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CONCEPTUAL FRAMEWORK LINKING RESOURCE SIZE AND RECREATIONAL USE

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CONCEPTUAL FRAMEWORK LINKING RESOURCE SIZE

AND RECREATIONAL USE

by

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Participation in recreational activities at natural resource systems is important to many people. However, the use of these resource systems can cause negative social and ecological impacts. To manage the potential negative impacts of resource use, natural resource managers must have the ability to quantify and monitor the amount of use that is occurring. Unfortunately, it is difficult and costly to quantify and monitor resource system use. Natural resource management would benefit from uncovering a simple, easily accessible metric that could predict resource system use. The size of a resource system is related to social and ecological aspects of the resource system and ultimately could predict the quantity of resource system use. A resource size-use relationship is a valuable tool that could enable natural resource managers the ability to quantify use on systems that have not been sampled, produce broad-scale estimations of resource use, highlight resource systems that are receiving more or less use than predicted by their size, further their understanding of how use might change if a resource system's size changes, and learn about the heterogeneity of different types of users. For example, within recreational fisheries, waterbody size and angler effort could be utilized as a proxy for resource system size and use. Recreational fisheries managers then could utilize the resource size-use relationship to improve the management of recreational fisheries by examining waterbody size-angler effort relationships. One use of waterbody size-angler

effort relationships is to compare how unique types of anglers differ in how their angler effort relates to waterbody size. One way to differentiate anglers is based on how they access the waterbody. Comparisons of the waterbody size-angler effort relationships for each angler-access type highlight the differences in the composition of angler effort for each angler-access type along the gradient of waterbody sizes. Bank angler effort is dominant at smaller waterbodies, whereas boat angler effort is dominant at larger waterbodies. Differences in the composition of angler-access types demonstrates the importance of recreational fisheries managers considering waterbody size and angler-access types. Management actions affect angler-access types uniquely and the composition of angler-access type changes as waterbody size changes. Thus, fisheries managers could include waterbody size when considering management decisions. The framework of the resource system size-use relationship is valuable to natural resource management, as it can produce broad-scale estimations of resource system use, guide the allocation of management resources according to expected resource system use, predict how changes in resource system size may affect use, and highlight how different user groups may interact with resource systems of various sizes.

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Glossary

Term	Definition
Resource system	A specified, designated managed area containing forested areas, wildlife, or water systems, such as a reservoir, mountain, or wildlife refuge (Ostrom, 2009)
Resource use	Participation in a recreational activity on a resource system.
Angler effort	The number of angler hours that a waterbody receives.

CHAPTER 1: WATERBODY SIZE AND ANGLER EFFORT HIGHLIGHTS THE RESOURCE SIZE-USE RELATIONSHIP

Introduction

Participation in activities that depend on natural resources, such as fishing, birdwatching, and other nature-based recreation, is important worldwide as it is a main source of political support for land protection, contributes to societal economic development, and promotes environmentally conscience behaviors (e.g., Kacal, 2018; Thomas & Reed, 2019; Arlinghaus et al., 2020). However, use of natural resource systems (e.g., a specified, designated managed area containing forested areas, wildlife, or water systems, such as a reservoir, mountain, or wildlife refuge; Ostrom, 2009) can cause numerous negative social and ecological impacts, such as crowding and declines in biodiversity (e.g., Cole, 2001; Dudgeon et al., 2006; Thompson, 2015). Consequently, shifts and changes in the quantity of resource use may present problems for natural resources managers, such as reducing the population of target species by consumptive activities or degrading the environment through trampling of vegetation (e.g., Post et al., 2002; Cooke & Cowx, 2004; Monz et al., 2013). To effectively manage resource system use, natural resource managers must first know how much use resource systems are receiving. For many natural resource systems, however, the amount of use they receive is often not measured or tracked, as quantification of use is typically difficult and costly (e.g., Post et al., 2002; Hadwen et al., 2007; Trudeau et al., 2021). Identifying a cost-effective method for predicting use for a broad range of resource systems would be valuable to natural resource management.

The amount of use resource systems receive is not identical across multiple resource systems (e.g., Steffe et al., 2008; Askey et al., 2018; Hansen & Van Kirk, 2018; Thomas & Reed, 2019), as some resource systems cater to specific recreational activities. For example, a lake may provide opportunities for people to fish, swim, or boat, whereas a mountain may provide opportunities for people to hike, bike, watch wildlife, or hunt. We predict that not all lakes receive equal levels of fishing pressure and not all mountains host the same number of hikers (e.g., Mockrin et al., 2011; Lynch, 2014; Reilly et al., 2017). The spatial distribution and composition of natural resources across the landscape can contribute additional variation in resource system use across multiple resource systems (e.g., Carpenter & Brock, 2004; Parry et al., 2009; Wilson et al., 2016). The users of resource systems also contribute to the variation in resource system use (hereafter resource use), as users represent diverse and heterogeneous groups (e.g., Holland & Ditton, 1992; Connelly et al., 2001; Watkins et al., 2018). For instance, recreational anglers are geographically diffuse, diverse in their motivations, and behaviorally dynamic (e.g., Arlinghaus, 2006; Johnston et al., 2010; Golden et al., 2019). Similarly, hunters are heterogeneous in terms of where they hunt, how frequently they hunt, and their motivations to hunt (e.g., Hunt et al., 2005; Kerr & Abell, 2016; Hinrichs et al., 2020). Understanding how resource use varies from one resource system to another is the first step in predicting resource use across a range of resource systems.

The size of a resource system could provide utility in understanding how resource use varies from one system to another. Size is an important metric that drives both ecological and social aspects of natural resources, and thus, may serve as an important indicator for predicting resource system use. For aquatic systems, the size of floodplain waterbodies, along with depth and water clarity, is important in structuring fish assemblages (Miranda & Lucas, 2004; Lubinski et al., 2008; Miranda, 2011). Larger waterbodies typically have greater species richness for a variety of taxa and offer more diverse recreational opportunities compared to smaller waterbodies, as resource quality is typically related to resource size (e.g., Post et al., 2000; Hunt, 2005; Nikolaus et al., 2019). For terrestrial systems, land area determines habitat management and conservation costs (Armsworth et al., 2011). The size and density of urban green spaces within a neighborhood correlate with the number of visits to these urban green spaces (Neuvonen et al., 2007; Kaczynski et al., 2009; Sugiyama et al., 2010). Additionally, larger forest fragments are more useful for ecosystem goods and firewood compared to smaller forest fragments (Hartter, 2010). The relationships between resource system size and other aspects of resource systems, such as fish assemblage structure, available recreational opportunities, and usefulness for ecosystem goods indicate that resource size could serve as a useful predictor of resource use, with increases in resource size leading to a general increase in resource use.

Our goal was to determine if resource size could predict resource use. We used a large recreational fishery dataset from Nebraska, USA to explore the resource system size-use relationship. We hypothesized that there is a positive relationship between resource system size (i.e., waterbody size) and resource system use (i.e., angler effort; Figure 1.1), with resource system use increasing as resource size increases. Understanding the relationship between resource system size and use could allow natural resource managers to predict the amount of use resource systems are receiving with a cost-effective methodology. The potential resource system size-use relationship is a valuable tool that, if it exists, can be used to produce broad-scale estimations of resource system use, guide the allocation of management resources according to expected resource system use, predict how changes in resource system size may affect use, and highlight how different user groups may interact with various sized resource systems.

Methods

Study Area

We assessed resource use at 73 waterbodies throughout Nebraska, USA from 2009 through 2019 (Table 1.1). These waterbodies ranged in size from 1 to 12,141 ha (mean = 593 ha; standard deviation = 2,028 ha) and were constructed for a variety of purposes including flood control, irrigation storage, hydropower generation, and community recreation purposes. These waterbodies are spatially spread throughout Nebraska and represent a diversity of fishing opportunities (Pope et al., 2016; Kaemingk et al., 2020).

Angler Effort Estimations

We obtained angler effort estimations (hours spent fishing; i.e., resource use) from instantaneous counts of anglers at each waterbody. Counts occurred between sunrise and sunset from April through October. Angler-count days and times were randomly selected following a stratified multi-stage probability-sampling regime (Malvestuto, 1996). Angler effort estimations were calculated using previously outlined methods (Malvestuto et al., 1978; Pierce & Bindman, 1994; Pollock et al., 1994; Malvestuto, 1996; Pollock et al., 1997). We conducted angler counts for 10, 12, 20, or 24 days per month, depending on the size of the waterbody and logistics (Kaemingk et al., 2019).

During each month, angler counts were stratified by day type (i.e., weekdays and weekend days, holidays were either treated as weekend days or their own day type) and day periods (i.e., morning and afternoon). The number of counted anglers was multiplied by the number of hours in each survey period and divided by the probability of selecting a day period (0.5) to produce daily effort, which was multiplied by the number of days within a day type present in the month and summed across all day types to produce a monthly angler effort estimation. Monthly angler effort estimations were then summed to estimate angler effort from April through October, from here on referred to as annual angler effort. For waterbodies that were sampled multiple years, the amount of estimated annual angler effort was averaged across all years sampled.

Analysis

We compared multiple potential models to assess the resource system size-use relationship using annual extrapolated angler effort (hours) as a function of waterbody size (ha) as proxies for resource system use and size, respectively. We considered six models of the resource system size-use relationship, two linear models (one with untransformed data, one with $\log_{10}$-transformed data), two segmented linear models (one with untransformed data, one with $\log_{10}$-transformed data), and two generalized additive models (GAMs; one with untransformed data, one with $\log_{10}$-transformed data). We $\log_{10}$-transformed waterbody size and angler effort to reduce heteroscedasticity and represent the likely diminishing effect of increasing waterbody size and angler effort, as the relative difference between waterbodies that are 1,000 and 2,000 ha is not the same as the relative difference between waterbodies that are 11,000 and 12,000 ha (Parsons & Kealy, 1992; Woolnough et al., 2009; Hunt & Dyck, 2011). We utilized the coefficient of determination (COD), corresponding p-values, utility rating, and a visual inspection of the residuals, to compare and ultimately select our resource system size-use relationship model to use moving forward. The utility rating is subjective, based on the assumed ease of interpretation and application of the model by natural resource managers. We conducted all analyses in R (R Core Team, 2017).

Results

Our waterbodies varied in terms of extrapolated annual effort, ranging from 81 hours to 161,774 hours (mean = 23,560 hours; standard deviation = 30,793 hours). The waterbody size-angler effort relationship was significant in all models (Table 1.2). The COD for the GAMs (Fig. 1.6; Fig. 1.7) were higher compared to the segmented models (Fig. 1.4; Fig. 1.5) and the linear models (Fig. 1.2; Fig. 1.3), however, all models had CODs of greater than 0.4. Similarly, the GAMs had the smallest p-values compared to all other models, however, all models had p-values of less than 1.2E-06. Ultimately, all models represent the resource system size-use relationship well, so we opted to select one of the models that scored best in the utility scale (i.e., the easiest to interpret and apply), which included our linear and log-linear models. The residuals of the linear model display more heteroscedasticity compared to the residuals of the log-linear model (Fig. 1.2; Fig. 1.3). Thus, we utilized the log-linear model as our model for resource system size and use.

Waterbody size was a significant predictor of angler effort across the 73 waterbodies evaluated ($r^2 = 0.60$, $p < 0.01$; Fig. 1.3). As waterbody size increased, so did the amount of angler effort ($\log_{10}[\text{use}] = 3.03406 + 0.56743 \times \log_{10}[\text{size}]$). The resource system size-use relationship for recreational angling at waterbodies in Nebraska had a slope of 0.57, indicating a positive relationship. The y-intercept for the resource system size-use relationship for recreational angling at waterbodies in Nebraska was 3.03. This y-intercept indicates that one-ha waterbodies receive approximately 1,100 hours ($10^{3.03}$; due to the usage of the natural log-transformed scales) of angler effort between April and October.

Discussion

We provided evidence that though natural resource use varied across multiple resource systems, resource system size can serve as a reliable indicator of expected resource system use. The relationship between resource size and resource use provides natural resource managers the ability to predict resource use based on the size of a resource system, a simple and readily available metric. Using these predictions, natural resource managers can produce broad-scale estimations of resource system use, guide the allocation of management resources according to expected resource system use, predict how changes in resource system size may affect use, and highlight how different user groups may interact with resource systems of various sizes.

Our model was built using extrapolated annual angler effort estimations from 73 diverse waterbodies throughout the state of Nebraska. Thus, we expect that our model truly represents the resource system size-use relationship for recreational angling in Nebraska. Our model, however, is defined by the waterbodies included in this study, and is not free of bias. All waterbodies studied were waterbodies that received angler effort. As a result, a y-intercept greater than zero was expected. We encourage future studies to replicate our work – in different regions, for different resource user groups, and across different spatial (e.g., local, regional, national) and temporal (e.g., seasonal, annual, decadal) scales – to improve our understanding of resource system size-use relationship within and across different resource systems for different user groups. Though we expect to find resource system size-use relationships for varying resource system types and user groups, we recognize that these relationships will likely be different, as different user groups likely interact with the respective resource systems in unique ways (e.g., Schroeder et al., 2006; Vasiljević et al., 2018; Kane et al., 2020). In other words, we expect the slope and y-intercept of the resource system size-use relationships to vary between different user groups and across different types of resource systems. Exploring these resource system size-use relationships for different user groups and types of resource systems will allow insight into how use increases as a function of resource system size for a range of user groups and types of resource systems.

The ability of resource system size to predict use once a model is developed provides an easy and cost-effective method of obtaining broad-scale natural resource use estimations. Natural resource managers can quickly estimate use for all the resource systems within their management region, including for resource systems that have not been sampled (Fig. 1.8A). Our statewide model can predict use at the individual waterbody level. The predicted levels of use can be summed to produce statewide estimates of resource system use. For instance, in Nebraska, public lakes and reservoirs are divided into 4 management districts. Based on our resource system size-use relationship, angler effort in the 4 districts range from about 852,000 angler hours to over 1,500,000 angler hours per district from April through October (mean = 1,187,638 hours;

standard deviation = 331,212 hours). By summing the predicted amount of angler effort for each district, we can predict that 4,750,551 hours of angler effort occurs on Nebraska's public lakes and reservoirs (excluding streams and rivers) from April through October each year. Ultimately, natural resource managers could produce statewide, regionwide, nationwide, and ultimately worldwide estimations of natural resource use by summing natural resource use estimations.

The resource system size-use relationship also provides utility in the prioritization and allocation of natural resource management funds. Predictions of use based on resource system size can highlight resource systems that are receiving more or less use than predicted by their size (positive or negative residuals; Fig. 1.8B). Natural resource managers can then use this information to help determine where to allocate management resources. When managers identify that a resource system is receiving more or less use than predicted by size, they may decide to invest more resources in that specific system, perhaps to improve the experiences of the natural resource users there, or managers may decide to divert resources to attempt to increase use at nearby resource systems. For example, angler effort typically increases after a fish stocking event (e.g., Loomis & Fix, 1998; Baer et al., 2007). Fish stockings could be directed at resource systems that are receiving less use than predicted based on their size. At the landscape-scale, the predicted amount of use in each management unit within a state or region could guide the allocation of resources across management units.

Another benefit of creating resource system size-use models is the ability to predict how resource system use might change if the size of a resource system were to change (Fig. 1.8C). For instance, water may be drained from a reservoir to manage fish populations or to repair physical structures of a waterbody (e.g., Chizinski et al., 2014). In 2009, a Nebraska reservoir decreased in size from 659 ha to 240 ha to allow for dam repair (Chizinski et al., 2014). Resource system size-use models could predict how much use might decrease with the reduction in resource system size. In this case, use of the 659 ha waterbody would drop from a predicted 42,200 hours of use to a predicted 24,600 hours of use between April and October if the waterbody remained at 240 ha in size. Indeed, Chizinski et al. (2014) documented a decrease in April-October angler effort in the year following the drawdown. Future changes to the size of waterbodies may occur as a result of climate change (e.g., Zou et al., 2017). This may lead to changes in habitat and fish populations present (e.g., McLean et al., 2016), and ultimately angler effort.

Finally, natural resource managers could use resource system size-use models to compare how multiple user groups differ in terms of how their use scales with increasing resource system size (Fig. 1.8D). Differences in the slope and the y-intercept of the resource system size-use relationships between multiple user groups can provide insight into how each group differs in terms of their interaction with the respective resource systems. For instance, different groups whose resource system size-use relationships are similar may present a higher risk of potential conflict. Alternatively, different groups whose resource system size-use relationships are different could present opportunities to natural resource managers to tailor management to each group on different systems. Comparisons could be made amongst groups comprised of similar users (e.g., bank anglers and boat anglers), groups comprised of unique users (e.g., hikers and mountain bikers), groups of similar users across different spatial areas (e.g., anglers in Nebraska and anglers in South Dakota), or groups of similar users across different timeframes (e.g., hunters in the spring and hunters in the fall). Comparing different user groups can allow natural resource managers to further understand the heterogeneity of natural resource users.

Utilizing resource system size-use models allows natural resource managers to start managing resource system use. Caution must be taken, however, when attempting to manage use at any given resource system. Users select resource systems based on a variety of factors, such as travel cost, accessibility, and perceived naturalness (e.g., Haener et al., 2001; Hunt, 2005; Wall-Reinius & Bäck, 2011; Mancini et al., 2019). Consequentially, management actions at one resource system may affect use within a region of resource systems (e.g., Martin and Pope, 2011; Martin, 2013; Chizinski et al., 2014). Any potential management action on a given resource system must consider how use may change on a variety of spatial scales, such as at a single resource system or across a region of resource systems. For instance, closing a reservoir to one or more distinct types of recreationists (e.g., closing a reservoir to boating to attempt to stop the spread of invasive species) could lead to decreased use at the closed waterbody, but may also lead to increased use at nearby waterbodies, acting as substitute sites to recreationists for the closed waterbody (e.g., Siderelis & Moore, 1998; Martin & Pope, 2011; Chizinski et al., 2014). Closing a resource system to one or more distinct types of recreationists may also lead to increased use of the closed resource system by other types of recreationists (e.g., closing a reservoir to boat angling may lead to increases in the amount of bank angling; Chizinski et al., 2014). Similarly, the development of new resource systems could lead to local and regional changes in resource use.

The demonstrated relationship between resource system size and use can change how our natural resources are managed by allowing managers to predict use through the development of resource system size-use models, providing broad-scale estimations of resource system use, guiding the allocation of management resources according to expected use, and highlighting how different user groups interact with natural resources. Developing resource system size-use models allows natural resource managers the opportunity to understand how much use is occurring across all resource systems. This resource system use information can be used to guide the allocation of management resources and management actions to ultimately avoid negative social and ecological impacts, optimizing recreational opportunities on the landscape.

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Table 1.1. Size, years sampled (from 2009 through 2019), and location (latitude, longitude) of each Nebraska, USA waterbody included in this study.

Waterbody	Size (ha)	Years Sampled	Latitude	Longitude
Benson	1	2019	41.297°	-96.019°
Fontenelle	1	2019	41.296°	-95.983°
Fremont 3	1	2010-2013	41.450°	-96.569°
Gracie Creek	1	2015-2018	41.926°	-99.320°
Hitchcock	1	2019	41.206°	-95.980°
Schwer	1	2019	41.168°	-96.054°
Towl	1	2019	41.235°	-96.059°
Walnut Grove	1	2019	41.208°	-96.151°
Fremont 13	1	2010-2012	41.439°	-96.534°
Fremont 14	2	2011-2013	41.438°	-96.533°
Fremont 17	2	2010-2013	41.440°	-96.548°
Fremont 19	2	2010-2011	41.437°	-96.538°
Halleck	2	2019	41.152°	-96.032°
Ta Ha Zouka	2	2010	42.010°	-97.419°
Fremont 4	2	2011-2013	41.450°	-96.574°
Fremont 11	3	2010-2013	41.443°	-96.542°
Fremont 12	3	2010-2013	41.440°	-96.536°
Kramer	3	2019	41.139°	-95.886°
Fremont 5	3	2010-2013	41.449°	-96.573°
Fremont 9	4	2010-2013	41.446°	-96.557°
Midlands	4	2019	41.119°	-96.040°
Fremont 1	4	2010-2013	41.450°	-96.564°
Fremont 2	5	2010-2013	41.450°	-96.564°
Fremont 7 & 8	5	2011-2013	41.450°	-96.581°
Fremont 16	5	2010-2012	41.441°	-96.555°
Fremont 18	5	2010-2013	41.438°	-96.540°
Wild Plum	6	2011	40.613°	-96.886°
Killdeer	6	2012	40.675°	-96.766°
Timber Point	11	2009	41.095°	-96.574°
Cottontail	12	2010	40.647°	-96.764°
Shadow	12	2019	41.119°	-96.040°
Whitehawk	12	2019	41.220°	-96.214°
Fremont 10	15	2010-2013	41.444°	-96.550°
Skyview	16	2010	42.041°	-97.439°
Merganser	17	2010-2011	40.601°	-96.857°
Prairie View	17	2019	41.373°	-96.198°
Red Cedar	20	2009	41.095°	-96.523°
Fremont 20	21	2010-2013	41.438°	-96.552°

Table 1.1 continued.

Waterbody	Size (ha)	Years Sampled	Latitude	Longitude
Fremont 15	22	2010-2013	41.439°	-96.538°
Meadowlark	22	2012	41.032°	-96.912°
Lawrence Youngman	24	2019	41.266°	-96.218°
Walnut Creek	28	2019	41.139°	-96.069°
Holmes	40	2009, 2011	40.777°	-96.638°
Prairie Queen	42	2019	41.160°	-96.110°
Wildwood	42	2010-2012	41.038°	-96.838°
Standing Bear	55	2019	41.314°	-96.132°
Olive Creek	71	2012	40.580°	-96.847°
Stagecoach	79	2009-2010	40.599°	-96.637°
Yankee Hill	84	2011	40.729°	-96.790°
Flanagan	89	2019	41.310°	-96.184°
Conestoga	93	2009	40.769°	-96.852°
Wehrspann	99	2019	41.166°	-96.155°
Zorinsky	103	2019	41.217°	-96.163°
Carter	121	2019	41.302°	-95.921°
Wagon Train	127	2011, 2012	40.626°	-96.579°
Bluestem	132	2010, 2012	40.627°	-96.794°
Ogallala	263	2009-2013	41.213°	-101.666°
Wanahoo	268	2013, 2017	41.235°	-96.615°
Pawnee	299	2009-2010, 2014-2018	40.847°	-96.868°
Box Butte	647	2011-2012	42.461°	-103.075°
Red Willow	659	2009-2012	40.359°	-100.671°
Enders	691	2009-2012	40.437°	-101.538°
Branched Oak	728	2009-2012, 2014-2016, 2018	40.982°	-96.855°
Medicine Creek	749	2009-2012	40.400°	-100.231°
Johnson	886	2012	40.696°	-99.872°
Sherman	1151	2009-2018	41.309°	-98.876°
Merritt	1176	2010-2016, 2018	42.626°	-100.871°
Sutherland	1214	2016, 2018	41.105°	-101.105°
Swanson	2013	2009-2011	40.161°	-101.068°
Calamus	2075	2009, 2015-2018	41.848°	-99.221°
Harlan	5463	2009-2017	40.086°	-99.216°
Lewis and Clark	11331	2009-2012	42.852°	-97.603°
McConaughy	12141	2009, 2011-2013, 2015-2018	41.248°	-101.683°

Table 1.2. Coefficient of determination, p-value, and utility rating (scale of interpretability and applicability of models, 1 = easy, 2 = moderate, 3 = difficult) for each of the models included in this study.

Model Name	Coefficient of Determination	P-Value	Utility Rating
Linear	0.41	8.45E-10	1
Log Linear	0.60	1.37E-15	1
Segmented	0.52	1.10E-06	2
Log Segmented	0.64	1.14E-06	2
GAM	0.68	<2.0E-16	3
Log GAM	0.66	<2.0E-16	3

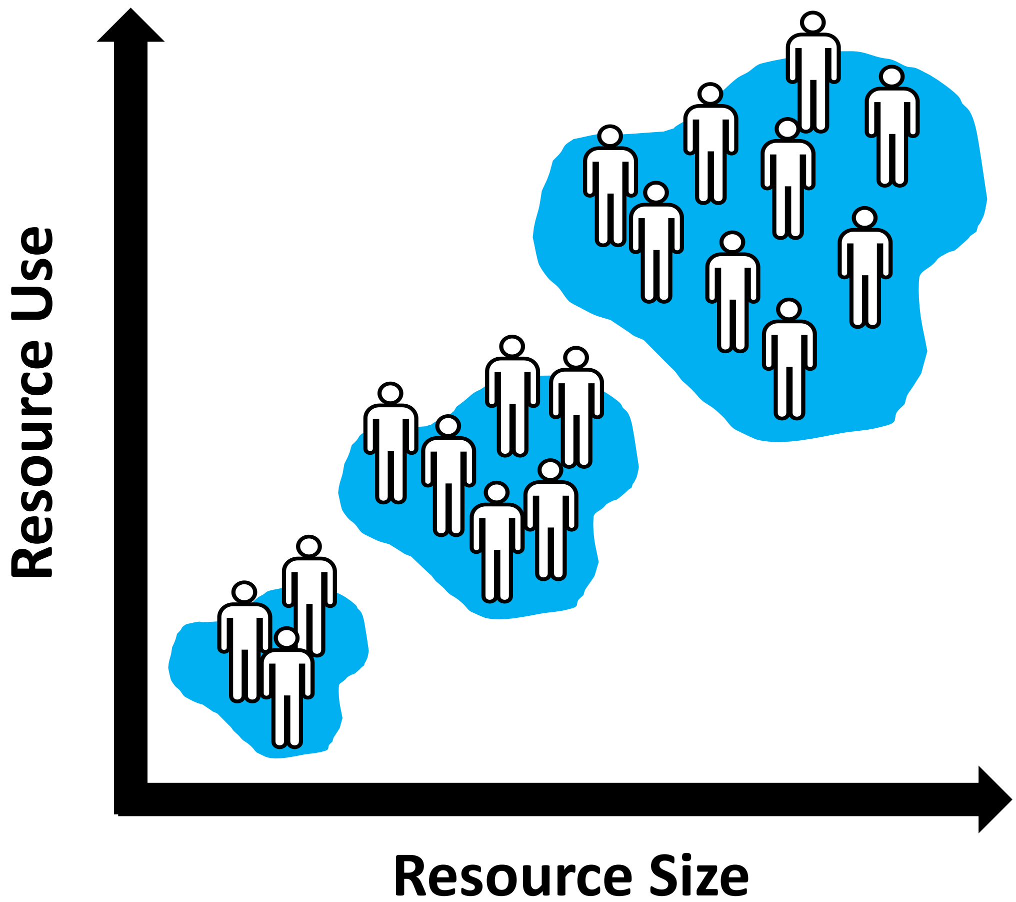

Figure 1.1. Conceptual figure highlighting the hypothesized positive relationship between resource size and resource use.

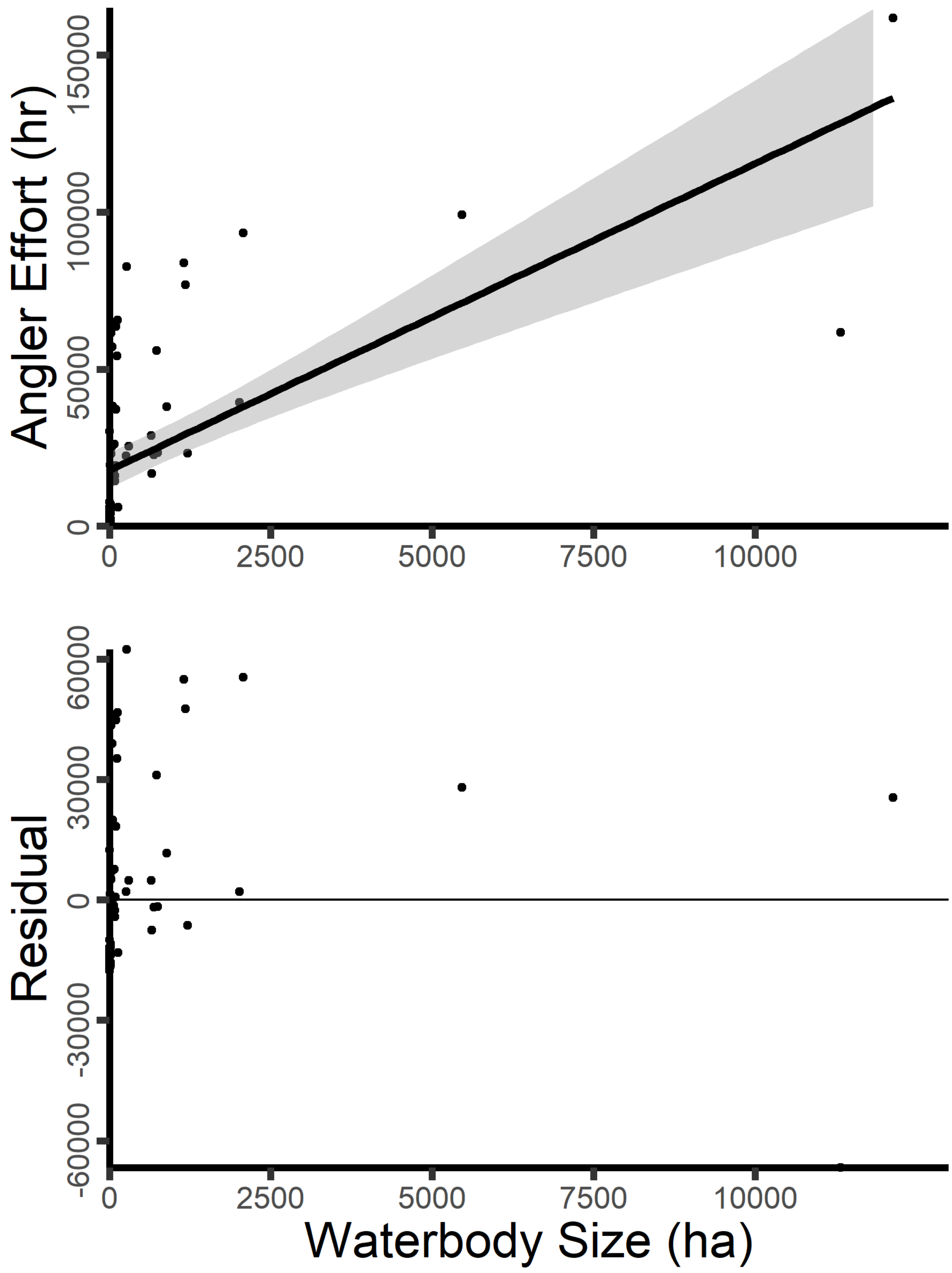

Figure 1.2. Linear model (top) and associated residuals (bottom) of the relationship between angler effort (hours) and waterbody size (hectares). Ribbon represents 95% confidence interval of the model and points represent waterbodies.

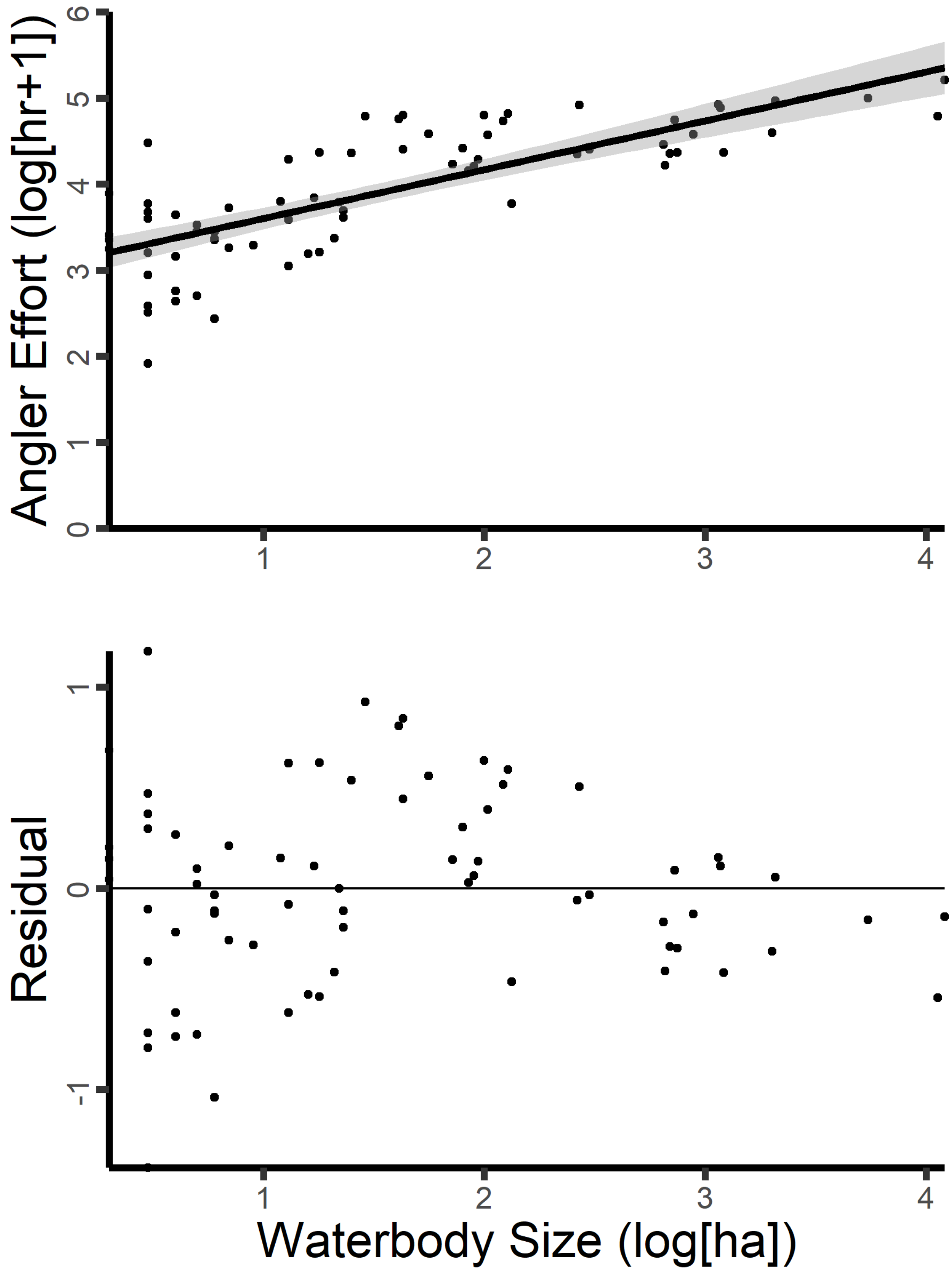

Figure 1.3. Linear model (top) and associated residuals (bottom) of the relationship between log-transformed angler effort (log_{10}[hours+1]) and waterbody size (log_{10}[hectares]). Ribbon represents the 95% confidence interval of the model and points represent waterbodies.

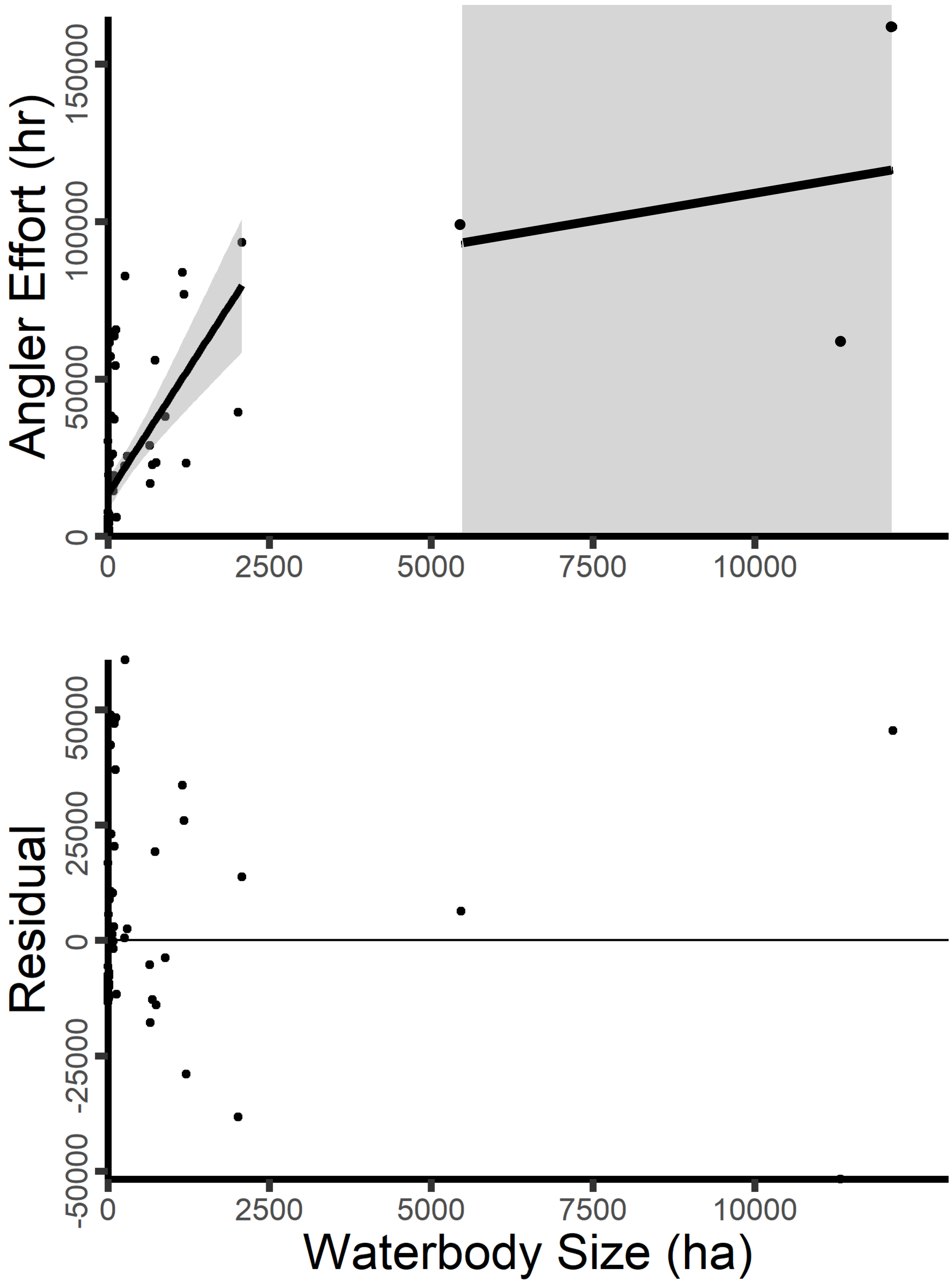

Figure 1.4. Segmented linear model (top) and associated residuals (bottom) of the relationship between angler effort (hours) and waterbody size (hectares). Ribbon represents the 95% confidence interval of the model and points represent waterbodies. Note: The 95% confidence interval for the larger waterbodies expands beyond the range included in this figure.

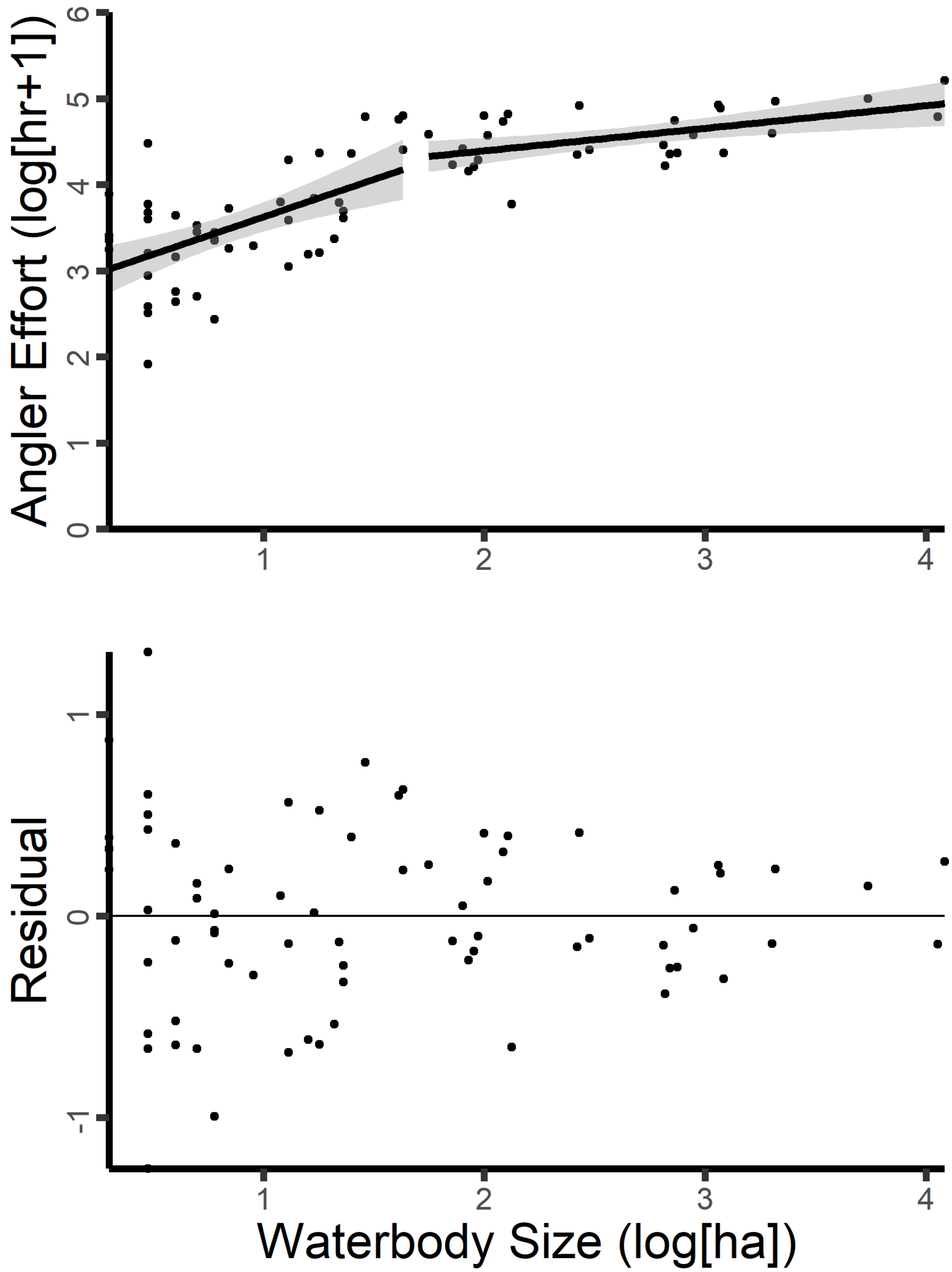

Figure 1.5. Segmented linear model (top) and associated residuals (bottom) of the relationship between log-transformed angler effort (log_{10}[hours+1]) and waterbody size (log_{10}[hectares]). Ribbon represents the 95% confidence interval of the model and points represent waterbodies.

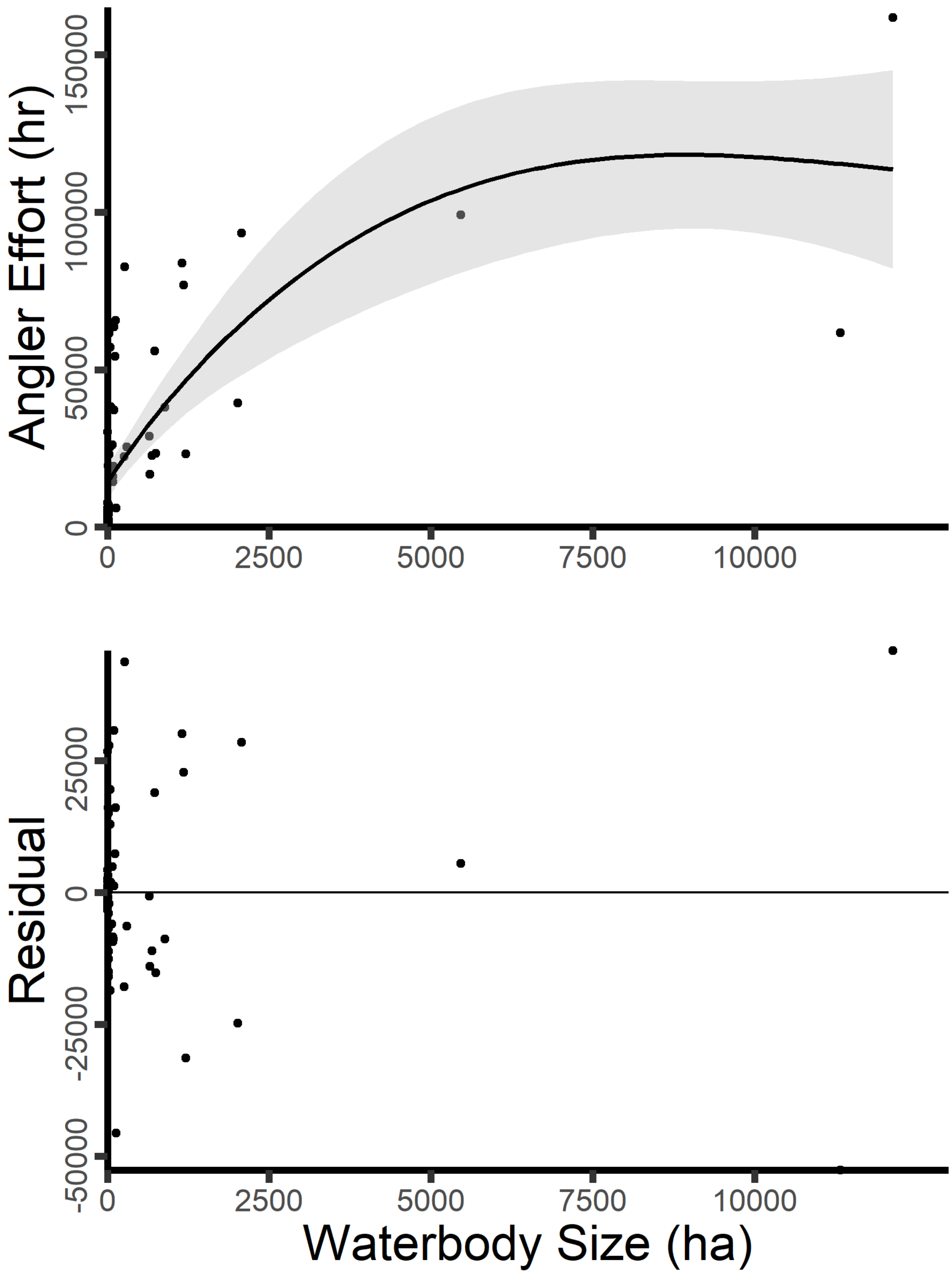

Figure 1.6. Generalized additive model (top) and associated residuals (bottom) of the relationship between angler effort (hours) and waterbody size (hectares). Ribbon represents the 95% confidence interval of the model and points represent waterbodies.

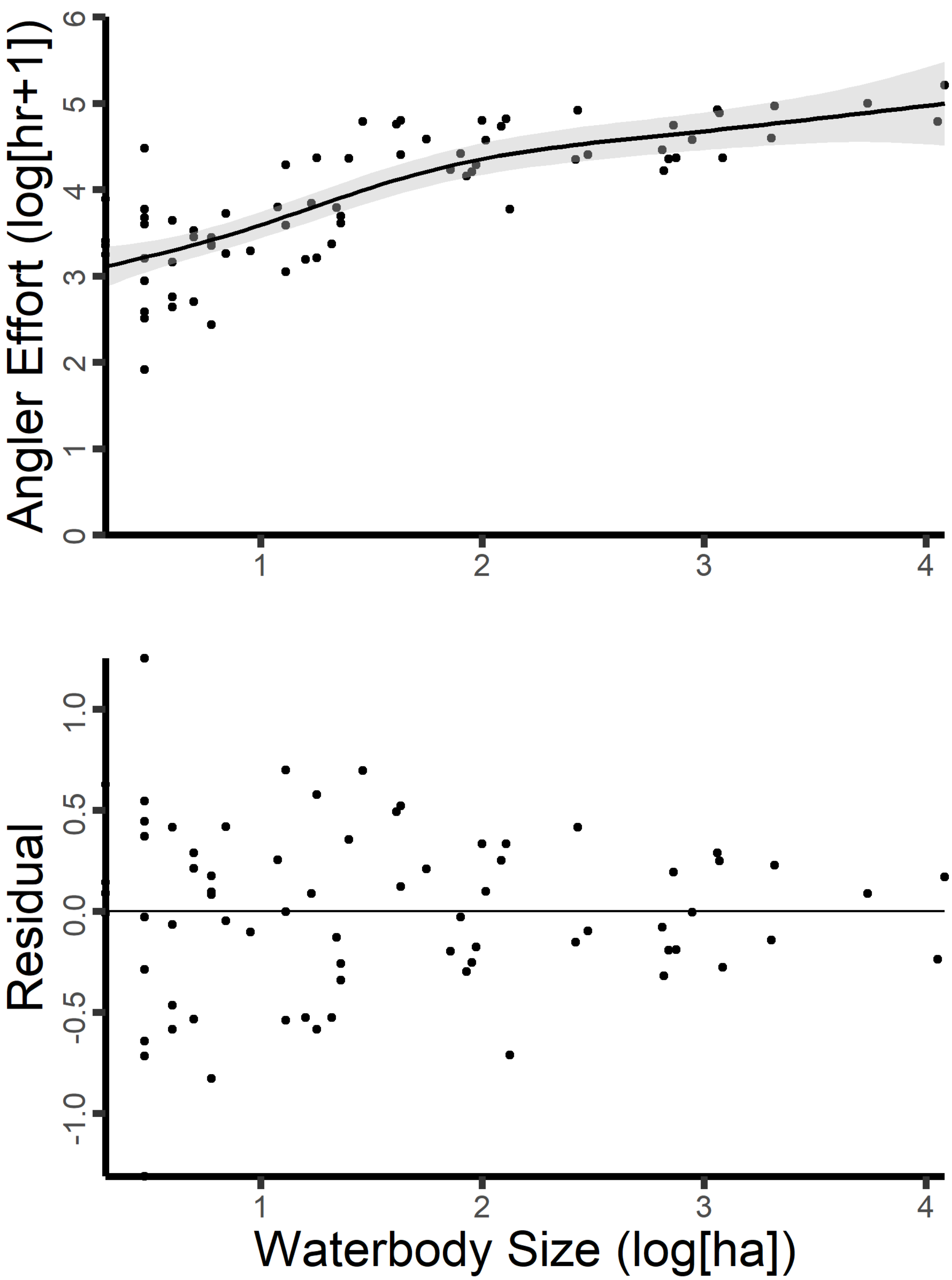

Figure 1.7 Generalized additive model (top) and associated residuals (bottom) of the relationship between log-transformed angler effort (log_{10}[hours+1]) and waterbody size (log_{10}[hectares]). Ribbon represents the 95% confidence interval of the model and points represent waterbodies.

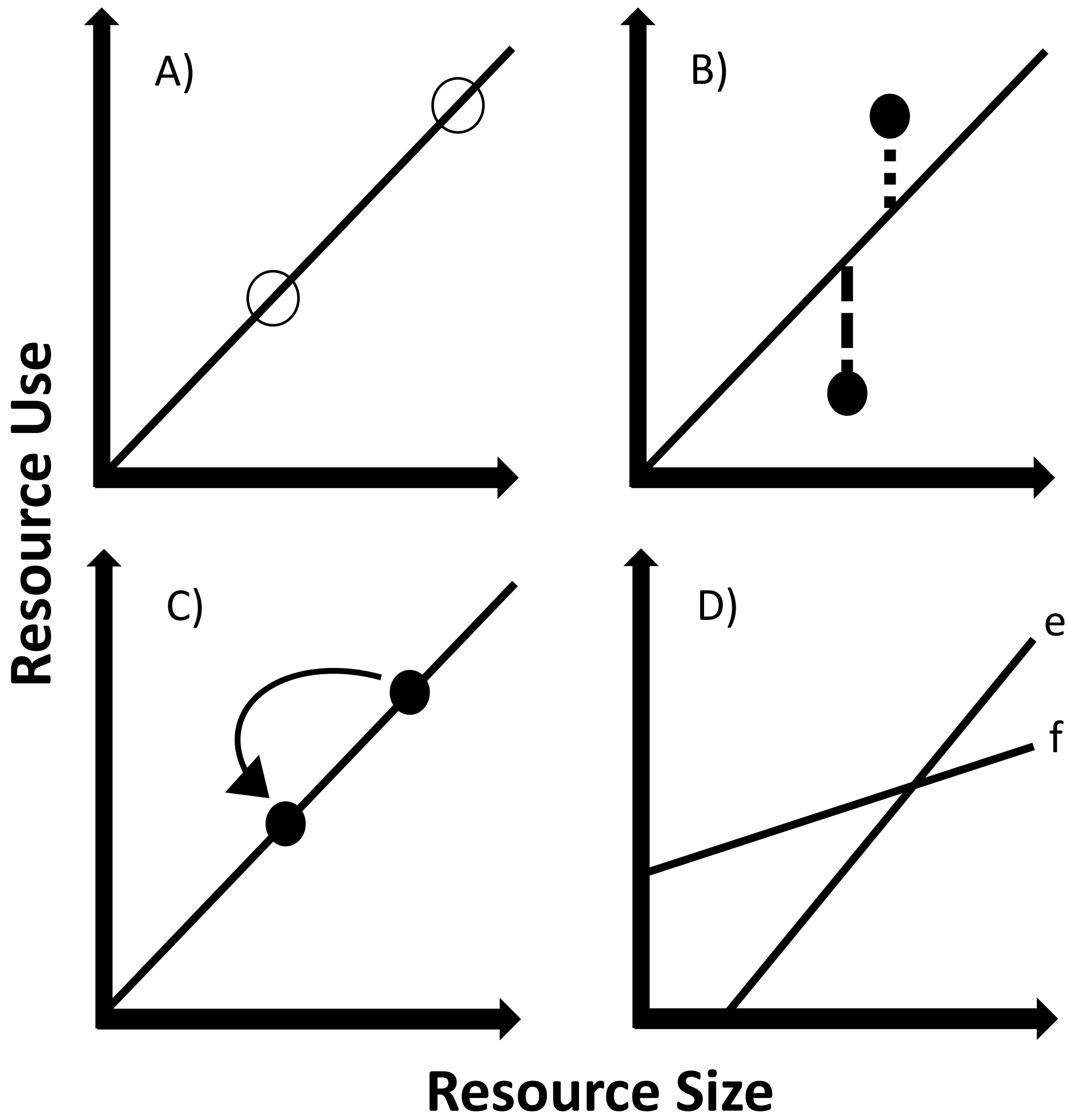

Fig. 1.8. Conceptual applications of the natural resource size-use relationship by natural resource managers. A) Predict the amount of use that unstudied (open dots) resource systems receive. B) Guide the allocation of management funds and effort by highlighting resource systems that are receiving more (above line) or less (below line) use than predicted by size. C) Determine how much resource system use will change if resource system size changes. D) Reveal differences in the resource size-use relationships among heterogenous user groups (e.g., groups e and f).

CHAPTER 2: WATERBODY SIZE REVEALS HETEROGENOUS ANGLER USE

Introduction

Angler effort is a key aspect of recreational fisheries, serving as a measure of fishery attractiveness, a management performance metric, and a prominent variable used to estimate catch, harvest, and mortality rates (Cooke & Cowx, 2004; van Poorten & Brydle, 2018; Askey et al., 2018; Gundelund et al., 2020). The degree of influence that anglers have on fish populations is largely determined by the amount of angler effort exerted (Fayram et al., 2006). Changes in angler effort have both social and ecological consequences, such as changes in levels of societal environmental responsibility and changes to the size structure of a fish population (e.g., Pauly et al. 1998; Arlinghaus et al., 2002; Kearney 2002). Thus, monitoring the amount of angler effort is needed to quantify the effects anglers are having on recreational fisheries. Not all anglers, however, affect fish populations in the same way (Dorow et al., 2010; Johnston et al., 2010). Recreational anglers also vary in how they access a waterbody (i.e., via a boat or the bank). Consequently, bank angler effort is likely different from boat angler effort, in terms of the impact (e.g., catch and harvest rates) each angler-access type has on fish populations and other aspects of recreational fisheries (Pope et al., 2016). Consequently, recreational fisheries management would benefit from an improved understanding of how angler effort from each angler-access type is distributed across waterbodies.

The relationship between resource size and resource use has been documented and can be used to predict angler effort based on waterbody size (Chapter 1). However, the specific resource size-resource use relationship (i.e., y-intercept and slope) is likely different for each angler-access type. The difference in waterbody size-angler effort relationship between bank and boat anglers could be solely a difference in magnitude, or a difference in slope and magnitude (Fig. 2.1). If the difference was solely magnitude, fisheries managers would not need to consider waterbody size when attempting to manage angler effort for each angler-access type. However, if there are differences in magnitude and slope, fisheries managers would need to consider both waterbody size and angler-access type when attempting to manage angler effort, as management actions would likely affect each angler-access type uniquely as waterbody size changes.

Identifying waterbody size-angler effort relationships for each angler-access type could provide valuable insights for fisheries managers. For example, if angler effort for both angler-access types is unique to waterbody size, then the composition of angler-access types across a continuum of waterbody sizes becomes a valuable tool for fisheries managers. Knowing the composition of angler-access types would provide insight on how these anglers are affecting the fishery, due to their differences in party size, angler trip lengths, and the number of fish released and harvested (Kane et al., 2020). Fisheries managers can shift the composition of angler types, as management decisions like size limits and license regulations can impact the composition of angler types (Johnston et al., 2010). For example, boat anglers catch and harvest more walleye and white bass compared to bank anglers (Pope et al., 2016). If fisheries managers are noticing changes in the size structure of either fish population on a waterbody dominated by boat angler effort, they may consider targeting management actions to focus on boat anglers.

Based on behavioral differences between bank and boat anglers (Kane et al., 2020), we predicted that the relationship of waterbody size and angler effort would differ for each angler-access type (Fig. 2.1). Our objective was to evaluate how the waterbody size-angler effort relationships for bank and boat anglers differed. Knowledge of how waterbody size influences angler effort for each angler-access type could improve the management of recreational fisheries, by determining whether fisheries managers need to consider angler-access composition and waterbody size when conducting management actions on recreational fisheries. Establishing angler-access type and resource use relationships will afford fisheries managers opportunities to enact effective management actions to improve recreational fisheries.

Methods

Study Area

We quantified angler effort using instantaneous counts of anglers at each waterbody from April through October at 73 waterbodies throughout Nebraska, USA from 2009 through 2019 (Table 1.1). These waterbodies ranged in size from 1 to 12,141 ha (mean = 593 ha; standard deviation = 2,028 ha) and were constructed for a variety of purposes including flood control, irrigation storage, hydropower generation, and community recreation purposes. These waterbodies are spatially spread throughout Nebraska, represent a diversity of fishing opportunities, reside in urban and rural settings, and vary in participation patterns between bank and boat anglers (Pope et al., 2016; Kaemingk et al., 2020; Kane et al., 2020).

Creel Surveys

We obtained angler effort estimations (hours spent fishing; i.e., resource use) from instantaneous counts of anglers at each waterbody. Counts occurred between sunrise and sunset from April through October. Sampling days and angler-count times were randomly selected following a stratified multi-stage probability-sampling regime (Malvestuto, 1996). Angler effort estimations were calculated using previously outlined methods (Malvestuto et al., 1978; Pierce & Bindman, 1994; Pollock et al., 1994; Malvestuto, 1996; Pollock et al., 1997). We conducted angler counts for 10, 12, 20, or 24 days per month, depending on the size of the waterbody and logistics (Kaemingk et al., 2019). During each month, angler counts were stratified by day type (i.e., weekdays and weekend days, holidays were either treated as weekend days or their own day type) and day periods (i.e., morning and afternoon). The number of counted anglers was multiplied by the number of hours in each survey period and divided by the probability of selecting a either day period (0.5) to produce daily effort, which was multiplied by the number of days within a day type present in the month and summed across all day types to produce a monthly angler effort estimation. Monthly angler effort estimations were then summed to estimate angler effort from April through October, from here on referred to as annual angler effort. For waterbodies that were sampled multiple years, the amount of estimated annual angler effort was averaged across all years sampled.

Analysis

We used linear models to assess relationships between waterbody size and annual angler effort, using the expression:

$$A \sim W \qquad (1)$$

where A is the $\log_{10}$-transformed extrapolated angler effort estimations (bank or boat) and W is the $\log_{10}$-transformed size of the waterbody in hectares. We used analysis of covariance (ANCOVA) to test for differences in the waterbody size-angler effort relationships between angler-access types. We then used the coefficient of determination (r^2) and corresponding p-value to evaluate the strength and determine significance ($\alpha = 0.05$) of these waterbody size-angler effort relationships, respectively. We used the log of waterbody size and extrapolated angler effort estimations, as it demonstrates the resource system size-use relationship well, represents the likely diminishing effect of increasing waterbody size and counted anglers, and reduces heteroscedasticity (i.e., Parsons & Kealy, 1992; Woolnough et al., 2009; Hunt & Dyck, 2011; Chapter 1). Analyses were performed in R (R Core Team, 2017).

Results

Bank angler effort ranged from 44 to 52,771 hours of angler effort (mean = 10,395; median = 4,749; standard deviation = 12,505), and boat angler effort ranged from 0 to 151,382 hours of angler effort (mean = 13,160; median = 1,771; standard deviation = 25,720). As waterbody size increased, so did the amount of angling effort for both angler-access types. The waterbody size-angler effort relationships were different for each angler-access type [$F_{1,142} = 63.47$; $p < 0.01$]. Annual bank ($r^2 = 0.28$; $p < 0.01$) and boat ($r^2 = 0.68$; $p < 0.01$) angler efforts were related to waterbody size (Fig. 2.2.). Bank angler effort ($\log_{10}[\text{effort}] = 3.14404 + 0.\ 33546 \times \log_{10}[\text{size}]$) has a greater y-intercept and a shallower slope, compared to boat angler effort ($\log_{10}[\text{effort}] = 1.10213 + 1.20985 \times \log_{10}[\text{size}]$). Bank angler effort had a y-intercept of 3.14, meaning that approximately 1,380 hours of bank angler effort is expected at a 1 ha waterbody ($10^{3.14}$). Boat angler effort had a y-intercept of 1.10, meaning that approximately 12 hours of boat angler effort is expected to be counted at a 1 ha waterbody ($10^{1.10}$). Bank angler effort had a slope of

0.34 and boat angler effort had a slope of 1.21. These slopes indicate that angler effort is increasing as waterbody size increases for both angler-access types.

Discussion

Differences in the y-intercepts and slopes of the waterbody-size angler effort relationships for each angler-access type indicate that each angler-access type uniquely interacts with changes in waterbody size. Angler effort for each angler-access type was most different at the smallest and largest waterbodies. This presents management opportunities for recreational fisheries managers. At the smallest waterbodies, bank angler effort dominates boat angler effort, whereas at the largest waterbodies, boat angler effort dominates bank angler effort (Fig. 2.3). Fisheries managers may have to decide if that is how they want angler effort to be distributed across waterbody sizes or if they want to attempt to spread effort for both angler-access types more evenly across waterbody sizes. Additionally, management actions will likely have different effects at smaller and larger waterbodies, as the anglers exerting effort at these waterbodies are different (i.e., statewide regulations will affect smaller waterbodies differently than they will affect larger waterbodies). Consequently, fisheries managers must consider waterbody size and angler-access type composition when implementing management actions across a range of waterbody sizes.

In addition to angler-access differences in the slopes and y-intercepts of the waterbody size-angler effort relationships, there was a difference in the strength of the waterbody size-angler effort relationships. The waterbody size-angler effort relationship was stronger for boat angler effort (r^2 = 0.86) compared to bank angler effort (r^2 = 0.19).

Thus, boat angler effort predictions are likely to be more precise compared to bank angler effort predictions. This difference is valuable to fisheries management as it highlights that bank angler effort is more variable than boat angler effort, at least in terms of how angler effort relates to waterbody size. The difference in the strength of waterbody size-angler effort relationships between each angler-access type may be, in part, driven by the metric we used to measure waterbody size. We measured waterbody size using surface area. Waterbody surface area is often used as a proxy of lake attractiveness for recreational boaters (e.g., Bossenbroek et al., 2007; Muirhead & MacIssac, 2011; Hunt et al., 2019). However, this may not necessarily be as applicable for bank anglers, as bank anglers can only access near-shore areas of a waterbody (Chizinski et al., 2018). Additionally, bank anglers also fish near available infrastructure or access points (e.g., Altieri et al., 2012; Hunt et al., 2019; Mann & Mann-Lang, 2020), and most bank anglers' fish within 120 meters of available parking areas (Harmon et al., 2018). Thus, the distance of accessible shoreline, number of access points, or the amount of available infrastructure may be a more valuable metric for predicting bank angler effort, compared to surface area. However, surface area provided a reasonable prediction of bank angler effort and could be used to inform management decisions.

The shift in angler effort compositions with changes in waterbody size can be valuable to fisheries managers, as each angler-access type may perceive or be affected by management actions uniquely (e.g., Kane et al., 2020). For example, boat anglers express a greater preference for native fish and are more likely to use live bait compared to bank anglers (Lindgren, 2006; Edwards et al., 2016). Banning live bait or stocking non-native fish species at a specific waterbody is likely to differ in how it affects anglers, depending on whether bank or boat anglers dominate angler effort at the waterbody. Fisheries managers should include waterbody size as a part of their management considerations, as the composition of angler-access types differs along the continuum of waterbody sizes.

Predicting how angler effort responds to waterbody size for each angler-access type provides fisheries managers an understanding of how the composition of angler-access types is expected to change in response to different water levels. For example, in 2009, Red Willow Reservoir in Nebraska, USA had an emergency drawdown to repair damage to the reservoir's dam (Chizinski et al., 2014). The drawdown resulted in the surface area shrinking from 659 ha to 240 ha. At 659 ha, boat anglers would be expected to account for 79% of the effort at the reservoir. That percentage would shrink to 64% at a 240-ha waterbody. Indeed, the composition of anglers did change as a result of the Red Willow drawdown, with bank anglers accounting for a higher proportion of angler effort in the year following the drawdown compared to the year prior (Chizinski et al., 2014). In the future, climate changes may lead to more frequent changes in the size of many waterbodies (e.g., Zou et al., 2017), shifting the composition of angler effort. Understanding how the composition of angler-access types is expected to change with changes in the sizes of waterbodies is crucial to understand potential shifts in user groups and to properly manage recreational fisheries in the future.

Like the differences in waterbody size-angler effort relationships between each angler-access type, differences in the size of parties, angler trip lengths, and number of fish released and harvested also exists between angler-access types (Kane et al., 2020). We expect party size, angler trip lengths, and the number of released and harvested fish to be inherently connected to angler effort, as each attribute can either be a factor in the calculations of angler effort or is likely to change with changes in angler effort. Thus, both changes in waterbody size or management actions that alter angler effort are likely to lead to changes in social and ecological attributes such as party size, angler trip lengths, and the number of released and harvested fish.

Ultimately, angler-access types respond uniquely to waterbody size. These differences represent an opportunity for improvement in the management of recreational fisheries. Further exploration into a more representative metric for predicting bank angler effort will continue to improve the ability for fisheries managers to include the composition of angler-access types into future fisheries management plans. Recreational fisheries management will benefit from considering the composition of angler effort across a range of waterbody sizes.

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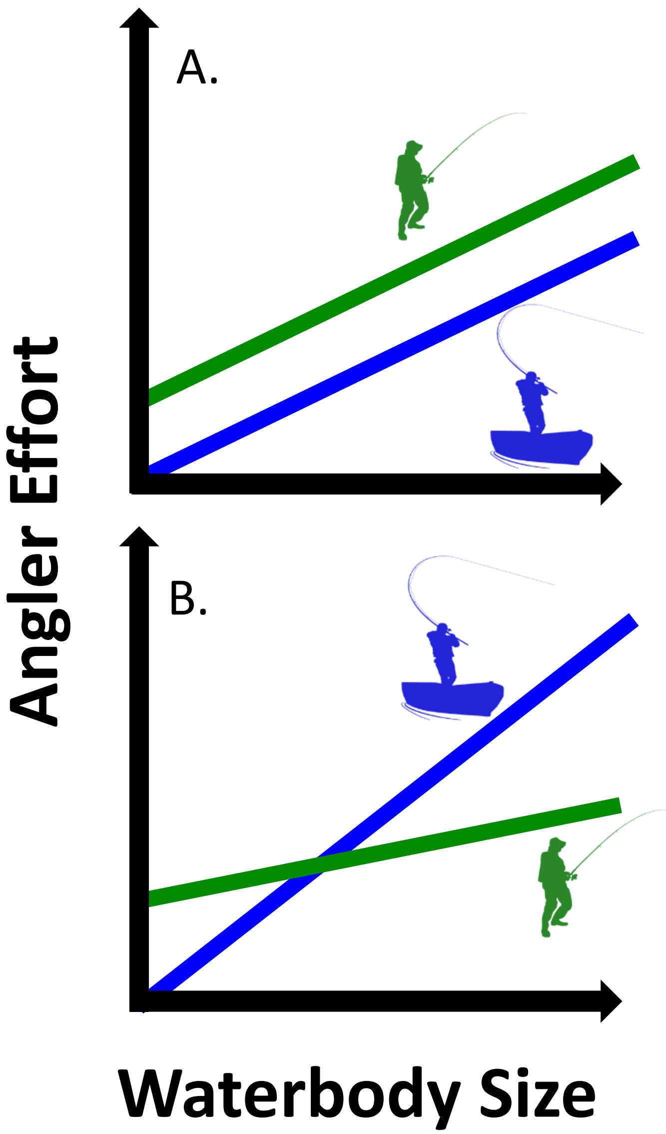

Figure 2.1. Conceptual figure displaying potential relationships between bank (green) and boat (blue) angler efforts with waterbody size: A) waterbody size-angler effort relationships have the same slope and different y-intercepts for each angler-access type, indicating only a difference in magnitude of angler effort. B) Waterbody size-angler effort relationships have different slopes and y-intercepts for each angler-access type, indicating that each angler-access type is interacting differently with the resource as waterbody size increases.

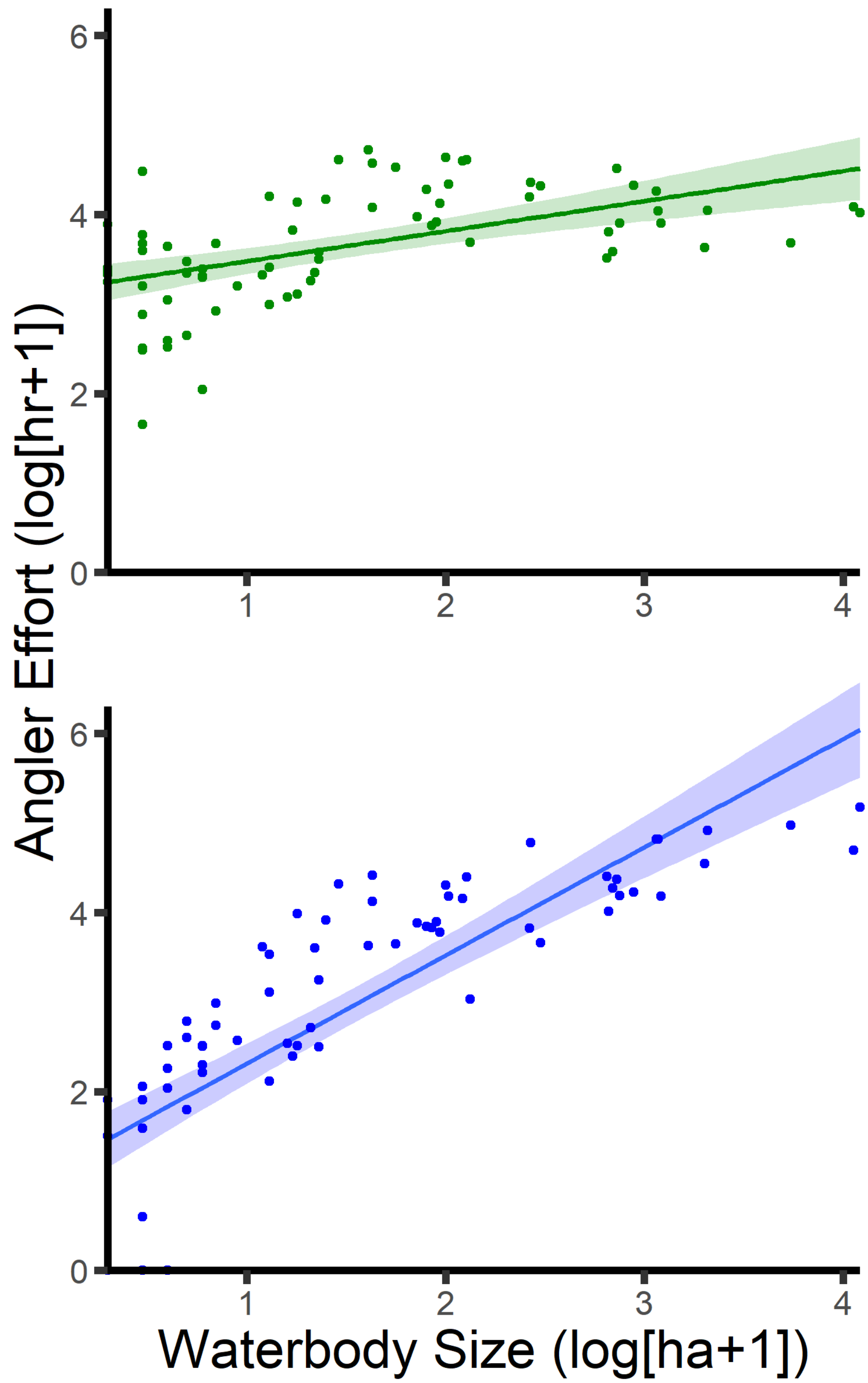

Figure 2.2. Linear models displaying relationships between bank (top, green; $\log_{10}$[bank effort] = 3.1913 + 0. 0.3185 × $\log_{10}$[waterbody size]) and boat (bottom, blue; $\log_{10}$[boat effort] = 1.25434 + 1.16097 × $\log_{10}$[waterbody size]) angler efforts and waterbody size. Ribbons represent 95% confidence intervals of linear models and points represent each waterbody.

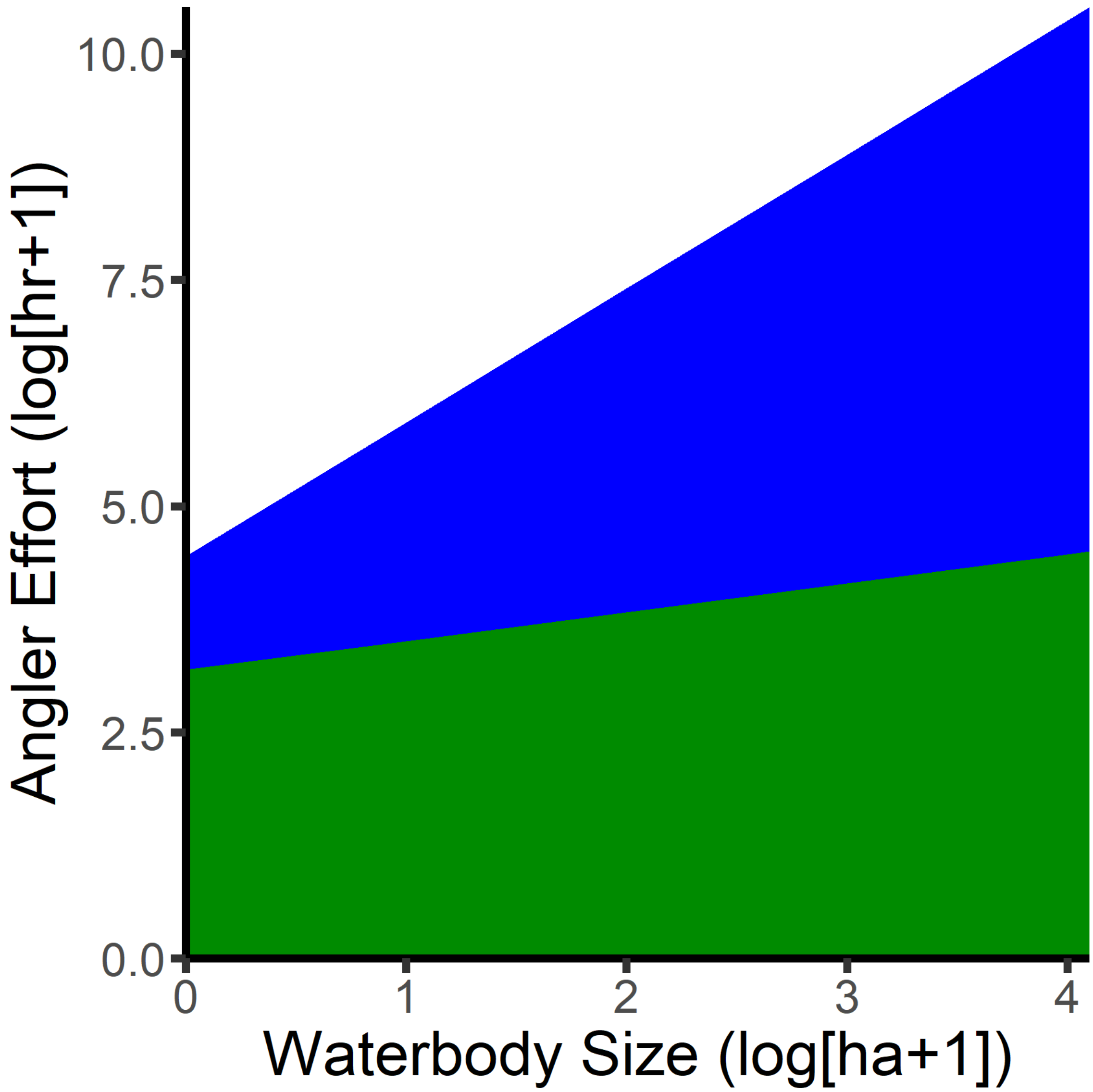

Figure 2.3. Contributions of bank (green) and boat (blue) angler efforts ($\log_{10}$[angler hours + 1]) to the total amount of angler effort across the spectrum of waterbody size ($\log_{10}$[hectares + 1]).

CHAPTER 3: MANAGEMENT RECOMMENDATIONS AND FUTURE RESEARCH QUESTIONS

Management Recommendations

The resource system size-use relationship is a valuable concept that can improve the ability of natural resource managers to manage resource system use. Natural resource managers can develop resource system size-use models to: 1) Predict the amount of use that unstudied systems receive, 2) Obtain broad-scale estimations of resource system use, 3) Guide the allocation of resources by highlighting resource systems that are receiving more or less use than predicted by their size, 4) Gain insights on how use of resource systems may change if the size of the resource system changes, and 5) Compare two or more resource system size-use relationships to understand how user groups vary in their use of resource systems.

For many types of resource systems, measuring or tracking use across all resource systems in a management area is not possible, due to the cost and difficulty of doing so (e.g., Post et al., 2002; Hadwen et al., 2007; Trudeau et al., 2021). The established resource system size-use relationship suggests natural resource managers could stratify resource systems by size and sample randomly within each strata to monitor the levels of use of certain-sized systems. Doing so would allow resource managers to understand how any statewide management decision affects use at various sized resource systems. This would also enable natural resource managers the opportunity to build accurate resource size-use models.

Recreational fisheries represent one type of resource system in which managers may benefit from utilizing resource system size-use relationships and models. Within recreational fisheries, a common method to group anglers is by how they access the fishery, via the bank or a boat. Each angler-access type varies in behavior and allocation of angler effort according to waterbody size (Chapter 2; Kane et al., 2020). Bank angler effort dominates boat angler effort at smaller waterbodies and boat angler effort dominates bank angler effort at larger waterbodies. The composition of angler-access types at various waterbodies should be considered before implementing management actions. The relationship between waterbody size and boat angler effort was stronger than that of waterbody size and bank angler effort. Consequently, fisheries managers must recognize that bank angler effort is likely more variable than boat angler effort at similar-sized waterbodies, and fisheries managers may have more confidence in boat angler effort predictions compared to bank angler effort predictions.

Anglers represent a heterogeneous group in terms of their behavior (Johnston et al., 2010; Carruthers et al., 2019; Matsumura et al., 2019), and even anglers of the same angler-access type are likely to differ in their behavior. Anglers with different types of boats (e.g., canoe, kayak, or motorized boat) could respond uniquely to waterbody size (Wu & Pelot, 2007). The same is likely true for anglers that vary in terms of what species they are targeting or in their levels of specialization (e.g., Beardmore et al., 2011; Beardmore et al., 2013; Johnston et al., 2015). Fisheries managers should continue to compare the waterbody size-angler effort relationships of different groups of anglers to effectively manage effort, minimizing negative social and ecological impacts.

Future Research Questions

- Does variability in annual angler effort differ across waterbody sizes?
- How do changes in water level, both seasonally and annually, affect the quantity and type of angler effort?
- Is there a more appropriate measure of waterbody size for bank anglers than surface area?
- What are the within and cross-scale management effects of increasing or decreasing angler effort at a single waterbody?
- Does building a new waterbody or renovating a different waterbody attract new angler effort or attract angler effort from other waterbodies?
- What is the contribution of ice anglers to overall angler effort? How does ice angler effort relate to waterbody size?
- What insights can the resource system size-use relationships provide to potentially improve R3 (recruit, retain, and reactivate) efforts?
- There are discontinuities in the size of waterbodies in Nebraska (Kaemingk et al., 2019). How do those discontinuities affect the waterbody size-angler effort relationship?
- The composition of waterbody sizes differs for each management district in Nebraska (Table 3.1). Does this affect how each district is managed?
- The overall human population is distributed differently from angler effort in Nebraska (Table 3.2). Does this affect the waterbody size-angler effort relationships for each angler-access type?
- How does the number of unique anglers' factor into the waterbody size-angler effort relationship? Is the higher quantity of angler effort at larger waterbodies comprised of more, less, or a similar number of anglers compared to the lesser quantity of angler effort at smaller waterbodies?
- The addition or subtraction of resource users or resource systems, among other things, may lead to changes in the resource size-use relationship. How often should the resource size-use relationship and model be evaluated and re-calibrated?
- Do the resource size-use models represent a social-ecological carrying capacity?

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Table 3.1. Number of waterbodies, surface area (ha), and cumulative angler effort estimations (hours) from each Nebraska Game and Parks Commission fisheries management district (NE = Northeast, NW = Northwest, SE = Southeast, SW = Southwest) and waterbody size category (XS = extra small, S = small, M = medium, L = large; Kaemingk et al., 2019) in Nebraska, USA.

	Waterbody Size Category				
District	XS	S	M	L	Total
Number of Waterbodies					
NE	123	2	4	2	131
NW	128	13	13	4	158
SE	154	7	2	1	164
SW	178	0	5	10	193
TOTAL	583	22	24	17	646
Surface Area (ha)					
NE	1910	284	1097	14215	17506
NW	2886	1898	3824	3852	12460
SE	2150	875	557	728	4310
SW	1363	0	1883	25614	28860
TOTAL	8309	3057	7361	44409	63136
Estimated Angler Effort (hours)					
NE	535848	37153	105669	277901	956571
NW	702254	245127	354148	205423	1506952
SE	632735	121502	53304	44548	852089
SW	535124	0	155157	744658	1434939
TOTAL	2405961	403782	668278	1272530	4750551

Table 3.2. Total angler effort (hours), human population size, and per capita effort (angler hours per person) of each Nebraska Game and Parks Commission fisheries management district in Nebraska, USA.

District	Total Effort	2019 Population	Per Capita Effort
NE	956571	266458	3.6
NW	1506952	90678	16.6
SE	852090	1261412	0.7
SW	1434938	315860	4.5
TOTAL	4750551	1934408	2.5

Appendix 1. Size (ha), times sampled (number of years from 2009 through 2019), and means and standard deviations (SD) for total, bank, and boat angler effort estimates (hr) for each Nebraska, USA waterbody included in this study.

	Total Effort		Bank Effort		Boat Effort			
Waterbody	Mean	SD	Mean	SD	Mean	SD	Size	Times Sampled
Fremont 3	2550	812	2519	826	31	26	1	4
Gracie Creek	2233	507	2153	429	80	149	1	4
Hitchcock	2253	NA	2253	NA	0	NA	1	1
Towl	7767	NA	7767	NA	0	NA	1	1
Walnut Grove	1773	NA	1773	NA	0	NA	1	1
Benson	4716	NA	4716	NA	0	NA	2	1
Fontenelle	1587	NA	1587	NA	0	NA	2	1
Fremont 13	324	128	321	129	3	6	2	3
Fremont 14	81	30	44	28	38	49	2	3
Fremont 17	873	1011	760	1007	113	30	2	4
Fremont 19	384	306	304	260	80	47	2	2
Halleck	30222	NA	30222	NA	0	NA	2	1
Schwer	3975	NA	3975	NA	0	NA	2	1
Ta-Ha-Zouka	5940	NA	5940	NA	0	NA	2	1
Fremont 11	1435	922	1111	939	325	135	3	4
Fremont 12	571	262	390	180	181	115	3	4
Fremont 4	435	192	328	128	108	65	3	3
Kramer	4368	NA	4368	NA	0	NA	3	1
Fremont 5	2818	363	2211	392	607	203	4	4
Fremont 9	504	181	442	148	62	47	4	4
Midlands	3357	NA	2955	NA	402	NA	4	1
Fremont 1	2768	803	2443	841	325	125	5	4
Fremont 16	2303	616	1987	425	317	217	5	3
Fremont 18	2232	582	2034	501	198	96	5	4
Fremont 7 and 8	273	204	110	110	163	142	5	3
Fremont 2	5296	1014	4749	927	547	168	6	4

Appendix 1. continued.

Waterbody	Total Effort mean	Total Effort SD	Bank Effort mean	Bank Effort SD	Boat Effort mean	Boat Effort SD	Size	Times Sampled
Wildplum	1804	NA	835	NA	970	NA	6	1
Killdeer	1961	NA	1589	NA	372	NA	8	1
Timber Point	6236	NA	2103	NA	4133	NA	11	1
Cottontail	3855	NA	2564	NA	1291	NA	12	1
Shadow	19389	NA	15996	NA	3393	NA	12	1
White Hawk	1113	NA	984	NA	129	NA	12	1
Fremont 10	1543	271	1200	136	343	168	15	4
Skyview	6963	NA	6716	NA	246	NA	16	1
Merganser	1614	389	1288	172	326	217	17	2
Prairie View	23454	NA	13686	NA	9768	NA	17	1
Red Cedar	2334	NA	1820	NA	514	NA	20	1
Fremont 20	6224	878	2228	709	3996	829	21	4
Fremont 15	4091	1604	3779	1538	312	75	22	4
Meadowlark	4934	NA	3163	NA	1771	NA	22	1
Lawrence Youngman	23019	NA	14832	NA	8187	NA	24	1
Walnut Creek	61506	NA	40758	NA	20748	NA	28	1
Holmes	57025	10656	52771	9530	4254	1126	40	2
Prairie Queen	63519	NA	37248	NA	26271	NA	42	1
Wildwood	25388	2351	12016	1409	13372	963	42	3
Standing Bear	38238	NA	33756	NA	4482	NA	55	1
Olive Creek	17017	NA	9410	NA	7607	NA	71	1
Stagecoach	26179	381	19167	532	7012	151	79	2
Yankee Hill	14322	NA	7492	NA	6830	NA	84	1
Flanagan	16047	NA	8196	NA	7851	NA	89	1
Conestoga	19320	NA	13263	NA	6057	NA	93	1
Wehrspann	63519	NA	43401	NA	20118	NA	99	1

Appendix 1. continued.

Waterbody	Total Effort		Bank Effort		Boat Effort		Size	Times Sampled
	mean	SD	mean	SD	mean	SD		
Zorinsky	37086	NA	21765	NA	15321	NA	103	1
Carter	54195	NA	39798	NA	14397	NA	121	1
Wagon Train	65675	1455	40647	2124	25029	669	127	2
Bluestem	5939	1892	4861	1646	1078	246	132	2
Ogallala	22375	4242	15687	2905	6688	2131	263	5
Wanahoo	82706	45800	22681	10858	60025	34941	268	2
Pawnee	25476	11285	20885	9770	4591	1783	299	7
Box Butte	28851	12869	3240	2034	25262	11328	647	2
Red Willow	16649	5783	6363	2742	10286	6450	659	4
Enders	22643	6100	3826	1975	18816	5461	691	4
Branched Oak	55902	10493	32464	10235	23438	4011	728	8
Medicine Creek	23352	7679	7946	5108	15406	4854	749	4
Johnson	37995	NA	21015	NA	16979	NA	886	1
Sherman	83855	26179	18179	5525	65675	22720	1151	10
Merritt	76884	15951	10955	1914	65929	15188	1176	8
Sutherland	23203	9284	7968	2636	15235	6648	1214	2
Swanson	39463	12514	4270	1521	35193	11061	2013	3
Calamus	93427	17848	11185	5635	82243	13772	2075	5
Harlan	99131	36648	4820	2970	94311	34698	5463	9
Lewis and Clark	61681	22292	12177	3304	49456	19006	11331	4
McConaughy	161774	57142	10393	4901	151381	53501	12141	8