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Spatial and temporal behavioral differences between angler-access types

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ABSTRACT

Recreational angler surveys typically collect information on how anglers access a fishery. Yet, it is unclear how this information is useful for fisheries management and conservation. The objective of this study was to compare behavior (e.g., party size, time fished, and numbers of fish released and harvested) of bank and boat anglers, representing two angler-access types. Bank and boat anglers were surveyed across 29 Nebraska waterbodies from April through October, 2007–2017. We documented behavioral differences between bank and boat anglers that varied as a function of waterbody size and season. Patterns of party size, time fished, and numbers of fish released and harvested for bank and boat anglers differed across extra small, small, medium, and large waterbodies and across spring, summer, and fall. How anglers choose to access a fishery appears to be a source of heterogeneity within angler populations. Accounting for these spatial and temporal behavioral differences between angler-access types will be important for designing and implementing management regulations. We predict that angler-access types may respond uniquely to different management actions (e.g., size and bag limits, access maintenance, and cleanliness of amenities) that could lead to local and regional changes within and across fisheries (e.g., shift the composition of angler-access types). Continued collection and assessment of angler-access information is warranted and should lead to improved management and conservation of recreational fisheries.

1. Introduction

Recreational surveys of anglers commonly record information pertaining to how anglers access a fishery or anglers mode of fishing (Pollock et al., 1994; Jakus et al., 1998; Chizinski et al., 2014a). Standard creel surveys typically collect angler-access data to estimate effort and catch for both bank and boat anglers (Lockwood, 1997; Soupir et al., 2006; Chizinski et al., 2014a). Our profession's long-term accounting for different angler-access types suggests that this information is important (Lockwood, 1997; Soupir et al., 2006; Chizinski et al., 2014a). Even so, we currently lack a clear understanding of the relationship between how anglers access and interact with a fishery, and the utility of this information for fisheries management and conservation. Collecting angler-access information could be of little value if it is unrelated to social-ecological interactions within and across fisheries through time, but alternatively could provide great insight if differences exist between angler-access types. Furthermore, identifying which attributes are different between angler-access types would be valuable for improving recreational fishery data collection, monitoring, and management.

Recreational anglers predominately access a fishery from a bank (i.e., fishing from the shore or a non-floating device) or from a boat (i.e., fishing from a floating device). A few studies have indirectly compared attributes of bank and boat anglers, which primarily focused on attributes unrelated to fish catch and harvest (Palm and Malvestuto, 1983; Hudgins, 1984; Chizinski et al., 2014a). For example, bank anglers visited more lakes within a small complex of lakes, suggesting that bank anglers are more mobile than boat anglers and are willing to visit multiple lakes within a single trip (Chizinski et al., 2014a). Daily trip expenditures also varied between angler-access types; bank anglers typically spent less than boat anglers (Palm and Malvestuto, 1983). Motivations may also differ between angler-access types. Bank anglers identified that eating fish and privacy were important whereas boat anglers highlighted that catching trophy fish and being outdoors were essential (Hudgins, 1984). Further, management actions, such as plant removal, could be viewed differently (i.e., positively or negatively) depending on how anglers access a fishery (Henderson et al., 2003).

Comparisons have also been made between bank and boat anglers in terms of their catch, although these evaluations are much more limited compared to non-catch attributes. In southern Portugal, catch rates for

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bank anglers were lower than catch rates for boat anglers (Veiga et al., 2010). Bank anglers may be more successful at catching certain species, such as littoral-dwelling bluegill *Lepomis macrochirus* and common carp *Cyprinus carpio* (Pope et al., 2016). Boat anglers, in contrast, may be more successful at catching pelagic-dwelling fish such as walleye *Sander vitreus* and white bass *Morone chrysops*. According to the same study, largemouth bass *Micropterus salmoides* catch rates were similar for bank and boat anglers (Pope et al., 2016). Collectively, these differences suggest that attributes of bank and boat anglers may vary through space and time; however, it is unclear which attributes vary and the implications of this heterogeneity is unknown for fisheries management and conservation.

We aimed to compare angler behavior between two access types using a multi-waterbody (N = 29) and multi-year (2007–2017) dataset. We compared four commonly collected angler attributes (i.e., basic creel survey information) that were used to assess behavior between bank and boat anglers. We predicted to find differences in party size, time fished, fish released, and fish harvested between bank and boat anglers, given these two angler-access types could vary in motivations and their access to certain habitats. Variations in angler motivations and habitat access is predicted to create behavioral differences across space (i.e., waterbodies) and time (i.e., seasons) for bank and boat anglers (Pope et al., 2016; Chizinski et al., 2018; Kaemingk et al., 2019).

2. Methods

2.1. Study sites and angler interviews

Creel surveys were conducted at 29 waterbodies across Nebraska, U.S.A. (Table 1) that varied by use for bank and boat anglers (Fig. 1). Waterbodies were developed for multiple purposes such as hydropower generation, irrigation storage, flood control, sand-pit mining, and recreational fishing. Waterbodies were grouped by surface area into extra small (0.04–104 ha), small (115 − 182 ha), medium (223 − 465 ha), and large (648-12,141 ha) waterbodies (Kaemingk et al., 2019). Fish communities were diverse and anglers targeted multiple species within and across these waterbodies (Pope et al., 2016). Waterbodies were sampled over 11 years (2007–2017) during spring (April, May), summer (June, July, August), and fall (September, October). Anglers were categorized as either bank (i.e., fishing from the bank or shore) or boat (i.e., fishing from a boat or a floating device). We surveyed anglers onsite at each waterbody according to previously described methods (Malvestuto, 1996; Kaemingk et al., 2018). We conducted at least 30 interviews for bank anglers and at least 30 interviews for boat anglers at each waterbody (i.e., a minimum of 60 interviews total per waterbody; Table 1). Interviews included in this assessment were completed trips (i.e., we excluded incomplete trips) and conducted at the party level where the representative of each party completed the survey.

For each interview, we collected information on the number of anglers in the party, fishing trip beginning and ending times, numbers of fish caught, and whether caught fish were released or harvested. From this information, we extracted four attributes to characterize behavior of bank and boat anglers. We explored behavioral differences between angler types using party size, time fished, fish released, and fish harvested. Party size was the number of individuals traveling together for the purpose of recreational fishing. Time fished was the duration of fishing for the party, calculated by subtracting beginning time from ending time and reported in decimal hours. Fish released was the total number of fish caught and released by each party. Fish harvested was the total number of fish caught and harvested by each party. We included these behavioral attributes in our study because this information is commonly collected in most traditional creel surveys and therefore should reveal basic angler-type differences that will be useful for fisheries management and conservation. Furthermore, we assessed differences in these attributes between angler types across seasons (i.e., spring, summer, and fall) and waterbody sizes (i.e., extra small, small, medium, and large). Previous work has highlighted the importance of including spatial and temporal aspects to help explain patterns in angler heterogeneity (van Poorten and Post, 2005; Papenfuss et al., 2015;

Table 1
Physical characteristics, waterbody size (XS = extra small, S = small, M = medium, L = large; Kaemingk et al., 2019), years surveyed, and number of completed bank and boat interviews at each waterbody surveyed.

Waterbody	Latitude (N)	Longitude (W)	Surface Area (ha)	Waterbody Size	Years Surveyed	Number of Bank Interviews	Number of Boat Interviews
Branched Oak	40.981971°	−96.855125°	728	L	2009-2012, 2014- 2016	806	763
Calamus	41.847825°	−99.220833°	2075	L	2009, 2011-2017	671	3017
Conestoga	40.769101°	−96.851692°	93	XS	2009	30	55
Enders	40.437152°	−101.538343°	691	L	2007-2012	122	1042
Fremont 1	41.449811°	−96.561444°	5	XS	2010-2013	111	35
Fremont 15	41.439332°	−96.538281°	20	XS	2010-2013	119	30
Fremont 2	41.449891°	−96.564144°	6	XS	2010-2013	206	72
Fremont 20	41.437707°	−96.551542°	21	XS	2010-2013	145	405
Fremont 5	41.449296°	−96.572580°	4	XS	2010-2013	106	57
Harlan	40.057313°	−99.272493°	5463	L	2009-2017	868	6763
Holmes	40.776446°	−96.638317°	40	XS	2009, 2011	68	330
Johnson	40.696404°	−99.871988°	886	L	2011-2012	485	425
Lewis and Clark	42.852479°	−97.603113°	11331	L	2009-2012	406	1733
McConaughy	41.248224°	−101.683402°	12141	L	2009-2017	245	3570
Medicine Creek	40.399800°	−100.231497°	749	L	2007-2012	246	853
Merritt	42.627675°	−100.871769°	1176	L	2009-2015	243	2813
Ogallala	41.213610°	−101.666085°	263	M	2009-2013	210	187
Olive Creek	40.580063°	−96.846971°	71	XS	2012	90	76
Pawnee	40.846719°	−96.867721°	299	M	2009-2010, 2014-2017	500	332
Red Willow	40.358777°	−100.671773°	659	L	2007-2012	361	726
Sherman	40.302863°	−98.885985°	1151	L	2009-2011, 2013-2017	535	2491
Stagecoach	40.599319°	−96.637292°	79	XS	2009-2010	119	96
Sutherland	41.104676°	−101.105632°	1214	L	2016	198	213
Swanson	40.161328°	−101.068364°	2013	L	2007-2012	190	1351
Wagon Train	40.625825°	−96.579415°	127	S	2011-2012	385	185
Wanahoo	41.234510°	−96.614971°	268	M	2012-2013, 2016	602	2027
Wildwood	41.037704°	−96.838281°	42	XS	2010-2012	268	112
Willow Creek	42.175267°	−97.569451°	283	M	2010	46	110
Yankee Hill	40.728949°	−96.789979°	84	XS	2011	106	61

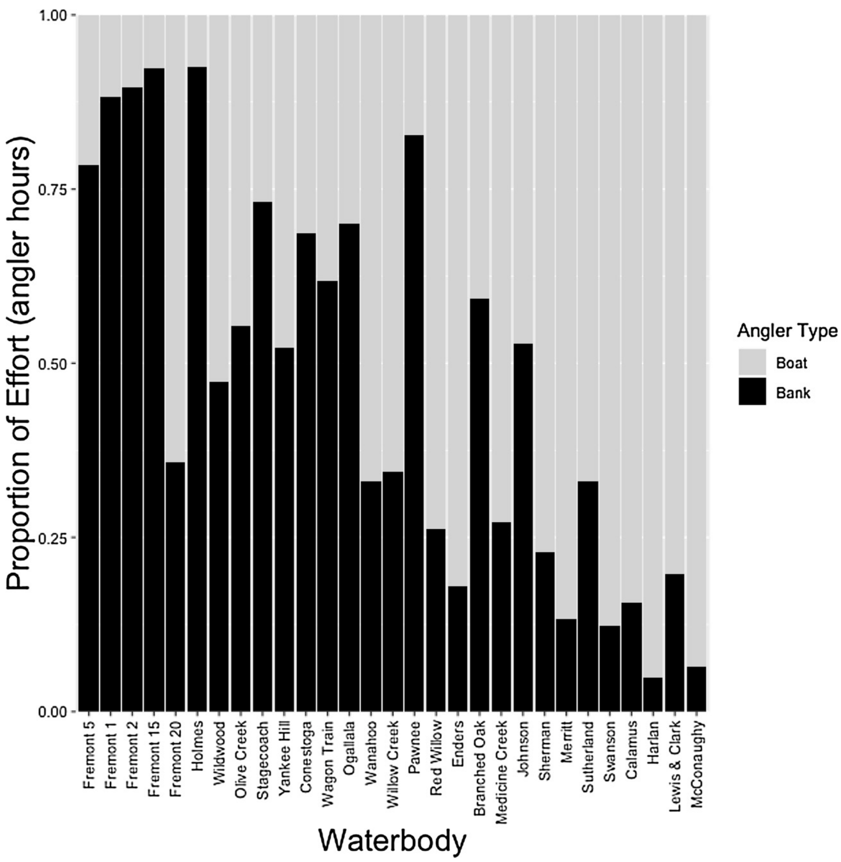

Fig. 1. Proportion of estimated effort (angler hours) for bank and boat anglers across 29 Nebraska waterbodies during 2007–2017. Angler effort was collected from onsite surveys using a stratified multistage sampling regime (Malvestuto, 1996; Kaemingk et al., 2018). Waterbodies are arranged from smallest (left) to largest (right) surface area.

Kaemingk et al., 2018, 2019; Matsumura et al., 2019).

2.2. Analysis

We used linear mixed effects models with normal (Gaussian) distributions to evaluate behavioral differences between bank and boat anglers. We developed a set of models for each behavioral attribute, using information at the fishing party level (Tables 2 and 3). Angler type, waterbody size, and season were included as fixed effects for each model. We explored the potential for interactions among these fixed effects to help explain differences in party size, time fished, fish released, and fish harvested. Waterbody and year were included as random effects in all models, and depending on the attribute, we also included party size or party effort (party size × time fished) to control for variation in these factors on time fished, fish released, and fish harvested across parties (Table 3). For example, we included party size in competing models used to explain angler-type differences in time fished to account for different party sizes.

We used an information theoretic approach to evaluate model performance and selected the most parsimonious model among the seven candidate models for each attribute. Our global model included a three-way interaction among angler type, waterbody size, and season. We also included a null model (i.e., intercept and random effects) among our candidate models. We used Akaike Information Criterion corrected for small sample sizes (AIC_c) to determine which of the seven models best fit our data to explain variation for each attribute. Candidate models with a $\Delta AIC_c \leq 2$ were further considered to be important for explaining differences between angler types (Burnham and Anderson, 2002). Analyses were performed in R (R Development Core Team, 2014) using the lme4 package (Bates et al., 2015).

3. Results

Bank and boat anglers varied in their behavior across the 29 waterbodies surveyed. Bank-angler parties averaged 1.9 anglers per party (range: 1–13), whereas boat-angler parties averaged 2.2 anglers per party (range: 1–13). Bank anglers averaged 3.25 h (range: 0.32–69.16) fished per trip, whereas boat anglers averaged 4.96 h (range:

Table 2
List of variables, abbreviations, descriptions, and options used in our mixed effects models to explain behavioral attribute differences between bank and boat anglers.

Variable	Abbreviation	Description	Options
Angler type	A	How anglers access a fishery	Bank, boat
Waterbody size	W	Waterbody size categories as defined by Kaemingk et al. (2019)	Extra small, small, medium, large
Season	S	The season in which the fishing trip occurred	Spring, summer, fall
Waterbody	B	The waterbody on which the fishing trip occurred	See Table 1
Year	Y	The year in which the fishing trip occurred	2007–2017
Party effort	E	Number of angler hours (P × T)	0.3–899.3
Party size	P	Number of anglers traveling together for the purpose of fishing	1–13
Time fished	T	Number of hours a party spent fishing	0.3–69.2
Fish released	R	Number of fish caught and released	0–313
Fish harvested	H	Number of fish caught and harvested	0–99

Table 3
List of all candidate models used to evaluate differences in party size (P), time fished (T), and numbers of fish released (R) and harvested (H) between bank and boat anglers. Angler type (A), waterbody size (W), and season (S) served as fixed effects and waterbody (B), year (Y), party size [log(P)], and party effort [log(E)] were included as random effects, depending on the model and variable of interest. See methods and Table 2 for more information.

Model	Model Equation
Party Size	
Null	P ~ (1|B) + (1|Y)
A	P ~ A + (1|B) + (1|Y)
A*S	P ~ A*S + (1|B) + (1|Y)
A*W	P ~ A*W + (1|B) + (1|Y)
A + W + S	P ~ A + W + S + (1|B) + (1|Y)
A*W + A*S	P ~ A*W + A*S + (1|B) + (1|Y)
A*W*S	P ~ A*W*S + (1|B) + (1|Y)
Time Fished	
Null	T ~ (1|B) + (1|Y) + log(P)
A	T ~ A + (1|B) + (1|Y) + log(P)
A*S	T ~ A*S + (1|B) + (1|Y) + log(P)
A*W	T~ A*W + (1/B) + (1|Y) + log(P)
A + W + S	T ~ A + W + S + (1|B) + (1|Y) + log(P)
A*W + A*S	T ~ A*W + A*S + (1|B) + (1|Y) + log(P)
A*W*S	T~ A*W*S + (1|B) + (1|Y) + log(P)
Fish Released	
Null	R ~ (1|B) + (1|Y) + log(E)
A	R ~ A + (1|B) + (1|Y) + log(E)
A*S	R ~ A*S + (1|B) + (1|Y) + log(E)
A*W	R~ A*W + (1|B) + (1|Y) + log(E)
A + W + S	R ~ A + W + S + (1|B) + (1|Y) + log(E)
A*W + A*S	R ~ A*W + A*S + (1|B) + (1|Y) + log(E)
A*W*S	R~ A*W*S + (1|B) + (1|Y) + log(E)
Fish Harvested	
Null	H ~ (1|B) + (1|Y) + log(E)
A	H ~ A + (1|B) + (1|Y) + log(E)
A*S	H ~ A*S + (1|B) + (1|Y) + log(E)
A*W	H ~ A*W + (1|B) + (1|Y) + log(E)
A + W + S	H ~ A + W + S + (1/B) + (1|Y) + log(E)
A*W + A*S	H ~ A*W + A*S + (1|B) + (1|Y) + log(E)
A*W*S	H ~ A*W*S + (1|B) + (1|Y) + log(E)

Table 4
Model selection results for Akaike's Information Criteria (AIC_c), corrected for small sample sizes, to evaluate differences in party size (P), time fished (T), and numbers of fish released (R) and harvested (H) between bank and boat anglers (Table 3). Models include angler type (A), waterbody size (W), and season (S) as main effects. Number of parameters (k), corrected Akaike value (AIC_c), delta Akaike value (ΔAIC_c), and Akaike weight ($wAIC_c$) are provided for each model. The most supported models ($\Delta AIC_c \leq 2$) are in **bold**.

Model	k	AIC_c	ΔAIC_c	$wAIC_c$
Party Size				
A*W + A*S	**15**	**110209.4**	**0.00**	**0.97**
A*W*S	27	110216.4	7.03	0.03
A + W + S	10	110312.3	102.92	0.00
A*S	9	110316.1	106.76	0.00
A*W	11	110603.4	394.08	0.00
A	5	110715.2	505.81	0.00
Null	4	111260.8	1051.48	0.00
Time Fished				
A*W*S	**28**	**176408.6**	**0.00**	**1.00**
A*W + A*S	16	176422.7	14.07	0.00
A*W	12	176507.1	98.46	0.00
A + W + S	11	176882.3	473.71	0.00
A*S	10	176910.5	501.89	0.00
A	6	176998.4	589.80	0.00
Null	5	178797.8	2389.13	0.00
Fish Released				
A*W + A*S	**16**	**304069.1**	**0.00**	**0.54**
A*W*S	**28**	**304069.5**	**0.35**	**0.46**
A*S	10	304088.5	19.36	0.00
A + W + S	11	304106.1	36.99	0.00
A*W	12	304194.4	125.29	0.00
A	6	304215.5	146.36	0.00
Null	5	304298.4	229.24	0.00
Fish Harvested				
A*W*S	**28**	**261119.2**	**0.00**	**1.00**
A*W + A*S	16	261188.0	68.76	0.00
A*S	10	261202.6	83.44	0.00
A + W + S	11	261280.4	161.16	0.00
A*W	12	261364.7	245.46	0.00
A	6	261378.4	259.24	0.00
Null	5	261385.4	266.20	0.00

0.33–26.53) fished per trip. Bank anglers averaged 3.9 fish released per trip (range: 0–161), whereas boat anglers averaged 6.7 fish released per trip (range: 0–313). Bank anglers averaged 2.2 fish harvested per trip (range: 0–61), whereas boat anglers averaged 3.7 (range: 0–99) fish harvested per trip.

In general, angler behavior was best explained by some form of interaction among angler type, waterbody size, and season (Table 4; Fig. 2). The null model was the least supported for all attributes despite containing the fewest parameters. The most supported model used to understand variation in party size included two-way interactions between angler type and waterbody size and angler type and season (Supporting Information Table S5). Party size differed across waterbody size for bank and boat anglers; small waterbodies received the largest bank angler parties and large waterbodies received the largest boat angler parties. Party size was also greatest during the summer and least during the fall for bank and boat anglers (Fig. 2). A three-way interaction among angler type, waterbody size, and season best explained patterns in time fished (Supporting Information Table S6). Therefore, patterns in time fished depends on both waterbody size and season for bank and boat anglers (Fig. 2). For fish released, two candidate models were supported that included one with two-way interactions between angler type and waterbody size and between angler type and season (Supporting Information Table S7), and the other model a three-way interaction among angler type, waterbody size, and season. Thus, the number of fish released by bank and boat anglers depends on both waterbody size and season. The model that best explained fish harvested included a three-way interaction among angler type, waterbody size, and season (Supporting Information Table S8). Similar to the number of fish released, the number of fish harvested depends on waterbody size and season for bank and boat anglers.

4. Discussion

Anglers represent a heterogeneous population that varies in motivations, specializations, and preferences (Fedler and Ditton, 1994; Connelly et al., 2001; Pope et al., 2016). How anglers choose to access a fishery could represent a substantial source of this variation (Chizinski et al., 2014a; Edwards et al., 2016; Pope et al., 2016). As a result, continued collection and assessment of different angler types is warranted. We demonstrated that behavioral attributes of bank and boat anglers vary across waterbody sizes and seasons. Recognizing and accounting for these changes in angler behavior could be invaluable for developing and establishing management and conservation goals and objectives. Understanding the general composition of angler types at a waterbody will be an important first step. For example, management actions may be quite different for waterbodies that receive mostly bank (e.g., Holmes) or boat (e.g., Harlan) angling effort compared to waterbodies that receive similar bank and boat angling efforts (e.g., Yankee Hill; Fig. 1). Management actions, such as modifying harvest regulations, will likely impact each angler-type differently and could lead to spatial and temporal changes in the level of catch-and-release mortality (Kerns et al., 2012). Successful implementation of management actions at a waterbody will therefore depend on waterbody size, season, and the composition of bank and boat anglers.

Size of waterbody is an important predictor of recreational fishery dynamics (Lyach and Čech, 2018; Chizinski et al., 2018; Kaemingk et al., 2019). Landscapes with greater waterbody-size diversity are

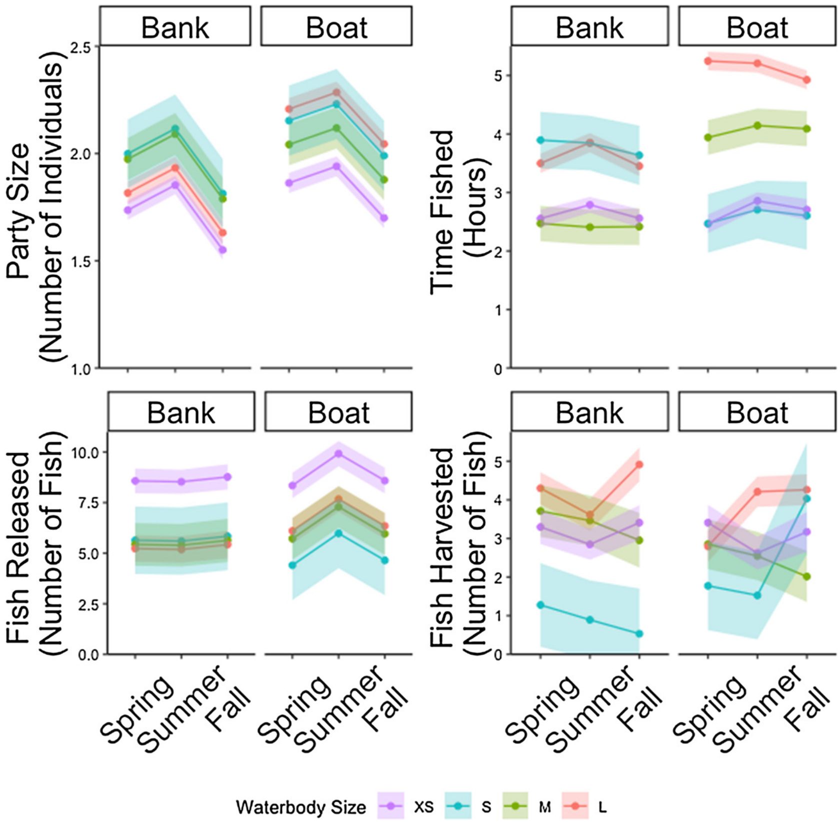

Fig. 2. Spatial (waterbody size) and temporal (season) behavioral patterns between bank and boat anglers for party size (number of anglers), time fished (hr), fish released (number of fish released), and fish harvested (number of fish harvested) using data collected at 29 Nebraska waterbodies during 2007–2017 (Table 1). Angler behavioral patterns from the most supported model for each attribute (Table 4) are presented using the R ggplot2 package (R Development Core Team, 2014; Wickham, 2016) that includes model estimates (dots), directionality (lines), and standard error (ribbons).

expected to create and attract greater angler-type diversity (Kaemingk et al., 2019). Bank and boat anglers appeared to respond uniquely to different waterbody sizes, suggesting that anglers may consider both their mode of access and waterbody size in the site-selection process. The decision on where to fish may be further complicated by their target species. Certain species may be more available in the limnetic zone, which could preclude bank anglers from targeting and catching these fish. Bank anglers can only fish littoral habitat, whereas boat anglers can choose to fish littoral and limnetic habitats (Chizinski et al., 2018). The ratio between littoral and limnetic zones will vary according to the size of waterbody and could lead to different behaviors by bank and boat anglers.

Seasonal dynamics also appear to modify the behavior of bank and boat anglers. The seasonal changes between bank and boat anglers was strongly dependent on waterbody size. Access to certain habitats may become more limited for certain angler types and waterbody sizes from spring to summer. Take, for instance, vegetation growth and its ability to modify angler behavior. Waterbodies with a greater limnetic zone can become dominated by aquatic vegetation and consequently deter bank anglers (Hoyer and Canfield, 1996). Boat anglers may be less affected by increased summer growth and expansion of aquatic vegetation. Seasonal changes in fish behavior, such as inshore and offshore movements (Keast and Fox, 1992; Kaemingk et al., 2011), may also cause a shift in angler behavior for different angler types.

Access changes at a waterbody, such as increasing the number of boat ramps or amount of accessible shoreline, may affect social-ecological dynamics within and across waterbodies. For example, the composition of angler types dramatically shifted from predominantly boat anglers to a more even composition of bank and boat anglers following a drawdown of a large Nebraska reservoir (Chizinski et al., 2014b). This change in angler-type composition could reflect a local or a regional shift in bank and boat angler composition. A local shift in angler-type composition could occur if anglers decided to switch from boat fishing to bank fishing after boat ramps became unusable. Alternatively, a regional shift in composition could occur if boat anglers decided to fish elsewhere. These local or regional changes in angler types are expected to modify party size, time fished, and numbers of fish released and harvested. Management actions have the ability to shift angler types and could be a method for achieving management and conservation goals and objectives. Monitoring changes in angler types is extremely important and could be used as an indicator to detect a variety of important social-ecological dynamics within and across fisheries, such as degraded access and seasonal fish movements.

Several important questions remain regarding how an angler chooses to access a fishery, which according to our results will lead to unique spatial and temporal differences in angler behavior and social-ecological dynamics. Does this decision represent a specialization continuum, where most anglers begin bank fishing and some eventually transition and become boat anglers (or vice versa)? Do cultural and socioeconomic factors determine how an angler accesses a fishery (Palm and Malvestuto, 1983)? Perhaps some anglers commonly use both access types, depending on waterbody size, season, and target species. For example, anglers may be flexible and transition from using the bank earlier in the year to a boat later in the year. A deeper understanding is required to begin predicting how individuals adopt certain angler-access strategies and the dynamic nature of this decision.

In summary, collecting and assessing angler-access information could aid in establishing and achieving fishery objectives. Angler-access information likely exists for several fisheries (e.g., via creel surveys), but we surmise that most agencies are not leveraging this information to its full potential. Anglers represent a heterogeneous group and how they access a fishery represents an important component of this variation. Bank and boat angler behavior differed according to waterbody size and season; ignoring these spatial and temporal differences could lead to undesirable consequences at local and regional levels (Matsumura et al., 2019; Carruthers et al., 2019). Tracking and managing changes in angler heterogeneity will ultimately improve the management and conservation of these important social-ecological systems.

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Declaration of Competing Interest

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Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.fishres.2019.105463.

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