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Local Angler Knowledge Reveals Declines in Fishing Quality for Black Bass in Lakes of Eastern Ontario

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ABSTRACT

Local ecological knowledge can be useful to assess data-limited fisheries such as the Ontario Black Bass (*Micropterus* spp.) recreational fishery. We surveyed local anglers using the Life History Calendar approach to determine if there were perceived changes in fishing quality for Black Bass in eastern Ontario across different time periods. For both species (Largemouth Bass and Smallmouth Bass), respondents noted declines in numbers and body sizes of their catch across most of the time periods (1975–2025) with sharp declines beginning in 2005. The reported declines were notably consistent across the waterbodies studied and did not differ across different user types (e.g., tournament anglers vs. other anglers). The results of this study show that anglers overwhelmingly perceive that the quality of bass fishing in eastern Ontario has deteriorated over the past few decades, highlighting the (1) utility of using local angler knowledge to complement traditional stock assessment methods and (2) the need to consider alternative monitoring and management strategies to reverse those declines.

1 | Introduction

Attention to the effectiveness of recreational fisheries management has increased substantially over the last few decades. That change is likely due to the popularity of recreational fishing worldwide, as well as the complex nature of fisheries management and its potential impacts on fish populations and fishing quality (e.g., Post et al. 2002; Cooke et al. 2015; Arlinghaus et al. 2019). Managers have recognized the need to protect recreationally important fish species for the diverse socio-economic benefits that support the lives and livelihoods within the industry (e.g., Arlinghaus and Cooke 2009). Successful fisheries management outcomes depend on an array of complex factors that all work together as an adaptive, socio-ecological system (McClanahan et al. 2009; Woods et al. 2022). These systems not only require consistent feedback of information among user groups, but also require an ongoing understanding of the individual, population, and ecosystem components of both the system itself and the people who use them (see Arlinghaus et al. 2017). For management to succeed, there must be a clear understanding of the state of the fishery stock being managed (Arlinghaus et al. 2013; Post 2013). Without this information, it is unlikely that policies and management strategies can effectively achieve their overall conservation or management goals and deliver a sustainable fishery (Post 2013). Despite this, oftentimes our knowledge of the state of fishery stocks is less than desirable, with key data being either incomplete or nonexistent. As a result, it is possible that current management strategies and regulations for certain recreational fisheries are unknowingly failing to meet management goals.

One way to address the lack of data on the state of the target population and thereby aid in developing successful management strategies for those fisheries is to look at a given fishery through the lens of local people who have knowledge about that fishery (see Johannes et al. 2000). Fisheries are often data-deficient or data-poor for a variety of reasons (Chrysafi and Kuparinen 2016). Traditional survey methods such as creel surveys often cannot cover the spatiotemporal extent of a recreational fishery, including the different methods, access points, and duration of fishing used by different anglers (e.g., National Research Council 2006). Additionally, traditional monitoring methods such as capture-mark-recapture surveys or netting techniques (e.g., gill, hoop, trap netting) often require human and financial resources that are unfeasible by monitoring bodies and are insufficient in capturing certain fish species, especially given the large spatial scale of waterbodies (e.g., there are over 18,000 lakes in Ontario greater than 50 ha; Ontario Ministry of Natural Resources 2008). Beyond monitoring, there are resource deficiencies that hinder management efficacy (Potts et al. 2020) in that it is challenging to determine harvest and illegal capture rates. These factors lead to large knowledge gaps within monitoring bodies that can be partially supplemented by local or Indigenous knowledge (e.g., Neis 1992; Neis, Schneider, et al. 1999; Neis, Felt, et al. 1999). The practice of including local knowledge in monitoring and management has been used for a number of data-limited recreational fisheries in North America through direct angler surveys (e.g., Bonefish *Albula vulpes* and Atlantic Tarpon *Megalops atlanticus*; Rehage et al. 2019; Griffin et al. 2023). As another example, historical records were developed through angler knowledge for the Rockfish (*Sebastes* spp.) fishery in Puget Sound, Washington, that lacked information on past abundance, distribution, size structure, and catch (Beaudreau and Levin 2014). This type of knowledge, known as local ecological knowledge (LEK), is held by users who acquire information about ecological trends through their observations over time (e.g., Johannes 1989; Olsson and Folke 2001; Davis and Wagner 2003).

Knowledge collected by users is complex and can include "a complete body of knowledge [...] developed by peoples [...] who have extended histories of interaction with the natural environment" or the "totality of all knowledge and practices [...] used in the management of socio-economic, spiritual and ecological facts of life" although ultimately there is a blurred line between the type of local knowledge used and what kind of information can be collected by it (explicit or implicit; Onyancha 2024). Nonetheless, relying on the knowledge of the most experienced stakeholders is especially appropriate for uncovering in-depth perspectives on resource issues (Davis and Wagner 2003). The use of LEK in conjunction with traditional and Indigenous knowledge has been a topic of study for decades and has been used extensively in fisheries for detecting overfishing, habitat loss, stock trends, recovery plans, threats, and effectiveness of a regulation (e.g., Johannes 1989; Berkes 1993; Johannes et al. 2000; Olsson and Folke 2001; Hind 2015). In fact, anglers and fishers are oftentimes at the forefront of identifying key issues that may be missed by larger monitoring programs, and have been used worldwide (e.g., Beaudreau and Levin 2014; Sawchuk et al. 2015; Florisson 2015; Thurstan et al. 2016; Rehage et al. 2019; Kroloff et al. 2019). Most famously, it has become clear in retrospect that the use of LEK could have prevented fishery disasters, such as the Atlantic Cod fishery collapse that occurred due to overfishing of Cod stocks in the Atlantic off the coast of Newfoundland (Neis 1992; Neis, Schneider, et al. 1999). In this case, commercial fishers had long reported changes in abundance and size structure of Cod stocks before the collapse actually hit in the early 1990s. It is through these learned experiences that we understand that the involvement of resource users in conservation and management can prove to be highly beneficial if their knowledge is included in an appropriate manner to enhance our understanding of under-monitored fish stocks (Arlinghaus and Cooke 2009; Aswani et al. 2018; Berkes and Nayak 2018).

In the United States and Canada, the management of two species of Black Bass, Largemouth Bass (*Micropterus nigricans*; LMB) and Smallmouth Bass (*Micropterus dolomieu*; SMB), is an important task for fisheries managers due to their popularity with anglers (Quinn and Paukert 2009; Long et al. 2015). As species that are largely released post capture, they have become the "face" of catch-and-release recreational fisheries—a movement popularized in the 1970s that focuses on capturing and releasing fish without harvest, thus aiming to decrease mortality and protect the fishery (Barnhart 1989; Quinn and Paukert 2009; Long et al. 2015). Release rates for Black Bass are high even when bass fishing effort or harvest is not regulated (Myers et al. 2008). Despite the prominence of catch-and-release angling among bass anglers, research over the past several decades has posited that, even in a catch-and-release event, there can be impacts to fish on an individual and population level (e.g., Bartholomew and Bohnsack 2005). In the context of Black Bass, for example, fish may suffer immediate or post-release mortality from stressors such as prolonged air exposure and exhaustion or injury associated with the fishing event (Kerns et al. 2016). In addition, sub-lethal stressors and injury can interrupt parental care, increasing the chances of brood abandonment with associated impacts on population recruitment (Suski et al. 2003; Philipp et al. 2009; Philipp, Claussen, et al. 2023; Philipp, Zolderdo, et al. 2023).

Monitoring Black Bass populations in Ontario has proven challenging. In 2008, the Ontario Ministry of Natural Resources introduced the Broad-scale Monitoring (BsM) program (Ontario Ministry of Natural Resources 2008) that involves a random sampling of various lakes across Ontario that is repeated in five-year cycles, and is mostly focused on capturing trends in three (non-*Micropterus*) species of recreational importance: Brook Trout (*Salvelinus fontinalis*), Lake Trout (*Salvelinus namaycush*), and Walleye (*Sander vitreus*). The program mandates that all lakes containing one of the three above species are to be monitored in every cycle (known as "trend" lakes), while all other lakes are randomly sampled, leaving many lakes' data absent or deficient. Furthermore, whereas the BsM program aims to representatively sample all depths of each lake, there are certain constraints with deploying survey gillnets in areas of the littoral zone where there can be high amounts of vegetation, woody material, and recreation by the public. This impedes the ability of the survey to capture bass effectively because these fish often stay in the littoral zone for much of the ice-free period. As a result of these issues and the relatively infrequent use of creel surveys in Ontario, there is little information on the state of Black Bass populations. Thus, current management strategies may be insufficient in protecting SMB and LMB in parts of Ontario, and thus eastern Ontario (known as Fisheries Management Zone 18—FMZ 18) provides a good case study and model of how LEK can support the management and monitoring of data-limited recreational fisheries.

Currently, Black Bass are managed through open and closed seasons, bag limits, and slot size limits, with the former two being more common across the 20 FMZs (Ontario Ministry of Natural Resources 2025). Ostensibly, closed season regulations for Black Bass angling are used to allow Bass to successfully reproduce in the spring (Ontario Ministry of Natural Resources 2025). Due to the overlap of the bass closed season with open seasons for other species (allowing for accidental and intentional capture of SMB and LMB during their reproductive period), it is clear that these regulations are not protecting Black Bass to their full extent (Philipp et al. 1997; Suski et al. 2002; Kubacki et al. 2002; Tufts et al. 2019; Philipp, Claussen, et al. 2023; Philipp, Zolderdo, et al. 2023). That disconnect is because the closed fishing regulation is extremely difficult to evaluate and enforce, and differences exist between the timing of annual closed season dates and the actual timing of the reproductive seasons for bass (due to variation in the rising spring water temperatures among lakes and across years). Ontario, however, does use Freshwater Protected Areas (FPAs), with over 600 FPAs across Ontario aiming to protect aquatic ecosystems and species, although a majority of these have not been studied for efficacy and effectiveness (Zolderdo et al. 2024), do not encompass habitats that are conducive to bass spawning and are largely unknown. As a result, without consistent bass-oriented monitoring, it is impossible to know if current management strategies are protecting bass. Alternative monitoring methods, such as the use of LEK, should be developed, that is, ones that specifically complement current Black Bass monitoring strategies, with the results of this monitoring being used to assess how well the different bass management strategies are working.

1.1 | Rationale

The Ontario Ministry of Natural Resources (2015) published a "Provincial Fish Strategy for the Future" that highlighted some of the major objectives of fisheries-related projects going forward. Among the objectives listed in this document were the following:

- Objective 1: Protect the composition of native fish communities and
- Objective 2: Create effective regulations, policies, and practices to guide present and future actions and decisions

Black Bass are widespread throughout Ontario, and their status is not considered a concern, even though the true state of the fishery has not been identified; a trend shared with the fisheries for other fish species in Canada (Post et al. 2002). Unfortunately, without the required population data, it is impossible to make informed management decisions, and we may proceed with ongoing regulations that do harm or are unable to prevent population collapses (e.g., Neis 1992).

Ad hoc discussions with local anglers, however, suggest that the fishery has decreased in quality over the years. As a result, to prevent the common phenomenon of "too late" enactment of policies needed to protect one of the most important recreational fisheries in Canada (Oro and Martínez-Abraín 2023), we submit that it is important to consider the perceptions of changes in the fishery held by stakeholders who frequently use and rely on its resources. As such, we addressed a need for the use of alternative monitoring strategies for data-limited species, such as LMB and SMB in eastern Ontario, and hypothesize that over time there has been a decrease in angling quality across the region (consistent with Post et al. 2002's observation that fisheries' decline in the recreational sector often go unnoticed by management bodies). Thus, the objective of this study was to use a mixed-methods survey using the Life History Calendar approach (as adapted to recreational fisheries by Rehage et al. 2019) to assess the LEK concerning the perceived changes in Black Bass population catch rates and size structure over the last 50 years in FMZ 18 and to use the results to inform future management decisions. Our study was focused on recreational anglers, some of whom may identify as Indigenous, although we did not explicitly ask individuals to indicate their Indigenous status. Thus, while the now widely accepted term for this type of research is Indigenous and Local Knowledge (see https://www.ipbes.net/indigenous-local-knowledge), that term seems disingenuous here, given the focus on the recreational sector, and we embrace the term LEK for this study.

2 | Methods

2.1 | Study Area and Lake Selection

All waterbodies selected for survey participation in this study are located in FMZ 18 in Eastern Ontario, Canada, an area bounded by Lake Ontario and the St. Lawrence River to the south, the Ottawa River to the Northeast, and the borders of FMZ 15 and 17 to the west. The waterbodies ($n = 16$; Figure 1) considered in this study were lakes Opinicon, Charleston, Big Rideau, Lower Rideau, Upper Rideau, Loughborough, Newboro (including Benson, Indian, Clear, Mosquito, and Loon Lakes), Dog and Cranberry, Mississippi, White, Sand, Bobs, Otter, Devil, Wolfe, and Upper and Lower Beverley, plus the Rideau River (between Manotick and Kemptville, which is rather lentic given dam and lock infrastructure). There are 613 lakes in FMZ 18 larger than 50 ha, many of which are inaccessible and remote. Therefore, purposive sampling was used to ensure that accessible lakes that have received consistent angling pressure over time were included. To further build the sample, we relied on local angler knowledge and also knowledge held by nonangling members of local lake and cottage associations in a snowball sampling approach (Dusek et al. 2015), where experts further identified other experts familiar with fishing on FMZ 18 lakes to better reduce bias resulting from over- or underestimating catches over time by including diverse user groups (Jones et al. 2025).

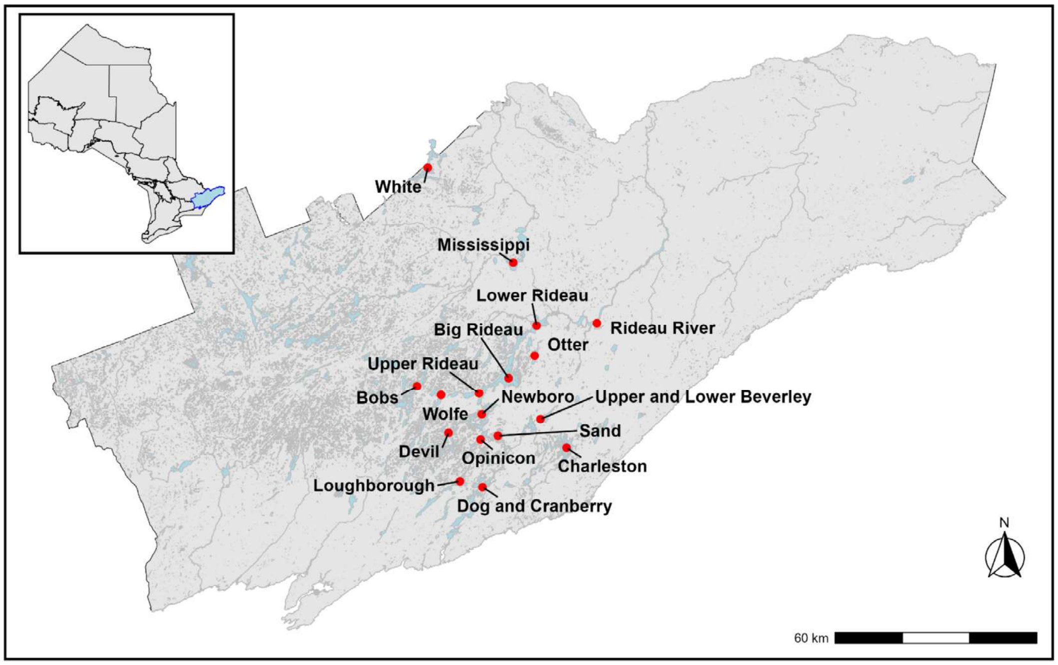

FIGURE 1 | The location of fisheries management zone (FMZ) 18 highlighted in blue among the 20 fisheries management zones in Ontario, Canada (top left) and the location of the 16 lakes and waterbodies surveyed in this study, located within FMZ 18.

2.2 | Survey Development and Participant Recruitment

A semi-structured, mixed-methods survey was developed that included both closed- and open-ended questions to capture angler knowledge (e.g., Huntington 2000). The survey was delivered using Qualtrics (Qualtrics, Provo, UT), an online survey delivery tool that allows for some of the more complex branching and display logic used in the survey questions. The survey contained a total of 34 questions, 9 of which were open-ended questions and 25 that were closed-ended exploring angler demographics, Black Bass fishing practices and trends and thoughts on current threats and management (see Appendix 1). Closed-ended questions were used to collect demographic and categorical data to make direct comparisons among lakes. For open-ended questions, we wanted to collect a more detailed scope of angler values and beliefs and to measure their support for alternative Black Bass management methods in FMZ 18 (e.g., Young et al. 2016). Ultimately, this project was developed to answer a suite of questions. Several questions, including Q19–Q24 and Q30–Q37, were not included here but will be explored in the future as part of a body of work on angler acceptance of alternative management strategies. Four closed-ended questions were in the format of the Life History Calendar (LHC) approach as recently applied by Rehage et al. (2019) and adapted from Freedman et al. (1988), where respondents were asked to score their fishing experience (on a scale of 1–5) based on the numbers and sizes of the Bass that they had caught on various FMZ 18 lakes over different time periods that ranged up to 50 years (time periods being 1975–1984, 1985–1994, 1995–2004, 2005–2014, 2015–2019, 2020–2025), capturing the broadest possible age demographic of anglers. Our scale of 1–5 was chosen to allow individuals to recall differences between time periods without overwhelming individuals with subtle, but larger ordinal scales (e.g., a scale of 1–10). The aim of the LHC, further developed by Rehage et al. (2019), is to use spatiotemporal cues to help respondents recall recreational fishery conditions over time, thus allowing individuals to better recall events in relation to other events (Belli et al. 2001; Glasner et al. 2015; Morselli et al. 2016). The LHC approach, adapted from Rehage et al. (2019), was used here in the context of Black Bass in Eastern Ontario. Participants were only asked about lakes where they had previously fished and about time periods relevant to their fishing experiences. The survey design and participant recruitment methods were cleared by the Carleton University Research Ethics Board-B (CUREB-B; Clearance #122461) on November 29, 2024, and the survey was subsequently launched on December 9th, 2024, and closed on February 17, 2025.

Participants were sampled purposively by recruiting individuals with extensive knowledge about angling on our selected FMZ 18 lakes. Anglers were also asked to distribute the survey to other known anglers and groups in a snowball sampling approach to help reach the target population (e.g., Dusek et al. 2015). It was important to use nonrandom sampling because otherwise it would have been less likely that we would fully reach our target demographic that included both avid anglers and other individuals who may have perceived declines in a fishery. Although non-probabilistic survey methods suffer from some challenges (e.g., unknown response rate, potential selection bias), they are increasingly embraced within the recreational fisheries research and monitoring space, given the ability to target active anglers (Howarth et al. 2024). The survey was originally shared via social media (i.e., Twitter/X, Bluesky, Facebook/Meta) on known angling pages and with groups formed by stakeholders on various lakes with the intent that key participants would see the post and further share the survey with other individuals. Original posts were made in December 2024, in the following groups: "613 Bass'n," "the Conservation Group of the Bass Anglers Sportsmans Society," the "Fish'n Canada Fan Page," "the Ontario Fishing Club," and "Anglers of Eastern Ontario" as well as other local Facebook groups for cottage associations and outdoor recreation groups. Additional posts were made in January 2025. On January 15th, we launched a 7-day paid ($200 CAD) Facebook campaign to boost the post among users within 100 km of Portland, Ontario, (on the Rideau Lakes chain) with interests listed as bass fishing, fishing, or recreational fishing. Targeted emails were also distributed to lake associations, which led to survey invitations being shared with various lake association members via newsletters, emails, and websites. Respondents were filtered through initial screening questions asking about their experience in fishing FMZ 18 and through the removal of respondents who did not complete at least 75% of the survey (mostly reflecting individuals who had not completed the LHC questions and thus were less likely to be "expert" knowledge users).

2.3 | Quantitative Analyses

In total, 354 surveys were used in the statistical analysis. Statistical analyses were completed using Rstudio (2024.12.0; Posit Team 2024) via R version 4.4.0 (R Core Team 2024), and all figures were generated using the *ggplot2* (Wickham 2016) and *rpart.plot* packages (Milborrow and Milborrow 2019). Linear regression spline models were fitted using the *spline* package (Perperoglou et al. 2019) to assess the change in fishing score over a time period of 1975–2025. The number of degrees of freedom (df) used in the spline model was confirmed using the Akaike Information Criterion (AIC) for model complexity and fit (Aho et al. 2014). We tested and contrasted models using a multiway ANOVA containing the effects of time period, property ownership on a study lake, angler experience, use of electronics in fishing, if the respondent had fished tournaments, and perceived changes in angling pressure and illegal angling to see if they impacted the average fishing score as it pertained to numbers (relative) and size of LMB and SMB on the 16 lakes. These predictors were chosen after completing a Variance Inflation Factor (VIF) analysis to test for correlations between variables (Daoud 2017) and represent variables that can impact how an angler may perceive declines in the fishery (e.g., an individual who uses electronics to capture fish may hypothetically report lesser declines or someone who angles often and in tournaments may perceive more extreme declines). Respondents were asked to rate their experience fishing (scale of 1–5) for each waterbody and time period selected. These scores were then averaged for each time period, lake, species, and "treatment" (numbers vs. sizes). The fishing score was collected separately for LMB numbers, LMB sizes, SMB numbers, and SMB sizes. Time period was used as a continuous variable to allow for the spline to compute an overall trend for the time period of 1975–2025. Additionally, treating certain categorical variables as continuous can make for easier interpretation of relationships, especially if changes are likely gradual and not abrupt (Lazic 2008). All other variables were categorical. For significant variables, a marginal means test for adjusted average fishing scores and a Tukey's post hoc test for pairwise differences was performed using the *emmeans*

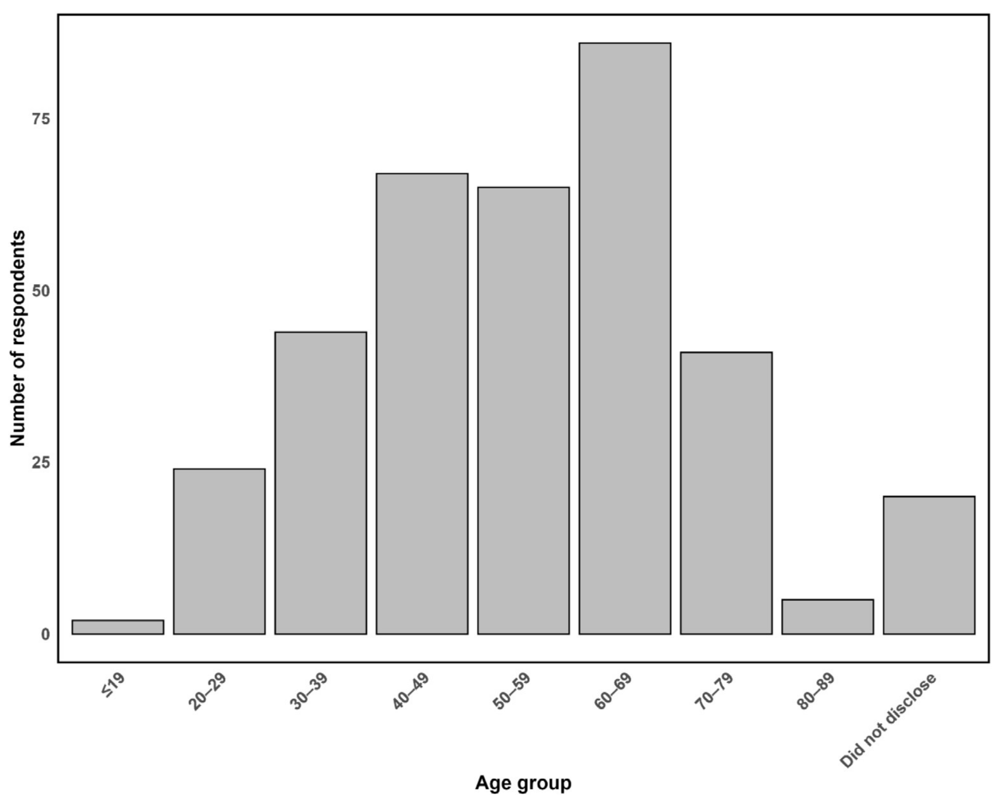

FIGURE 2 | Age range histogram showing the age range of our respondents ($n = 364$). A majority of respondents were aged between 30 to 79 ($n = 303$).

TABLE 1 | Results of a multiway ANOVA with associated *F* values and *p* values for different predictors and their effect on average fishing scores (a) relative numbers of LMB, (b) relative size of LMB, (c) relative numbers of SMB and (d) relative sizes of SMB with significant predictors for average scores bolded.

	df	Sum sq	Mean sq	*F*	*p*
(a) LMB numbers					
Time period	6	6199	1031	16,515	**< 0.001**
Lake	15	1050	70	1120	**< 0.001**
Property ownership	1	< 0.001	< 0.001	< 0.001	0.99
Angler experience	2	< 0.001	< 0.001	< 0.001	1
Electronic use	4	< 0.001	< 0.001	< 0.001	1
Angling pressure	3	< 0.001	< 0.001	< 0.001	1
Illegal angling	3	< 0.001	< 0.001	< 0.001	1
Tournament	1	< 0.001	< 0.001	< 0.001	0.99
	35,497	2217	0.062		
(b) LMB sizes					
Time period	6	6829	1138	16,541	**< 0.001**
Lake	15	1473	98	1427	**< 0.001**
Property ownership	1	< 0.001	< 0.001	< 0.001	0.99
Angler experience	2	< 0.001	< 0.001	< 0.001	1
Electronic use	4	< 0.001	< 0.001	< 0.001	1
Angling pressure	3	< 0.001	< 0.001	< 0.001	1
Illegal angling	3	< 0.001	< 0.001	< 0.001	1
Tournament	1	< 0.001	< 0.001	< 0.001	0.99
	35,497	2442	0.069		
(c) SMB numbers					
Time period	6	1382	230	1626	**< 0.001**
Lake	15	5867	391	2761	**< 0.001**
Property ownership	1	< 0.001	< 0.001	< 0.001	0.99
Angler experience	2	< 0.001	< 0.001	< 0.001	1
Electronic use	4	< 0.001	< 0.001	< 0.001	1
Angling pressure	3	< 0.001	< 0.001	< 0.001	1
Illegal angling	3	< 0.001	< 0.001	< 0.001	1
Tournament	1	< 0.001	< 0.001	< 0.001	0.99
	35,168	4982	0.142		
(d) SMB sizes			1382	230	1626
Time period	6	3062	510	3626	**< 0.001**
Lake	15	4439	296	2103	**< 0.001**
Property ownership	1	< 0.001	< 0.001	< 0.001	0.99
Angler experience	2	< 0.001	< 0.001	< 0.001	1
Electronic use	4	< 0.001	< 0.001	< 0.001	1

(Continues)

TABLE 1 | (Continued)

	df	Sum sq	Mean sq	F	p
Angling pressure	3	<0.001	<0.001	<0.001	1
Illegal angling	3	<0.001	<0.001	<0.001	1
Tournament	1	<0.001	<0.001	<0.001	0.99
	35,168	4989	0.141		

Note: This table shows that time periods and lakes were the only significant predictors for fishing scores.

package (Lenth 2024) where time period from the spline model was parsed out by selecting for specific time periods as splines do not measure specific time period but an overall fit across the entire length of the model.

3 | Results

3.1 | Description of Participants

Of the 632 original survey respondents, 278 were removed for less than 75% survey completion and for selecting "No" to either of the first two survey screening questions:

1. Please choose if you consent to being a part of our angler survey.
2. Have you ever fished for Black Bass (Smallmouth bass or Largemouth bass) on any of the following waterbodies: Big Rideau Lake (including Lower Rideau), Upper Rideau Lake, Newboro Lake (including Indian, Clear Mosquito and Loon Lake), Rideau River between Manotick and Kemptville, Loughborough Lake, Cranberry and Dog, Otter, Charleston, Opinicon, Sand, Bobs, Mississippi Lake, Upper/lower Beverley, White Lake, Devil Lake, and/or Wolfe Lake?

A total of 354 respondents remained for analysis. A majority of the respondents in our sample were between the ages of 30 to 79 (303 individuals, 86%), with the youngest and oldest respondents being 17 and 89, respectively (Figure 2). Of these respondents, 216 (61.2%), 122 (34.6%), and 15 (4.2%) considered themselves advanced, intermediate, and beginner-level anglers, respectively. Respondents were mostly non-cottage owners ($n=234$, 66.7%) as opposed to cottage owners ($n=117$, 33.3%) on our study lakes. Most respondents fished between 6 and 50 days per year ($n=255$, 72%), whereas 55 (15.6%) individuals spent more than 50 days fishing per year, and 42 (11.9%) fished less than 5 times a year. Of people who angled, 86 (24.7%) have not used any electronic equipment (e.g., forward-facing sonar) to aid in their angling experience, while 262 (75.3%) have used electronic equipment to aid in catching fish. Individuals who participate in tournament angling events represent roughly half the sample, with 166 (46.9%) participating in tournaments and 188 (53.1%) not participating. A majority of respondents ($n=217$, 61.8%) released all the bass they captured, while 118 (33.6%) kept between 1 and 5 bass per year, and only 16 (4.6%) chose to harvest their bass consistently. Additionally, respondents perceived increases in both angling pressure ($n=262$, 78.2%) and illegal angling ($n=187$, 55.8%) over the course of their time in FMZ 18.

3.2 | Temporal Trends of Black Bass Numbers and Size

Separate linear spline models were fit for the average fishing score for LMB and SMB for both relative numbers and sizes (four total). Across all lakes, respondents perceived that there was a significant decrease in the number and size of LMB caught per unit effort from over the last 50 years for LMB numbers ($F_{35497,6}=16514.46$, $p=<0.001$; Table 1), LMB sizes ($F_{35497,6}=16540.78$, $p=<0.001$), SMB numbers ($F_{35168,6}=1626.389$, $p=<0.001$), and SMB sizes ($F_{35168,6}=$ 3626.225, $p=<0.001$). Those respondent-perceived changes, however, differed across individual lakes for LMB numbers ($F_{35479,15}=1120.367$, $p=<0.001$; Table 1), LMB sizes ($F_{35479,15}=1426.906$, $p=<0.001$; Table 1), SMB numbers ($F_{35168,15}=$ 2760.936, $p=<0.001$) and SMB sizes ($F_{35168,15}=$ 2102.92, $p=$ <0.001). Property ownership, angler experience, and use of electronics had no impact on any of the fishing scores; they were all not significant (all $p \geq 0.99$). Additionally, perceived changes in angling pressure and illegal angling were not significant factors in this study (all $p \geq 0.99$).

Adjusted mean marginal effects fitted by the spline models for average fishing numbers and sizes are shown in Table 2. The results of Tukey's post hoc test for adjusted marginal means fitted by the spline models across time periods (Table 3) showed that respondents perceived a decrease in the relative numbers of LMB (a decrease of 26%) and SMB (a decrease of 20%; Figures 3a, 4a) beginning in 1975, with significant declines across most time-period intervals (Table 3a,c, all $p \leq 0.001$). The only exceptions to this in consecutive time periods were a significant increase in LMB numbers between 1975 and 1985 (Table 3a, $p<0.001$) and in SMB numbers between 1995 and 2005 (Table 3c, $p=0.006$). Similarly, relative fish sizes saw a decrease (Figures 3b, 4b) across all time periods for LMB (a decrease of 31%; Table 3b, $p<0.001$) and across most time periods for SMB (a decrease of 26%), with the exception of an increase between 2005 to 2015 (Table 3d, $p<0.001$). Overall, of the 16 lakes examined, 15 showed decreases in LMB numbers (Table 4a) and all lakes showed decreases in reported sizes (Table 4b), while SMB numbers reported decreases in 10 lakes (Table 4c) and 13 reported decreases in SMB sizes (Table 4d). Scores for numbers and sizes of LMB and SMB differed between lakes, but generally showed a decreasing trend among most lakes for LMB numbers (Figure 5) and sizes (Figure 6) since 1975, with a sharp decrease beginning

TABLE 2 | Marginal effect tests used to adjust the average fishing score over different relevant time periods for (a) relative numbers of LMB, (b) relative size of LMB, (c) relative numbers of SMB and (d) relative sizes of SMB showing decreases across a majority of the time periods.

Year	Adjusted fishing score	SE	df	Lower CI	Upper CI
(a) LMB numbers					
1975	4.270	0.005	35,497	4.259	4.280
1985	4.301	0.005	35,497	4.291	4.310
1995	4.268	0.005	35,497	4.258	4.277
2005	4.204	0.005	35,497	4.195	4.214
2015	3.868	0.005	35,497	3.859	3.877
2020	3.508	0.005	35,497	3.499	3.518
2025	3.160	0.005	35,497	3.150	3.169
(b) LMB sizes					
1975	4.477	0.006	35,497	4.466	4.488
1985	4.203	0.005	35,497	4.193	4.213
1995	4.067	0.005	35,497	4.057	4.077
2005	3.887	0.005	35,497	3.877	3.897
2015	3.604	0.005	35,497	3.594	3.614
2020	3.341	0.005	35,497	3.331	3.351
2025	3.090	0.005	35,497	3.080	3.099
(c) SMB numbers					
1975	3.835	0.008	35,168	3.819	3.851
1985	3.536	0.007	35,168	3.521	3.550
1995	3.316	0.007	35,168	3.302	3.331
2005	3.343	0.007	35,168	3.329	3.357
2015	3.419	0.007	35,168	3.404	3.433
2020	3.330	0.007	35,168	3.315	3.344
2025	3.083	0.007	35,168	3.069	3.097
(d) SMB sizes					
1975	4.056	0.008	35,168	4.040	4.072
1985	3.800	0.007	35,168	3.785	3.814
1995	3.450	0.007	35,168	3.436	3.464
2005	3.390	0.007	35,168	3.375	3.404
2015	3.442	0.007	35,168	3.428	3.457
2020	3.301	0.007	35,168	3.287	3.315
2025	3.019	0.007	35,168	3.005	3.033

in 2005 (25% for numbers and 21% decrease for sizes). Decreases were less prominent for SMB numbers (Figure 5) and SMB sizes (Figure 6) among the entirety of the time periods studied, but showed a sharper decrease after 2005 (8% for numbers and 11% for sizes). Post hoc tests between lakes were completed but not reported due to the number of significant lake combinations across all lakes (most lakes were significantly different from each other) and to focus on more relevant regional differences.

4 | Discussion

4.1 | Decreases in the Abundance and Sizes of Black Bass

This study was conducted as an indirect "Call to Action" for several important reasons. Firstly, there is currently little information on the state of the Black Bass fishery throughout Ontario and

TABLE 3 | Tukey post hoc results for average scores over time adjusted with a marginal effects test using a linear spline model for (a) relative numbers of LMB, (b) relative size of LMB, (c) relative numbers of SMB and (d) relative sizes of SMB.

	Estimate	SE	df	*T*	*p*	Lower CI	Upper CI
(a) LMB numbers							
1975–1985	0.031	0.005	35,497	−5.788	**< 0.001**	0.0212	0.0408
1975–1995	−0.002	0.005	35,497	0.348	0.999	−0.0118	0.0078
1975–2005	−0.065	0.005	35,497	12.279	**< 0.001**	−0.0748	−0.0552
1975–2015	−0.402	0.005	35,497	75.468	**< 0.001**	−0.4118	−0.3922
1975–2020	−0.762	0.005	35,497	143.053	**< 0.001**	−0.7718	−0.7522
1975–2025	−1.11	0.005	35,497	208.473	**< 0.001**	−1.1198	−1.1002
1985–1995	−0.033	0.005	35,497	6.706	**< 0.001**	−0.0428	−0.0232
1985–2005	−0.096	0.005	35,497	19.746	**< 0.001**	−0.1058	−0.0862
1985–2015	−0.433	0.005	35,497	88.805	**< 0.001**	−0.4428	−0.4232
1985–2020	−0.792	0.005	35,497	162.67	**< 0.001**	−0.8018	−0.7822
1985–2025	−1.141	0.005	35,497	234.168	**< 0.001**	−1.1508	−1.1312
1995–2005	−0.064	0.005	35,497	13.04	**< 0.001**	−0.0738	−0.0542
1995–2015	−0.4	0.005	35,497	82.099	**< 0.001**	−0.4098	−0.3902
1995–2020	−0.76	0.005	35,497	155.964	**< 0.001**	−0.7698	−0.7502
1995–2025	−1.108	0.005	35,497	227.462	**< 0.001**	−1.1178	−1.0982
2005–2015	−0.336	0.005	35,497	69.059	**< 0.001**	−0.3458	−0.3262
2005–2020	−0.696	0.005	35,497	142.924	**< 0.001**	−0.7058	−0.6862
2005–2025	−1.045	0.005	35,497	214.422	**< 0.001**	−1.0548	−1.0352
2015–2020	−0.36	0.005	35,497	73.864	**< 0.001**	−0.3698	−0.3502
2015–2025	−0.708	0.005	35,497	145.362	**< 0.001**	−0.7178	−0.6982
2020–2025	−0.348	0.005	35,497	71.498	**< 0.001**	−0.3578	−0.3382
(b) LMB size							
1975–1985	−0.274	0.006	35,497	49.072	**< 0.001**	−0.2858	−0.2622
1975–1995	−0.41	0.006	35,497	73.449	**< 0.001**	−0.4218	−0.3982
1975–2005	−0.59	0.006	35,497	105.633	**< 0.001**	−0.6018	−0.5782
1975–2015	−0.873	0.006	35,497	156.287	**< 0.001**	−0.8848	−0.8612
1975–2020	−1.136	0.006	35,497	203.291	**< 0.001**	−1.1478	−1.1242
1975–2025	−1.388	0.006	35,497	248.366	**< 0.001**	−1.3998	−1.3762
1985–1995	−0.136	0.005	35,497	26.642	**< 0.001**	−0.1458	−0.1262
1985–2005	−0.316	0.005	35,497	61.817	**< 0.001**	−0.3258	−0.3062
1985–2015	−0.599	0.005	35,497	117.177	**< 0.001**	−0.6088	−0.5892
1985–2020	−0.862	0.005	35,497	168.547	**< 0.001**	−0.8718	−0.8522
1985–2025	−1.114	0.005	35,497	217.811	**< 0.001**	−1.1238	−1.1042
1995–2005	−0.18	0.005	35,497	35.175	**< 0.001**	−0.1898	−0.1702
1995–2015	−0.463	0.005	35,497	90.535	**< 0.001**	−0.4728	−0.4532
1995–2020	−0.726	0.005	35,497	141.905	**< 0.001**	−0.7358	−0.7162

(Continues)

TABLE 3 | (Continued)

	Estimate	SE	df	T	p	Lower CI	Upper CI
1995–2025	−0.977	0.005	35,497	191.168	**< 0.001**	−0.9868	−0.9672
2005–2015	−0.283	0.005	35,497	55.36	**< 0.001**	−0.2928	−0.2732
2005–2020	−0.546	0.005	35,497	106.73	**< 0.001**	−0.5558	−0.5362
2005–2025	−0.798	0.005	35,497	155.994	**< 0.001**	−0.8078	−0.7882
2015–2020	−0.263	0.005	35,497	51.37	**< 0.001**	−0.2728	−0.2532
2015–2025	−0.515	0.005	35,497	100.634	**< 0.001**	−0.5248	−0.5052
2020–2025	−0.252	0.005	35,497	49.263	**< 0.001**	−0.2618	−0.2422
(c) SMB numbers							
1975–1985	−0.299	0.008	35,168	36.27	**< 0.001**	−0.3147	−0.2833
1975–1995	−0.519	0.008	35,168	62.856	**< 0.001**	−0.5347	−0.5033
1975–2005	−0.492	0.008	35,168	59.645	**< 0.001**	−0.5077	−0.4763
1975–2015	−0.416	0.008	35,168	50.458	**< 0.001**	−0.4317	−0.4003
1975–2020	−0.505	0.008	35,168	61.232	**< 0.001**	−0.5207	−0.4893
1975–2025	−0.752	0.008	35,168	91.124	**< 0.001**	−0.7677	−0.7363
1985–1995	−0.219	0.007	35,168	29.904	**< 0.001**	−0.2327	−0.2053
1985–2005	−0.193	0.007	35,168	26.292	**< 0.001**	−0.2067	−0.1793
1985–2015	−0.117	0.007	35,168	15.958	**< 0.001**	−0.1307	−0.1033
1985–2020	−0.206	0.007	35,168	28.077	**< 0.001**	−0.2197	−0.1923
1985–2025	−0.453	0.007	35,168	61.699	**< 0.001**	−0.4667	−0.4393
1995–2005	0.026	0.007	35,168	−3.612	**0.006**	0.01228	0.03972
1995–2015	0.102	0.007	35,168	−13.946	**< 0.001**	0.08828	0.11572
1995–2020	0.013	0.007	35,168	−1.827	0.53	−0.0007	0.02672
1995–2025	−0.233	0.007	35,168	31.795	**< 0.001**	−0.2467	−0.2193
2005–2015	0.076	0.007	35,168	−10.334	**< 0.001**	0.06228	0.08972
2005–2020	−0.013	0.007	35,168	1.785	0.558	−0.0267	0.00072
2005–2025	−0.26	0.007	35,168	35.407	**< 0.001**	−0.2737	−0.2463
2015–2020	−0.089	0.007	35,168	12.119	**< 0.001**	−0.1027	−0.0753
2015–2025	−0.336	0.007	35,168	45.741	**< 0.001**	−0.3497	−0.3223
2020–2025	−0.247	0.007	35,168	33.622	**< 0.001**	−0.2607	−0.2333
(d) SMB size							
1975–1985	−0.256	0.008	35,168	31.137	**< 0.001**	−0.2717	−0.2403
1975–1995	−0.606	0.008	35,168	73.658	**< 0.001**	−0.6217	−0.5903
1975–2005	−0.666	0.008	35,168	80.966	**< 0.001**	−0.6817	−0.6503
1975–2015	−0.613	0.008	35,168	74.576	**< 0.001**	−0.6287	−0.5973
1975–2020	−0.754	0.008	35,168	91.734	**< 0.001**	−0.7697	−0.7383
1975–2025	−1.036	0.008	35,168	126.024	**< 0.001**	−1.0517	−1.0203
1985–1995	−0.35	0.007	35,168	47.828	**< 0.001**	−0.3637	−0.3363
1985–2005	−0.41	0.007	35,168	56.048	**< 0.001**	−0.4237	−0.3963

(Continues)

TABLE 3 | (Continued)

	Estimate	SE	df	*T*	*p*	Lower CI	Upper CI
1985–2015	−0.357	0.007	35,168	48.86	**<0.001**	−0.3707	−0.3433
1985–2020	−0.498	0.007	35,168	68.16	**<0.001**	−0.5117	−0.4843
1985–2025	−0.78	0.007	35,168	106.728	**<0.001**	−0.7937	−0.7663
1995–2005	−0.06	0.007	35,168	8.22	**<0.001**	−0.0737	−0.0463
1995–2015	−0.008	0.007	35,168	1.032	0.947	−0.0217	0.00572
1995–2020	−0.149	0.007	35,168	20.332	**<0.001**	−0.1627	−0.1353
1995–2025	−0.431	0.007	35,168	58.9	**<0.001**	−0.4447	−0.4173
2005–2015	0.053	0.007	35,168	−7.188	**<0.001**	0.03928	0.06672
2005–2020	−0.089	0.007	35,168	12.112	**<0.001**	−0.1027	−0.0753
2005–2025	−0.371	0.007	35,168	50.681	**<0.001**	−0.3847	−0.3573
2015–2020	−0.141	0.007	35,168	19.299	**<0.001**	−0.1547	−0.1273
2015–2025	−0.423	0.007	35,168	57.868	**<0.001**	−0.4367	−0.4093
2020–2025	−0.282	0.007	35,168	38.569	**<0.001**	−0.2957	−0.2683

Note: The significant time periods are bolded.

how it has changed over time. Secondly, measuring how a fishery has changed over time requires long-term attention. While local anglers in our study lakes had been reporting a decrease in the size and number of bass for many years, those anecdotal reports have never been collected or assessed in a rigorous manner. Our study is the first to use angler knowledge to explore the state of a recreational Black Bass fishery outside of traditional creel surveys or angler diaries. Findings revealed that over the span of 50 years (starting in 1975), anglers reported consistent and significant declines in the relative numbers and sizes of LMB and SMB across lakes in Eastern Ontario. As posited in the last 20 years (Johannes et al. 2000; Murray et al. 2006; Beaudreau and Levin 2014), this study shows that the use of Indigenous and local knowledge (in our case—anglers with unknown Indigeneity) can be a useful tool in determining various changes in data-deficient fisheries as has long been utilized in various commercial and artisanal fisheries around the world (for a few recent examples see: Bender et al. 2014; Santos Thykjaer et al. 2020; Almojil 2021; Veneroni and Fernandes 2021; Macedo et al. 2025). Despite this, there is a greater need to explore its use in the context of recreational fisheries, which falls behind in its use of local knowledge beyond uses such as log books, diaries, creel surveys (Zale et al. 2013), and more recently, angler apps (Venturelli et al. 2017). Similar to our study, other recreational fisheries that have been assessed using local knowledge show declines that were not previously reported through traditional means of monitoring (Rehage et al. 2019; Griffin et al. 2023).

It is possible that increasing angling pressure across all study lakes in FMZ 18 has led to higher mortality through harvest and negative catch-and-release practices. However, it is important to note that LMB and SMB are generally considered hardier fish species when compared to other highly pressured species (see Salmonids; e.g., Meka and McCormick 2005) and that the practice of catch-and-release is widely prevalent in eastern Ontario. It is possible that increasing levels of illegal (out of season) fishing of nesting LMB and SMB over the last 50 years may have caused some of these population declines. In fact, oftentimes, angling pressure and illegal angling often increase in parallel to one another (e.g., Philipp et al. 1997). It has been posited that as angling pressure increases (as reported for this region), nesting success and recruitment of both LMB and SMB decrease in parallel to the timelines explored in this study (e.g., Philipp, Claussen, et al. 2023; Philipp, Zolderdo, et al. 2023). It is well documented that sustainable Black Bass populations are highly dependent on strong juvenile recruitment into a population. If juveniles survive their first year (predation, prey acquisition, first overwintering period), then mortality drops off significantly (Kramer and Smith Jr 1962; Keast and Eadie 1985; Sargent and Gross 1986; Olson 1996). Another important observation is that none of the other demographic data used in this study (e.g., angler experience, number of days fished, use of technology, etc.) significantly affected the perception of these observed declines. Most importantly, the declines were reported consistently across most study lakes. These data suggest that either (1) most study lakes have experienced increased illegal fishing pressure over time, particularly during the reproductive period (2) there have been high levels of fishing mortality for Black Bass (either harvest or release mortality), or (3) there is some larger, regional driver that is explaining some of this observed decrease. Indeed, large-scale drivers like climate change (Hunt et al. 2016; Nyboer et al. 2021; Lynch et al. 2024) have been shown to also have an impact on fish populations for inland recreational fisheries. Exactly what these drivers could be in eastern Ontario needs to be further explored in the context of the Black Bass fishery and could be studied in conjunction with the health of other fish populations. Because most stressors rarely act alone (Jackson et al. 2016), conserving bass populations will likely need to be accomplished through a suite of efforts that mitigate various stressors along with collaborations with local anglers and other relevant stakeholders and rightsholders.

Similar to above, we suggest that there may be changes to these fisheries that are difficult to measure and are more complex

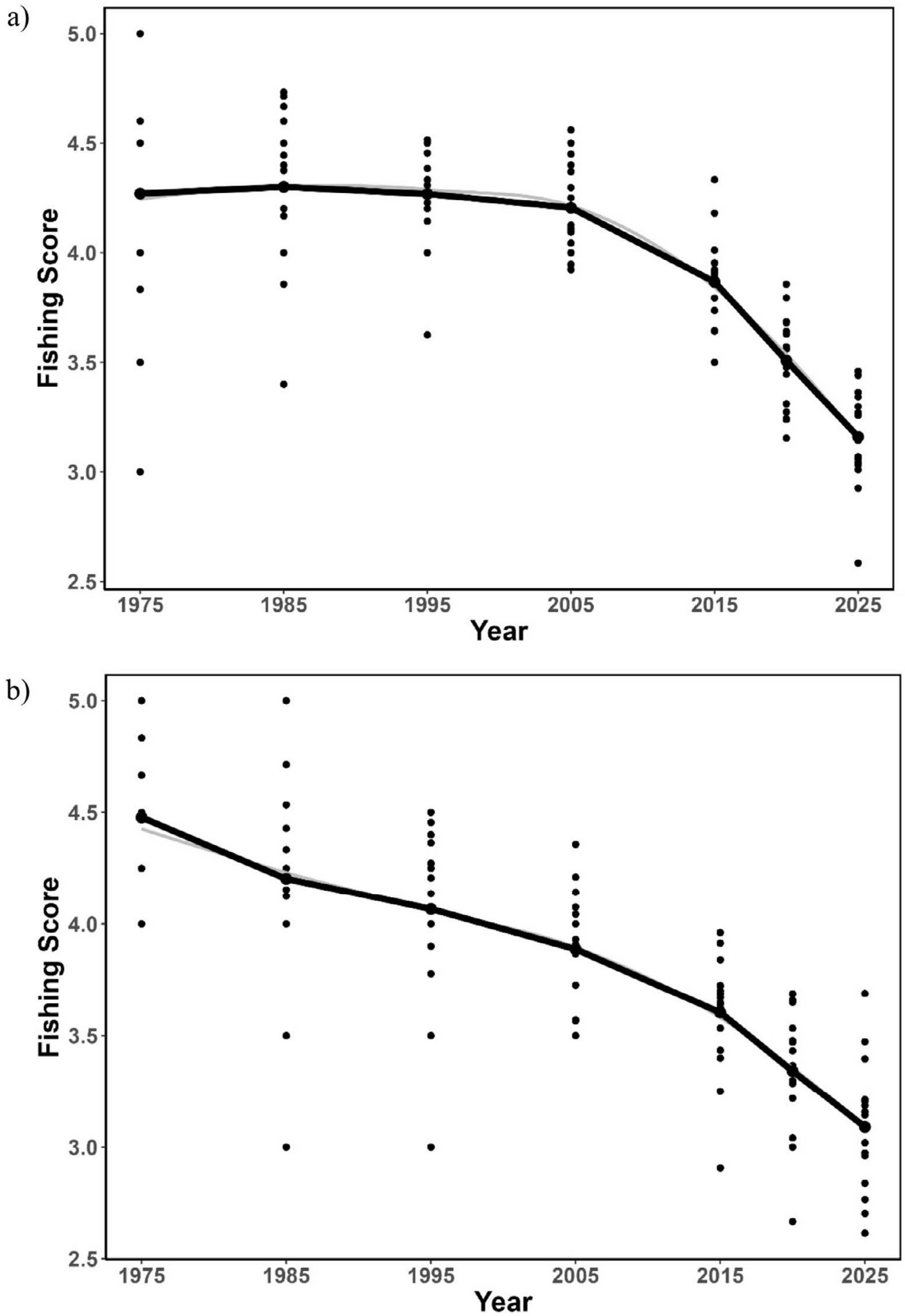

FIGURE 3 | Adjusted means using marginal effects fit by the spline model (black) and raw mean fishing scores (gray) for relative Largemouth bass numbers (a) and relative Largemouth bass sizes (b) decreased in 16 lakes surveyed in FMZ 18 from years 1975 to 2025. Mean fishing scores per lake represented by black dots with a line of best fit illustrating overall trend.

than simply a function of increased angling effort and fishing mortality. Beyond the direct impact of recruitment overfishing on population numbers, recreational fisheries-induced evolution (FIE; Philipp et al. 2015; Hessenauer et al. 2015; Dunlop et al. 2018) may be adding to the declines in the numbers and sizes of bass, and this has been a highly studied mechanism in the context of LMB and SMB in eastern Ontario. Declines in reported catches may also reflect a decrease in "catchability" because of selection for less aggressive individuals, either as a result of increased mortality of bolder individuals or a decrease in reproductive success of individuals that exhibit lower levels of parental care (Philipp et al. 2009, 2015; Sutter et al. 2012). Because LMB and SMB provide parental care during the reproductive period, natural selection favors individuals that are larger (i.e., having more energy to defend) and more aggressive (better at defending the nest; Wiegmann and Baylis 1995; Suski and Ridgway 2007; Gingerich and Suski 2011). As a result, if a larger, more aggressive individual

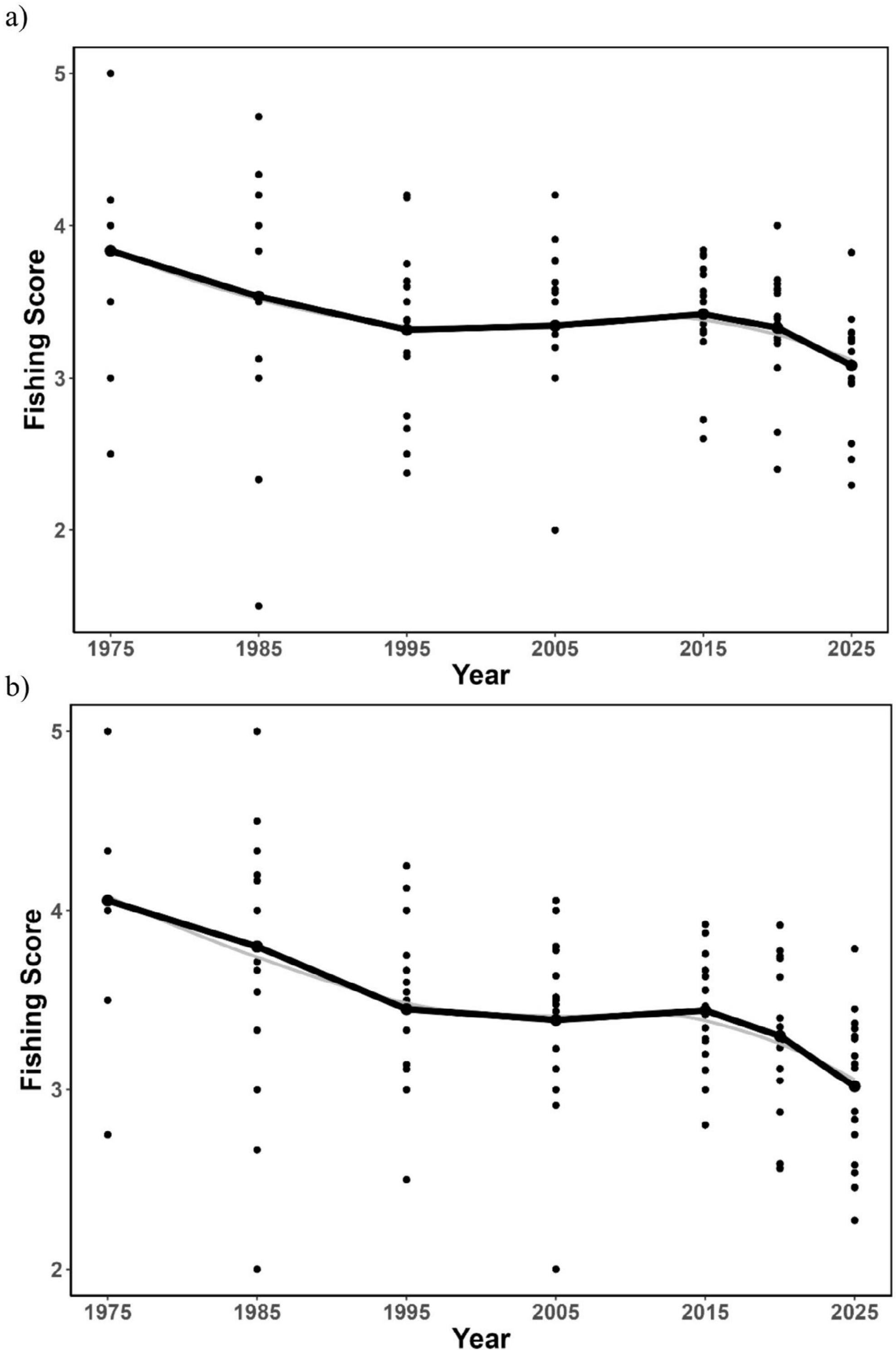

FIGURE 4 | Adjusted means using marginal effects fit by the spline model (black) and raw mean fishing scores (gray) for Smallmouth Bass numbers (a) and relative Smallmouth Bass sizes (b) decreased in 16 lakes surveyed in FMZ 18 from years 1975 to 2025. Mean fishing scores per lake represented by black dots with a line of best fit illustrating overall trend.

is captured more easily while defending its nest and subsequently produces fewer (or no) offspring, it will not be able to pass on those traits successfully (Cooke et al. 2007; Philipp et al. 2009, 2015; Sutter et al. 2012). In addition, fish in the family *Centrarchidae* are highly plastic in their age at maturation (Aday et al. 2003, 2004; Cooke and Philipp 2009), and that is driven by social and environmental conditions, which would be influenced if larger, more aggressive individuals decreased in a population. Indeed, Philipp et al. (2009) showed that aggression in LMB is a heritable trait, suggesting that over time, with enough angling pressure, a large, aggressive population could be replaced with a smaller, less aggressive one. In reality, it is unclear how much FIE relative to recruitment overfishing could be impacting fish populations in the

TABLE 4 | The percent change, earliest and latest mean scores and the direction of the change shown for each Lake for (a) LMB numbers, (b) LMB sizes, (c) SMB numbers and (d) SMB sizes.

Lake	Earliest score	Latest score	Percent change (%)	Change direction
(a) LMB numbers				
Big Rideau (including Lower Rideau)	4.5	3.3	−26.72	**Decreased**
Bobs	4	3.27	−18.22	**Decreased**
Charleston	5	3.03	−39.34	**Decreased**
Cranberry and Dog	4.5	3.44	−23.54	**Decreased**
Devil	4	3.06	−23.53	**Decreased**
Loughborough	4.4	3.07	−30.25	**Decreased**
Mississippi	4	3.01	−24.74	**Decreased**
Newboro	3.83	3.36	−12.25	**Decreased**
Opinicon	4.6	3.34	−27.35	**Decreased**
Otter	3	3.04	1.39	Increased
Rideau River (between Manotick and Kemptville)	4	2.58	−35.39	**Decreased**
Sand	3.5	3.26	−6.91	**Decreased**
Upper Rideau	4.17	3.46	−16.95	**Decreased**
Upper and Lower Beverley	5	3.26	−34.81	**Decreased**
White	4.5	3.14	−30.16	**Decreased**
Wolfe	5	2.93	−41.48	**Decreased**
(b) LMB sizes				
Big Rideau (including Lower Rideau)	4.25	3.4	−20.08	**Decreased**
Bobs	4	3.2	−19.92	**Decreased**
Charleston	5	3.02	−39.62	**Decreased**
Cranberry and Dog	4.33	3.47	−19.86	**Decreased**
Devil	3.5	2.76	−21.01	**Decreased**
Loughborough	5	3.19	−36.3	**Decreased**
Mississippi	4	2.84	−29.03	**Decreased**
Newboro	4	3.21	−19.71	**Decreased**
Opinicon	4.67	2.97	−36.28	**Decreased**
Otter	4	3.1	−22.5	**Decreased**
Rideau River (between Manotick and Kemptville)	4	2.61	−34.64	**Decreased**
Sand	4.5	3.14	−30.16	**Decreased**
Upper Rideau	4.25	3.69	−13.21	**Decreased**
Upper and Lower Beverley	5	3.16	−36.86	**Decreased**
White	4.83	2.7	−44.09	**Decreased**
Wolfe	5	2.96	−40.77	**Decreased**
(c) SMB numbers				
Big Rideau (including Lower Rideau)	3.5	3.39	−3.28	**Decreased**

(Continues)

TABLE 4 | (Continued)

Lake	Earliest score	Latest score	Percent change (%)	Change direction
Bobs	4	2.96	−25.91	**Decreased**
Charleston	5	3.29	−34.12	**Decreased**
Cranberry and Dog	1.5	3.24	115.87	Increased
Devil	3	3	0	No change
Loughborough	3	3.24	7.94	Increased
Mississippi	4.33	2.97	−31.35	**Decreased**
Newboro	3	3.26	8.56	Increased
Opinicon	2.5	2.3	−8.15	**Decreased**
Otter	3	3.26	8.7	Increased
Rideau River (between Manotick and Kemptville)	4	2.57	−35.78	**Decreased**
Sand	3	3.09	3.03	Increased
Upper Rideau	4	3.82	−4.41	**Decreased**
Upper and Lower Beverley	5	3.3	−34	**Decreased**
White	4.17	2.46	−40.85	**Decreased**
Wolfe	5	3.17	−36.52	**Decreased**
(d) SMB sizes				
Big Rideau (including Lower Rideau)	3.5	3.45	−1.4	**Decreased**
Bobs	4	3.12	−21.94	**Decreased**
Charleston	5	3.15	−37.08	**Decreased**
Cranberry and Dog	2	3.19	59.52	Increased
Devil	4	2.54	−36.54	**Decreased**
Loughborough	5	2.75	−45	**Decreased**
Mississippi	3.33	2.88	−13.65	**Decreased**
Newboro	2.75	3.37	22.6	Increased
Opinicon	3.5	2.27	−35.06	**Decreased**
Otter	4	3.3	−17.5	**Decreased**
Rideau River (between Manotick and Kemptville)	4	2.58	−35.45	**Decreased**
Sand	3.5	2.83	−19.05	**Decreased**
Upper Rideau	3.67	3.79	3.29	Increased
Upper and Lower Beverley	5	3.34	−33.16	**Decreased**
White	4.33	2.46	−43.33	**Decreased**
Wolfe	5	3.29	−34.29	**Decreased**

Note: Lakes in which these scores decreased are bolded.

wild, and it is difficult to separate these effects from other potential drivers. Changes, over time, not only in numbers but also in population size structure, however, do suggest that FIE could be a factor in driving the changes reported by anglers in eastern Ontario, especially when coupled with increased angling pressure on a largely catch-and-release fishery.

4.2 | Local Knowledge as a Tool in the Monitoring Toolbox

This study has also highlighted the utility of LEK in the monitoring of recreational fisheries, especially if much about the state of the fishery is unknown. The lakes included in our study: Lower

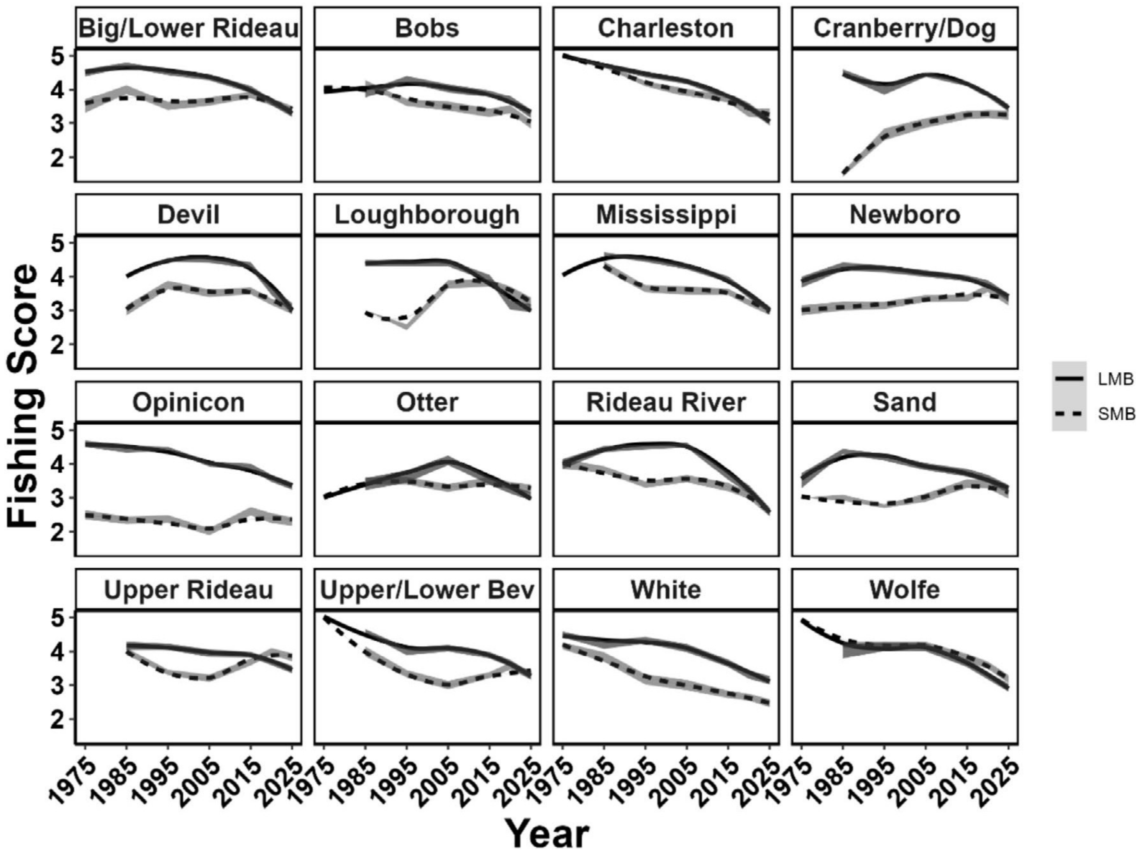

FIGURE 5 | Mean fishing scores for relative Largemouth and Smallmouth Bass numbers with lines of best fits for Largemouth Bass trends are shown as solid lines and Smallmouth Bass trends as dashed lines. Shaded areas represent 95% confidence intervals.

Rideau, Cranberry, Devil, Loughborough, Mississippi, Newboro, Opinicon, Otter, Upper Rideau, White, Wolfe, and Upper and Lower Beverley Lakes, as well as the Rideau River, have never been monitored using Ontario's BsM program (available at: https://tinyurl.com/4tdvbr9s). Defining who are the expert knowledge holders (Davis and Wagner 2003) and defining if information is considered viable knowledge (Johannes 1989; Davis and Ruddle 2010) is important to determine the validity of LEK as a robust tool for ecological monitoring in fisheries (Neis 1992), although even in the absence of true understanding of validity, it may be important to integrate LEK as part of the "toolkit" used to assess populations. Local resource users (in this case, anglers) are often the first to notice differences in their local resource systems and in many cases are stewards of those resources (e.g., Berkes et al. 2000; Johannes et al. 2000). This has been true for commercial and artisanal (local, community) small-scale fisheries in the past (e.g., Neis 1992; Murray et al. 2006; Bender et al. 2014; Martins et al. 2018; Castagnino et al. 2023). It is important to note that it can be difficult to reliably identify which users, such as the ones in our study, are considered to hold "expert" knowledge (Davis and Wagner 2003), especially within the context of snowball sampling (Neis, Felt, et al. 1999). Thus, it is important to mention our attempts to tease out differences among angler demographics, so as to not assume all respondents were "experts." Despite that, even in the absence of "expert" identification, a diverse array of perspectives from users is also beneficial to alleviate biases formed from specific groups (Jones et al. 2025). To better understand how different angler experience factors impact reported quality of fishing, our study asked anglers to identify their experience levels and time spent fishing. Resoundingly, across all levels of experience, declines were reported. Additionally, the filtering out of those who did not answer the LHC questions (< 75% survey completion) served as a way to further safeguard against non-"expert respondents" (in the sense that some individuals may not actually know about a fishery). Thus, as an aggregate of all anglers, the results of the present study show that even in a catch-and-release fishery context, this knowledge could be important in predicting fishery health, especially as interventions for saving natural resources often come at a time when it is "too little, too late" (Oro and Martínez-Abraín 2023).

In our study, we attempted to estimate how average fishing quality has changed over time by asking anglers to recall changes in relative number and size metrics rather than exact metrics for these variables. This is especially important as respondents were asked to recall fishing quality as far back as 50 years ago, and our study, like others, may be limited in its ability to conclude long-term inferences due to this recall bias. Any study that asks for recall over large temporal scales is likely introducing some amounts of recall bias (Daw 2010), although the use of recalled knowledge, even in cases where there are recall discrepancies among different demographic groups, can be accurate in predicting long-term changes in fisheries harvest (see Castello et al. 2024). In this study, sharper declines were reported after 2005, suggesting that while some recall bias may have occurred, this was overall minimal. Additionally, the LHC approach, adapted by Rehage et al. (2019) for recreational fisheries, aims to alleviate some of these recall biases by asking respondents to

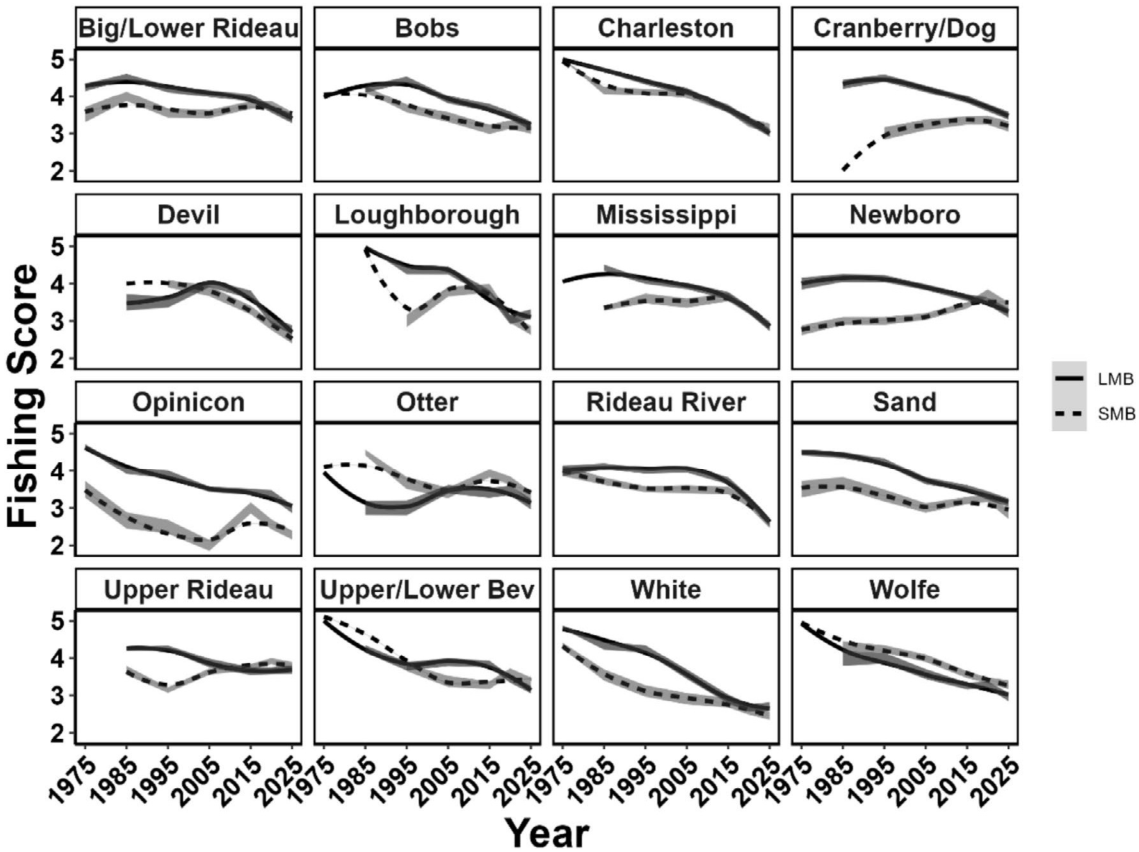

FIGURE 6 | Mean fishing scores for relative Largemouth and Smallmouth Bass sizes with lines of best fits for Largemouth Bass trends are shown as solid lines and Smallmouth Bass trends as dashed lines. Shaded areas represent 95% confidence intervals.

recall events in relation to other events, triggering better memory recall (Freedman et al. 1988). Another phenomenon that often permeates fisheries conservation is the shifting baseline paradigm, that is, where individuals at different time points misperceive the current ecological situation (e.g., number of fish) as the "baseline" or new "norm," meaning that changes in fishery health may not be detected by subsequent generations (Pauly 1995; Daw 2010; Soga and Gaston 2018). In our study, clear declines were perceived across the entire span of the recall period (1975–2025), especially for LMB, with steep declines during a more recent time period (2005–2025) for both species, suggesting that shifting baselines have minimally impacted perceptions of fishing quality over time, as these sharp declines were reported in the most recent time periods, although this cannot be entirely ruled out as a limitation. There were a few instances of increases between time periods, although this was likely due to inflated numbers on a few lakes due to low angling pressure at certain time periods (see Figures 5, 6). Fisheries also suffer greatly from hyperstability, and fish populations usually need to be quite low before anglers notice declines in metrics such as Catch per Unit Effort (CPUE) or changes in population size structures (Erisman et al. 2011; Ward et al. 2013; Maggs et al. 2016; Feiner et al. 2020). This issue is likely exacerbated by anglers who consider themselves "advanced" or those who spend substantial time fishing lakes in FMZ 18 (a majority of respondents in this study), because these individuals are likely to be able to catch fish at relatively higher rates even in a declining fishery. As a result, the perceived declines reported in this study are likely indications of actual declines in the Black Bass fishery. Equally interesting is that Black Bass are not currently harvested at high levels in these lakes, showing that declines can even occur for fish that are mostly caught and released. Declines in a fishery can also be a catalyst for depensatory feedback loops (lower populations are more at risk to decreases), described by Post et al. (2002) as part of a "hidden collapse." As the number of anglers in an already high-pressure fishery increases (like our study lakes in FMZ 18), it may be possible that declines in catches reported herein may be occurring more broadly. We encourage more effort devoted to bespoke fisheries assessment (e.g., nearshore netting, electrofishing transects, creel surveys) in key Black Bass waters of Ontario to provide long-term field-collected data to complement the LEK methods used here.

5 | Conclusion

Detailed information on the fishery health of Black Bass populations across Eastern Ontario is not currently available. Within a large array of lakes, anglers surveyed reported significant decreases over the last 50 years in the average numbers and body sizes of LMB and SMB that were caught during their angling trips. Coupled with recent key studies highlighting the negative consequences of angling for Black Bass during the reproductive period (Philipp, Claussen, et al. 2023; Philipp, Zolderdo, et al. 2023), this study reveals the need to develop, test, and implement alternative management strategies to protect the future Black Bass fishery. Unfortunately, changes in policies and/or regulations often do not occur until there are drastic changes in the health of a resource (e.g., Oro and Martínez-Abraín 2023), which is often too late to prevent significant negative changes in fish populations (as per Post et al. 2002). Although the cure for that lag is to collect relevant information to inform decision makers, that takes time and money, and so it is rarely achieved. Unfortunately, there are still key barriers to transferring knowledge into action (e.g., Young et al. 2013, 2016; Nguyen et al. 2018). This study is part of a timely portfolio showing that even a catch-and-release fishery can be vulnerable to declines if not monitored to determine if management actions are sufficient (outlined by Post et al. 2002; Post et al. 2025). There is a growing recognition of the benefits that can be derived from LEK (i.e., it is way more than just "fish stories"; see Silvano and Valbo-Jørgensen 2008), especially when it provides information on changes over time (Martínez-Candelas et al. 2025). Given the inherent challenges with monitoring Black Bass populations and limited resources for doing so, there is a need to consider other monitoring approaches that rely on LEK (or ILK, where appropriate).

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Artificial Intelligence tools were not used in the writing or preparation of this manuscript.

Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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Appendix 1

Understanding the State of the Black Bass Fishery in FMZ 18 in Eastern Ontario

Q1 *Understanding the state of black bass fisheries and fisheries management based on angler surveys in Water Bodies of FMZ 18 in Eastern ON* The purpose of this survey is to help our research team understand trends in Black Bass (Smallmouth and Largemouth bass) populations and understand current angler attitudes toward existing regulations and management techniques. These results will help inform future management decisions for the long-term conservation of these species. All participants will remain anonymous. If you change your mind about your participation, you have until April 30th, 2025 to withdraw from this study. We are excited to hear from you: individuals who are directly impacted by black bass management in FMZ 18 of Eastern Ontario. Please feel free to distribute this survey to other anglers in FMZ 18: https://carletonu.az1.qualtrics.com/jfe/form/SV_81dTW7MGdUfUcwm This project is funded by Carleton University. This research has been cleared by Carleton University Research Ethics Board-B Clearance #122461. Should you have any ethical concerns with the study, please contact the REB Chair, Carleton University Research Ethics Board-B (ethics@carleton.ca). Please choose if you consent to being a part of our angler survey:

a. Yes
b. No

Q2 Have you ever fished for Black Bass (Smallmouth bass or Largemouth bass) on any of the following waterbodies: *Big Rideau Lake (including Lower Rideau), Upper Rideau Lake, Newboro Lake (including Indian, Clear Mosquito and Loon Lake), Rideau River between Manotick and Kemptville, Loughborough Lake, Cranberry and Dog, Otter, Charleston, Opinicon, Sand, Bobs, Mississippi Lake, Upper/lower Beverley, White Lake, Devil Lake and/or Wolfe Lake?*

a. Yes
b. No

Q3 What is your year of birth?

Q4 What is your gender identity?

a. Male
b. Female
c. Nonbinary/third gender
d. Prefer not to say
e. Other

Q5 Do you own shoreline property on any of the listed lakes?

a. Yes
b. No

Q39 If you own shoreline property on the listed lakes, please let us know which one(s). Select all that apply.

a. Big Rideau Lake (including Lower Rideau Lake)
b. Newboro Lake (including Indian, Clear Mosquito and Loon Lake).
c. Rideau River (between Manotick and Kemptville)
d. Upper Rideau Lake.
e. Loughborough Lake
f. Cranberry and Dog Lakes.
g. Charleston Lake
h. Lake Opinicon
i. Mississippi Lake (Ontario)
j. White Lake
k. Otter Lake
l. Sand Lake
m. Bobs Lake
n. Upper/lower Beverley Lake.
o. Devil Lake
p. Wolfe Lake.

Q7 Please list any lake associations, fishing clubs, or other relevant environmental organizations in FMZ 18 to which you belong.

Q8 What level of angler would you classify yourself?

a. Beginner
b. Intermediate
c. Advanced

Q9 In the last 12 months, how many days have you fished in FMZ 18?

a. Less than 5 days.
b. 6–15 days
c. 16–29 days
d. 30–50 days
e. 50+ days
f. none

Q10 In the last 12 months, how many days have you fished for *Largemouth or Smallmouth bass* in FMZ 18?

a. Less than 5 days.
b. 6–15 days
c. 16–29 days
d. 30–50 days
e. 50+ days
f. none

Q13 Have you fished in a bass tournament/derby over the last 12 months? How many?

Q14 Do you use boat-based electronics (e.g., cameras, SONAR, etc.) to help you with fishing? If yes, please tell us how long ago you started to use them regularly:

a. Less than 5 years ago
b. 6–10 years ago
c. 11–14 years ago
d. 20+ years ago
e. I do not use electronics to fish

Q15 Do you receive any sort of income from your fishing activities (e.g., fishing guide, professional angler, fishing social media celebrity)?

a. Yes
b. No

Q16 How many years have you fished for Black Bass in FMZ 18?

a. 1–4 years
b. 5–9 years
c. 10–14 years
d. 15–19 years
e. 20–24 years
f. 25–29 years
g. 30–34 years
h. 35–39 years
i. 40–44 years
j. 45–49 years
k. 50+ years

Q17 On a scale of 1 to 10, how important is recreational fishing in your life? One is "not at all important" and 10 is "very important."

Not at all important	Slightly important	Moderately important	Very important	Extremely important

Q18 Please tell us in what ways recreational fishing is important in your life:

a. To enjoy nature
b. To spend time with friends/family
c. To catch high numbers of fish
d. To catch large fish
e. To catch fish for consumption
f. To relax
g. Other

Q37 If you selected "other" for the previous question, please tell us below how recreational fishing is important to you.

Q19 When you catch Black Bass what do you do with the fish (please check one only)?

a. I always release the bass
b. I practice selective harvest – keeping enough for 1 to 5 meals a year
c. I keep the majority of the bass I capture
d. I keep all the bass I capture

Q20 Which of the following lakes do you fish (select all that apply)?

a. Big Rideau Lake (including Lower Rideau Lake)
b. Newboro Lake (including Indian, Clear Mosquito and Loon Lake)
c. Rideau River (between Manotick and Kemptville)
d. Upper Rideau Lake.
e. Loughborough Lake
f. Cranberry and Dog Lakes
g. Charleston Lake
h. Lake Opinicon
i. Mississippi Lake (Ontario)
j. White Lake
k. Otter Lake
l. Sand Lake
m. Bobs Lake
n. Upper/lower Beverley Lake.
o. Devil Lake
p. Wolfe Lake

Q21 Please indicate how much of a threat the following are to current Black Bass populations in Eastern Ontario.

Q22 Do you feel that there should be changes in how the bass fishery is currently managed?

a. Yes
b. No
c. Not sure

Q23 If you answered yes in the previous question, please describe some of the changes you would want to see:

Q24 How can we improve collaboration across various stakeholder groups (e.g., cottagers, tournament anglers, managers) to improve bass populations and their management? Please use the space below:

Q25 Are there any lakes in FMZ 18 that you feel have been overfished for *Largemouth or Smallmouth bass*? If yes, please list below:

Q26 *FOR LARGEMOUTH BASS*: On a scale of 1–5 (with 5 being very good and 1 being very poor) please rate your fishing experience in terms of the *number of Largemouth bass* you caught across different time periods and lakes fished. ONLY RESPOND FOR LAKES AND TIME PERIODS FOR WHICH YOU HAVE EXPERIENTIAL KNOWLEDGE AND LEAVE OTHERS BLANK. Please type in the numbers 1–5 in each space.

Q27 *FOR LARGEMOUTH BASS*: On a scale of 1–5 (with 5 being very good and 1 being very poor) please rate your experience with the *size (length and weight)* of the fish you caught across different time periods and lakes fished. ONLY RESPOND FOR LAKES AND TIME PERIODS FOR WHICH YOU HAVE EXPERIENTIAL KNOWLEDGE AND LEAVE OTHERS BLANK. Please type in the numbers 1–5 in each space.

Q28 *FOR SMALLMOUTH BASS* On a scale of 1–5 (with 5 being very good and 1 being very poor) please rate your fishing experience in terms of the number of Smallmouth bass you caught across different time periods and lakes fished. ONLY RESPOND FOR LAKES AND TIME PERIODS FOR WHICH YOU HAVE EXPERIENTIAL KNOWLEDGE AND LEAVE OTHERS BLANK. Please type in the numbers 1–5 in each space.

Q29 *FOR SMALLMOUTH BASS*: On a scale of 1–5 (with 5 being very good and 1 being very poor) please rate your experience with the size (length and weight) of the fish you caught across different time periods and lakes fished. ONLY RESPOND FOR LAKES AND TIME PERIODS FOR WHICH YOU HAVE EXPERIENTIAL KNOWLEDGE AND LEAVE OTHERS BLANK. Please type in the numbers 1–5 in each space.

Q30 How do you feel the amount of angling pressure on lakes in FMZ 18 has changed over time?

a. Increased

b. decreased

c. Stayed the same

d. Not sure

Q31 How do you feel the amount of illegal fishing (fishing for bass out of season or harvesting fish over bag limits) on lakes in FMZ 18 has changed over time?

a. Increased

b. Decreased

c. Stayed the same

d. Not sure

Q32 To help increase the number of bass that can successfully make it into the population, seasonal Black Bass spawning sanctuaries are currently being tested on Lake Opinicon and Charleston Lake. These involve closing areas of the lake to all fishing during the entirety of the bass reproductive season (April 15th–first Saturday of July). Do you believe this is an effective strategy for the conservation of bass in FMZ 18?

a. Yes

b. No

Q33 Based on your answer to the previous question, please let us know why or why not below:

Q34 Would you be open to bass spawning sanctuaries being implemented more broadly in FMZ 18 bass waters?

a. Yes

b. No

Q35 Based on your answer to the previous question, please let us know why or why not below:

Q36 How do you believe implementing bass spawning sanctuaries will affect property values?

a. It will increase property values

b. It will decrease property values

c. It will have no impact on property values

d. Not sure

Q37 How do you believe that implementing bass spawning sanctuaries is likely to affect tourism?

a. It will increase tourism.

b. It will decrease tourism.

c. It will have no impact on tourism.

d. Not sure.