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ARTICLE

Dispersal Patterns of Largemouth Bass and Smallmouth Bass Following Early-, Mid-, and Late-Season Fishing Tournaments in an Eastern Ontario Lake

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Abstract
Black bass fishing tournaments with conventional weigh-ins tend to displace fish from their capture site and often release fish within close proximity to the weigh-in site. Tournaments often include Largemouth Bass *Micropterus salmoides* and Smallmouth Bass *M. dolomieu* and occur throughout fishing seasons; however, there have yet to be any systematic congeneric comparisons across different seasons. Objectives of our study were to (1) assess post-tournament dispersal of Largemouth Bass and Smallmouth Bass (i.e., short-term stockpiling—accumulation of fish around weigh-in site <1 month after tournament) across seasons, and (2) determine the success of return to the main basin. Research took place on Big Rideau Lake in eastern Ontario and included a preseason control ($N = 30$) where fish were captured, acoustically tagged, and released at the site of tournament weigh-in (Rideau Ferry). Tournament-caught bass ($N = 88$ total) were tagged at three tournaments that spanned June (early season), August (midseason), and October (late season). Our results indicated a brief short-term stockpiling (within 300 m) in all seasons, and all detected fish eventually returned to the main basin. Tournament-caught Largemouth Bass tended to take longer to disperse from the release site following the midseason tournament (4.6 d); Smallmouth Bass tended to disperse from release site <1 d following all treatments. Similarly, tournament-caught Largemouth Bass exposed to the midseason tournament tended to take the longest to redistribute to the main basin (238 d) in comparison to other treatments. Although Smallmouth Bass tended to redistribute to the main basin faster than Largemouth Bass, late-season Smallmouth Bass tended to redistribute the slowest (101 d) following tournament release. Although fish do survive and eventually return to the main basin, displacement may have broader ecological consequences (i.e., large-scale displacement of top predators, adverse effects on recruitment) such that there would be merit in more catch–weigh–release formatted events.

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Anglers have competed in black bass *Micropterus* spp. fishing tournaments for over 70 years, with a notable increase in popularity during the 1970s (Schramm et al. 1991). Coined by Shupp (1979) as the renaissance of bass management and research, the 1970s tournament boom has set the foundation for bass tournament research today. Over the past 40 years, live-release events have continued to become increasingly conspicuous throughout North America. Based on a 1989 survey of fishery management agencies, an estimate of 29,500 tournaments were occurring annually on North American inland waters, with the majority (i.e., 77.8%) of those competitive events targeting black bass (Schramm et al. 1991). Driscoll et al. (2012) noted a 124% increase (41,939) in the average annual number of black bass tournaments in southeastern states between 2004 and 2009. Inevitably, the frequency of events is an underestimate because smaller-scale events may go unreported. The continued increase in frequency, coupled with a large demand for innovative developments to efficiently target bass (e.g., bass boats, motors, angling equipment, onboard sonar, and fish finders), emphasizes the need for research to keep pace with the ever-evolving recreational sport (Cooke et al. 2021). Moreover, because tournaments target the heaviest fish of a population (Meals and Miranda 1994), and do so with great efficiency (Detmer et al. 2020), it is important for managers and tournament organizers to be equipped with the necessary science to make informed decisions regarding the fishery.

Throughout a typical catch-and-release bass tournament, anglers "blast off" from a designated area (often within close proximity to a public or private boat launch), fish within a designated area, and target the heaviest Largemouth Bass *Micropterus salmoides* and Smallmouth Bass *M. dolomieu* for a cash prize. Anglers retain their catches in an operating live well and are often limited to a five-fish limit onboard at any given time. Fish may be "culled up" throughout the day by releasing a smaller catch from the live well when a larger fish is landed. Typically, at the end of a 6–8-h event day, anglers transport fish back to the weigh-in site, where a weighmaster determines the winners for the heaviest bag of fish (i.e., five-fish bag limit in most cases) or the heaviest individual fish. Following weigh-ins, fish are often released within close proximity to the weigh-in site, or anglers are asked to distribute fish to deeper water. On occasion, live-release boats are used, but they tend to be limited to the largest events. Although some studies have identified bass tournaments as having negligible impacts at the population level (Driscoll et al. 2007; Hysmith et al. 2014), there remains a need to better understand the cumulative effects of catch-and-release tournaments (Philipp et al. 1997; Kerns et al. 2012). Since few studies quantify population-level impacts, it is important for researchers to study outcomes of bass fishing tournaments in an effort to provide managers with empirical evidence to support best practices for competitive black bass events. The breadth of research focused on organized events has contributed valuable science for refining tournament guidelines (summarized in Gilliland and Schramm 2009). Although there are newer tournament formats that involve capture, weigh, and release at the boat (Cooke et al. 2020), weigh-in at central sites remains common, and the displacement of fish remains one of the biggest issues in bass fishing tournaments today.

Over 15 years ago, a survey of North American fishery management agencies revealed that the most commonly stated issues related to tournaments concerned the effects of displacement on tournament-caught fish (Kerr and Kamke 2003). Previous studies have also recommended modifications to tournament release practices (Wilde 2003), yet the shift towards a catch–weigh–release format (Cooke et al. 2020) has yet to become a customary practice in bass fishing tournaments today. Over 20 years of studies that examined post-tournament dispersal of black bass indicate that an average of 26% of Smallmouth Bass and 51% of Largemouth Bass stay concentrated at the tournament release site (within 1.6 km of weigh-in site), and only 14% of Largemouth Bass and 32% Smallmouth Bass return to their site of capture (see meta-analysis by Wilde 2003). However, most of this research does not compare Largemouth Bass and Smallmouth Bass in the same water bodies despite both species often being targeted simultaneously during a competitive event. For example, studies by Richardson-Heft et al. (2000), Ridgway (2002), and Brown et al. (2015) focus on post-tournament dispersal of Largemouth Bass, and studies by Ridgway and Shuter (1996) and Slagle et al. (2020) examine post-tournament dispersal of Smallmouth Bass. Additionally, no studies to our knowledge have assessed how displacement effects are mediated by season. It is well known that home range size and mobility of bass vary seasonally (e.g. Lewis and Flickinger 1967; Savitz et al. 1993; Hanson et al. 2008), so it is reasonable to assume that the timing of displacement may influence the behaviour of the released fish. Seasonal temperatures will also factor into the physiological expense from exposure to a bass fishing tournament. The exercise performance of a fish is limited by temperature (Kieffer 2000), and the physiological challenges associated with catch-and-release fishing has a cost (Cooke et al. 2002; Suski et al. 2003, 2004; Sullivan et al. 2015). Although there is a wealth of knowledge surrounding the effects of tournaments on a fishery, questions persist today. With the increasing frequency of tournaments occurring throughout the open-fishing season, questions need to be answered regarding how the time of season in which a tournament occurs affects fish, as well how both targeted species involved in a tournament respond to the associated stressors (i.e., Largemouth Bass and Smallmouth Bass).

The objectives of our study were to (1) assess post-tournament dispersal of Largemouth Bass and Smallmouth Bass (i.e., short-term stockpiling) across seasons, and (2) determine the success of return to the main basin. To answer these questions, we acoustically tagged preseason-control and tournament-caught Largemouth Bass and Smallmouth Bass exposed to an early- (June), mid- (August), and late-season (October) tournament, and we tracked fish using a passive datalogging receiver array for 2 years. We conducted this study on Big Rideau Lake in eastern Ontario, which has bass tournaments that target Largemouth Bass and Smallmouth Bass and run from the season opening (third Saturday in June) until late October. Big Rideau is a heavily fished water body and has an interesting configuration where many of the tournament weigh-in sites occur at the northeastern end of the lake, which is separated from the main basin by a long narrow channel.

METHODS

Study design.— Acoustic transmitters (LOTEK L-AMT-8.2, 20-s burst rate; 9 mm × 23 mm; 3.5 g) were implanted into 60 Largemouth Bass (LMB, 432 mm ± 38 TL, mean ± SD) and 58 Smallmouth Bass (SMB, 433 mm ± 45 TL, mean ± SD) between June and October 2017. Control fish (LMB: mean TL = 424 mm, SD = 42; SMB: mean TL = 408 mm, SD = 40) were acoustically tagged (June 7–11) prior to the bass season opener to avoid capturing fish previously displaced. Control fish were caught using rod and reel, tagged, and released at the tournament release site (Figure 1). Tournament-caught fish (Table 1) were acoustically tagged following tournament weigh-in at three large tournaments (80–100 boats) in the early season (June), midseason (August), and late season (October). At the time of this study, the Ontario Ministry of Natural Resources and Forestry did not require permits for events that do not hold bass (i.e., anglers bring their own fish for weigh-in and subsequently release their own fish). Because of this paucity, it is challenging to determine the frequency of bass tournaments on Big Rideau Lake. Many events may go unnoticed.

Acoustic telemetry.— Extensive use of acoustic telemetry has been instrumental in investigating fine-scale and broadscale movements of black bass (Ridgway and Shuter 1996; Ridgway 2002; Cooke et al. 2004; Carter et al. 2012; Brown et al. 2015). Movements of Largemouth Bass and Smallmouth Bass were passively tracked using datalogging submersible hydrophone receivers (Lotek, Newmarket, Ontario; WHS4250L, 416.7 kHz). An array of seven receivers (Figure 1) were initially deployed June 2–3, 2017 prior to acoustically tagging fish and were kept active through 2019. Big Rideau Lake and Lower Rideau Lake flow freely under Rideau Ferry bridge. We deployed one receiver on the northeast side of Rideau Ferry bridge to determine if tagged fish caught in Big Rideau chose to redistribute to Lower Rideau Lake following release (Figure 1). We deployed another receiver within close proximity to the tournament release site to obtain the first detection/start time of control and tournament-tagged fish released. Remaining receivers were placed at choke points in the channel from the tournament release site to the channel outlet to the main basin at Rocky Narrows (Figure 1).

Surgical procedures.— Fish were placed dorsal side down in a surgery trough with gills submerged under a continual flow of lake water. To immobilize fish for surgery, Smith-Root electric fish-handling gloves were positioned on the head and caudal peduncle (as per suggested glove positioning). Gloves were set to the lowest current setting (4 mA), and current strength was increased if full-body flinches persisted. Correct current setting was reached when immobilization was achieved along with continuous opercular respiration.

A small incision (<1 cm) was made ventrally on the midline, posterior to the pectoral girdle. An acoustic transmitter was initiated and inserted into the body cavity of the fish, and 1–2 simple interrupted sutures (PDS II polydioxanone suture, violet monofilament, 2-0) were used to close the incision. Once the electric fish-handling gloves were removed from fish, immediate recovery occurred. Use of this approach meant that fish were not burdened with the "hangover" associated with chemical anesthesia (reviewed in Reid et al. 2019). Fish were released following surgery at the tournament release site (Figure 1).

Tournament fish transfer.— A fast pace of tournament tagging was carried out. Our team consisted of five individuals; one fish handler, one recorder, one fish tagger, one individual in charge of fish welfare in holding tanks, and one individual who received fish from anglers and gathered capture information. The tagging team was located on a research vessel, anchored in the general area where anglers release fish following weigh-in (Rideau Ferry; Figure 1). Anglers volunteered their fish to our research boat and were shown a map of Big Rideau Lake (sectioned into ~1-km transects). Anglers were asked to indicate on the map where fish were captured, and the arbitrary number associated with that location was recorded. Upon initial transfer from angler to research team, fish were placed in a water filled trough for processing. Species, TL, map location, implantation of external identification tag (dart tags; Floy Manufacturing), and any additional notes of fish status were recorded. If anglers were unsure of capture location, fish were released

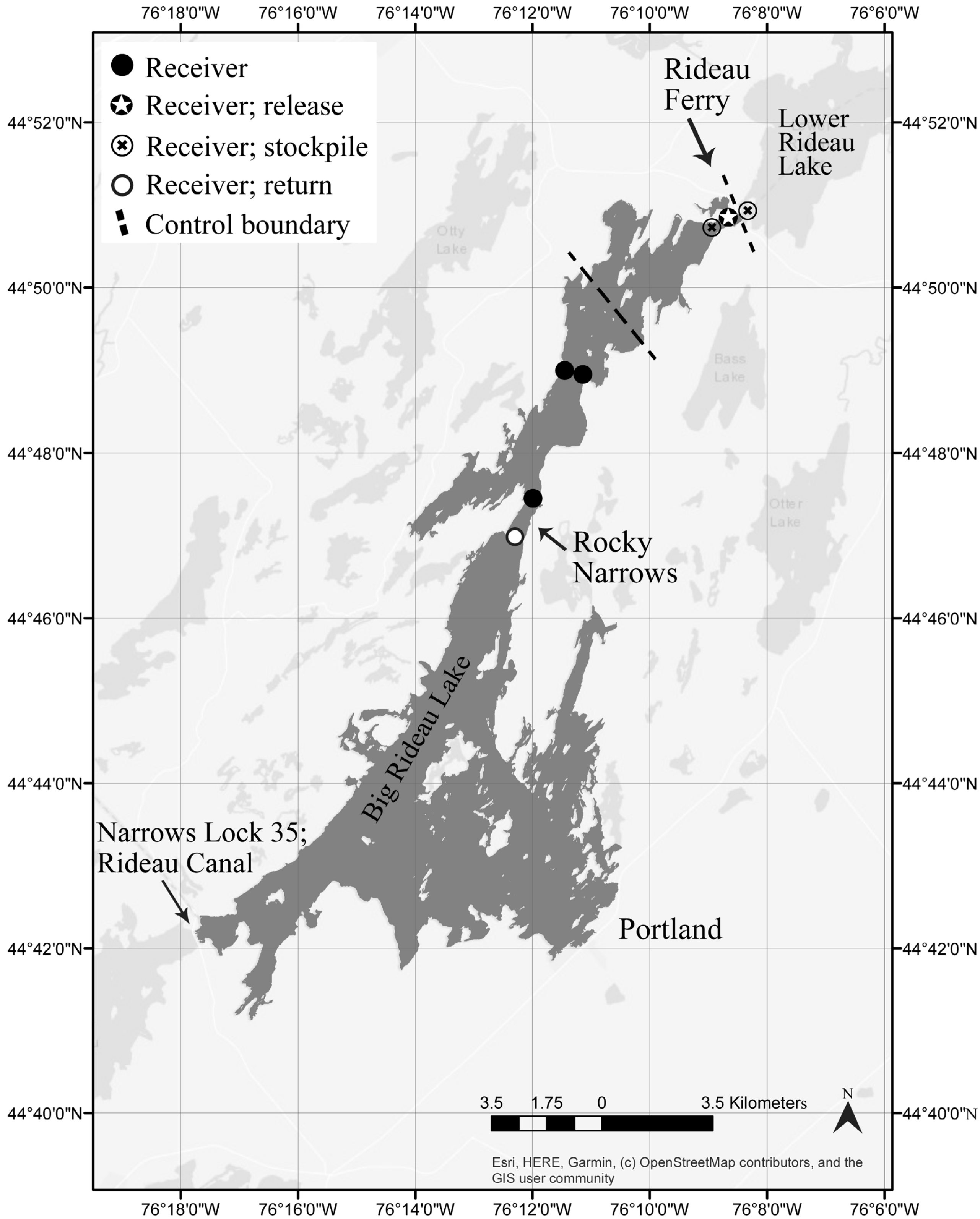

FIGURE 1. Map of Big Rideau Lake, Ontario, displaying acoustic receiver array (denoted as black dots), control fish angling boundaries (denoted as dotted line), tournament release site (denoted as a star), "stockpiling" receivers (denoted as a black "x"), and the "return" receiver (denoted as a white dot).

TABLE 1. Quantitative data of Largemouth Bass (LMB) and Smallmouth Bass (SMB) exposed to one of four treatments (control, early-season tournament [June], midseason tournament [August], or late-season tournament [October]), displaying sample sizes in Kaplan–Meier analyses for (1) time to leave tournament release site (i.e., stockpiling), and (2) time to return to the main basin in Big Rideau Lake, Ontario.

Treatment	Surface water temp. (°C) range	Species	Mean TL ± SD (mm)	*N* acoustic tag	% of tagged fish (stockpiling analysis)	Stockpiling *N*	% of tagged fish (return analysis)	Return *N*
Control	18–20	LMB	424 ± 42	15	73	11	73	11
Control	18–20	SMB	408 ± 40	15	80	12	73	11
Early	22–24	LMB	434 ± 22	15	87	13	87	13
Early	22–24	SMB	423 ± 43	15	87	13	87	13
Mid	24–26	LMB	412 ± 39	17	88	15	65	11
Mid	24–26	SMB	419 ± 28	14	86	12	79	11
Late	12–14	LMB	466 ± 22	13	69	9	69	9
Late	12–14	SMB	484 ± 20	14	93	13	57	8

without acoustic tags. All other fish were held in large tanks (379 L) with floating rubberized mesh for cover and a continual replenishment of fresh lake water.

Data management.— We used telemetry data to determine (1) the time (in d) for detected fish to leave the tournament release site (within 300 m) and (2) the time (in d) for detected fish to return to the main basin. Raw telemetry data (June 2017 to November 2019) were filtered using LOTEK WHS-4250 software to remove all tag detections differing from acoustic tag IDs used in this study. Next, data were imported to R (RStudio version 1.1.383), where a loop was created to filter out false detections (Tuononen 2019).

Statistical analyses.— Crude estimates of displacement distances were determined using the measurement function in Google Earth to plot the distance (m) from the angler-reported capture site to the tournament release site. Parameters for the mean TL and the mean displacement distance were statistically analyzed between treatment groups using a one-way ANOVA in IBM SPSS Statistics version 25. All assumptions were met for the TL of bass and displacement distances. The data had normal distribution, a homogeneity of variance, and samples were independent of each other. All statistical assessments were conducted at an α level of 0.05. In the event that statistical significance between groups was identified, a post hoc Tukey's honestly significant difference test was used to determine where significant differences were between groups.

Stockpiling analysis.— We used the filtered data to determine the time (in d) for control and tournament-caught fish to leave the tournament release site. As defined by Maynard et al. (2017), short-term stockpiling refers to fish that remained concentrated at the release site for <1 month. Due to the relatively narrow lake configuration at Rideau Ferry, a detection gate was set up at the closest choke points upstream and downstream of the release site (Figure 1). Although the defined radius of stockpiling is variable among tournament studies (reviewed in Wilde 2003), we determined 300 m from the release site to be the most favorable location for detecting fish that passed through the choke point on either shoreline. All tagged fish with a discernable release start-time, logged on the receiver at the release site, were used to determine dispersal rates of Largemouth Bass and Smallmouth Bass. Some initial detections did not match our documented release time, and therefore these fish were removed from the analysis. Since there were a fair number of fish removed prior to analysis, the percentage of detected fish analyzed has been identified in Table 1. Initial fish detection on receivers either upstream or downstream of the tournament release site were fish deemed to have left the release site (Figure 1). Differences between groups (i.e., control, early-, mid-, and late-season tournament) were tested using a Kaplan–Meier survival curve implemented in SPSS version 25. All assumptions of the Kaplan–Meier analysis were met: (1) the event status was collectively exhaustive, (2) the time to the event was precisely measured, (3) left-censoring was avoided, (4) independence of censoring and the event, and (5) no secular changes were present. In the event that statistical significance between groups was identified, a log-rank (Mantel–Cox; $\alpha = 0.05$) post hoc test was conducted. We report dispersal patterns of the median proportion of detected fish, as well as 100% of detected fish, because the behavioral tendencies of the median proportion of fish is statistically more representative of the tagged population (Figure 2).

Return analysis.— Similarly, we used a Kaplan–Meier survival curve to determine the time for fish to return to the main basin. All tagged fish with a discernable release start-time logged on the release receiver were used to determine return rates of Largemouth Bass and Smallmouth Bass. Initial fish detection on the receiver within close proximity to the main basin were considered to have

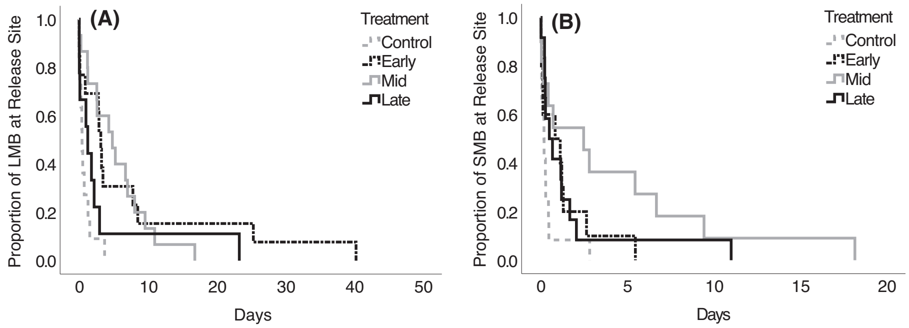

FIGURE 2. Kaplan–Meier curve displaying time (d) for detected **(A)** Largemouth Bass and **(B)** Smallmouth Bass to leave the tournament release site (within 300 m) in Big Rideau Lake, Ontario. The step pattern displays the proportion of fish at the release site following tag and release (day 0) of fish in the control, early-season tournament, midseason tournament, and late-season tournament treatments.

returned (Figure 1). The quantity of receivers in this study limited our ability to observe fish movement throughout the whole lake. Therefore, prior to fish tagging, it was determined that all fish displaced from the main basin were considered to have returned when detected at the entry to the main basin (Figure 1). Differences between groups (i.e., control, early-season, midseason, and late-season tournament) were tested using a Kaplan–Meier survival curve implemented in SPSS version 25. The five Kaplan–Meier assumptions outlined in the stockpiling analysis above were met for the return data set. The log-rank (Mantel–Cox) test was analyzed for statistical significance ($\alpha = 0.05$).

RESULTS

Tournament fish were captured throughout Big Rideau Lake between Rideau Ferry bridge, Narrows Lock 35, and the main basin adjacent to Portland, Ontario (Figure 1). The TL of tagged Largemouth Bass (432 mm ± 38 mean ± SD) and Smallmouth Bass (433 mm ± 45, mean ± SD) was generally similar across all treatments. However, the mean TL of late-season tournament fish was significantly larger (LMB, $F = 7.2$, $df = 3$, $P < 0.0001$; SMB, $F = 13.9$, $df = 3$, $P < 0.0001$). Tournament-caught Largemouth Bass ($N = 45$) were displaced on average 10.5 km ± 7.37 (mean ± SD) from the main basin to the tournament release site, and tournament-caught Smallmouth Bass ($N = 43$) were displaced on average 12.14 km ± 6.98 (mean ± SD). There was no difference in displacement distances for Largemouth Bass ($F = 0.79$, $df = 3$, $P = 0.46$), and Smallmouth Bass ($F = 0.36$, $df = 3$, $P = 0.70$) exposed to early-season, midseason, and late-season tournaments.

Stockpiling at Tournament Release Site

Stockpiling is defined in this study as the concentration of released, tournament-caught fish (Richardson-Heft et al. 2000) that remain within 300 m of the release site. All detected fish did leave the release site; however, short-term stockpiling did occur following all treatments. Fifty percent of detected Largemouth Bass left the tournament release site between 9.6 h (control) and 4.6 d (midseason tournament). However, 100% of early-season, tournament-caught Largemouth Bass took up to 40.3 d to leave the release site (Table 2). Fifty percent of detected Smallmouth Bass left the tournament release site between 3 h (early-season tournament) and 13.8 h (midseason tournament). It took at most 18.2 d (midseason tournament) postrelease for all detected Smallmouth Bass to leave the site (Table 2). Largemouth Bass exposed to one of four treatments (control, early-season tournament, midseason tournament, or late-season tournament) exhibited a significant difference (Mantel–Cox; df = 3, $P < 0.01$) between treatments in the time to leave the tournament release site (within 300 m).

TABLE 2. Time (d) for Largemouth Bass and Smallmouth Bass to leave the tournament release site (within 300 m) in Big Rideau Lake, Ontario, following tag and release of control, early-season tournament (June), midseason tournament (August), and late-season (October) tournament fish.

	Time (d)		Time (d)	
	Largemouth Bass		Smallmouth Bass	
	50% detected	100% detected	50% detected	100% detected
Control	0.4	3.7	0.2	2.8
Early season	3.0	40.3	0.1	5.5
Midseason	4.6	16.8	0.7	18.2
Late season	2.2	23.3	0.4	11.0

Return to Main Basin

All detected fish returned to the main basin; however, returns often took considerable time. Fifty percent of detected Largemouth Bass returned to the main basin between 3.6 months (early-season tournament) and 7.8 months (midseason tournament) following tournament release. All detected Largemouth Bass returned to the main basin within 18.5 months after tournament release (midseason tournament) (Figure 3). Fifty percent of detected Smallmouth Bass returned to the main basin between 13 d (control) and 3.3 months (late-season tournament) postrelease (Table 3). A log-rank (Mantel–Cox) analysis within each species group showed no difference between the four treatment groups (df = 3, $P > 0.05$). As a caveat, fish were considered to have "returned" when detected at the entry to the main basin (Figure 1); however, this does not signify a return to their capture site.

DISCUSSION

Stockpiling

As observed by Maynard et al. (2017), our results also indicate that short-term stockpiling of both species did occur following all treatments; however, dispersal rates were variable between species and season. In general, the Smallmouth Bass left the release site faster than Largemouth Bass for all treatments, and the slowest time to leave the tournament release site was for fish exposed to the midseason tournament (Table 2; Figure 2). Tournaments that adhere to a shore-based weigh-in format tend to release fish within close proximity to the weigh-in site. Some larger events employ a live-release boat to redistribute fish following weigh-in; however, this is not a common practice among events of differing sizes (e.g., smaller club tournaments, which are the most common). Tournament-caught fish are conceivably some of the heaviest individuals of the population and post-tournament release of tens to hundreds of trophy-sized fish in a localized area brings in to question the biological consequences of this practice. Additionally, consecutive use of a popular release site (i.e., over multiple days or distinct competitions) may result in stockpiling events that overlap in space and time (i.e., concentration of tournament-caught fish remaining at release site; Richardson-Heft et al. 2000), possibly exacerbating challenges associated with stockpiling. Hunter and Maceina (2008) estimated a 50–100% increase in resident black bass biomass (6–9 kg/ha) within 2 km of the tournament release site. To our knowledge, this is the first study to examine systematic congeneric seasonal comparisons of stockpiling at a tournament release site.

Seasonal comparisons indicated that Largemouth Bass tended to leave the release site most quickly following the late-season tournament (2.2 d; Table 2), and the slowest to disperse were those exposed to a midseason tournament (4.6 d). The longest period of time for 100% of detected Largemouth Bass to leave the release site occurred 40.3 d following the early-season tournament (Figure 2). These results are generally consistent with other findings that Largemouth Bass tend to exhibit short-term stockpiling following post-tournament release (7–14 d; Richardson-Heft et al. 2000; Ridgway 2002). In comparison, Smallmouth Bass tended to disperse from the release site within the first day following all treatments (Figure 2). Similar to post-tournament dispersal rates of previous studies (0.5–30 d; Ridgway and Shuter 1996; Bunt et al. 2002), Smallmouth Bass left the release site the fastest following the early-season tournament (0.1–5.5 d) and the slowest following a midseason tournament (0.7–18.2 d; Table 2). Fish in all treatments were also exposed to electro-immobilization during surgical implantation of an acoustic tag (<5 min) prior to release. This may have influenced immediate postrelease behavior; however, research has shown minimal disturbances associated with these methods (Prystay et al. 2017; Abrams et al. 2018; Reid et al. 2019).

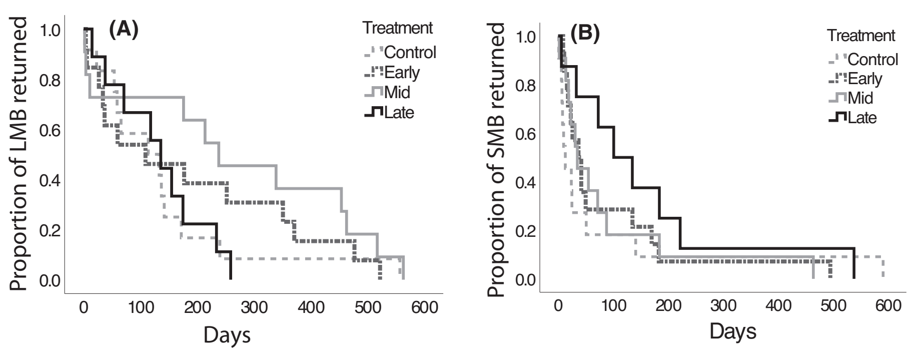

FIGURE 3. Kaplan–Meier curve displaying the time (d) for detected **(A)** Largemouth Bass and **(B)** Smallmouth Bass to return to the main basin in Big Rideau Lake, Ontario. The step pattern displays proportion of fish returned to the main basin following release (day 0) of fish tagged in the control, early-season tournament, midseason tournament, and late-season tournament treatments.

TABLE 3. Time (d) for Largemouth Bass and Smallmouth Bass to return to the main basin following tag and release of control, early-season tournament (June), midseason tournament (August), and late-season (October) tournament fish in Big Rideau Lake, Ontario.

	Time (d)		Time (d)	
	Largemouth Bass		Smallmouth Bass	
	50% detected	100% detected	50% detected	100% detected
Control	114	557	13	591
Early season	109	522	37	495
Midseason	238	563	35	464
Late season	136	259	101	538

While challenging to isolate the potential mechanisms explaining post-tournament dispersal rates, considerable research has indicated the role of temperature in the stress response and mortality of caught-and-released fish (reviewed in Gale et al. 2013). In this study, fish exposed to higher water temperatures (i.e., the midseason tournament) tended to stockpile at the release site for the longest period of time in comparison to early- and late-season tournaments (Tables 1 and 2). As ectotherms, fishes are limited in terms of exercise performance in many ways by temperature (Kieffer 2000), and catch-and-release fishing during relatively higher water temperatures can pose additional physiological challenges (Siepker et al. 2007). Higher water temperatures cause black bass to increase oxygen uptake, while water often contains less available oxygen. Short-term stockpiling may be indicative of a post-tournament recovery period, and unsurprisingly this time period was extended following the midseason tournament (Table 2). However, it is well known that the home range size and locomotory activity patterns of black bass vary seasonally (Lewis and Flickinger 1967; Savitz et al. 1993; Hanson et al. 2008). As such, the patterns observed here may be independent of any physiological stress associated with capture and handling and may simply reflect seasonal variation in the behavior of fish and how they respond to displacement.

Return to the Main Basin

Detected Largemouth Bass tended to return to the main basin in a range of ~3.5 months following the early-season tournament (June) to ~7.8 months following the midseason tournament (Table 3; Figure 3), and all detected fish eventually returned by ~1.5 years after the tournament. Notably, the slowest return to the main basin by Largemouth Bass followed the midseason tournament in August, where fish were exposed to comparably higher water temperatures (Table 1). Exposure to tournament displacement at relatively higher water temperatures may have delayed Largemouth Bass redistribution; however, Mesing and Wicker (1986) determined that the greatest average daily movements occurred in June and abruptly decreased during summer periods with higher water temperatures. This indicates that at a time when Largemouth Bass are decreasing their average daily movements during periods of relatively higher water temperatures, large-scale displacement can greatly alter the length of time it takes for the fish to return to the main basin (Figure 2).

Detected Smallmouth Bass tended to return faster than Largemouth Bass, with a return rate ranging from ~1 month (early season and midseason) to ~3 months following a late-season tournament (Figure 3), and all detected Smallmouth Bass returned by ~1.5 years after release (Tables 1 and 3). Since the tournament release site is generally characterized as a relatively shallow, weedy habitat (depth of ~4 m), Smallmouth Bass may have dispersed faster than Largemouth Bass in an effort to locate a preferentially deeper, cooler habitat (Suski and Ridgway 2009) where the water column reaches 100 m depth in the main basin. Notably, detected Smallmouth Bass tended to take the longest to return following a late-season tournament in October. Fall water temperatures have been shown to influence the degree of seasonal movements of Smallmouth Bass (Carter et al. 2012). A large-scale tournament displacement event presents new behavioral challenges during a period of time when fish are being prompted by fall water temperatures and other cues to move to suitable overwintering habitats (Langhurst and Schoenike 1990).

Findings of this study demonstrate an extended period of time for both Largemouth Bass and Smallmouth Bass to return to the main basin; however, these results must be evaluated in light of some limitations. Due to an insufficient number of receivers available to detect fish movement throughout the entire main basin, reports of fish return rates (Figure 3; Table 3) are an underestimate for the time it would take for tournament-caught fish to return to their capture site. The main basin offers ample opportunity for Largemouth Bass and Smallmouth Bass to locate suitable habitat along their possible movement back to their capture location, and therefore the entrance to the main basin was deemed to be a reasonable proxy for the time to return. These extended time periods to return to the main basin of the lake may function as harvest from main-lake populations or a restructuring of bass populations in ways that managers may not understand (Ricks and Maceina 2008). Future research could determine more precise time estimates for Largemouth Bass and Smallmouth Bass to return to capture sites within the main basin by deploying a larger receiver array. Although this would provide more accurate time estimates of "return to capture site" within the main basin, the identified delay in return should be sufficient evidence to support discussions of adopting a catch–weigh–release format or a hybrid approach to eliminate issues discussed in this paper (Cooke et al. 2020).

Mortality

Improvements to live-well procedures (e.g., constant use of an aerator), tournament rules (e.g., reduced bag limits), and improvements to weigh-in procedures have contributed greatly to decreasing post-tournament mortality rates over the past several decades (Wilde 1998; Wilde et al. 2002; Maynard et al. 2017). Post-tournament mortality rates associated with tagged fish in this study were very low, which is typical for the majority of tournaments (see review by Wilde 1998). Upon initial data review, some tagged fish were removed from the study due to unusable tag detections (Table 1), but fish with a discernable release time exhibited very low mortality rates post-release. Only one mortality in this study was documented for a Largemouth Bass exposed to a late-season tournament (represents ~2% of all tournament-tagged Largemouth Bass released in this study). That individual was continuously detected at the tournament release receiver for >150 d following release and therefore assumed to be a mortality. A caveat to this perceived low morality rate may also be attributed in part to high-grading fish for tagging. Tournament fish in the best perceived condition were selected for tagging and therefore may not be completely representative of the released population. Even with high-grading selection, fish were also exposed to electrosedation and surgery to implant transmitters (both of which can lead to mortality; Cooke et al. 2011) throughout a range of temperatures (e.g., June, August, and October; range of 18–26°C) and still exhibited high survival rates. Although tournaments in this study used dry weigh-ins (wet weigh-ins are optimal for fish welfare; Tufts and Morlock 2004), the common thread was a well-organized weigh-in (e.g., anglers placed fish into fish bags only when called for weigh-in) and a subsequent prompt release of fish. These tournaments were not using sophisticated weigh-in fish care systems, yet their methods of quickly releasing fish was sufficient to sustain relatively low initial mortality rates—even during the midseason tournament when surface water temperatures were 24–26°C (Table 1). Tournaments that minimize the amount of time a fish is out of the live well for a weigh-in procedure will inevitably reduce air exposure time and handling stress associated with this practice. This study reiterates the findings of others that indicate relatively low postrelease mortality of tournament-caught fish (Wilde et al. 2002) as well as the importance of angler adoption of live-well management best practices and a well-managed weigh-in and release procedure (Cooke et al. 2020).

Conclusion

Evidence in this paper supports previous findings that indicate stockpiling and large-scale displacement to be a persistent biological concern surrounding tournament practices today. Stockpiling does occur for both Largemouth Bass and Smallmouth Bass; however, it is generally for short periods of time, varying seasonally and by species. Notably, tournament-displaced fish do return to the main basin, although it can take over one year to do so. Equipping managers with systematic congeneric seasonal comparisons of Largemouth and Smallmouth bass exposed to competitive events offers empirical evidence to support the reassessment of common tournament displacement practices. We encourage managers to consider adopting a catch–weigh–release format when possible. Doing so eliminates the biological costs associated with tournament displacement. Moreover, this could alleviate potential conflicts among lake users. In the event that a shore-based weigh-in is required, it is suggested that managers assess release locations to ensure most suitable habitat for recovery of both target species postrelease. Another possibility is for managers to adopt a hybrid approach with adaptive management based on water temperature conditions (i.e., implementation of the catch–weigh–release format during relatively hotter periods of the tournament season). Since black bass events have displaced fish to a common weigh-in site for decades, and these fish are arguably some of the heaviest in the population (Kelley 1962), it would be valuable for future research to focus on examining angler perceptions and willingness to adopt alternate weigh-in methods.

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