

ARTICLE

Oklahoma Bowfishing Values and Perspectives toward Nongame Fishes and Their Management

Betsey York* 

Oklahoma Department of Wildlife Conservation, Post Office Box 53465, Oklahoma City, Oklahoma 73152, USA

Jason D. Schooley 

Oklahoma Department of Wildlife Conservation, Post Office Box 1201, Jenks, Oklahoma 74037, USA

Dennis L. Scarnecchia

Department of Fish and Wildlife Sciences, University of Idaho, Moscow, Idaho 83844-1136, USA

Abstract

In response to lacking information on bowfishing, bowfishers, and management planning nationwide, a survey was sent to 15,000 licensed Oklahoma anglers (bowfishers and non-bowfishers) in 2021. Respondents ($n = 1,346$) were mainly male (73%) and white (74%), had an annual/5-year license (46%) or a lifetime license (39%), and had an average age of 48 (1,182 respondents provided demographics). Questions to bowfishers gauged the importance of bowfishing compared to other fishing activities; trip frequency and motivation; where, when, and which species were targeted; the utilization of fish taken; and attitudes regarding bowfishing regulations. An estimated 24% of licensed anglers had bowfished before. Bowfishing participation in the previous year had more than doubled (4% in 2018 to 9.1% in 2020). Most (57%) had bowfished for 3 years or less; 49% identified as beginners, 43% identified as intermediate, and 8% identified as advanced. Overall, most bowfishing occurred by day (54%), in early summer (May–July), from shore (49%), and in rivers and streams (67%) or reservoirs (53%). Bowfishers sought carps (85%), gars (74%), and buffalofishes (32%). Bowfishers typically used shot fish for fertilizer or buried them (48%), used them for animal consumption (35%) or human consumption (32%), or returned them to the water (20%). Compared to non-bowfishers, bowfishers reported a wider diversity of acceptable outcomes for fish species taken with any fishing method, particularly the nongame fishes. Most bowfishers (86%) and non-bowfishers (94%) trusted the state management agency to appropriately manage native, nongame fishes. Bowfishers were mixed on their support for or opposition to having bowfishing regulations for these species. Some respondents noted that regulations would result in them bowfishing less (23%) or quitting bowfishing completely (6%). Thirty-two percent of non-bowfishers expressed interest in bowfishing in the future. The results of this survey will be used in Oklahoma and elsewhere to aid in designing sustainable bowfisheries that serve the broader public interest while conserving native, nongame species.

Modern bowfishing, the taking of freshwater and marine fishes with a bow and arrow or crossbow, is widespread in North America and is regarded as one of the fastest growing types of recreational fishing in the United States (Schooley and Scarnecchia 2021). Recent reviews of the sport have highlighted that the technological

development and increased popularity of bowfishing have occurred with few or no regulatory controls to protect native, nongame fish species (Scarnecchia and Schooley 2020; Scarnecchia et al. 2021). Concurrently, recent life history research on native species commonly targeted by bowfishers, such as buffalofishes *Ictiobus* spp.

*Corresponding author: betsey.york@odwc.ok.gov

Received March 3, 2022; accepted May 20, 2022

(Catostomidae) and gars (Lepisosteidae), indicates that these species are long lived, may recruit irregularly or episodically, and generally employ life history strategies requiring the maintenance of larger, older females in the stocks (Lackmann et al. 2019, 2021; Daugherty et al. 2020; Snow et al. 2020; Radford et al. 2021). Mature female fish are often disproportionately targeted by bowfishing due to their larger size compared to males in most species (Quinn 2010; Kelley 2012; Stein et al. 2019). Native species taken continue to be held in low social regard, subjected to wanton waste, and deemed undeserving of protections on take (e.g., bag limits or size limits: Orth 2017; Scarnecchia and Schooley 2020; Schooley and Scarnecchia 2021) that are routinely afforded to sport fish species as necessary for their long-term conservation (Rypel et al. 2021; Scarnecchia et al. 2021).

Oklahoma has vibrant and growing recreational bowfisheries for a variety of native and nonnative, nongame species (Schooley and Scarnecchia 2021). Oklahoma Department of Wildlife Conservation (ODWC), the state's primary fisheries management agency, has in recent times come to view bowfishing as a sport deserving of proactive management. Oklahoma Department of Wildlife Conservation strives for sustainability of native species while potentially providing increased opportunities for take of invasive carps (Cyprinidae) and other nonnative fishes that are detrimental to native species conservation (Schooley and Scarnecchia 2021). Although the growth in bowfishing interest is positive from the perspective of a state agency recruiting, retaining, or reactivating fishing license buyers, it must also be practiced consistent with native species conservation, sustainable public benefits, and sound, long-term public policy (Scarnecchia and Schooley 2020; Lackmann et al. 2021).

Nationally, fundamental information on the many dimensions of bowfishing and bowfishers is lacking (Molinario 2019). Fewer than 10 papers have appeared on the sport—nearly all of them localized within portions of individual states and limited in the scope of information sought and provided. Quinn (2010) reported on the take of bowfishing from six Arkansas tournaments and identified Catostomidae (buffalofishes and suckers), gars (Lepisosteidae), and the Common Carp *Cyprinus carpio* as the most common fish taken. Bowfisher values, attitudes, and preferences were not surveyed. In South Dakota, Longmire (2012) surveyed hook-and-line angler opinions regarding bowfishers and bowfishing but did not survey the bowfishers. Molinano (2019) surveyed 576 bowfishers over 16 Illinois tournaments in 2017 and 2018 for species taken and angler preferences and habits. Bennett et al. (2015) surveyed a specialized demographic of bowfishers at three 2011 bowfishing tournaments for Alligator Gar *Atractosteus spatula* in the Trinity River, Texas, and via an online survey of Texas Bowfishing Association members. Lahn

(2018) developed policy recommendations regarding wanton waste from bowfishing of stingrays of the Alabama coast. Scarnecchia and Schooley (2020) approached the history, development, and status of bowfishing from a wider, national perspective. However, human dimensions information on bowfishing at state, multi-state, regional, and national levels is lacking and has been identified as a primary need for better understanding the sport's often-avid participants (Bennett et al. 2015; Molinano 2019; Scarnecchia and Schooley 2020).

As a first step toward that goal, we report on a state-wide, in-depth bowfishing survey of fishing license holders by ODWC involving both bowfishers and non-bowfishers. The primary objective of the survey was to obtain baseline information on values, attitudes, perspectives, and preferences about this understudied sport from its largely unsurveyed constituency (Lackmann et al. 2021) and from non-bowfishers licensed to fish. We sought perspectives of licensed non-bowfishers, beginning bowfishers, and advanced bowfishers on several national management challenges presented by the sport: social value of fishes, use of targeted fish, wanton waste, and take limits and other regulatory options. Information obtained was designed to provide relevant data for developing a sustainable management framework for the growing sport of bowfishing that provides angler opportunity while ensuring necessary species protections (Scarnecchia and Schooley 2020; Schooley and Scarnecchia 2021). The survey was also designed for formulating effective campaigns to educate bowfishers and non-bowfishers on the value of native and nongame fishes. Our survey was tailored for Oklahoma waters, species, and bowfishers. However, since there are no directed management plans strictly for bowfishing in any of the 50 states (Scarnecchia and Schooley 2020), we also prepared the survey with the intent of it being a useful template for surveys to be improved upon by other state, federal, or tribal agencies charged with managing bowfisheries in their regions and localities.

METHODS

The survey instrument.—The survey consisted of 47 questions (Appendix). After verifying the respondents' identities (question 1), the survey split respondents into two groups: bowfishers and non-bowfishers (question 2, required). Questions 3–22 were designed to broadly gauge bowfishers' general level of involvement in bowfishing; the importance of bowfishing compared to other fishing activities; how frequently, where, and when they bowfished; which species were targeted; and the ultimate utilization or fate of the fish taken. Within the survey, respondents were provided with a graphic depicting several species, a list of species common names, and a hyperlink to the fish identification section of the ODWC Web site. Questions 23–25 gauged bowfishers' attitudes regarding bowfishing

regulation by ODWC. Question 26 queried the suitable uses for nongame species typically targeted by bowfishing compared to the catch of game fishes by other fishing methods. Questions 27, 28, and 30 assessed bowfishers' motivations for participation in the sport, classifying seven possible factors motivating participation: trophies, taking many fish, seeing fish to target, being outside, seeing fish in general, enjoying time with family/friends, and the challenge of bowfishing. Factors were ranked on a scale of 1 (most important) to 7 (least important). Question 29 queried interest in participating in a future focus group on bowfishing. Questions 31–38 targeted non-bowfishers with fishing licenses and asked relevant parallel questions on factors motivating participation in their (non-bowfishing) methods. Questions 39–46 asked for demographic information of all respondents. Question 47 provided an opportunity for open-ended comment about bowfishing or fisheries management.

The survey was conducted using a push-to-Web methodology (Lynn 2020). We sent out two rounds of postcard invitations via the mail, as only 54% of Oklahoma's fishing license population database had a valid e-mail address on file. The invitation postcard included a quick response (i.e., QR) code to scan or a URL that could be entered into their Internet browser, both of which linked them to an online site containing the survey. The landing page asked for a uniquely assigned survey identification (ID) code from the postcard so that we could track respondents between the two mailings and ensure that each respondent was included only once in the final data set.

Sample selection.—The survey was sent to 15,000 randomly selected anglers from an altered population of resident fishing license holders. There is no specific license for bowfishing in Oklahoma. This group included all those with active fishing privileges from January 1, 2020, to June 23, 2021. We utilized results of a previous (2019) angler survey to inform the development of the altered population from which the survey recipients were selected. In the 2019 survey of licensed anglers in Oklahoma (York 2019), we asked respondents if they had bowfished in the past 12 months. Four percent had done so ($n = 1,361$). We evaluated the demographics of this 2019 respondent group and noted that the average age was about 10 years younger than the overall population of license holders. We drew a stratified random sample focused on a slightly younger age-group (average age = 43) to match the average age of bowfishers on the 2019 survey of statewide anglers (York 2019).

When comparing participation rates between fishing license holders on this survey and the previous statewide license holder survey (York 2019), we weighted the current survey results to align with the age structure of the fishing license holder population. Weighting factors (Table 1)

TABLE 1. Weighting factors (by age) used when comparing bowfishing survey responses to previous surveys of the general population of Oklahoma fishing license holders.

Age bin	Unweighted proportion of sample (%)	License holder population proportion (%)	Weighting factor
10–24	9.80	11.58	1.182
25–34	12.84	18.35	1.429
35–44	18.71	20.07	1.073
45–54	23.24	17.96	0.773
55–64	28.06	18.55	0.661
65+	7.35	13.36	1.818

ensured that assessments of bowfishing growth were not an artifact of sampling methods.

Invitation distribution.—The first postcard invitation to complete the online survey was sent to the 15,000 licensed anglers on July 16, 2021. The second postcard invitation was sent to 14,627 anglers on July 28, 2021. Between the two survey invitation postcards, we sent e-mail reminders to bowfishers with a valid e-mail address on file, which constituted 8,013 nonrespondents on July 27, 2021, and 7,357 nonrespondents on August 6, 2021. We also posted information about the survey on ODWC social media pages on July 28, 2021, to encourage those that had been invited to take part in the survey to follow the link they had received in the mail. The survey was not posted for all to participate.

Efforts were taken to ensure that little sampling bias was present. Several survey recipients called by telephone to inform us that they did not have access to a computer or the Internet. For those that contacted ODWC, the senior author (B. York) conducted their survey over the phone. Lack of Internet access was not a likely factor biasing response rate, as 88% of Oklahoma hunting license holders in 2020 reported having internet access (York 2021). However, certain nonrespondents did not receive e-mail reminders because they had opted out of our online survey software (1.0%) or because the e-mail was returned as undeliverable (5.5%). These nonrespondents did receive postal mail reminders to complete the survey.

To ensure accurate representation of the respondent population, care was taken to identify and remove (1) duplicate responses from individuals or (2) responses from individuals that were not in the original sample. If duplicate ID numbers were entered, only the more complete response was retained, and demographic data were checked against the demographics of the ID number in the original sample from the license database. Internet protocol (IP) addresses were also analyzed, and duplicates were removed where appropriate, which included nine

total entries removed (four from respondents who said they had bowfished and five from respondents who said they had not bowfished). Twenty-six respondents who did not bowfish and seven respondents who had bowfished did not enter an ID number; all were retained within the data set because these respondents passed the quality control measures.

Statistical analyses and margin of error.—Respondent subgroups were statistically compared (when sample sizes allowed) by using a chi-square (χ^2) test of significance within R statistical software. Statistical significance was evaluated at $\alpha = 0.05$. Paired comparisons had 1 df; otherwise, the df are individually reported. With the number of responses, at 95% confidence, when all bowfishers were used in an analysis we had a margin of error of 5–6%. This margin of error is generally accepted in the social sciences, particularly for an exploratory study looking at a new population of anglers that have not been surveyed before (Dillman et al. 2014). In some instances, when exploring specific subgroups of respondents our sample decreased to 100, which, at 95% confidence, predicted the population only within $\pm 10\%$ of what was reported. These latter results were viewed as trends in data rather than statistically verified, especially if there was little difference between response categories. Statistical significance testing was only performed on sample sizes for which the margin of error remained below 6%.

RESULTS

We received 1,346 responses from our sampled fishing license holders. Out of 15,000 invitations, we were notified that two invitations were sent to deceased license holders. Although we did have 445 e-mail invitations bounce and 80 respondents who had opted out of e-mails, these individuals received mail invitations. Removing the two known-deceased fishing license holders from our possible contacted anglers, our effective response rate was 9.0%.

Demographics

The respondent sample was 73% male and 27% female ($n = 1,182$), which closely approximated the sex ratio within the population of resident fishing licenses sold (72% male and 28% female). Among those respondents who bowfished, 90% were male; among non-bowfishers, 68% were male. The respondent average age was 48; the average age of the license holder population was 43. No significant differences were found between bowfishers and non-bowfishers in income ($\chi^2 = 9.56$, $df = 7$, $P = 0.22$) or race/ethnicity ($\chi^2 = 7.01$, $df = 8$, $P = 0.54$). Among bowfishers (mean age = 45.4), 56% had lifetime angling licenses, whereas only 34% of non-bowfishers (mean age = 48.2) had lifetime licenses ($\chi^2 = 44.37$, $P < 0.001$).

Bowfishing Activity and Importance

Twenty-four percent of all respondents had bowfished in Oklahoma at some point in their life ($n = 1,364$). Of those that had bowfished in the past, only 38% (101 bowfishers) had bowfished in the most recent 12-month period; therefore, an estimated 9.1% of licensed resident anglers in 2020 had bowfished in the most recent 12-month period. The most popular fishing method used in the most recent 12-month period by those that had bowfished was, in order: (1) rod and reel, (2) bowfishing, and (3) juglines. Among those that had bowfished in the most recent 12-month period, only 6% said that bowfishing was their most commonly practiced fishing method. Bowfishers more commonly used a greater diversity of fishing methods (excluding bowfishing) in a year compared to non-bowfishers (e.g., more juglines, noodling, trotlines, and limblines; $\chi^2 = 48.03$, $df = 4$, $P < 0.001$; Figure 1). For all subsequent analyses, all bowfishers, whether they had participated in the past 12 months or not, were included in results. In terms of the importance of bowfishing when compared to other fishing activities, only 6% of bowfishers said that bowfishing was more important, 35% said that it was equally important, and 59% said that it was less important.

Bowfishing Skill and Experience

Bowfishers reported participating in the sport an average of 10 d/year compared to an average of 56 d participating in any fishing method. When asked to self-rate their skill in bowfishing ($n = 263$), only 8% of bowfishers rated themselves as advanced, 43% rated themselves as intermediate, and 49% rated themselves as beginners. Too few respondents self-rated as advanced to allow confidence in prediction from this group. Therefore, intermediate and advanced categories were thereafter combined into an “experienced” category (50.6% of bowfisher respondents) for

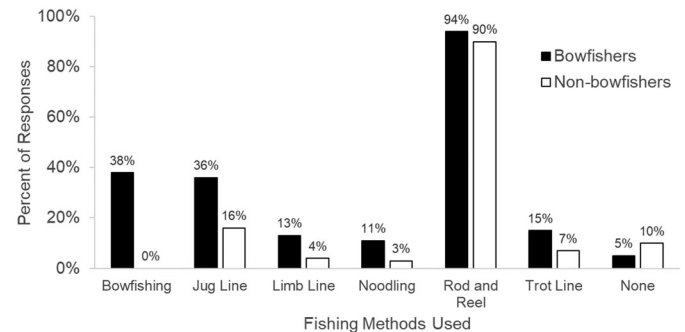


FIGURE 1. Oklahoma bowfishers ($n = 265$) and non-bowfishers ($n = 957$) were identified based on the respondents' stated participation in the sport. Respondents were secondarily asked what fishing methods they used in the previous 12 months.

comparison against the beginner category (49.4% of bowfisher respondents).

Number of years of bowfishing experience was examined as an indirect rating of participation and avidity. The number of years bowfished was evenly distributed, with 27% reporting as having bowfished less than 1 year, 30% reporting 1–3 years, 18% reporting 4–10 years, and 24% reporting more than 10 years (Figure 2). Years of experience in bowfishing was not necessarily correlated with a bowfisher's self-assessment of skill; 96% of those who had bowfished less than 1 year rated themselves as beginners, whereas only 23% of those who had bowfished more than 10 years rated themselves as advanced.

Information on Bowfishing Trips

Bowfishing participants reported traveling an average of 51 km one way for their fishing trips. The highest months of participation were May, June, and July. Fifty-four percent of bowfishers participated mainly during the day, 29% participated mainly at night, and 16% participated about equally during day and night. Bowfishers who rated themselves as beginners reported bowfishing more commonly during the day (61%) compared to only 48% of experienced bowfishers ($\chi^2 = 8.86$, $P = 0.01$). Forty-nine percent of participants reported bowfishing mainly from the shore, 35% reported bowfishing mainly from a boat, and the remainder reported bowfishing about equally from shore and from a boat. Beginners were more likely to bowfish from the shore (61%), whereas experienced individuals bowfished from the shore or from a boat equally (each 38%). Most night bowfishing was done from a boat (76%), whereas most day bowfishing was done from the shore (76%). When asked if they primarily bowfished recreationally or competitively, 92% of bowfishers only bowfished recreationally, 6% occasionally bowfished competitively, and 3% bowfished recreationally and competitively about equally. Bowfishers most commonly fished rivers and streams (67% of respondents), followed by

reservoirs (53%), ponds (27%), and tailwaters below dams (26%). More night bowfishing was done in reservoirs (66% of respondents selected this option) than in rivers (54%); rivers were bowfished more during the day (74%) than reservoirs (43%).

Locations of the most frequently reported bowfishing sites in the state were categorized into five regions: northeast (NE), southeast (SE), southwest (SW), and northwest (NW), with additional locations within the Oklahoma City metropolitan area classified as “Central.” A slight majority of response locations were clustered in the NE (51%), and a vast majority of responses were in the eastern half of the state (NE and SE combined; 83%), which can be associated with the more numerous large reservoirs in eastern Oklahoma and matches the general trend of fishing pressure in Oklahoma. The most popular locations identified by bowfishers were all reservoirs: Fort Gibson Lake (21 responses), Grand Lake (20), Lake Texoma (16), and Lake Eufaula (16). The most popular rivers identified were the Arkansas River (13 responses) and the Red River (10). However, many rivers in Oklahoma span multiple regions of the state so the responses on usage of rivers could not be categorized by region.

Bowfishing Species Preference and Take

When respondents were asked which one or more of three species groups (carps, gars, or buffalofishes) they typically targeted while bowfishing, 85% of respondents selected carps, 74% selected gars, and 36% selected buffalofishes. In Oklahoma, the following species may be encountered within the carp, gar, and buffalofish groups, respectively: Bighead Carp *Hypophthalmichthys nobilis*, Black Carp *Mylopharyngodon piceus*, Common Carp, Grass Carp *Ctenopharyngodon idella*, and Silver Carp *H. molitrix*; Alligator Gar, Longnose Gar *Lepisosteus osseus*, Shortnose Gar *L. platostomus*, and Spotted Gar *L. oculatus*; and Bigmouth Buffalo *Ictiobus cyprinellus*, Black Buffalo *I. niger*, and Smallmouth Buffalo *I. bubalus*. Two respondents wrote in responses for Freshwater Drum *Aplodinotus grunniens*, and one person wrote in catfish (Ictaluridae), of which only Flathead Catfish *Pylodictis olivaris* can be legally taken with bowfishing in Oklahoma. When asked to select which species group they most preferred to target, 46% of respondents selected gars, 44% selected carps, and 8% selected buffalofishes. A follow-up question asked respondents which species group they most often ended up shooting/attempting to shoot. Forty-eight percent selected carps, 41% selected gars, and 8% selected buffalofishes (Figure 3). When experienced and beginner bowfishers were compared, both groups tended to prefer similar species, with beginners slightly preferring carps and experienced bowfishers narrowly preferring gars, but results did not meet statistical significance ($\chi^2 = 6.57$, $P = 0.09$). Experienced bowfishers also showed a greater

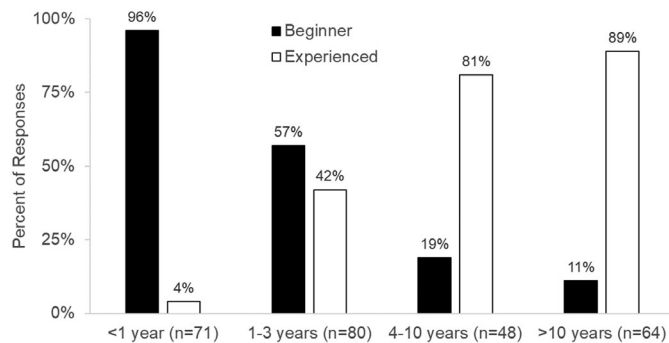


FIGURE 2. Experience level (years) of Oklahoma bowfishing survey respondents categorized by self-assessed rating of experience. Self-ratings of intermediate and advanced were pooled as “experienced.”

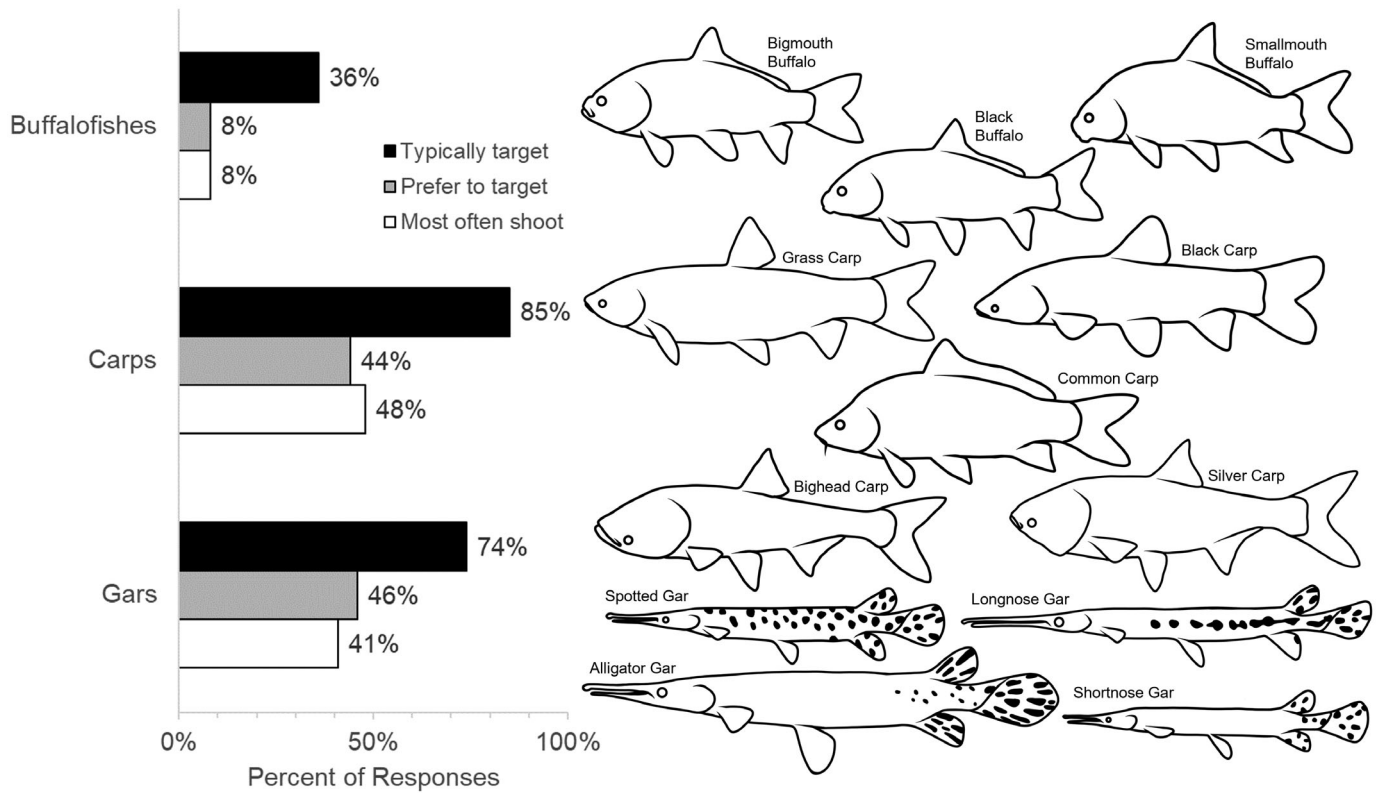


FIGURE 3. Species groups identified by Oklahoma bowfishing survey respondents ($n = 257$) as most typically targeted (multiple selections allowed), preferred to target, and most often shot. Illustrations courtesy of H. Hershey.

preference (11%) than beginners (4%) for buffalo-fishes (Table 2).

In comparing the type of water body and the species group most preferred, gars tended to be more highly targeted by bowfishers in rivers and tailwaters below dams. In ponds and reservoirs, bowfishers targeted gars and carps similarly (Table 3). Carps were more preferred by daytime bowfishers, whereas gars were more preferred by night bowfishers, but results did not meet statistical significance ($\chi^2 = 9.74, P = 0.14$).

The mean take of fish per species group per bowfishing trip, across all water body types, was 4.03 gars, 4.21 buffalo-fishes, 5.14 carps, and 1.67 fish whose species identification was uncertain (i.e., reported as “unsure of species” by bowfishers; Table 3). Although the total daily individual take reported by bowfishers ranged as high as 95 fish,

TABLE 3. Average reported daily take by Oklahoma bowfishers among different fish taxonomic groups and water body types.

Waterbody type	Average reported daily take		
	Carps	Gars	Buffalo-fishes
Reservoirs	5.70	4.18	4.70
Ponds	3.64	3.62	3.83
Tailwaters below dams	5.20	4.83	5.81
Rivers and streams	5.23	4.16	4.36
Overall	5.14	4.03	4.21

including 45 gars, 35 buffalo-fishes, and 15 carps, only 8% of bowfishers reported taking more than 20 fish, 15% reported taking 15 or more fish, and 30% reported taking

TABLE 2. Proportions of take by fish taxonomic group and average numbers of fish taken per trip for Oklahoma bowfishers that were self-rated as experienced or beginner.

Bowfisher category	Carps (%)	Gars (%)	Buffalo-fishes (%)	Other (%)	Average number of fish taken per trip
Experienced ($n = 131$)	38	48	11	3	12.16
Beginner ($n = 124$)	50	44	4	2	5.00

10 or more fish in an average trip. While the number of bowfishers who reported participating in competitive bowfishing tournaments was low ($n = 21$; 8%), these individuals reported higher estimated daily take (16.5 fish) than recreational bowfishers (8.4 fish).

A Successful Trip: Motivations and Desired Outcomes

Both bowfishers and non-bowfishers were queried on the characteristics of a successful fishing or bowfishing trip. Bowfishers were asked to rank seven proposed factors about both bowfishing and non-bowfishing trips from 1 (most important) to 7 (least important; Table 4), whereas non-bowfishers were asked only to rank the same factors about non-bowfishing trips. For both groups, “time spent with family and/or friends” was consistently ranked as the most important factor, followed by “being outside.” Bowfishers ranked “challenging fish to shoot” as the reason least likely to contribute to a successful fishing trip. For non-bowfishers, “catching a lot of fish” was the factor related to fishing that rated highest, while catching a trophy fish was rated lowest. Responses generally indicated that both bowfishers and non-bowfishers prioritized more intrinsic aspects of their fishing activities rather than actual or quantifiable fishing achievements (Table 4).

Acceptable Outcomes for Fish Taken by Bowfishing

Bowfishers were asked to select all of the typical outcomes of shot fish after their bowfishing trip. Thirty-five percent said animal consumption, 33% said fertilizer use, 32% said human consumption, 20% said return of fish to the water, and 15% said burial. Only four respondents said that they burned fish or discarded them at the boat ramp. Some bowfishers also wrote in responses that they gave away their shot fish to those that would eat them or they used fish taken as cut bait for catching other species. To explore potential differences in perceptions of acceptable outcomes of taken fish between bowfishers and non-bowfishers, we asked both groups what they generally

believed were acceptable outcomes for six different types of fish, including game fishes (black basses *Micropterus* spp., catfishes, and trouts) and nongame fishes (carps, gars, and buffalofishes). Bowfishers typically selected a more diverse spread of acceptable outcomes, particularly for the nongame species targeted by bowfishing (Figure 4). Bowfishers and non-bowfishers tended to agree that the acceptable outcomes for black basses, catfishes, and trouts included human consumption or return of fish to the water (presumably an immediate, live release, as is typical in catch-and-release fisheries). An interesting result was that human consumption of black basses was regarded as an acceptable outcome for bowfishers but less so for non-bowfishers (Figure 4). Additional examination of acceptable outcomes was provided through the aggregation of species into different groups or subgroups: game (black basses, catfish, and trout); nongame (buffalofishes, carps, and gars); native, nongame (buffalofishes and gars); and nonnative, invasive (carps). Both bowfishers and non-bowfishers reported that game fishes were more acceptable for human consumption than nongame fishes ($\chi^2 = 323.43$, $P < 0.0001$ and $\chi^2 = 2,035.91$, $P < 0.0001$, respectively), with the latter reported as more likely to be buried or used as fertilizer (Figure 5). However, responses of both bowfishers ($\chi^2 = 6.95$, $P < 0.01$) and non-bowfishers ($\chi^2 = 13.79$, $P < 0.001$) indicated that burial or use as fertilizer was more acceptable for nonnative, invasive species than for native, nongame species. Neither group preferred native, nongame species more than nonnative invasives for human consumption (Figure 5).

Trust, Regulations, and Regulation Impacts

Eighty-six percent of bowfishers said that they trusted ODWC to appropriately manage native, nongame fishes targeted by bowfishers, while 8% said that ODWC should do more and 6% said that ODWC should do less. Among experienced bowfishers, 84% expressed trust in ODWC, whereas 88% of beginners expressed trust. Of those that

TABLE 4. Factors contributing to a successful fishing trip for bowfishers (bowfishing trip and non-bowfishing trip) and non-bowfishers. Factor scores (1 = most important; 7 = least important) are averaged (avg.) and ranked within fisher/trip combinations. Factors within rows were considered equivalent.

Bowfishing trip		Angling trip		
Factor	Rank (avg.)	Factor	Bowfishers rank (avg.)	Nonbowfishers rank (avg.)
Time spent with family/friends	1 (2.56)	Time spent with family/friends	1 (2.94)	1 (2.72)
Being outside	2 (2.84)	Being outside	2 (3.09)	2 (3.08)
Seeing the fish I intended to target	3 (3.63)	Seeing the fish I intended to target	6 (4.40)	5 (4.29)
Seeing any fish	4 (4.04)	Seeing any fish	7 (4.51)	6 (4.40)
Successfully shooting a lot of fish	5 (4.30)	Catching a lot of fish	3 (3.64)	3 (3.63)
Successfully shooting a trophy fish	6 (4.56)	Catching a large trophy fish	4 (4.15)	7 (4.68)
Challenging fish to shoot	7 (4.79)	Having a good fight with the fish	5 (4.22)	4 (4.20)

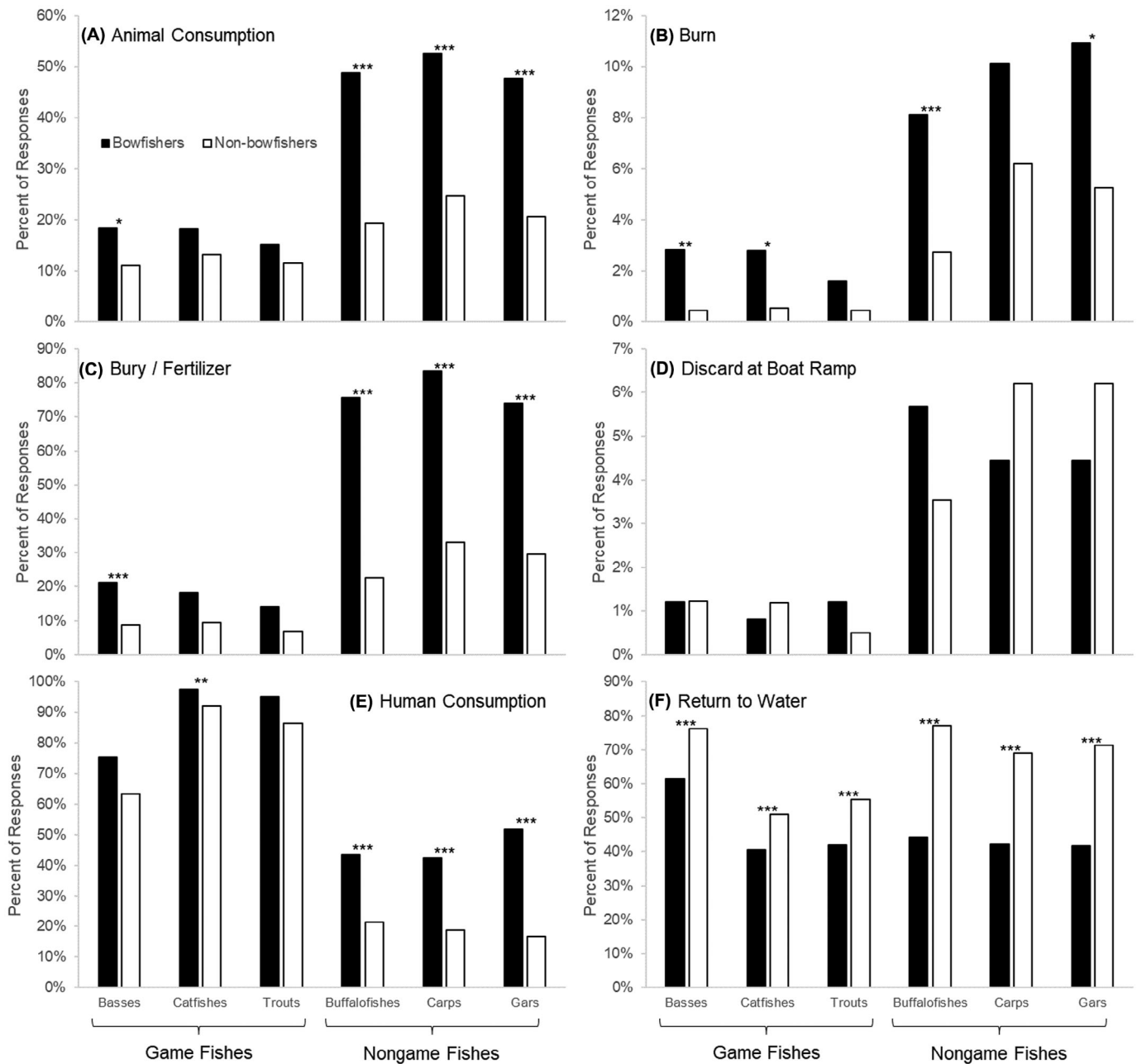


FIGURE 4. Acceptable outcomes (A)–(F) for game and nongame fish groups (caught with any fishing method) as reported by Oklahoma bowfishing survey respondents (bowfishers and non-bowfishers). Paired columns denoted by asterisks are significantly different (chi-square test: * $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$).

did not bowfish, 94% trusted ODWC management, while 4% said that ODWC should do more and 2% said that ODWC should do less.

When bowfishers were asked whether they would support or oppose bowfishing regulations for native, nongame species, the most selected answer was neutral (36%), followed by oppose (35%) and support (29%). There was no significant difference in support or opposition based on

bowfishers' most preferred species group target ($\chi^2 = 12.00$, $df = 12$, $P = 0.45$). Beginners were more neutral on regulations than experienced bowfishers (42% and 31%, respectively); experienced bowfishers tended to have more opposition toward regulations on native, nongame species compared to beginners (40% and 30%, respectively). Those that fished more days per year also tended to have stronger opposition to regulations (opposed respondents

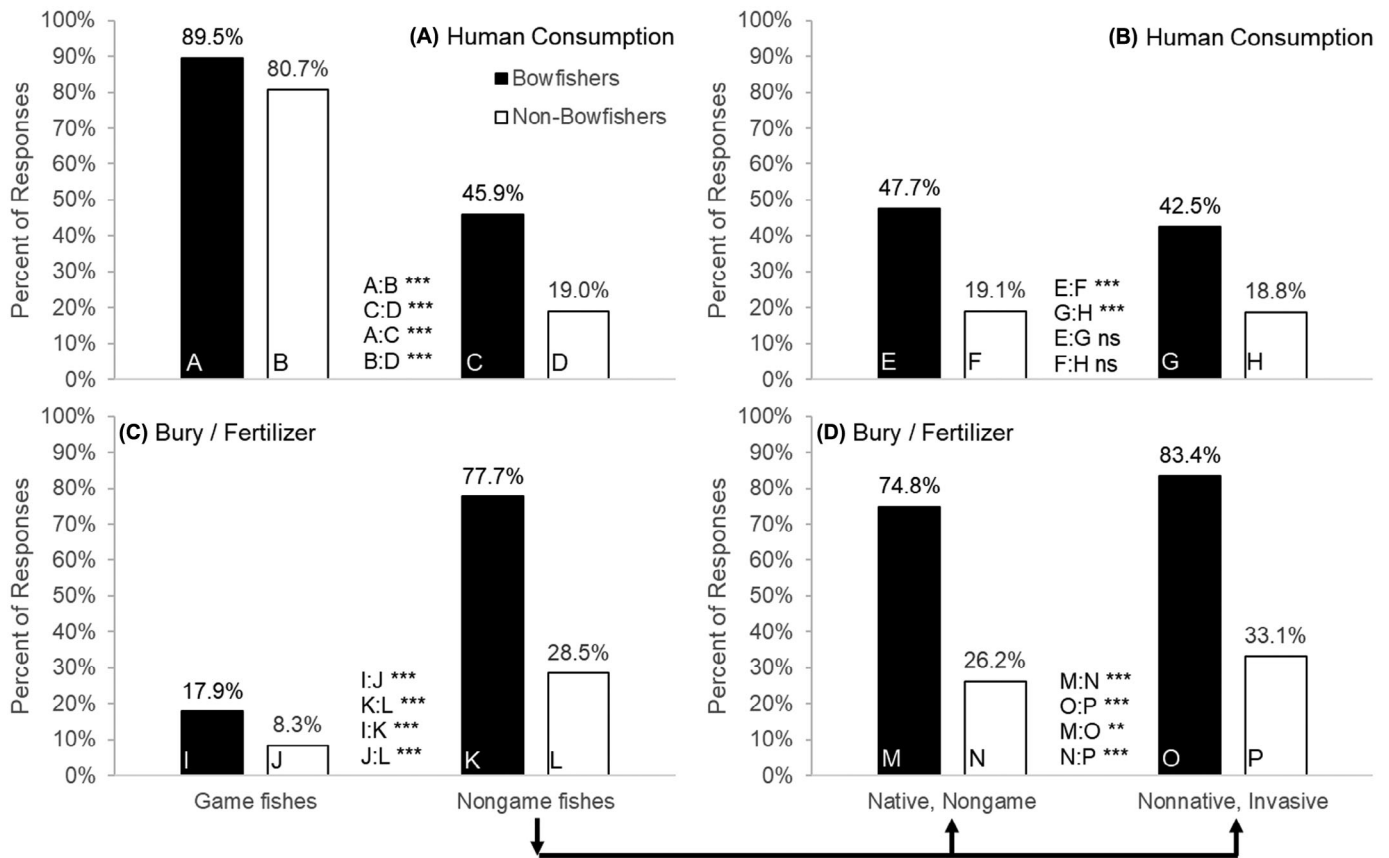


FIGURE 5. Comparison of acceptable outcomes of (A) human consumption and (C) burial or use as fertilizer for aggregated game fishes (black basses, catfishes, and trouts) and nongame fishes (buffalofishes, carps, and gars) taken by Oklahoma bowfishers and non-bowfishers. (B), (D) Similar comparisons are reported for aggregated native, nongame fishes (buffalofishes and gars) and nonnative, invasive fishes (carps). Columns (indicated by capital letters) were pairwise compared using a chi-square test; comparisons are denoted by asterisks when significant (** $P < 0.01$, *** $P < 0.001$) or are labeled as nonsignificant (ns).

bowfished an average of 16.2 d; supportive respondents bowfished on average 5.8 d). Finally, those that had bowfished in the most recent 12-month period tended to have stronger opposition to regulations (50% of active bowfishers opposed regulations compared to 35% of respondents who had bowfished but not in the past 12 months).

When Oklahoma anglers were asked how regulations on native, nongame species would affect their future participation in bowfishing, 70% of bowfishers stated that there would be no change in their activity, 23% said that they would bowfish less, 6% said that they would quit bowfishing altogether, and 2% said that they would bowfish more. Experienced bowfishers claimed a higher potential change in bowfishing under regulations than beginners; 28% of experienced respondents said they would bowfish less, whereas only 17% of beginner respondents made the same claim. Of those bowfishers that trusted ODWC to manage native, nongame fish ($n = 223$; 86% of bowfishers), 33% opposed regulations for native, nongame species and 20% would bowfish less if there were regulations in place.

Future of Bowfishing

Thirty-two percent of respondents that had not bowfished in the past said that they would be interested in participating in bowfishing in the future. Men were slightly more interested in bowfishing than women (37% and 24%, respectively), and women indicated that they were unsure about future bowfishing participation significantly more often than men (29% and 23%, respectively; $\chi^2 = 15.41$, $P < 0.01$). Future interest by license type (e.g., lifetime, annual, senior) was relatively similar except for senior license holders, only 27% of whom were interested in bowfishing. By contrast, 36% of annual license holders were interested. When those expressing interest in bowfishing in the future were asked what had prevented them from trying it in the past, a lack of knowledge (52%) was the reason most often reported, followed by not knowing anyone who bowfishes (44%) and not knowing where to go (39%). Thirty-one percent of respondents said that they lacked the time for bowfishing, and another 20% listed a range of other reasons, including the lack of equipment.

There were no apparent differences in barriers to bowfishing by age (average age ranged from 37.6 to 40.5 for each selected barrier), but lack of knowledge was selected most often by females (70%), whereas lack of time was selected most often by males (34%). Not knowing someone who bowfished or where to bowfish were responses selected equally across gender.

DISCUSSION

A Baseline Survey of Bowfishers

This first in-depth survey of Oklahoma bowfishers is one of the few such surveys in the United States that have provided some baseline information and quantitative insights into the poorly documented sport of bowfishing and its broader constituency. However, as in all surveys, results must be interpreted with regard to the constituency queried and response rates. For example, our survey covered a broad spectrum of license holders from non-bowfishers (68% male) through advanced bowfishers (95% male). In contrast, the study by Bennett et al. (2015) involved a more focused sample of 15 tournament bowfishers for Alligator Gars and 82 members of the Texas Bowfishing Association (97% male). Those respondents would be expected to be a more specialized demographic that is more immersed in the sport (i.e., more likely advanced bowfishers) than the average bowfisher respondent from Oklahoma. Results support this expectation. Whereas 79% of the Texas sample of bowfishers reported that bowfishing was their most important fishing activity and 44% indicated that it was their most important outdoor activity of any kind, the sample of Oklahoma bowfishers in our study was less focused. Only 6% of the Oklahoma bowfishers indicated that it was their most commonly practiced fishing method, and 59% indicated that bowfishing was less important than other fishing methods. Seventy-one percent of respondents from the Texas study (Bennett et al. 2015) had bowfished in a tournament during the previous 12-month period, whereas only 36% of the Oklahoma bowfishers had bowfished in any manner (tournament or not) during the previous 12 months. Mean age of bowfishers was older in the Oklahoma sample (48 years) versus the Texas sample (34 years), suggesting that the Texas sample consisted of a higher percentage of more youthful, almost exclusively male enthusiasts who were more driven to tournament involvement. Such enthusiasts may more likely belong to organized groups, such as bowfishing associations.

These differences in sampling approaches and the different characteristics of respondents corresponded to some other notable differences in responses between our study and that of Bennett et al. (2015). Bowfishing from shore

was the most common approach used by the Oklahoma bowfishers, as was fishing in rivers, whereas the Texas bowfishers fished nearly exclusively by boat (86% of fishing days) and fished more often in reservoirs. A higher level of involvement among the Texas bowfishers sampled was therefore associated with a large investment in equipment. Bennett et al. (2015:12) concluded that the bowfishers in their study “appeared to be a dedicated constituency with specialized boats and equipment.” With that higher investment in equipment perhaps comes a higher expectation for take. The Texas bowfishers that were queried most commonly sought buffalofishes, whereas Oklahoma bowfishers most commonly sought and took carps and gars.

The differences between our study of Oklahoma bowfishers and the Bennett et al. (2015) study involving a different demographic of Texas bowfishers underscore the critical importance for managers of identifying the constituency that they are querying and, as accurately as possible, the composition of the “public” for whom management is being conducted and regulations enacted. Ultimately, long-term conservation of native species and sustainable management of bowfishing under the public trust doctrine for the public as a whole must take precedence over the different preferences of component user groups (Scarnecchia et al. 2021).

Other, more specific results of our study deserve interpretation. For example, shore fishing during daytime predominated among Oklahoma bowfishers, even with recent advances in lighting systems in boats that have greatly increased the opportunities and safety for night bowfishing (Scarnecchia and Schooley 2020). Shore fishing during daytime may cost less and require less planning, favoring participation by more casual bowfishers. In our study, lakes and reservoirs were also fished more at night than were rivers. Peden et al. (2020) found that general safety issues (e.g., danger of drowning) are of substantially greater concern for boaters on rivers than on lakes. Bowfishing at night on lakes and reservoirs, as opposed to rivers, is consistent with the safer and more relaxing conditions more commonly encountered, especially during the calm conditions that are most favorable for successful bowfishing. Night fishing with all gears and on all waters also presents special challenges for managers in monitoring and enforcement (Cooke et al. 2017), sometimes resulting in fishery closures at night to reduce illegal take and improve stock assessments. Under the current near absence of regulation of bowfisheries, however, night fishing may be primarily chosen when targeting species that are more available to being taken at night, rather than to circumvent regulations. The higher preference for carps by daytime bowfishers in contrast to the higher preference for gars by night bowfishers may be driven by the movement patterns and habitat usage of these species groups.

Common Carp are often accessible by day, whereas gars are preferentially more active at night, associated with increased feeding (Goodyear 1967; Snedden et al. 1999). Various future limits on take, if implemented, may also be expected to change participation, for example, in rates of day versus night bowfishing. Our new knowledge of bowfisher preferences regarding preferred bowfishing locations, day versus night bowfishing, and species sought and taken may provide bases for improving the design of fisheries and creel surveys of this constituency.

Value of Native, Nongame Fishes

The differences in perceptions, opinions, and social value toward native, nongame species expressed by Oklahoma bowfishers versus non-bowfishers provided some new insights. Prior to this study, bowfisher opinions in social media postings indicated to us that bowfishers generally have held native, nongame fish in low regard (Scarnecchia and Schooley 2020). In this study, however, non-bowfishers expressed even less recognition than bowfishers of the suitability of nongame species for human consumption. Among the acceptable outcomes presented to survey respondents, we held human consumption as the option representative of the greatest social value, although the questions were not specifically articulated in this manner. Bowfishers in our study were twice as likely as non-bowfishers to view native, nongame fishes as edible (Figure 5). Reasons for this difference are unstudied but may relate to the lower exposure of non-bowfishers to these species. Many native, nongame species, such as gars and buffalofishes, are not commonly targeted (and their incidental capture may be rare) or preferred by anglers (York 2019); bowfishers may therefore more often encounter these species. Humans have a long history of testing novel fish for consumption (Morgan and Ho 2018; House 2019); unusual fish, especially large ones, more commonly taken by bowfishers might be much more likely to be evaluated by them for edibility. The perception of the two groups toward the nongame species might therefore differ, as perception and familiarity play large roles in acceptance of new foods, including fish (Tuorila and Hartmann 2020).

Acceptable outcomes of native, nongame species differed in other ways between bowfishers and non-bowfishers. Bowfishers indicated that they were still more likely to bury native, nongame species or use them as fertilizer than to eat them, whereas non-bowfishers reported that they were most likely to return nongame fish to the water. Comparisons of the two groups utilizing the outcome “returned to water” require caution, however, as it was not specified in the survey whether the fish was returned alive, as would be typical in catch-and-release angling for black basses and other game species (Bartholomew and Bohnsack 2005; Brownscombe et al. 2017; Maynard et al. 2017), as opposed to being returned dead or

severely injured, which would be typical for buffalofishes captured by bowfishing (Scarnecchia and Schooley 2020). “Return to water” may have two distinctly different meanings and outcomes for different respondents. Additional caution may be warranted in interpreting responses regarding animal consumption. Animal consumption could mean consumption by pets or other domesticated animals (Charlebois et al. 2010), which could be considered a beneficial use of shot fish. Alternatively, animal consumption may mean consumption (scavenging) by wild animals, such as aquatic turtles, vultures, or raccoons. Outcomes of returning the fish to the water or discarding the fish at the boat ramp (an illegal method of disposal in Oklahoma) or elsewhere would then be similar. More refinement in questions on these topics is needed on future surveys.

One specific regulatory action that could change the perceived low value of native, nongame fish, as shown in social media comments and in the comments in this survey (York and Schooley 2021), would be to create regulations preventing the immediate release of shot native, nongame fishes, most of which would presumably die from their wounds. The fate of fish released by bowfishers therefore differs from the documented low mortality rate of catch-and-release angling for multiple game species, such as the black basses (Maynard et al. 2017). By allowing the immediate release of shot fish, agencies reinforce the perception of the low value of these species to the public (Scarnecchia et al. 2021). The practice of “shoot and release” is prohibited in 42 states as of February 2021 (A. Lackmann, University of Minnesota, personal communication). In the eight states where this practice is legal, half of them (Idaho, New Mexico, Montana, and Wyoming) relegate the practice only to certain waters or certain species (e.g., Common Carp). The remaining four states (Alabama, North Carolina, Oklahoma, and Tennessee) have no restrictions on waters, and native, nongame fishes are regulated similarly to nonnative invasives. Agencies can assist in species conservation by placing a higher value on their beneficial use. Ultimately, agencies have a responsibility to ensure the sustainable take of native, nongame species within the philosophies of the public trust doctrine and the North American Model of Wildlife Conservation (<https://www.fishwildlife.org/landing/north-american-model-wildlife-conservation>) to use or dispose of any remains in a legal and ethical manner.

Informational campaigns by management agencies such as ODWC can raise awareness and appreciation for native, nongame species and can help to dispel the outmoded notion of the native species as inedible, rough, or “trash” fish in need of eradication (Scarnecchia 1992; Adams et al. 2019; Rypel et al. 2021). Our survey results may indicate a lack of public knowledge and/or exposure to the ecosystem benefits of native, nongame fish. The

important role of native species in aquatic ecosystems and in maintaining species balance in fish communities, and thereby aiding sportfishing, has long been known (Scarnecchia 1992). Further, these species are highly edible when taken and handled in a responsible and sustainable way. Awareness campaigns, such as Adams et al. (2019) for #GARWEEK and subsequent efforts by ODWC, reinforce that native, nongame fishes are valuable and play important roles within their aquatic communities. These targeted campaigns can demonstrate that the removal of native, nongame species with the aim of benefiting other, more traditionally preferred species is harmful rather than beneficial (Rypel et al. 2021).

Regulations and Their Impacts

Although a large majority of bowfishers (86%) and non-bowfishers (94%) indicated that they trusted the state management agency (ODWC) to effectively manage native, nongame species targeted by bowfishing, as of 2022 bowfishing is largely unregulated in Oklahoma and in states nationwide (Scarnecchia and Schooley 2020). In Oklahoma, species that are commonly targeted—both native, nongame species, such as gars (except the Alligator Gar) and suckers (Catostomidae), and nonnative invasives, such as carps—have no daily bag limits or size limits (Schooley and Scarnecchia 2021). Under favorable circumstances of timing, habitat, and species behavior, the take of large numbers of fish within a single bowfishing outing is not only possible but legal. While these circumstances may be rare, the glorification of some high-take bowfishing outings can be observed on social media, often portrayed in a similar, heroic manner as the take of a single trophy fish, with numbers of fish used as a surrogate for fish size (Scarnecchia and Schooley, in press). Although unlimited take of nonnative, invasive species is likely beneficial for native aquatic communities and habitats and may be a sound management strategy in a well-designed fishery, unlimited take of native, nongame fishes may be detrimental to local stocks (Scarnecchia and Schooley 2020; Scarnecchia et al. 2021). Contemporary research on the life history of native, nongame species indicates long life spans and uneven recruitment for many of these species (Lackmann et al. 2019; reviewed by Scarnecchia and Schooley 2020), necessitating judicious regulation of bowfishing take of native species. Although more detailed evidence is needed from studies in Oklahoma waters and on the impacts of bowfishing on Oklahoma native, nongame species, the great longevity and episodic recruitment described from research on buffalofishes and gars in other states can be expected to apply to the same species in Oklahoma waters.

This survey also provided insights on the general types of potential regulatory measures that may be effective if needed for native species conservation and how such regulations might impact bowfishing participation and

opportunity for take. Experienced bowfishers reported more than twice the average take of native and nonnative species combined (12 fish/trip) relative to beginners (5 fish/trip). Had a bowfishing aggregate bag limit (all species, native and nonnative) been in place at the time of this survey, aggregate daily limits of 10, 15, or 20 fish of all species would have impacted only 30, 15, and 8% of bowfishers. In all cases, a majority of bowfishers would not be affected. However, any bag limits (species specific or aggregate) enacted for native species conservation need not include nonnative, invasive species, potentially resulting in considerable bowfishing opportunity while limiting take of native species as needed. Despite the rationale for this general approach (Scarnecchia and Schooley 2020; Rypel et al. 2021), our survey results indicate that any regulation, regardless of its impacts on a minority of bowfishers or bowfishing trips, will likely inspire some opposition from tenured bowfishers. One of the attractions of bowfishing has historically been the ability to take larger numbers of fish than might be possible when taking many terrestrial species. Even for a scarce species, such as the Alligator Gar, Bennett et al. (2015) found that 43% of Texas tournament bowfishers considered the one-fish bag limit too restrictive. Ultimately, support of bowfishers for native species conservation would be critical to the success of any regulations enacted.

Strategies for monitoring bowfishing.—The very small portion of Oklahoma bowfishers participating in the sport competitively in tournaments (92% reporting recreational participation only) has implications for monitoring the sport and the fish take. Complete, unbiased creel censuses of bowfishing would require a mixture of tournament and nontournament sampling. Tournament data alone probably do not accurately represent the recreational majority of the constituency, the size of fish of a given species available (e.g., Longnose Gar in Illinois: Stein et al. 2019), the preferred time/location methods for participation, or the impacts of bowfishing take on species. Tournament sampling, however, remains important for stock assessment and management of bowfisheries. Data such as numbers and types of nongame species taken are a critical component of stock assessment; such data are taken most simply at tournaments, with their concentration of bowfishers and their communal location for measuring and weighing fish and centralized disposal of shot fish (e.g., Quinn 2010; Stein et al. 2019). Fish taken in bowfishing tournaments, which in some cases can number in the thousands of native, nongame fishes, are a valuable and increasingly indispensable source for life history data on these species (Lackmann et al. 2019; Scarnecchia and Schooley 2020). Acquiring these data via traditional dispersed collection efforts would entail the capture and sacrifice of many fishes at high cost. Challenges to using tournament-shot fish for acquisition of data on the

impacts of bowfishing are several. First, tournament rules often allow for culling prior to weigh-in of the 10–20 largest fish. These culled fish may be discarded on the water, where legal, or en route to weigh-in via other acceptable means. Accounting for culled fish would be essential to evaluation of tournament take. Second, though tournament-shot fish are a valuable source of life history data (i.e., population age and size structure), tournament rules often allow for the aggregation of fish from multiple water bodies within a larger region, sometimes statewide. Prioritizing survey efforts at single-location bowfishing tournaments (i.e., one reservoir or one river reach) would yield robust stock assessment data, resulting in more meaningful management conclusions.

For nontournament situations, cost-effective efforts to gather similar data from recreational bowfishers will need to be developed through individual cooperative arrangements, through effectively designed creel surveys, or by using a top-down approach with local or statewide bowfishing organizations. All of these avenues require funding and the development of effective communication channels between the management agencies, such as ODWC, and bowfishers.

The percentages of respondents reporting bowfishing activity on the various types of waters (lakes, reservoirs, ponds, rivers, and tailwaters) also have implications for monitoring of bowfishing. A moderate percentage of respondents (26.7%) reported bowfishing on ponds, many of which are privately owned in Oklahoma and not subject to oversight by ODWC. While it would be difficult to monitor or manage the sport and its impacts on private waters (if deemed necessary), the higher-priority, larger segment of bowfishers fishing on public waters (reservoirs, rivers, streams, and tailwaters) can be monitored via access point or roving creel surveys. Among these location types, ODWC may have the greatest initial success with tailwaters due to their relatively small number and well-defined spatial area. Bowfishing is not universally permitted in Oklahoma tailwaters, further limiting the locations where bowfishers would be active. Similar logistical considerations may apply in other states. York and Schooley (2021) found that the type of location targeted by bowfishers differed by region of the state.

The Future of Bowfishing and Its Management

Results of this study show an increase in interest and participation in bowfishing consistent with the nationwide ascendance of the sport (Scarnecchia and Schooley 2020). In the 2019 Oklahoma angler survey, only 4% of licensed anglers reported bowfishing in the previous 12 months (York 2019). The doubling in bowfishing participation reported in this study since then (9.1%)—that is, a doubling of participation in bowfishing from license year 2018 to license year 2020—is not unexpected. It may accurately

represent increasing popularity or may also represent higher general participation in fishing of all kinds, perhaps associated with the COVID-19 pandemic or related factors (Midway et al. 2021). Additional insights were obtained that bowfishers, as a constituency, appeared to have a higher participation level in fishing overall than non-bowfishers. Not only were they twice as likely to use their license privileges in the previous 12 months, they also reported participating in a wider diversity of fishing activities (e.g., limblines, noodling, trotlines), at times two- to threefold more, than non-bowfishers. Our finding that more bowfishers than non-bowfishers were lifetime license holders may be indicative of a greater commitment to fishing. Deeper analyses of the license-buying histories of bowfishers and non-bowfishers may provide insights on whether bowfishers are indeed more active and committed to all types of fishing in Oklahoma and elsewhere. The creation, management, and promotion of sustainable bowfishing opportunities in various states may serve to recruit license buyers while encouraging bowfishers to target non-native, invasive fishes (Quinn 2010; Scarnecchia and Schooley 2020).

The number of current active bowfishers as well as the high rate of potential interest from those that have not bowfished provides a strong indication that this survey and other efforts related to native, nongame species targets of the sport are appropriately timed. In alignment with a growing sport, many bowfishers surveyed were new to the sport (57% had bowfished fewer than 3 years) or rated themselves as beginners (49%). While only 24% of respondents had ever bowfished and only 9.1% were active participants (i.e., had bowfished in the past year), nearly one-third of the non-bowfishing respondents indicated an interest in trying bowfishing. Inasmuch as all three of the reported barriers to bowfishing relate to inadequate information, barriers to bowfishing could be lowered with a concerted outreach and education program.

In the future, fisheries design, appropriate regulations, and adequate monitoring will be important aspects of sustainable bowfishing management. Attempts to enhance and promote growth of bowfishing must emphasize non-native invasives and should coincide with appropriate management protections for the native, nongame species potentially impacted by bowfishing (Hilsabeck et al. 2017; Scarnecchia and Schooley 2020). In Oklahoma and nationally, very few native, nongame species are managed by harvest regulations. To monitor the expansion of bowfishing, it would also be prudent for ODWC and other state agencies to develop targeted surveys like ours and to repeat them at regular intervals of no greater than 3–5 years. It may also be beneficial to target different bowfishing and angler populations in more detail (i.e., messaging that is targeted to beginners or youths). To aid in information exchange, the development of focus groups

mentioned in survey question 29 is expected to be a valuable resource for managers. Such groups can be used to fill any knowledge gaps of surveys, allow collaboration with constituency leaders, and enhance methodologies for data collection from nontournament bowfishers.

ACKNOWLEDGMENTS

We thank the numerous Oklahoma fishing license holders who responded to this survey. K. Cunningham, C. Jager, C. Porter, and R. Snow from ODWC provided valuable feedback on the manuscript. A. Lackmann (University of Minnesota) provided information on legality of “shoot and release” in the United States. H. Hershey provided illustrations of nongame fishes. Funding was provided by ODWC. There is no conflict of interest declared in this article.

ORCID

Betsey York  <https://orcid.org/0000-0003-4124-9737>

Jason D. Schooley  <https://orcid.org/0000-0003-1726-0602>

REFERENCES

- Adams, K. A., A. T. Taylor, R. A. Snow, and M. J. Porta. 2019. #GARWEEK: insight from a social media outreach campaign about Alligator Gar in Oklahoma. *Proceedings of the Oklahoma Academy of Science* 99:31–40.
- Bartholomew, A., and J. A. Bohnsack. 2005. A review of catch-and-release angling mortality with implications for no-take reserves. *Reviews in Fish Biology and Fisheries* 15:129–154.
- Bennett, D. L., R. A. Ott, and C. C. Bonds. 2015. Surveys of Texas bow anglers, with implications for managing Alligator Gar. *Journal of the Southeastern Association of Fish and Wildlife Agencies* 2:8–14.
- Brownscombe, J. W., A. J. Danylchuk, J. M. Chapman, L. F. G. Gutowsky, and S. J. Cooke. 2017. Best practices for catch-and-release recreational fisheries—angling tools and tactics. *Fisheries Research* 186:693–705.
- Charlebois, P., S. Parks, K. TePas, and M. Peterson, editors. 2010. Asian carp marketing summit Illinois–Indiana Sea Grant, Publication IISG-11094, West Lafayette, Indiana. Available: <https://hdl.handle.net/2142/99797>. (February 2022).
- Cooke, S. J., R. J. Lennox, S. D. Bower, A. Z. Horodysky, M. K. Tremi, E. Stoddard, L. A. Donaldson, and A. J. Danylchuk. 2017. Fishing in the dark: the science and management of recreational fisheries at night. *Bulletin of Marine Science* 93:519–538.
- Daugherty, D. J., A. H. Andrews, and N. G. Smith. 2020. Otolith based age estimates of Alligator Gar assessed using bomb radiocarbon dating to greater than 60 years. *North American Journal of Fisheries Management* 40:613–621.
- Dillman, D. A., J. D. Smyth, and L. M. Christian. 2014. Internet, phone, mail, and mixed-mode surveys: the tailored design method, 4th edition. Wiley, Hoboken, New Jersey.
- Goodyear, C. P. 1967. Feeding habits of three species of gars, *Lepisosteus*, along the Mississippi Gulf Coast. *Transactions of the American Fisheries Society* 96:297–300.
- Hilsabeck, R., T. Thomas, N. Grider, M. McClelland, and D. Stephenson. 2017. Fish species management plan for Alligator Gar (*Atractosteus spatula*) in Illinois. Illinois Department of Natural Resources, Office of Conservation, Springfield.
- House, J. 2019. Insects are not “the new sushi”: theories of practice and the acceptance of novel foods. *Social and Cultural Geography* 20:1285–1306.
- Kelley, S. W. 2012. Age and growth of spawning Longnose Gar (*Lepisosteus osseus*) in a north central Texas reservoir. *Western North American Naturalist* 72:69–77.
- Lackmann, A. R., A. H. Andrews, M. G. Butler, E. S. Bielak-Lackmann, and M. E. Clark. 2019. Bigmouth Buffalo *Ictiobus cyprinellus* sets freshwater teleost record as improved age analysis reveals centenarian longevity. *Communications Biology* 2(1):article 197.
- Lackmann, A. R., B. J. Kratz, E. S. Bielak-Lackmann, R. I. Jacobson, D. J. Sauer, A. H. Andrews, M. G. Butler, and M. E. Clark. 2021. Long-lived population demographics in a declining, vulnerable fishery—Bigmouth Buffalo (*Ictiobus cyprinellus*) of Jamestown Reservoir, North Dakota. *Canadian Journal of Fisheries and Aquatic Sciences* 78:1486–1496.
- Lahn, R. A. 2018. Wanton waste policy recommendation: stingray bow hunting. *Applied Science and Innovative Research* 2:208–213.
- Longmire, C. L. 2012. Spearfishing and bowfishing in South Dakota: resident hook/line angler opinion survey. South Dakota Game, Fish and Parks, Report HD-6-12-AMS, Pierre.
- Lynn, P. 2020. Evaluating push-to-web methodology for mixed-mode surveys using address-based samples. *Survey Research Methods* 14:19–30.
- Maynard, G. A., T. B. Mihuc, V. A. Sotola, D. E. Garneau, and M. A. Malchoff. 2017. Black bass dispersal patterns following catch-and-release tournaments on Lake Champlain. *North American Journal of Fisheries Management* 37:524–535.
- Midway, S. R., A. J. Lynch, B. K. Peoples, M. Dance, and R. Caffey. 2021. COVID-19 influences on US recreational angler behavior. *PLoS (Public Library of Science) ONE* 16(8):e0254652.
- Molinaro, S. 2019. The population dynamics of Shortnose Gar in the Illinois River to inform management of an emerging recreational fishery. Master's thesis. University of Illinois, Urbana-Champaign.
- Morgan, M., and Y. Ho. 2018. Perception of Asian carp as a possible food source among Missouri anglers. *Human Dimensions of Wildlife* 23:491–498.
- Orth, D. 2017. Bowfishing for “rough” fish. Virginia Tech Ichthyology Class blog (June 1, 2017), Blacksburg, Virginia. Available: vtichthyology.blogspot.com/2017/06/bowfishing-for-rough-fish-by-don-orth.html. (January 2022).
- Peden, A. E., S. M. Willcox-Pidgeon, J. P. Scarr, and R. C. Franklin. 2020. Comparing rivers to lakes: implications for drowning prevention. *Australian Journal of Rural Health* 28:568–578.
- Quinn, J. W. 2010. A survey of bowfishing tournaments in Arkansas. *North American Journal of Fisheries Management* 30:1376–1384.
- Radford, D. S., A. R. Lackmann, C. J. Moody-Carpenter, and R. E. Colombo. 2021. Comparison of four hard structures including otoliths for estimating age in Blue Suckers *Cypleptus elongatus*. *Transactions of the American Fisheries Society* 150:514–527.
- Rypel, A. L., P. Saffarinia, C. C. Vaughn, L. Nesper, K. O'Reilly, C. A. Parisek, M. L. Miller, P. B. Moyle, N. A. Fanguie, M. Bell-Tilcock, D. Ayers, and S. R. David. 2021. Goodbye to “rough fish”: paradigm shift in the conservation of native fishes. *Fisheries* 46:605–616.
- Scarnecchia, D. L. 1992. A reappraisal of gars and Bowfins in fisheries management. *Fisheries* 17(5):6–12.
- Scarnecchia, D. L., and J. D. Schooley. 2020. Bowfishing in the United States: history, status, ecological impact, and a need for management. *Transactions of the Kansas Academy of Science* 123:285–338.

- Scarnecchia, D. L., and J. D. Schooley. In press. Trophies, technology, and timescape in fisheries management, as exemplified through Oklahoma's world record Paddlefish *Polyodon spathula*. Fisheries. DOI: 10.1002/fsh.10764.
- Scarnecchia, D. L., J. D. Schooley, A. R. Lackmann, S. J. Rider, D. K. Riecke, J. McMullen, J. E. Ganus, K. D. Steffensen, N. W. Kramer, and Z. R. Shattuck. 2021. The Sport Fish Restoration Program as a funding source to manage and monitor bowfishing and monitor inland commercial fisheries. Fisheries 46:595–604.
- Schooley, J. D., and D. L. Scarnecchia. 2021. Bowfishing in Oklahoma. Outdoor Oklahoma (January/February):26–37.
- Snedden, G. A., W. E. Kelso, and D. A. Rutherford. 1999. Diel and seasonal patterns of Spotted Gar movement and habitat use in the lower Atchafalaya River basin, Louisiana. Transactions of the American Fisheries Society 128:144–154.
- Snow, R. A., M. J. Porta, and D. M. Bogner. 2020. Examination of the current Oklahoma state record Smallmouth Buffalo. Proceedings of the Oklahoma Academy of Science 100:16–21.
- Stein, J. A., S. King, K. Stanhope, T. McNamara, S. Molinaro, T. Leek, and J. Mattes. 2019. Research and analysis of fisheries in Illinois, final performance report, 1 July 2018–30 June 2019. Illinois Natural History Survey, Federal Aid Project F-69-R, Segment 32, Champaign.
- Tuorila, H., and C. Hartmann. 2020. Consumer responses to novel and unfamiliar foods. Current Opinion in Food Science 33:1–8.
- York, B. 2019. 2019 Oklahoma angler survey. Oklahoma Department of Wildlife Conservation, Oklahoma City.
- York, B. 2021. 2020 Game harvest survey. Oklahoma Department of Wildlife Conservation, Oklahoma City.
- York, B., and J. D. Schooley. 2021. 2021 Oklahoma bowfishing survey. Oklahoma Department of Wildlife Conservation, Oklahoma City.

Appendix: Survey Instrument

Hello, please enter your unique survey ID number to be taken to the survey.

Your unique survey ID number can be found above your name and address on the front of the postcard that was mailed to you. If you are responding via an email link, you may leave this blank and proceed to the next page.

1 Survey ID Number: _____

Bowfishing is a method of fishing that uses specialized archery equipment to shoot and retrieve fish. Fish are shot with an arrow that is attached with a special line to a reel mounted on the bow. Bowfishing is a legal method of take in Oklahoma for both native nongame and non-native invasive fishes.

Your answers to this survey will remain anonymous and will only be shared as pooled results. Your participation in this survey will assist fisheries biologists with better managing fish in Oklahoma.

2 Have you ever gone bowfishing in Oklahoma?

- a Yes...**please continue to section A.**
- b No...**please continue to section B.**

Section A: Questions for those that have bowfished in Oklahoma

3 What fishing methods have you used in the past 12 months? *Check all that apply.*

- a Rod and reel
- b Trot line
- c Limb line
- d Jug line
- e Bowfishing
- f Noodling
- g Other, please specify
- h I have not fished in the last 12 months

4 What fishing method have you used **most often** in the past 12 months? *Please select only one.*

- a Rod and reel
- b Trot line
- c Limb line
- d Jug line

- e Bowfishing
 - f Noodling
 - g Other
 - h I have not fished in the last 12 months
- 5 Compared to your other fishing activities...
- a ...bowfishing is less important
 - b ...bowfishing is equally important
 - c ...bowfishing is more important
- 6 Compared to your other outdoor activities (camping, hiking, sports, etc.)...
- a ...bowfishing is less important
 - b ...bowfishing is equally important
 - c ...bowfishing is more important
- 7 How would you rate your experience as a bowfisher?
- a Beginner
 - b Intermediate
 - c Advanced
- 8 How many total years have you bowfished?
- a Less than one
 - b 1–3 years
 - c 4–10 years
 - d Over 10 years
- 9 Do you primarily bowfish recreationally (for fun) or competitively (in tournaments)?
- a I ONLY bowfish recreationally
 - b I bowfish primarily for recreation and occasionally for competition
 - c I fish both about equally
 - d I bowfish primarily in competitions and occasionally for recreation
 - e I ONLY bowfish for competition
- 10 Approximately how many days per year do you bowfish in Oklahoma? _____
- 11 Approximately how many days per year do you fish using **any** method in Oklahoma? _____
- 12 How many miles (one-way) do you typically travel to bowfish in Oklahoma? _____
- 13 What months do you typically bowfish? *Check all that apply*
- a January
 - b February
 - c March
 - d April
 - e May
 - f June
 - g July
 - h August
 - i September
 - j October
 - k November
 - l December

- 14 Do you primarily bowfish at night or during the day?
- At night
 - During the day
 - I fish both about equally
- 15 Do you primarily bowfish from the shore or from a boat (either motorized or not)?
- From the shore
 - From a boat
 - I fish from both about equally
- 16 What types of waterbodies have you bowfished in Oklahoma? *Select all that apply.*
- Reservoirs
 - Ponds
 - Tailwaters below dams
 - Rivers and streams
- 17 What location in Oklahoma do you most frequently bowfish (e.g. Red River, Fort Gibson Lake, private ponds, etc.): _____

For the following questions, we will be referring to the following species:

[A graphic depicting Alligator Gar, Bigmouth Buffalo, and Silver Carp was accompanied by a list of Oklahoma species within the groups: gars, buffalo, carps. Additionally, a hyperlink was provided to the ODWC website's fish identification page.]

- 18 What types of fish do you typically target while bowfishing? *Check all that apply.*
- Gars
 - Buffalofishes
 - Carps
 - Other, please specify
- 19 What do you most prefer to target while bowfishing? *Please select only one.*
- Gars
 - Buffalofishes
 - Carps
 - Other, please specify
- 20 What species do you **most often** shoot/attempt to shoot while bowfishing? *Please select only one.*
- Gars
 - Buffalofishes
 - Carps
 - Other, please specify
- 21 How many of the following types of fish do you typically shoot per day? *If you do not shoot that kind of fish, please enter a zero.*
- Gars: _____
 - Buffalofishes: _____
 - Carps: _____
 - Unsure of species: _____
 - Other: _____
- 22 What do you typically do with your fish after a bowfishing trip? *Check all that apply.*
- Human consumption
 - Animal consumption
 - Fertilizer use

- d Bury
- e Return to water
- f Discard at boat ramp
- g Burn
- h Other, please specify

- 23 Do you trust the Oklahoma Department of Wildlife Conservation to appropriately manage **nongame native** fishes (gar, buffalofish, etc.) targeted by bowfishers?
- a Yes
 - b No, the Wildlife Department should do more
 - c No, the Wildlife Department should do less
- 24 Would you support or oppose bowfishing regulations (e.g. bag limits or size limits) for **nongame native** species (i.e. buffalofishes, gar, etc.)?
- a Strongly oppose
 - b Oppose
 - c Neutral
 - d Support
 - e Strongly support
- 25 How would the introduction of bowfishing regulations for **nongame native** species affect your future participation in bowfishing in Oklahoma? *Similar to the above question, this might mean bag limits or size limits for Oklahoma native species such as gar, buffalo fishes, etc.*
- a I would quite bowfishing
 - b I would bowfish less
 - c No change
 - d I would bowfish more
- 26 In your opinion, what are acceptable outcomes for the following groups of species after being caught with any fishing method? *Select all that apply.*

Human consumption	Animal consumption	Fertilizer use	Bury	Return to water	Discard at boat ramp	Burn
Buffalofishes						
Carps						
Catfishes						
Gars						
Trouts						
Black basses						

- 27 Please rank the following aspects in terms of how much they contribute to a successful **bowfishing** trip with 1 being most important and 7 being least important. You may select NA for any aspects that do not contribute.
- a Successfully shooting a large trophy fish
 - b Successfully shooting a lot of fish
 - c Seeing the fish species that I intended to target
 - d Being outside
 - e Seeing any fish
 - f Enjoying time spent with family/friends
 - g A challenging fish to shoot

For the next question, we would like you to think about fishing methods other than bowfishing.

- 28 Please rank the following aspects in terms of how much they contribute to a successful **fishing** trip (non bowfishing) in your mind with 1 being most important and 7 being least important.
- a Catching a large trophy fish
 - b Catching a lot of fish
 - c Seeing the fish species that I intended to target
 - d Being outside
 - e Seeing any fish
 - f Enjoying time spent with family/friends
 - g Having a good fight with the fish

As a bowfisher, we would like to know a little bit more about the sport and those that participate in it...

- 29 Would you be willing to participate in a bowfishing focus group? If so, please leave your email address here and we will contact you. Your email will only be used to contact you about a focus group, it will not be tied to your responses to the rest of the survey: _____

- 30 Please share with us what you most enjoy about bowfishing: OPEN ENDED

MOVE TO SECTION E.

Section B: Questions for those that have not bowfished in Oklahoma

- 31 What fishing methods have you used in the past 12 months? *Check all that apply.*

- a Rod and reel
- b Trot line
- c Limb line
- d Jug line
- e Noodling
- f Other, please specify
- g I have not fished in the last 12 months

- 32 What fishing method have you used **most often** in the past 12 months? *Please select only one.*

- a Rod and reel
- b Trot line
- c Limb line
- d Jug line
- e Noodling
- f Other
- g I have not fished in the last 12 months

- 33 In your opinion, what are acceptable outcomes for the following groups of species after being caught with any fishing method? *Select all that apply.*

Human consumption	Animal consumption	Fertilizer use	Bury	Return to water	Discard at boat ramp	Burn
-------------------	--------------------	----------------	------	-----------------	----------------------	------

Buffalofishes
Carps
Catfishes
Gars
Trouts
Black basses

34 Please rank the following aspects in terms of how much they contribute to a successful **fishing** trip (non bowfishing) in your mind with 1 being most important and 7 being least important.

- a Catching a large trophy fish
- b Catching a lot of fish
- c Seeing the fish species that I intended to target
- d Being outside
- e Seeing any fish
- f Enjoying time spent with family/friends
- g Having a good fight with the fish

35 Do you trust the Oklahoma Department of Wildlife Conservation to appropriately manage **nongame native** fishes (gar, buffalofish, etc.) targeted by bowfishers?

- a Yes
- b No, the Wildlife Department should do more
- c No, the Wildlife Department should do less

36 Do you have interest in participating in bowfishing?

- a Yes...**move to section C**
- b No...**move to section D**
- c I do not know...**move to section E**

Section C: Those with an interest in bowfishing who have not bowfished before

37 What has prevented you from going bowfishing? *Select all that apply*

- a Lack of knowledge
- b Not sure where to go
- c Do not know anyone who bowfishes
- d Lack of time
- e Other, please specify

MOVE TO SECTION E.

Section D: Those with no interest in bowfishing who have not bowfished before

38 Why are you uninterested in bowfishing? OPEN ENDED

MOVE TO SECTION E.

Section E: Demographics of all respondents

39 Have you heard of the Oklahoma Department of Wildlife Conservation's Explore Bowfishing program?

- a Yes
- b No

40 What is your gender?

- a Female
- b Male
- c Prefer not to say

41 What type of fishing license did you have in the past 12 months?

- a Annual/5-year
- b Senior
- c Lifetime
- d Tribal compact

- 42 Do you belong to any fishing organizations?
- a Yes
 - b No
 - i If yes, what angler organizations do you belong to?
- 43 What is your race or ethnicity?
- a Asian
 - b Black or African American
 - c Hispanic or Latino
 - d Middle Eastern or North African
 - e Multiracial or multiethnic
 - f Native American or Alaska Native
 - g Native Hawaiian or other Pacific Islander
 - h White
 - i Another race or ethnicity please describe below
 - j Self-describe: _____
- 44 How old are you? _____
- 45 What is your home zip code? _____
- 46 What is your total household income?
- a Less than \$20,000
 - b \$20,000 - \$34,999
 - c \$35,000 - \$49,000
 - d \$50,000 - \$74,999
 - e \$75,000 - \$99,999
 - f \$100,000 - \$149,999
 - g \$150,000 or more
 - h Prefer not to say
- 47 Do you have any other thoughts or concerns about bowfishing/fisheries management you would like to share with the Wildlife Department? OPEN ENDED