in a live well for 2 h, fish were placed dorsal side down in a water-filled trough for blood sampling and were not anesthetized following the best practices outlined by Lawrence et al. (2020). A single blood sample (≤1 mL) was obtained from each fish via caudal venipuncture. Blood was collected from the caudal vasculature using 1-mL syringes (tipped with 21-gauge needles) that were rinsed with heparin solution, and the sample was held on ice. The blood samples were obtained in less than 3 min to avoid confounding associated with handling stress (Lawrence et al. 2018). The culling apparatus was also removed during this time. Whole blood was immediately measured for glucose and lactate concentrations (see below). The remaining whole-blood sample was placed in an ice-water slurry (<7 h) prior to centrifugation (3 min at 6,000 rotations/min).

Plasma was decanted in the laboratory, flash-frozen, and stored at −80°C for later analysis of plasma cortisol and osmolality concentrations.

After the blood was collected, reflex indicators and injury (resulting from treatment) scores were assessed again. The fish were then PIT-tagged (Biomark, Inc.) along their left side near the dorsal fin to prevent their re-use in the experiment. Fish behavior at the time of release was recorded as either swimming away strongly (score = 1) or swimming away sluggishly (score = 2). After releasing the fish, the conditions of the live well (temperature and DO) were documented. At no point in time was the fish held with a vertical lip hold device, lower jaw hold, or from the culling device itself so as to reduce confounding handling stress associated with these techniques (Skaggs et al. 2017).

The sixth treatment was a bleed control group ($n = 15$). Similar to the other treatments, these fish were landed, placed in a water-filled trough, and measured for TL. The bleed control group was sampled for blood immediately (see above for methods; Lawrence et al. 2018). Fish were PIT-tagged, and behavioral observations upon release were documented.

Blood and plasma analysis.— Blood glucose and blood lactate concentrations (mmol/L) were obtained in the field using a commercially available portable glucose meter (Accu-Chek Compact Plus; Hoffman-La Roche, Mississauga, Ontario) and lactate meter (Lactate Plus; Nova Biomedical, Mississauga). Both meters have been previously validated for use in teleost fishes (reviewed by Stoot et al. 2014). A single blood lactate reading from the bleeding control group fell below the lower detection limit (0.3 mmol/L) of the device. The reading was therefore included in the analyses as 0.3 mmol/L as a conservative estimate for treatment comparisons. Plasma cortisol concentrations were analyzed in the laboratory using a radioimmunoassay kit (ImmuChem Cortisol-Coated Tube RIA Kit; MP Biomedicals, Solon, Ohio). This assay has been validated for use in teleost fishes (reviewed by Gamperl et al. 1994) and has been widely used in centrarchid fishes (Cook et al. 2012; McConnachie et al. 2012; Lawrence et al. 2018). Osmolality was also analyzed in the laboratory by using a vapor pressure osmometer (VAPRO Vapor Pressure Osmometer 5600; ELITechGroup, Puteaux, France).

Statistical analysis.— All statistical analyses were conducted using R version 3.6.2 (R Core Team 2013) and RStudio version 1.2.5033 (RStudio Team 2020). Blood parameters were fitted with general linear models, with treatment as the only predictor variable. Fish lengths were not included in the analyses as these did not differ across treatments ($F = 1.630$, $P = 0.166$). General linear models were analyzed using the Anova() function from "car" (Fox and Weisberg 2019). Post hoc analyses were then conducted for each model using the glht() function from "multcomp" (Hothorn et al. 2008). Blood physiology figures were generated using "ggplot2" (Wickham 2016). All analyses were conducted at significance level $\alpha = 0.05$.

RESULTS

Blood Physiology

Plasma cortisol titers differed by treatment grouping ($F = 3.54$, $P = 0.007$). Fish from the lasso treatment group had higher mean cortisol titers than the bleed control group by ~63 ng/mL ($P = 0.009$; Figure 2). Mean plasma cortisol concentrations did not differ significantly among the rest of the treatment groupings. Blood glucose levels varied by treatment grouping in our experiment ($F = 4.30$, $P = 0.002$). Mean blood glucose levels for fish from the live-well control and lasso treatment were significantly higher than the bleed control by ~1.6 mmol/L ($P = 0.026$) and 2.4 mmol/L ($P = 0.002$), respectively (Figure 3); however, they did not differ significantly among the rest of the treatment groupings. Blood lactate levels also varied by treatment grouping in our experiment ($F = 25.42$, $P < 0.0001$). All treatment groups had significantly higher blood lactate than the bleed control (Figure 4). Moreover, the pincher treatment was found to have higher mean blood lactate concentrations than the stringer treatment by ~3.4 mmol/L. Mean blood lactate concentrations did not differ significantly among the rest of the treatment groupings. Mean plasma osmolality samples did not vary by

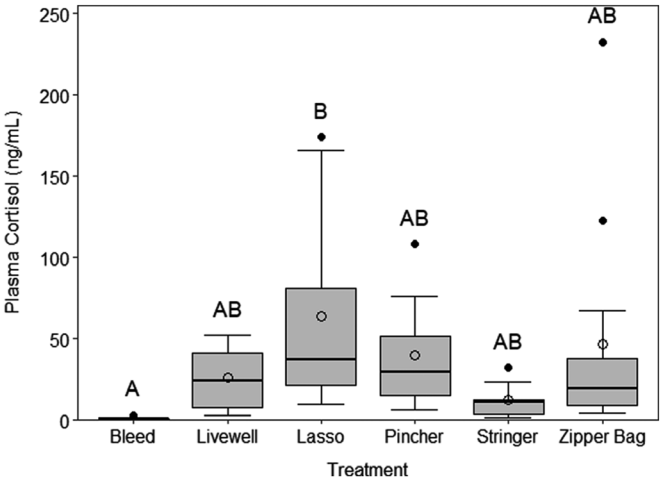

FIGURE 2. Plasma cortisol concentrations (ng/mL) after 2 h of live-well confinement for Largemouth Bass subjected to one of six treatments (bleed control: $n = 15$; live-well control: $n = 12$; lasso: $n = 8$; pincher: $n = 8$; stringer: $n = 9$; zipper bag: $n = 12$). The bleed control was sampled immediately after capture. The box plot shows both mean (open circle) and median (black line) values, with box boundaries at the first and third quartiles, whiskers denoting the highest and lowest values within 1.5× the interquartile range of the first and third quartiles, and black dots representing outliers. Letters denote significant differences between groups.

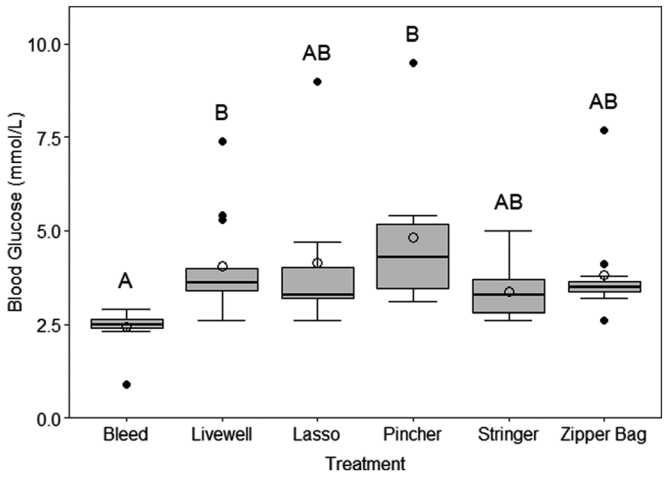

FIGURE 3. Blood glucose concentrations (mmol/L) after 2 h of live-well confinement for Largemouth Bass subjected to one of six treatments (bleed control: $n = 15$; live-well control: $n = 13$; lasso: $n = 8$; pincher: $n = 8$; stringer: $n = 9$; zipper bag: $n = 12$). The bleed control was sampled immediately after capture. The box plot shows both mean (open circle) and median (black line) values, with box boundaries at the first and third quartiles, whiskers denoting the highest and lowest values within 1.5× the interquartile range of the first and third quartiles, and black dots representing outliers. Letters denote significant differences between groups.

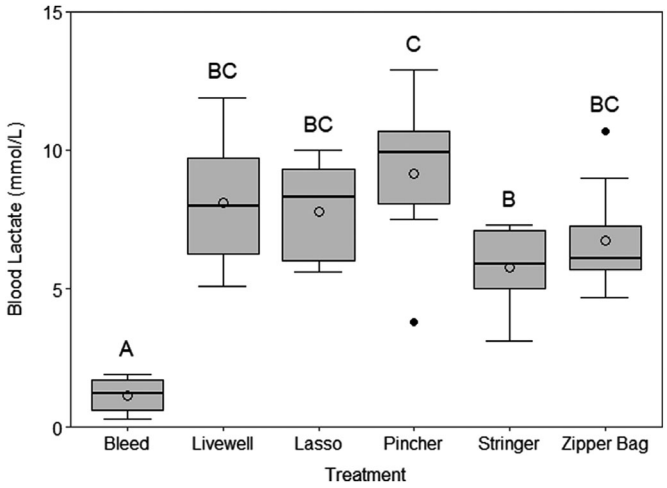

FIGURE 4. Blood lactate concentrations (mmol/L) after 2 h of live-well confinement for Largemouth Bass subjected to one of six treatments (bleed control: $n = 13$; live-well control: $n = 12$; lasso: $n = 7$; pincher: $n = 6$; stringer: $n = 8$; zipper bag: $n = 11$). The bleed control was sampled immediately after capture. The box plot shows both mean (open circle) and median (black line) values, with box boundaries at the first and third quartiles, whiskers denoting the highest and lowest values within 1.5× the interquartile range of the first and third quartiles, and black dots representing outliers. Letters denote significant differences between groups.

treatment grouping in our experiment ($F = 1.32$, $P = 0.268$; Figure 5).

Reflex Indicators and Injuries

All Largemouth Bass had all reflexes intact upon capture and release. After capture and at the time of introduction to the experiment, no obvious external injuries (aside from the hook wound) were visible. However, at the conclusion of the live-well retention period all bass in the lasso and stringer groups showed signs of injury (Table 1). The injuries for the stringer treatment were considered minor, with all scoring 1, whereas five of the fish in the lasso treatment had severe injuries, scoring 3. Injuries were associated with the site of stringer insertion through the flesh of the lower jaw and often included some level of tearing or abrasion. The lasso injuries were typically characterized as bruising around the caudal peduncle. Largemouth Bass in the pincher and zipper bag groups had very minor injuries (i.e., negligible or not visible to the naked eye) upon release. All but three Largemouth Bass behaved normally upon release, swimming away from the boat. The three that did not immediately swim away (i.e., within 3 s) were from the live-well control, pincher, and lasso groups. These fish did leave within 10 s and did not represent any form of systematic treatment-level impact. Temperature and oxygen conditions (temperature = 24.5 ± 0.9°C; $DO = 7.7 \pm 0.6$ mg/L; $DO_{sat} = 93.6 \pm 8.6\%$) upon fish release from the live wells were the same as initial conditions.

DISCUSSION

Blood Physiology

To our knowledge, this is the first study conducted on the physiological effects of tournament culling techniques on Largemouth Bass. This study revealed that some culling techniques can impair the recovery of Largemouth Bass during live-well retention. Baseline levels of blood parameters from fish sampled immediately after capture were comparable to those reported in previous studies of centrarchid fishes, indicating that our control fish were reflective of a resting state (Suski et al. 2004; McConnachie et al. 2012; Abrams et al. 2018; Lawrence et al. 2018). However, our live-well control is most relevant here because fish in that treatment represented individuals exposed to tournament conditions without any culling apparatus.

In response to the stressors associated with tournament angling, including handling, air exposure, and confinement, teleosts typically exhibit a generalized stress response, which often includes a rise in circulating levels of cortisol, glucose, and—if oxygen availability is limited in some manner or if fish are exhausted—lactate (reviewed by Wendelaar Bonga 1997; Barton 2002). Because coping with a

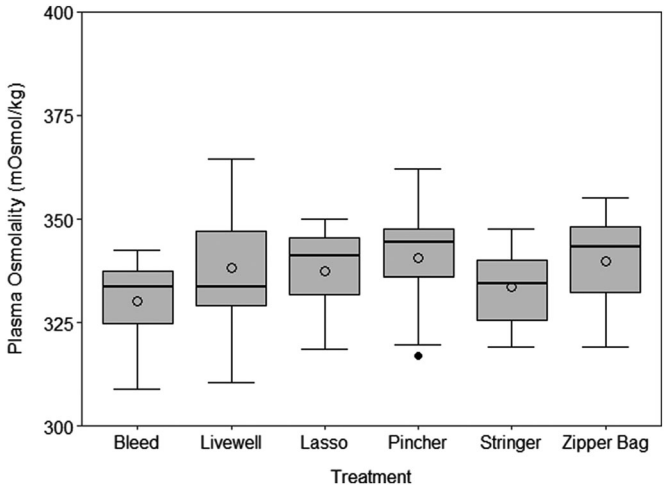

FIGURE 5. Plasma osmolality concentrations (milliosmoles [mOsm]/kg) after 2 h of live-well confinement for Largemouth Bass subjected to one of six treatments (bleed control: $n = 15$; live-well control: $n = 13$; lasso: $n = 8$; pincher: $n = 8$; stringer: $n = 9$; zipper bag: $n = 12$). The bleed control was sampled immediately after capture. The box plot shows both mean (open circle) and median (black line) values, with box boundaries at the first and third quartiles, whiskers denoting the highest and lowest values within 1.5× the interquartile range of the first and third quartiles, and black dots representing values falling outside this range.

TABLE 1. Number of injuries after 2 h of live-well confinement for Largemouth Bass subjected to one of six treatments (bleed control, live-well control, lasso, stringer, pincher, and zipper bag). Bleed control was not confined to a live-well and was immediately released following sampling. Injuries were scored from 0 to 3, with 0 representing no injury, 1 representing a minor injury, 2 representing a moderate injury, and 3 representing a severe injury.

	Score			
Treatment	0	1	2	3
Bleed control	15	0	0	0
Live-well control	13	0	0	0
Lasso	0	1	2	5
Pincher	5	3	0	0
Stringer	0	9	0	0
Zipper bag	9	3	0	0

stressor is generally considered to be an energetically demanding process (reviewed by Sokolova 2013), these changes are necessary to support a return to homeostasis and steady-state conditions (reviewed by Schreck and Tort 2016). Thus, the higher circulating concentrations of cortisol, glucose, and lactate in our culling treatment fish and in live-well controls appear to indicate that these animals are exhibiting signs of stress, as has previously been observed in bass tournament studies (e.g., Suski et al. 2004). The elevated plasma cortisol levels (relative to angled controls) suggest that the hypothalamic–pituitary–interrenal axis was being upregulated and was coordinating the stress response (Suski et al. 2004; Lawrence et al. 2018). Interestingly, the magnitude of the cortisol response differed amongst our culling treatment groups, suggesting differences in how the stressor is perceived by the animal as well as device-specific stressors (e.g., abrasion, restriction of movement, piercing injuries, etc.). The fish in the lasso treatment had higher mean cortisol levels than fish in the bleeding control group but were not otherwise different from other groups, including the live-well control. Clearly, further research is needed to address variation in the perceived stress state associated with these devices. The elevated plasma cortisol in our fish is likely enhancing gluconeogenic activity, a known function of cortisol in teleosts (Mommsen et al. 1999), resulting in the observation of elevated blood glucose levels in culling treatment fish relative to the angled controls. This release of glucose in circulation is likely important for facilitating the energetic needs in coping with the stressor (Schreck and Tort 2016). Fish in the pincher treatment and live-well control had uniformly elevated blood glucose levels.

Live-well control and fish from all culling treatments exhibited high circulating levels of blood lactate. This condition is typical of live-well-confined fish (Killen et al. 2003; Suski et al. 2004) and is thought to be the product of a recovery from the use of burst swimming during capture (Kieffer 2000) and/or potential limitations in oxygen uptake availability during air exposure (Ferguson and Tufts 1992) or in the live well (Furimsky et al. 2003; Suski et al. 2004). It is not associated directly with changes in plasma cortisol (see Lawrence et al. 2018). It appears that live-well-confined Largemouth Bass exhibited a change in acid–base status resulting from either capture or issues associated with live-well confinement. We cannot differentiate between the two at this time, but the finding does suggest that our fish are experiencing an oxygen debt that must subsequently be repaid (see Wood 1991; Milligan 1996). Furthermore, mean blood lactate levels in culling treatments did not differ from one another with the exception of the pincher and zipper treatments (which yielded the highest and lowest mean blood lactate levels, respectively, of the culling treatments). Different culling methods may therefore exacerbate the severity of this oxygen debt, as differences in the application of these devices may lead to differences in handling and air exposure times or may impair ventilation during retention (for mouth-related culling gear). At present, this idea remains purely speculative. Despite shifts in lactate, osmolality values did not differ significantly from the control values. Typically, during prolonged periods of stress, osmotic balance can change in freshwater fish as ions are lost from the plasma (Killen

et al. 2003, 2006). Our findings suggest that culling does not lead to a net change in ions in Largemouth Bass, consistent with previous studies demonstrating that live-well confinement did not negatively impact the ion balance in fish (Suski et al. 2004; Killen et al. 2006).

Reflexes and Injury

All treatments showed no impairment of reflexes over the 2-h retention period. This is likely due to low air exposure times, as culling was done while each fish was submerged in a water-filled trough. Longer air exposure times (120 s) are known to cause reflex impairment (Brownscombe et al. 2015; Cooke et al. 2016). Additionally, longer fight times cause fish to become exhausted, further impairing their reflexes; however, since fight times were standardized (20 s) this likely had little effect (Cooke et al. 2016). Because all reflex indicator scores were 0, they could not be used to predict physiological responses (or vice versa), which is consistent with previous studies indicating that physiological responses often fail to be associated with reflex impairment (Davis et al. 2001; Davis 2010; Cooke et al. 2013; Brownscombe et al. 2015).

All culling devices caused at least minor injuries, with the zipper bag and pincher treatments being the least likely to cause an injury. All fish in the stringer and lasso treatments were injured, and the lasso was the only device to cause severe injuries. It does not appear that injury caused by culling devices is related to stress level, as responses in the stringer treatment were the most similar to control values even though all fish subjected to that device were injured. Hooking in noncritical anatomical locations causes minor injuries (e.g., Pelzman 1978; Arlinghaus et al. 2008; Wilde and Pope 2008), which may be similar to the injuries caused by the stringer (i.e., puncture of tissue). Because the stringer is attached in a nonlethal area, it is likely not a large stressor: Wilde and Pope (2008) reported a 98% survival rate for Largemouth Bass hooked in nonlethal areas. In fact, a study of different retention gears on Smallmouth Bass *M. dolomieu* revealed that metal stringer clips placed through the membranes posterior to the lower jaw caused relatively little injury (aside from the puncture) and were less injurious than clips placed through the gills (Cooke and Hogle 2000). The lasso treatment caused the most severe injuries based on macroscopic visual assessment. At the end of the 2-h holding period, bruising, slime loss, and redness were observed where the lasso was in place. We were unable to assess the longer-term impacts of such dermal and soft-tissue injuries, which could result in delayed infections. The zipper bag treatment caused minor macroscopic injuries on three fish, consistent with handling fish in small-mesh nets (Colotelo et al. 2013). Overall, it seems that injury caused by the culling devices was independent of physiological responses at the time scales studied here. However, it is also important to note that we only quantified macroscopic injury, and even something as apparently benign as the zipper bag could lead to opportunistic *Saprolegnia* infections after several days, as has been observed with simple pot traps (Cooke et al. 1998).

Management Implications

This is the first assessment of the effects of different culling devices on the physiology of Largemouth Bass. Overall, two of the four culling devices (i.e., lasso and pincher) yielded physiological stress responses that were most differentiated from fish that were confined in the live well but not subjected to a culling treatment. However, the lasso culling apparatus that was placed around the caudal peduncle caused some level of dermal injury, which may make the fish vulnerable to subsequent opportunistic infections. The fish that were exposed to the lasso and pincher clip treatments generally experienced the greatest level of physiological disturbance. That said, we presume that these devices simply retard recovery. Under benign environmental conditions, this would likely not be problematic for fish; however, during warmer temperatures or if fish are exposed to a waterless weigh-in, the delay in recovery during live-well retention may lead to more extreme physiological disturbance. Although we did not have cameras in the live wells, we speculate that the pincher either impeded ventilation (contributing to acidosis) or elicited attempts by the fish to remove the clip, causing the fish to be highly active. Importantly, we observed no mortality in the study and fish were vigorous at the time of release. Selection of culling devices that minimize injury and stress contributes to maintaining the welfare status of fish involved in competitive angling events. Future studies should continue to assess different culling systems with a focus on quantifying delayed mortality, which would most likely arise from injury sites becoming infected (e.g., in the lasso treatment). Further study may also be conducted with higher sample sizes to expose more in-depth physiological responses, pinpointing the specific mechanisms and systems driving these responses.

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