Fisheries, 2025, **50**, 66–74
https://doi.org/10.1093/fshmag/vuae003
Advance access publication: January 23, 2025
Perspective

Emerging live sonar technologies in freshwater recreational fisheries: Issues and opportunities

Steven J. Cooke[1,*], Ben C. Neely[2], Caleb T. Hasler[3], Jason D. Schooley[4], Jacob W. Brownscombe[1,5], Luc LaRochelle[1], Andy J. Danylchuk[6], Taylor L. Hunt[7], and Jacob D. Norman[8]

[1]Department of Biology and Institute of Environmental and Interdisciplinary Science, Carleton University, 1125 Colonel By Dr., Ottawa, Ontario, K1S 5B6, Canada
[2]Kansas Department of Wildlife and Parks, Emporia, Kansas, USA
[3]Department of Biology, The University of Winnipeg, Winnipeg, Manitoba, Canada
[4]Oklahoma Department of Wildlife Conservation, Jenks, Oklahoma, USA
[5]Fisheries and Oceans Canada, Great Lakes Laboratory for Fisheries and Aquatic Sciences, Burlington, Ontario, Canada
[6]Department of Environmental Conservation, University of Massachusetts Amherst, Amherst, Massachusetts, USA
[7]Victorian Fisheries Authority, Queenscliff, Victoria, Australia
[8]Texas Parks and Wildlife Department, Tyler, Texas, USA

*Corresponding author: Steven J. Cooke. Email: Steven_Cooke@carleton.ca

ABSTRACT

Debate about the potential benefits and risks of live sonar technology (also known as live imaging sonar and forward-facing sonar) in freshwater recreational fisheries includes growing discussions regarding regulation. Synthesizing sparse literature, experiences of the coauthors, and observations from traditional and social media, we revealed a varied range of potential outcomes for fisheries when this technology is used. Of particular concern is the ability to find fish that were previously cryptic and to target them in ways that increase capture efficiency (e.g., through snagging where legal or more accurately presenting lures or baits); thus, increasing catchability. Conflicting views within the recreational fishing community about the "fair chase" aspect of this technology have prompted discussions regarding regulations. We anticipate continued debate around this topic and hope that this paper will inspire more empirical research (ecological and human dimensions) to provide resource managers and the recreational fishing community with insights and guidance on how to ensure that live sonar is used in ways that benefit fisheries management and stakeholder interests.

INTRODUCTION

The efficiency of recreational anglers has increased significantly during the past century following innovations in tackle, equipment, and techniques. However, the past several decades have been characterized by rapid technological development that has catapulted fishing forward in ways that were unimaginable (Cooke et al., 2021). Even an angler attempting to stick with the basics will be hard pressed to find a fishing rod that is not engineered from space-age materials or hooks that have not been chemically sharpened. The recreational fishing sector represents big business (valued at over US$44 annually; https://bit.ly/3XRJpl1) with various manufacturers and vendors using creative marketing to sell anglers the latest gear that is intended to help catch fish—or perhaps to give the angler the confidence that they will be successful and hooking and landing their target species. Research and development by the fishing industry and transferrable innovations in other sectors (e.g., military), have modernized fishing. Moreover, social media and dedicated fishing channels enable information to be shared rapidly (Lennox et al., 2022), promoting new technology and techniques, encouraging anglers to embrace new fishing technology, and increased its accessibility (Cooke et al., 2021).

Fisheries managers are often left playing catch-up as new gears and technologies are developed and commercialized (Cooke et al., 2021). In most cases those innovations (e.g., a new lure color or fishing line or technique) are highly unlikely to have a meaningful impact on fish populations or aquatic ecosystems. However, on occasion, some changes garner the attention of the fisheries management community. Recent innovations in that

Received: June 16, 2024. **Revised:** August 24, 2024. **Accepted:** August 29, 2024

Figure 1. Angler in Australia using live sonar technology while fishing for Murray Cod. Photo Credit: Chris Galea.

respect include recreational-grade, commercially available live sonar (also known as live imaging sonar and forward-facing sonar) that provides unprecedented real-time imagery to help anglers locate and capture fish (See Figure 1; Cooke et al., 2021). Live sonar is often paired with other innovations, such as GPS features that allow anglers to plot their position on the water. Nowhere has the advent of live sonar been more visible than in competitive black bass *Micropterus* spp. events where many (most!) professionals have their boats rigged with live sonar and multiple displays to the point where their casting decks look like NASA mission control. Those early adopters are inspiring others to follow suit. Compared to older generation "fish finder" technologies, this equipment has increased the efficiency of avid anglers and created significant controversy. From anglers to fishing tournament organizers to resource managers, the merits of live sonar have increasingly become a point of discussion prompting dialogue (e.g., about "fair play"; see Hummell & Foster, 1986). Indeed, social media and traditional media outlets have been buzzing with diverse perspectives on whether such technology should be embraced or restricted (see Table 1).

Herein, we explore questions regarding this rapidly emerging and high-profile topic with a focus on outlining the issues and opportunities broadly within the recreational fisheries sector in freshwater environments. We do not pass judgement on whether this technology is "good or bad," but, rather, we simply raise issues that need to be considered (Figure 2). There is relatively little published work on this topic (literally a handful of studies thus far, although we are involved with or aware of many others in the works) so we rely heavily on the experience of the coauthors (who are all working on this in various ways) and our observations from traditional and social media where live sonar has been discussed extensively. Through this overview, we acknowledge the need for research to bolster an evidence-based approach to help guide decision making about the use of this technology.

TECHNOLOGY OVERVIEW

Fish finding technology is not a new tool for anglers and has been around for decades. The first generation of fish identifying sonars was a "flasher" (e.g., Lowrance Fish Lo-K-Tor) produced in 1957. Flashers have an internal spinning wheel that projects lights to depict the bottom of a waterbody, bottom composition, physical structure, and fish. This technology provided real-time data to anglers on what was directly below the surface with an acoustic cone angle between 8–20°. Around 1975, sonar companies began to incorporate thermal paper into their fish finders that printed a history of the detected fish and structure. This technology was then revolutionized in 1984 when liquid crystal displays replaced thermal paper (e.g., Humminbird LCR 2000). This technology, which is often referred to as dual spectrum (2D) sonar, is still used today and is standard equipment on fishing boats. These 2D sonar units have advanced over time and modern transducers have acoustic cone angles between ~50° (50 kHz) and ~15° (200

Table 1. Quotes from various online and print media articles about live sonar and its emergence in recreational fishing. What is noteworthy is the extent of debate occurring within the recreational fishing community about the benefits and risks of the technology, what it means for fishing, and what it means for fisheries management.

Quotes on live sonar and recreational fishing
"Literally redefining open water fishing, this technology offers a simple, yet profoundly impactful benefit: Seeing what's ahead of you before what's ahead of you sees you" (Brown, 2022).
"If you are not scoping, you are hoping" (No Specific Attribution. Something commonly stated by tournament anglers).
"With real-time visuals, anglers can now pinpoint the exact whereabouts of fish, giving them a distinct advantage in targeting specific areas" (Carter, 2024).
"Forward-facing sonar eliminates the guesswork and maximizes angling efficiency" (Brown, 2022).
"Covering water without this technology can quickly eat away at your fishing time and lead to an unsuccessful day if you're not around fish" (Hangg, 2024).
"Nowadays, if you don't have this technology, you are automatically handicapped so badly that you simply can't compete" (Cemele, 2024).
"The emergence of forward-facing sonar as an essential pro-fishing tournament tool is convincing weekend anglers that it's well worth it" (Brown, 2022).
"Ultimately, tournament fishing will need to strike a balance between incorporating emerging technologies and preserving traditional practices" (George, 2023).
"… it would be a mistake to continue to allow FFS in professional (B.A.S.S. tournament) events. It threatens the integrity of what true bass fishing is … You can't really understand how this technology undermines the sport unless you do it at my level" (Clark Wendlandt, Pro B.A.S.S. Angler, Public Facebook Post).
"The argument in this case isn't if we should have the technology, but rather how we manage the fishery because of it" (Robertson, 2024).
"When it comes to controversial technology like LiveScope, ActiveTarget, and Mega Live, there will never be a true right or wrong" (Cemele, 2024).

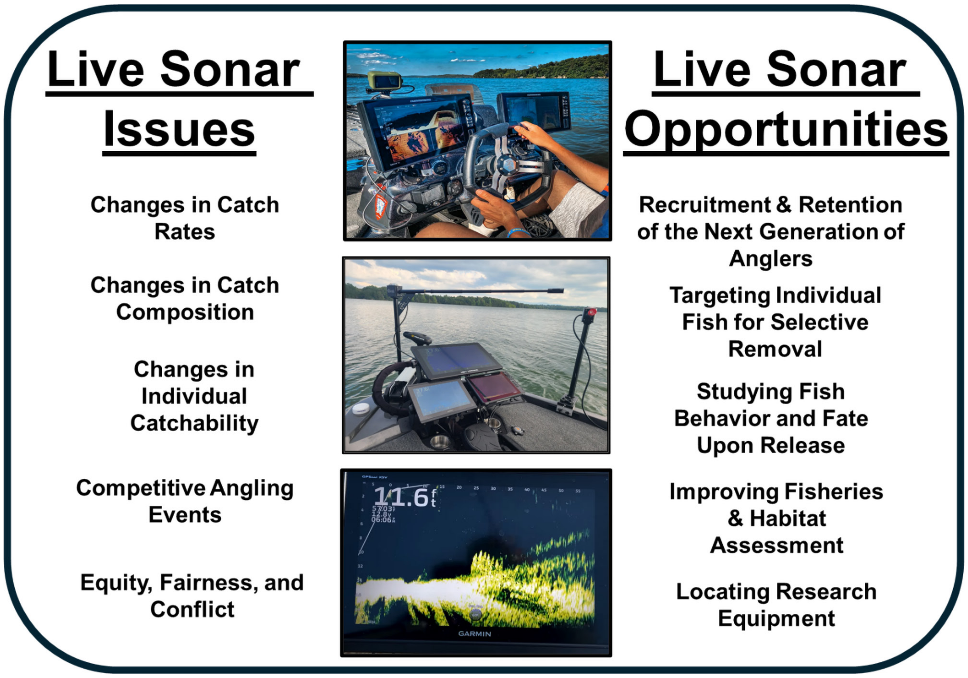

Figure 2. Summary of potential live sonar issues and opportunities as well as several images illustrating in practice what such technology looks like when deployed in a recreational fishing context.

kHz). In 2005, new technology became available that allowed anglers to get a snapshot recording of structure horizontally (side-to-side of the boat) rather than vertically (i.e., directly below). This technology, termed side imaging, provided a clear, slightly delayed (i.e., not real-time) picture of structure. This structure can be scanned up to 243 m away using transducers that emit frequencies from 455 kHz up to ~1 MHz and have a cone angle of 75° up to 86° (Humminbird Mega+), respectively. Further, in 2012 side imaging technology was modified to project images in a 360° format providing a historical picture of structure in a complete circle around the transducer.

More recently, a new sonar platform that shows images in real-time has become available for the recreational market and is constantly improving. This technology has existed for some time for military and research purposes (see Wei et al., 2022) but was expensive and not easily adaptable to a recreational context until recently. This first iteration of live imaging sonar for recreational use was launched by Garmin in 2015 (Panoptix), which was available in either a down- or forward-facing model. This model of live imaging transducer had a frequency of 417 kHz, a beam width of 120° x 20° (forward) or 120° x 90° (down), and a maximum depth of 91 m. The most recent version of live imaging uses transducers that have a frequency between 530 kHz and 1100 kHz and an expanded beam width of 135° x 20° (Garmin LVS 34). Paired with parallel advancements in color display technologies and computing power, modern live sonar transducers and high-resolution displays provide improved and clearer images.

Live sonar provides an instantaneous image in nearly three dimensions. This allows anglers to see how far away fish and bottom structure are, and the respective depths in real-time, rather than a delayed snapshot as was the case with older technology. Using live imaging sonar, anglers can now find fish and habitat at unprecedented distances and fish suspended in the water column without having to physically relocate by panning the transducer. Beyond finding, identifying, and size-approximating fish at a distance, live imaging sonar has provided anglers the ability to watch the behavior of fish as they swim and interact with lures across horizontal and vertical space. Live sonar outputs can also be streamed to augmented reality glasses so anglers do not have to look down at a screen (https://bit.ly/3ZGJUkq) or in professional tournaments those outputs can be fed directly to real-time broadcasts so viewers can watch what the angler is seeing.

ISSUES

Changes in catch rates

There is widespread belief in the angling community that in many situations, sonar—particularly live sonar—can increase angler efficiency and fish harvest. Wisconsin anglers aided by traditional sonar had greater catch rates than those unassisted (Feiner et al., 2020); however, evaluations of live sonar have limited or conflicting results. Creel surveys were used to assess catch and harvest of crappies (i.e., Black Crappie *Pomoxis nigromaculatus,* and White Crappie *P. annularis*) in Arkansas and Texas impoundments. In both states, anglers using live sonar captured more fish per hour than those without the technology. Harvest rates were similar between user groups in Arkansas (Zellers, 2022) but anglers using live sonar had greater harvest efficiency in Texas (D. Smith, Louisiana State University, personal communication). Creel data were also used to assess influence of live sonar use on catches in both open-water and ice fisheries in Minnesota with no discernable patterns observed (N. Rydell, Minnesota Department of Natural Resources, unpublished data). Controlled experiments were conducted in two Kansas impoundments to measure effects of live sonar on catches of crappies and Blue Catfish *Ictalurus furcatus* by casual anglers and no difference was detected between live sonar users and nonusers for either species (Neely et al., 2023a, 2023b).

Available research to this point suggests that live sonar may not be as universally advantageous to all anglers, as believed. However, there is evidence that some avid or skilled users (e.g., fishing guides, tournament anglers) may be more effective than anglers without access to live sonar. In Oklahoma, Paddlefish *Polyodon spathula* anglers assisted by licensed fishing guides using live sonar caught and released significantly more fish than unassisted anglers (Oklahoma Department of Wildlife Conservation, unpublished data). Additional study of how live sonar has affected catch efficiency of the most skilled and avid users would be beneficial to inform management as the technology improves, becomes more accessible, and new users become more skilled. Contextualizing catch rates and mortality, whether from harvest or release mortality, is needed to understand whether there are concerns for a given fishery. Although we were unable to locate any science on the topic, concerns have been raised about live sonar directly impacting fish behavior (and, thus, catch rates) either through the avoidance of live/high frequency sonar (note: fish hearing is restricted to low frequencies [Hawkins, 1981] so this is likely not an issue) or the fact that fish have been repeatedly chased/fished for by anglers using such technology.

Changes in catch composition

Live sonar can allow anglers to identify and target certain species and sizes of fish; thus, there are concerns that doing so may change the catch composition. If there are changes in catch composition through selective harvest or catch-and-release of larger fish, there are concerns that changes in population structure of targeted species could ensue. Conversely, if anglers can identify and target species and sizes, there is potential for greater angler satisfaction, reduced bycatch, and reduced impacts to nontarget individuals or species (e.g., avoiding spawning fish species during closed seasons). Quantitative studies investigating the impact of live sonar on catch composition to date are limited and results are mixed. Neely et al., (2023a) investigated concerns of anglers' selectively catching the largest crappies in the population in a Kansas reservoir using a controlled experiment and found no difference among live sonar users and nonusers in sizes of crappies caught. Similarly, Zellers, (2022) reported that creel surveys in Arkansas showed no statistical difference in the sizes of Crappie harvested. In contrast, in Oklahoma anglers assisted by licensed fishing guides using live sonar caught and kept significantly larger/older and more female Paddlefish than unassisted snag anglers (Oklahoma Department of Wildlife Conservation, unpublished data). In Australia, there is evidence that live sonar allows anglers to target and catch larger Murray Cod *Maccullochella peelii* (Victorian Fishing Authority, unpublished data). Greater quantitative data are required to understand changes in catch composition related to use of live sonar.

Changes in individual catchability

The use of live sonar has the potential to increase catchability, thus, removing the largely random element (see Lennox et al., 2017) that has historically been pervasive when angling. In essence, anglers can selectively target which fish to catch based on what they see in real time on their sonar. This was apparent at the 2024 B.A.S.S. event on the St. Lawrence River/Lake Ontario where professional angler Clark Wendlandt reflected on his experience and stated that he only casted at Smallmouth Bass *Micropterus dolomeiu* that were "at least 3 pounds" as evident from his live sonar equipment. Live sonar can enable anglers to find fish in habitats where they were previously de facto "protected" through cryptic seasonal habitat use. For example, in Texas reservoirs, trophy black bass (presumably a mix of Largemouth Bass *M. nigricans* and Florida Bass *M. salmoides*) are now being targeted in winter at depths of 10–15 m where they were previously difficult to target. Those fish are subject to extreme barotrauma with the potential for size-selective mortality. Increased catchability means there is a greater risk of hooking-mortality impacts and repeated effects of barotrauma, air exposure, and injuries.

Potential impacts on fish may vary based on whether anglers are targeting solitary versus schooling fish. For example, in the case of trophy species such as Murray Cod or Muskellunge *Esox masquinongy*, live sonar could be used to repeatedly cast, follow, and essentially harass trophy fish (that are presumably major contributors to breeding) and eventually induce a strike or alter behavior. In fact, we are aware of anecdotal reports from fishing guides in Oklahoma repeatedly targeting (with live sonar) and capturing numerous record-sized Paddlefish over time (identifying repeat captures from physical characteristics in photographs; Scarnecchia & Schooley, 2022) with unknown impacts on fish health and condition. Such issues could be magnified during the breeding period. For schooling species, like Yellowbelly *Macquaria ambigua* and crappies, the technology may be more focused on the school rather than individual fish, which could be less impactful than targeting individual fish. Another issue involves the increased catchability and targeting of previously uncatchable fish or aggregations, which could lead to hyperstability of catch rates, masking potential declines in abundance, assuming that managers are using angler catch rates as a proxy for abundance. In summary, live sonar facilitates catching fish that may have been previously less catchable, thus, removing the insurance policy that used to be provided by hidden/uncatchable fish. Moreover, if the selective removal or mortality of fish being targeted by live sonar represent a unique part of the population (e.g., unique traits), then artificial selection is possible.

Live sonar and competitive angling events

Views differ among fishing tournament organizers regarding the fairness of using live sonar. Motivations of tournament organizers in the permission or prohibition of such technology likely considers the perspectives of participants, spectators, corporate sponsors, and their organizational philosophies. Perhaps the most prominent group in freshwater fishing tournaments is the Bass Anglers Sportsman Society (B.A.S.S.; https://www.bassmaster.com), which announced in October 2023 the formation of a committee to examine the role of live sonar in competitive bass fishing—specifically, the "technology's impact on competition, fan experience, and bass populations" (B.A.S.S., 2023). The organization further cited that despite the technology being available since 2015, the investigative efforts are justified by accelerated adoption of this technology, eliciting, "Positive and negative response, especially during the latter half of the 2023 season." B.A.S.S. reported on those findings in early September of 2024. The proposed changes are too complex to fully share here (they vary across their series; see https://bit.ly/3zSv3Zv) but they include limiting the number and type of transducers (B.A.S.S. will provide a list of approved makes/models) and the screen surface area (55 in) on a boat (which was done at least in part for safety), and selecting some water bodies where live sonar would be less helpful (e.g., very shallow waters with extensive vegetation). In late summer of 2024, the National Professional Fishing League instituted an outright ban on use of live sonar during practice and competition, whereas Major League Fishing adopted rules more similar to B.A.S.S. but also instituted limits on the number of days an angler could use live sonar during an event.

Tournaments pursuing other taxa (and not sponsored by sonar manufacturers) have been quicker to prohibit live sonar. Upon witnessing the sudden impact of live sonar on tournament catches in July 2022, the Professional Musky Tournament Trail prohibited live sonar for the remainder of 2022 and subsequent trails (https://bit.ly/4dulb67). The decision to ban live sonar technology was based on direct polling of angler teams (T. Widlacki, Professional Musky Tournament Trail President/Tournament Director, personal communication). The long-held (est. 1978) and largest of its kind, annual Ozark Snagmasters Paddlefish Snagging Tournament on Lake of the Ozarks, Missouri, banned live sonar in April 2024, additionally labeling the event as a "NON-professional tournament." On the heels of the announcement, this reservoir yielded a new world record Paddlefish (74.76 kg) snagged using live sonar in March 2024, besting three previous live-sonar-aided world records from Oklahoma (Scarnecchia & Schooley, 2022). The nonprofit Touring Anglers Association (https://touringanglersassociation.com) evolved partly in response to the expansion of live sonar usage and has pledged to "Take bass fishing back to grass roots," by prohibiting usage of and requiring the removal of live sonar equipment to participate in their April 2024 Georgia tournament boasting $225,000 in cash prizes.

Fundamental to the argument supporting the use of live sonar in non-snagging tournaments is that no amount of sonar technology will force the fish to bite; therefore, the technology can only enhance the catches of an already-proficient angler. Within the technological advances that influence tournaments, "fairness" will likely continue to be individually defined. If the participants and fans of a fishing circuit are clamoring for a rule change, organizers will consider this within the larger goals of their organization. As stated in a recent angling article, some believe that "Ultimately, tournament fishing will need to strike a balance between incorporating emerging technologies and preserving traditional practices" (George, 2023).

Equity, fairness, and conflict

Based on narratives and discussions by anglers and angling organizations, equity and fairness related to live sonar devices deserves attention. From a financial point of view, the cost of this equipment ranges in the thousands of dollars. This investment may not be cost-prohibitive for avid anglers who spend tens of thousands of dollars on boats, trucks, tournament fees, etc.; however, capital costs are likely a barrier to use for new or casual anglers. Moreover, for shore anglers such technology is not readily usable. In Manitoba, Canada, fisheries managers have noted that trophy-seeking and/or tournament anglers are investing in live sonar but not the more harvest-oriented, casual anglers (C. Hasler, University of Winnipeg, personal communication). Ultimately though, from a financial point of view, the inequality between live sonar users and non-live sonar users may be a matter of desire and priorities. As such, the inequality is no different than what might exist for any other recreational activity.

There may, however, be a fairness and equity issue if live sonar devices increase the quality or quantity of fish captured, whereby anglers using live sonar disproportionately have access to more fish than anglers not using the technology. Some anglers (often from marginalized, economically depressed immigrant communities) depend on recreationally caught fish for food (Nyboer et al., 2022) and they would be highly unlikely to have access to live sonar technology. Fairness can also manifest in other ways. For example, in Australia, the Murray Cod has been referred to as a fish of 1,000 casts, and capturing Murray Cod > 1 m in length is considered a fish of a lifetime to many anglers. With live sonar devices, it is not uncommon for average anglers to capture a Murray Cod of a lifetime during their first few outings using live sonar, which presumably means more of these big fish are being captured. For example, it is reasonable to assume "x%" of angled fish will be either harvested intentionally or contribute to loss from the population because of post-release mortality. In the case of anglers who use live sonar, they may handle more fish due to the increase in angling success than the casual angler. Thus, from a total number of fish negatively impacted point of view, anglers using live sonar may have a greater impact on fish populations than casual anglers without access to such technology.

Not all anglers may view live sonar the same as some likely embrace the technology and claim to have a deeper appreciation for their target species and fish behavior. It could be argued that anglers with a deeper appreciation are also greater conservation and management advocates for the species they target. Others may believe live sonar is a detriment to their traditional fishing experience. Some Murray Cod anglers argue that the use of live sonar is resulting in a loss of "Murray Cod culture," where the experience of planning trips, fishing equipment, tactics, blind casts, and long hours immersed in nature that may eventually result in catching a big cod and be celebrated by friends and family, is being replaced with a different fishing experience due to live sonar. There are some groups on social media entirely focused on shaming those using this technology (see @livescope_losers_downunder). There are also some caveats. Avid anglers who fish in streams, shallow lakes, and water bodies are not likely to benefit from live sonar. Live sonar has the potential to further polarize subsectors within the recreational fishing community (Arlinghaus, 2005), which may dilute efforts for finding common ground among groups related to broader objectives of conservation and management of recreational fisheries.

A forthcoming study in Oklahoma by the Oklahoma Department of Wildlife Conservation (Jason Schooley, Oklahoma Department of Wildlife Conservation, personal communication) focused on fishing guides revealed that although only 46.5% of guides used live sonar, it was ranked as most important among other technologies and sources of information. By comparison, down-imaging sonar was used by 83.9% of guides and was ranked fifth according to importance. The study also revealed that within guides grouped by species targeted, users of live sonar were more harvest-oriented compared to nonusers. Future studies such as these will be needed to inform discussions about ethics as well as how and why such technology is being used by different groups.

REGULATION OF LIVE SONAR TECHNOLOGY

Fisheries management agencies may be increasingly lobbied by some stakeholders to consider regulating the use of live sonar in recreational fisheries. Regulation of recreational fisheries has been traditionally focused on a combination of creel bag and size limits (output controls), closed seasons and gear restrictions (input controls; Radomski et al., 2001; Cooke and Cowx, 2006). These measures help minimise the risk of overharvest, meet social expectations, and maintain the social and economic benefits of recreational fishing. Agencies may increasingly be asked to consider restricting the use of live sonar over fears of overfishing and fishing impacts, including changes in fish behavior and perceived unfairness. Angler values and the concept of "fair chase" are presumably on the minds of fisheries managers, but values-based restrictions (e.g., "fly fishing only") tend to be approached with caution because they limit participation, especially among less avid participants.

Suggestions on live sonar may include restricting use in some jurisdictions, fisheries for key species, or implementing live sonar "free waters" where the use of live sonar would be prohibited (akin to "fly only" or "lure only" waters in some recreational fisheries). The authors are unaware of any regulations for live sonar that have been implemented by a fisheries management agency. Recently, the Wisconsin Department of Natural Resources consulted stakeholders about the extent of support for banning the use of live sonar in all Wisconsin waters (https://bit.ly/4dujy8A).

Regulation of live sonar in recreational fisheries management has not occurred largely due to a lack of information, which indicates the need to do so. Overfishing, such as significant increases in fishing mortality, harvest rates, or changes in fish population size structure, or socio-economic impacts, such as reduced fishing satisfaction or participation (and associated impacts on local economies and livelihoods) have only begun to be documented (Kerkhove et al., 2024). In addition, the regulation of live sonar may be challenging as it potentially impacts live sonar equipment manufacturer trade and associated economic benefits. Additional considerations include negative impacts on small businesses relying on live sonar to generate revenue, such as fishing guides, tournament anglers, and equipment rental companies. Lastly, the enforcement of regulating live sonar may also be problematic in terms of (1) defining where live imaging sonar starts, compared with other recent sonar advancements, such as side imaging as well as various sonar frequencies and directions, and (2) defining who is catching the fish if a guide is using live sonar to target and hook a fish, yet a client may land the fish.

Given the yet-to-be-identified need to regulate live sonar, more proactive approaches to develop harvest frameworks that are resilient to increases in harvest and catch-and-release impacts may be useful. Proactive approaches can be implemented through the development of managed-harvest or manage-use frameworks that are resilient to changing angler dynamics and behaviors associated with adoption of emerging technologies (Scarnecchia & Schooley, 2022). For example, Oklahoma Paddlefish have traditionally only been available to snag anglers during spring spawning migrations upriver. Proliferation of live sonar in these fisheries has effectively opened snag opportunities year-round, creating concern about increased release mortality during warmer months. Rather than trying to regulate use of live sonar, a more effective approach may be to create a snagging season during periods of cooler water temperature.

We put forward that novel proactive management approaches, as opposed to reactive regulatory action on technology (discussed in Cooke et al., 2021) may be required in future regulation of recreational fisheries that incorporate the use of live sonar. Communication among fisheries management agencies whereby they share their experiences and concerns will be essential.

OPPORTUNITIES

Recreational-grade live sonar developed for anglers is more affordable and accessible than such gear made specifically for the military or science community and can easily be adapted to small boats used by most freshwater fisheries research and management bodies. For example, live sonar can be used to improve fisheries assessment and research. Live sonar shows potential for assessing abundance as has been documented with proof-of-concept studies in aquaculture ponds (Gutiérrez-Estrada et al., 2022), not unlike what is now being done with recreational-grade side scan sonar (e.g., Lawson et al., 2020; Wolfenkoehler et al., 2023). Live sonar has also been used for pilot studies to evaluate Blue Catfish electrofishing capture susceptibility. There is much opportunity to combine or compare live sonar with traditional fisheries independent sampling methods such as electrofishing and netting. Live sonar has been used to monitor the fate of world-record Paddlefish after snag–weigh–release and to assess the immediate (< 1 min) fate of Black Crappie showing signs of barotrauma released under ice. Also, when other techniques have been ineffective, live sonar has been used in Neosho River, Oklahoma, to selectively target large Bighead Carp *Hypopthalmicthys nobilis* for life history research and removal. From a habitat assessment perspective, live sonar has the potential to be used to quantify fish use of sunken trees, rock piles, and artificial structures, thus informing future habitat augmentation efforts or be used in telemetry studies to obtain detailed habitat data (e.g., Driscoll et al., 2024). It could also be used to identify spawning habitats or spawning activity in areas that are otherwise challenging to assess. For telemetry studies, live sonar could also be useful for locating and retrieving receiver infrastructure, which contains valuable data (Smith et al., 2024).

Despite concerns, live sonar may help to engage the next generation of anglers. For example, live sonar can help anglers learn about fish behavior and begin to make connections between habitat quality and fish habitat selection. Moreover, for younger anglers familiar with video gaming technology, live sonar represents the "gamification" of fishing. That has the potential to help address the four R's—recruitment, retention, and reactivation of license buyers, as well as relevancy among the younger generations. Fishing tournaments that use live sonar and are available on TV or on live Internet often visualize an angler's live sonar screen (as a screen within a screen) on top of the traditional angler video feed.

RESEARCH NEEDS RELATED TO LIVE SONAR

From the very first year live sonar was introduced to the public, anglers of all backgrounds and avidity have typically adopted one of two perspectives: (1) "Technology has gone too far," or (2) "It is legal and I want it." While the initial concerns surrounding this technology focused on the potential to overfish sport fish populations, information gleaned from early studies in Kansas, Arkansas, and Texas have demonstrated this to not be a warranted concern under all situations. Further, popular species such as black basses are typically catch-and-release fisheries. While traditional population dynamics (e.g., recruitment, growth, mortality) are still important, future research on sonar technologies would benefit from greater fishery-dependent data, such as catchability and human dimensions data. For example, how might anglers view increased access to fish that historically were exposed to minimal angling pressure? If a popular sport fish is receiving increasing pressure every year, could the proportion of naive, aggressive fish be decreased, ultimately resulting in reduced catch rates for all angler groups (i.e., contributing to fishing-induced evolution)? Another key question is what management strategies would be most effective for addressing any of the aforementioned concerns? How satisfied are anglers, both live sonar users and nonusers, with our fisheries? Have perceptions changed about what is considered a good or bad day of fishing? Is there a potential to drive a large divide among user groups, which could impact how often or where anglers fish? And how does the use of live sonar impact catches for anglers of different skill level. Live sonar may not be the silver bullet at the population level that many initially feared, but it has still been one of the most debated advancements in the fishing industry in several decades, if not longer. Fisheries scientists must first understand the underlying population dynamics of their fisheries, to determine if traditional population metrics are of concern. However, it will be imperative for scientists to closely monitor fishery dependent data closely as that is ultimately what fisheries management is based on. Addressing the aforementioned questions will require empirical studies (both natural science and social science) and perhaps modification of traditional monitoring activities (e.g., asking about use of live sonar in creel surveys or via angler apps; see Guiot et al., 2024).

CONCLUSIONS

The rapid emergence of affordable live sonar devices is being embraced by some in the recreational fishing community (Table 1). The technology is revolutionizing fishing and in doing so has raised a number of issues related to biology (e.g., potential for overfishing, selective harvest) and social conflict. Debate at tackle stores, on social media, and in traditional media about what live sonar means in terms of fairness will continue to reach fisheries managers and policymakers. Interestingly, the freshwater live sonar controversy was preceded in competitive saltwater fishing by "omnidirectional" sonar- reported to effectively de-

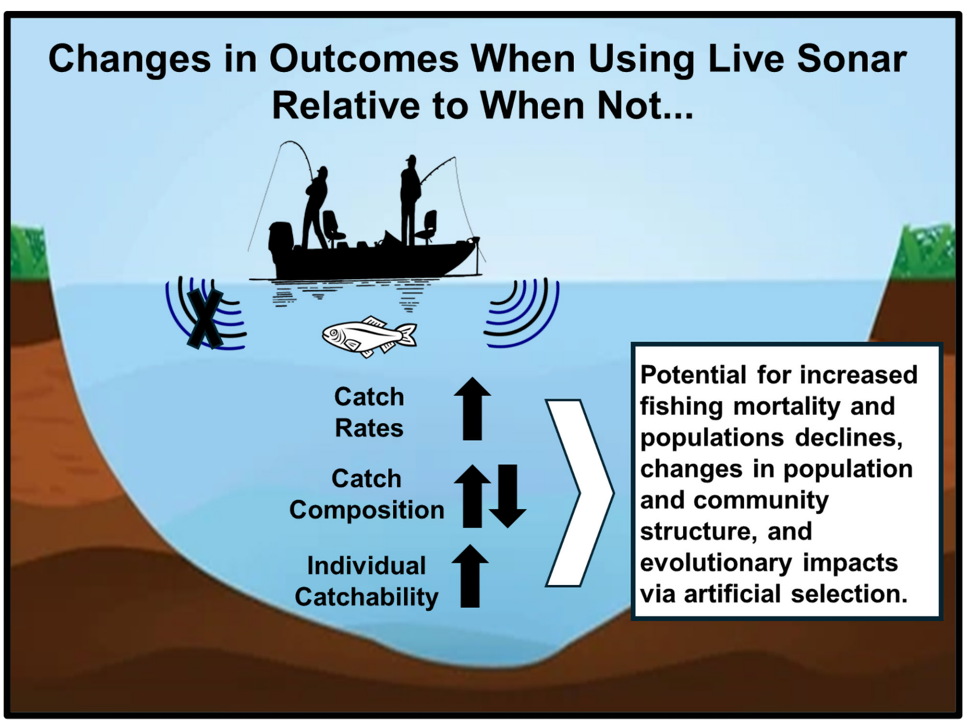

Figure 3. Potential changes in outcomes when using live sonar technology relative to when not in a recreational fishing context.

tect target fish from a mile away in all directions (see https://bit.ly/4eHTKax). There are potential opportunities for embracing this technology to support fisheries research and assessment while also focusing on connecting a new version of fishing (high technology!) with youth and new anglers. No technology is static and there are already suggestions that the next suite of innovations will involve artificial intelligence where algorithms will predict fish behavior and even suggest optimal fishing tactics (https://bit.ly/3NapVD3). It is worth asking whether fisheries professionals and anglers are overreacting to this issue. We have approached this paper from a neutral perspective, but also admit that within our authorship team we had diverse perspectives. What is clear is that there are major science gaps, many of which are not easily addressed and will require creativity. Those science gaps span the natural (e.g., fishery-dependent data to quantify potential fishery impacts) and social (e.g., understand perspectives of different stakeholders) sciences.

It is not the role of science to make management decisions; rather, it is to inform them. Decisions around use of live sonar will certainly need to be informed by science, and by the diverse stakeholders, rights holders, industry players, and user groups that are active in the recreational fishing arena. Efforts to revise management strategies to protect against any possible negative impacts of live sonar use (see Figure 3) will presumably be easier and more broadly palatable than regulating the technology itself but there may be instances where those efforts are also necessary. We must emphasize that this is a rapidly evolving research space with much work underway. Currently, the evidence base is sufficiently sparse that it is difficult (and indeed irresponsible) to make broad generalizations about the impact of live sonar on freshwater fisheries. Efforts to rush to conclusions (good or bad) about the consequences of live sonar need to be tempered with that reality. As the evidence base grows there will be need for additional synthesis to inform and enable evidence-based decision making. Although we focused here on freshwater contexts, we also encourage similar research and discourse related to marine recreational fisheries.

CONFLICTS OF INTEREST

S. J. C. and A. J. D. are both on the editorial board of *Fisheries* but were not involved in the handling of the manuscript. All coauthors are avid anglers and practicing fisheries professionals.

ACKNOWLEDGMENTS

We thank our colleagues and other members of the recreational fisheries community in sharing ideas that became the basis for this work. This is a perspective article and despite our efforts to be impartial, non-judgemental, non-prescriptive, and balanced we note that our perspectives may different from those of our employers. We are grateful to two anonymous referees for providing thoughtful comments on our paper.

REFERENCES

Arlinghaus, R. (2005). A conceptual framework to identify and understand conflicts in recreational fisheries systems, with implications for sustainable management. *Aquatic Resources, Culture and Development*, *1*, 145–174. https://doi.org/10.1079/ARC200511

B.A.S.S (Bass Anglers Sportsman Society). (2023, October 13). B.A.S.S. creates committee and institutes technology reviews for 2024 Elite Series season. https://bit.ly/3Tss4hf

Brown, D. A. (2022, April 15). Eyes on the prize: forward-facing sonar eliminates the guesswork and maximizes angling efficiency. *Wide Open Spaces*. https://bit.ly/3ZoYk8M

Carter, B. (2024, April 24). How far is too far? The controversy surrounding forward facing sonar in professional bass fishing. The Bass Cast. https://bit.ly/4eoFUcv

Cermele, J. (2024, January 2). The unwinnable battle over forward-facing sonar. *Outdoor Life*. https://bit.ly/3B3dkPv

Cooke, S. J., & Cowx, I. G. (2006). Contrasting recreational and commercial fishing: searching for common issues to promote unified conservation of fisheries resources and aquatic environments. *Biological Conservation*, *128*, 93–108. https://doi.org/10.1016/j.biocon.2005.09.019

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. *Reviews in Fish Biology and Fisheries*, *31*, 253–288. https://doi.org/10.1007/s11160-021-09643-1

Driscoll, M. T., Norman, J. D., Bennett, D. L., Metz, B. K., & Smith, D. R. (2024). Movement, home range, and structural habitat use of the Largemouth Bass complex in two large Texas reservoirs. *North American Journal of Fisheries Management*, *44*, 572–589. https://doi.org/10.1002/nafm.10996

Feiner, Z. S., Latzka, A. W., Wolter, M. H., Eslinger, L. D., & Hatzenbeler, G. R. (2020). Assessing the rage against the machines: do ice anglers' electronics improve catch and harvest rates? *Fisheries*, *45*, 327–333. https://doi.org/10.1002/fsh.10427

George, J. (2023, September 13). The biggest controversy in bass fishing: forward facing sonar. *Guidefishing*. https://bit.ly/4eo85rJ

Guiot, D. L., Lundgren, S. A., Phelps, Q., Kim, H., & Lynott, S. (2024). Evaluating exploitation of White Crappie and Black Crappie in three southeast Kansas Rreservoirs. *Journal of Applied Ichthyology*, *2024*, 7632622. https://doi.org/10.1155/2024/7632622

Gutiérrez-Estrada, J. C., Pulido-Calvo, I., Castro-Gutiérrez, J., Peregrín, A., López-Domínguez, S., Gómez-Bravo, F., Garrocho-Cruz, A., & de la Rosa-Lucas, I. (2022). Fish abundance estimation with imaging sonar in semi-intensive aquaculture ponds. *Aquacultural Engineering*, *97*, 102235. https://doi.org/10.1016/j.aquaeng.2022.102235

Hanggi, S. (2024, February 16). Advantages and disadvantages of forward-facing sonar. *Wired2Fish*. https://bit.ly/3XnsfeL

Hawkins, A. D. (1981). The hearing abilities of fish. In *Hearing and sound communication in fishes*, (pp. 109–137). Springer.

Hummel, R. L., & Foster, G. S. (1986). A sporting chance: relationships between technological change and concepts of fair play in fishing. *Journal of Leisure Research*, *18*, 40–52. https://doi.org/10.1080/00222216.1986.11969644

Kerkhove, A. M., Trudeau, A., Jensen, O. P., Isermann, D. A., Dombrowski, P. A., Latimer, A. M., & Feiner, Z. S. (2024). Understanding the role of recreational angling technology in angler expectations of catch, trip catch, and angler satisfaction. *Fisheries*, *49*, 464–475. https://doi.org/10.1002/fsh.11157

Lawson, K. M., Ridgway, J. L., Mueller, A. T., Faulkner, J. D., & Calfee, R. D. (2020). Semiautomated process for enumeration of fishes from recreational-grade side-scan sonar imagery. *North American Journal of Fisheries Management*, *40*, 75–83. https://doi.org/10.1002/nafm.10373

Lennox, R. J., Alós, J., Arlinghaus, A., Horodysky, A., Klefoth, T., Monk, C. T., & Cooke, S. J. (2017). What makes fish vulnerable to capture by hooks? A conceptual framework and a review of key determinants. *Fish and Fisheries*, *18*, 986–1010. https://doi.org/10.1111/faf.12219

Lennox, R. J., Sbragaglia, V., Vollset, K. W., Sortland, L. K., McClenachan, L., Jarić, I., Guckian, M. L., Ferter, K., Danylchuk, A. J., Cooke, S. J., Arlinghaus, R., & Twardek, W. M. (2022). Digital fisheries data in the Internet age: emerging tools for research and monitoring using online data in recreational fisheries. *Fish and Fisheries*, *23*, 926–940. https://doi.org/10.1111/faf.12663

Neely, B. C., Koch, J. D., & Gido, K. B. (2023a). Evaluating effects of live-imaging sonar on angler catch of crappies in a Kansas impoundment. *Fisheries*, *48*, 49–53. https://doi.org/10.1002/fsh.10863

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

Nyboer, E. A., Embke, H. S., Robertson, A. M., Arlinghaus, R., Bower, S., Baigun, C., Beard, D., Cooke, S. J., Cowx, I. G., Koehn, J. D., Lyach, R., Milardi, M., Potts, W., & Lynch, A. J. (2022). Overturning stereotypes: the fuzzy boundary between recreational and subsistence inland fisheries. *Fish and Fisheries*, *23*, 1282–1298. https://doi.org/10.1111/faf.12688

Radomski, P. J., Grant, G. C., Jacobson, P. C., & Cook, M. F. (2001). Visions for recreational fishing regulations. *Fisheries*, *26*, 7–18. https://doi.org/10.1577/1548-8446(2001)026%3C0007:VFRFR%3E2.0.CO;2

Robertson, R. (2024, February 27). More fishing and less drama. *In-Fisherman*, https://bit.ly/4gqDV9s

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

Smith, K. A., Bzonek, P. A., & Brownscombe, J. W. (2024). A novel technological approach to recover aquatic research equipment from depth. *Fisheries*, *49*, 263–268. https://doi.org/10.1002/fsh.11074

Wei, Y., Duan, Y., & An, D. (2022). Monitoring fish using imaging sonar: capacity, challenges and future perspective. *Fish and Fisheries*, *23*, 1347–1370. https://doi.org/10.1111/faf.12693

Wolfenkoehler, W., Long, J. M., Gary, R., Snow, R. A., Schooley, J. D., Bruckerhoff, L.A., & Lonsinger, R. C. (2023). Viability of side-scan sonar to enumerate Paddlefish, a large pelagic freshwater fish, in rivers and reservoirs. *Fisheries Research*, *261*, 106639. https://doi.org/10.1016/j.fishres.2023.106639

Zellers, R. (2022). *Angler survey study shows no impact from live sonar*, Arkansas Game and Fish Commission, Camden. https://bit.ly/3TagcxI