North American Journal of Fisheries Management, 2026, **00**, 1–11
https://doi.org/10.1093/najfmt/vqag064
Published: 2 September 2026
Special Section

American Fisheries Society

Downloaded from academic.oup.com/najfm/advance-article/doi/10.1093/najfmt/vqag064/8780178 by Maryland Department of Natural Resources user on 02 September 2026

Special Section on Black Bass 2025 Symposium Proceedings

Influence of live-imaging sonar on black bass catch: A multifishery analysis of professional tournaments

Ryan A. Gary[1,*], Joseph W. Love[1], and Steven Bardin[2]

[1]Maryland Department of Natural Resources, Freshwater Fisheries and Hatcheries Division, Annapolis, Maryland, USA
[2]Major League Fishing, Denver, Colorado, USA

*Corresponding author: Ryan A. Gary. Email: ryan.gary@maryland.gov.

Abstract

***Objective*: To determine (1) if average catch rates or average weight of black bass *Micropterus* spp. differed between periods of live-imaging sonar (LIS) use and nonuse for avid anglers across a diverse range of fisheries and (2) if the frequency of LIS-facilitated catches was associated with specific fishing habitat characteristics.**

***Methods*: We analyzed catch data from professional anglers across eight Major League Fishing events in 2025. The tournament rules restricted the use of LIS to one of three daily competition periods. A linear mixed-effects model was used to assess if LIS had an effect on catch or fish weight. The fixed effects included LIS use, fishery, and tournament day, with an interaction term used to evaluate whether LIS efficacy was contingent on specific fisheries. To account for repeated measures and individual angler skill, angler identity as a random effect was used. We also explored how selected habitat aspects of fisheries related to the use of LIS to catch black bass. Contingency analyses were used to examine relationships with water body type, habitat cover complexity, and water depth.**

***Results*: The influence of LIS on catch rates varied by fishery, with notable increases occurring at Lakes Conroe and Murray. Generally, the weight of the black bass that were caught did not significantly differ between LIS and non-LIS periods. A greater percentage of black bass was caught by anglers who were using LIS in areas that were ranked as lentic water versus rivers or creeks as well as in low-complexity habitat cover. Additionally, anglers who caught fish in deep water had nearly three times the likelihood of using LIS.**

***Conclusion*: Although anglers were more likely to catch fish with LIS in deeper, less structured environments, it appears to offer limited utility in shallow, complex shoreline habitats. Therefore, the risk of increased exploitation due to LIS may be inherent in fisheries with deeper, less structured habitats or seasonal pelagic opportunities. By standardizing angler avidity and accounting for angler skill in our models, this study provides an isolated measure of LIS use and benefit. This highlights the necessity for fisheries managers to account for avidity bias and water body morphology when considering the effects of widespread adoption of LIS in a fishery.**

Keywords: black bass, fisheries management, forward-facing sonar, hydroacoustics, *Micropterus*, tournament fishing

Lay summary

Live-imaging sonar may help anglers catch more, but not necessarily larger, bass. Both the use of live-imaging sonar and catch increase in deep, open water rather than shallow cover. Managers should evaluate how a lake's depth and habitat influence the effectiveness of live-imaging sonar when considering the effects of widespread adoption of the technology on their fishery.

Received: April 8, 2026. **Revised:** June 5, 2026. **Accepted:** July 21, 2026
© American Fisheries Society 2026. All rights reserved. For commercial re-use, please contact reprints@oup.com for reprints and translation rights for reprints. All other permissions can be obtained through our RightsLink service via the Permissions link on the article page on our site—for further information please contact journals.permissions@oup.com.

Introduction

Understanding the effects of advanced angling technologies on fishery population dynamics is crucial for modern fisheries management. Although traditional tools like creel and length limits are used to prevent overexploitation, the rapid development of new technologies can create challenges for maintaining resilient fisheries (Cooke et al., 2021; Pope et al., 2014). Technological innovation has historically been a primary driver of change in angling methods, ranging from improved terminal tackle to advanced sonar (Cooke et al., 2021). Anglers frequently embrace these innovations to increase their catch and satisfaction. However, advancements can also trigger ethical debates over concerns about fair chase and the potential for overexploitation that results in subsequent user conflicts (Birdsong et al., 2021; Cooke et al., 2021; Devall & Harry, 1981; Hummel & Foster, 1986).

A prominent recent advancement is the introduction of recreational-grade live-imaging sonar (LIS), also referred to as forward-facing sonar. Live-imaging sonar has long proven its utility in high-resolution ecological monitoring, including the identification and enumeration of migrating salmonids in turbid environments (Belcher et al., 2002) and the observation of fish behavior and passage efficiency at hydroelectric facilities (Moursund et al., 2003). However, until recently, this technology has not been available as a recreational tool for anglers. First popularized by Garmin in 2018 as LiveScope (Garmin, 2025), it has since been embraced by other leading recreational hydroacoustic manufacturers, including Humminbird (MEGA Live Imaging) and Lowrance (ActiveTarget). Unlike traditional sonar, which typically relies on a single hydroacoustic beam, LIS uses multiple high-frequency beams to produce real-time, video-quality imagery (Munnelly et al., 2024). The transducer is typically mounted to a trolling motor or a specialized independent pole, giving anglers the ability to rotate the sensor 360 degrees to scan large areas rather than relying on boat movement for image generation.

Live-imaging sonar has become popular among those targeting freshwater species like Black Crappie *Pomoxis nigromaculatus*, White Crappie *P. annularis*, and Largemouth Bass *Micropterus nigricans* (Henry et al., 2026; Neely et al., 2023b; Smith et al., 2025). Oppositional perceptions that LIS enables anglers to identify specific areas and even target individual large fish (Scarnecchia & Schooley, 2022) have raised concerns that it may lead to recruitment overfishing and a reduction in population size structure. The Mississippi Department of Wildlife, Fisheries, and Parks (MDFWP) recently reduced the creel limit by 33% on four prominent crappie fisheries, a measure prompted by survey results showing an increase in both LIS prevalence and catch rates (K. Meals, MDFWP, personal communication). Additionally, nationwide black bass *Micropterus* spp. tournament organizations like Bass Angler Sportsman Society and Major League Fishing have instituted rules limiting the use of LIS.

Due to concerns from recreational anglers and significant media coverage, scientific evaluations of LIS have increased in recent years; however, they lack consistent findings. Some controlled experiments report no significant difference in catch rates or fish size for species like crappie or Blue Catfish *Ictalurus furcatus* (Neely et al., 2023a, 2023b; Zellers, 2022). Conversely, other research suggests that LIS users achieve significantly higher catch and harvest rates, particularly for certain size-classes (Henry et al., 2026; Smith et al., 2025). Smith et al. (2025) found significantly higher catch and harvest rates of crappie in two out of three fisheries, suggesting differences in the efficacy the technology among fisheries. These mixed results could stem from a multitude of factors, including variations among habitats, water body morphology, or angler avidity. Because avid anglers are more likely to invest in expensive technology (Bryan, 1977; Ditton et al., 1992; Koemle et al., 2021), studies that do not control for avidity may inadvertently measure angler skill rather than the efficacy of the technology itself.

By using results from professional black bass tournaments, we assessed data from anglers with high avidity and skill, a critical component in isolating technological efficacy from individual proficiency. Additionally, these data encompass diverse fisheries, allowing for an assessment of the efficacy of LIS across a variety of water body morphologies and habitats. This approach is particularly warranted because tournament organizations increasingly impart restrictions on the use of LIS and fishery managers are actively seeking to address emerging ethical and biological concerns. Consequently, this study design allows us to elucidate both the social and scientific concerns of tournament directors and fishery managers by evaluating the performance of LIS across a diverse array of fisheries at the highest skill level for anglers.

Our objectives were to determine (1) whether average catch rates or average weight of black bass differed between periods of LIS use and nonuse for avid anglers across a diverse range of fisheries and (2) whether the frequency of LIS-facilitated catches was associated with specific fishing habitat characteristics. We hypothesized that using LIS would result in higher catch rates and larger fish, on average, across all fisheries. Furthermore, we hypothesized that there were significant relationships between the frequencies of LIS-facilitated catches and three habitat categories: water body type, habitat cover complexity, and water depth.

Methods

Study area and data source

Data were derived from eight professional catch–weigh–release black bass tournaments on Major League Fishing's Bass Pro Tour between February and August 2025. These events were distributed across the United States, encompassing diverse latitudes, species compositions, and ecosystems (Figure 1). The study sites included impounded rivers (Lake Conroe, Texas; Lake Murray, South Carolina; Guntersville Lake, Alabama; Chickamauga/Nickajack, Tennessee; Kentucky Lake, Kentucky), a natural lake chain (Harris Chain of Lakes, Florida), a tidal freshwater river (Potomac River, Maryland), and a freshwater bay (Saginaw Bay, Michigan).

Data collection and standardization

A maximum of 66 anglers competed for at least 2 d in each event before the field was narrowed for the final rounds. To

Downloaded from academic.oup.com/najfm/advance-article/doi/10.1093/najfmt/vqag064/8780178 by Maryland Department of Natural Resources user on 02 September 2026

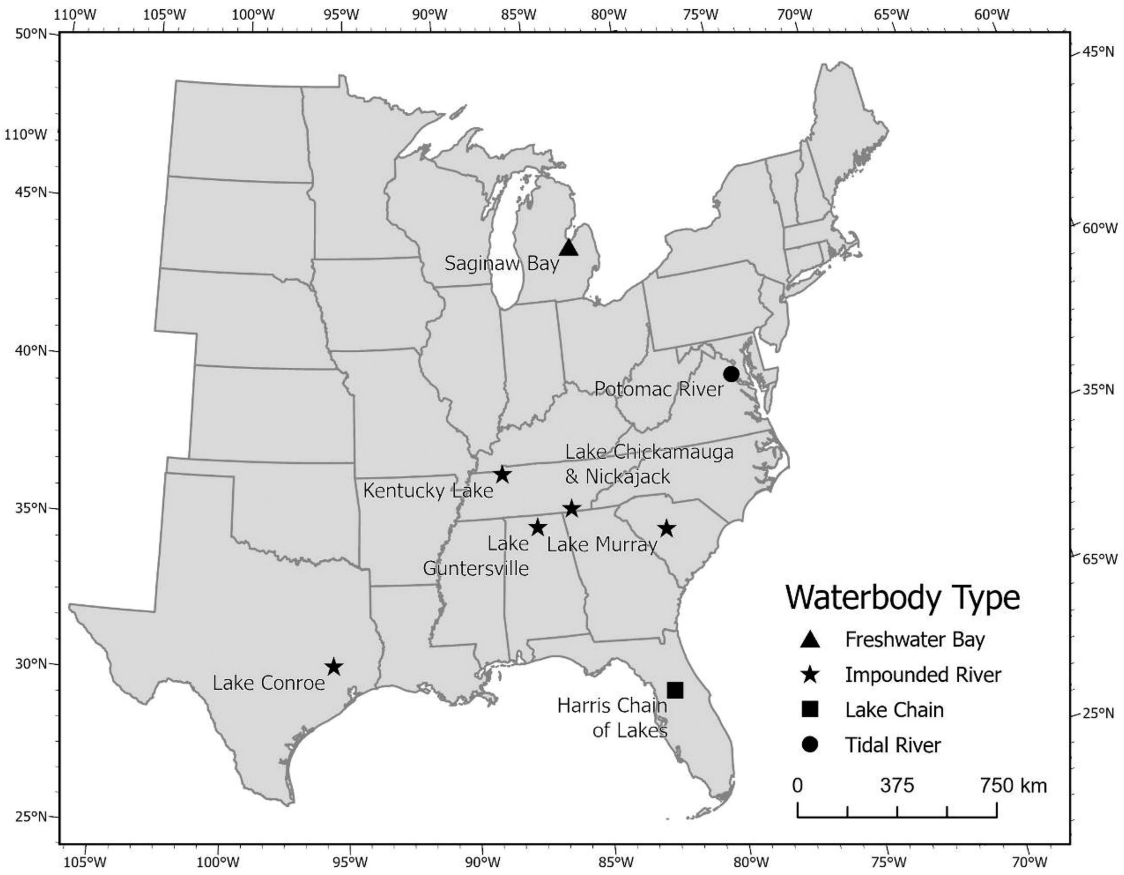


Figure 1 Geographic distribution and classification of eight Major League Fishing Bass Pro Tour events across the eastern United States in 2025. The locations include freshwater bay (triangle), impounded river (star), lake chain (square), and tidal river (circle).

maximize the comparable sample size and mitigate bias from high-performing anglers, only data from the first 2 d of competition were analyzed. Each competition day consisted of three 2.5-h periods beginning at 0800 hours, separated by 15-min intervals. Anglers were permitted to use LIS during any single period per day but were restricted from using it during the remaining two periods. Additionally, anglers had the option to abstain from using LIS for a given competition day. All anglers were provided with lock boxes that made their LIS transducers unavailable unless unlocked, which was monitored by on-boat officials to ensure compliance.

Catch data were recorded in real-time by on-boat officials for every scorable fish. The minimum weight threshold for a scorable fish depended on the fishery, either 0.68 kg or 0.91 kg. This threshold was determined for each fishery based on historical monitoring data that were provided by state fish and wildlife agencies. Upon capture, the anglers weighed each fish using a calibrated Bubba Smart Fish Scale; if the fish met the weight threshold, the official recorded the observation. The recorded data for each capture included angler identity, spatial coordinates, weight (lb, oz), water body type, lure type, habitat cover type, water depth below the boat (ft), competition period, and whether the angler had actively used LIS to catch the fish. The water body types included rivers, creeks, bays or pockets, and lakes. The on-boat officials categorized aquatic habitat cover by selecting from 25 specific types, which we grouped into six categories: **high-complexity natural** (e.g., brush, rock, timber, submerged vegetation), **moderate-complexity natural** (stumps, emergent vegetation), **moderate-complexity artificial** (e.g., boat dock or marina, bridge, riprap), **low-complexity structural** (e.g., bluff or wall), **low-complexity topographic** (hump, offshore, point), and **unclassified** (other).

A tiered classification system was employed to categorize angler periods into LIS use and non-LIS use. Primary classification was based on official tournament results, which identified the specific period each day during which an angler chose to use LIS; the remaining two periods were consequently designated as non-LIS. If tournament results indicated no selected LIS period for a given day, all periods were initially classified as non-LIS unless individual fish observations in a given period were noted as being caught actively using LIS. To ensure data integrity, the tournament results were cross validated against individual catch observations. Any discrepancies, such as records indicating fish that were actively caught with LIS during multiple periods or outside of the officially designated LIS period, resulted in that angler's data being omitted from the analysis for that tournament day. A total of 687 individual fish observations and their corresponding 146 competition periods were excluded from analysis due to inconsistent data entry that precluded definitive categorization of the period as LIS or non-LIS use.

Catch per unit effort (hereby referred to as "catch rate") was defined as the total fish caught divided by the period

Downloaded from academic.oup.com/najfm/advance-article/doi/10.1093/najfmt/vqag064/8780178 by Maryland Department of Natural Resources user on 02 September 2026

duration (h) for each angler's individual competition periods. Periods where no fish were caught were included in the catch rate analysis. Mean fish weight per period was calculated by converting the total weight in pounds and ounces to kilograms and dividing the total weight of all of the captured fish by the total number of captured fish during that period. Periods during which no fish were caught were not included in the analyses of mean fish weight. Although the data set included Largemouth Bass, Spotted Bass *Micropterus punctulatus*, and Smallmouth Bass *M. dolomieu*, species-specific trends in LIS effects on catch rate or mean weight were not differentiated in this study because more than 91% of the fish identifications were noted as Largemouth Bass.

Statistical analysis

We tested the hypotheses that LIS use would result in a greater average catch rates and weight of captured fish by using two linear mixed-effects models, with catch rate and fish weight as the dependent variables. For both models, the fixed effects included LIS (i.e., LIS period versus non-LIS period), fishery (i.e., name of the fishery), the interaction between LIS and fishery, and tournament day. Tournament day was included to account for variance owed to different environmental fishing conditions between days at the same fishery. The interaction term was included to test whether the effect of LIS use on catch rate differed among the fisheries. To account for repeated measures across periods, angler identity was treated as a random effect in both models. The structural equation for the linear mixed-effects models that were used to evaluate both catch rate and mean weight are denoted as follows:

$$Y_{ijkl} = \beta_0 + \beta_1(LIS_i) + \beta_2(Fishery_j) + \beta_3(LIS_i \times Fishery_j) + \beta_4(Day_k) + u_l + \varepsilon_{ijkl}$$

where Y_{ijkl} represents the dependent response variable (catch rate or fish weight), β_0 is the global intercept, and β_1 through β_4 represent the fixed-effect coefficients for LIS use, fishery, their interaction, and tournament day, respectively. The term u_l represents the random intercept for individual angler identity to account for repeated measures, and ε_{ijkl} represents the residual error.

The overall significance of the fixed effects was evaluated using type II Wald chi-square tests of deviance (Wald χ^2). Because the interaction between LIS use and fishery was a primary focus of this study, we conducted post hoc pairwise comparisons using estimated marginal means. This post hoc analysis used the fitted values from the linear mixed-effects models to estimate catch rates and mean weights, allowing for the evaluation of LIS use between individual fisheries. Degrees of freedom for these pairwise comparisons were estimated using the Kenward–Roger approximation, and we assumed normal variance in the dependent variables for each treatment effect. Statistical analyses were conducted in program R (R Core Team, 2023) using the "lme4" package for mixed-effects modeling (Bates et al., 2015), the "car" package for deviance testing (Fox & Weisberg, 2019), and the "emmeans" package for post hoc pairwise comparisons (Lenth, 2023).

We tested the hypothesis that there were significant relationships between the frequencies of LIS-facilitated catches and habitat categories: water body type, habitat cover complexity, and water depth. Officials did not note whether the fish was caught actively using LIS for 2,622 individual observations, which were excluded from these data analyses. We ranked the habitat data prior to the analysis and treated the ranks as categories in contingency tables. The type of water body that was being fished was ranked based on its presumed velocity, high to low: river (rank 1); creek (rank 2); bays or pockets (rank 3); and lower, mid, or upper lakes (rank 4). Habitat cover complexity was ranked from highly complex submerged habitat to open water: natural complex habitat (rank 1), natural moderate-complexity habitat (rank 2), artificial moderate-complexity habitat (rank 3), low complexity (rank 4), and open water (rank 5). Two observations with unclassified habitat cover were excluded from analysis. Water depth was ranked as shallow to deep, with five equidistant increments: 0–5 ft, 5.1–10 ft, 10.1–15 ft, 15.1–20 ft, and greater than 20 ft.

We conducted three separate χ^2 analyses to compare the frequencies of LIS-facilitated catches with those that were made without LIS across multiple habitat categories. The χ^2 analysis used the column (i.e., rank) and row (i.e., LIS use) totals in the contingency table to compute the expected number of observations per cell if the habitat category had no effect. The χ^2 statistic summarized the difference between the expected and observed frequency. When the χ^2 was significantly larger than zero, then we concluded that there was a large difference between the expected and observed frequencies. When the χ^2 was not statistically different from zero, then we concluded that the pattern in the contingency table was no different than what would be expected if the counts were distributed at random. For our analyses, we assumed that the catch of a fish with or without LIS was independent of habitat rank. However, anglers may have chosen to fish specific habitat types during a LIS period; whether a fish was landed did not necessarily depend on that choice because of other effects such as weather, water clarity, and chance. The contingency tests with χ^2 analyses were done with Sigmaplot (version 15, 2022; Inpixon).

Results

Across eight tournament events, 73 professional anglers recorded 12,324 catches over 7,267.5 angler-hours. Approximately 31% of these captures occurred during 740 LIS periods, whereas the remaining 69% were recorded during 2,167 non-LIS periods. Bass had an average weight of 1,125.5 g (SE = 3.3) and ranged between 680 and 4,252 g. The most common habitat where fish were caught included shallow waters (44%), cover that was naturally complex (33.2%), and bays or pockets (13.1%).

Influence of LIS on catch rate

The linear mixed-effects model revealed that the overall influence of LIS on black bass catch rates was significant (Wald $\chi^2 = 93.16$, $P < 0.001$; Table 1), with anglers generally experiencing increased catch rates during LIS periods.

Downloaded from academic.oup.com/najfm/advance-article/doi/10.1093/najfmt/vqag064/8780178 by Maryland Department of Natural Resources user on 02 September 2026

Table 1 Summary statistics for the linear mixed-effects model evaluating the influence of live-imaging sonar (LIS) on black bass catch rates. Fixed effects (β_i; Fishery, LIS use, tournament day, and the interaction between Fishery and LIS use) with degrees of freedom (df) were evaluated using type II Wald chi-square (χ^2) tests of deviance. Variance components (σ^2) and standard deviations (SDs) are provided for the random effect of individual angler identity to account for repeated measures, alongside the residual variance. Abbreviation is as follows: NA = not applicable.

Type	Component	Parameter	df	χ^2	*P*	σ^2	SD
Fixed effect	Fishery	β_1	7	515.89	2.20×10^{-16}	NA	NA
Fixed effect	LIS use	β_2	1	93.16	2.20×10^{-16}	NA	NA
Fixed effect	Tournament day	β_3	1	11.02	0.0009031	NA	NA
Fixed effect	Fishery × LIS use	β_4	7	52.92	3.85×10^{-05}	NA	NA
Random effect	Angler (Intercept)	u_1	NA	NA	NA	0.085	0.29
Random effect	Residual	ε_{ijkl}	NA	NA	NA	1.757	1.326

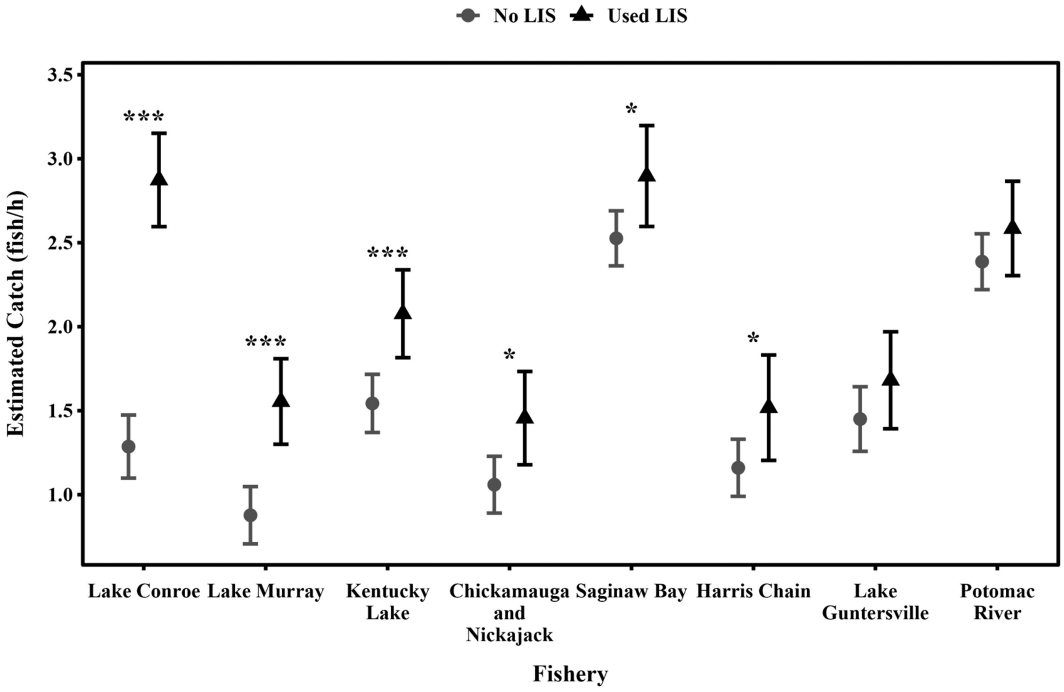


Figure 2 Estimated marginal means of black bass catch (fish/h) across eight Major League Fishing Bass Pro Tour events in 2025, comparing periods where anglers used live-imaging sonar (LIS: black triangles) with periods where LIS was not used (gray circles). The error bars represent 95% confidence intervals. The estimates were derived from a linear mixed-effects model specifying LIS use, Fishery, tournament day, and the Fishery × LIS interaction as fixed effects, with individual angler identity treated as a random effect. The asterisks denote statistically significant differences in catch rates between LIS and non-LIS periods within a specific fishery based on post hoc pairwise comparisons using the Kenward–Roger approximation for degrees of freedom (*$P < 0.05$, **$P < 0.01$, ***$P < 0.001$). The fisheries are arranged along the *x*-axis in descending order of LIS effect size, calculated as the difference between predicted means with and without LIS.

However, the efficacy of the technology was strongly dependent on the specific fishery, as evidenced by a significant interaction between LIS use and fishery (Wald $\chi^2 = 52.92$, $P < 0.001$; Table 1). Additionally, a significant main effect of tournament day was observed (Table 1), indicating a general decrease in catch rates on the second day of competition across all venues.

Post hoc pairwise comparisons of estimated marginal means highlighted that the LIS advantage was not universal (Figure 1). The most pronounced increase in catch rate occurred at Lake Conroe, where LIS periods yielded an estimated 1.59 more fish per hour than non-LIS periods ($t = 9.73$, $P < 0.001$). Significant increases associated with LIS use were also observed at Lake Murray, Kentucky Lake, Chickamauga and Nickajack, Saginaw Bay, and the Harris Chain of Lakes (Figure 2).

Conversely, there was no statistical advantage to using LIS during two events. Average catch rates did not differ significantly between LIS and non-LIS periods at Lake Guntersville ($P = 0.172$) or the Potomac River ($P = 0.213$). Notably, no fishery exhibited significantly higher average catch rates during non-LIS periods than during LIS periods. Finally, variance

Downloaded from academic.oup.com/najfm/advance-article/doi/10.1093/najfmt/vqag064/8780178 by Maryland Department of Natural Resources user on 02 September 2026

components from the random effect indicated that individual angler skill accounted for a relatively small proportion of the total variance in average catch rates ($\sigma^2 = 0.086$) relative to residual factors ($\sigma^2 = 1.757$).

Influence of LIS on fish weight

In contrast to catch rates, the linear mixed-effects model evaluating mean weight indicated that LIS use had no significant overall effect on the average weight of captured black bass (Wald $\chi^2 = 0.03$, $P < 0.868$; Table 2). The mean weight of fish was almost entirely dictated by the specific fishery (Table 2), with Lake Murray and Lake Guntersville having the largest weights. Additionally, tournament day had no significant effect on average weight (Table 2).

However, a significant interaction between LIS use and fishery (Wald $\chi^2 = 22.16$, $P = 0.002$) indicated that technology was associated with mean fish weight depending on the venue (Table 2). The post hoc comparisons showed that at Saginaw Bay, LIS use was associated with catching significantly larger fish (+0.18 kg, $t = 2.58$, $P = 0.009$). Conversely, at the Harris Chain of Lakes, the non-LIS periods yielded significantly larger fish than the LIS periods (+0.22 kg, $t = 2.99$, $P = 0.003$). At the remaining six fisheries, LIS use had no detectable association with the mean weight of fish caught (Figure 3).

The variance components that were extracted from the model revealed that the random effect of angler identity accounted for virtually zero variance in the mean weight of captured fish ($\sigma^2 = 0.0018$, residual $\sigma^2 = 0.310$). This indicates that once the lake environment and specific technology use were accounted for, individual angler identity did not significantly influence the mean weight of the fish caught.

Habitat conditions

The use of LIS to catch black bass was significantly related to ranks for water body type, $\chi^2(3) = 79.52$; $N = 9{,}702$; $P < 0.001$, and ranks for habitat cover complexity, $\chi^2(4) = 466.26$; $N = 9{,}599$; $P < 0.001$. A greater percentage of black bass was caught by anglers who were using LIS in areas that were ranked as lentic water (rank = 4) versus rivers or creeks (Figure 4) as well as low-complexity habitat cover (Figure 4).

As ranked depth increased, so did the use of LIS to catch black bass (Figure 4). The reported use of LIS to catch black bass was significantly related to the ranks of fishing depth, $\chi^2(4) = 664.38$; $N = 9{,}702$; $P < 0.001$. In shallow water, the use of LIS to catch bass was low (ranks 1, 2; Figure 4) despite the majority of catches from a water depth less than 3 m ($N = 7{,}571$ of 9,702 total catches). Most anglers did not report catching black bass from water that was deeper than 3 m. Given these observations, we performed a post hoc retrospective odds ratio test to determine the odds of a black bass being caught with LIS in deep water (>3 m) relative to observations within the data set. The anglers who caught fish in deep water had greater odds of using LIS when doing so, by an estimated 2.90 times (95% CI: [2.63, 3.21]), which was significantly greater than 1.0, $\chi^2(1) = 462.32$; $N = 9{,}702$; $P < 0.0001$.

Discussion

Technological advances such as LIS are frequently embraced by anglers with the intention of increasing their catch or satisfaction (Cooke et al., 2021). As these technologies become more accessible to anglers, fish populations may become more vulnerable to exploitation. Although black bass fisheries are characterized by a culture of catch-and-release fishing, increased catch rates of fish or elevated frequency of live-well retention during tournaments may shift exploitation rates from their current baselines. Henry et al. (2026) found that overall catch rates and the catch rates of larger (≥406 mm) Largemouth Bass were greater for anglers who used LIS at Lake Talquian (Florida, USA). Although we also found that catch rates for avid anglers could be higher, apart from Saginaw Bay, we found that average black bass weight was not significantly greater during LIS periods. Therefore, the risk of increased exploitation due to LIS may not be universal; rather, it may depend on the water body morphology and specific habitat characteristics.

The use and benefits of LIS in specific habitats are particularly evident when examining how traditional angling effort interacts with complex cover. Angler effort is rarely distributed uniformly, as individuals often disproportionately target specific features such as shorelines (Matthias et al., 2014) and submerged vegetation or spawning habitats during spring (Hargrove et al., 2018). Although our results indicate that LIS may increase catch rates, its efficacy may not translate to

Table 2 Summary statistics for the linear mixed-effects model evaluating the influence of live-imaging sonar (LIS) on black bass weight (mean weight). Fixed effects (β_i; Fishery, LIS use, tournament day, and the interaction between Fishery and LIS use) with degrees of freedom (df) were evaluated using type II Wald chi-square (χ^2) tests of deviance. Variance components (σ^2) and standard deviations (SDs) are provided for the random effect of individual angler identity to account for repeated measures, alongside the residual variance. Abbreviation is as follows: NA = not applicable.

Type	Component	Parameter	df	χ^2	*P*	σ^2	SD
Fixed effect	Fishery	β_1	7	723.32	2.2×10^{-16}	NA	NA
Fixed effect	LIS use	β_2	1	0.03	0.8684	NA	NA
Fixed effect	Tournament day	β_3	1	1.30	0.2547	NA	NA
Fixed effect	Fishery × LIS use	β_4	7	22.16	0.0024	NA	NA
Random effect	Angler (Intercept)	u_l	NA	NA	NA	0.004	0.019
Random effect	Residual	ε_{ijkl}	NA	NA	NA	0.064	0.252

Downloaded from academic.oup.com/najfm/advance-article/doi/10.1093/najfmt/vqag064/8780178 by Maryland Department of Natural Resources user on 02 September 2026

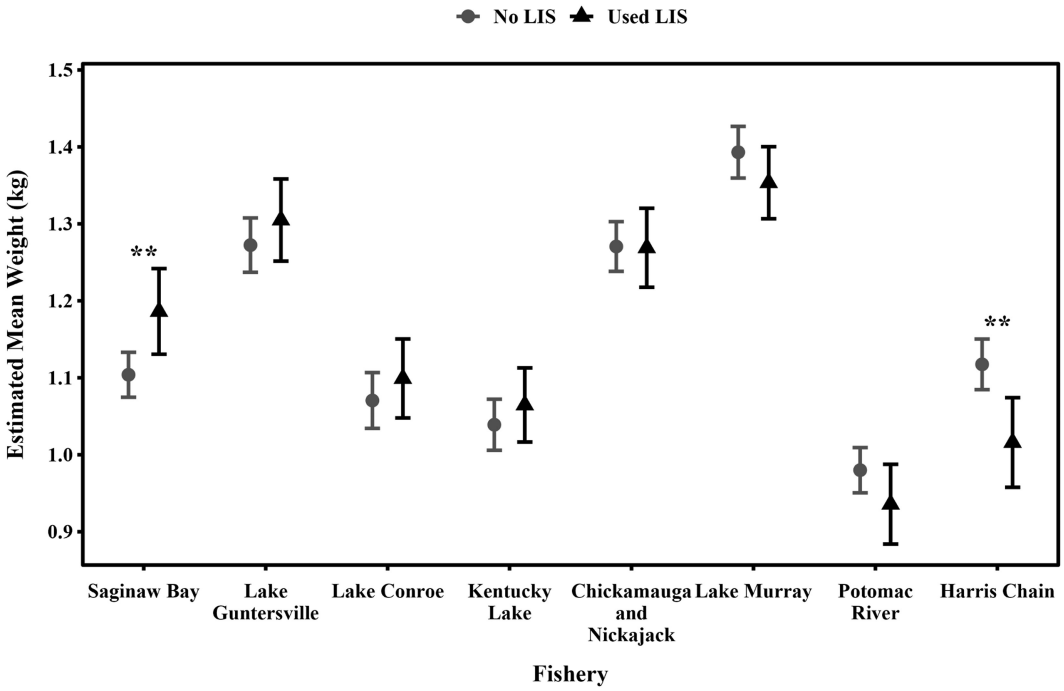


Figure 3 Estimated marginal means weight (kg) of black bass across eight Major League Fishing Bass Pro Tour events in 2025, comparing periods where anglers used live-imaging sonar (LIS; black triangles) with periods where LIS was not used (gray circles). The error bars represent 95% confidence intervals. The estimates were derived from a linear mixed-effects model specifying LIS use, Fishery, tournament day, and the Fishery × LIS interaction as fixed effects, with individual angler identity treated as a random effect; zero-catch periods were excluded from this analysis. The overall fixed-effect interaction between Fishery and LIS use was not statistically significant ($P = 0.127$), indicating that LIS did not consistently yield larger fish across all environments. The asterisks denote localized statistically significant differences based on post hoc pairwise comparisons ($^{*}P < 0.05$, $^{**}P < 0.01$, $^{***}P < 0.001$). The fisheries are arranged along the *x*-axis in descending order of LIS effect size, calculated as the difference between predicted means with and without LIS.

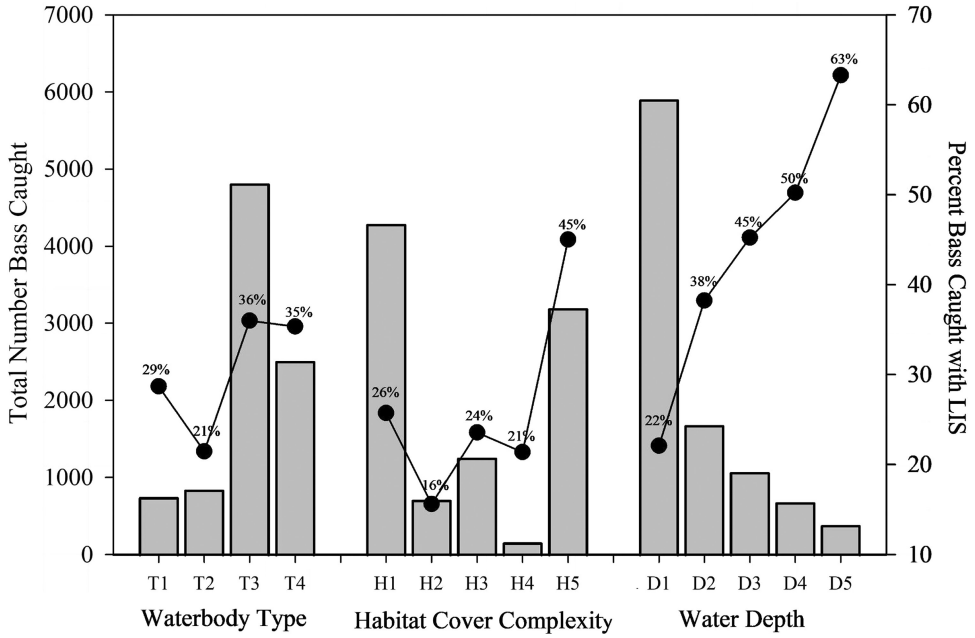


Figure 4 Total number of black bass caught during Major League Fishing Bass Pro Tour events in 2025 (gray columns) for habitats ranked by their water body type (T1 = river, T2 = creek, T3 = bays or pockets, and T4 = lower, mid, or upper lakes), habitat cover complexity (H1 = high-complexity natural, H2 = moderate-complexity natural habitat, H3 = moderate-complexity artificial habitat, H4 = low-complexity structural, H5 = low-complexity topographic), and water depth (D1 = 0–5 ft, D2 = 5.1–10 ft, D3 = 10.1–15 ft, D4 = 15.1–20 ft, and D5 = greater than 20 ft). The right *y*-axis provides the percentage of total bass that was caught while using live-imaging sonar (black circles and numerical values).

Downloaded from academic.oup.com/najfm/advance-article/doi/10.1093/najfmt/vqag064/8780178 by Maryland Department of Natural Resources user on 02 September 2026

shallow, complex areas where angler effort is often distributed. For example, catch rates on the Potomac River and Lake Guntersville, where anglers often fish shorelines, shallow water, and submerged vegetation, remained statistically similar regardless of LIS use. Additionally, the Harris Chain of Lakes, a shallow, hyper-eutrophic system in north-central Florida, was the only fishery with a significant increase in the weight of fish that were caught when anglers were not using LIS. These observations suggest that when a water body is shallow with complex habitat, it may decrease the use and advantage of LIS, and by extension the potential for an increase in exploitation.

Although LIS may offer limited advantages in shallow complex shoreline habitats (Cooke et al., 2025), our results suggest that it likely provides an advantage in fisheries where water body morphology is deeper and less complex. This disparity is particularly relevant when considering the life history of black bass, which often involves seasonal transitions from shallow littoral zones to dense aggregations in deeper offshore areas during late fall and winter (Bunt et al., 2021; Todd & Rabeni, 1989; Winter, 1977). Such high-density congregations in relatively open water may render fish more susceptible to detection and capture via LIS, potentially leading to seasonal variations in the technology's efficacy. Additionally, by making it efficient to locate offshore congregations of fish, LIS may allow anglers to exploit a subset of the population that was previously unavailable to anglers. Although our study design did not explicitly account for seasonality, the two highest increases in catch rates, observed at Lake Conroe (February) and Lake Murray (March), coincided with periods when fish typically occupy deeper overwintering or prespawn habitats. Conversely, the only fisheries where LIS use provided no significant advantage were Lake Guntersville (April) and the Potomac River (June), when fish seasonally occupy shallower complex environments. These patterns suggest that seasonal habitat selection by fish and water body morphology may influence the vulnerability of black bass to LIS.

The increased exploitation of deeper habitats that is facilitated by LIS exposes black bass to heightened levels of fishing mortality through cumulative factors. In catch-and-release-dominated fisheries, such as recreational or tournament black bass fishing, exploitation is primarily a function of delayed mortality rather than harvest (Allen et al., 2008). A primary concern in depths greater than 6 m is barotrauma (Feathers & Knable, 1983). The shift in angling pressure because of LIS may necessitate a greater emphasis on fizzing, the manual venting of the swim bladder, as a vital technique for mitigating gas expansion injuries (Brownscombe et al., 2017; Siepker et al., 2007). Although postrelease survival for fish that are released immediately remains generally high (Sass et al., 2018), the physiological stress of barotrauma is exacerbated by possession-based tournament formats. By increasing access to previously unavailable fish, LIS may exert a larger population effect than traditional harvest via repeated capture, live-well confinement, and barotrauma that compromise recovery and reduce overall survival probabilities (Keretz et al., 2018; Siepker et al., 2007). Furthermore, if LIS-driven catch rates enable more anglers to reach their bag limits during these events, the cumulative fishing mortality for the population could rise (Love, 2019; Love et al., 2017). Given that habitat quality influences the level of catch-and-release mortality that a fishery can sustain (Love, 2024), management efforts such as habitat restoration or creation (Allen & Tugend, 1995) paired with the continued promotion of safe handling best management practices are necessary to ensure the long-term stability of the fishery (Gilliland & Schramm, 2009).

A distinction between this study and recent evaluations of LIS efficacy is the use of a data set that accounts for angler avidity. Angler skill and avidity are correlated with the adoption of specialized angling tools, where highly committed anglers prioritize the acquisition of specialized gear and technology (Bryan, 1977; Ditton et al., 1992; Koemle et al., 2021). Consequently, if avidity is not standardized, disparities between LIS users and nonusers in standard creel surveys may be confounded with the skill of the user rather than the efficacy of the technology. By using Major League Fishing professional anglers, we accounted for avidity, providing a more isolated measure of LIS efficacy. Our findings indicate that across diverse fisheries, anglers with similar avidity do not generally catch significantly heavier black bass using LIS. Additionally, despite similar avidities, some fisheries, such as lakes Conroe and Murray, may be more conducive to increased catch rates with LIS use. For fisheries managers, these findings reinforce the need to measure the influence of LIS on exploitation in deference to avidity bias to ensure representative modeling of exploitation (Hunt et al., 2013).

The necessity of accounting for this bias may depend on the proliferation of LIS use among fisheries. Current creel surveys indicate that adoption rates vary significantly among angler populations, depending on location and time elapsed since the technology's inception. Henry et al. (2026) reported that 16% of anglers who were surveyed at Lake Talquin (Florida) used LIS. Similarly, 19% of surveyed license holders (1,550 respondents) by the Maryland Department of Natural Resources reported using LIS in February 2025 (R. A. Gary, unpublished data). Some fisheries exhibit higher adoption rates. Thornton and Wright (2023) found that approximately 62% of anglers who were fishing crappies and 48% of anglers who were fishing black bass at Oak Creek Reservoir, Texas, used LIS. In three other Texas reservoirs, Smith et al. (2025) reported that 49% to 67% of total fishing effort that was directed to three crappie fisheries was attributed to LIS users. These percentages may increase as the equipment becomes more affordable and popularized, as evidenced by Mississippi reservoirs where LIS use surged from 20% to 70% in just 3 years (Meals, personal communication). In fisheries with low LIS adoption, the efficacy of the technology is more likely to be confounded by angler skill. Therefore, continuous monitoring of both adoption rates and angler avidity is essential to accurately isolate the true effects of LIS.

The use of LIS has evolved from a resource for anglers to learn more about the subsurface environment they are fishing (Cooke et al., 2025) to a necessity for some anglers to maintain competitiveness in tournaments. For our study, we assumed that anglers used LIS to observe and purposely catch a fish during a period. However, anglers may have used LIS

Downloaded from academic.oup.com/najfm/advance-article/doi/10.1093/najfmt/vqag064/8780178 by Maryland Department of Natural Resources user on 02 September 2026

for other purposes during their periods, such as locating habitat or identifying areas where fish do not occur, thereby reducing the number of casts and search times for areas. Proactive restrictions may be necessary in some situations (Cooke et al., 2021). As a result of increased LIS use, the MDFWP reduced creel limits in their crappie fisheries in 2024 (Meals, personal communication). However, Smith et al. (2025) indicated that even with greater catch and harvest by anglers who use LIS, fishing mortality of crappies was unlikely to cause overfishing in Texas reservoirs where growth rates were high. Reflecting these concerns in competitive fishing, the Bass Anglers Sportsman Society joined Major League Fishing in 2026 by partially restricting use of LIS during their tournament season. Rather than concern for overfishing, these organizations implemented the restrictions to reduce the perceived unfair advantage among anglers and foster competitive balance. While establishing tournament regulations remains strictly the purview of private tournament organizations, the depth- and habitat-specific relationships identified in this study offer an objective, empirical baseline for directors who are seeking to voluntarily integrate biological and environmental insights into future tournament structures or conservation frameworks.

Historically, technological advancements have consistently increased fishing efficiency, often necessitating regulatory intervention to prevent overexploitation (Cooke et al., 2021; Post et al., 2002). The adoption of LIS represents the latest iteration of this trend, challenging resource managers on both ecological and social fronts. Although early management strategies have largely been reactive or based on ethical principles, further empirical research on the ecological effects of LIS will be critical for guiding future regulatory frameworks. For example, Smith et al. (2025) demonstrated that a fishery's population dynamics can account for an increased efficiency of the technology. However, our findings suggest that certain populations may still face heightened vulnerability, particularly when exploitation is driven by factors other than direct harvest. Quantifying these effects is further complicated by the fact that adoption of LIS among anglers remains varied, influenced by both financial cost and individual preferences for traditional fishing methods. Ultimately, as LIS technology continues to evolve, it will prompt ongoing discussions within the fisheries management and angling community regarding the intersection of technological efficiency and the ethics of the sport.

Data availability

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

Ethics approval

This research followed all state guidelines for tournament fish handling.

Funding

There is no funding to disclose while conducting this research.

Conflicts of interest

There are no conflicts of interest to disclose while conducting this research.

References

Allen, M. S., & Tugend, K. I. (1995). Effects of a large-scale habitat enhancement project on habitat quality for age-0 Largemouth Bass at Lake Kissimmee, Florida. In D. P. Philipp & M. S. Ridgway (Eds.), *Black bass: Ecology, conservation, and management* (Symposium 31, pp. 265–276). American Fisheries Society.

Allen, M. S., Walters, C. J., & Myers, R. (2008). Temporal trends in Largemouth Bass mortality, with fishery implications. *North American Journal of Fisheries Management*, *28*, 418–428. https://doi.org/10.1577/M06-264.1

Bates, D., Mächler, M., Bolker, B., & Walker, S. (2015). Fitting linear mixed-effects models using lme4. *Journal of Statistical Software*, *67*, 1–48. https://doi.org/10.18637/jss.v067.i01

Belcher, E., Hanot, W., & Burch, J. (2002). Dual-frequency identification sonar (DIDSON). In *Proceedings of the 2002 International Symposium on Underwater Technology* (Catalogue Number 02EX556, pp. 187–192). IEEE. https://doi.org/10.1109/UT.2002.1002424

Birdsong, M., Hunt, L. M., & Arlinghaus, R. (2021). Recreational angler satisfaction: What drives it? *Fish and Fisheries*, *22*, 682–706. https://doi.org/10.1111/faf.12545

Brownscombe, J. W., Danylchuk, A. J., Chapman, J. M., Gutowsky, L. F. G., & Cooke, S. J. (2017). Best practices for catch-and-release recreational fisheries: Angling tools and tactics. *Fisheries Research*, *186*, 693–705. https://doi.org/10.1016/j.fishres.2016.04.018

Bryan, H. (1977). Leisure value systems and recreational specialization: The case of trout fishermen. *Journal of Leisure Research*, *9*, 174–187. https://doi.org/10.1080/00222216.1977.11970328

Bunt, C. M., Jacobson, B., Fernandes, T., Ridgway, L., & McMeans, B. (2021). Site fidelity and seasonal habitat preferences of Largemouth Bass (*Micropterus salmoides*) in a temperate regulated reservoir. *Hydrobiologia*, *848*, 2595–2609. https://doi.org/10.1007/s10750-021-04582-1

Cooke, S. J., Neely, B. C., Hasler, C. T., Schooley, J. D., Brownscombe, J. W., LaRochelle, L., Danylchuk, A. J., Hunt, T. L., & Norman, J. D. (2025). Emerging live sonar technologies in freshwater recreational fisheries: Issues and opportunities. *Fisheries*, *50*, 66–74. https://doi.org/10.1093/fshmag/vuae003

Cooke, S. J., Venturelli, P., Twardek, W. M., Lennox, R. J., Brownscombe, J. W., Skov, C., Hyder, K., Suski, C. D., Diggles, B. K., Arlinghaus, R., & Danylchuk, A. J. (2021). Technological innovations in the recreational fishing sector: Implications for fisheries management and policy. *Review of Fish Biology and Fisheries*, *31*, 253–288. https://doi.org/10.1007/s11160-021-09643-1

Devall, B., & Harry, J. (1981). Who hates whom in the great outdoors: The impact of recreational specialization and technologies of play. *Leisure Sciences*, *4*, 399–418. https://doi.org/10.1080/01490408109512977

Downloaded from academic.oup.com/najfm/advance-article/doi/10.1093/najfmt/vqag064/8780178 by Maryland Department of Natural Resources user on 02 September 2026

Ditton, R. B., Loomis, D. K., & Choi, S. (1992). Recreation specialization: Re-conceptualization from a social worlds perspective. *Journal of Leisure Research*, *24*, 33–51. https://doi.org/10.1080/00222216.1992.11969870

Feathers, M. G., & Knable, R. R. (1983). Effects of decompression on Largemouth Bass. *North American Journal of Fisheries Management*, *3*, 86–90. https://doi.org/10.1577/1548-8659(1983)3<86:EODULB>2.0.CO;2

Fox, J., & Weisberg, S. (2019). *An R companion to applied regression* (3rd ed.). Sage.

Garmin. (2025). *Panoptix LiveScope system*. https://www.garmin.com/en-ZA/p/591379/

Gilliland, G., & Schramm, H. (2009). *Keeping bass alive: A guidebook for tournament anglers and organizers*. Bass Anglers Sportsman Society.

Hargrove, J. S., Allen, M. S., Weyl, O. L. F., Crandall, C. A. C., & Austin, J. D. (2018). Global patterns in the motivations and behaviors of tournament anglers targeting bedding bass. *North American Journal of Fisheries Management*, *38*, 334–345. https://doi.org/10.1002/nafm.10027

Henry, R. D., Strickland, P. A., & Winstead, M. R. (2026). Differences in catch rates of Black Crappie and Largemouth Bass anglers using forward-facing sonar in Lake Talquin, Florida. *North American Journal of Fisheries Management*, *45*, 993–1000. https://doi.org/10.1093/najfmt/vqaf083

Hummel, R. L., & Foster, G. S. (1986). A sporting chance: Relationships between technological change and concepts of fair play in fishing. *Leisure Sciences*, *8*, 31–54. https://doi.org/10.1080/00222216.1986.11969644

Hunt, L. M., Sutton, S. G., & Arlinghaus, R. (2013). Illustrating the critical role of human dimensions research for understanding and managing recreational fisheries within a social-ecological system framework. *Fisheries Management and Ecology*, *20*, 111–124. https://doi.org/10.1111/j.1365-2400.2012.00870.x

Keretz, K. R., Dinken, C. P., Allen, P. J., Colvin, M. E., & Schramm, H. L., Jr. (2018). The effect of water temperature, angling time, and dissolved oxygen on the survival of Largemouth Bass subjected to simulated angling and tournament handling procedures. *North American Journal of Fisheries Management*, *38*, 606–622. https://doi.org/10.1002/nafm.10058

Koemle, D., Beardmore, B., Dorow, M., & Arlinghaus, R. (2021). The human dimensions of recreational anglers targeting freshwater species in coastal ecosystems, with implications for management. *North American Journal of Fisheries Management*, *41*, 1572–1590. https://doi.org/10.1002/nafm.10672

Lenth, R. V. (2023). *emmeans: Estimated marginal means, aka least-squares means* (R package version 1.8.4-1) [Computer software]. https://CRAN.R-project.org/package=emmeans

Love, J. W. (2019). The wisdom of Thanos in fishery science: Why manage catch-and-release fisheries? *Fisheries*, *44*, 216–224. https://doi.org/10.1002/fsh.10219

Love, J. W. (2024). A GIS-based approach for managing catch-and-release fisheries. *Ecological Modelling*, *491*, Article 110674. https://doi.org/10.1016/j.ecolmodel.2024.110674

Love, J. W., Groves, M., & Williams, B. D. (2017). Fishing mortality and habitat loss affect Largemouth Bass fishery in the Potomac River (Maryland). *Journal of Fish and Wildlife Management*, *8*, 140–153. https://doi.org/10.3996/022016-JFWM-015

Matthias, B. G., Allen, M. A., Ahrens, R. N. M., Beard, T. D., Jr., & Kerns, J. A. (2014). Hide and Seek: Interplay of fish and anglers influences spatial fisheries management. *Fisheries*, *39*, 261–269. https://doi.org/10.1080/03632415.2014.903836

Moursund, R. A., Carlson, T. J., & Peters, R. D. (2003). A fisheries application of a dual-frequency identification sonar acoustic camera. *International Council for the Exploration of the Sea Journal of Marine Science*, *60*, 678–683. https://doi.org/10.1016/S1054-3139(03)00036-5

Munnelly, R. T., Castillo, J. C., Handegard, N. O., Kimball, M. E., Boswell, K. M., & Rieucau, G. (2024). Applications and analytical approaches using imaging sonar for quantifying behavioral interactions among aquatic organisms and their environment. *International Council for the Exploration of the Sea Journal of Marine Science*, *81*, 207–251. https://doi.org/10.1093/icesjms/fsad182

Neely, B. C., Koch, J. D., & Gido, K. B. (2023a). Effects of live-imaging sonar on Blue Catfish angler success, perception, and behavior. *Transactions of the American Fisheries Society*, *43*, 1765–1771. https://doi.org/10.1002/nafm.10958

Neely, B. C., Koch, J. D., & Gido, K. B. (2023b). Effects of live-imaging sonar on crappie catch rates in small impoundments. *Fisheries*, *48*, 49–53. https://doi.org/10.1002/fsh.10863

Pope, K. L., Allen, C. R., & Angeler, D. G. (2014). Fishing for resilience. *Transactions of the American Fisheries Society*, *143*, 467–478. https://doi.org/10.1080/00028487.2014.880735

Post, J. R., Sullivan, M., Cox, S., Lester, N. P., Walter, E. A., Shuter, N. B., Westover, P. A., Cornelisse, R. I. C., Gerhardt, D. R., & Thompson, B. D. (2002). Canada's recreational fisheries: The invisible collapse? *Fisheries*, *27*, 6–17. https://doi.org/10.1577/1548-8446(2002)027<0006:CRF>2.0.CO;2

R Core Team. (2023). *R: A language and environment for statistical computing* [Computer software]. R Foundation for Statistical Computing. https://www.R-project.org/

Sass, G. G., Gaeta, J. W., Allen, M. S., Suski, C. D., & Shaw, S. L. (2018). Effects of catch-and-release angling on a Largemouth Bass (*Micropterus salmoides*) population in a north temperate lake, 2001–2005. *Fisheries Research*, *204*, 95–102. https://doi.org/10.1016/j.fishres.2018.02.012

Scarnecchia, D. L., & Schooley, J. D. (2022). Trophies, technology, and timescape in fisheries management, as exemplified through Oklahoma's world record Paddlefish *Polyodon spathula*. *Fisheries*, *47*, 381–394. https://doi.org/10.1002/fsh.10764

Siepker, M. J., Ostrand, K. G., Cooke, S. J., Philipp, D. P., & Wahl, D. H. (2007). A review of the effects of catch-and-release angling on black bass, *Micropterus* spp.: Implications for conservation and management of populations. *Fisheries Management and Ecology*, *14*, 91–101. https://doi.org/10.1111/j.1365-2400.2007.00529.x

Downloaded from academic.oup.com/najfm/advance-article/doi/10.1093/najfmt/vqag064/8780178 by Maryland Department of Natural Resources user on 02 September 2026

Smith, D. R., Bennett, D. L., Norman, J. D., & Allen, M. S. (2025). Live-imaging sonar use in Texas crappie fisheries: Examining population-level responses due to potential increases in exploitation. *Fisheries*, *50*, 151–162. https://doi.org/10.1093/fshmag/vuae015

Thornton, B., & Wright, L. (2023). *Oak Creek Reservoir, 2022 fisheries management survey report* (Federal Aid Project F-221-M-4). Texas Parks and Wildlife.

Todd, B. L., & Rabeni, C. F. (1989). Movement and habitat use by stream-dwelling Smallmouth Bass. *Transactions of the American Fisheries Society*, *118*, 229–242. https://doi.org/10.1577/1548-8659(1989)118<0229:MAHUBS>2.3.CO;2

Winter, J. D. (1977). Summer home range movements and habitat use by four Largemouth Bass in Mary Lake, Minnesota. *Transactions of the American Fisheries Society*, *106*, 323–330. https://doi.org/10.1577/1548-8659(1977)106<323:SHRMAH>2.0.CO;2

Zellers, R. (2022). *Angler survey study shows no impact from live sonar*. Arkansas Game and Fish Commission.

Downloaded from academic.oup.com/najfm/advance-article/doi/10.1093/najfmt/vqag064/8780178 by Maryland Department of Natural Resources user on 02 September 2026