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MANAGEMENT BRIEF

Effects of Common Angler Handling Techniques on Florida Largemouth Bass Behavior, Feeding, and Survival

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Abstract

Black bass *Micropterus* spp. support popular freshwater sport fisheries in North America. Bass anglers commonly adopt catch and release as a conservation practice, and frequently over 75% of angled black bass are released back into the water. If fish survive the angling event, the practice of catch and release as an alternative to harvest reduces direct mortality, but it has the potential to affect the postrelease feeding behavior and survival of the fish. The act of lifting black bass for handling, hook removal, and photograph opportunities may cause stress and injury, and the degree of injury sustained could be influenced by fish size. Holding fish in a tilted grip by the jaw has raised concern among anglers about potential damage to jaw musculature and tendons, as they may not support the fish's body weight out of water, particularly for trophy bass. We conducted an experiment with Florida Largemouth Bass *M. salmoides floridanus* to evaluate the relative differences in survival, jaw mechanics, and feeding success after the use of three common handling treatments: (1) a vertical hold using a lip-grip device (vertical treatment); (2) a tilted, one-handed grip using only the lower jaw (horizontal treatment); and (3) two-handed support to the lower jaw and body (support treatment). The time taken by fish to regain equilibrium and resume normal swimming behavior after handling differed among the three treatments; the recovery period was shortest for fish in the support treatment (mean ± SD = 7 ± 10 s; vertical treatment: 33 ± 74 s; horizontal treatment: 12 ± 16 s). Minor injuries (e.g., abrasions and sores) and diseases (e.g., tumors and fungus) tended to increase after handling across the entire sample. Results suggested no evidence of handling-specific differences in fish feeding behavior, jaw adjustments, and mortality after release. However, based on our results, we recommend that anglers use two-handed support to handle Florida Largemouth Bass, thus minimizing the mean amount of time for an individual fish to regain equilibrium after an angling event.

Black bass *Micropterus* spp. support popular freshwater sport fisheries throughout North America, and more than 25,000 bass fishing tournaments occur across the USA each year (Shupp 1979; Schramm et al. 1987, 1991; Suski et al. 2006; Allen et al. 2008). Over time, the typical behavior of bass anglers has evolved from following obligatory size limit regulations to practicing voluntary catch and release (Policansky 2002). Currently, the popularity of bass angling continues to increase, and anglers often release over 75% of angled bass (Siepker et al. 2006; Myers et al. 2008), with increasing voluntary release of legal-sized fish (Myers et al. 2008).

Catch-and-release angling may cause stress and injury to fish during handling by anglers. Numerous studies have evaluated injuries, physiological effects, and mortality in relation to hooking, air exposure, and temperature during catch-and-release angling (Gustaveson et al. 1991; Cooke et al. 2002; Cooke and Suski 2005; Arlinghaus et al. 2007; Arlinghaus and Hallermann 2007; Rapp et al. 2014). Feeding behavior and

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growth effects from hooking injuries depend on the seriousness of the injury (Pope and Wilde 2004). Cumulative effects of stressors on fish behavior and physiology are potential concerns and may ultimately influence vital rates, such as growth and survival (Gustaveson et al. 1991; Schramm et al. 1991; Meals and Miranda 1994; Cooke et al. 2002; Siepker et al. 2006; Danylchuk et al. 2007, 2008; Gould and Grace 2009).

Photographs of bass anglers supporting their catch by the jaw have raised concerns from anglers and conservationists about the potential damage to jaw musculature and tendons (Shultz 2014). Experts believe that putting much weight on the jaw can cause irreparable damage to the fish's jaws and internal organs (Grubich 2004; Shultz 2014). Danylchuk et al. (2008) and Gould and Grace (2009) showed that handling fish with lip-grip devices can cause mouth injuries and alter vertebral alignment in bonefish *Albula* spp. and Barramundi Perch *Lates calcarifer*. The jaw musculature and tendons of black bass may be inadequate to support their body weight during handling out of the water. If handling causes jaw damage, it may affect natural feeding mechanics involving major jaw movement patterns (Nyberg 1971; Winemiller and Taylor 1987). Jaw damage can ultimately impede growth and survival. Thus, an understanding of the relative effects of common handling methods is important for identifying the factors that influence fish injuries, growth rates, and mortality.

Our objective was to assess differences in recovery time, feeding behavior, and mortality of Florida Largemouth Bass *M. salmoides floridanus* after exposure to one of three commonly observed handling practices. Handling treatments included (1) a vertical hold using a lip-grip device; (2) a tilted grip using only the lower jaw; and (3) two-handed support to the lower jaw and body. We hypothesized that the use of a tilted grip on the lower jaw to handle fish would negatively influence survival, jaw mechanics, and feeding success relative to the other two handling treatments.

METHODS

Study fish.—We conducted the experiment with 90 hatchery-conditioned Florida Largemouth Bass at the Florida Bass Conservation Center, part of the Florida Fish and Wildlife Conservation Commission's (Florida FWC) Richloam State Fish Hatchery (Sumter County). The fish remained in indoor raceways for 18 months prior to the experiment, and they were regularly offered live prey (mainly koi, an ornamental variant of the Common Carp *Cyprinus carpio*). Prior to the start of the experiment, each fish received a PIT tag for individual identification.

Treatments and experimental design.—We subjected each fish to one of three treatments based on common handling practices observed in angler photographs submitted to the Florida FWC's Trophy Catch program. Treatments consisted of (1) a vertical hold using a lip-grip device (hereafter, vertical treatment); (2) a tilted, one-handed grip using the lower jaw (horizontal treatment); and (3) two-handed support on the lower jaw and body (support treatment; Figure 1). We conducted three trials with 10 fish per handling treatment, and data from all three trials were pooled for analysis.

Prior to the experiment, 90 fish were held in a communal raceway with recirculating water and controlled temperature. The water temperature was set based on the optimal temperature (~24°C) for Largemouth Bass *M. salmoides* in aquaculture (Coyle et al. 2009). Fish were anesthetized with a low dose of tricaine methanesulfonate (MS-222; 0.025 g/L) to prevent self-induced injury from fish's attempts to evade net capture. We chose fish at random and removed them from the water with a dip net. Immediately after net capture, each fish was weighed (kg) and scanned for a PIT tag. A string of colored yarn was tied through the dorsal fin to permit identification on underwater cameras. The fish were then subjected to the chosen handling treatment (vertical, horizontal, or support) for 1 min while being held out of water to recreate a handling event. Air temperature during the trials was approximately 27°C. Any injuries from the treatment (e.g., bleeding, visible abrasions, or contusions) and any pre-existing diseases (e.g., cloudy eyes or tumors) were photographed and noted while the fish was held out of water. After the 1-min treatment period, the fish was released into a holding raceway that was specific to the given treatment.

The design consisted of one concrete raceway (0.76-m depth) divided into three 7.7- × 2.4-m sections using wire-mesh dividers to separate treatment groups. Environmental conditions and water quality were controlled in each raceway section.

Underwater cameras (GoPro Hero 3 and Hero 4 series) were positioned in opposite corners of each treatment section of the raceway. Two cameras filmed each treatment for a full-coverage view of each raceway, with a total of six cameras operating per trial. We filmed each treatment section of the raceway during posttreatment release of each fish after handling and during feeding trials. Posttreatment video was used to quantify the cumulative time (s) taken by the fish to (1) regain normal equilibrium, (2) resume swimming behavior in a controlled and directed manner, and (3) cease jaw adjustments (defined below). A normal equilibrium designation required the bass to be level in the water column and parallel to the bottom (neither the head nor the tail was higher than the other; White et al. 2008). To be considered at normal equilibrium, fish could not exhibit leaning or rolling (White et al. 2008). Jaw adjustments included any opening and closing movements of the mouth during the immediate period (5–10 min) after handling and release back into the water. Mouth movement was considered a jaw adjustment only after the fish was back in the water and no human hands were on the fish at any point. Mouth movements directed at other fish, indicating potential social interaction or prey strike behavior, were considered jaw adjustments as they related to the handling treatment. Jaw adjustments were classified according to their intensity (e.g., major, moderate, or

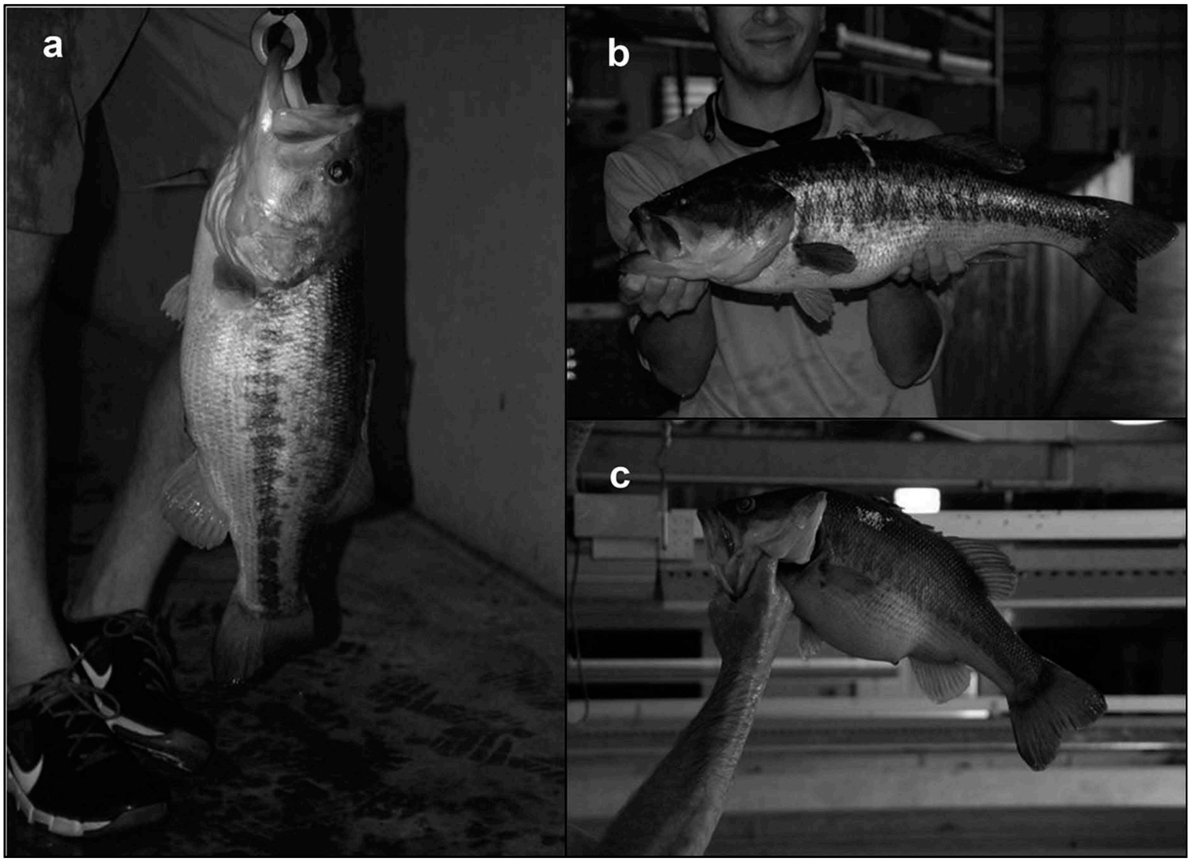

FIGURE 1. Handling treatments that were applied to Florida Largemouth Bass: **(a)** vertical hold by use of a lip-grip device (vertical treatment), **(b)** two-handed support to the jaw and body (support treatment), and **(c)** tilted, one-handed grip of the lower jaw (horizontal treatment).

minor). A major jaw adjustment included a full extension of the jaw and/or a substantial side-to-side head shake. A substantial head shake could be classified as a side-to-side movement of the head approximately 30° or farther from center (0°). A minor jaw adjustment included small and brief (<1 s) open-and-close movements of the mouth wherein the jaw was not opened beyond approximately 25% of potential extension. Postrelease behavior that was classified as a minor jaw adjustment never included a head shake. Finally, a moderate jaw adjustment was intermediate between the major and minor adjustments as described above. Jaw adjustments that were classified as moderate included open-and-close movements of the mouth greater than 25% of jaw extension but less than a full jaw extension. Moderate jaw adjustments could include a head shake, but only slight head movements were considered in the moderate category. A slight head shake was characterized as a side-to-side head movement less than 30° from center (0°). Up-and-down-oriented head movements were not observed during this study. A grid system was not used to quantify the behavioral observations; thus, all classifications were based on approximate and relative observations.

Feeding behavior was observed for each treatment group in two feeding trials conducted at 4 and 5 d posttreatment. Feeding trials consisted of releasing a single prey item every 30 s until 75 prey items were introduced. Number of prey was dependent on the interest displayed by the Florida Largemouth Bass during the feeding trials. The first 20 prey items were assessed during video analysis. Prey species consisted of Bluegills *Lepomis macrochirus* or koi, and prey size ranged from approximately 5 to 10 cm. Underwater cameras were set up in the same configuration as used in the posttreatment observations described above. Cameras recorded video throughout the feeding trials for 1 h. Prey strike effectiveness and chasing behavior were quantified and compared across all treatments. Prey strike effectiveness was defined by the end result of the strike (i.e., the prey was captured, escaped, or was ignored). The consumption of prey items was also documented in situ through direct observation to supplement video observations when comparing feeding success.

The day after the second feeding trial, we transported fish to outdoor ponds (0.081 ha; 0.2 acres), where they were held for a 30-d posttreatment mortality assessment. At the end of the 30-d period, the ponds were drained and the specimens were recovered. We weighed and observed injuries in recovered specimens and scanned them for PIT tag identification. Mortality events were recorded based on PIT tag identification of carcasses as observed by on-site hatchery personnel or after pond draining. Florida Largemouth Bass that were recovered alive were stocked into public fishing lakes after the experiment was completed.

Statistical analysis.—Weight distribution among handling treatments was compared with ANOVA after $\log_{10}$ transformation. We analyzed injuries from the treatment and at 30 d posttreatment by using Pearson's chi-square (χ^2) analysis. Posttreatment recovery time was compared among treatment groups by using ANOVA and post hoc Tukey's honestly significant difference analysis after square-root transformation. The influence of weight over recovery time was tested with ANCOVA. Jaw adjustment, prey strike effectiveness, chasing behavior, and prey consumption were compared across treatments by using Pearson's χ^2 test. We classified prey strike effectiveness into one of three categories: (1) the fish consumed the prey, (2) the fish displayed no interest in the prey, or (3) the fish attempted to consume but ultimately released the prey after a strike. Chasing behavior was classified in two categories based upon whether the fish chased the prey or not. We employed a two-sample *t*-test to compare the effectiveness of data collected using video and in situ observations of prey consumption. Individual changes in weight ($\log_{10}$ transformed) at 30 d posttreatment were analyzed with a *t*-test to understand weight fluctuation due to treatments. Mortality after the fish were transported to the outdoor ponds and during the 30-d period after the feeding trial was compared across treatments with Pearson's χ^2 test. Normality and homogeneity of variance were tested with *Q*–*Q* plots. The significance level α was set at 0.05 for all analyses.

RESULTS

Weights of individual Florida Largemouth Bass ranged from 1.08 to 3.84 kg (mean ± SD = 2.28 ± 0.58 kg), and no significant difference in weight was detected among the three handling treatments (ANOVA: $F_{2,\ 87} = 0.02$, $P > 0.05$). Pre-existing external injuries and abnormalities (i.e., sores, small tumors, and abrasions) were observed in 10% ($n = 9$) of the fish that were used in the experiment. These injuries were typically observed in the frontal area (i.e., mouth, opercula, and eyes). The mean number of pre-existing injuries in fish was not significantly different among treatments ($\chi^2 = 0.74$, df = 2, $P > 0.05$).

Recovery time after handling differed among the three treatments (ANOVA: $F_{2,\ 87} = 9.92$, $P < 0.05$). Post hoc Tukey's honestly significant difference test indicated that recovery time did not differ between fish subjected to the support treatment and those that received the horizontal treatment ($P > 0.05$), but significant differences in recovery time existed between fish in the support treatment (recovery time: range = 1–53 s; mean ± SD = 7 ± 10 s) and those in the vertical treatment (range = 3–363 s; mean ± SD = 33 ± 74 s), which displayed longer recovery times ($P < 0.05$; Figure 2). Recovery time of fish handled via the horizontal treatment was intermediate between those of the other two treatment groups (recovery time: range = 3–96 s; mean ± SD = 12 ± 16 s). The ANCOVA results indicated no significant effect of fish weight on recovery time (ANCOVA: $P > 0.05$).

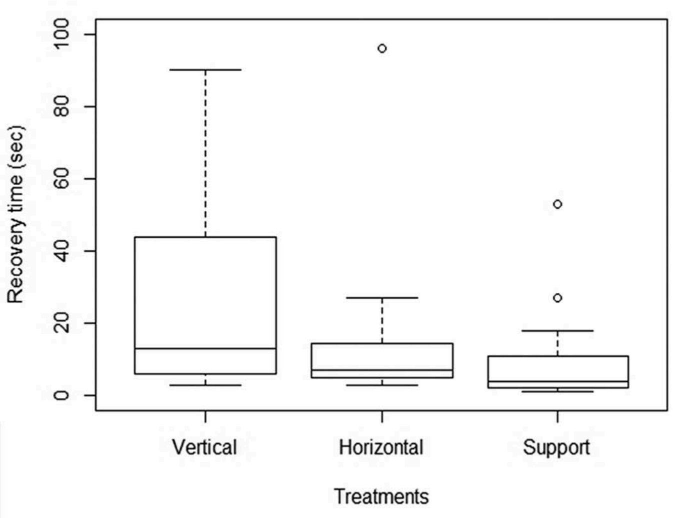

FIGURE 2. Total recovery time (s) of Florida Largemouth Bass after being subjected to one of three handling treatments (vertical, horizontal, or support; defined in Figure 1). Recovery time was defined as the cumulative time taken by the fish to (1) recover normal equilibrium, (2) resume swimming behavior in a controlled and directed manner, and (3) cease displaying jaw adjustments.

Number of jaw adjustments made by fish during the recovery period did not differ significantly among treatments ($\chi^2 = 5.09$, df = 4, $P > 0.05$). The horizontal treatment was the only treatment in which major jaw adjustments were observed: 17 (52%) of 33 observed adjustments by fish in the horizontal treatment were categorized as major, while only four adjustments (12%) were moderate and 12 adjustments (36%) were minor. Most of the jaw adjustments observed in the other two treatment groups were minor (support: 77% minor and 23% moderate; vertical: 100% minor). Multiple jaw adjustments made by individual fish were only observed in 10 of the 90 cases. Seven of those 10 fish were subjected to the horizontal treatment, and three received the support treatment. The maximum number of jaw adjustments observed in an individual Florida Largemouth Bass was four (horizontal treatment).

Counts of prey consumption detected by in situ and video observations were not significantly different among treatments ($t = -0.91$, df = 32, $P > 0.05$; Figure 3). Florida Largemouth Bass feeding success did not significantly differ ($\chi^2 = 1.6$, df = 2, $P > 0.05$; Figure 4). Failed strikes on prey items were also not significantly different across treatments ($\chi^2 = 3.3424$, df = 4, $P > 0.05$). Frequency of chasing behavior did not differ among the treatment groups ($\chi^2 = 0.98$, df = 2, $P > 0.05$), occurring during 69–76% of the prey item release events. Feeding effectiveness (i.e., number of prey that were successfully consumed) did not

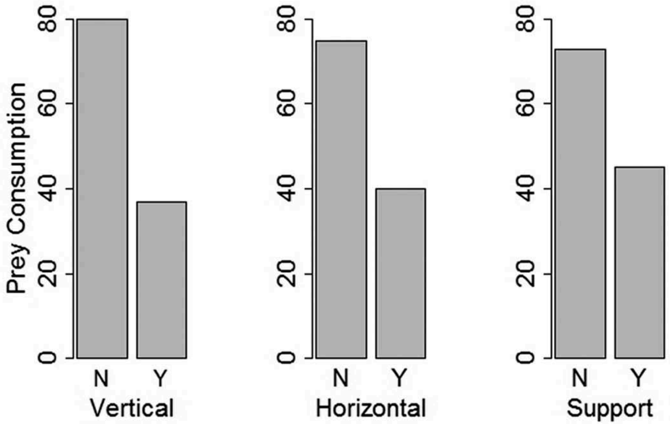

FIGURE 3. Number of live prey items (Bluegills and koi) that were consumed (Y = number of prey consumed; N = number of prey not consumed) by Florida Largemouth Bass belonging to the three handling treatment groups (vertical, horizontal, and support treatments; defined in Figure 1).

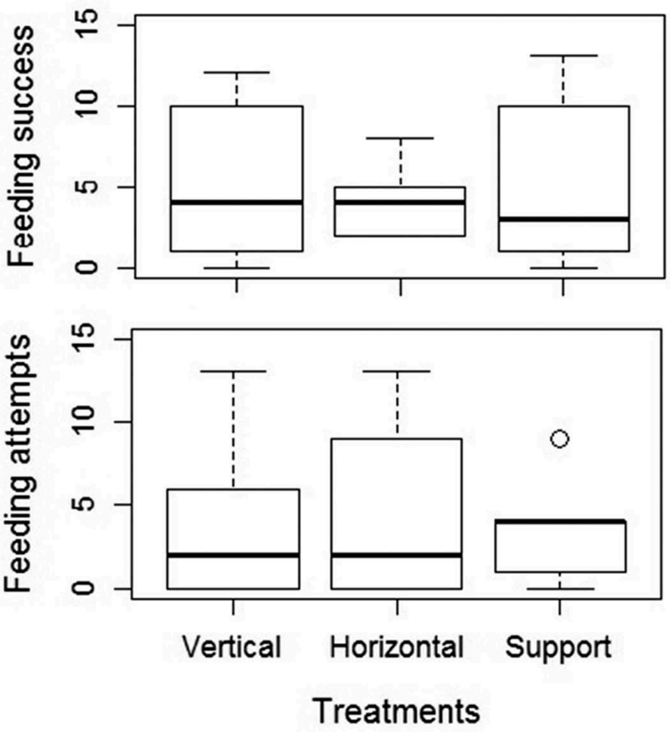

FIGURE 4. Comparison of effective prey consumption (feeding success) and feeding attempts made by Florida Largemouth Bass belonging to the three handling treatment groups (vertical, horizontal, and support treatments; defined in Figure 1). The line within the box represents the median, the ends of the box represents the 25th and 75th quartiles, and the ends of the dashed lines represent the maximum and minimum values in the range. The open circle represents an outlier that exceeds 1.5× the range of the box.

TABLE 1. Results of *t*-tests comparing weight changes in Florida Largemouth Bass 30 d after being subjected to one of three handling treatments (described in Methods).

	Weight (kg) before trials		Weight (kg) after trials		
Treatment	Mean	SD	Mean	SD	*P*
Vertical	2.26	0.57	1.96	0.63	>0.05
Horizontal	2.27	0.58	1.81	0.74	<0.05
Support	2.29	0.59	1.63	0.96	<0.01

show a significant difference for any treatment during the second feeding trial (conducted 24 h after the first feeding trial; horizontal treatment: $\chi^2 = 0.0018$, df = 1, $P > 0.05$; support treatment: $\chi^2 = 0.22$, df = 1, $P > 0.05$; vertical treatment: $\chi^2 = 0.39$, df = 1, $P > 0.05$). In some cases, the camera failed to record the fate of prey items, so it is possible that several of the feeding bouts went undetected.

Examination of the fish at 30 d posttreatment indicated an increase in external injuries from 10% to 18% (17 of 90 fish) across the entire sample. The observed injuries included red pharyngeal plates, inflamed gill arches, dorsal abnormalities, frontal sores, and red lesions on jaws. The occurrence of injury did not significantly differ among the treatments ($\chi^2 = 4.49$, df = 2, $P > 0.05$). Disease symptoms (e.g., cloudy eyes; fungus between the eyes, on the gills, and on the anterior dorsal area) were observed in 8% of the overall sample. After the 30-d posttreatment period, decreases in weight were observed in all treatment groups, and fluctuations significantly differed from the original weight recorded ($P < 0.05$; Table 1). Mortality was 36%, with no significant differences observed among treatments ($P > 0.05$).

DISCUSSION

In high-effort, catch-and-release-based fisheries like those for black bass, it is important to understand how handling procedures influence fish behavior, growth, and survival. We predicted that handling Florida Largemouth Bass by using a tilted grip on only the lower jaw would negatively influence survival, jaw mechanics, and feeding success relative to the other two handling treatments. However, we found no evidence of handling-specific differences in fish feeding behavior, jaw adjustments, or mortality after release. Results did suggest that handling methods could affect short-term recovery time and behavior. Injuries did not significantly differ among handling treatments, and we found no evidence that mortality varied among the treatments.

In our analysis of mean recovery time, fish that were handled with vertical lip grips took the longest time to regain equilibrium, followed by fish in the horizontal treatment and those in the support treatment. Reiss et al. (2007) suggested that unhooking devices and handling tools (e.g., vertical-grip devices) could be used to effectively resuscitate exhausted or stressed fish. However, Riddiford (1978) and Danylchuk et al. (2007) proposed that the use of vertical lip grips would influence recovery time, ultimately increasing vulnerability to predation. Other studies have reported that the use of lip-grip devices can be more invasive than supporting methods (Danylchuk et al. 2008; Gould and Grace 2009). Gould and Grace (2009) found that using a lip grip with no additional support on the body created small holes in the membrane of the lower jaw in Barramundi Perch. Danylchuk et al. (2008) reported similar injuries in bonefish, such as tears and holes in the soft tissue of the lower jaw. We observed no direct injuries (i.e., tears or holes) due to the use of lip-grip devices on Florida Largemouth Bass. However, the mean recovery time of fish that were held by this method was longer than that observed for the other two handling methods. Based on our results, use of two-handed support leads to shorter mean recovery time than the use of vertical and tilted jaw grips.

The frequency and severity of jaw adjustments displayed during the recovery period were greater for individuals that were subjected to the horizontal treatment than for individuals that were exposed to the vertical and support treatments. This result agrees with Shultz (2014), who stated that use of the jaw to bear the fish's body weight can be detrimental. Future studies should assess whether holding the fish by the lip in a horizontal orientation causes problems with feeding mechanics or other injuries in other fish species; in the case of Florida Largemouth Bass, we found short-term effects but no evidence that feeding was negatively affected. Feeding success was similar among the three handling treatments; however, fish that were subjected to the horizontal treatment displayed a greater frequency of ineffective strikes on prey (17% [19 of 112]). Thus, our results indicated that the use of different common handling methods influenced short-term behavior (e.g., mouth adjustments), but no significant difference in foraging efficiency, long-term behavior, or survival was observed.

A notable finding was that weight decreased significantly in all treatment groups over the course of the experiment. Prolonged time to resume feeding after catch-and-release and competitive angling tournaments was observed in fish even when netted underwater (Siepker et al. 2006). Although feeding behavior did not differ among the three treatments, body weight decreased significantly, suggesting some impairment relative to normal behavior. Thus, the handling event likely had prolonged effects on behavior and recovery that were not apparent from the foraging experiment alone. The density of prey items released into the research ponds may also have been inadequate to support good condition and growth of Florida Largemouth Bass.

The treatment-related injuries observed in this study were not considered to be fatal, and the use of lip grips or two-handed support did not influence mortality directly, confirming the results of previous studies (Danylchuk et al. 2008; Gould and Grace 2009). Pre-existing injuries that were observed during the experiment were potentially associated with collisions or conditions experienced during captivity, as described by Moring (1982) and Higuchi et al. (2013). Abnormalities observed at 30 d posttreatment may have been influenced by physiological changes associated with fish transport, which can alter homeostasis, cause immunosuppression, and increase vulnerability to pathogens (Anderson et al. 1982; Ventura and Grizzle 1987; Anderson 1990; Gustaveson et al. 1991). Combined angling practices and drastic homeostatic changes can lead to elevated mortality in response to angling events (Siepker et al. 2006). However, fish mortality in our study was not attributable to any specific handling treatment.

We did not incorporate an untreated control group (i.e., fish that were not handled at all) into our study design. The lack of a control group limited our ability to infer overall effects due to the handling methods. However, we were able to assess the relative differences among three commonly used handling methods. The practice of catch-and-release angling often necessitates some manner of handling prior to fish release, and our interest was to evaluate the relative differences in effects from these popular handling methodologies.

Our results suggested that three common handling practices produced no discernible effects on jaw adjustments, feeding behavior, and mortality in Florida Largemouth Bass. However, we found direct effects on recovery time. An overall increased tendency toward injury and diseases due to handling was observed across all treatments, but significant differences were not detected among treatments.

Future studies evaluating the effects of different handling practices on black bass should employ a wider size range of individuals. Our experimental population failed to encompass the maximum attainable size observed for Florida Largemouth Bass (Clugston 1964). Responses to anaerobic activity, stressors, angling, and live-well retention may differ between trophy-sized fish and smaller individuals (Schmidt-Nielsen 1984; Goolish 1991; Meals and Miranda 1994; Weathers and Newman 1997; Wilde 1998; Ostrand et al. 1999). The Florida FWC's Trophy Catch program designates "lunker" bass as those weighing 3.63–4.49 kg and designates "trophy" bass as those weighing 4.54–5.85 kg. Big bass programs in Florida and Texas categorize 5.90-kg and larger individuals as the top tier in trophy bass weight. Future studies like ours could be improved by evaluating effects on larger bass. The largest fish in this study was 3.84 kg, placing it in the lunker bass category according to the Florida FWC.

Currently, no evidence exists for growth and survival differences among individuals subjected to common handling practices associated with catch-and-release angling. Our experiment did not assess additional factors related to catch-and-release angling (i.e., hooking mortality, angling disturbance, air exposure, temperature, etc.). These factors were previously implicated in a study of long-term growth and survival of Largemouth Bass (Cooke et al. 2002).

Anglers should exercise caution to minimize the potential for injury, damage, and disease when handling fish. Additional studies conducted in both natural and simulated environments will be necessary to describe different magnitudes of physiological and angling stressors, thus permitting an evaluation of differences among common handling practices. As described by Cooke et al. (2002), bass anglers will likely embrace small, research-driven changes that minimize disturbance, facilitate recovery, and enhance the survival of caught-and-released bass. Reductions in the impacts of any element comprising the cumulative effects of the catch-and-release process may contribute to an increase in overall fish survival. Researchers should continue to evaluate the effects of handling practices on angled Florida Largemouth Bass in order to sustain this socially and economically valuable species.

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