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Short communication

The post-release behaviour and fate of tournament-caught smallmouth bass after 'fizzing' to alleviate distended swim bladders

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ABSTRACT

In recreational fishing, barotrauma occurs when fish that are angled from deep water are rapidly brought to the surface, causing a number of injuries and physiological alterations associated with gas expansion (such as distended swim bladders) that may impede swimming and prevent the fish from returning to depth. By deflating the swim bladder using a hypodermic needle (a process called "fizzing") fish typically can return to depth. However, little is known about its consequences and efficacy on wild fish. At a competitive smallmouth bass (*Micropterus dolomieu*) angling event on Rainy Lake in northwestern Ontario, we evaluated the effects of post-weigh in fizzing on the behaviour and short-term survival of three treatment groups after release: (i) barotrauma fish without fizzing ($N = 8$); (ii) barotrauma fish that were fizzed ($N = 9$); (iii) fish without signs of barotrauma that were fizzed ($N = 10$) (sham control). Small external radio transmitters were affixed to the fish and tracked for 4 days. Fish were released at a common site and we assessed their dispersion at specific distances from the release site (50, 250, and 2000 m). All fish survived the 4-day monitoring period. No differences were observed in the time it took each group to disperse from the release site. Furthermore, there was no statistical evidence that fizzing influenced mean daily movements relative to controls, though a consistent trend was noted where fish that were fizzed displayed greater movement than non-fizzed fish with distended swim bladders. This study revealed that fizzing by trained experts is not detrimental to barotrauma fish. However, if done improperly there is risk to vital organs suggesting that there is merit in exploring other less invasive approaches to recompressing fish. Because our statistical power was generally low, further research is needed to determine whether fizzing should be encouraged or dissuaded to maintain the welfare status of the fish, decrease sublethal impairments, and reduce mortality.

1. Introduction

Of numerous factors contributing to the stress and disturbances of tournament-caught fish (summarized in Cooke et al., 2002; Siepker et al., 2007), little attention has been directed towards the problem of rapid depressurization, which occurs when fish are removed from deep water and rapidly brought to the surface. This rapid decrease in pressure allows gas to expand in the swim bladder and blood vessels when there is not sufficient time for depressurization. Consequently, it can lead to considerable impacts on the physiological and physical conditions of decompressed fish (Feathers and Knable, 1983; Morrissey et al., 2005; Rummer and Bennett, 2005; Gravel and Cooke, 2008). Symptoms include: expanded swim bladder, abnormal or erratic swimming behaviour, internal and/or external haemorrhaging, ocular pressure, stomach eversion, formation of gas bubbles in the circulatory system, gills, heart, and brain, and other critical tissue damage (Feathers and Knable, 1983; Morisssey et al., 2005; Rummer and Bennett, 2005; Gravel and Cooke, 2008). Physiologically, these fish show elevated levels of lactate, glucose (Gravel and Cooke, 2008) and tissue damage indicators (Morrissey et al., 2005) in the blood. Of particular importance, a distended swim bladder will prevent a fish from returning to depth leaving them susceptible to harsh environmental conditions, predation, and other injuries.

Barotrauma may be an important issue in bass tournaments, since fish are brought from depth and then held in livewells under atmospheric pressure for up to 10 h (Schramm et al., 1991). Consequently, fish are unable to return to depth and this leads to the continued expansion of gases within the swim bladder and blood vessels (Lee, 1992). Tournaments are also inherently stressful to the fish involved (Cooke et al., 2002; Killen et al., 2003; Suski et al., 2004), and the increase in stress and injury associated with barotrauma may lead to fish being released in a state

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that may not be conducive to its welfare or survival. Recent work by Gravel and Cooke (2008) used biotelemetry to reveal that smallmouth bass (*Micropterus dolomieu*) that suffered barotrauma experienced behavioural and physiological disturbances and faced higher probability of death relative to fish without barotrauma. Since post-tournament behaviour and survival of smallmouth bass were significantly affected by barotrauma, there is a need to develop ways to mitigate or reduce its impacts.

Many methods have been developed to alleviate factors that cause stress and mortality to fish during catch-and-release (Cooke and Suski, 2005). However, little scientific research has been conducted to validate ways of mitigating decompression of fish. A hypodermic needle is often used to deflate the distended swim bladder (Kerr, 2001), a process known as "fizzing". Still, few studies have been conducted regarding the effects of fizzing on the long-term survival of the fish, and of those conducted to date, none have revealed definitively whether to "fizz or not to fizz" (as reviewed by Kerr, 2001). Consequently, government natural resource agencies have been unable to develop policies to advocate or oppose the use of this technique to increase survival rates of fish suffering from barotraumas (Kerr and Kamke, 2003). At present, there is apprehension about fizzing because of the potential to inadvertently puncture vital organs and introduce pathogens. In addition, it is unknown whether the fizzed fish are behaviourally compromised and may be unable to swim effectively to avoid predators or forage for food (Shasteen and Sheehan, 1997). Most studies to date on fizzing have been completed in laboratories (e.g., Keniry et al., 1996; Shasteen and Sheehan, 1997), or using mark recapture methods (e.g., Lee, 1992; Bruesewitz et al., 1993). There are currently no telemetry studies that have evaluated the effect of fizzing in the wild where fish are potentially subject to predation and other environmental conditions.

The purpose of this study was to evaluate the consequences of fizzing on tournament caught smallmouth bass and to determine whether fizzing is an effective means of remedying the consequences of distended swim bladders. Our study had three main objectives. First, we assessed survival rates in fish with and without barotrauma. Next, we examined the effects of fizzing on the survival of barotrauma and non-barotrauma fish. Last, we evaluated the effects of fizzing on the post-release behaviour and movement of telemetered fish. Based on previous studies, we expected that barotrauma fish would exhibit higher mortality (Gravel and Cooke, 2008) and greater levels of physiological disturbance (Morrissey et al., 2005) than fish with no barotrauma. Furthermore, we predicted that barotrauma fish that were subjected to fizzing would have an increased survival rate over barotrauma fish that were not fizzed (Keniry et al., 1996; Collins et al., 1999). Finally, we predicted that fish with barotrauma that were not fizzed would take the longest to disperse from the release site (Gravel and Cooke, 2008).

2. Methods

2.1. Study site and tournament

This study was conducted at a smallmouth bass live-release tournament involving 70 boats with 140 anglers (29 and 30 September 2007) held in northwestern Ontario on Rainy Lake (48°50′20″N, 93°37′20″W) where researchers have previously documented post-tournament barotrauma (Gravel and Cooke, 2008). The mean water temperature during this 2-day period was approximately 15.6 °C and anglers were free to target fish across a range of depths (max lake depth = 49.1 m). Tournament anglers were allowed to weigh up to five smallmouth bass per tournament day aiming for the greatest combined weights over the 2-day tournament. Fish in the tournament were captured by rod-and-reel, and were held in livewells for up to 9 h. In order to weigh their fish, anglers brought fish to shore in water-filled plastic bags, and fish were transported in water basins to the wet weigh-in via an all terrain vehicle. For our study, we intercepted randomly chosen fish immediately after weigh-in, but prior to their placement into a live-release pontoon boat where they were kept until release (up to 3 h; Gravel and Cooke, 2008).

2.2. Treatments and experimental procedure

Fish were placed into three treatment groups. Smallmouth bass showing signs of barotrauma, characterized by bloating (severe body distension), loss of equilibrium and haemorrhaging in more than one location on the body were randomly placed into two treatment groups. The first group: (i) included fish with signs of barotrauma with swim bladders left intact ($N = 8$), the second group; (ii) included fish with barotrauma with swim bladders that were manually punctured ($N = 9$). A third treatment group (sham) (iii) consisted of fish that showed no signs of barotrauma but were subjected to swim bladder puncture ($N = 10$). All intercepted fish were held in observation containers (approx. 50 L) filled with lake water for several minutes. Dissolved oxygen of water in these containers was kept over 5 mg/L. The swim bladder was punctured (i.e., fizzed) while the fish was submerged in water using a 21-gauge, 1.5 in., hypodermic needle. The needle was inserted underneath the scale at a 45° angle towards the head, through the skin to a depth of approximately 10–15 mm, and into the swim bladder. The insertion point occurred where a line from the dorsal origin of the pectoral fin and the fourth dorsal spine intersected. The fish was gently squeezed until no more gas bubbles were released. This procedure was performed by the same researcher for all fish. A dissection of a smallmouth bass had been performed prior to the experimental fizzing to ensure that the insertion of the needle was correctly positioned, since no study on the fizzing of smallmouth bass has been done in the past.

2.3. Physiological assessment

We assessed the physiological condition of individual fish after they were removed from an observation container. Fish were submerged in a V-shaped trough in a supine position and restrained, with wet hands, by the lower jaw and body. A 1.5 mL non-lethal blood sample (using a 3 mL vacutainer, lithium heparin anticoagulant, Becton-Dickson, Inc., Franklin Lakes, NJ) was taken at the caudal haemal arch using venipuncture technique (Gravel and Cooke, 2008).

Lactate and glucose levels were immediately measured by adding approximately 10 μL of blood to handheld lactate (Lactate Pro LT-1710 portable lactate analyzer, Arkray, Inc., Kyoto, Japan) and glucose (Accu-check glucose meter, Roche diagnostics Corp., Indianapolis, IN) meters, as per Gravel and Cooke (2008). Prior to analysis, meters were set and calibrated appropriately according to the manufacturer guidelines. The physiological results derived from the hand-held meters have been shown to be similar to laboratory values for fish and other animals (Morgan and Iwama, 1997; Wells and Pankhurst, 1999; Pyne et al., 2000; Venn Beecham et al., 2006).

2.4. Radio telemetry

Immediately following the blood sampling, small flattened external-radio transmitters were attached (<1 g in water; approx. 4 mm × 15 mm × 18 mm with 20 cm trailing antennas and 9 day life expectancy) to the dorsal surface of the fish at the junction of the soft and spiny dorsal fins (approx. 5 mm ventral to the dorsal midline) following techniques described in Cooke (2003). To summarize, while the fish remained in the sampling trough, two 22-gauge hypodermic needles mounted on 3 mL syringes were used

to pass stainless steel wires (threaded through the transmitter), through the dorsal musculature. On the opposite side, the needles were removed and the wires were twisted with a backing plate to secure it. In addition, each fish was affixed with an anchor tag (Floy Manufacturing, Inc., Washington) into the dorsal musculature for external identification.

Telemetered fish were held in a transport tank (approx. 200 L) mounted in a boat until a dozen fish were tagged for the first release (approx. 1 h holding time). Tagged fish were transported to a common release site which would be characterized as "unsuitable" habitat for smallmouth bass (i.e., little cover, sparse weeds, mud bottom). Releasing fish at such a site meant that they were likely to leave in search of better habitat. This approach also mimicked common tournament release procedures. The release site selected was the same as that described by Gravel and Cooke (2008). Fish were released two separate times (approx. 1.5 h apart), but all released on day 2 of the tournament.

We radio-tracked fish for 96 h (>72 h is considered long-term for post-release monitoring; Pollock and Pine, 2007) or until they moved beyond the release site (approx. 2 km as per Gravel and Cooke, 2008) using a 3-element yagi antenna and two radio telemetry receivers (SRX_400, Lotek Wireless, Newmarket, ON and IC-R20, Irvine, CA). Immediately after release, fish were tracked approximately every hour for the first 5 h to assess immediate post-release behaviour. Fish were then located by boat tracking, once every day and their location (based on zero point tracking) was recorded with a handheld GPS. These positions were used to evaluate post-release behaviour of fish by determining their movement patterns: the distance moved per tracking day and their dispersal from the release site.

2.5. Statistical analysis

The mean concentration of blood lactate and glucose of each treatment group were compared using one-way analysis of variance (ANOVA). The same method was also used to evaluate the differences in the mean total lengths of fish for each treatment group. We used ArcGIS9, ArcMap Version 9.2 to map individual positions of each telemetered fish for every tracking day and generate distances between sequential points. We used a one-way ANOVA to compare the mean daily movement of individuals in each treatment group over the entire study period. Additionally, we compared the probability of each treatment group being within a specified distance from the release site (50 and 250 m) using a univariate survival analysis with censoring. All statistical analyses were performed using JMPIN Version 4.0 (SAS Institute, Cary, NC) and the level of significance for all tests (α) was set to 0.05. Data for the mean daily movement of fish were $\log_{10}$ transformed to normalise the data.

3. Results and discussion

Fish in each treatment group were of similar size ($P = 0.071$, mean total length ± std error: 449 ± 4.2 mm) and their initial physiological state, indicated by blood concentrations of lactate and glucose, did not differ between treatment groups ($F_{24,2} = 1.043$, $P = 0.367$, $F_{24,2} = 2.339$, $P = 0.118$ for lactate and glucose, respectively) (Fig. 1). Although the physiological assessment of tournament-caught smallmouth bass was not the primary focus of this study, it did provide context for the condition of fish at the end of the tournament. Similar to Gravel and Cooke (2008) we found no difference in the blood glucose and lactate concentrations between tournament-caught fish that were decompressed and those that were not, indicating that the collective tournament procedures and weigh-in event were stressful. Hence, any efforts to reduce stress

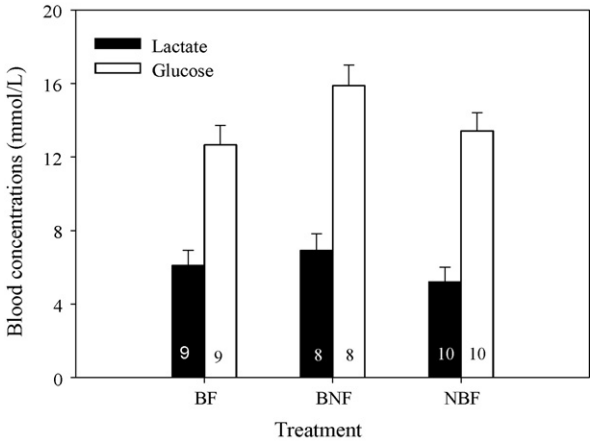

Fig. 1. Lactate and glucose plasma levels in relation treatment groups barotrauma and fizzed (BF), barotrauma and not fizzed (BNF) and no barotrauma and fizzed (NBF).

by enabling fish to return to depth have the potential to be beneficial.

We observed no mortality in any fish, whereas previous studies have shown significant mortality in fish with barotrauma (e.g., Feathers and Knable, 1983; Keniry et al., 1996; Gravel and Cooke, 2008). Of these studies, Gravel and Cooke (2008) was the only one to use telemetry to track post-tournament smallmouth bass in the wild and found nearly 40% mortality in fish with barotrauma. In the present study, we used the same criteria as Gravel and Cooke (2008) to assess barotrauma (e.g., using external signs such as distended swim bladders, loss of equilibrium, and external haemorrhaging). Still, the incidence of fish floating on the surface was higher in the study by Gravel and Cooke (2008). Seasonal variation in temperatures and angler targeting behaviour (fishing deeper water during 2006 tournament) may account for the difference in the severity of barotrauma between Gravel and Cooke (2008) and this study.

To date, fizzing has been the most common method used to recompress fish. Similar to past studies on gas bladder deflation, we found no mortality in fish with barotrauma that were subjected to fizzing (e.g., Bruesewitz et al., 1993; Shasteen and Sheehan, 1997). Other studies recorded mortality but found no significant difference between deflated fish and non-deflated fish (e.g., Lee, 1992; Gitschlag and Renaud, 1994), and some studies have shown a positive effect of artificial swim bladder deflation on yellow perch (Keniry et al., 1996), black sea bass and vermillion snapper (Collins et al., 1999). However, the majority of these studies had limitations such as confinement to laboratories, cages or pens, or used tag returns, which do not allow for assessment of fish in the wild. Furthermore, these studies can introduce cage-, tag-, and laboratory-related mortality obscuring the effects of barotrauma and deflation. Our study is the first to evaluate the effects of fizzing on smallmouth bass in the wild and in a tournament setting using telemetry where fish are subjected to multiple stressors. In general, we found that the effect of fizzing was not detrimental to fish, however, it was not beneficial either. Since the severity of barotrauma in this study was potentially low, it is possible that fizzing was not necessary, as the benefits of deflation increase with depth of capture (Collins et al., 1999). Nonetheless, fish that were fizzed were unable to maintain equilibrium in the holding tank prior to fizzing, which suggests that fizzing was required. Deflation should occur once the fish is landed rather than fizzing several hours after the landing of fish, for which the benefits of fizzing may be minimal.

Unlike any other previous studies, the use of telemetry allowed us to assess the effects of fizzing on the post-tournament behaviour

Table 1
Results of one-way analysis of variance of mean daily distance traveled for all treatment groups.

Day	d.f.	*F*-ratio	*P*	Observed power	Least significant number
1	2	0.167	0.848	0.073	434
2	2	2.137	0.146	0.383	34
3	2	0.095	0.062	0.062	699
4	2	1.203	0.328	0.223	48

of smallmouth bass and to quantify their movement. As such, no other studies provide appropriate data for comparison. In contrast to our predictions, this study demonstrated that fizzing had no significant influence on the mean daily movement of fish in the various treatment groups (Table 1) suggesting that fizzing provides no benefit to fish suffering from barotrauma. However, we found a consistent trend where fizzed fish moved further than unfizzed fish, around twice as far overall (Fig. 2). Although there was no statistical significance, it should also be noted that our power was generally low, suggesting that a larger sample size would yield a significant difference, particularly on days 2 and 4 of our analysis (Table 1). Furthermore, by summing the mean daily movements of each treatment group, we found that fizzed fish moved nearly twice the distance of non-fizzed fish, which implies that fizzing may be able to enhance the movement of fish suffering from barotrauma. However, further research is needed using a larger sample size.

Past studies have indicated that smallmouth bass disperse from the release site, and some return to their captured locations (summarized in Siepker et al., 2007). For this reason, we anticipated fish to exit the release site over time and that deflated fish as well as control fish would evacuate the release site the fastest (Gravel and Cooke, 2008). However, we observed that the time it took for fish in all treatments to disperse 50, 250 m, or to exit the release site (>2 km) did not differ from each other ($P = 0.082$, 0.316, and 0.756, respectively). After 19 h, all fish in the sham control group had dispersed at least 50 m, while it took unfizzed barotrauma fish and fizzed barotrauma fish 42 and 64 h, respectively (Fig. 3a). 90 h post-release, only the sham control fish were able to completely disperse 250 m from the release site (Fig. 3b). At this time, there was a 19% probability that fizzed barotrauma fish would still be within 250 m, and a probability of 29% for unfizzed barotrauma fish to be within this distance (Fig. 3c). In addition, none of the groups were able to completely exit the release site (>2 km) at the end of the study period (90 h post-release). Barotrauma fish that were not fizzed had the highest probability of being within the release site up to 90 h

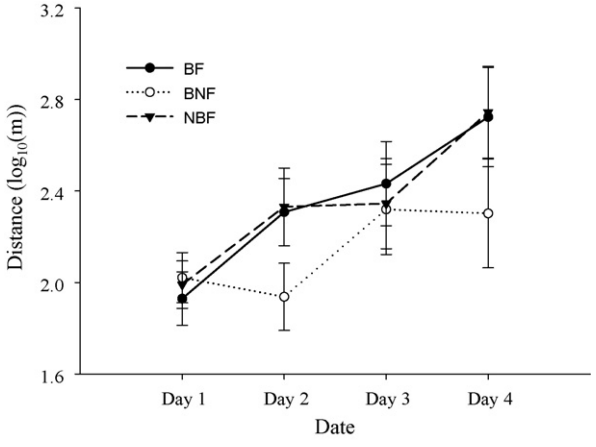

Fig. 2. Mean daily movement (distance traveled) performed by fish with barotrauma and fizzed (BF; $6 \leq N \leq 8$), fish with barotrauma and not fizzed (BNF; $5 \leq N \leq 8$), and fish with no barotrauma and not fizzed (NBF; $5 \leq N \leq 9$).

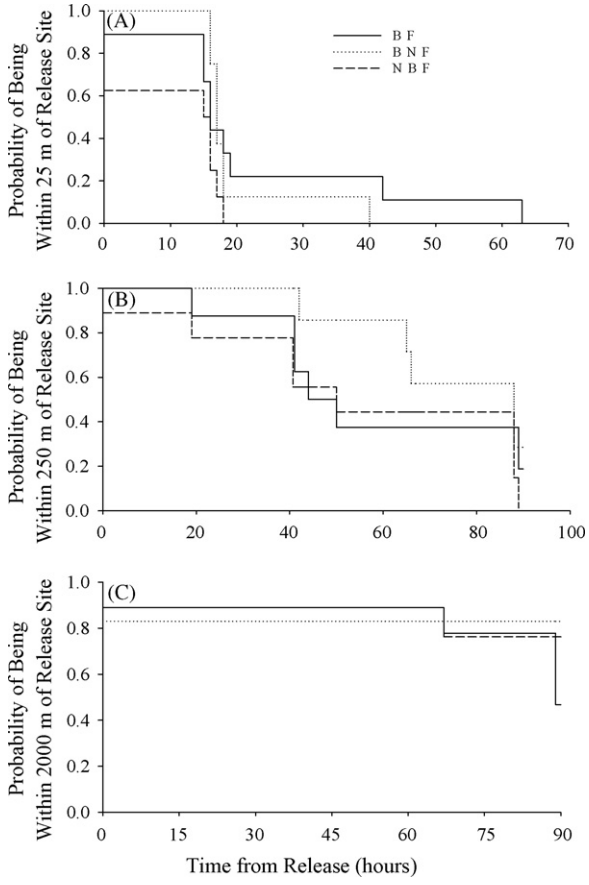

Fig. 3. Probability of being within 50 m (A), 250 m (B), and 2000 m (C) of release site for fish with barotrauma and fizzed (BF; $8 \leq N \leq 9$), fish with barotrauma and not fizzed (BNF; $7 \leq N \leq 8$), and fish with negligible barotrauma and fizzed (NBF; $8 \leq N \leq 9$). Sample sizes ranges per day and per treatment group.

(83%) after release, whereas fizzed barotrauma fish were the least likely to be found within the release site (47%). These findings are consistent with our prediction but are not statistically significant and it should be noted that our statistical power was generally low. Again, we noted a consistent trend showing that undeflated fish with expanded swim bladders move less and take slightly longer to exit the release site. In a similar study, Gravel and Cooke (2008) found that fish with severe barotrauma took significantly longer to disperse from the release site. This delay was potentially caused by some impairment that delayed their departure, suggesting energetic exhaustion or physiological disturbance (Gravel and Cooke, 2008). Since all treatment groups did not differ in dispersal, the effects of fizzing did not benefit fish with distended swim bladders. However, physiologically, tournament conditions can be confounded with the effects of decompression and fizzing, which can result in similar behaviours among treatment groups, including the sham control.

Fizzing appeared to help fish regain equilibrium and resubmerge themselves and the swim bladders of fizzed fish were deflated with no immediate harmful effect recorded. We observed that fizzed fish were found at the bottom (but rightside up) of the observation containers, while unfizzed fish floated on their sides or backs prior to release. Several studies have argued that fizzing can reduce some problems associated with barotrauma (i.e., allowing fish to return to depth), but it may have little effect on any tissue and physiological damage that have already been inflicted (e.g., Morrissey et al., 2005; Hannah and Matteson, 2007). This is of particular concern in tournaments where fish are held in live-wells at atmospheric pressure for several hours prior to release. Further-

more, most black bass fizzing procedures available are specified for largemouth bass (e.g., Lee, 1992; Shasteen and Sheehan, 1997), and to our knowledge, no literature on the fizzing of smallmouth exists. To identify and validate the fizzing procedure (i.e., locate landmarks for the puncture), we dissected a smallmouth bass. Relative to largemouth bass, the location to deflate an expanded smallmouth bass swim bladder is more anterior. Consequently, fizzing location appears to vary among different fish species, even among closely related congenerics, and benefits of fizzing may also vary between species (Collins et al., 1999; Burns and Restrepo, 2002).

Several tools have been used to manually deflate expanded swim bladders such as, hypodermic needles of various gauges (e.g., Shasteen and Sheehan, 1997; Collins et al., 1999), tagging guns (e.g., Keniry et al., 1996; Bruesewitz et al., 1993), Sea Grant cannula tool (Collins et al., 1999), fish hooks (Gitschlag and Renaud, 1994), knives (Forrester, 1954), weighted hooks, and weighted cages. For our study, we used a 21-gauge, 1.5 in. hypodermic needle; though we recommend a larger gauge as it would increase the rate of deflation and avoid plugging of the needle. Furthermore, we recommend hypodermic needle as its puncture would heal the fastest noted by Shasteen and Sheehan (1997) who reported swim bladders healed slower for larger incisions (0.5 cm) made in the swim bladder of largemouth bass than for needle punctures (17 h). Other observations demonstrated swim bladders healed within 4 days for red snapper and red grouper (Burns and Restrepo, 2002), and healed relatively quickly in burbot (within 8 weeks; Bruesewitz et al., 1993). These findings confirm that fizzing is not unfavourable to barotrauma fish; however, accidental punctures of other organs can have adverse effects (as reviewed by Kerr, 2001). In out study, the same individual (trained in fizzing) did all of the fizzing and such standardization is unlikely among anglers.

In summary, our field study revealed that fizzing did not result in mortality. However, we also observed no mortality among fish with barotrauma that were not fizzed. Our behavioural analyses revealed no significant differences among treatments although there was some evidence that fish that were fizzed diffused from the release site more rapidly than unfizzed fish with barotrauma. Work from this study has direct implications for recreational fisheries where decompression is an important issue. Preliminary behavioural findings from our study may be valuable for marine angling and tournaments as regaining immediate equilibrium and swimming abilities would highly benefit marine species that reside in environments where predation is frequent and conditions can be harsh. Furthermore, since the location for optimal fizzing and the fizzing landmarks have been found to vary among species, managers that endorse fizzing need to offer training and information regarding appropriate situations and locations to fizz. This information must include needle insertion points for all different species that reside in the associated water body. Benefits of fizzing will depend on the depth of capture, the species, and the severity of tissue and physiological damage. Fisheries managers and anglers need to take into account these factors before advocating fizzing of fish and must be aware that fizzing can only help some problems associated with barotrauma and that tissue and other internal damage can only be avoided by fishing shallower. Releasing fish immediately after capture may reduce physiological disturbance from holding fish in livewells for extended periods (e.g., Suski et al., 2004) but will not eliminate incidences of barotrauma. Continued research is needed to develop and validate other less invasive approaches to recompressing fish in order to maintain their welfare and increase survival.

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