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Effects of Recreational Fishing Gear Type on Reflex Impairment and Post-Release Swimming Activity of Smallmouth Bass

Luc LaRochelle[1] | Joseph Bernardi[1] | Jamie C. Madden[1] | Jacob W. Brownscombe[2] | Alyssa M. Goodenough[1] | Andy J. Danylchuk[3] | Steven J. Cooke[1]

[1]Fish Ecology and Conservation Physiology Laboratory, Department of Biology and Institute of Environmental and Interdisciplinary Science, Carleton University, Ottawa, Ontario, Canada | [2]Great Lakes Laboratory for Fisheries and Aquatic Sciences, Fisheries and Oceans Canada, Burlington, Ontario, Canada | [3]Department of Environmental Conservation, University of Massachusetts Amherst, Amherst, Massachusetts, USA

Correspondence: Luc LaRochelle (larochelle96@gmail.com)

Received: 8 June 2024 | **Revised:** 20 November 2024 | **Accepted:** 21 November 2024

Funding: This work was funded by the Anderson Family Foundation, the Natural Sciences and Engineering Research Council of Canada, and the Canada Foundation for Innovation.

Keywords: angling | catch-and-release | exhaustion | gear type | *Micropterus dolomieu*

ABSTRACT

Recreational anglers have access to a diverse range of rod and line strengths that enable them to choose equipment that can enhance their ability to effectively target and capture specific fish of a given body size. However, anglers may not always select the appropriate gear type for the targeted species. Here, we assessed the effect of gear setup on immediate reflex impairment and short-term post-release swimming behavior of Smallmouth Bass (*Micropterus dolomieu*) for 10-min. Smallmouth Bass were caught by angling in water temperatures of 22.7°C–26.2°C using ultralight or medium spinning gear. Fight times were longer for fish captured on ultralight gear than medium gear, and fight times were longer for larger fish. Generally, fight times > 18 s resulted in one or more immediate reflex impairments, while fish with fight times < 18 s had no immediate reflex impairments. Post-release swimming activity was only influenced by gear type used. Upon release, Smallmouth Bass captured using ultralight gear spent more time sustained swimming than those caught using medium gear type that spent more time resting. Given that fight times were longer for Smallmouth Bass captured using ultralight gear, they were conceivably more exhausted. This increased post-release swimming activity indicates that fish may need to engage in sustained swimming to facilitate physiological recovery. Our findings suggest that anglers should select gear types that minimize fight times to avoid reflex impairments and extended periods of post-release sustained swimming needed for recovery.

1 | Introduction

Catch-and-release (C&R) angling, whether voluntary or to comply with regulations, is practiced with the assumption that fish will survive the interaction with minimal injury and fitness impairments (Wydoski 1977; Cooke and Schramm 2007). Considering the annual C&R of billions of fish by anglers (Cooke and Cowx 2004), scientific findings should guide development of best practices for anglers (Elmer et al. 2017). Indeed, when science-based best handling practices are followed and fish to be released are in a good welfare state, sub-lethal stressors (disease resistance, growth, fitness) and mortality can be reduced relative to fish that are mishandled (Bartholomew and Bohnsack 2005; Arlinghaus et al. 2007). Yet, much guidance provided to anglers (see Pelletier, Hanson, and Cooke 2007) or shared within the angling community (Danylchuk, Tiedemann, and Cooke 2017; Sims and Danylchuk 2017) has not been formally evaluated. This may be problematic because decisions made by anglers prior to capturing fish (e.g., gear selection) and during the interaction with fish (e.g., handling and air exposure) can influence outcomes of a C&R event (Cooke and Suski 2005; Brownscombe et al. 2017).

Anglers have been recommended to use "appropriate" gear when targeting specific fish species to minimize fight time and the level of exhaustion experienced by individual fish (Cooke and Suski 2005; Brownscombe et al. 2017). Aspects of gear selection (i.e., rod power and line strength) can influence fight duration (as seen in Cooke, Cooke, and Brownscombe 2016). "Appropriate" is a subjective term that balances angler enjoyment, ability of gear to enable optimal use (e.g., ability to cast a lure of a given size), and land a fish in a reasonable time. In many cases, longer fight times result in greater depletion of energy stores (e.g., glycogen, ATP, phosphocreatine) and accumulation of anaerobic by-products such as muscle lactate (Gustaveson, Wydoski, and Wedemeyer 1991; Wood 1991; Kieffer et al. 1996). Fish that are exhausted at the time of landing (due to long fight times) may experience immediate reflex impairments such as loss of equilibrium and reduced ability for burst swimming, which can negatively affect fitness (e.g., the ability to detect and avoid predators; Danylchuk et al. 2007; Brownscombe et al. 2014; Lennox et al. 2024). Reflex impairment levels are also highly indicative of physiological stress levels and long-term fate (i.e., mortality; Davis 2010; Raby et al. 2012). Furthermore, exhausted fish may be altered in their post-release behavior in other ecologically relevant contexts, such as failing to seek refuge, return to their school, or migrate for spawning (Schreck, Olla, and Davis 1997; Arlinghaus et al. 2007, 2009).

To date, very few studies have found that longer fight times related to different gears translate into immediate impairment and exhaustion levels at the time of release (Brownscombe et al. 2015; Cooke, Cooke, and Brownscombe 2016). Fight duration is related to physiological status (Gustaveson, Wydoski, and Wedemeyer 1991; McLean et al. 2020; Blyth and Bower 2022; Holder et al. 2022) and body size for a wide range of species (Casselberry et al. 2023). Furthermore, rod strength and line strength (i.e., ultralight vs. medium gear) affected fight time and reflex impairment of Largemouth Bass (*Micropterus nigricans*), with fish captured on ultralight gear fighting significantly longer and having higher levels of reflex impairment than fish caught on medium gear (Cooke, Cooke, and Brownscombe 2016). However, that study only assessed immediate reflex impairment and not post-release behavior of fish that is an excellent biomarker for assessing welfare state (Schreck, Olla, and Davis 1997; Barton 2002; Cooke and Suski 2005) and recovery of fish in the wild (Milligan, Hooke, and Johnson 2000).

Biologgers equipped with tri-axial acceleration sensors are a relatively novel and useful tool for estimating overall dynamic body acceleration (ODBA, i.e., swimming activity) and assessing other post-release behaviors such as depth and temperature use during C&R research in wild fish (Whitney et al. 2016; Bieber et al. 2022; Louison, LaRochelle, and Cooke 2023). These instruments have been used to assess differences in post-release behaviors following air exposure, different handling practices, and recovery tactics (Brownscombe et al. 2013; LaRochelle et al. 2021; Madden et al. 2024). With only minor limitations (e.g., species specificity), assessment of post-release locomotor activity has the potential to act as a biomarker to provide valuable insight into fish responses to angling interactions (Whitney et al. 2016; Chhor et al. 2022). Impairments observed during a short-term post-release period have previously been connected to long-term fate and survival of wild fish (Iwama et al. 1997; Huntingford et al. 2006). Fisheries interactions often result in increased oxygen demand, decreased or increased post-release locomotor activity (varies among species and contexts), and disorientation that can make fish more vulnerable to predation (Cooke et al. 2000; Cooke and Suski 2005; Danylchuk et al. 2007).

Our objective was to determine if gear type and fight time influenced reflex impairment and short-term (10 min) post-release swimming activity of Smallmouth Bass (*M. dolomieu*). To assess welfare outcomes of capturing fish with different gear types, we captured Smallmouth Bass using two different gear types that varied in strength (ultralight power with monofilament line and medium power with stronger braided line). Smallmouth Bass were used as a model species because they are often targeted by anglers using a variety of gear types and are often voluntarily released after capture (Quinn and Paukert 2009).

2 | Methods

Smallmouth Bass were caught with angling gear from Big Rideau Lake located in Ontario (44.7706° N, 76.2152° W) during August 17–29, 2020, and August 29–September 6, 2023. Surface water temperature during sampling (range = 22.7°C–26.2°C; mean = 23.9°C) was warmer than the optimal water temperature for Smallmouth Bass (22°C, Whitledge, Hayward, and Rabeni 2002; Carter et al. 2012). Smallmouth Bass were captured on either a 152-cm ultralight fast-action rod with a line rating of 0.45–4.8 kg and 1.8-kg break-strength monofilament line without fluorocarbon leader or a 213-cm medium-fast-action rod with a line rating of 2.7–5.4 kg and 4.5-kg braided line with 4.5-kg fluorocarbon leader. Gear selection was determined by considering conventional upper and lower limits of gear used by Smallmouth Bass anglers, to illustrate how gear selection might influence immediate reflex impairment level and post-release locomotor activity of Smallmouth Bass. The drag of each reel was set to rod and line strength (close to the breaking point) to maximize rod power and prevent the line from breaking while angling. Lures used to capture Smallmouth Bass were ~50 mm in length with a single barbed hook that ranged in size from size 1 to 1/0 (Ned rig, drop shot, or jig with soft plastic grub).

After a Smallmouth Bass was hooked, the fish was landed as fast as possible within constraints of the gear type (ensuring the line did not break). When hooked, a stopwatch was used to record fight time (to the nearest second). Smallmouth Bass brought to the boat were grabbed by the lower jaw (a net was not used), the fight time was stopped, and the hook was removed while the fish was in the air. Hooks were all removed in less than 20 s by hand or with hemostats. Fish that were gut hooked were omitted from this study after cutting the line to avoid mortality and eliminate confounding effects of gut hooking on reflex impairment and post-release behavior (Cooke and Danylchuk 2020). After hook removal, fish were placed into a V-shaped trough filled with fresh lake water and measured in total length (TL, mm). Only Smallmouth Bass longer than 250 mm were used for this study to ensure that fin movement was not hindered by the attached biologger.

After measuring TL, Smallmouth Bass were placed into a live well filled with fresh lake water and three immediate reflex impairment levels were assessed (equilibrium, tail grab, and body flex). These predictors were chosen due to their reliable nature as indicators of vitality in teleost fishes (Davis 2010; Raby et al. 2012) and are among the most commonly used to assess consequences of fisheries interactions (Lennox et al. 2024). Tail grab and body flex provided information on the immediate exhaustion level of the fish, while equilibrium indicated the immediate fate of the fish (i.e., mortality status; see Lennox et al. 2024). Equilibrium was tested by inverting fish while submerged in water, and if the fish reorientated itself ventral side down within 3 s, it was not impaired and passed the test. Tail grab was tested by grasping the fish around the caudle peduncle, and if the fish swam away while the tail was being grabbed within 5 s, it was not impaired and passed the test. Body flex was tested by grasping the fish in the middle of the body, and if the fish contracted their body within 5 s, it was not impaired and passed the test. Times for each test were based on previous studies that used these reflex impairment tests (Raby et al. 2012; Brownscombe et al. 2013; Donaldson et al. 2013; Lennox et al. 2024). Tests were conducted in the same order to ensure consistency for all Smallmouth Bass and each test was scored either a pass (score = 0) or fail (score = 1), which was then totaled across all reflexes. The final reflex score was converted into a proportion (0–1), wherein a fish that scored 1 failed all reflex impairment tests. Reflex impairment tests were completed by the angler that captured the fish, and all individuals were experienced conducting these tests.

Following reflex assessment tests, a harness created from a Velcro strap and a tri-axial accelerometer biologger (Axy-Depth dataloggers; TechnoSmArt, Guidonia Montecelio, Italy, 12 × 31 × 11 mm; 7.5 g in air) was fastened to the fish on the ventral posterior side of the pelvic fin and released for 10 min (see LaRochelle et al. 2021, 2022). The biologger harness was attached to 29.4 kg braided fishing line and a 61 cm medium heavy ice fishing rod with the bail open to allow the fish to swim freely. At the end of the monitoring period, a quick tug on the line released the Velcro harness to recover the biologger. Tri-axial accelerometer biologgers were used to measure surges in acceleration on pitch, roll and yaw axes at a sample rate of 25 Hz with an 8-bit resolution (smallest magnitude of change that could be recorded) to provide efficient temporal resolution and clear data on activity (Brownscombe et al. 2018). Monitoring behavior for 10 min after release provided data on variation in swimming behavior and patterns as an indicator of the fate of each fish (Beitinger 1990; Brownscombe et al. 2014). As a measure of locomotor activity, overall dynamic body acceleration (ODBA) in gravitational units (g) was calculated by summing dynamic acceleration on all three axes, after removing static acceleration due to gravity with a 2-s box smoother (Shepard et al. 2008; Brownscombe et al. 2018). ODBA was used as a proxy for locomotor activity and behavior (Halsey, Shepard, and Wilson 2011).

Statistical analyses were conducted in Rstudio (2023.06.2+561; Posit Team 2024), Version 4.3.1 (R Core Team 2023). Figures were created using the *ggplot2* package (Wickham 2016). A linear model was fit with fight time as the response variable and the interaction between gear type and TL as the predictor variable, followed by a least-square means test using the *lsmeans* function in the *emmeans* package (Lenth 2023) to test differences in fight time between gear types. Next, two separate ordinal regression models using the *clm* function in the *ordinal* package (Christensen 2022) were fit with reflex impairment score as the response variable and gear type as a predictor variable in one model and fight time as the predictor variable in a second model. Two separate models were used due to collinearity between gear type and fight time. Each reflex impairment (equilibrium, tail grab, and body flex) were modeled separately with binomial models (family = logit). Each reflex response model was fit separately with gear type and fight time as predictors due to correlation between predictor variables.

Post-release swimming activity types were identified using the *kmeans* function based on ODBA data for 1-min periods during the 10-min post-release monitoring period. A linear mixed-effects model using the *lmer* function in the *lmerTest* package (Kuznetsova, Brockhoff, and Christensen 2017) was fit with post-release behavior type as the response variable, and minutes post-release, tackle type, fight time, and reflex score as predictor variables. Fish ID was treated as a random variable to account for repeated measures on each individual. This model was followed by a Tukey post hoc test using the *glht* function in the *multcomp* package (Hothorn, Bertz, and Westfall 2008) to test differences in swimming activity types for significant predictor variables. Finally, a one-way ANOVA using the *aov* function was used to test the difference in time spent resting, sustained swimming, and burst swimming for each gear type. This model was followed by a Tukey post hoc test using the *glht* function.

3 | Results

Of 49 Smallmouth Bass caught (mean TL = 308 ± 8 mm SE), 27 were caught using the ultralight gear (mean TL = 303 ± 10 mm SE) and 22 were caught with the medium gear (mean TL = 315 ± 12 mm SE). TL did not differ significantly between gear types used ($F_{47,1} = 0.574$, $p = 0.452$). Fight time was significantly influenced by the interaction between gear type and TL ($F_{45,1} = 13.407$, $p < 0.001$), and fight time increased more rapidly with fish size for the ultralight gear (Figure 1). Fight time of fish caught on medium gear (mean = 14 ± 2 s SE) was significantly shorter ($t_1 = -7.546$, $p < 0.001$) than for fish caught on ultralight gear (mean = 37 ± 2 s SE).

Immediate reflex impairment of Smallmouth Bass were not influenced by gear type ($x^2 = 0.332$, $p = 0.565$), but were significantly influenced by fight time ($x^2 = 9.058$ $p = 0.003$; Figure 2). None of the Smallmouth Bass lost equilibrium prior to release, but 59% failed the tail grab reflex test, which was significantly influenced by fight time ($z = -2.855$, $p = 0.004$), but not gear type ($z = -1.174$, $p = 0.240$). Fish that passed the tail reflex test fought

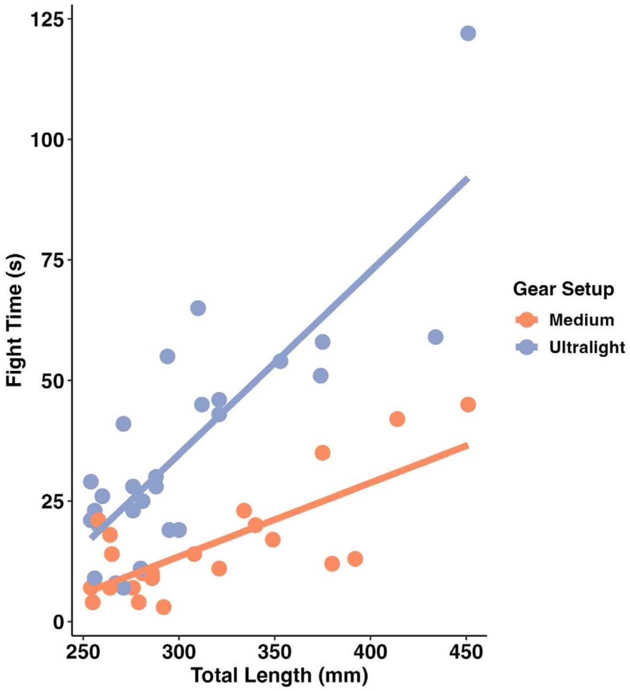

FIGURE 1 | Fight time of Smallmouth Bass (*Micropterus dolomieu*) in relation to total length (mm) captured on medium and ultralight angling gear in Big Rideau Lake, Ontario, Canada, during August 17–29, 2020 and August 29–September 6, 2023.

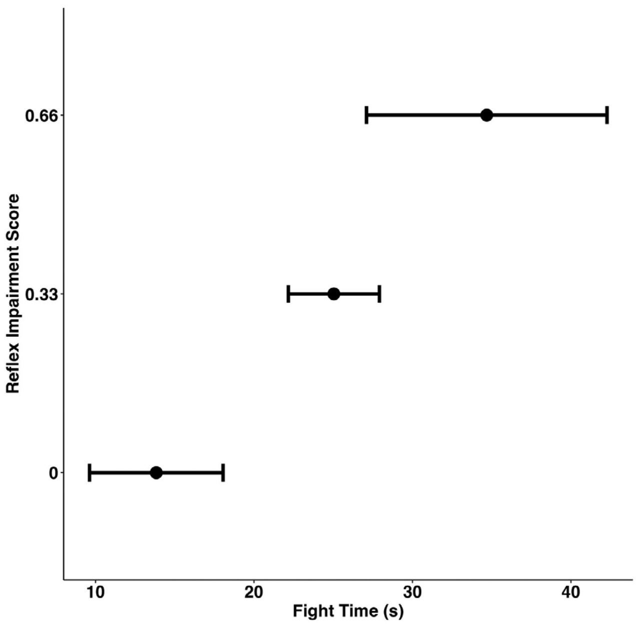

FIGURE 2 | Fight time (mean ± standard error) in relation to reflex impairment score of Smallmouth Bass (*Micropterus dolomieu*) caught by angling in Big Rideau Lake, Ontario, Canada, during August 17–29, 2020 and August 29–September 6, 2023. A score of 0 represents a Smallmouth Bass that did not have any reflex impairments, while a reflex score of 1 is a fish that was completely impaired.

for a shorter time (mean = 15 ± 3 s SE) than those that failed the tail reflex test, which fought longer (mean = 32 ± 4 s SE). Of the 43% of Smallmouth Bass that failed the body flex test, gear type ($z = 0.332$, $p = 0.740$) and fight time ($z = -1.335$, $p = 0.182$) did not significantly influence body flex.

Three post-release swimming activity behaviors were identified for Smallmouth Bass that included sustained swimming (cluster 1; range = 1.15–2.62 g, mean = 1.63 ± 0.03 g SE), resting (cluster 2; range = 0.00–1.15 g, mean = 0.68 ± 0.02 g SE), and burst swimming (cluster 3; range = 2.72–5.77 g, mean = 3.69 ± 0.21 g SE). Post-release swimming activity was not significantly influenced by time during the monitoring period, immediate reflex impairment, or fight time (Table 1). However, post-release swimming activity was significantly influenced by gear type (Table 1). Fish that were captured on ultralight gear engaged in more sustained swimming and less resting time than those captured with the medium gear (Figure 3; $z = -2.119$, $p = 0.034$). Time spent in various swimming behaviors differed significantly among fish captured on medium ($F_{63,2} = 106.300$, $p < 0.001$) and ultralight ($F_{78,2} = 33.150$, $p < 0.001$) gear. Swimming activity types differed significantly among fish captured with medium gear (Table 2), and similarly for those captured on ultralight gear (Table 2).

4 | Discussion

We found that fight time of Smallmouth Bass increased with TL of fish and was longer for ultralight gear, similar to a previous study of Largemouth Bass in warm water temperatures (25°C–27°C) (Cooke, Cooke, and Brownscombe 2016). Longer fight times on ultralight setups are likely because the ability to combat a fish is limited by the capacity of the gear used (i.e., breaking point) (Cooke, Cooke, and Brownscombe 2016; Chiaramonte et al. 2018). After setting the drag to rod and line limitations, the maximum strength of ultralight gear is less than medium gear, which implies that anglers should consider the heightened risk of gear breakage (e.g., line, rod) and their ability to retrieve fish that resist being reeled in as part of the fight or flight reaction (Kieffer 2000). The duration a fish is fought on the end of a fishing line is likely contingent on several factors, including fish size, fishing gear used, angler skill level, and behavior (Brownscombe et al. 2015; Cooke, Cooke, and Brownscombe 2016; Chiaramonte et al. 2018). The longer fight times of bigger (longer) fish in our study were likely because larger fish, within and among species, tend to have greater scope to combat the resistance imposed by anglers and the gear used (Thorstad et al. 2003; Casselberry et al. 2023).

Our results suggest that regardless of gear type, longer fight times (> 18 s) resulted in greater immediate reflex impairment levels, similar to other studies that showed fight time can have a cascading effect on physiological stress response, immediate reflex impairment, post-release swimming activity, swimming patterns, and predator avoidance (Danylchuk et al. 2007; Brownscombe et al. 2014; LaRochelle et al. 2023), and post-release survival of fish (reviewed in Brownscombe et al. 2017). We found no differences in immediate reflex impairment levels between ultralight and medium gears, although gear type influenced post-release swimming activity of Smallmouth Bass and lost reflex responses when fight times exceeded 18 s, perhaps because burst swimming can only occur for < 20 s in

TABLE 1 | Linear mixed-effects model of swimming activity (response variable) in relation to minutes post-release, gear type (medium or ultralight angling gear), reflex impairment score, and fight time (predictor variables), with Fish ID as a random effect to account for repeated measures of individual Smallmouth Bass (*Micropterus dolomieu*) in Big Rideau Lake, Ontario, Canada, during August 17–29, 2020 and August 29–September 6, 2023.

Variable	Sum sq	Mean sq	NumDF	DenDF	*F*-value	*p*
Minutes post-release	3.339	0.371	9	432	1.425	0.175
Gear type	1.256	1.256	1	44	4.825	**0.034**
Reflex impairment score	0.793	0.396	2	44	1.522	0.229
Fight time	0.138	0.138	1	44	0.530	0.470

Note: Bold *p*-values indicate significance at $p \leq 0.05$.

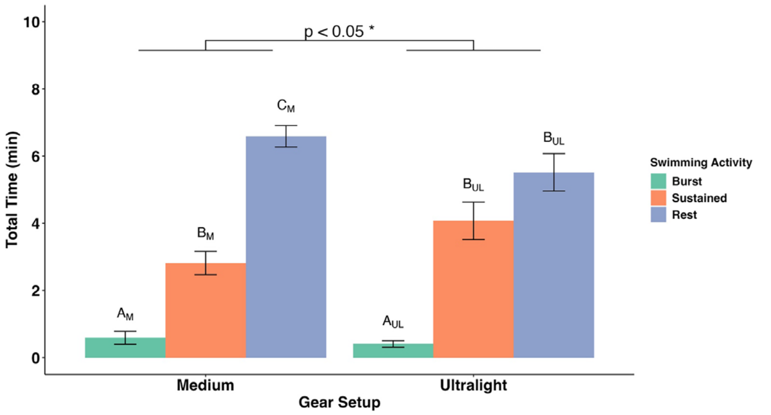

FIGURE 3 | Total time (mean ± standard error) spent in burst, sustained, and resting swimming activity during a 10-min post-release period by Smallmouth Bass (*Micropterus dolomieu*) caught on medium and ultralight angling gear in Big Rideau Lake, Ontario, Canada, during August 17–29, 2020 and August 29–September 6, 2023. The *p*-value and bracket represent a significant difference in swimming activity between gears, and letters represent differences in behavior within each gear. Subscript "M" is for medium gear and "UL" is for ultralight gear.

TABLE 2 | Tukey post hoc comparisons of time spent engaging in three swimming activities for Smallmouth Bass (*Micropterus dolomieu*) captured on medium and ultralight gear in Big Rideau Lake, Ontario, Canada, during August 17–29, 2020 and August 29–September 6, 2023.

Gear setup	Comparison	Estimate	SE	*t* Value	*p*
Medium	Sustained—Burst	2.227	0.416	5.354	**< 0.001**
	Rest—Burst	6.000	0.416	14.424	**< 0.001**
	Rest—Sustained	3.773	0.416	9.070	**< 0.001**
Ultralight	Sustained—Burst	3.667	0.647	5.665	**< 0.001**
	Rest—Burst	5.111	0.647	7.897	**< 0.001**
	Rest—Sustained	1.444	0.647	2.232	0.072

Note: Bold *p*-values represent significance at $p \leq 0.05$.

fish (Beamish 1978). Smallmouth Bass must have experienced some physiological impairments, given our results and previous research (Plaut 2001). However, loss of reflex impairments occurred in relatively warm water in our study (22.7°C–26.2°C) and no fish lost equilibrium. Surprisingly, we found no relationship between immediate reflex impairment levels and post-release swimming activity of Smallmouth Bass, which might suggest that post-release swimming activity is a better metric for assessing subtle differences (e.g., gear type) in impairments that occur during angling events.

In our study, Smallmouth Bass engaged in three different post-release swimming activities that differed between gear types, which has previously been shown to be a useful metric for assessing stress of fish in the wild (Schreck, Olla, and Davis 1997; McLean et al. 2020; LaRochelle et al. 2021; Skov et al. 2023; Howell et al. 2024). Fish that engage in low- to moderate-speed sustained swimming after release can recover from exhaustive exercise faster than fish held in still water (Milligan, Hooke, and Johnson 2000). Burst swimming is an anaerobic process that is limited by glycogen stored within white muscle tissue (Kieffer 2000). The glycogen reserve is used to fuel rapid bursts of swimming when fighting against the angling gear and immediately after release when escaping, which leads to an accumulation of anaerobic by-products like blood lactate (Gustaveson, Wydoski, and Wedemeyer 1991; Wood 1991; Kieffer et al. 1996). We found that ultralight gear led to longer fight times than medium gear, which suggests that fish were more exhausted, although Smallmouth Bass caught using ultralight gear spent more time swimming at low- to moderate-speed sustained swimming and less time resting than those caught using medium gear. These results suggest that Smallmouth Bass captured on ultralight gear, which had longer fight times and presumably more anaeerobic by-products in their blood, spent more time in sustained swimming after release to potentially facilitate metabolic recovery (Milligan, Hooke, and Johnson 2000). Blood lactate removal from the blood stream can be facilitated by post-release sustained swimming because of elevated blood flow from aerobic exercise and subsequentially increased oxygen delivery that results from increased blood flow (Milligan 1996; Kieffer 2000). Furthermore, sustained swimming increases aerobic energetic demand, compared to fish that spend more time resting (minimal energetic cost), due to increased cardiac output and associated ventilation rate (Jones and Randall 1978). Meanwhile, Smallmouth Bass captured using medium gear setup spent more time resting presumably because they did not have the same level of physiological disturbance necessitating sustained swimming to enable recovery so they could rest and conserve energy while addressing their oxygen debt. We did not collect blood samples that could have clarified such effects, but added stress associated with collecting blood samples (extra handling) could have affected post-release behavior of fish (Wendelaar Bonga 1997). Future studies that use post-release behavior of fish to assess recovery should aim to collect blood samples to relate to observed swimming patterns.

Anglers adopting best practices for C&R across a variety of species (Brownscombe et al. 2017) should match their gear to the target species to reduce fight times and potential negative impacts on fish welfare (Cooke and Suski 2005; Pelletier, Hanson, and Cooke 2007). We found that gear type influenced fight time, which subsequently influenced immediate reflex impairment and short-term post-release swimming activity of Smallmouth Bass. Our findings reinforced that fish length influenced fight duration. Although we only studied Smallmouth Bass, we suggest that anglers catching-and-releasing any species should use heavier angling gear to reduce fight time of bigger fish, to minimize risk of immediate reflex impairments and increased levels of post-release sustained swimming that is presumably used to remove anaerobic by-products. Avoiding long fight times and subsequent impairments can be important for the fate of fish in systems with abundant predators that need energy reserves for burst swimming to escape predators (Jain and Farrell 2003). However, using heavy angling gear may not be practical for all species, fish sizes, and angling techniques, which introduces additional challenges for providing recommendations for appropriate gear selection. Consequently, we suggest that anglers consider gear selection based on minimizing exhaustion associated with increased fight times by seeking to use the heaviest gear feasible without compromising their angling capabilities due to lack of sensitivity or incompatibility with a lure.

Acknowledgments

We would like to thank the reviewers and editors for their thoughtful and insightful feedback. LaRochelle is supported by a scholarship from the Natural Sciences and Engineering Research Council of Canada. The Ministry of Natural Resources and Forestry provided scientific collection permits, and animal care protocols were approved by Carleton University.

Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

Data will be made available upon reasonable request.

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