Do Angler Handling Practices Influence the Short-Term Post-Release Behaviour of Black Bass?

by

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Abstract

Black bass (*Micropterus spp.*) are a popular group of sportfish in North America, caught year-round, providing economic benefits to local communities. Anglers often release Black bass due to seasonal regulations, tournament regulations or because of personal conservation ethic, with the expectation that released fish will survive the angling interaction. Biologgers were used to analyse the short-term post-release behaviour of Black bass that were angled and released during different seasons of the year. Black bass exposed to sub-freezing windchill temperatures during ice fishing had reduced skin temperatures and increased locomotory activity. The type of weigh-in format influenced the water temperature and depth selected during the short-term post-release period, while also influencing locomotory activity of Black bass. Fish held in livewells demonstrated increased locomotory activity and selected shallower and warmer waters relative to controls. These findings will help to inform the development of best practices for catch and release.

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Chapter 1: General Introduction

1.1 Recreational Angling

Recreational angling is a leisure activity enjoyed worldwide. This activity occurs year-round and spans across various habitats from offshore saltwater regions to montane freshwater streams. In developed countries, nearly 1 in 10 people partake in angling, accounting for more than 220 million people (Arlinghaus et al. 2019). Recreational angling provides numerous social, economic, nutritional and human wellbeing benefits (Cooke and Cowx 2006, Cooke and Schramm 2007, Arlinghaus et al. 2019). Anglers engage in recreational angling for various reasons, traditionally with a focus on harvesting the catch, but more recently, it has become a sport where fish are primarily released (Arlinghaus et al. 2007). Catch-and-release (C&R) is simply the act of returning a fish to the water after capturing it. Fish are released in order to comply with size restrictions and season closures, or due to personal angler conservation ethics (Pitcher and Hollingworth 2002, Arlinghaus et al. 2007). Also, C&R angling is increasing in popularity as a voluntary action and is a dominant practice for recreational anglers targeting fish in freshwater (Arlinghaus et al. 2002, Cowx 2002, Cooke and Cowx 2004, Freire et al. 2012, Cooke et al. 2015). Release rate of fish in Canadian waters from 1985 to 2010 increased by 37% and in 2010, and exceeded 60% of the total number of fish caught in the recreational fishery (Brownscombe et al. 2014a). More recently, the release rate of fish caught in Canadian waters is nearly 80% (Fisheries and Oceans Canada 2015). Overall, the general consensus is that most fish survive C&R events with limited impacts on their fitness and that C&R is an effective conservation and management tool to ensure sustainability of fisheries (Wydoski 1977, Cooke and Schramm 2007, Cooke et al. 2015). Although these beliefs are often held by anglers practicing C&R angling, in some scenarios mortality is not negligible and can represent a threat to the sustainability of fish populations (Muoneke and Childress 1994, Bartholomew and Bohnsack 2005).

1.2 Stressors Present During Typical Angling Events

It is clear that many factors can determine the fate of a fish that is released. Outcomes can include a reduction in fitness, injuries, alterations in physiology and behaviour, and in extreme instances mortality of the fish (Ferguson and Tufts 1992, Muoneke and Childress 1994, Arlinghaus et al. 2007, Danylchuk et al. 2007a). Often, factors creating stress upon angled fish are a result of choices made by anglers prior to capturing fish (e.g. gear selection), while other stressors are created at the point where anglers are in possession of the fish (e.g. handling time, air exposure), hooking injuries (i.e., deep hooking, blood), and of course, the additional stressors created by various environmental factors present at the time of the interaction (e.g. water temperature and chemistry, ambient air temperature, predators, current velocity, water depth) (Muoneke and Childress 1994, Dunmall et al. 2001, Bartholomew and Bohnsack 2005, Cooke and Suski 2005, Pelletier et al. 2007, Brownscombe et al. 2017). It is known that air exposure is one of the most challenging aspects of a C&R event (Cooke and Suski 2005, Cook et al. 2015). The majority of research on the interaction between angler and fish during C&R event has been focused during warm periods of the year (warm water and air temperatures), while little focus has been placed on the extent of C&R during the winter with sub-freezing temperatures. Further, with newly designed weigh-in formats gaining popularity, little research has investigated the potential differences in the post-release behaviour associated with weighing Black bass immediately in the boat compared to the traditional weigh-in formats where fish are confined to the livewell and placed on a scale.

1.3 Quantifying Altered Fish Behaviour

Stress events encountered by fish lead to biochemical and physiological changes, that ultimately have the potential to alter their behaviour and ability to perform various functions (Schreck 1990, Schreck et al. 1997). Compensation to the allostatic load has negative impacts on behaviour, creating an elevation in energetic cost by depletion of energy stores and reduces the long-term fitness of the fish (Schreck 1981, Cooke and Suski 2005). When a fish is released after encountering a C&R event, respiration is increased due to elevated oxygen demand and the cardiac output is nearly doubled that of the resting rate (Beitinger 1990, Iwama et al. 1997, Kieffer 2000, Huntingford et al. 2006, Davis 2010). Generally speaking for most fish species, metabolic rate usually recovers to its normal activity within 8-12 hours of the disturbance, while cardiovascular and respiration rates may return to normal levels within 1-3 hours of the stress event (Kieffer 2000). In extreme instances of stress, Gingerich et al. (2007) revealed that ventilation is depressed when presented with elevated water temperatures and increasing amounts of air exposure. Moreover, tissue energy stores are rapidly depleted and metabolic by-products (e.g., lactate) accumulate in tissues (Kieffer 2000). Collectively, these physiological alterations have the potential to influence locomotor abilities such that the fishes swimming abilities could be impaired (Cooke and Suski 2005, Arlinghaus et al. 2009). Clear indicators of altered fish swimming behaviour are evident with deviation in routine movements (frequency and duration of movements), swimming speed, distance travelled, position in water column, displacement patterns, ability to maintain position in current and the ability to return to the site of capture (Schreck 1990, Calfee et al. 2016). After encountering stressors caused from an angling event, fish suffer from cognitive impairment and become disorientated (Cooke et al. 2014). As a result of these various impairments, fish have a reduced ability to seek refuge and shelter and are subject to an increased risk of predation (Danylchuk et al. 2007b, Arlinghaus et al. 2009, Brownscombe et al. 2013, Cooke et al. 2014). Finally, during this post-release period, fish can fail the ability to seek and capture prey (Schreck 1990).

1.4 Biologgers

Biologgers are an electronic device that can be attached to an animal that can collect and record information on the device. In recent years, the use of tri-axial accelerometer biologgers equipped with temperature and pressure (depth) sensors has allowed scientists to focus on how different handling practices and scenarios effects the short-term swimming activity, depth and water temperature selected by fish during the post-release period (Halsey et al. 2009, Gleiss et al. 2011, Brownscombe et al. 2014b, Wright et al. 2014). When attached to an animal, tri-axial accelerometers measure the acceleration (movement) of the animals in all three dimensions. Utilizing these tri-axial accelerometers, it is now possible to study animals in the wild in their natural environment and not in the laboratory. Obtaining fine-scale movement information from tri-axial accelerometer loggers makes them an excellent tool to calculate overall dynamic body acceleration (ODBA) and vectorial dynamic body acceleration (VeDBA), which are great proxies for understanding the swimming activity and field metabolic rate of fish (Wilson et al. 2006, Gleiss et al. 2011, Brownscombe et al. 2018). Biologgers allow us to look at how various situations (e.g., angling events) influence an animal. Further, it allow us to relate behaviour of fish after different angling handling practices, such as what an angler does with a fish when it is in their possession.

Often called the master factor in fish, water temperature is the dominant abiotic factor that controls fish behaviour, swimming activity and physiological processes (Fry 1971, Beitinger and Fitzpatrick 1979, Ultsch 1989). Cardiac parameters and metabolic rate are also closely related to the water temperature (Fry 1971, Cooke et al. 2003). Mortality rate and fish swimming activity increases with warmer temperatures, while lower temperatures generally reduce mortality rate and swimming activity levels (Gingerich et al. 2007, Bartolini et al. 2015). In bodies of water that stratify, water temperature and depth are closely related, but can vary from winter to summer. Fisheries interactions usually lead to an increase oxygen consumption and reduction in locomotor abilities (Cooke and Suski 2005), and reduction in locomotion can increase the risk of predation (Cooke et al. 2000, Danylchuk et al. 2007b). Using the information gathered from tri-axial accelerometers, short-term behaviour could be used to predict the long-term fate, fitness and survival of fish after experiencing different handling practices. This information is vital for anglers and fisheries managers where C&R angling is prominent and essential for the sustainability of precious fisheries in freshwater and saltwater.

1.5 Research Rationale and Objectives

The overall goal of my research during my thesis was to identify how anglers may alter the short-term post-release behaviour of fish based on their handling practices after various C&R scenarios. My first objective was to understand the impact that winter fishing conditions (i.e., windchill, ice) may have on the physical condition and short-term post release behaviour of a freshwater fish. Largemouth bass (*Micropterus salmoides*) were caught while ice fishing and various environmental factors (i.e., windchill, wind speed and weather conditions) were measured, including the skin temperature after various air exposures durations. The post-release behaviour of Largemouth bass was then monitored for 10 minutes to understand how various lengths of air exposures and ice exposures, in conjunction with harsh environmental factors, alters the post-release behaviour of fish during the winter. My second objective was to assess if, and how, different tournament weigh-in formats alters the post-release behaviour of Black bass. To do so, Largemouth bass and Smallmouth bass (*Micropterus dolomieu*) were caught by angling and subject to one of the three weigh-in formats: a catch, weigh and immediate release weigh-in format, a water weigh-in and a dry weigh-in. Their post-release locomotor activity, water temperature and water depth selection were monitored for a 10-minute period. Together, these findings will help inform fisheries managers, tournament organizers and most importantly, the anglers, on the best practices for handling fish during sub-freezing periods of the year and how to select appropriate weigh-in formats when organizing large competitive Black bass tournaments.

Both of my chapters focus on Black bass (*Micropterus spp.*) because of their popularity across North America (Duttweiler 1985). They are commonly targeted by recreational anglers and often the targeted species for competitive tournament events (Cooke et al. 2002b), with the vast majority of the captured fish being released after the angling event (Duttweiler 1985, Schramm et al. 1991b). Black bass angling is a large industry in North America, providing immense economic benefit for tackle store and companies, restaurants and lodgment accommodations (Schramm et al. 1991a). There is rich literature that has investigated the influence of C&R angling and live-release tournaments on the physiology of Black bass (Furimsky et al. 2003, Suski et al. 2003a, Suski et al. 2004). Yet, little research and less information is known surrounding the post-release behaviour of Black bass after experiences C&R angling events.

Chapter 2: Ice-fishing handling practices and their effects on the short-term post-release behaviour of Largemouth bass

2.1 Abstract

Numerous studies have investigated the impacts of catch-and-release on the post-release behaviour of fish during periods characterized by warm air and water temperatures. Comparatively little is known about the post-release behaviour of fish caught while ice fishing. Largemouth bass (LMB), a popular sportfish in North America, is sometimes encountered during ice fishing and is often released due to angler conservation ethic or to comply with regulations. To examine the impacts of ice angling on the post-release behaviour of LMB, we exposed them to a range of handling practices and assessed their skin temperatures prior to release, as well as short-term post-release swimming activity using biologgers equipped with a tri-axial accelerometer, temperature and pressure sensors. Skin temperature of LMB had a significant positive relationship with windchill temperature. Generally, the longer that LMB were exposed to air or placed on the ice, the colder their skin became. Overall, water depth and water temperature selected by LMB increased with time during the post-release period. Overall dynamic body acceleration (ODBA), a proxy for locomotory activity, decreased as time progressed in the release period, while ODBA decreased with increasing depth and water temperatures. LMB with warmer skin temperatures had lower locomotory activity compared to those with colder skin temperatures. Further, the effect of skin temperature on locomotory activity became more amplified with increasing depth and warming water temperatures selected by LMB post-release. Anglers practicing catch-and-release angling during the winter should adopt best handling practices by reducing the time fish are removed from the water when windchill temperatures are sub-freezing to avoid alteration in post-release behaviour.

Keywords: accelerometer, catch-and-release, angling, *Micropterus salmoides*, winter biology, freshwater

2.2 Introduction

Recreational angling is a leisure activity enjoyed worldwide, year-round, in different climates, and spans across various habitats from saltwater to freshwater. Fish that are angled recreationally are sometimes harvested for food (Cooke et al. 2018), or may be caught and released (Arlinghaus et al. 2007). Although some catch-and-release (C&R) is voluntary (Pitcher and Hollingworth 2002), often times anglers are required to release fish to comply with fishing regulations (e.g., closed seasons, slot size limits; (Cooke and Schramm 2007)). There has been a great amount of research on the effects of C&R on the survival and sublethal outcomes for a wide range of freshwater and marine fish after an interaction with an angler (reviewed in Bartholomew and Bohnsack 2005, Arlinghaus et al. 2007). Such knowledge has informed fisheries management regulations and has also equipped anglers with best practices to improve the welfare of angled fish (reviewed in Brownscombe et al. 2017). Until recently, the majority of this research has focused on fish angled during the open water seasons. In contrast, comparatively little is known about outcomes for angled fish that are caught during the winter through the ice.

In cold climate regions where winter is often accompanied with ice cover on freshwater systems (McMeans et al. 2020, Studd et al. 2021), ice fishing is a common recreational activity but it comes with added problems of fish care when practicing C&R due to the presence of extreme cold temperatures (Deroba et al. 2007). Fish that are angled during the colder periods of the year show a reduced response to stress and a reduced mortality rate compared to when angled and released in warmer water temperatures (Louison et al. 2017a, Louison et al. 2017b, Twardek et al. 2018). Nonetheless, fish that are removed from the water are exposed to a combination of air and wind (windchill) and thus undergo a rapid change in the ambient temperature during periods with sub-freezing temperatures. It is known that damage to essential tissues can occur when aquatic ectotherms are exposed to air temperatures near or below freezing, and this exposure can prolong the recovery period (Warrenchuck and Shirley 2002). For example, extensive damage to epithelial tissues (eyes, skin and gills) of fish occurs as a result of air exposure during cold periods, which can impair physiological functions (Tilney and Hocutt 1987). Similarly, Haukenes et al. (2009) observed that exposure to freezing temperatures promoted cellular damage to the gill structure of tanner crabs (*Chionoecetes bairdi*) which had a negative impact on oxygen uptake.

Many studies have identified the risks and damage caused to fish when exposed to air in warm temperatures (Cook et al. 2015), but limited research has been focused on the extent of damage that is associated with C&R angling during the winter period when air temperatures are sub-freezing (Gale et al. 2013). There are many challenges with trying to investigate the effects of C&R angling during the winter, including ice cover that makes it difficult to observe fish once released. Common approaches to studying C&R in the winter involves holding fish in a net below the ice for a 24-48-hour period to characterize mortality (Twardek et al. 2018, Logan et al. 2019). Although these studies assessed post-release survival, little information is available about the immediate post-release behaviour of fish after encountering an ice-fishing C&R event.

In recent years, the use of biologgers has enabled researchers to assess the short-term behaviour of fish in the wild (Cooke et al. 2016) including in the context of C&R (Donaldson et al. 2008a). For example, tri-axial accelerometer, pressure and temperature sensors on electronic tags can be used to quantify short-term swimming activity, depth and water temperature used by fish during the post-release period (Bettoli and Osborne 1998, Freire et al. 2012, Brownscombe et al. 2013, Ferter et al. 2015, Lennox et al. 2018, Holder et al. 2020). Angling often leads to physiological alterations characterized by heightened cardiovascular and respiratory activity (Cooke et al. 2001), depleted tissue energy stores and alterations in blood chemistry (Ferguson and Tufts 1992, Kieffer 2000), which collectively contribute to swimming impairments, disorientation, increased risk of predation and loss of equilibrium (Kieffer 2000, Cooke et al. 2002a, Cooke and Philipp 2004, Danylchuk et al. 2007b). Deviations in routine swimming behaviour and patterns during the short-term post-release period are good proxies for determining the long-term fate of fish, which is often correlated with the survival of fish (Beitinger 1990, Brownscombe et al. 2014c). It is also known that cold water temperatures delay the response to stress created from being air exposed (Louison et al. 2017a, Louison et al. 2017b), which further warrants the need for assessing the post-release behaviour of fish captured in the winter. As previously mentioned, exposure to harsh environmental conditions with sub-freezing temperatures promotes the risk of freezing and damaging essential tissues and fins (Tilney and Hocutt 1987), which may impact the locomotory capabilities of a fish.

Largemouth bass (*Micropterus salmoides*) (LMB) are a popular sportfish species in recreational angling that is primarily C&R and a common target species for competitive tournaments (Cooke et al. 2002a). There are various ways that LMB are regulated across jurisdictions, with fisheries regulations in some northern jurisdictions (e.g., parts of Ontario and Michigan) that do not permit targeting LMB during the winter (closed season), while other areas allow a winter C&R angling season for LMB. Some jurisdictions even permit the harvest of LMB during the winter. With little knowledge about how this valued species responds to angling stressors in the winter, it is difficult to determine which best practices should be encouraged when handling LMB in both jurisdictions that allow anglers to target LMB in the winter or where they are encountered incidentally. Although the biological basis for regulations that limit fishing for LMB in the winter is unclear, it is presumably to reduce stress prior to reproduction (i.e., spring spawning), to reduce potential for overharvesting while LMB are aggregated in the winter, and/or to protect LMB when they are primarily in deep water and at risk of barotrauma (Gustaveson et al. 1991b, Morrissey et al. 2005, Granfors 2013). While there is limited information available associated with the impacts of air exposure of LMB during sub-freezing temperatures, Bieber et al. (2019) found that swimming performance of Bluegill (*Lepomis macrohirus*) was significantly reduced when exposed to sub-freezing temperatures for 5 minutes. As suggested by Bieber et al. (2019), reducing air exposure duration during sub-freezing temperatures would ensure the survival of released *Centrarchidae* species.

The objective of this study was to examine how LMB respond to a C&R event in the winter. Specifically, we quantified how different air and ice exposures during a typical C&R event under a range of winter conditions (i.e., windchill, wind speed) influenced skin temperature and post-release behaviour of LMB. Data were recorded on biologgers attached to wild LMB caught in the winter using Velcro harnesses for roughly ten minutes. This study provides insight on how environmental conditions and angler behaviour influence the behaviour and condition of LMB angled in the winter.

2.3 Materials and Methods

2.3.1 Fish Capture and Tagging

LMB were captured between January 24th, 2020 and February 12th, 2020 in Elbow Lake in South Frontenac, Ontario, Canada (44°28'27.2"N, 76°25'43.0"W). LMB were captured by two different angling techniques: still lines (tip-ups) and actively jigging with ice fishing rods. Tip-ups were spooled with 9.1 kg breaking strength braided Dacron line and tipped with a 4.5 kg breaking strength fluorocarbon leader line to a single barbless size 4 Gamakatsu octopus hook, baited with a dead minnow. Ice fishing rods used were medium light to medium action rods, spooled with 2.7 kg to 3.6 kg breaking strength monofilament or braided line. Small invertebrate-like plastics and jigging spoons (tipped with a piece of minnow) were used to actively jig LMB. All fish were captured and released between 5.5 meters and 6.5 meters of water. Once fish were landed, they were transferred to a water filled trough and total length (mm) was measured. All locomotory, water temperature and water depth data were collected on Axy-Depth biologgers (12 x 31 x 11 mm, 7.5 g in air; TechnoSmArt, Guidonia Montecelio, Italy) epoxied to an acrylic plate (1 mm thick) and secured to the mid-section of the LMB using a Velcro strap (Figure 1; see Chhor et al. In Press). These tri-axial biologgers had the same configuration parameters across all fish in the study. The acceleration (g) of LMB was measured across three axes (A_x = surge, A_y = sway, A_z = heave, with respect to attachment orientation) with a sample rate of 25 Hz at an 8-bit resolution. This model of biologger has a temperature resolution of ± 0.1ºC and a depth resolution of ± 5 cm. As described in Shepard et al. (2008), Brownscombe et al. (2018), static acceleration (gravity) was removed from the dynamic acceleration (fish movement) using a 2 second box smoother. Overall dynamic body acceleration (ODBA), an index of locomotor activity (Halsey et al. 2009, Gleiss et al. 2011, Brownscombe et al. 2013, Wright et al. 2014), was calculated using the absolute sum of the dynamic acceleration from all three axes (A_X, A_Y and A_Z) (Halsey et al. 2011). Biologgers were placed on the ventral side of the fish, between the two pectoral fins. Fixing the biologgers to the fish took place in the trough, keeping the fish submerged in water, immediately after taking length measurements.

Attachment process of the biologger with the Velcro harness never exceeded 60 seconds. Once the biologger was attached, LMB were immediately released (control fish), or subjected to an additional handling treatment (see below). After the treatment process and prior to being resubmerged and released, skin temperature of the fish was recorded with an infrared temperature meter (± 1 °C, AstroAl, Placentia, California, United-States of America). Windspeed (km/h) and windchill (°C) was also measured using a handheld weather station (wind speed ± 5%, ± 2 °C, Hold Peak, Zhuhai, China). Prior to release, a Velcro harness to which the biologgers were affixed, was attached to a rod and reel that was spooled with 13.6 kg breaking strength braided line to allow for retrieval of the accelerometer, including the harness, at the end of the monitoring period. The bail of the spinning reel was kept open, allowing the fish to freely swim with the biologger for 10 -minute post-release monitoring period after which the bail of the reel was closed, creating tension on the braided line allowing the Velcro harness, including the biologger, to unstrap and dislodge from the fish. The logger package was then retrieved (i.e., reeled in). The location of the attachment strap was standardized for all fish (Figure 2.1).

2.3.2 Treatments

Fish were exposed to different air and ice exposure treatments, including (0, 10, 30, and 90 seconds) of exposure, upon capture of the LMB. Each exposure treatment besides the control treatment (0 seconds), was comprised of two separate treatments, where fish were removed from the water and were either held in air or laid on the ice for the duration of the exposure period (zero, 10-air, 10-ice, 30-air, 30-ice, 90-air, 90-ice). These chosen durations represent a range of common exposure periods seen in ice angling events (Gingerich et al. 2007, Louison et al. 2017b).

2.3.3 Data Analysis

Model assumptions were checked following the outlined protocols in Zuur et al. (2010). For the purpose of this study, minutes post-release was treated as ordinal numbers accounting for individual minute blocks from the 10-minute post-release monitoring period. All models had fish length as a covariate to account for the size differences among the various treatment (Table 2.1). The model with skin temperature as the response variable was fit with a linear model using *lm* with windspeed (km/h), windchill (°C) and treatment as predictor variables. All other models were fit using a linear mixed effects model (*lmer*) function from the *nlme* package (Pinheiro et al. 2020). Analysis of variance (ANOVA), with a threshold alpha value of 0.05 (95% confidence), was then used to determine the significant predictors in the *lm* and *lmer* model, which were then followed up with a Dunnet or Tukey post-hoc test with the *glht* function from the *multcomp* package (Hothorn et al. 2008). A one-way ANOVA was used to determine if there were any differences in windchill temperatures across treatments, which was then followed up with a post-hoc test to identify pairwise differences. All analyses ware preformed in R (3.6.2) via R Studio (version 1.2.5033).

For the linear mixed effects model with ODBA as the response variable, treatment, windchill, water temperature, minutes post-release and the interaction of treatment and minutes post-release were fit as the predictor variables. Due to restrictions on correlated predictor variables (depth and water temperature), another model with ODBA as the response variable was also fit with treatment, windchill, depth, minutes post-release and the interaction of treatment and minutes post-release were fit as the predictor variables. Model with water temperature as the response variable was fit with treatment, windchill, minutes post-release and the interaction between treatment and minutes post-release as the predictor variables. Similarly, a model with the relationship of water depth and temperature as the response variable was fit with treatment, windchill, minutes post-release and the interaction between treatment and minutes post-release as the predictor variables. Finally, to understand how the interaction of external environment factors (out of water) interacting with the internal environmental factors (in the water) influence the locomotory activity, a second model with ODBA as a response variable was fit with skin temperature, the residuals from the relationship of water temperature and water depth, and the interaction of skin temperature with the residuals of the water temperature and depth relationship. All linear mixed effect models were fit with fish ID as the random effect variable to account for repeated measures across individuals.

2.4 Results

2.4.1 Fish Metrics

A total of sixty-three LMB (mean ± (S.D.) total length (L_T) = 356 ± 36 mm, 263– 430 mm range) were captured for this study and each fish was only used once (Table 1). There was a significant difference between the mean lengths of LMB among the various treatments (ANOVA, $F_6 = 11.244, p < 0.001$) and therefore body sizes was incorporated into analysis models to account for this body size effect.

2.4.2 Skin Temperature

There was a positive relationship between LMB skin temperature and windchill temperature (r^2=0.53, $F_{620,1} = 264.095, p < 0.001$) (Figure 2.2), an index accounting for body heat loss of an individual at a given ambient temperature with the combination of wind speed. Wind speed alone did not have a significant effect on skin temperature ($F_{620,1} = 2.772, p = 0.096$). Skin temperature had a significant negative relationship with the total length of LMB

($F_{620,1} = 29.978, p < 0.001$). There was a significant difference in the windchill temperature between treatments ($F_{620,6} = 15.357, p < 0.001$) and the 90-air exposure handling treatment had significantly elevated windchill temperature compared to the control treatment, which was not air exposed ($t = 3.631, p = 0.002$; Figure 2.3). Skin temperature of LMB was significantly different among handling treatments ($F_{621,6} = 14.670, p < 0.001$; Figure 2.4). Skin temperatures were lower in all air and ice exposure treatments, compared to the control treatment with no exposure period. Within the air exposure treatments, the greatest difference in skin temperature was in the 30 second exposure ($t = -5.228, p < 0.001$), followed by the 10 second air exposure ($t = -3.168, p = 0.009$) and lastly the 90 second air exposure ($t = -2.853, p < 0.026$). As for LMB skin temperatures in the ice exposure treatments, compared to the control treatment, the biggest difference was seen in the 30 second ice exposure ($t = -7.665, p < 0.001$), followed by the 90 second ice exposure ($t = -5.233, p < 0.001$), and finally the 10 second ice exposure ($t = -5.015, p < 0.001$). There was also a greater reduction in skin temperature in LMB that are put on the ice, compared to those just air exposed (Figure 2.4).

2.4.3 Post-Release Behaviour

As the monitoring period progressed, LMB used significantly warmer ($F_{630,8}$ = 46.004, p = < 0.001) and deeper water ($F_{630,8}$ = 23.419, p = < 0.001) following release, specifically when compared to the first minute of monitoring (Figure 2.5). There was also a significant positive relationship between windchill temperature and water temperature selected during the release period ($F_{630,1}$ = 5.028, p = 0.028). There was no significant relationship between windchill temperatures experienced and the depth selected by LMB upon release ($F_{630,1}$ = 2.787, p = 0.099). LMB that experienced colder windchill were found in cooler water temperatures when released. There was no significant effect of treatment ($F_{630,48} = 0.649$, $p = 0.691$), nor the interaction between treatment and minutes post-release on the water temperature selected during the post-release period ($F_{630,48} = 0.847$, $p = 0.759$). There was also no significant effect of treatment ($F_{630,1} = 0.723$, $p = 0.631$), or the interaction of treatment and minutes post-release on the selected water depth during the post-release period ($F_{630,48} = 0.786$, $p = 0.850$). Fish size did not influence water depth ($F_{630,1} = 0.003$, $p = 0.960$) or water temperature selected when released ($F_{630,1} = 0.297$, $p = 0.588$).

Locomotory activity (ODBA) of LMB significantly decreased as depth ($F_{630,1} = 56.373$, $p < 0.001$) and water temperature increased ($F_{630,1} = 5.432$, $p = 0.021$; Figure 2.6). ODBA did not differ between treatments in the model with depth ($F_{630,6} = 0.901$, $p = 0.497$) and water temperature ($F_{630,6} = 1.041$, $p = 0.407$). However, there was a significant negative relationship between ODBA and time post-release in the depth model ($F_{630,8} = 177.606$, $p < 0.001$) and water temperature model ($F_{630,8} = 157.482$, $p < 0.001$). There was a significant difference in ODBA over the course of the post-release monitoring period (Figure 2.7). Windchill and ODBA had a significant positive relationship in the model with ODBA as the response variable and depth as a predictor variable, ($F_{630,1} = 4.122$, $p = 0.048$). LMB experienced a reduction in locomotion after being exposed to colder windchill temperatures. Fish size did not significantly influence locomotory activity upon release in the water depth model ($F_{630,1} = 0.237$, $p = 0.628$), nor did fish size significantly influence activity in the water temperature model ($F_{630,1} = 0.406$, $p = 0.526$).

Skin temperature alone did not have a significant effect on ODBA of LMB ($F_{630,1} = 1.414$, $p = 0.238$). When considering the interaction effect of skin temperature with the residuals obtained from the relationship between water temperature and water depth, there is a significant positive relationship on the locomotory activity of LMB ($F_{630,1} = 15.788$, $p < 0.001$). Therefore, as water depth and water temperature selected increased during the post-release period, the greater the effect skin temperature had on the locomotory activity of LMB.

2.5 Discussion

Fish become prone to an extreme and abrupt gradient in ambient temperature when anglers remove fish from the water post-capture during the winter, given the variation in air temperatures and wind intensities. Environmental conditions have an important influence on ectothermic organisms and their behaviour (Magnuson et al. 1979, Deroba et al. 2007). Skin temperature of LMB was lowest during exposure periods where windchill temperatures were the coldest (Figure 2.2). There was a significant positive relationship between windchill temperatures and skin temperature of LMB in the winter. Skin temperature of LMB was also negatively influenced by the body size of fish. Colder skin temperatures were observed in larger fish as they have more skin exposure, allowing for greater amounts of heat loss when removed from the water. As noted by Ortega et al. (2017), wind speed and windchill temperatures increases the rate of heat exchange between animals, specifically ectotherms, and their surrounding environment (Porter and Gates 1969, Stevenson 1985). Wind also increases the rate of water loss in ectotherms with wet skin, further increasing desiccation (Winne et al. 2001). Air temperature is often one of the most important driving factors that determines the response and recovery rate of fish after an air exposure event (Arlinghaus et al. 2007, Gingerich et al. 2007, Cook et al. 2015). Colder skin temperatures in LMB were present in all treatments that removed fish from the water, compared to the control treatment (0 seconds) that did not remove LMB from the water (Figure 2.4). Post-capture, there are several reasons fish may be removed from the water, including hook(s) extraction, weighing and measuring the fish, and/or an admiration period (including taking photographs; Cooke and Suski (2005)). LMB that were removed from the water and air or ice exposed for a longer period of time, generally experienced a greater amount of heat loss with a reduction in skin temperature (Figure 2.4). Although skin temperature rarely drops below 0°C, it is critical to keep in mind that the skin temperature of LMB, an ectotherm, prior to being removed from the water, is that of their previous environment (~ 4°C). It is clear that increasing time that fish are removed from the water and exposed to sub-freezing windchill temperatures, greater the potential for windchill temperatures to negatively affect the skin temperature of the fish via rapid cooling and/or contact freezing.

Generally, skin temperature decreased as time removed from the water increased. This trend was also present in LMB placed on the ice during the exposure period. LMB placed on the ice typically showed greater heat loss with colder skin temperatures compared to those only exposed to air. This suggests that anglers should consider not placing fish on the ice or snow while removed from the water. Although it seems that the average skin temperature is elevated (warmer) in the 90 second exposure treatments, further investigation indicates that individuals in these treatments experienced warmer mean windchill temperatures when removed from the water, supporting that windchill temperatures has a significant impact on the skin temperature (Figure 2.3). Consideration must also be place on the difference in amount of skin that is exposed to windchill between air and ice treatments. LMB that are held strictly in the air, have their entire body exposed to the windchill, whereas LMB that were placed on the ice only had one side of the body exposed to the windchill. However, there is limited knowledge available surrounding the extent of physiological damage and behaviour changes associated with fish that are caught, exposed to environmental elements during cold temperatures and released back into cold water

(Deroba et al. 2007). In fact, the extent of the damage caused by air exposure with the added stress of temperature in fish, is very context specific to the ambient air temperature that fish are air exposed to (Cook et al. 2015, Raby et al. 2015, Bieber et al. 2019). In fact, majority of the catch-and-release studies have focused on the challenges associated with air exposures during warm periods of the year, focused on the physiological damages, resulting in immediate, or delayed mortality (Cooke and Suski 2005). Consequently, there is a paucity of research and understanding regarding how these same air-exposure events affect fish during the winter with the presence of harsh environmental conditions.

During the winter, it is common that cooler water temperatures remain near the surface of lakes with warming at depth (typically to 4°C). Upon release, it was clear that LMB progressively selected deeper and warmer water as time increased during the post-release period (Figure 2.5). Although the amount time spent removed from the water exposed to air or on ice did not have a direct significant effect on the depth and water temperature selected during the post-release period, windchill temperatures did have a significant effect on the water temperature selected upon release by LMB. Specifically, LMB that experienced warmer windchill temperatures were found to select warmer water temperatures. As previously mentioned, environmental conditions play an important role in fish behaviour (Magnuson et al. 1979, Deroba et al. 2007). Fish that experience warmer windchill temperatures are more likely to select warmer water temperatures during the post-release period in attempts to avoid a large fluctuation in body temperature compared to the surrounding environmental temperature, in this case the water temperature. Fish that experienced colder windchill temperatures when removed from the water and exposed to air or ice, remained in slightly shallower and cooler water temperatures for a greater duration in the post-release period. Similar to water depth and temperature selected during the post-release period, locomotory activity of LMB decreased as time progressed during the monitoring period (Figure 2.7), regardless of the exposure length and type. There was a negative relationship between swimming activity levels of LMB and the depth and water temperature selected during the post-release period. LMB that were found in deeper and warmer water had reduced amounts of locomotory activity, as compared to those that were found in cooler shallower water (Figure 2.6).

Stress response from air exposure is often delayed in colder water temperatures, compared to in warm water temperatures where there is often an immediate response (Louison et al. 2017a, Louison et al. 2017b). Our findings further support previous knowledge that water temperature is an important influence on fish behaviour. However, there was an increase in locomotory activity seen in LMB that selected shallower and cooler water upon release. Although previous studies indicate that fish have greater levels of locomotory activity in warmer water (Hasler et al. 2009), results from this study suggest that fish caught-and-released during the winter, after experiencing an ice angling event, have reduced locomotory activity in warmer water at the bottom of the lake, compared to fish shallower in the water column in cooler water (Figure 2.6). These findings suggest that air and ice exposure may show some immediate behaviour alterations upon release, compared to what was previously presumed about cold water responses in fish, but further investigation is required. As seen in Cooke et al. (2003), disturbances created by an angling event, with the added stresses created from an air exposure period, may have caused an elevation in heart rate when returned to the water, which could have also increased the cardiac output of LMB upon release due to oxygen debt (Priede 1974, Wardle and Kanwisher 1974). Nonetheless, the reason for increased locomotory activity in cooler water warrants further investigation.

There was a significant interaction of skin temperature and relationship between water depth and temperature on the locomotory activity of LMB during the post-release period. As previously mentioned, locomotory activity had a negative relationship with water depth and temperature selected during the post-release period. LMB that selected deeper and warmer water temperature had reduced (colder) skin temperature compared to the individuals in shallower and cooler water. In other words, when LMB selected deeper and warmer water temperatures, the effect of skin temperature was amplified on locomotory activity. We can conclude from this that removing LMB from the water, when windchill temperatures are predominantly cold, reducing the skin temperature, the greater the increase in locomotory activity of LMB. When LMB were not removed from the water (control treatment), warmer skin temperatures were present with lower levels of locomotory activity. This increase in locomotory activity, a clear alteration of behaviour, may indicate that there is impairment associated with these reduced skin temperatures. Previous studies have shown that when fish are removed from the water during periods with sub-freezing temperatures, are prone to damage to their essential tissues including fins, gills, and eyes (Tilney and Hocutt 1987). Damage to these soft tissues may result in impaired locomotory ability, inhibited oxygen uptake capacity, and reduced visual sensory ability (Boutilier 1990, Ferguson and Tufts 1992, Suski et al. 2004). During this study, only short-term behaviour was investigated and does not provide information on how skin temperature might alter and impact the long-term fate of fish captured and released during the winter. Although there is limitation associated with monitoring behaviour for a short period of time (first 10-minutes post-release), there is sufficient evidence supporting the link between immediate impairments from stress (reflex action mortality predictors - RAMP) with the long-term fate of released fish (Raby et al. 2012). Further, Brownscombe et al. (2013) revealed that there is a link between immediate reflex impairment and short-term behaviour of fish released from fisheries related stressors. Further work is needed to understand the extent of physical damage associated with winter exposure in fish. Nonetheless, based on our findings we recommend anglers consider reducing the amount of time fish are kept out of the water in sub-freezing temperatures, while also avoiding placing fish on the ice or snow if they are fish they intend to be released. Although there was no significant difference between the air and ice treatments with respect to the duration they were removed from the water, skin temperature of fish placed on the ice or snow was slightly lower than the LMB that were only held in the air (Figure 2.4).

2.6 Tables & Figures

Table 2.1 Total amount of Largemouth bass (*Micropterus salmoides*) per treatment, including the size of range within each treatment and the average size with the standard deviation.

Treatment	***n***	**Mean (mm) ± S.D.**	**Smallest (mm)**	**Longest (mm)**
Control	10	383 ± 34	315	430
10 sec air	10	370 ± 23	330	401
10 sec ice	10	340 ± 33	290	380
30 sec air	7	356 ± 58	272	425
30 sec ice	11	357 ± 35	284	385
90 sec air	8	338 ± 39	263	374
90 sec ice	9	364 ± 22	325	405

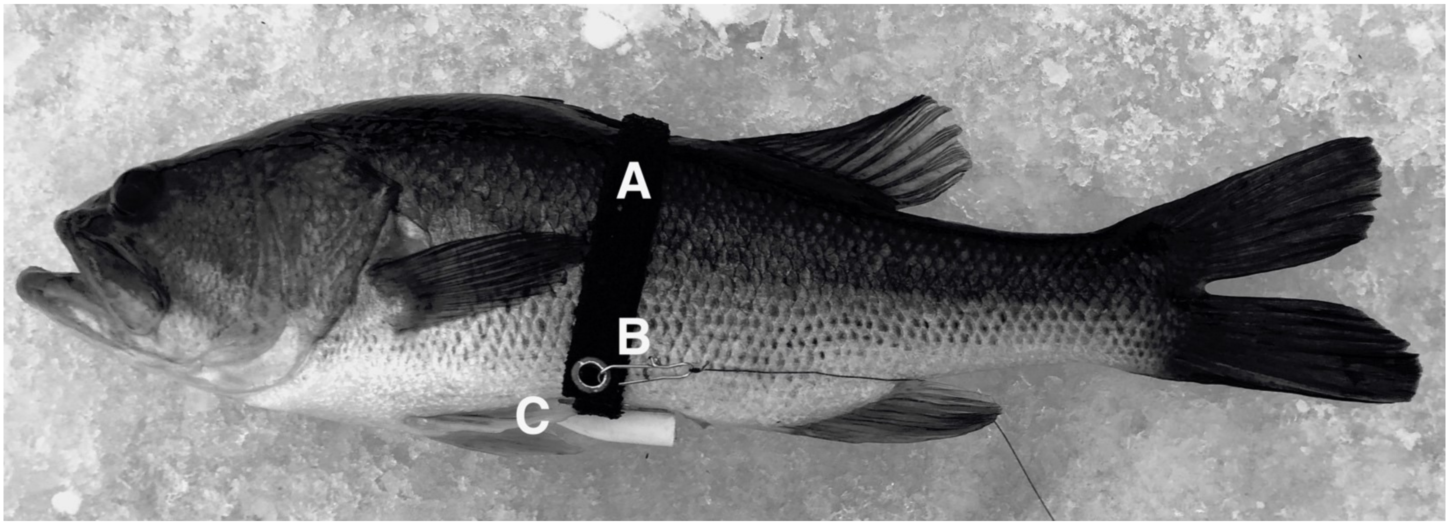

Figure 2.1 Largemouth bass (*Micropterus salmoides*) with the Velcro strap (A) configuration used. The fast-attach clip (B) is used for retrieval of the biologger at the end of the trials. The biologger is placed on the ventral side of the Largemouth bass between the pectoral fins (C).

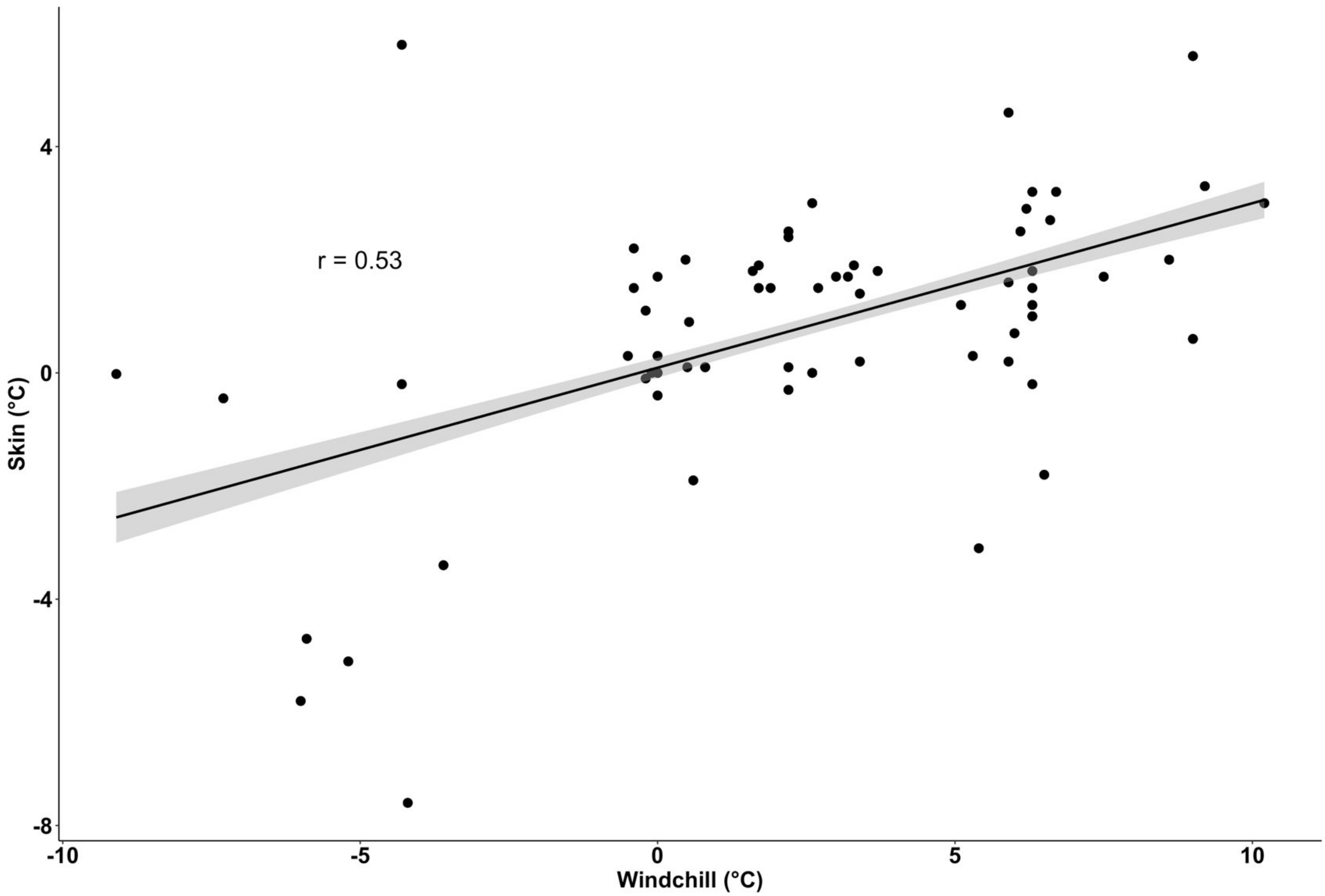

Figure 2.2 Linear relationship between windchill and skin temperature of Largemouth bass (*Micropterus salmoides*) taken after being exposed to various air or ice exposures. Shaded area around the line of best fit represents the 95% confidence interval (y= 0.091 + 0.291x).

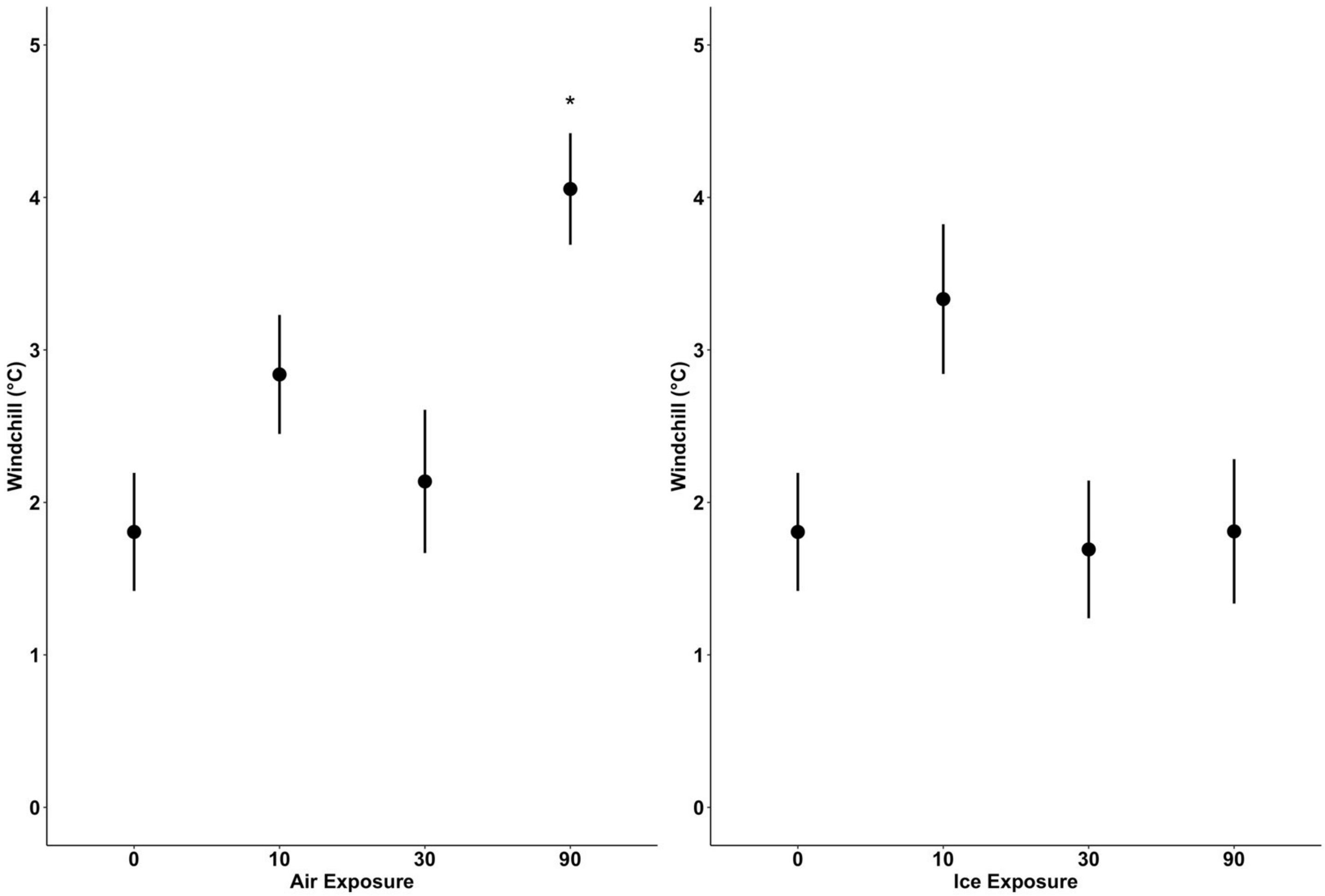

Figure 2.3 Mean windchill experienced (n = 63, 2.47 °C ± 0.17 °C SE) by Largemouth bass (*Micropterus salmoides*) during an air exposure period for 10 seconds (n = 10, 1.19 °C ± 0.24 °C SE), 30 seconds (n = 7, 2.14 °C ± 0.47 °C SE) and 90 seconds (n = 8, 4.06 °C ± 0.37 °C SE). Mean skin temperature of Largemouth bass after experiencing an ice exposure for 10 seconds (n = 8, 3.33 °C ± 0.49 °C SE), 30 seconds (n = 11, 1.69 °C ± 0.45 °C SE) and 90 seconds (n = 9, 1.81 °C ± 0.47 °C SE) is also shown in the figure. Asterisks indicate the level of significance between 0 second exposure, control treatment (n = 10, 1.81 °C ± 0.39 °C SE) and the respective air or ice exposure.

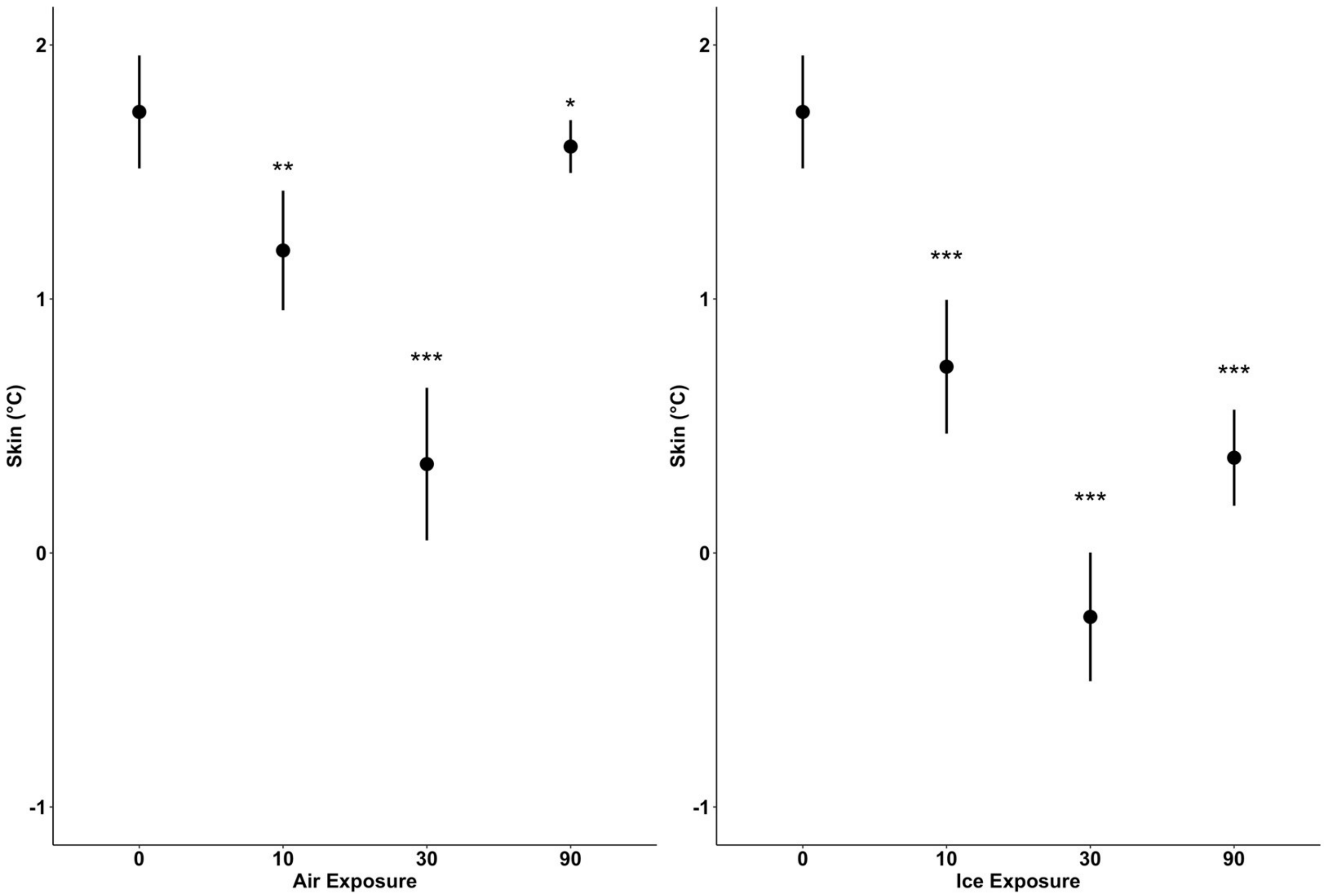

Figure 2.4 Mean skin temperature (n = 63, 0.81°C ± 0.09 °C SE) of Largemouth bass (*Micropterus salmoides*) after experiencing an air exposure for 10 seconds (n = 10, 1.19 °C ± 0.24 °C SE), 30 seconds (n = 7, 0.35 °C ± 0.30 °C SE) and 90 seconds (n = 8, 1.60 °C ± 0.10 °C SE). Mean skin temperature of Largemouth bass after experiencing an ice exposure for 10 seconds (n = 8, 0.73 °C ± 0.26 °C SE), 30 seconds (n = 11, -0.25 °C ± 0.25 °C SE) and 90 seconds (n = 9, 0.38 °C ± 0.19 °C SE) is also shown in the figure. Asterisks indicate the level of significance between 0 second exposure, control treatment (n = 10, 1.74 °C ± 0.22 °C SE) and the respective air or ice exposure.

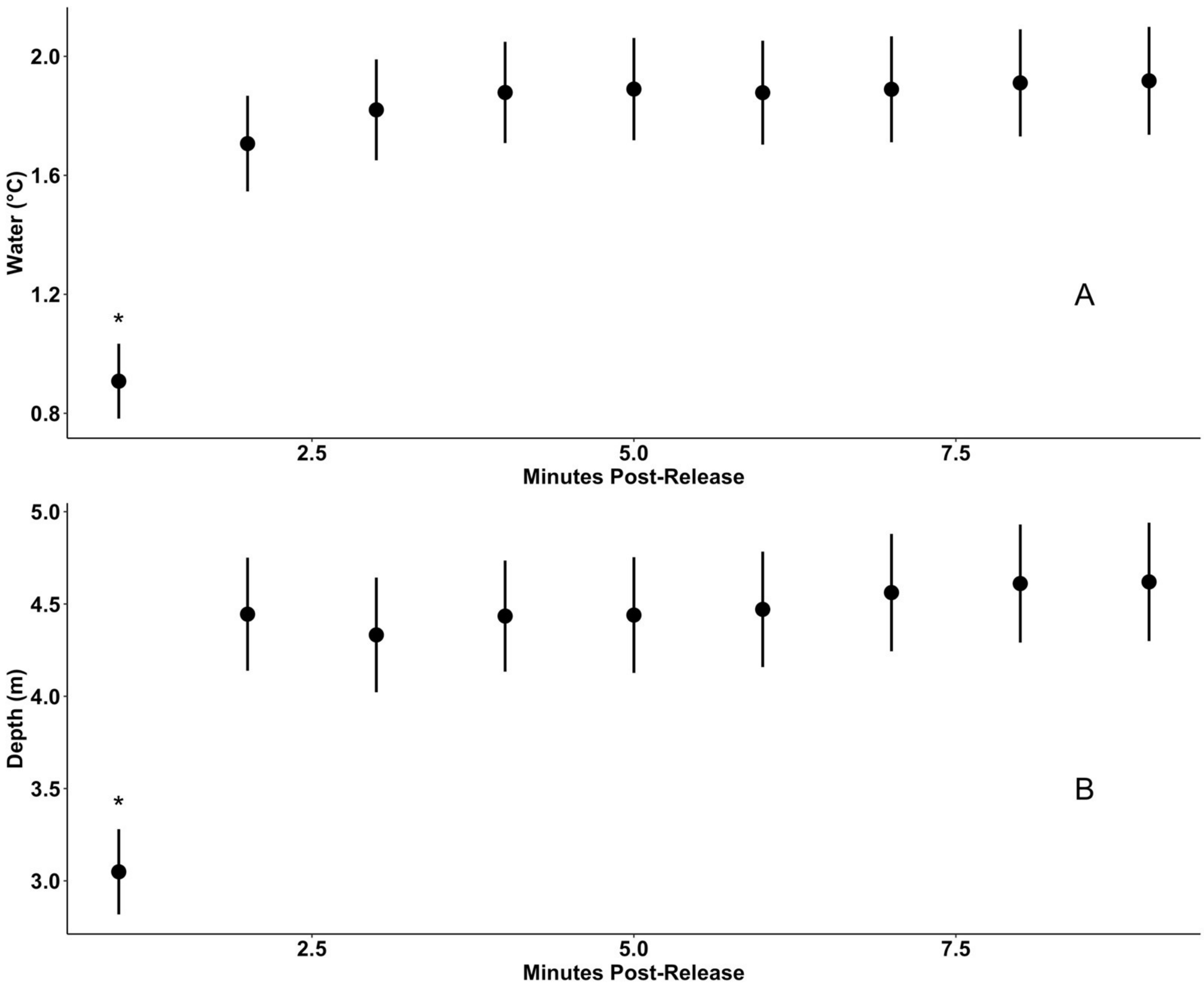

Figure 2.5 Two-part figure representing the progressive increase of mean water temperature (4.33 °C ± 0.10 °C SE) (A) and mean depth (1.76 m ± 0.06 m SE) selected (B) by Largemouth bass (*Micropterus salmoides*) during the nine-minute post-release period. Asterisks are used to indicate water temperature and depth selected during the first minute post-release was significantly different than the following minutes post-release.

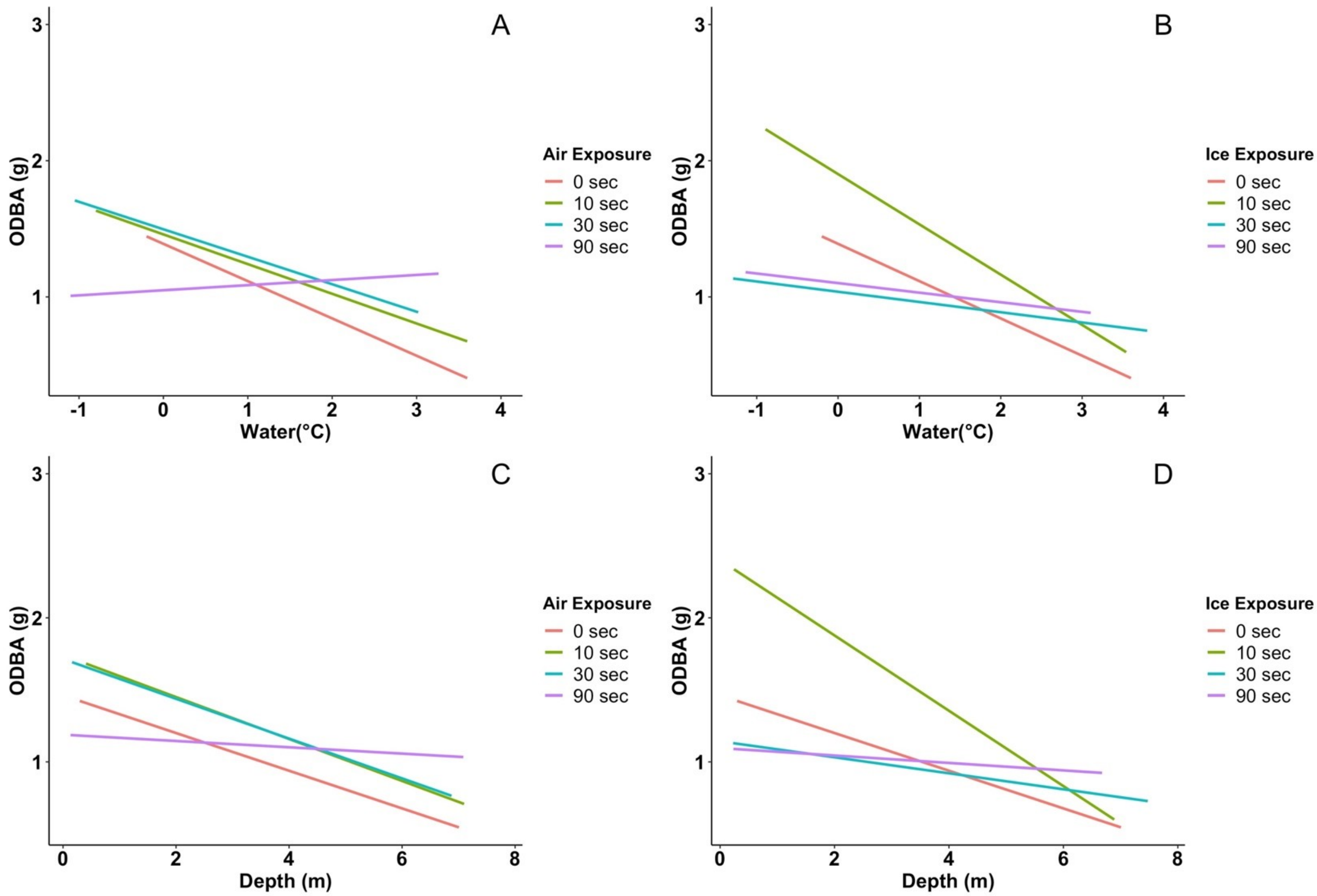

Figure 2.6 Change in the mean overall dynamic body acceleration (ODBA) of Largemouth bass (*Micropterus salmoides*) when selecting different water temperatures and depth during the post-release period. The various colours represent different air or ice exposures experienced by the Largemouth bass prior to release. Figure A shows the change in locomotory activity when selecting water temperatures upon release after an air exposure, or ice exposure (B). Figure C shows the change in locomotory activity when selecting water temperatures upon release after an air exposure, or ice exposure (D). Colours within the figures represent the various durations of exposure.

Chapter 3: A comparison of different tournament weigh-in formats on the short-term post-release behaviour of Black Bass using biologgers

3.1 Abstract

Black bass (*Micropterus spp.*) live-release tournaments are a popular activity in North America. Efforts continue to further increase survival and enhance welfare of fish released from competitive angling events. Recently, some tournaments have adopted a new weigh-in format where Black bass are weighed immediately (hanging from a scale in air) and released at the capture location. More conventional tournaments involve retaining Black bass in a livewell and deliver them to a central location to be weighed (wet or dry weigh-in). We used biologgers that measure swimming activity, depth selection and water temperature selection to examine how different weigh-in formats alter post-release behaviour of Smallmouth Bass (*M. dolomieu*) and Largemouth Bass (*M. salmoides*). All fish showed a significant decrease in swimming activity as time progressed during the 10-minute monitoring period, regardless of the weigh-in format. Swimming activity remained elevated (i.e., hyperactivity) for a longer period of time for Black bass that were retained in livewells compared to the catch, weigh and release weigh-in format and the control (fish caught and immediately released without air exposure). Swimming activity of Black bass tended to decrease as they achieved greater depths with cooler water temperatures. For both species, water temperature selected post-release was influenced by the weigh-in format. Black bass that were dry weighed and wet weighed spent more time in warmer water temperatures than fish caught, weighed and released, or those caught and immediately released. This study suggests that tournament organizations need to carefully select weigh-in location, allowing easy access to refuge (i.e., similar habitat complexity to capture location) with cooler water temperatures commonly associated with deeper water to reduce behavioural alterations associated with wet and dry weigh-ins. These results also suggest that catch, weigh and release formats might be beneficial for Black bass during periods of the year with elevated water temperature.

Key Words: Tournament Angling, Air Exposure, Catch-and-Release, Livewell, Weigh-in

3.2 Introduction

Live-release competitive angling events that target Black bass (*Micropterus spp.*) are popular in North America with over ten thousand events held annually (Duttweiler 1985, Schramm et al. 1991b). Competitive angling events provide immense economic benefits for rural communities by supporting local tackle stores, restaurants, hotels and rental accommodations (Schramm et al. 1991a). Yet, concerns have been raised about the impacts that live release tournaments have on the sustainability of Black bass populations (Holbrook 1975, Barnhart 1989, Schramm and Gilliland 2015) with evidence for such impacts being equivocal (e.g., Driscoll et al. (2007), Hysmith et al. (2014), Sylvia et al. (In Press)). Interest remains in identifying strategies to further reduce mortality and improve the welfare of fish in Black bass tournaments (Schramm and Gilliland 2015).

With the popularity of competitive Black bass angling events in recent decades, strong emphasis has been placed on catch-and-release tournament formats in accordance with jurisdictional regulations, permitting and licensing, tournament organization rules, and the conservation ethic of anglers (Duttweiler 1985, Schramm et al. 1991b). Yet, not all fish survive these events and therefore the risk of tournament mortality has been identified as a concern (Schramm et al. 1991a, Schramm et al. 1991b, Wilde 1998). There is evidence that physiological disturbances, physical body damage and mortality are associated with Black bass tournaments and are more common with tournament caught fish compared to a typical catch-and-release scenario, due to the fish being handled for a longer period of time while retained in livewells and displaced from their site of capture (Hayes et al. 1995). Tournament directors and organizations are constantly trying to improve tournament protocols with new weigh-in formats and procedure to maximize the welfare of fish, and ultimately reduce risk of mortality (e.g., Tufts and Morlock (2004); Schramm and Gilliland (2015)).

The most common Black bass tournament format allows anglers to fish for 6-8 hours while they attempt to catch a limit of 5 fish (most common, either restricted to one or multiple Black bass species, and with a minimum fish length set by the tournament directors (usually ranging from 310-381 mm). Strict penalties are in place for dead fish during these tournaments, creating a strong incentive for anglers to ensure their fish are brought to the weigh-in station alive. Black bass are usually brought to one central location to be weighed by tournament officials and the Black bass are either released at the weigh-in location or placed into a live release boat to be transported and released at a different location. Two common weigh-in formats are used for this style of event; a dry weigh-in format where fish are placed into a plastic container without any water to be weighed and a newer water weigh-in format, where the fish remain in water the entire time they are being weighed (Tufts and Morlock 2004). Weigh-in format for the event is usually determined by the hosting organization, but there are some instances when a regulatory body (e.g., government natural resource management agency) may have policies regarding tournament weigh-in format. Many studies have explored the potential factors that cause physiological alterations and mortality in Black bass prior to weigh-ins, such as water temperature of the waterbody (Schramm et al. 1987, Bennett et al. 1989), water conditions of livewells including water temperature, ammonia and dissolved oxygen levels in the livewell (Plumb et al. 1988, Hartley and Moring 1993, Kwak and Henry 1995, Suski et al. 2006), injuries related to hooking and physiological alterations related to fight duration (Pelzman 1978, Schramm et al. 1987, Gustaveson et al. 1991a), duration of tournaments (Bennett et al. 1989), and fish size (Meals and Miranda 1994). Other studies have focused on the implications that poorly organized (or executed) weigh-in procedures can have on the survival of Black bass (Hartley and Moring 1995, Weathers and Newman 1997). Further, rough water which is usually a result of high winds can prolong the duration of time Black bass spend in the livewell and has an impact in the overall welfare of Black bass prior to release (Kwak and Henry 1995, Brooke et al. 2020). Individual angler experience and knowledge related to fish welfare while being held in the livewell, can have an influence on the survival of Black bass being released (Edwards et al. 2004).

In recent years, a new tournament format has been embraced by some tournament organizers. This new tournament format prevents anglers from holding fish in their livewells and is a catch, immediate weigh and release format (reviewed in Cooke et al. 2020). During events with this format, when a Black bass is caught, it is immediately weighed on a scale affixed to the jaw of the fish with a mechanical grip by a tournament official and then released. The angler that has the largest accumulated weight (or length for some events), regardless of the total number of fish captured during the tournament hours, is the winner of the tournament. Currently, this tournament style and weigh-in format has been embraced mostly by large organizations associated with the professional circuits and less so with small club events (notwithstanding kayak-based tournaments which have long used such an approach). Due to the need for a tournament official (scrutineer) in each of the competitors' boat, it is hard for small tournament series, organizations and clubs to recruit personnel to officiate all the registered boats of the tournaments. Some smaller events (such as the aforementioned kayak competitions) tend to use photo or video documentation emphasizing that there are ways to adopt this method even in smaller club tournaments where it is impractical to use scrutineers. This new format reduces the possible risks of Black bass mortality associated with poor livewell conditions and/or poor weigh-in conditions and procedures (Cooke et al. 2020). Moreover, this tournament format considerably reduces the displacement of Black bass (Wilde 2003). It is well known that Black bass caught during an angling event experience physiological alteration while confined to a livewell and during the subsequent weigh-in procedure (Cooke et al. 2002b, Suski et al. 2003a, Suski et al. 2004), which may also contribute to behavioural impairments post-release.

Although the potential benefits of this new tournament format include eliminating the risk of stress during livewell confinement, inevitable subsequent handling (e.g., during culling) and fish displacement, there has been no research that explicitly compares the effects of these different tournament formats on fish welfare. Such differences could include effects on immediate short-term behaviour and fine scale movement of Black bass after experiencing different live release weigh-in formats. Previous research has revealed that stress indicators prior to, and shortly after handling, are correlated with the long-term fate and survival of fish (Beitinger 1990, Iwama et al. 1997, Huntingford et al. 2006, Davis 2010). Moreover, behaviour is a highly relevant indicator of fish stress for individuals in the wild (Schreck et al. 1997). For example, Raby et al. (2012) showed that immediate behaviour assessed using reflex impairments (higher reflex action mortality predictors - RAMP) was strongly correlated with longer-term behaviour and post-release survival of fish.

Biologgers equipped with acceleration (see Halsey et al. (2009), Gleiss et al. (2011)), temperature and pressure (depth) sensors are growing in popularity, allowing scientists to focus on how different fish handling practices influence the short-term behaviour of fish (Halsey et al. 2009, Gleiss et al. 2011, Brownscombe et al. 2013, Wright et al. 2014). Obtaining fine-scale swimming activity information from tri-axial accelerometer biologgers makes this method an excellent tool to calculate overall dynamic body acceleration (ODBA), which is a useful proxy for understanding the locomotion and field metabolic rate of fish (Wilson et al. 2006, Gleiss et al. 2011, Brownscombe et al. 2018). Moreover, because fish are ectotherms, the thermal environment selected by fish after release can also indicate the welfare status and health condition of the fish. Similarly, because fish live in a three-dimensional world, depth selection is also a relevant indicator of fish welfare status and health condition.

The objective of this study was to understand if and how different tournament weigh-in formats impact the short-term post-release behaviour (i.e., swimming activity, water temperature selection and depth selection) of Black bass. To do this, we captured Smallmouth Bass (SMB; *Micropterus dolomieu*) and Largemouth Bass (LMB; *M. salmoides*) by means of angling in a popular tournament lake in Eastern Ontario and attached biologgers to them to assess their short-term behaviour in the wild after exposure to various simulated Black bass tournament weigh-in formats. The various weigh-in formats consisted of a catch, weigh and release, or retention in the livewell and then subject to a dry or wet weigh-in, all typical weigh-in formats seen in competitive Black bass tournaments. We also included a control treatment where fish were angled and immediately released without an air exposure period. It is not possible to tag a fish without catching and handling it, but by landing the fish rapidly and eliminating air exposure it serves as a relevant control. To our knowledge, this study is the first to compare the effects of different tournament weigh-in formats on the post-release behaviour of Black bass. The findings arising from this study will inform tournament organizers and fisheries managers about practices that maximize the welfare of Black bass in waterbodies where there are competitive angling events.

3.3 Methods

3.3.1 Fish Capture and Tag Attachment

All LMB and SMB were captured between July 1st and August 17th, 2020, from Big Rideau Lake (44°43.887' N, 76°13.975' W) in Eastern Ontario. Both species were captured by means of active angling using artificial lures according to the target species and habitat. Artificial lures had single barbed or multiple trebles barbed hooks that were used with conventional fishing rods and reels, ranging from medium power to extra heavy power rods, paired with braided fishing line between 4.5 and 22.7 kg. Once landed, fish were brought into the boat by hand (i.e., no net used) and the hook(s) removed by hand or with the aid of homeostats, with all air exposure associated with hook removal being less than 10 seconds. Deeply hooked fish were omitted from the study. Once the hook(s) were removed, fish were placed in a trough with fresh lake water to be identified by species, measured for the total length (mm) and received an external anchor tag (related to another study). Each day a focus was placed on capturing either LMB or SMB in order to keep the two species separated and avoid cross-species interactions.

Activity, depth and temperature data were collected on Axy-Depth dataloggers (TechnoSmArt, Guidonia Montecelio, Italy; 12 x 31 x 11 mm; 7.5 g in air) that were epoxied to a small piece of 1 mm thick acrylic plate and secured to the mid-section of the fish using a Velcro® strap. Biologgers were placed on the ventral side of the fish, between the two pelvic fins (*Figure 1*). All the biologgers were attached in the same way, compressing the dorsal fins to ensure precision of the results across all fish used in the study. During the process of biologger attachment, fish were always submerged in lake water while in the measuring trough. Biologgers were attached to the Black bass before beginning the weigh-in process. Prior to release, a fast-attach clip with 13.6 kg braided fishing line was attached to the Velcro® strap that was fastened to the fish. Black bass were then released for a 10-minute post-release monitoring period, with the bail of the reel open allowing the fish to swim freely. Once the 10-minute post-release period was finished, the bail of the reel was closed, and a firm tug was given on the braided fishing line dislodging the Velcro® strap including the biologger from the fish, and then it was retrieved by reeling it back to the boat. The same approach has been used to study the behaviour of LMB captured and released while ice fishing (LaRochelle et al. 2021).

Treatments

Treatments were conducted for LMB and SMB separately, and only fish with a minimum of 300 mm TL were included. There was a maximum of five Black bass of one species captured and held together in the livewell of a Ranger RT178C (95 liters). The livewell pump was always on keeping a constant amount of fresh oxygenated water into the livewell (3,028 liters per hour). Fish in the livewell were identified by their external anchor tag and the time of capture and release were recorded. Black bass placed in the livewells were monitored for any symptoms related to barotrauma. When Black bass were removed from the livewell, they were placed in a trough where the biologger was attached (as described previously) and then placed into a tournament weigh-in bag with 11.4 liters of water for 1 minute. Black bass were then removed individually and placed into a plastic basket without anything to prevent them from moving for 30 second and then released, simulating a dry weigh-in (dry treatment). Similarly, fish were removed from the livewell, placed in the trough where the biologger was attached, and the fish were then placed into the tournament weigh-in bag for 1 minute. The fish was then removed and placed into a plastic basket which was suspended into a larger bucket containing 33 liters of water. The plastic basket, while suspended in the larger container, did not contain enough water for the fish to swim. Black bass were held in this basket for 30 seconds without any preventive measures to restrict movement (flopping) and then released, typical of a wet weigh-in format (wet treatment). Black bass captured for the catch, weigh and release weigh-in format or for the control were immediately placed into the water filled trough once the hook was removed. Once in the trough, the biologgers were attached to the Black bass. The Black bass was then removed to be weighed using a plastic jaw lip grip (The Fish Grip™), while hung vertically for 15 seconds in air, and then released (weigh-release treatment), or immediately released as the reference control treatment for each species (C&R). For the purpose of this study, we considered the C&R treatment to be the closest approximation to "normal" behaviour and thus discuss changes in behaviour in other treatments relative to this control.

3.3.2 Data Analysis

The acceleration (g) of LMB and SMB was measured across three axes (A_x = surge, A_y = sway, A_z = heave, in respect to attachment orientation) with a sample rate of 25 Hz at an 8-bit resolution. The model of biologger used had a temperature resolution of ± 0.1ºC and a depth resolution of ± 5 cm. Static acceleration (gravity) was removed from the dynamic acceleration (fish movement) using a 2 second box smoother, as described in Shepard et al. (2008), Brownscombe et al. (2018). The ODBA was then obtained by summing the absolute dynamic acceleration from all three axes (A_X, A_Y and A_Z) (Wilson et al. 2006, Halsey et al. 2011), which served as a measure of the post-release swimming activity. All analysis was conducted in R (3.6.2) via R Studio (version 1.2.5033). Statistical models for SMB and LMB were analyzed separately following the recommendations of Garland and Adolph (1994). All models for both species were fit using the *lmer* function from the *nlme* (Pinheiro et al. 2020). In all models, minutes post-release was treated as ordinal numbers accounting for individual minute blocks from the 10-minute post-release monitoring period. For both species, the response variable

ODBA was fit with treatment, water temperature, minutes post-release, time held in the livewell and the interaction of treatment with minutes post-release as the predictor variables. Analysis of variance (ANOVA), with a threshold alpha value of 0.05 (95% confidence), was used to analyze *lmer* models to find the significant predictor variables. The significant predictor factors were then followed up with a Tukey post-hoc test. To understand the temperature used during the post-release period, a model with water temperature as the response variable was fit with treatment, minutes post-release, time held in the livewell and the interaction of treatment with minutes post-release as predictor variables. Finally, a model with ODBA as the response variable and was fit with the residuals of covarying variables; water temperature and water depth, as the predictor, to understand the relationship between the position selected within the water column and locomotory activity level of Black bass. All models included fish ID as a random effect variable to account for the repeated measures of individuals. The significant predictor variables were further analyzed using a post-hoc test with the *glht* function from the *multcomp* package (Hothorn et al. 2008). All graphs were produced using *ggplot2* (Wickham 2016) in R Studio. All values represent the mean value ± the standard deviation (SD). We present results separately for LMB and SMB without any formal statistical comparison given the inherent problems with doing two-species comparative studies (Garland and Adolph 1994) but consider the species-specific trends in the discussion.

3.4 Results

3.4.1 Smallmouth Bass

In total, 62 SMB (380 ± 47 mm) were angled and subjected to one of four treatments: C&R treatment (n = 17, 377 ± 41 mm), weigh-release treatment (n = 15, 393 ± 42 mm), dry treatment (n = 15, 380 ± 56 mm) and wet treatment (n = 15, 370 ± 47 mm). Fish were placed in the livewell for a maximum of 510 minutes (146 ± 173 minutes), to simulate the typical duration a SMB might spend in a livewell during a tournament day. No SMB in this study showed symptoms or impairments related to barotrauma. There was no significant difference of length within the SMB treatments ($F_{3,58} = 0.731$, $p = 0.54$). The amount of time SMB spent in the livewell did not influence the post-release swimming activity ($F_{1,577} = 0.414, p > 0.05$). There was a significant positive relationship with water temperature and the swimming activity during the post-release period ($F_{1,577} = 12.165, p < 0.001$). Across all weigh-in formats, swimming activity significantly decreased as time progressed during the post-release period ($F_{9,577} = 22.539, p < 0.001$). Swimming activity during the first minute post-release was significantly greater than each corresponding minute after that (*Figure 2*). Also, swimming activity differed significantly between weigh-in formats during the first minute post-release ($F_{3,58} = 3.92, p = 0.013$). During the initial minute post-release, swimming activity was significantly greater in SMB from the control treatment compared to the individuals subject to the wet treatment ($t_3 = -3.43, p = 0.006$). Total amount of time that SMB spent in the livewell did not significantly influence the post-release water temperature selection ($F_{1,578} = 0.417, p > 0.05$). Water temperature selected during the post-release period by SMB significantly differed based on the weigh-in format ($F_{3,578} = 7.080, p < 0.001$; *Figure 3*). The SMB released from the control treatment selected cooler water temperatures compared to the SMB released after being subject to the wet treatment ($z_3 = 3.766, p < 0.001$). Water temperatures selected by SMB during the post-release period were significantly cooler for SMB that were in the weigh-release treatment, compared to SMB that were held in the livewell and subject to the wet treatment ($z_3 = 3.974, p < 0.001$). Overall, the SMB from the weigh-in formats that released fish at the site of capture (control and immediate weigh and release) selected cooler water, compared to the fish placed in the livewell (*Figure* 3). There was also a significant negative relationship between the minutes post-release and water temperature ($F_{9,578} = 12.015, p < 0.001$; *Figure* 3). Finally, there was a significant positive relationship with the swimming activity of SMB and the residuals from water depth and temperature, which covary ($F_{1,578} = 10.761, p < 0.001$). Swimming activity of LMB was higher in the warm shallow water and swimming activity decreased as the fish reached greater depths which also tended to be cooler.

3.4.2 Largemouth Bass

A total of 56 LMB (382 ± 46 mm) were captured by means of recreational angling and were subject to one of four treatments; C&R treatment (n = 15, 382 ± 53 mm, mean total length, SEM), weigh-release treatment (n = 13, 383 ± 50 mm, mean total length, SEM), dry treatment (n = 12, 380 ± 42 mm, mean total length, SEM) and wet weigh-in treatment (n = 16, 385 ± 35 mm, mean total length, SEM). All LMB were placed in the livewell for a maximum of 510 minutes (151 ± 163 minutes), to simulate the typical duration a LMB might spend in a livewell during a tournament day. No LMB in this study showed symptoms or impairments related to barotrauma. There was no significant difference of LMB length within the treatments ($F_{3,52} = 0.735$, p = 0.535). Time spent in the livewell did not significantly influence the post-release swimming activity of LMB ($F_{1,517} = 2.182, p = 0.145$) The swimming activity of LMB significantly decreased as the time progressed during the post-release period ($F_{9,517} = 38.909, p < 0.001$; *Figure 2*). The interaction between weigh-in format and minutes post-release had a significant effect on the swimming activity ($F_{27,517} = 1.794, p = 0.009$). Only during the third minute post-release, did the swimming activity significantly differ. The LMB subject to the dry treatment had increased swimming activity compared to the control treatment LMB ($t_3 = 2.661, p = 0.048$). Also, swimming activity was significantly greater during the first minute post-release, compared to the following minutes, across all weigh-in formats, during the monitoring period. Duration of time LMB spent in the livewell did not influence the water temperature selection ($F_{1,590} = 2.086, p = 0.154$). The weigh-in format had a significant effect on the water temperature selected by LMB during the post-release period ($F_{3,518} = 8.252, p < 0.001$; *Figure* 3). There was no significant difference between the LMB in the control treatment and the weigh-release treatment ($z_3 = 0.392, p = 0.978$). Further, there was also no significant difference in water temperature used upon release between the dry treatment and the wet treatment ($z_3 = - 0.03, p = 1.000$). However, there was a significant difference in water temperature selected by LMB from the control treatment compared to the LMB from the dry treatment ($z_3 = 4.169, p < 0.001$) and the wet treatment ($z_3 = 4.352, p < 0.001$). The LMB in the wet and dry treatment selected warmer water temperatures during the monitoring period compared to the control treatment LMB. Weigh-release treatment LMB also selected significantly cooler water temperature during the post-release period compared to the fish subjected to the dry weigh-in ($z_3 = 3.884, p < 0.001$) and the wet weigh-in ($z_3 = 4.049, p < 0.001$). Overall, the LMB from the weigh-in formats that released fish at the site of capture (control and immediate weigh and release) selected cooler water, compared to the fish placed in the livewell (*Figure* 3). There was a significant negative relationship between the minutes post-release and the water temperature selected by LMB during the monitoring period ($F_{9,590} = 35.411$, $p < 0.001$). The interaction of treatment and the minutes post-release indicated that LMB that were subject to dry and wet treatments selected significantly warmer water temperatures compared to the fish that were subject to the control and weigh-release treatments. Lastly, there was a significant positive relationship with the swimming activity of LMB and the residuals between water depth and temperature, which covary ($F_{1,578} = 10.613, p = 0.002$). Swimming activity of LMB was higher in the warm shallow water and swimming activity decreased as the fish reached greater depths which also tended to be cooler.

3.5 Discussion

Regardless of Black bass species, there is a degree of disorientation associated with being confined to a livewell, displaced from the capture location and then released in new habitat (Wilde 2003). The higher levels of swimming activity associated with the selection of shallow warm water (*Figure 3*), suggests displaced Black bass that were livewell confined are engaging in a searching behaviour when released, while the animal explores their new environment (Blake 1981, Richardson-Heft et al. 2000, Ridgway 2002). This searching behaviour is demonstrated by both SMB and LMB during the first few initial minutes of the post-release monitoring period, as the livewell confined Black bass that were displaced show an increased level of swimming activity during these initial release minutes relative to the catch-and-release (control) and catch, immediately weigh and release treatments (*Figure 2*).

During the period of livewell confinement, Black bass are presented with an opportunity to recover from the angling event, given the livewell conditions are adequate (e.g., dissolved oxygen, water temperature and water chemistry) (Suski et al. 2004). Depending on the time of the year and the waterbody Black bass are being caught from, the depth of capture may be of concern for adequate livewell conditions for recovery from angling exhaustion. Livewells typically draw water for recirculation from surface water, often being warmer temperature and less oxygenated water than the habitat of capture. Black bass being caught at depth in cooler water may experience barotrauma, which can be exacerbated during the period of livewell confinement (Elliott et al. 2021) and during these situations, the livewell may not provide an adequate recovery period. The Black bass from this study that were captured and placed in the livewell did not demonstrate symptoms of barotrauma (i.e., inflation of the air bladder, protruding stomach, bulging eyes) while confined to the livewell.

Habitat selection upon release could be a behavioural response intended to help facilitate the recovery from the exhaustive exercise as a result of the angling event and handling stress (Cooke et al. 2002b, Cooke et al. 2003, Suski et al. 2003a, Suski et al. 2004). In our study, the SMB and LMB that were caught and immediately released, or caught, immediately weighed and then released, selected deeper water with cooler water temperatures. The physiological challenges created from exercise during an angling event (e.g., increased heart rate, as seen in Cooke et al. (2003)), creates an oxygen debt, which may lead to selection of deeper and cooler water with greater abundance of dissolved oxygen facilitating the recovery period. Tournaments with central weigh-ins present additional physiological challenges of a handling period and/ or air exposure for Black bass (Cooke et al. 2002b, Suski et al. 2003a, Suski et al. 2004), which we simulated in this study. Further, one of the most challenging aspects of catch-and-release angling is the air exposure period (Cooke and Suski 2005, Cook et al. 2015), which may explain the slightly deeper and cooler water selected by fish that are released after a dry weigh-in compared to the wet weigh-in where little to no air exposure challenges the fish.

As previously mentioned, livewells may permit an opportunity for Black bass, if water conditions are adequate, to recover from the angling event (Suski et al. 2004). Yet, fish are then introduced to bags for transfer which may lead to rapid degradation of water quality and physiological alterations (Suski et al. 2004). Overall, the behavioural differences present in the water temperature selection may be attributed to the fact that recovery from angling exercise warrants the need for oxygen rich, cooler water temperatures, post-release. This can also be said for air exposed Black bass induced by the dry weigh-in period, compared to those that remained in the water for the weigh-in with little to no air exposure period (*Figure 3*).Previous knowledge from a laboratory setting that locomotory activity of Black bass is increased in warmer waters, while a reduction in swimming activity is often associated with cooler water temperatures (Hasler et al. 2009). Our study presents similar results relating swimming activity with water temperature and depth selection in a wild population of Black bass. With the livewell potentially being utilized for recovery from angling exhaustion (Suski et al. 2004) and current knowledge that swimming activity is increased in warm waters, it is possible that Black bass released after being confined to a livewell and weighed are altering their behaviour (relative to the control) to select warm shallow waters. Selecting these shallow warmer waters allows Black bass to increase their swimming activity while they search and explore their new environment.

Overall, this study provides tournament organizers and fisheries managers with knowledge to make decisions about fish welfare. The SMB and LMB immediately weighed upon entering the boat and released in at the location of capture show minimal deviation in post-release behaviour (i.e., water temperature selection and swimming activity) relative to control fish that are caught and immediately released. Using this knowledge, tournament organizers will be able to better chose the appropriate tournament format for the time of the year that they want to host tournaments. This type of weigh-in, where Black bass are caught, weighed and immediately released would be beneficial for tournaments that occur during hot summer days when water temperature is high. In addition, Black bass that are caught from depths are often subject to barotrauma and placing them in the livewell will often exacerbate the impacts associated with the change in pressure when held at ambient atmospheric pressure (Elliott et al. 2021). Allowing fish to return to deeper and cooler water immediately (*Figure 3*) can reduce the risks associated with placing Black bass in the livewell (Lee 1992). Furthermore, dispersal behaviour of Black bass and the ability to return to their capture site varies by species when they are released at a central location where the weigh-in takes place (Wilde 2003, Siepker et al. 2007, Abrams et al. 2021).

Though this study had a limitation with only monitoring the behaviour of released Black bass for a short monitoring period post-release, previous knowledge provides a clear connection between deviation in the immediate post-release behaviour of fish and their long-term fate (Beitinger 1990, Brownscombe et al. 2013). This information should be considered by tournament organizers and regulators when determining the format of tournaments, while also placing critical consideration on the area the central weigh-in/release location is held to help facilitate the ability of the fish to seek refuge in their new environment with minimal swimming activity levels related to the selection of shallow warm water post-release (*Figure 3*). In situations where Black bass will be kept in the livewell, tournament organizers should strive to practice weigh-in methods that promote keeping the fish in water at all times, reducing the air exposure period that is often associated with Black bass tournaments. Reducing the amount of time tournament fish are removed from the water and placed on the scales, or held in the air for pictures, should be considered as the standard for weigh-in tournaments. Although our data does not provide direct support for this recommendation, there is sufficient evidence that suggests that air exposure is one of the most challenging aspects of an angling event for fish so minimizing air exposure during the weigh-in period could benefit Black bass post-release (Cooke and Suski

2005, Cook et al. 2015). We anticipate greater adoption of the catch-weigh-release format of tournaments in the coming years (see Cooke et al. (2020)) which greatly reduces the risk of stress, behavioural alterations, and mortality associated with livewell retention and weigh-in.

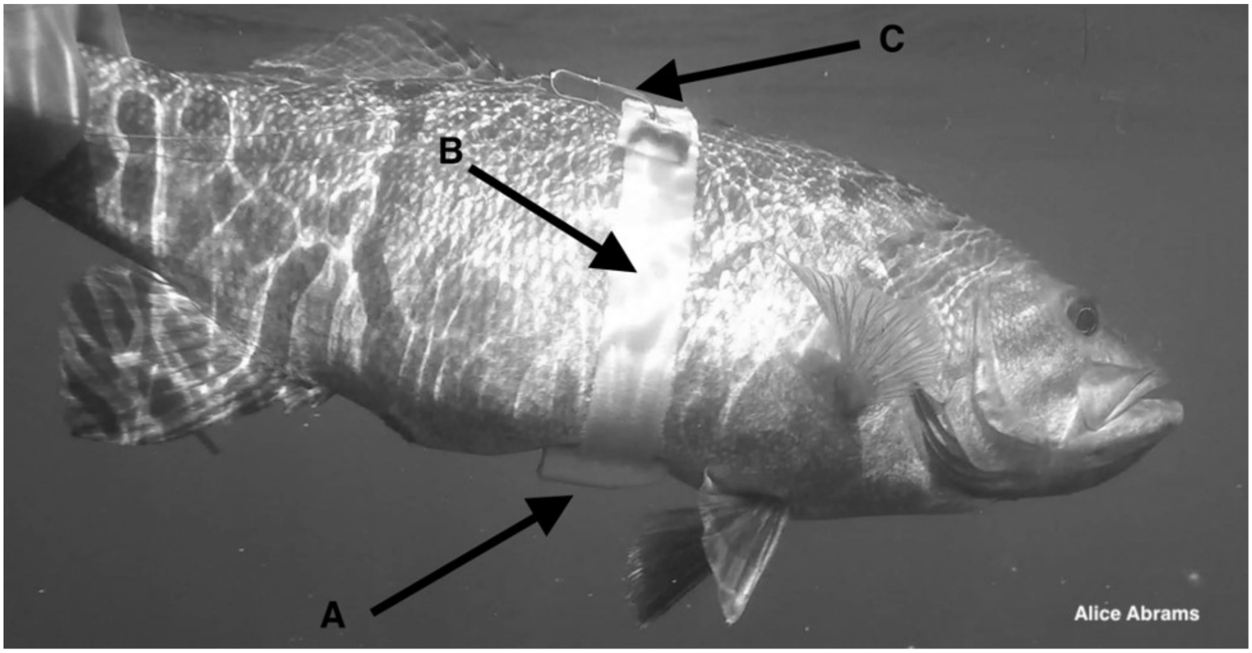

Figure 3.1 Smallmouth Bass with biologger (A) attached using a Velcro® strap (B). Braided line was tied to a quick release clip (C) fastened to the Velcro® strap for retrieval of the biologger at the end of the 10-minute monitoring period.

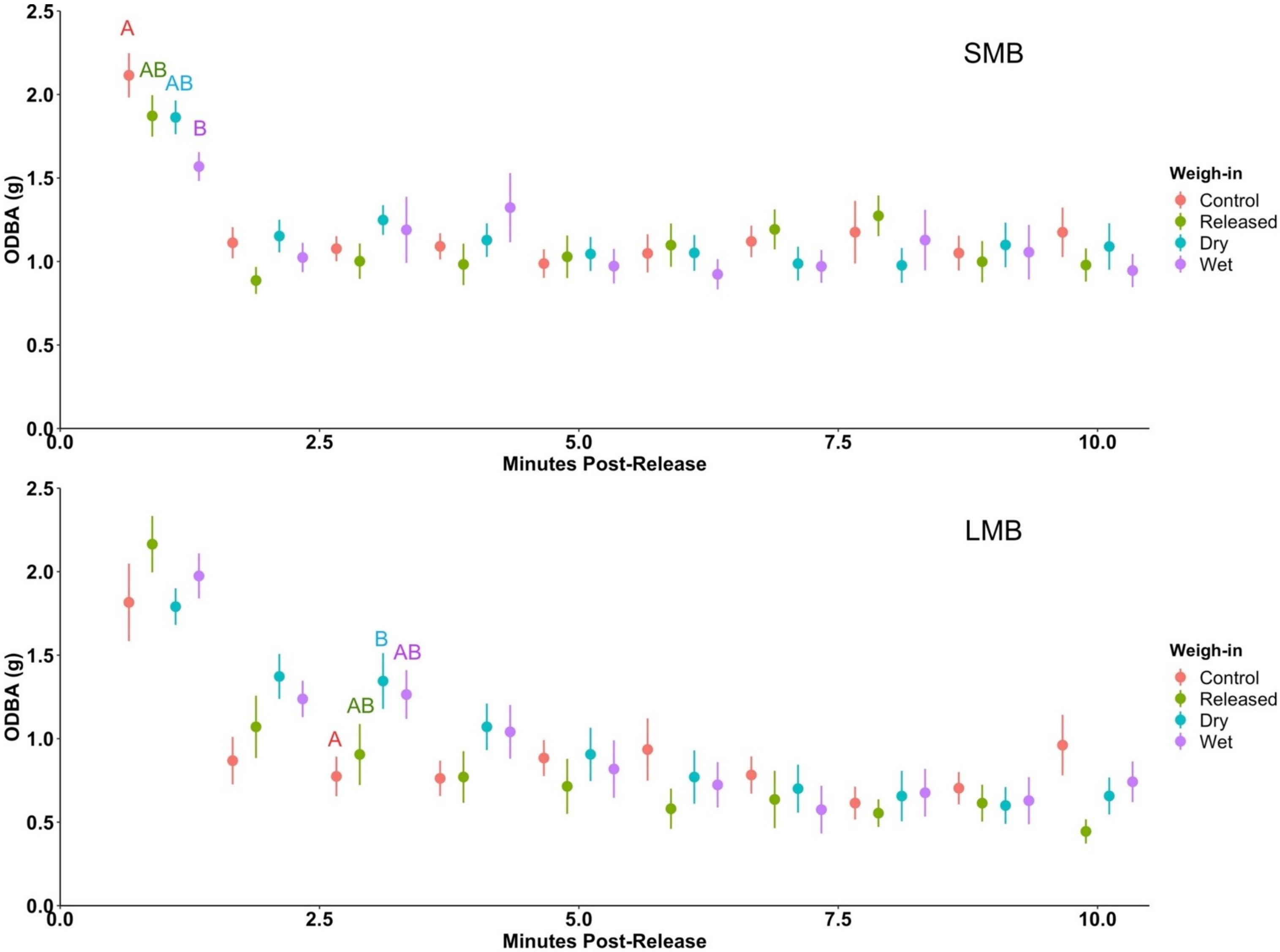

Figure 3.2 Mean OBDA of Smallmouth Bass (SMB; n = 62, 1.15 g ± 0.03 g SE) and Largemouth Bass (LMB; n = 56, 0.93 g ± 0.03 g SE) each minute following release during the 10-minute post-release monitoring period. Weigh-in formats are differentiated by colours and the letters represent the dissimilarities among treatments.

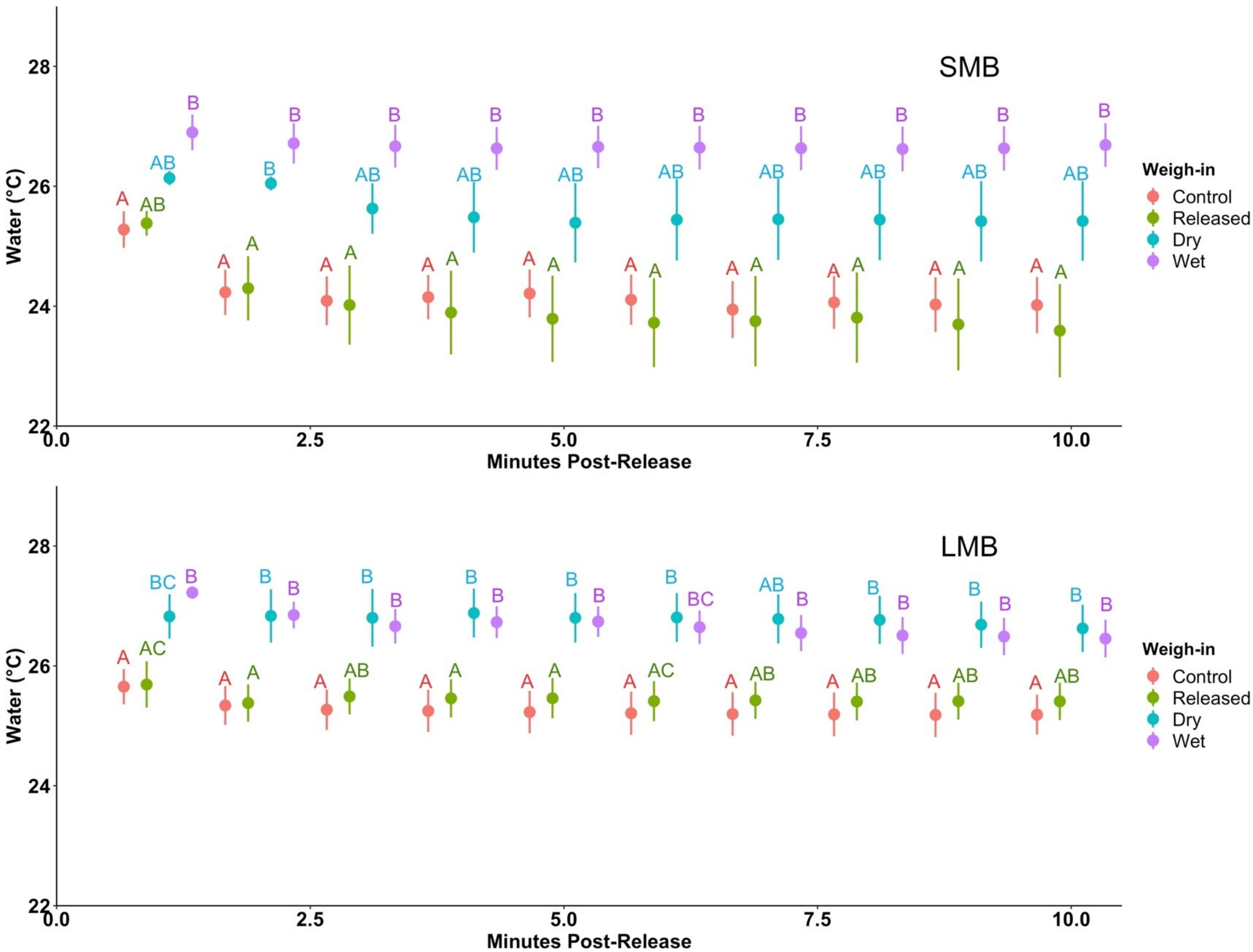

Figure 3.3 Mean water temperature selected by Smallmouth Bass (SMB; n = 62, 25.09 °C ± 0.09 °C SE) and Largemouth Bass (LMB; n = 56, 26.03 °C ± 0.06 °C SE) at each minute during the 10-minute post-release period. Weigh-in formats are differentiated by colours and the letters represent the dissimilarities among treatments.

Chapter 4: General Discussion

My thesis set out to identify how fish handling practices by recreational anglers during the winter and summer influenced the short-term post-release behaviour of Black Bass. Often fish from recreational fisheries are released because it is mandated in order to comply with jurisdictional regulations, tournament rules, or in accordance with angler personal conservation ethics. Since C&R angling occurs worldwide and occurs a lot, it is often used as an effective management and conservation tool for fisheries managers. If C&R is to be an effective management tool, it is vital that the majority of fish being released are able to survive the angling interaction with minimal impact to their fitness.

In Chapter 2, I investigated how various air and ice exposures during sub-freezing conditions influenced the post-release behaviour of Largemouth Bass. During Chapter 2, Largemouth bass were captured by means of angling during the winter and exposed to a period in the air or on the ice, while measurements of wind speed and windchill were taken, including the skin temperature of the fish prior to release. A tri-axial accelerometer harness was attached to the Largemouth bass prior to release to monitor how various environmental factors, during the winter, might have influenced the short-term post-release behaviour after different handling practices. The findings from this chapter suggest that skin temperature has a positive relationship with the windchill temperature experienced by fish. What was clear is that skin temperature showed greater deviation in skin temperature with longer removal periods, compared to the control fish (not removed from the water). Larger Largemouth bass had colder skin temperatures when removed from the water. Largemouth bass that were larger had more skin exposed to the wind with more area for it to act upon, which promoted greater amounts of water loss and resulted in reduced skin temperature of the fish. Fish that were removed from the water for greater durations of time, with colder windchill temperatures, selected shallower and cooler water upon release. Swimming activity had a negative relationship with water temperature and depth. There is a degree of cold shock with fish being removed from the water and exposed to sub-freezing temperatures. Prior to being removed from the water, these fish were acclimatized to water temperatures around 4°C and then quickly removed from the water and exposed to sub-freezing temperatures. Although most literature focuses on the large change in the water temperature as a result of cold shock (Donaldson et al. 2008b), these same principles could be seen when air exposed. There is a large temperature gradient presents when removing a fish from the water in the winter creating possible complication associated with cold shock (Donaldson et al. 2008b). Although skin temperature was measured and used as the main source of fish body temperature in this study, there is little knowledge on the extent that skin temperature influences the animal overall. More investigation is needed related to the skin temperature of fish and how it influences the whole animal, to the influence it has at the cellular level in a catch-and-release context. During cold periods of the year, especially when wind speeds are elevated, anglers should reduce the amount of time their catch is removed from the water in order to minimize the cooling of the skin temperature. Further, larger fish (trophy) tended to have colder skin temperature because they have more skin area exposed. Post-release behaviour is influenced by these colder skin temperatures and lengthy exposure periods, which influenced the post-release behaviour of Largemouth bass. This is the first study to understand the how windchill influenced the skin temperature and the short-term post-release behaviour of fish caught and released in the winter when sub-freezing temperatures are prominent. Although this study only focused on one species, Largemouth bass, these same principles can be applied to other species that are often targeted by anglers during the winter when temperature are near, or below, zero degrees Celsius.

During Chapter 3, I investigated how different tournament weigh-in formats influenced the short-term post-release behaviour of Black Bass. Smallmouth bass and Largemouth bass were captured with angling gear and then subject to a weigh-in procedure from one of the various popular tournament weigh-in formats (catch, weigh and immediate release, dry weigh-in and wet weigh-in). They were then released with a tri-axial accelerometer harness attached to them to understand how different tournament weigh-in formats effect the short-term post-release behaviour. Weigh-in format used in tournaments influenced the short-term post-release behaviour of Black bass. Overall, swimming activity decreased as time post-release increased for both species. Further, water temperature and depth selected upon release was associated with the type of weigh-in experienced. The fish that were placed in the livewell and dry or wet weighed, selected shallower and warmer water. Those weighed immediately selected deeper and cooler water. Generally, in the summer, greater dissolved oxygen concentrations are associated with colder water (until the thermocline), which could allow for a faster recovery period from the angling event experienced by fish caught, immediately weighed and then released. Post-release locomotory activity of Black bass decreased as the depth selected increased and water temperature simultaneously decreased. Elevated locomotor activity associated with Black bass released from the livewell treatments (dry and wet weigh-in) may be the result of a recovery period (Suski et al. 2004) and from disorientation related to being displaced to a new habitat, away from their capture location (Wilde 2003). These findings suggest that tournament organizers need to strategically consider central weigh-in location to allow fish easy access to deep, cool water with adequate refuge (similar to capture location) upon release. Tournament organizers should also consider using catch, immediately weigh and release formats when water temperatures are elevated, or fish are pre-spawn (building nests), spawning (laying eggs) or post-spawn (protecting eggs and fry guarding). Although we do not encourage targeting Black bass during spawning periods, the catch, immediate weigh and release weigh-in format is the most likely format to mitigate negative impacts on recruitment that is associated with catching fish during the spawn (Cooke et al. 2000, Suski et al. 2003b), removing fish from their spawning habitat and displacing them to a central weigh-in location (Ostrand et al. 2004) . Although this study was only done with Black bass, these findings and suggestions related to weigh-in formats should be considered for other fish species in freshwater and saltwater, promoting a catch, weigh/ measure, release format.

The results and conclusions gathered from my thesis show that water temperature and depth selection upon release for Black bass is influenced by angler handling practices. Handling practices that have an increased duration for the handling period, often have different post-release water temperature selection associated with them, relative to handling practices where fish are immediately released. Swimming activity of released fish is closely related to the water temperature, which varies with the time of the year and how the waterbody is stratified. Emphasis should be placed on minimizing the time fish are removed from their natural environment, ensuring that relatively little deviation in normal behaviour will occur when released from an angling interaction.

The immediate short-term post-release period is an important time for recovery and predator avoidance for fish that experience an angling event. The short-term post-release period can influence the long-term fate of fish, which has been shown to be correlated with survival (Beitinger 1990, Brownscombe et al. 2014b). Further, Raby et al. (2012) previously showed that there is a link between RAMP and the long-term fate of released fish, while Brownscombe et al. (2013) found a link between RAMP and the short-term post-release behaviour. With this thesis it is clear that 10 minutes is generally sufficient when assessing the post-release period and looking for when the fish has returned to their regular routine, or homeostasis. The initial 5 minutes post-release are the most critical and all fish released from typical angling events seem to show similar behavioural patterns after the 5-minute period. This suggests that short term post-release behavioural studies should consider using the initial 5 minutes post-release as the new standard for these types of studies.

The overall goal of this thesis was to inform anglers what the best handling practices are and how their actions while handling Black bass, with the added stresses created from harsh environmental conditions (i.e., wind speed and windchill), can influence the post-release behaviour. Additionally, these findings will help inform tournament organizers and fisheries managers when choosing the most adequate tournament format based on the time of the year and weigh-in locations. Using social media outlets (i.e., Instagram, Twitter, Facebook, YouTube) and podcasts it is possible to share this information broadly with the angling community. Further, creating posters and info graphs for high density areas (i.e., tackle shops, water access points, boat launches) with anglers could significantly help get these messages across. Therefore, the science generated here, once shared with the angling community, has the potential to increase the welfare and survival of released fish, which will benefit populations of fish that are subject to intense angling pressure.

Additional research is still needed to further refine C&R practices. For example, further research should investigate the extent that air exposure with varying wind speeds, windchill and light intensity has on the skin temperature of fish and the results of how it alters the post-release behaviour of various fish species. Most of the research to date has focused on the air exposure during the warm periods of the year, while little research has focused on the influence that sub-freezing temperatures have on fish released from an angling event (reviewed in Gale et al. (2013)), which is relevant to many sport fish species in the Northern hemisphere. Although previous studies have shown that cold temperatures can damage essential soft tissues (Tilney and Hocutt 1987, Boutilier 1990, Ferguson and Tufts 1992, Suski et al. 2004), further investigation is needed to understand the extent that these damages can have on the short-term behaviour and long-term fate of released fish.

With the results from my third Chapter revealing that there is a difference in post-release behaviour following various weigh-in formats, further investigation is warranted to understand the mechanisms to why there is differences in post-release behaviour. It is known that water quality in the livewell is an important factor that influences the post-release welfare status of released Black bass (as seen in Suski et al. (2003a), Suski et al. (2004), Ostrand et al. (2011)). Since water conditions are an important factor influencing the welfare status (short-term and long-term) of Black bass that are released from livewells, greater knowledge must be gained on the effectiveness of popular livewell additives that are being used by tournament anglers (i.e., G-Juice™, Rejuvenate® and Please Release Me™). Moreover, with a new popular tournament weigh-in format gaining traction, the procedures and methods of how the fish is being weighed should be understood. Hanging a fish vertically to be weighed could increase the stress levels, including physical body damage. If this type of weigh-in format continues to gain popularity in the Black bass tournament industry, tournament organizer should investigate different formats that allow fish to be weighed immediately in the boat, while not hanging them vertically, also considering reducing the air exposure period (i.e., small water weigh-in contraptions on the boat).

Overall, future studies seek to further explore the link between the post-release behaviour, and the blood physiology of fish caught and released after different angler handling practices. This will allow fisheries scientists to understand the behavioural traits that are associated with various physiological alterations induced by various handling practices. Knowing this will help inform anglers on the best C&R methods to ensure fish are being returned to the water with good welfare status, ensuring that C&R angling can be a good conservation and management tool.

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Appendix A

A.1 Tukey post-hoc results of the selected water temperature by Smallmouth Bass (*Micropterus dolomieu*) after experiencing various weigh-in formats during each individual minute post-release. The significant differences are annotated in bold and italicized.

Minutes Post-Release	Released – C&R	Dry – C&R	Wet – C&R	Dry – Released	Wet – Released	Dry – Wet
			p values			
1	0.953	0.323	***0.009***	0.142	***0.003***	0.439
2	0.999	***0.005***	***<0.001***	***<0.001***	***<0.001***	0.602
3	1.000	0.101	***0.001***	0.094	***0.001***	0.427
4	0.984	0.259	***0.006***	0.151	***0.003***	0.415
5	0.946	0.419	***0.012***	0.188	***0.003***	0.384
6	0.962	0.336	***0.011***	0.160	***0.004***	0.455
7	0.995	0.259	***0.008***	0.189	***0.006***	0.494
8	0.989	0.322	***0.012***	0.209	***0.006***	0.488
9	0.977	0.325	***0.011***	0.178	***0.005***	0.470
10	0.953	0.323	***0.010***	0.142	***0.003***	0.439
			t_3 values			
1	-0.524	1.720	3.275	2.176	3.685	1.509
2	0.128	3.487	4.769	3.259	4.502	1.244
3	-0.108	2.337	3.914	2.373	3.902	1.530
4	-0.357	1.854	3.452	2.145	3.695	1.551
5	-0.552	1.543	3.198	2.032	3.638	1.605
6	-0.487	1.694	3.221	2.116	3.598	1.482
7	-0.237	1.854	3.315	2.029	3.446	1.417
8	-0.316	1.721	3.192	1.976	3.403	1.427
9	-0.410	1.715	3.216	2.061	3.518	1.457
10	-0.524	1.720	3.275	2.176	3.685	1.509

A. 2 Tukey post-hoc results of the selected water temperature by Largemouth Bass (*Micropterus salmoides*) after experiencing various weigh-in formats during each individual minute post-release. The significant differences are annotated in bold and italicized.

Minutes Post-Release	Released – C&R	Dry – C&R	Wet – C&R	Dry – Released	Wet – Released	Dry – Wet
			p values			
1	1.000	***0.036***	***0.001***	0.055	***0.003***	0.772
2	1.000	***0.011***	***0.005***	***0.020***	***0.010***	0.999
3	0.970	***0.019***	***0.022***	0.069	0.088	0.992
4	0.970	***0.007***	***0.009***	***0.030***	***0.041***	0.989
5	0.962	***0.011***	***0.008***	***0.048***	***0.041***	0.999
6	0.976	***0.012***	***0.015***	***0.042***	0.059	0.987
7	0.966	***0.013***	***0.027***	0.052	0.102	0.964
8	0.972	***0.015***	***0.033***	0.054	0.118	0.953
9	0.965	***0.020***	***0.033***	0.075	0.125	0.978
10	0.966	***0.024***	***0.035***	0.086	0.129	0.984
			t_3 values			
1	0.086	2.786	3.936	2.609	3.702	0.961
2	0.091	3.217	3.501	3.027	3.277	0.031
3	0.448	3.036	2.974	2.513	2.408	-0.280
4	0.446	3.391	3.314	2.858	2.737	-0.320
5	0.487	3.238	3.349	2.672	2.729	-0.132
6	0.416	3.223	3.121	2.725	2.582	-0.332
7	0.467	3.184	2.923	2.638	2.339	0.102
8	0.438	3.135	2.820	2.618	2.270	-0.525
9	0.470	3.021	2.828	2.478	2.245	-0.402
10	0.465	2.952	2.804	2.416	2.227	-0.355