Fish Kill Loss Valuation through Estimation of Angling Effort and Use Valuation on Three Mid-Size Alabama Rivers

by

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Abstract

State fisheries management agencies seek financial restitution following a fish kill. Economic losses due to fish kills on rivers have been underestimated in Alabama, as user loss values have not been included as a loss metric. Multiple surveys were used to gather effort and economic data on three Alabama Rivers. Trail cameras were used to monitor angler effort and to estimate the number of annual angler trips. Annual economic value of angling ranged from $600,000 - $1.8 million among the three rivers. Annual economic loss estimates due to fish kills ranged $60,000 - $5.4 million depending on the river and severity of the kill. By comparing trail camera effort estimates to those from bus-route surveys, effort was similar between methods but trail cameras were more cost efficient. Precise effort estimates can be obtained by sampling 40% of available camera images.

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List of Abbreviations

ADCNR	Alabama Department of Conservation and Natural Resources
ADEM	Alabama Department of Environmental Management
ANOVA	Analysis of Variance
BRS	Bus-Route Survey
CPE	Catch Per Effort
CS	Consumer Surplus
CVM	Contingent Valuation Method
HPE	Harvest Per Effort
TCM	Travel Cost Model
USEPA	United States Environmental Protection Agency
WTP	Willingness-To-Pay

Definitions of Note

Consumer Surplus	Willingness-to-pay for a recreational visit above and beyond a person's actual expenditures and is the area below the recreational visit demand curve and above the equilibrium travel cost (price) of a trip visit
Opportunity Cost	Measure in terms of value for the next best forgone alternative; in this study, also used in calculating a fraction of an angler's wage rate applied to the round-trip travel time to the recreation site and/or substitute sites.
Substitute Site	Similar site that could replace the study site and in this study was used as part of a substitute site opportunity cost in the travel cost models.
Trip	One angler fishing for a one-day period.
Visit	Fishing expedition for one angler and can be multiple days.
Travel Cost Method	Method to estimate travel costs (opportunity cost of travel plus actual expenditures) and visit frequency to establish angler visitation demand.
Willingness-to-pay	Maximum amount an angler is willing to pay for a fishing trip.
Contingent Valuation	Nonmarket valuation method used, in this study, to predict the change in the number of angler trips after a fish kill compared to the present state.

Chapter 1. General Introduction

Introduction

Fish kills are defined as “any sudden and unexpected mass mortality of wild or cultured fish,” regardless of whether causation is natural or artificial in nature. (Meyer and Barclay 1990; Lugg 2000). Although there is debate surrounding proximal causes of fish kills, studies have found that natural phenomena account for only small percentage of fish kills, but then may be caused by a combination of natural and anthropogenic factors (Lowe 1991; Hoyer et al. 2009; La and Cooke 2011; Phelps et al. 2019). Anthropogenic activity and alterations of landscape are thought to exacerbate the frequency and intensity of naturally-caused fish kills, while also being the direct cause of a large majority of fish kills in the United States. Summarizing peer-reviewed literature on fish kills spanning 1890-2006 by multiple state and federal agencies, La and Cooke (2011) found that over 66% of surveyed fish kills resulted from human activity, whereas natural causes accounted for only 10%. However, point-source pollution events, a historically common cause of large fish kills, are much less common now due to federal and state clean water laws enacted in the latter half of the 20th century (Hoyer et al. 2009; Keiser and Shapiro 2019). Regardless, spills of raw sewage, chemical toxins, agricultural fertilizers and pesticides, etc. are highly detrimental to fish populations and continue to cause many fish kills annually (Olmsted and Cloutman 1974; Meade 2004; Hoyer et al. 2009).

Thus, as anthropogenic activity continues to increase due to a growing human population, the number and severity of fish kills per year will likewise increase (Olmsted and Cloutman 1974; La and Cooke 2011; Fey et al. 2015; Till et al. 2019). This is supported by state and federal fish kill summaries. North Carolina Department of Water Quality (NCDWQ) yearly fish kill summaries from the 1980s showed that an estimated 2.5 million fish died in an average of 15 fish kill events annually, while 2008 alone saw 61 fish kill events resulting in approximately 7.5 million dead fish (NCDWQ 2008). Likewise, Florida Fish & Wildlife Conservation Commission (FWC) reports from the 1990s and 2000s showed increases in fish kill events and magnitude (FWC 2010). The U.S. Environmental Protection Agency (USEPA) has not released a nationwide summary of fish kill events since 1991; however, their last report, which covered the years 1980-1989, showed that fish kills increased in number reported from 243 in 1980 to 368 in 1989 cumulatively in 22 coastal states (Lowe 1991).

While concerning, increases in reported fish kill events over time may be due in part to increasing public concern and media coverage about water quality and environmental integrity (La and Cooke 2011; Phelps et al. 2019). Furthermore, the rise in reported and documented fish kills could be related to population increases in urban centers, as fish kills near metropolitan areas are likely reported more frequently and quickly (Lowe 1991; Phelps et al. 2019). Also, the rise of public demand for reducing the occurrence of fish kills may cause state agencies to devote more staff and resources to processing and documenting fish-kill events. Regardless, there remains a prevailing belief that fish-kill events remain underreported overall (USEPA 1975; Lugg 2000).

A major fish kill can lead to significant economic losses as well as declines in ecological health, and, if, these events are becoming more numerous, then a commensurate increase of economic losses due to fish kills would be expected (Olmstead and Cloutman 1974; Bryson et al. 1975; Meade 2004; La and Cooke 2011; King 2015). Economic losses relative to fish kills can include loss of fish biomass, investigative and restocking costs, habitat restoration costs, and losses due to decline in angler use and expenditures (Cowx et al. 2004; Nuhfer et al. 2009; Southwick and Loftus 2017). At the national and global scale, fish kills that occur in commercial and recreational fisheries have major economic implications. The USEPA estimated annual economic loss resulting from fish kills in the United States to be approximately $240 million from 1977 to 1987, or a total of $2.4 billion (Pimentel et al. 1993; La and Cooke 2011). A similar nationwide summary of fish kill losses today would likely produce an even higher figure due to inflation and potential increases in the frequency of fish kills (La and Cooke 2011; King 2015).

Following any public water fish-kill event in which the party responsible can be identified, state fisheries or pollution control agencies of the water body usually seek financial restitution for economic damages (Bryson et al. 1975; Southwick and Loftus 2017). These fines usually comprise investigative agency staff costs, replacement costs, biological interim loss value, user loss value, and, at times, nonuse value (Southwick and Loftus 2017). All are allowable expenses but not all are always utilized by government entities when levying fines for fish kill events (King 2015; Southwick and Loftus 2017). Replacement and staff costs are readily used due to the availability of these data, and biological interim loss value, or the quantification of the biological losses to a fishery from kill date to pre-kill state, is often used in fish kill loss valuations (Southwick and Loftus 2017). However, costs due to user loss are more difficult to derive because prior data on the economic value of a water body are necessary in order to estimate damages due to user loss (Connelly and Brown 1991; King 2015; Southwick and Loftus 2017). Lacking user value data, therefore, impedes a state agency from including a user loss metric in their fish kill loss valuations and, in turn, leads to state agencies underestimating the economic damages of fish kills (Southwick and Loftus 2017).

Two recent fish kills on the Mulberry Fork, Alabama, have demonstrated that fish kill loss assessments in Alabama suffer from this lack. These fish kills resulted in the estimated combined loss of 176,000 fish. This kill and a smaller kill, which saw a total of 508 fish killed, were valued by Alabama Department of Environmental Management (ADEM) and Alabama Department of Conservation and Natural Resources (ADCNR) at $869,464.31 in replacement, investigative, and biological interim loss costs (ADEM 2019 a; Floyd and McKee 2019). This was already a conservative estimate, as it was unlikely that all dead fish were counted. However, lacking the ability to include user loss value likely far underestimated the actual economic damage. Although ADCNR has a good understanding of economic use and angler effort occurring on reservoirs in the state (Hanson et al. 2002; McKee 2013; Lothrop et al. 2014; Gratz 2017; Plauger 2018). Similar data are not available for mid-sized rivers in Alabama, as these systems are sampled infrequently. Before ADCNR can integrate user loss metrics into fish-kill valuations on mid-size rivers, data on angler effort, expenditures, and contingent behavior following a fish kill are necessary.

In order to gather this necessary data, trail cameras were used to estimate angler effort, which is a prerequisite to calculating total angler trips (Lothrop 2014; Plauger 2018). Due to lack of information on the efficacy of estimating angler effort on rivers using trail cameras, trail camera effort estimates were compared to the bus-route survey effort estimates to validate their use. A roving survey complemented by a follow-up telephone survey was used to gather angler trip expenditures and other relevant data. All of these angler surveys, together, were used to address the following objectives:

1. Determine the percentage of sample days of trail camera images that must be analyzed in order to provide acceptable levels of accuracy and precision of use and effort estimates.
2. Assess the utility of trail cameras in estimating angler use and effort on Alabama Rivers by comparing estimates to bus-route survey effort estimates.
3. Evaluate the costs associated with estimating angler effort from bus-route surveys and trail cameras on Alabama Rivers.
4. Quantify recreational fishing effort on the Cahaba River, Locust Fork River, and the tailwater of the Coosa River below Jordan Dam.
5. Determine tax revenues related to angling on these rivers.
6. Quantify expenditures and consumer surplus values associated with mid-size river recreational anglers and kayakers using these three rivers, and determine tax revenues generated from angling and kayaking activities on these rivers.

Study Areas

The goals of this study focus on better understanding potential economic loss following a mid-size river fish kill and applying the findings to other rivers in the state. Therefore, when choosing study rivers, it was important that each were popular recreational fisheries that had a history of fish kills. Fish kills have been a common occurrence on the Cahaba River and its tributaries since 2012; ADEM and ADCNR investigated multiple fish and mollusk kills with damages totaling $80,352 in replacement and staff costs, 5,125 dead fish, and 350,906 dead mollusks (ADEM 2012; ADEM 2016; ADEM 2017 a; ADEM 2020). While there are no official fish-kill reports on the Locust Fork River, there have been numerous major fish kills in the Black Warrior River drainage, including a highly publicized kill on the Mulberry Fork in 2019 in which over 175,000 fish died and 50 river miles were adversely affected. Apart from multiple other smaller kills on the Mulberry Fork, the mainstem Black Warrior River suffered a kill of an estimated 1,031,249 fish with damages totaling $151,676 (ADEM 2006). Therefore, the Locust Fork River was chosen as a study river due to its proximity and similarity to these fisheries and because it was thought that angler use and effort on the Mulberry Fork may have been affected by the recent fish kills, potentially biasing user loss value estimates. Although the Coosa River has only experienced one major, documented fish kill over the last five years, it was chosen as a study river because of the high level of recreational use in the system (ADEM 2017 b).

Cahaba River

From its headwaters near Trussville, AL to its confluence with the Alabama River near Selma, AL, the Cahaba River flows approximately 307 km, with a drainage basin contained entirely within the state (Boschung and Mayden 2004). It flows through three main physiographic regions: Appalachian Plateau, Ridge and Valley, and Coastal Plain. Bedrock shoal, rocky substrate, and high stream gradient are characteristic of the first two regions; whereas, fine sand substrate, sinuous bends, and low gradient are customary of the Coastal Plain region. Due to this physiographic variation and a mild sub-tropical climate, diversity of fishes, mussels, aquatic invertebrates, and other lotic biota is particularly high in the Cahaba River (Pierson et al. 1989; Mette et al. 1996). This diversity includes ten fish and mussel species listed under the US Endangered Species Act (US Fish and Wildlife Service 2017). Moreover, The Nature Conservancy and American Rivers have listed the Cahaba watershed as being among rivers in need of the highest protection priority in the U.S. (Master et al. 1998). As it flows through the Birmingham metropolitan area, the Cahaba River also serves as an important municipal water source and is used for the disposal of industrial and domestic wastewater (Pitt and Dee 2000).

Because of its proximity to metro Birmingham, the Cahaba River is one of the most popular of rivers among canoeists and kayak anglers for recreational float trips in the state (Foshee 1975). Many well-maintained access points with highly visible signage allow for angling and kayaking trips of varying distances, likely further increasing the appeal for a large portion of the user base. The Cahaba River supports a variety of fisheries, the most popular of these being the black basses, Alabama Bass *Micropterus henshalli*, Cahaba Bass *Micropterus cahabae*, and Largemouth Bass *Micropterus salmoides*. Anglers target catfish, crappie *Pomoxis* spp., and sunfish *Lepomis* spp. as well.

As the extreme headwaters of the Cahaba River often lack the flow in the late spring and summer for creel clerks to navigate a canoe or kayak downstream, the study site was limited to the lower 221.5 km reach from White's Chapel Rd in Trussville to the confluence with the

Alabama River at Old Cahawba Park in Orrville. This was divided into three main sections as follows:

Upper (62.5 km; 9 access points)

White's Chapel Rd (Trussville) to County Rd 52 (Helena)

Middle (44.10 km; 5 access points)

Old Slab (Helena) to AL 25/Walnut St (Centreville)

Lower (114.75 km; 8 access points)

Harrisburg Rd (Centreville) to Old Cahawba Park/Capitol Ave (Orrville)

Each section was further subdivided by access points with segments between access points serving as sampling reaches (Table 1.1; Figure 1.1; Figure 1.2; Figure 1.3; Figure 1.4).

Coosa River

The Coosa River is heavily impounded with eight Alabama Power dams along its approximate 402 km route through the central part of the state. Each of these dams discharge almost directly into the upper reaches of the next downstream impoundment, therefore the Coosa River contains little riverine habitat (ADEM 2005). Jordan Dam is located 30 km upstream from the confluence of the Coosa and Tallapoosa rivers. This section contains the only riverine habitat of the Coosa River, and the 12 km reach between the dam and Wetumpka, Alabama, is particularly popular among anglers and kayakers alike (Jackson and Davies 1988). A class III rapid locally known as Moccasin Gap, a few other shoal complexes, and access to frequent shuttles provided by private outfitters in the area likely account for this section's popularity with whitewater enthusiasts. Multiple whitewater kayaking tournaments, the most widely attended being the Coosa River Whitewater Festival, have been held here since 1985.

This tailwater supports multiple warmwater fisheries. Anglers can target sunfish and catfish nearly year round. In late winter and early spring, white bass *Morone chrysops*, striped bass *Morone saxatilis*, and hybrid striped bass *M. chrysops X M. saxatilis* make a spawning run upstream, and are also a major draw for anglers. Although Largemouth Bass inhabit the area, the high quality Alabama Bass fishery attracts most anglers to this stretch of river. Due to this, kayak fishing tournaments from national and regional circuits have been a common occurrence for a number of years and are increasing in popularity of recent (Atkins 2017). Because the river abruptly transitions into a wide, deep coastal-plain river below Wetumpka, angler and recreational use sharply declines. Therefore, the study was conducted within an 11.46 km reach that consisted of only two access points and one sampling reach therein (Table 1.1; Figure 1.8).

Locust Fork River

The Locust Fork Riveris a 254 km tributary of the Black Warrior River that flows from Oneonta, Alabama to its confluence with the Mulberry Fork near Bessemer, Alabama (National Park Service 2016). The confluence with the Mulberry Fork occurs within the boundaries of the 3,723 ha Bankhead Reservoir. For nearly the entirety of its length, the Locust Fork River flows through the Cumberland Plateau, and being of moderate to high relief, rivers of this region are characterized by abundant riffle-run complexes and high gradient (Boschung and Mayden 2004). Thus, the Locust Fork River holds a number of class III and IV rapids making it a popular destination with whitewater kayakers and canoeists (Clonts and Malone 1988). The Alabama Cup Racing Association Whitewater Slalom Series has held multiple annual kayak races on the Locust Fork River since 1991. Anglers frequent the Locust Fork River for its quality black bass fishery as well. Large Alabama Bass and Largemouth Bass are a major attraction to kayak/canoe anglers, and the sunfish and catfish fisheries are popular also.

The upper headwaters of the Locust Fork River are subject to low water levels in summer and drought years, making the navigation and angler access difficult. Further, the lower portion near Bankhead Reservoir is wide, deep, and is more characteristic of an impoundment than a river, therefore the Locust Fork River study area was the 145.3 km reach from Lurleen Dr/County Rd 14 in Oneonta to Porter Rd in Quinton. This was divided into two main sections as follows:

- Upper (83.69 km; 10 access points)
  - Lurleen Drive (Oneonta) to Warrior Kimberly Rd (Warrior)
- Lower (61.64 km; 4 access points)
  - Mt. Olive Rd/Buck Short Bridge (Gardendale) to Porter Rd (Quinton)

The sections listed above were then subdivided by access points with areas in between access points serving as sampling reaches (Table 1.1; Figure 1.5; Figure 1.6; Figure 1.7).

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Tables

Table 1.1. Access points, reach distance, and estimated angler use for three sections on the Cahaba River, one section on the Coosa River, and two sections on the Locust Fork River.

River	Section	Access Points		Reach Distance (km)	Estimated Use
		Put in	Take out		
Cahaba	Upper				
		White's Chapel Parkway	Moon River	14.8	Moderate
		Moon River	Grant's Mill	8.2	High
		Grant's Mill	Old Overton Rd	11.1	Very High
		Old Overton Rd	Hwy 280	10.4	High
		Hwy 280	Sportsplex	9.8	Moderate
		Sportsplex	Lorna Rd	8.3	Moderate
		Lorna Rd	CR 52	15.7	Low
	Middle				
		Old Slab	Lebron Launch	3.21	Low
		Lebron Laucnch	CR 24/NWR	13.4	Very High
		CR 24/NWR	Caffee Creek/NWR	2.4	Very High
		Caffee Creek/NWR	Pratt's Ferry	8.4	Moderate
		Pratt's Ferry	Walnut Street	13.5	Moderate
	Lower				
		Harrisburg Rd	Onrow Tubbs Rd	18.2	Low
		Onrow Tubbs Rd	Sprott Bridge	19.3	Moderate
		Sprott Bridge	Radford Rd	12.4	Moderate
		Radford Rd	CR 6	14.7	Low
		CR 6	Hwy 80	15.7	Low
		Hwy 80	Hwy 22	19.9	Moderate
		Hwy 22	Old Cahawba Park	14.4	Low
Locust Fork	Upper				
		Lurleen Dr	Cold Branch Rd	16.1	Low
		Cold Branch Rd	Taylor Ford Rd	5.3	Moderate
		Taylor Ford Rd	King's Bend	11.1	Moderate
		King's Bend	Swann Bridge	6.7	High
		Swann Bridge	Nectar Bridge	6.7	High
		Nectar Bridge	CR 13	8.0	High

River	Section	Access Points		Reach Distance (km)	Estimated Use
		Put in	Take out		
		CR 13	Center Springs Rd	16.1	Moderate
Locust Fork		Center Springs Rd	Warrior-Trafford Rd	13.6	Moderate
		Warrior-Trafford Rd	Warrior-Kimberly Rd	12.7	Moderate
	Lower				
		Warrior-Kimberly Rd	Mt. Olive Rd	26.8	Low
		Mt. Olive Rd	Old Jasper Hwy	14.8	Low
		Old Jasper Hwy	Porter Rd	19.9	Low
Coosa					
		Jordan Dam Rapids	Wetumpka City Ramp	11.4	Very High

Figures

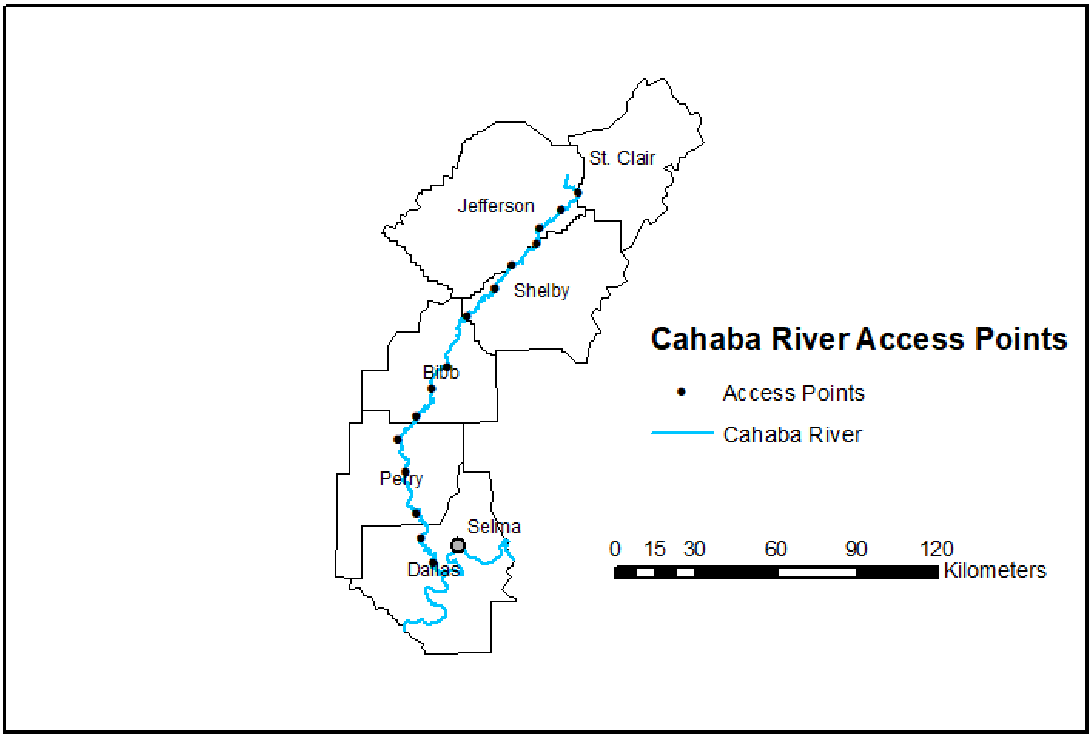

Figure 1.1. Access points on the Cahaba River.

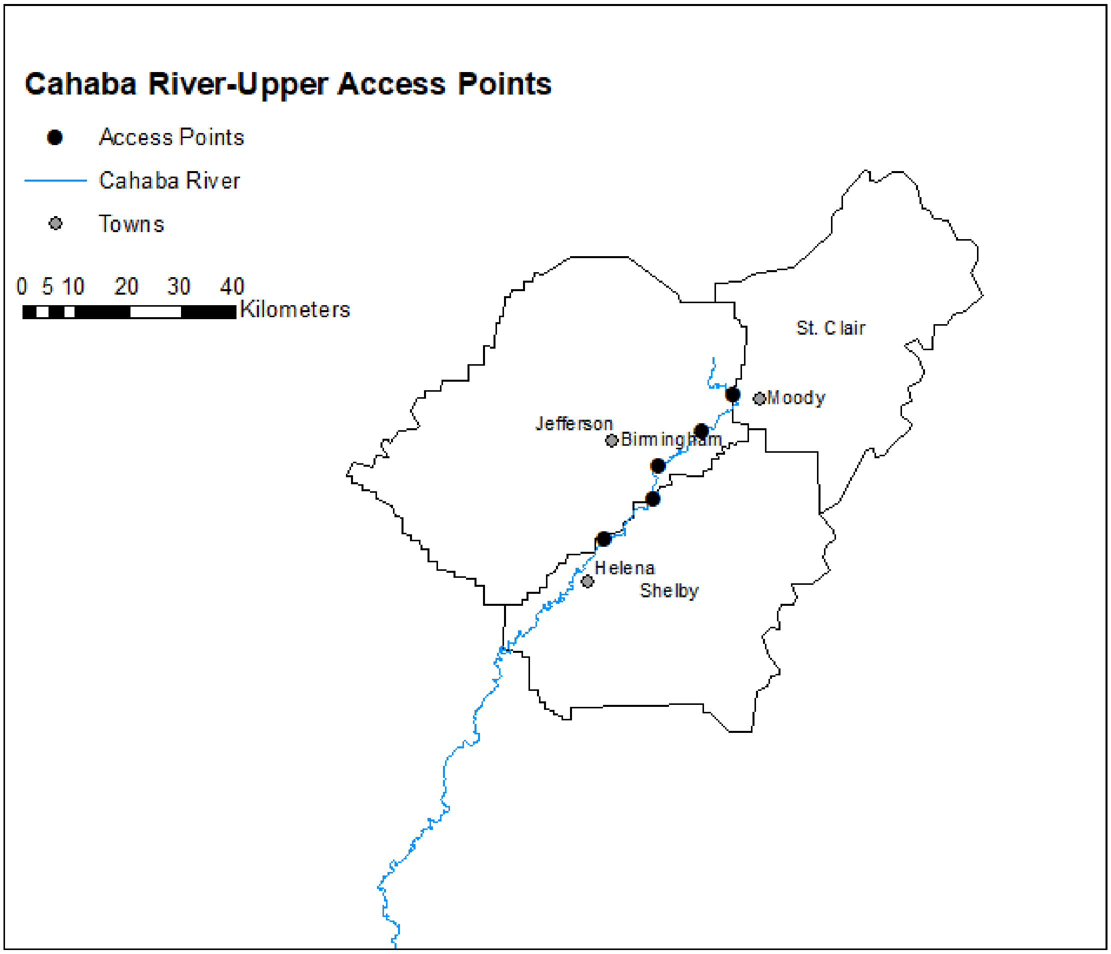

Figure 1.2. Access points in the upper section of the Cahaba River.

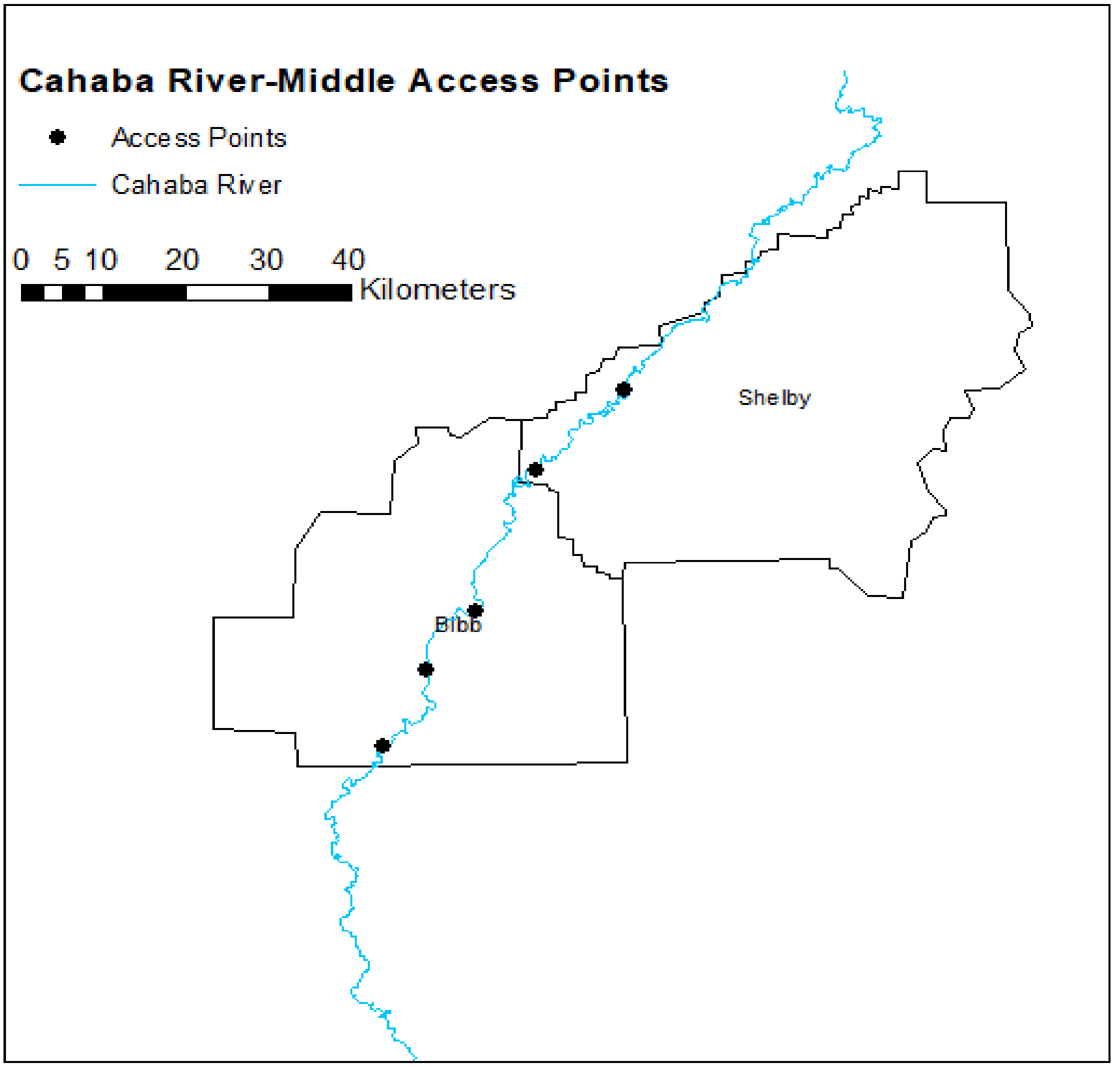

Figure 1.3. Access points on the middle section of the Cahaba River.

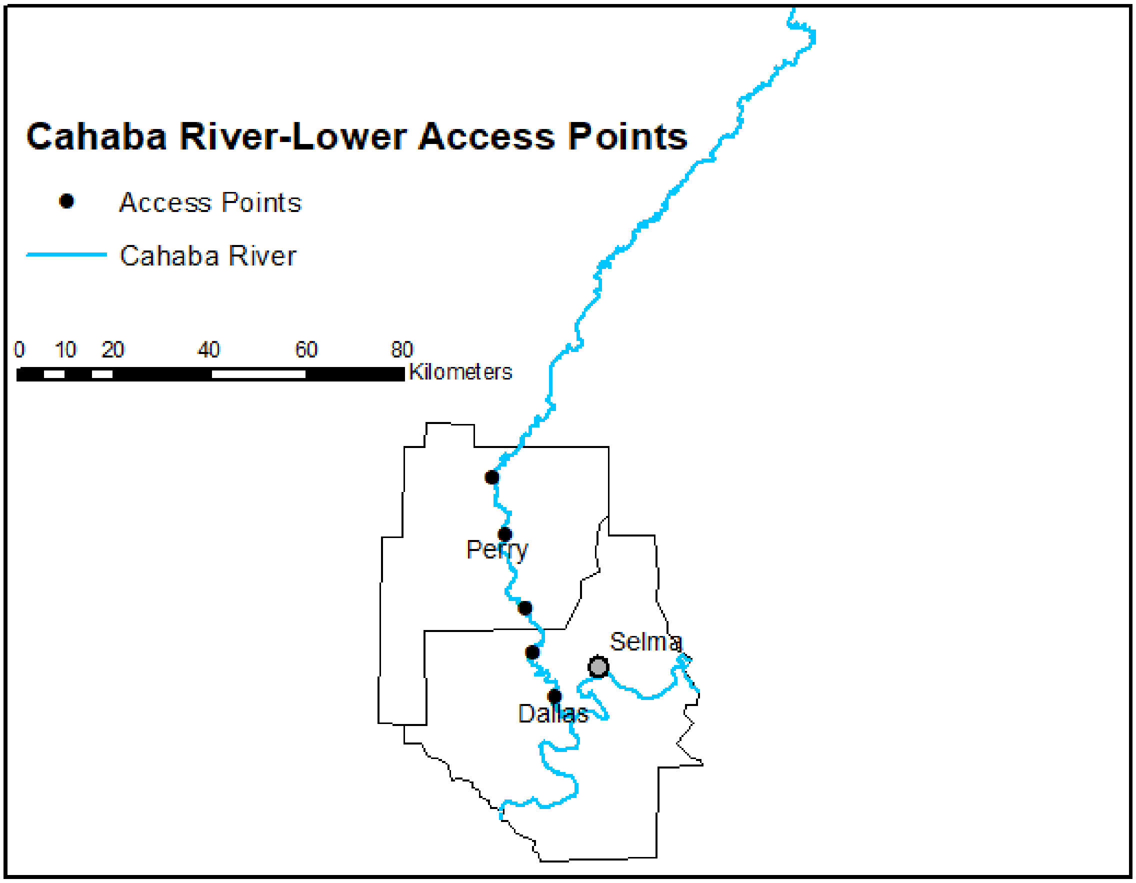

Figure 1.4. Access points on the lower section of the Cahaba River.

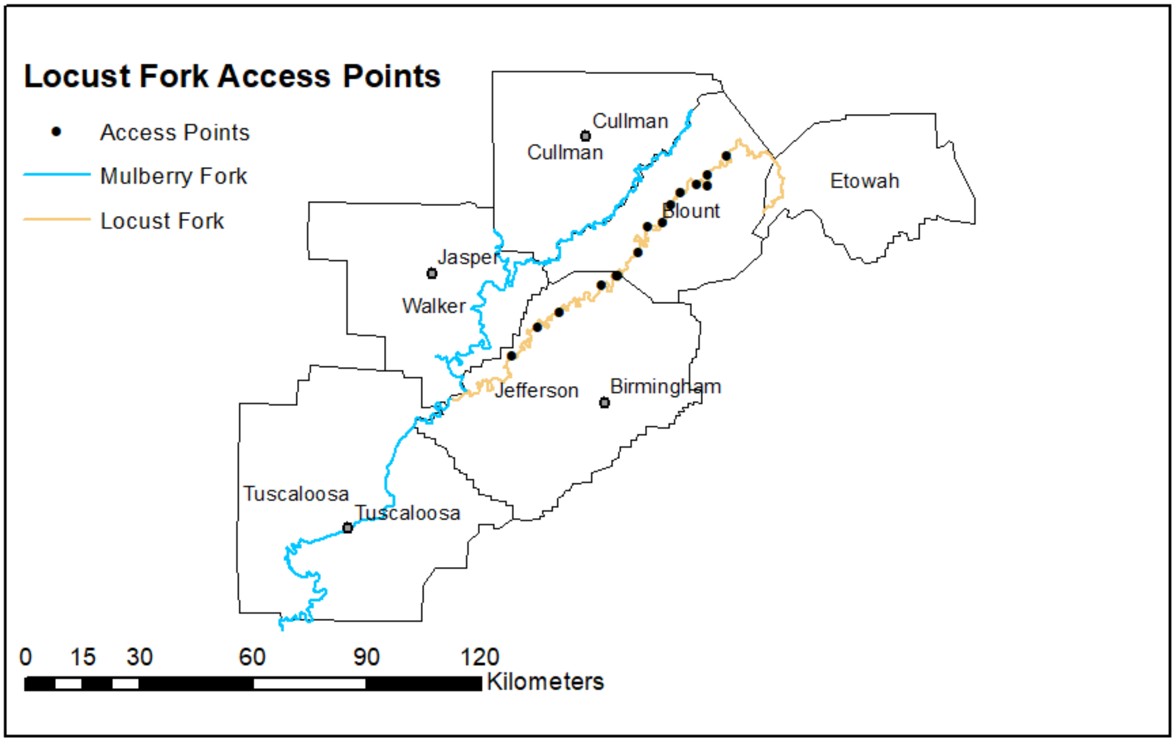

Figure 1.5. Access points on the Locust Fork River.

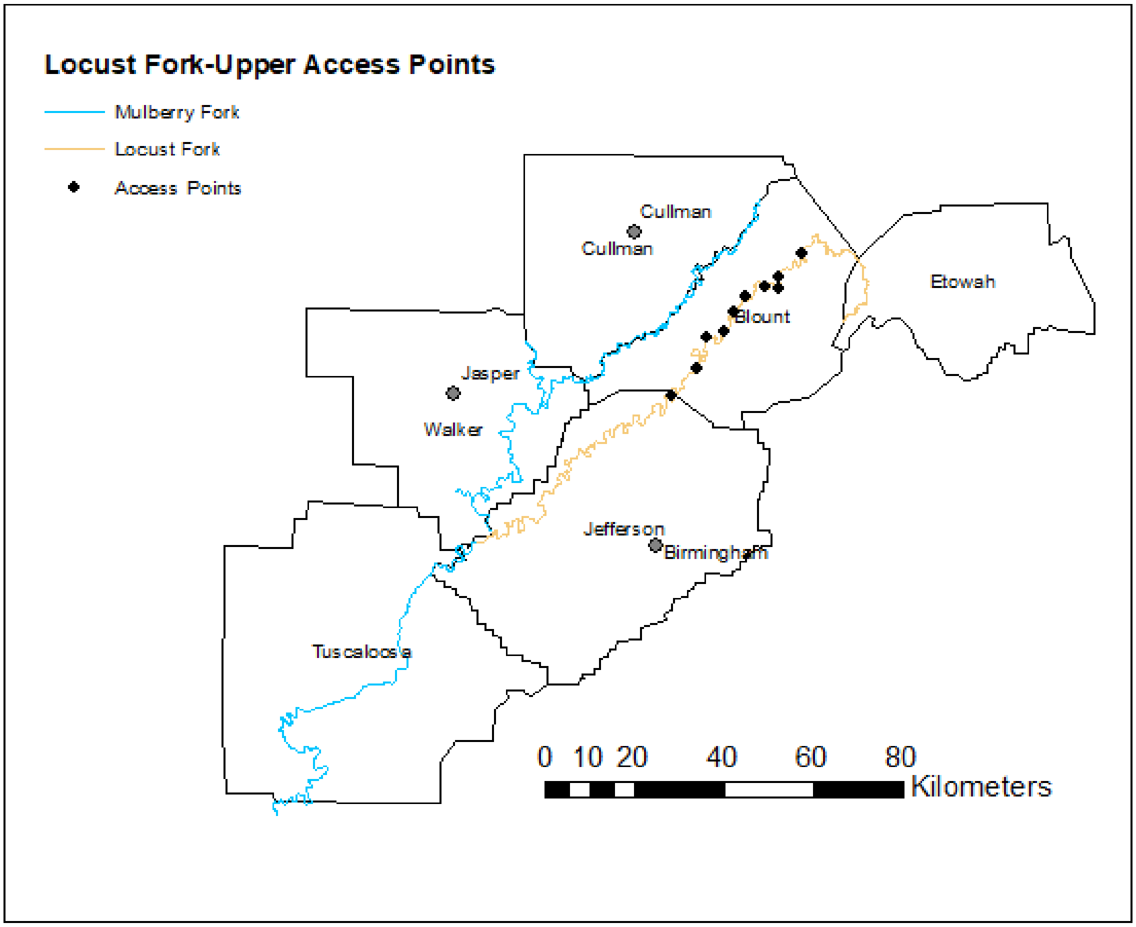

Figure 1.6. Access points on the upper section of the Locust Fork River.

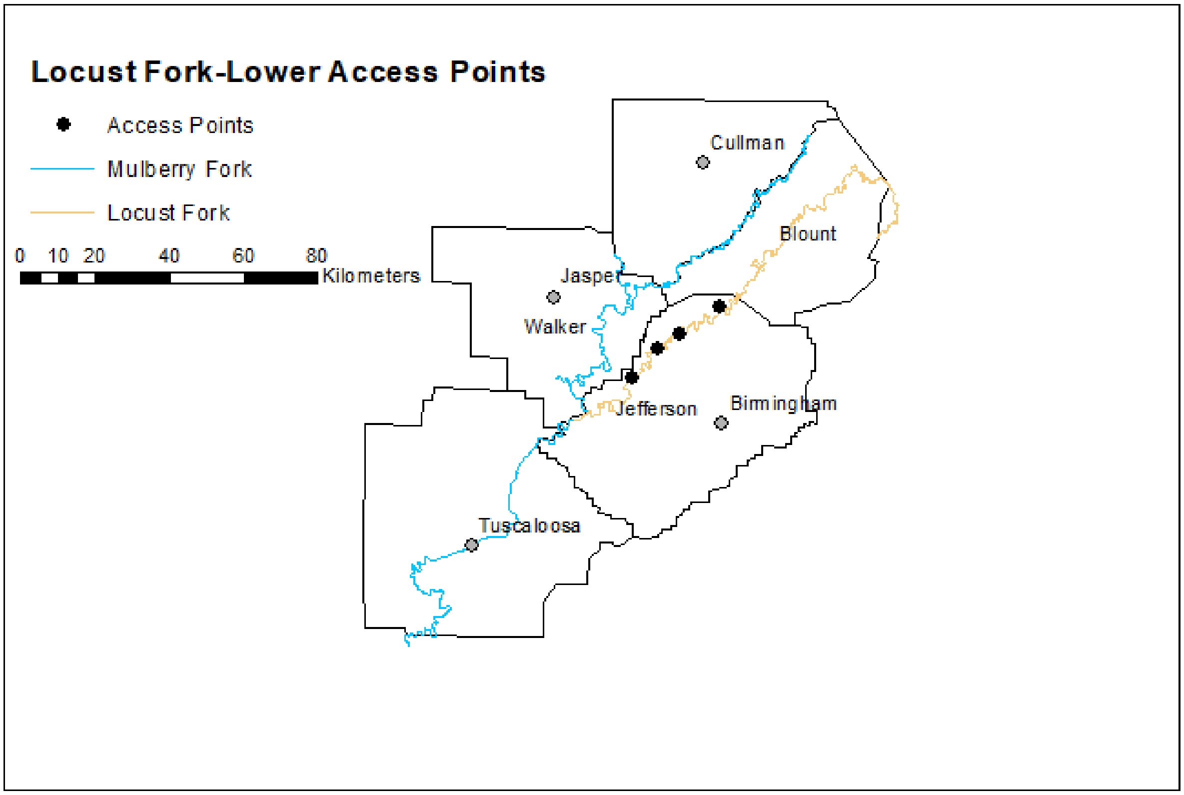

Figure 1.7. Access points on the lower section of the Locust Fork River.

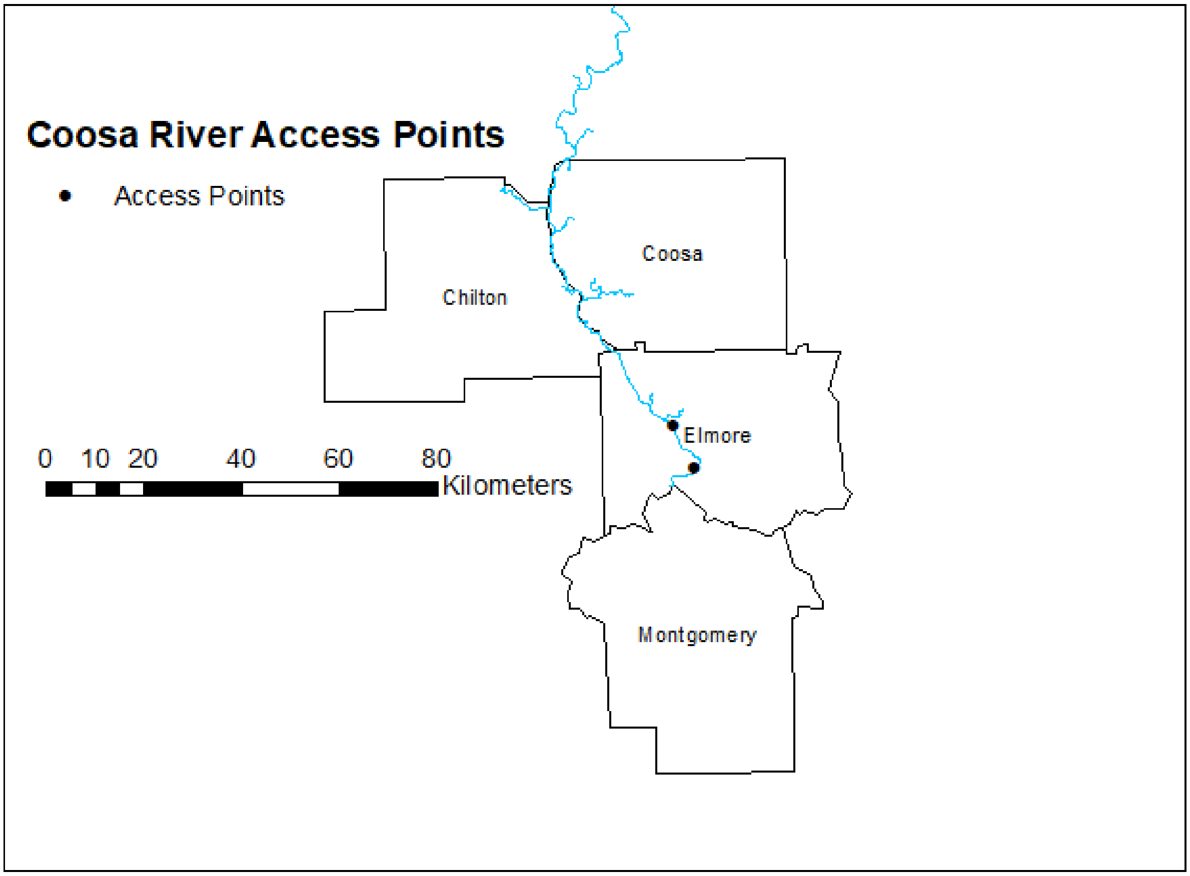

Figure 1.8. Access points on the Coosa River below Jordan Dam.

Chapter 2. Assessing the utility of trail cameras in estimating angler use and effort on the Locust Fork and Cahaba Rivers, Alabama

Introduction

Angler surveys have been an important tool of fisheries managers in assessing angler use and effort on waterbodies throughout the history of fisheries management (Pollock et al. 1994). Types of angler surveys are wide-ranging, as are the fisheries they are used to gather information on. In order to gather accurate and precise use and effort data, it is critical to implement the appropriate survey method for a given waterbody (Heggenes 1987). Types of surveys include off-site surveys, such as mail surveys and telephone surveys, and on-site surveys, such as roving surveys, access-point surveys, aerial count surveys, logbooks, and bus-route surveys. Many of these are used together as complemented surveys, because combining surveys has been shown to reduce use and effort biases that may be inherent to a single survey method (Malvestuto 1983; Pollock et al. 1994).

Since the late 1980s, the bus-route survey (BRS) has been a common method for sampling riverine fisheries. It involves a creel clerk visiting designated angler access points sequentially, each for a predetermined amount of time, and counting angler vehicles (Robson and Jones 1989). Angler effort hours for each access point and river can be estimated from a relationship between the time angler vehicles are present at an access point and the creel clerk's wait time at an access point (Robson and Jones 1989). It has been touted not only for its cost efficiency, when compared to other methods (i.e., roving surveys and aerial surveys), but also for allowing effective sampling of large geographical areas with low angling pressure among many angler access points such as on riverine fisheries (Robson and Jones 1989; Stanovick 1993; Chen and Woolcock 1999). As rivers are linear systems, angler effort is commonly spread out along their course, in many cases over hundreds of miles, unlike many impoundments and natural lakes (Smucker et al. 2010; Volstad et al. 2011). Woolcock and Kinloch (1995) found BRSs implemented on riverine systems provided angler effort estimates within 10% of the true value, when compared with known effort from a concurrent census.

Like any sampling method, the BRS is not without its disadvantages. Because angler vehicles or trailers are used to generate angler effort estimates, it does not account for anglers who accessed the resource by other means (i.e., walking, biking, all-terrain vehicles, etc.), which could underestimate angler effort. Further, high-use access points with many angler and non-angler users can be difficult for a creel clerk to keep track of angler parties, their corresponding effort, and the recreational purpose of each party. Both of the above problems are often compounded in urban areas, as diversity of recreational use is usually at its highest near large population centers (Stanovick and Nielsen 1991; Stanovick 1993). BRSs have also been found to underestimate shore, bank, and wading angling effort (Soupir et al. 2011). When employing a BRS, it is desirable, but rarely realistic, for access points to be single-use (e.g., angling) only. It is common for a creel clerk conducting a BRS to use boat trailers as the identifier for an active angler (Stanovick 1993; Woolcock and Kinlock 1995). However, this can also introduce bias into effort estimates, as distinguishing between boat trailers of non-angler parties and angler parties can be difficult (Robson and Jones 1989). This is a common problem with many angler survey methods and is often corrected for using proportions of anglers and non-anglers interviewed (Pollock et al. 1994; Lockwood 2000).

Distinguishing among user groups can be even more problematic in shallow, rocky rivers where anglers primarily fish in canoes and kayaks in lieu of conventional, outboard-powered boats. Canoe and kayak anglers commonly transport their vessels on top of their vehicles, making it harder to correctly distinguish between angler and non-angler vehicles. In cases when partitioning angler vehicles from other vehicles is difficult, estimates of angling effort become more uncertain. Despite these issues, past analyses of error and bias have shown bus-route surveys to be a statistically sound and valid method for estimating angler effort on rivers and other systems in which angler effort is distributed across large geographical areas (Stanovick 1993; Chen and Woolcock 1999; Soupir et al. 2006). As an additional benefit, past studies have also found bus-route surveys to be more cost-efficient than other traditional angler survey methods, such as aerial counts and roving counts (Stanovick 1993; Soupir et al. 2006).

However, technological advancements in trail camera technology and their potential applications in angler effort estimation have spurred the interest of fisheries management professionals. Trail cameras may provide a more cost efficient and accurate means of collecting angler effort data than traditional surveys like the BRS (Kristine 2012; Olsen and Wagner 2014; Hartill et al. 2020). This is due to their continuous, passive monitoring capabilities, requiring little on-site staff time, vehicle gas expenditures, and other costs associated with field sampling (Hining and Rash 2016; Eckelbecker 2019; Hartill et al. 2020; Dorsey 2020; Unger et al. 2020).

In fact, studies on lacustrine and marine fisheries have found angler effort estimation via trail cameras to provide estimates with similar or even higher precision at a lower cost than bus-route surveys and other angler survey methods (Ames and Schindler 2009; Wise and Fletcher 2013; Greenberg and Godin 2015). Using trail cameras, angler effort was estimated to be 22% higher than previously thought on a Texas reservoir, due to high daily angling effort occurring outside of standardized sampling timeframes (Olsen and Wagner 2014). To estimate angling effort in an Australian embayment, Wise and Fletcher (2013) found BRS costs to be $543,656 compared to $22,757 using trail cameras. Similarly, Ames and Schindler (2009) found a nearly 75% reduction in cost when camera surveys were compared to their traditional angler survey programs. Costs of using trail cameras will likely decline as the image analysis process is further automated and cellular trail cameras capable of sending images directly to a computer or phone become more reliable in rural areas with erratic cell coverage (Morrow et al. 2022).

Use of trail cameras come with their own set of limitations and drawbacks. An excessive amount of time is required to sort and analyze images prior to effort calculation. This will likely remain the case until further work is done on image analysis automation and further subsampling protocols are developed (Morrow et al. 2022). In terms of employee hours and cost, however, trail cameras have been found to be a better option than traditional survey methods (Kristine 2012; Smallwood et al. 2012; Hartill et al. 2020). Theft, vandalism, flooding, memory card malfunctions, low or dead batteries, and poor camera placement can all cause image data loss or corruption, which are issues that are foreign to other survey methods. Thus, continuity of a dataset is an issue commonly encountered with trail camera use (van Poorten 2015; Hartill et al. 2020). If multiple cameras are used, lost data can often be corrected by using image data from nearby cameras (Hartill et al. 2020). Factors that generally affect angling effort on a given day (e.g., holidays, weather, or season) are likely consistent among nearby access points also, allowing for missing data to be imputed for an affected camera (van Poorten et al. 2015; Hartill et al. 2020).

Study Objectives

Although many studies over the last decade have examined appropriate implementation of trail cameras to estimate angling effort on reservoirs, natural lakes, and marine systems, information on their efficacy in monitoring riverine systems is sparse. Before trail camera can be used to estimate effort on riverine systems with confidence, the reliability of their estimates needs to be evaluated. Given that BRSs have been the method of choice for surveying rivers, they would likely serve as a good candidate for comparison. As one of the major obstacles to using trail cameras is image processing time, further information on optimal subsampling strategies would also be of use to management agencies.

Therefore, the specific objectives of this study were to:

1. Determine the percentage of total sample days of trail camera images that must be analyzed in order to provide acceptable levels of accuracy and precision of use and effort estimates.
2. Compare precision and effort estimation of angling in three Alabama rivers between trail cameras and BRSs
3. Compare the costs associated with estimating angler effort between bus-route surveys and trail cameras on three Alabama rivers.

Methods

Bus-Route Surveys in the Field

In 2020, the Cahaba and Locust Fork Rivers were sampled on 2 five-day trips each month. Each river was sampled on one weekend day each trip and weekday sampling was partitioned so that each river was sampled on three occasions each month. Due to the low weekday angler effort observed from performing the bus-routes and a trail camera census in 2020, sampling protocol was different for 2021. The Cahaba and Locust Fork rivers were sampled on three-day trips every weekend of each month. The river to be sampled on the one available weekday on each trip was rotated weekly and each river was sampled on one weekend day each trip. Unlike the Cahaba and Locust Fork rivers, the Coosa River tailwater bus-route schedules did not change across years, and was surveyed four times a month on two weekdays and two weekend days each month. These sampling days were shifted as necessary to maintain the Cahaba and Locust Fork River sampling schedule, otherwise, Coosa River sampling days were randomly determined. In total, 67 bus-route surveys were performed on the Cahaba River, 43 on the Locust Fork River, and 35 on the Coosa River.

Sample days were divided into morning (sunrise to 12:00 PM) and afternoon (1:00 PM to sunset) shifts. Time permitting, one reach was sampled each shift for a total of two reaches being sampled per day. A stratified random non-uniform sampling design was used to determine the section sampled each shift (Malvestuto et al. 1978). Section was the only stratum for the BRS, as the substratum of sampling reach was removed due to logistical issues, such as traffic. Sections were chosen through weighted probabilities based on expected use at the section scale in 2020 and known probabilities from the trail camera data in 2021 (Table 2.2). Weighting these factors based on expected and known use meant creel clerks performed the BRS in sections with higher angler use and effort more often (Pollock et al. 1994).

BRSs were conducted from May through December 2020 and February 2021 through December 2021 on the Cahaba, Coosa, and Locust Fork rivers. All access points in the section determined to be sampled were visited sequentially at the beginning of each shift using a modified bus-route design (Pollock et al. 1994; Kinloch et al. 1997; Table 2.1). The starting place for bus routes are usually based on a randomly determined access point using a predetermined weighting system (Robson and Jones 1989). This was the case over the first three months of the bus-route survey. However, as a roving creel had to be performed following each BRS, routine traffic delays around the Birmingham-metro area made traveling back and forth along the route impractical. Using this strategy, bus-route times were excessive, often taking 5-6 hours to complete, leaving creel clerks with little time to complete the 8-15 km floats required by the roving component of the angler survey. Therefore, starting in August 2020 and continuing throughout the rest of the study, creel clerks started each BRS at either the uppermost or lowermost access point and visited each access point from there.

Creel clerks spent 10 minutes at each access point, counted all vehicles that appeared to be that of an angler or kayaker (i.e., canoe racks, trucks, or identifying gear present), and attempted to interview any anglers and kayakers that were present. All non-anglers utilizing the access point for other recreational purposes (i.e. swimming, picnicking, tubing, etc.) were tallied separately. The creel clerks then proceeded to the next access point and repeated this process until all access points within the section were visited.

Camera Placement and Image Analysis

Images from trail cameras served as a substitute for the instantaneous count and aerial surveys customarily employed on many roving creels done on reservoirs, while also allowing for a comparison with the bus-route survey (Hanson et al. 2002; McKee 2013; Gratz 2017; Plauger 2018). Spypoint Force-Dark (GG Telecom, Victoriaville, Quebec, Canada) trail cameras were mounted approximately 3m high in trees near all 38 access points in as discrete a location as possible while still allowing for a field of view that fully included entry and exit points. All cameras were locked and secured in a steel security box to deter theft and vandalism (Hining and Rash 2016). “Dummy” cameras (i.e., previously battered security boxes locked and secured to a tree) were installed in conspicuous sites to promote the belief that the camera in the area had already been stolen. This extra precaution was only taken in places where theft or vandalism had occurred previously.

All cameras were active from May through December 2020 and February through December 2021. Images were taken using the motion detection function utilizing a 10-second delay between captures. Camera maintenance was conducted monthly during the on-site survey period to ensure proper functioning, battery life, and to exchange memory cards (Stahr and Knudsen 2018; Eckelbecker 2019; Dorsey 2020). At the close of each month, images were downloaded to a computer, sorted by day and month, and stored for processing. Image clean up (i.e., deletion of images lacking anglers) and analysis took place from November to January each year. A census of all angler use and effort was performed in 2020, and these data were used for Objective 1. Results from that objective informed a subsampling regime that was used for the camera data in 2021.

An individual was only counted as an angler if they were in possession of fishing equipment in at least one image. Individuals seen again on another image day still needed to be in possession of fishing equipment on the corresponding day to be counted as anglers. Angler effort hour counts were subjected to the same protocol. An individual angler’s daily bank/wading angling effort was calculated by subtracting the entry image timestamp from the exit image timestamp. This only required image data from one camera. A similar protocol was used to estimate individual boat angling hours, but this calculation often required images from two cameras; one in which the angler or angler party can be seen launching and one in which they can be seen taking out.

Although relatively uncommon, missing image data due to theft, vandalism, memory card corruption, flooding, etc. was imputed from neighboring cameras by multiplying a daily angler count from the downstream camera by the mean trip length for that reach, according to suggestions of van Poorten et al (2015) and Hartill et al (2020). In total, 11 cameras in 2020 and 9 cameras in 2021 were lost, however data loss was minimal due to our protocol of verifying a camera’s presence during every bus-route survey and monthly camera maintenance trips. Spare trail cameras and equipment (i.e., extension ladder, drill and hardware, loppers, chainsaw, etc.)

needed for installation were kept on hand allowing for quick replacement of stolen or malfunctioning cameras.

Census and Subsampling

Angler use and effort from the 2020 sampling season on the Cahaba and Locust Fork rivers was estimated via a census, in which every angler and every angler hour present on the trail camera images were counted. This consisted of seven months of image data, from May to December. The original sampling timeframe for the first year was intended to be from March to December, but shipping delays of trail cameras due to Covid-19 complications delayed the beginning of the study until May. Coosa River angler use and effort was also initially intended to be included in this analysis, however recurring camera theft prevented its inclusion in the study. Therefore, no 2020 census data were available for the Coosa River.

In preparation for the analysis required to determine an optimal subsampling strategy for trail camera image data, angler use and effort for each available sample day (206) was summed across all 36 access points on the Cahaba and Locust Fork rivers. Assuming the census values to represent true angler use and effort values, these aggregate use and effort data were used in a bootstrap analysis in which the precision of the mean angler use and mean effort estimates were evaluated at varying percentages of sample days analyzed. Percent of sample days analyzed ranged from 10 – 100% in increments of 10%. Resampling was done with no replacement to prevent any given day from being sampled multiple times.

From the census, it was apparent that mean angler use and effort was higher for weekend days than weekdays, despite the disparity between the available sample days of each day type. There were 148 weekday and 58 weekend sample days available. Although total angler use (weekday = 2,662 anglers; weekend = 2,961 anglers) and effort (weekday = 8,594 h; weekend = 11,423 h) for each day type was similar, mean total weekday anglers was 18/d and mean total weekend anglers was 51/d. Mean total weekday angler effort was 58 h/d and mean total weekend angler effort was 196 h/d. Thus, not accounting for higher daily weekend use and effort may result in an underestimation of use and effort values in the resampling process. Therefore, four different day type weighting scenarios were included in the analysis as follows:

1. Simple random sample (i.e., no regard to day type); probability of weekdays and weekend days being sampled were relative to their proportions

2. High weekend/low weekday; 75% of the sample comprised of weekend days and 25% of weekdays
3. Half weekend/half weekday; 50% of the sample comprised of each day type
4. Low weekend/high weekday; 25% of the sample comprised of weekend days and 75% of sample comprised of weekdays

Aggregate use and effort data were resampled 1,000 times across the varying percentages of sample days analyzed and day type scenarios. Standard error and mean of each resulting estimate were then used to produce a coefficient of variation (CV) for each day type scenario and corresponding percentage of sample days analyzed. Choosing how many sample days and the proportion of weekday to weekend days to sample was based on the percent decrease of the CV, with a goal of sampling at the theoretical breakpoint after which the gain in precision of analyzing 10% more sample days of images is not worth the extra labor and processing time.

The 2021 trail camera images were then sampled according to these results with added weights for seasonality, as proportions of angler interviews from the roving survey by season showed that, dependent on the river, spring and summer months comprised 80 – 83% of total angler effort. However, seasonality was not included in the bootstrap analysis, due to time constraints.

Effort

Bus-Route Survey

Total vehicle hours (TVH) for each river section from the BRS was calculated using a modified version of the equation developed by Robson and Jones (1989) as follows:

$$TVH = BR(\sum v) * (\frac{m}{w}) \quad (1)$$

Where *BR* was the route time, *v* was the number of vehicles at an access point, *m* was angler vehicle minutes observed at an access point, and *w* was total wait time of the creel clerk. TVH was converted to angler hours (AH) by dividing TVH by the mean number of anglers in each angler party. For 2020, AH was then multiplied by 206, or the available number of angling days in the survey period (i.e., May – December) to estimate total annual angler effort. To estimate total angling effort for 2021, *AH* was multiplied by 365 days, or the total angling days available in a year.

Trail Cameras

In 2020, total effort was estimated via a census in which every angler and angler hour from the trail camera images were counted. Boat and bank angling hours were counted separately by section and access point and then summed for each section and river to yield total annual effort. Anglers that were wading were included with bank angling in both years. In 2021, a total of 125 days, 35% of the available 365 days, were analyzed. All images from weekend days were analyzed, so those daily effort hours were summed for a total annual weekend effort, whereas 36 weekdays (25%) of the 125 sample days were chosen randomly to be analyzed. The number of days sampled each month was stratified by season, as the proportions of angler interviews in 2020 demonstrated that 80 – 83% of the angling effort occurred in the spring and summer months. Sampling weights by season were as follows: spring (0.5), summer (0.31), fall (0.17), and winter (0.11). Weekday annual boat effort (E_{bt}) for each river section was calculated using the following equation:

$$E_{bt} = \bar{e}_{bt} / \rho_1 \qquad (2)$$

Where $\bar{e}_{bt}$ is mean weekday boat angler hours for a section of river and ρ_1 is the probability of a boat angler fishing within that section (Pollock et al. 1994). This value was then multiplied by the total number of weekdays in a year (260), producing an annual weekday boat effort value. The summation of the total weekday boat effort and total weekend boat effort yielded total annual boat effort for each river section; these values were summed to produce total annual boat effort for each river.

Bank weekday effort was calculated similarly, again based on weekday angler counts and hour counts from the 36 sample days using the following equation as described in (Pollock et al. 1994):

$$E_{bk} = \bar{e}_{bk} / \rho_1 \qquad (3)$$

Where $\bar{e}_{bk}$ is the mean weekday bank effort and ρ_1 is the probability of a bank angler fishing within that section. This value was then multiplied by the total number of weekdays (206) and then summed with the total bank weekend effort to yield total annual boat effort for each river section. Total bank effort for each section was then summed to produce total annual bank effort for each river. Total annual angling effort for each river was derived from the sum of total annual boat and bank effort.

Survey Cost Estimation

Annual costs associated with effort estimation via BRSs and trail cameras were compared for 2021. Costs associated with trail cameras were: the trail cameras, themselves, security boxes and python locks, mileage, per diem, and salary; whereas, those associated with BRSs were only mileage, per diem, and salary. Salary costs were estimated using an average technician and biologist hourly wage from state fisheries management agencies in the Southeastern United States. The hourly wage was multiplied by the total number of office and field hours estimated to be required for completion of each survey method (Table 2.4). Office labor hours for the trail camera method were estimated by keeping track of actual hours spent analyzing images in 2021. Office hours for the BRS were comprised of data entry and analysis hours.

Field hours related to trail cameras comprised time spent driving roundtrip to the study sites as well as time spent conducting maintenance and changing memory cards. For BRSs, field hours consisted of roundtrip driving time spent traveling to the study sites and time required to conduct the surveys. Per diem costs for BRSs were derived from the state of Alabama rate of \$100/d and \$85/d multiplied by the number of overnight days. Mileage costs were estimated using the 2021 standard mileage rate of \$0.56/mile multiplied by the number of miles driven for each method (United States Internal Revenue Service 2022).

Results

Census and Subsampling

In 2020, anglers fished an estimated 12,650 h on the Cahaba River and 7,368 h on the Locust Fork Rivers (Table 2.3). Collectively, a total of 20,018 angler hours occurred on these rivers from 5,623 total anglers. Mean angler effort was 3.6 hours.

A bootstrap analysis was performed for both angler use and effort. The relation between CV and percent of days analyzed was similar for angler use and angler effort. Across the four scenarios examining different proportions of weekday and weekend days sampled, all CVs were within 5 units of each other across scenarios (Figure 2.1; Figure 2.3). The simple random sample provided the highest precision at the lowest percentage of sample days analyzed and low weekend/high weekday (0.25 weekend/0.75 weekday) the least. The scenario (low weekend/high weekday) consistently produced estimates that were the least precise across all percentage of sample days analyzed categories. At 20% sample days analyzed, the scenario in which the weekday and weekend day sampling weights were equal at 0.5 provided the most precise estimate. At 30% sample days analyzed, all scenarios produced estimates with CVs from 11 to 13, except for the low weekend/high weekday scenario. As sample days were increased, from 40% through 50%, the scenario (0.75 weekend/0.25 weekday) provided the most precise estimate. From 60% to 90% of sample days analyzed, both the equal weighted (0.5 weekday/0.5 weekend) and 0.75 weekend/0.25weekday scenarios produced estimates with the highest precision. The CVs were equal, because at this sampling effort all weekend days (58) available for sampling were included in the sample.

To decide what percentage of sample days to analyze, a marginal analysis in which percent decrease between the percent days sampled categories was used. The percent decreases of the 0.75 weekend/0.25 weekday scenario are reported here (Table 2.6). From 10 – 20% of sample days analyzed, CV decreased by 30%. The largest percent decrease (39%) came from the increase from 30 – 40% of sample days analyzed, followed by 40 – 50% category which lead to a 31% decrease in CV%. Percent decreases ranged from 23 – 29% after this category.

The benefits of sampling beyond 30% of the available sample days were minimal across all day type scenarios. However, in an attempt to avoid overestimation of angling effort, we made the conservative choice of sampling 35% of the available sample days at high weekend/low weekday weights (0.75 weekend/0.25 weekday). Further regression analyses using these data will be used to further assess optimal subsampling strategies in the near future.

Mean angler use and effort estimates across all scenarios and percent of sample days analyzed levels, were fairly close to the census values (Figure 2.2; Figure 2.4). The scenario in which 10% of the sample days were analyzed with weights of 0.25 weekend/0.75 weekday produced the most biased estimate. This was 19,738 h, which was 98% of the census value of 20,018 h. Mean angler use (5,565) was underestimated in this scenario also, 58 anglers lower than the census value. However, this was still 99% of the census value of 5,623. At 20% sample days analyzed, the simple random sampling strategy overestimated effort by 200 hours and underestimated angler use by 55 anglers. Apart from those two cases, all sampling strategies produced mean count and effort estimates within 1% of the census values.

Effort Estimates between Survey Types

Effort estimates produced by the BRSs and trail cameras were similar (Table 2.3). Bus-route estimates were generally higher than trail camera estimates. In 2020, BRSs estimated that Cahaba River anglers fished 16,412 h (95% C.I. = 1,249 h), while angler effort was estimated at

12,650 h (95% C.I. = 2,267 h) using the trail cameras. Thus, the effort estimate from the BRS was 3,762 h higher than the trail camera estimate in 2020. Effort estimates for 2021 on the Cahaba River were very similar among surveys, as the BRS estimated 24,916 h (95% C.I. = 715 h) of angling effort and the trail camera method produced an estimate of 23,057 h (95% C.I. = 2,038 h). In this case, the BRS estimate was 1,859 h more than the trail camera estimate.

No trail camera effort estimate was available for the Coosa River in 2020 due to repeated camera theft, but effort was estimated to be 17,844 h (95% C.I. = 641 h) from the BRS. However, in 2021, the greatest disparity in effort estimates between the two survey methods was observed during this study. The BRS estimate was 8,962 h higher than that estimated from the trail cameras. The BRS effort estimate was 25,486 h (95% C.I. = 593 h) and the trail camera effort estimate was 16,504 h (95% C.I. = 1,586 h).

The BRS and trail cameras produced near identical effort estimates in 2020 on the Locust Fork River, 7,368 h (95% C.I. = 1,250 h) using trail cameras and 7,385 h (95% C.I. = 852 h) from the bus-route surveys. The Locust Fork River estimates for 2021 were the only instance in which trail cameras produced a higher effort estimate than the bus-route survey. The trail camera estimate was 10,730 h (95% C.I. = 1,430 h) and the bus-route survey estimate was 8,940 h (95% C.I. = 1,318 h), resulting in a difference of 1,790 h between the two methods.

Survey Costs

In total, 13 memory card/camera maintenance trips and 77 BRSs were conducted in 2021 (Table 2.2). Employee hours and costs associated with using trail cameras were lower than BRSs (Table 2.4; Table 2.5). Using trail cameras required fewer labor hours, a total of 253 h (97 office h; 156 field h) of labor, whereas 928 total hours (10 office h; 918 field h) went into estimating effort via the bus-route method.

The initial purchasing cost of the trail cameras ($10,200) was divided by the average useful life of trail cameras (4 years) to produce a useful life cost, which yielded an annual camera and supplies cost of $2,550 (Banjevic 2009). BRS mileage costs ($15,200) were $11,240 higher than mileage costs for the trail camera method ($3,960). Due to the increased amount of fieldwork required by the BRS, per diem costs for BRS ($7,200) were also higher than for trail cameras ($1,105).

Assuming an employee receiving an average state agency biologist wage ($22.22/h) in the Southeastern US processed the images and performed camera maintenance, total cost associated with employee salary was $5,621, whereas salary costs for the bus-route method under this scenario was $20,620 (Table 2.5). In total, using trail cameras in this scenario required $13,236 in expenses; much less than the BRS, which had a total cost of $43,020. Therefore, estimating angler effort by trail cameras was the cost-efficient option, as cost was $29,784 less than the BRS.

Costs associated with these same two methods using an average technician wage ($14.35/h) were understandably lower as it costs nearly $8/h less for a technician to perform the same tasks as it would a biologist. Technician salary was $3,629 for the trail camera method and $13,395 for the bus-route method (Table 2.5). Under this scenario, the BRS ($35,795) cost over twice as much to conduct as the trail camera method ($11,244).

Discussion

Bus-Route Surveys in the Field

Survey designs are often combined to reduce bias of effort estimates (Malvestuto et al. 1978; Soupir et al. 2006). Conducting a traditional BRS akin to that of Robson and Jones (1989) alongside a roving survey, oftentimes, proved difficult on these study rivers, due to the length of floats for the roving survey (5 – 25 km). The upper section of the Cahaba River posed the greatest obstacle, as Birmingham metro traffic was difficult to navigate in a timely manner in nearly all hours of a day. Stanovich (1993) also reported difficulty in sampling with a traditional bus-route design on the James River around Richmond, Virginia. His study was able to maintain the traditional design due to the complementary survey, an aerial count, being performed on separate days; also only a 16-km reach and two access points were reported as issues. In this study, 8 access points and 77 km of the Cahaba River were in Birmingham, which creates a large hindrance in implementing the traditional BRS. Due to rush-hour traffic, creel clerks often had to start roving surveys intended to be conducted in AM timeslots as late as 11:00 AM to 12:00 PM.

Modifying the bus-route to a sampling structure that had creel clerks only begin a route from the upstream-most or downstream-most access point of a section reduced by half the time required to complete a route. On days when lower-use sections were scheduled, creel clerks were able to conduct two bus-route surveys and two roving surveys. Although the Locust Fork and Coosa Rivers were able to be sampled using traditional bus-route design, they were sampled using the modified bus-route design to maintain consistency among study rivers. Losing the randomness of varying the beginning access point may have increased bias in this study;

however, it was necessary as many of the angler interviews came from the on-river roving survey and these interviews were critical in collecting the economic information for Chapter 3 (Chen and Woolcock 1999).

Camera Placement and Image Analysis

Using trail cameras on riverine systems has some unique advantages and disadvantages not previously mentioned in the literature. As in all creel survey designs, researchers should make every effort to understand the fishery intended to be studied; scouting access points and boat ramps prior to purchasing cameras is paramount to success. Also, choice of cameras must consider the objectives of each study. Each model has strengths and weaknesses; some have extremely fast trigger speed but low resolution, some a narrow field of view, some a slow recovery time between captures, and some a short range of motion detection. Battery life, waterproofing, image storage capacity, infrared capabilities, etc. can all vary considerably depending on manufacturers and models. Overlooking a feature as simple as an infrared emitter that produces a blinking light, in lieu of an undetectable "no glow" light can increase camera theft and data loss. All of these factors make it necessary to know ahead of time how a camera is going to be used because a particular model that may perform well on one system may not produce desired results on another. For example, information gathered from anglers and district biologists prior to the study indicated that use was likely to be relatively low and sporadic on the Cahaba and Locust Fork rivers. There were also only two boat ramps within the study areas on either river, so it was clear that time-lapse captures conventionally used for trailer counts may lead to missed angler counts and an underestimate of angler effort (van Poorten et al. 2015; Eckelbecker 2019). Therefore cameras with motion detection functions were used. In this case, trail cameras with fast trigger speeds, rapid recovery time, long detection range, and long battery life suited our purposes more than cameras with higher resolution quality and those with high image quality in low light conditions. Making these decisions can be expedited if trail camera experts are consulted after attaining the necessary background information for a study river. Trail camera consultants were instrumental in choosing the appropriate cameras to monitor the study rivers.

Camera placement also warrants careful consideration. First, cameras should not be mounted facing directly east or west, as direct sunlight near dawn and dusk can make distinguishing anglers from non-anglers difficult. Dawn and dusk are often hours in which angling activity is at its highest, therefore daily angling effort could be underestimated due to this (Deroba et al. 2007). When using the motion-detection function, cameras should be placed in the view of a choke point (i.e., narrow entry and exit point), whereas large areas such as parking lots, or a wide access point where bank angling is common would likely be more efficiently sampled with a time-lapse trigger (Hining and Rash 2016; Hartill et al. 2020). Either way routine maintenance of brush and limbs in the surrounding area of the camera is essential, as they can obscure angler activity and movements via wind may trigger the capture of thousands of unwanted images when using motion detection mode (Hining and Rash 2016). Cameras with fast trigger speeds can further exacerbate this issue, increasing image processing times dramatically. Rapid vegetative growth characteristic of the subtropics of the southeastern US made this a constant concern on the rivers in this study. However, it became apparent in the early stages of this study that keeping the area around a trail camera too well managed or devoid of vegetative growth greatly increases the likelihood of theft and vandalism. Thus, a tradeoff likely exists between unwanted images and reduced camera theft and vandalism, and this was often site-specific during this study. Placing trail cameras in birdhouses and other well-planned disguises can possibly mitigate this tradeoff somewhat (L. Dorsey, NCWRC, personal communication).

Hiding trail cameras in birdhouses and using battered security boxes from previously stolen cameras as decoys appeared to reduce theft and vandalism issues in this study. However, 35%, or 21 out of 60 total cameras over the two year study period had to be replaced once, but nearly 47% of this was due to extreme flood events or camera breakdowns due to unknown reasons. The most effective means of ensuring trail camera security was to position cameras as high up as possible and secure them so that the camera is angled down at the access point. In 2021, almost all of the cameras used in this study required a 24’ extension ladder for maintenance and memory card switches. Although inconvenient for the researcher (maintenance time for all 38 cameras nearly doubled), vandalism and theft became equally challenging. 13 cameras were lost to theft or vandalism in 2020, whereas only four were stolen or vandalized in 2021.

There are a few other rather simple practices that may seem of little consequence in the field, but make for easier image processing and may decrease instances of data loss. First, ensuring that time and date are correct each time before finishing maintenance and switching memory cards seems obvious, but can be easy to overlook when managing many cameras at a time. Weakening batteries also seem to cause erroneous date and time stamps, doubling the importance of checking date and time settings on each maintenance trip. If a researcher is aware that a camera is in a high use area or false captures are common, batteries should be changed on every maintenance trip. Generally, during this study batteries were changed on any camera that displayed battery life below 85%. For the particular camera models used in this study, battery life lower than this value increased the likelihood of corrupted image files and erroneous time stamps. Similarly, when using trail cameras to monitor angling activity, researchers should have plenty of spare memory cards on hand. This is particularly important when using motion detection capture in high use areas or where false captures are common. The vast amount of images captured and stored over a year when cameras are monitoring continuously can quickly decrease the life of a memory card. This can lead to card corruption and loss of image data. Because of this, researchers should consider retiring memory cards every 6 months or 1 year, dependent on how many images are being stored on a monthly basis. Five cards experienced corruption over the course of this study; however, image data were restored via professional data salvage specialists at relatively affordable costs.

Census and Subsampling

Results from the bootstrap analysis of angler effort on the Cahaba and Locust Fork rivers show that processing 35% of available sample days provides estimates with acceptable levels of precision. Although this is the first time a study of this kind has been performed on inland riverine fisheries, this is similar to the conclusions of other studies which focused on optimal subsampling strategies on other types of fisheries. A study on an Australian coastal fishery examining angler effort at three boat ramps concluded that analyzing images from 40% of the days within a year provided unbiased, precise, and accurate effort estimations (Afrifa-Yamoah et al. 2021). Images from the trail camera sample days may have been oversampled slightly in my study. Coefficient of variation (CV) was 0.12 at 30% and 0.07 at 40% of sample days analyzed, respectively, which is extremely precise. Processing only 30% of the sample days would have meant analyzing images from 110 days instead of 125 days. Another study on an Australian marine fishery found that analyzing images from only 60 days of the year provided a CV of 0.10 (Afrifa-Yamoah et al. 2021). Analyzing only 60 days of images (~17%) in this study would have meant accepting a slightly higher CV of 0.14. This is well below the threshold of what is considered an acceptable level of precision (0.3) angler surveys (Mills and Howe 1992;

Stanovick et al. 2002). However, to provide the best data for the economic analyses in this study (Chapter 3) under reasonable time constraints, 35% of the available sample days were analyzed.

This study did not relate cost directly to the subsampling process. Costs associated with attaining a given level of precision may be an important deciding factor for managing agencies seeking to estimate angler effort with trail cameras. However, results of this study found angler effort on rivers can be estimated with high precision at fairly low numbers of sample days analyzed as long as the appropriate sampling scheme is applied.

Effort

Although further analyses (i.e., ANOVAs, etc.) comparing the two methods is in order, trail cameras produced annual effort estimates that were comparable to the bus-route survey estimates (Table 2.3). Apart from the Locust Fork River effort estimate in 2021, the bus-route method consistently produced higher effort estimates than the trail cameras. In comparing aerial count surveys to bus-route survey estimates, Soupir et al. (2006) also found that the bus-route method nearly always produced the highest effort estimates. On these Alabama rivers, this may be due to misidentifying vehicles of recreational kayakers or canoeists as anglers during the BRS. In order for a vehicle to be counted as an angler vehicle, it had to either be a truck, SUV, fitted with a mounted canoe rack, or have angling gear present. Still, recreational kayaker use on these rivers is popular and many drive similar vehicles, so there is little doubt that this common bias influenced effort estimates from the BRS.

Confidence intervals calculated from the bus-route methods were narrower than that from the trail camera effort estimates, indicating that bus-route effort estimates were more precise. Because far more days (2020 = 206; 2021 = 146) were sampled on each river for the trail camera study than in the BRS, at most, 37 sample days per year, higher variation in daily effort likely accounts for this. With higher variation between the greater number of sample days, variance around the trail camera estimates likely increased. Further, daily trail camera estimates are continuous, in a sense, in that variation in effort within a given sample day is likely captured more completely, which could also increase variance around the estimates. The bus-route method, however, is more of an instantaneous count, usually taking place over less than half a day, it is probable that within day variation of effort was lower due to this also (Soupir et al. 2006).

Modifying the bus-route structure to decrease the time required to conduct the survey may have also played a role in higher effort estimates found by the bus-route. Creel clerks starting at either the upstream-most or downstream-most access points in a section may have inflated bus-route effort estimates (Chen and Woolcock 1999). Many of the access points, classified a priori as high use, were located along the middle of a route. Thus, more angler vehicles may have been at these middle access points by the time creel clerks arrived than if creel clerks visited these access points at the beginning of the day.

In order to acquire information on catch-per-effort, harvest-per-effort, among other data common to angler surveys, trail cameras still need be employed alongside another survey type, while the bus-route survey allows managers to estimate effort and collect other data of interest. Despite this, considering the long-standing use of bus-route surveys in effort estimation and the close proximity of the effort estimated through the use of trail cameras to the bus-route estimates, trail cameras appear to be an effective means of monitoring angler effort on riverine waterbodies.

Cost

Estimating effort by trail cameras offered a significant cost reduction when compared to the BRS (Table 2.5). The trail camera method was $24,000 - $30,000 cheaper than the bus-route method, similar to the cost savings seen in other studies. Ames and Schindler (2009) found a cost reduction of 75% when comparing camera costs to their standardized surveys. Likewise, in this study, the trail cameras offered nearly a 70% reduction in total cost. Many of the past cost-comparison studies were performed on marine fisheries, but cost reductions in the hundreds of thousands of dollars have been reported. For instance, Wise and Fletcher (2013) found using trail cameras to estimate angler effort to be $521,000 less than performing traditional bus-route surveys on an Australian embayment. As monitoring angler effort with trail cameras in their study cost approximately $33,000 annually, they saw a 93% decrease in cost.

Apart from the initial cost of purchasing cameras, much of the costs associated with using trail cameras to estimate angler effort comes from manually processing images, as image processing costs increase linearly with the number of sample days analyzed (Afrifa-Yamoah et al. 2021). As more information on precision and accuracy of subsampled trail camera effort data and automation of image processing becomes more widespread, the costs of using trail cameras will continue to decline (Morrow et al. 2022).

Passive monitoring capabilities of trail cameras also offer another benefit that are indirectly related to costs. An employee processing images is likely available to conduct more of their on-site typical duties (e.g., outboard maintenance, answering phone calls, data entry, etc.) concurrently, which could not be done during a BRS under most circumstances.

As a growing body of literature demonstrates the cost-efficiency and efficacy of monitoring angler effort with trail cameras across a wide range of waterbodies, more fisheries managers should consider implementing trail cameras into their standardized creel surveys. Although in order to collect catch and harvest data, some form of angler interview is still required. Aerial surveys, instantaneous counts, BRSs, and other angler count methods used to extrapolate information collected on site can be replaced by trail cameras with no sacrifice in accuracy and substantial gains in cost savings. While the current cost benefits provided by using trail cameras should already be of interest to managers, as image-processing automation software is developed further, effort estimation via trail cameras will likely offer an even cheaper option in the near future (Morrow et al. 2022). Implemented properly, trail cameras could drastically reduce the cost of angler surveys, making funds available to be used on other issues of interest to a managing agency (Wise and Fletcher 2013; Hartill et al. 2016; Eckelbecker 2019; Afrifa-Yamoah et al. 2021).

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Tables

Table 1.1. Access points, reach distance, and estimated angler use for three sections on the Cahaba River, one section on the Coosa River, and two sections on the Locust Fork River.

River	Section	Access Points		Reach Distance (km)	Estimated Use
		Put in	Take out		
Cahaba	Upper				
		White's Chapel Parkway	Moon River	14.8	Moderate (2)
		Moon River	Grant's Mill	8.2	High (3)
		Grant's Mill	Old Overton Rd	11.1	Very High (4)
		Old Overton Rd	Hwy 280	10.4	High (3)
		Hwy 280	Sportsplex	9.8	Moderate (2)
		Sportsplex	Lorna Rd	8.3	Moderate (2)
		Lorna Rd	CR 52	15.7	Low (1)
	Middle				
		Old Slab	Lebron Launch	3.21	Low (1)
		Lebron Laucnch	CR 24/NWR	13.4	Very High (4)
		CR 24/NWR	Caffee Creek/NWR	2.4	Very High (4)
		Caffee Creek/NWR	Pratt's Ferry	8.4	Moderate (2)
		Pratt's Ferry	Walnut Street	13.5	Moderate (2)
	Lower				
		Harrisburg Rd	Onrow Tubbs Rd	18.2	Low (1)
		Onrow Tubbs Rd	Sprott Bridge	19.3	Moderate (2)
		Sprott Bridge	Radford Rd	12.4	Moderate (2)
		Radford Rd	CR 6	14.7	Low (1)
		CR 6	Hwy 80	15.7	Low (1)
		Hwy 80	Hwy 22	19.9	Moderate (2)
		Hwy 22	Old Cahawba Park	14.4	Low (1)
Locust Fork	Upper				
		Lurleen Dr	Cold Branch Rd	16.1	Low (1)
		Cold Branch Rd	Taylor Ford Rd	5.3	Moderate (2)
		Taylor Ford Rd	King's Bend	11.1	Moderate (2)
		King's Bend	Swann Bridge	6.7	High (3)
		Swann Bridge	Nectar Bridge	6.7	High (3)

River	Section	Access Points		Reach Distance (km)	Estimated Use
		Put in	Take out		
Locust Fork	Upper				
		Nectar Bridge	CR 13	8.0	High (3)
		CR 13	Center Springs Rd	16.1	Moderate (2)
		Center Springs Rd	Warrior-Trafford Rd	13.6	Moderate (2)
		Warrior-Trafford Rd	Warrior-Kimberly Rd	12.7	Moderate (2)
	Lower				
		Warrior-Kimberly Rd	Mt. Olive Rd	26.8	Low (1)
		Mt. Olive Rd	Old Jasper Hwy	14.8	Low (1)
		Old Jasper Hwy	Porter Rd	19.9	Low (1)
Coosa					
		Jordan Dam Rapids	Wetumpka City Ramp	11.4	Very High (4)

Table 2.2. Sections weighted by ADCNR biologists and anglers, sections weighted by known use from 2020 trail camera data, actual percentage of sampling by section, number of times sampled, and number of interviews by section, Cahaba River, AL.

River	Section	ADCNR/angler weight (%)	Trail camera weight (%)	Actual (%)	Number of times sampled	Number of angler interviews	Number of recreational kayaker interviews
Cahaba	Upper	41	42	45	30	35	13
	Middle	43	37	34	23	17	10
	Lower	16	21	21	14	3	1
	Total	-	-	-	67	55	24
Locust Fork	Upper	80	0.78	86	37	41	16
	Lower	20	0.23	14	6	0	0
	Total	-	-	-	43	41	16
Coosa	Tailwater	-	-	-	35	135	21

Table 2.3. Trail camera and bus-route survey angler effort hour estimate totals for Cahaba, Locust Fork, and Coosa Rivers and 95% confidence intervals (in parentheses) in 2020 and 2021. Coosa River trail camera effort estimates for 2020 were unavailable due to camera theft. 2020 effort is derived from a 6-month sampling period (May-December) and 2021 effort a full year of sampling.

River	Cameras		Bus Route	
	2020	2021	2020	2021
Cahaba	12,650 (2,267)	23,057 (2,038)	16,412 (1,249)	24,916 (715)
Coosa	-	16,504 (1,586)	17,844 (641)	25,486 (593)
Locust Fork	7,368 (1,250)	10,730 (1,430)	7,385 (852)	8,940 (1,318)

Table 2.4. Employee hours associated with collecting angler use and effort with trail cameras and bus-route surveys on three rivers in Alabama in 2021.

Employee Hours	Cameras	Bus Route
Office	97	10
Field	156	918
Total	253	928

Table 2.5. Costs associated with collecting angler use and effort with trail cameras and bus-route surveys on three rivers at an average hourly entry-level fisheries biologist wage and entry-level technician wage across state fish and wildlife agencies in the Southeastern US in 2021. Mileage was calculated using standard mileage rage ($0.56/mile).

	Camera Cost ($)	Bus-Route Cost ($)
Cameras and Supplies*	2,550	-
Mileage	3,960	15,200
Biologist Salary ($22.22/hr)	5,621	20,620
Per Diem	1,105	7,200
Total	13,236	43,020

Cameras and Supplies*	2,550	-
Mileage	3,960	15,200
Technician Salary ($14.35/hr)	3,629	13,395
Per Diem	1,105	7,200
Total	11,244	35,795

* Useful life of trail cameras was calculated by dividing initial camera cost ($10,200) by 4 years, or the average life expectancy of trail cameras

Table 2.6. Percent decreases of CVs of the angler use and effort estimates between the different percent days sampled for the 0.75 weekend/0.25 weekday scenario from the bootstrap analysis.

	Percent of sample days analyzed (%)							
	10-20%	20-30%	30-40%	40-50	50-60	60-70	70-80	80-90
Percent Decrease in CV (%)	30.9	24.3	38.7	31.0	23.9	24.3	27.6	34.1

Figures

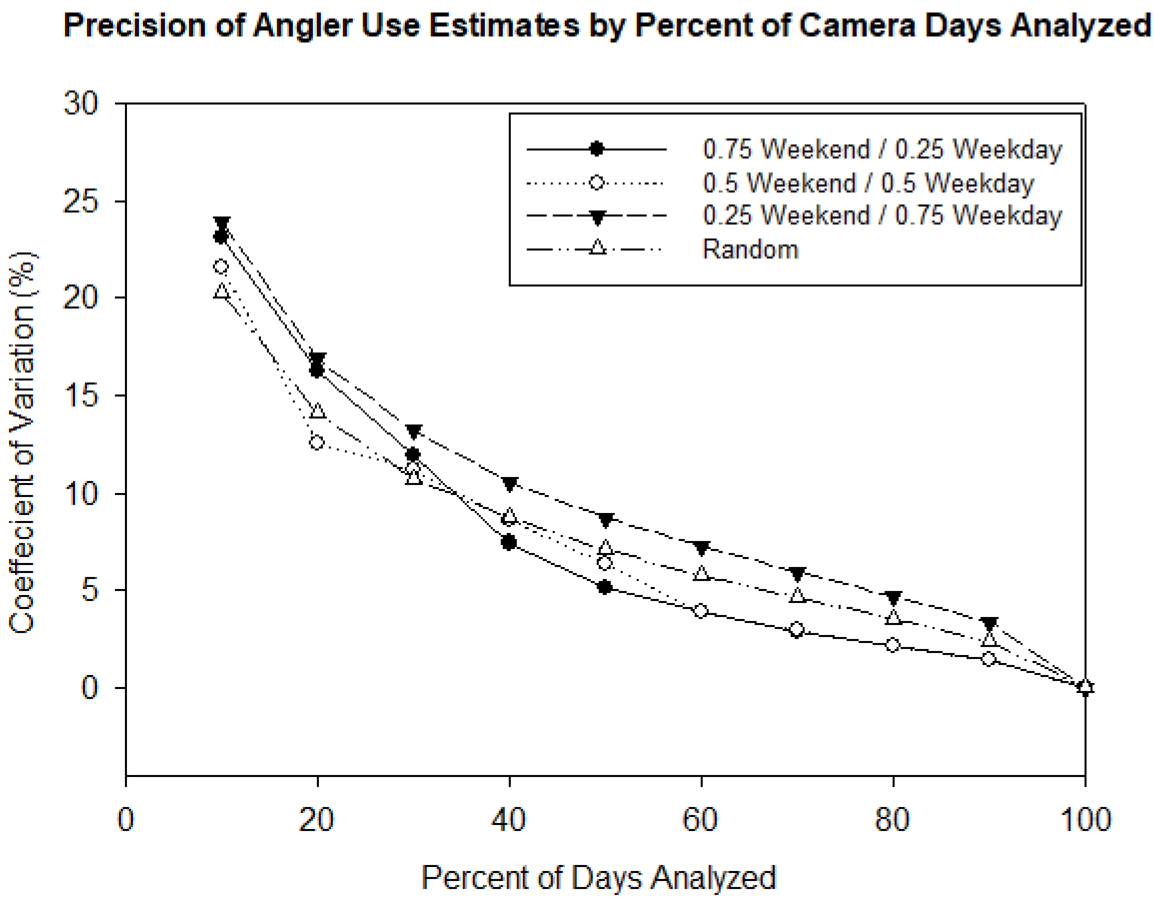

Figure 2.1. Coefficients of variation (%) for angler use estimates of four trail camera image sampling scenarios in terms of the probabilities of sampling weekday and weekend days.

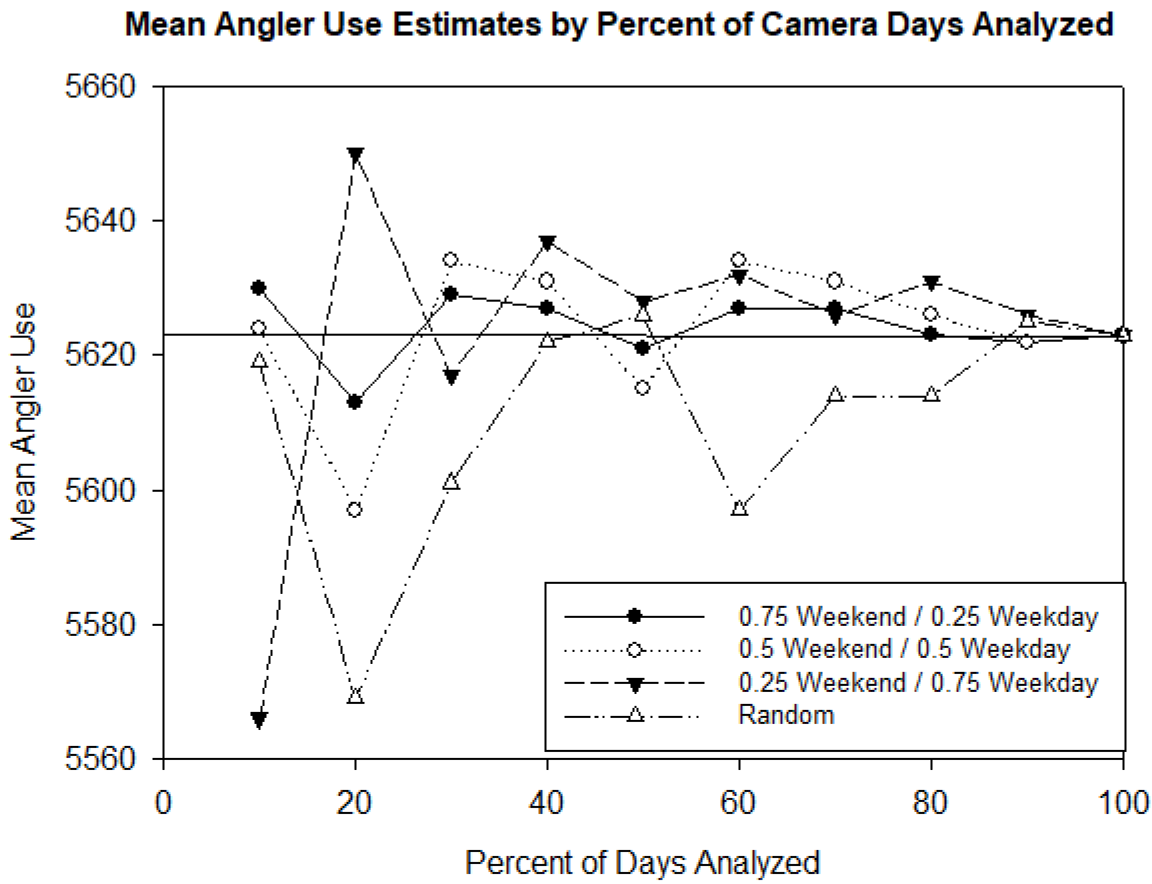

Figure 2.2. Mean angler use estimates of four trail camera image sampling scenarios in terms of the probabilities of sampling weekday and weekend days. The solid horizontal line corresponds to the number of anglers counted from the 2020 angler use census.

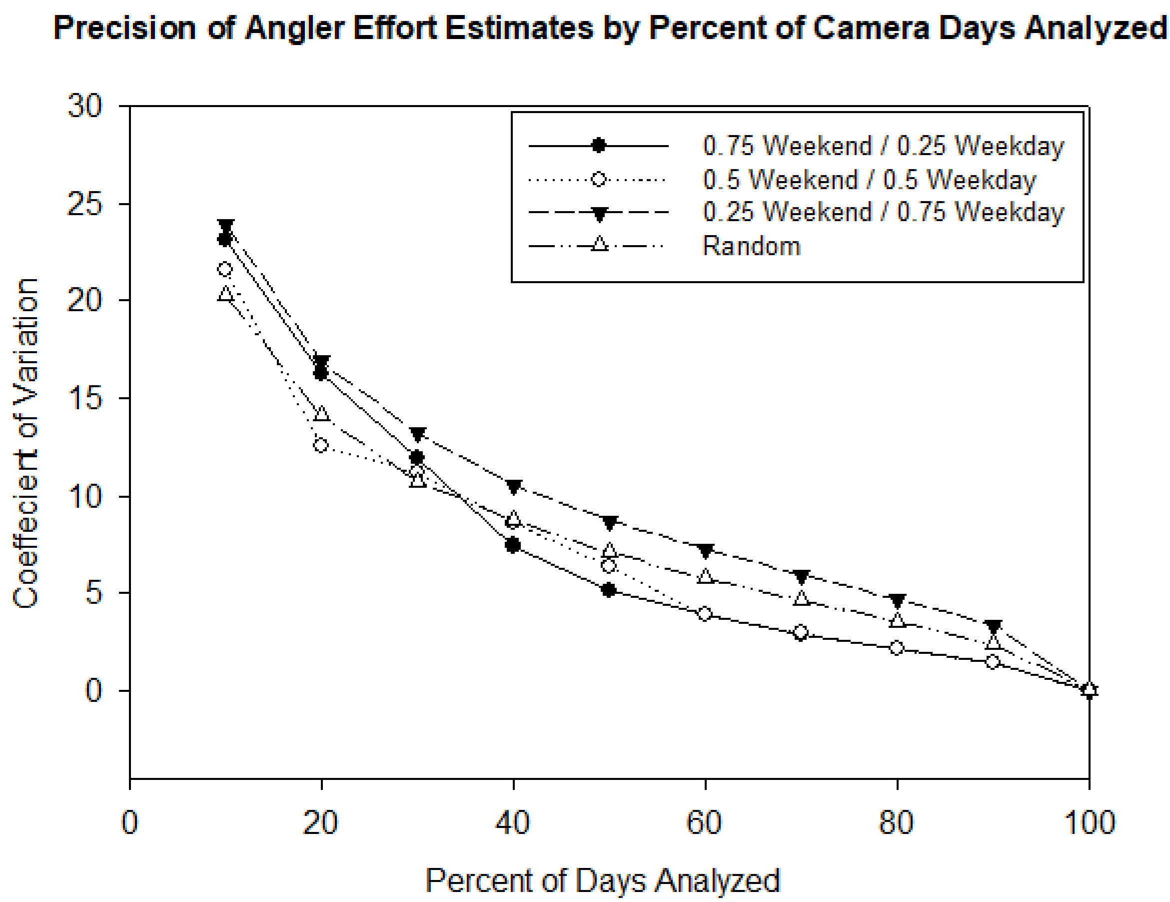

Figure 2.3. Coefficients of variation for angler effort of four trail camera image sampling scenarios in terms of the probabilities of sampling weekday and weekend days.

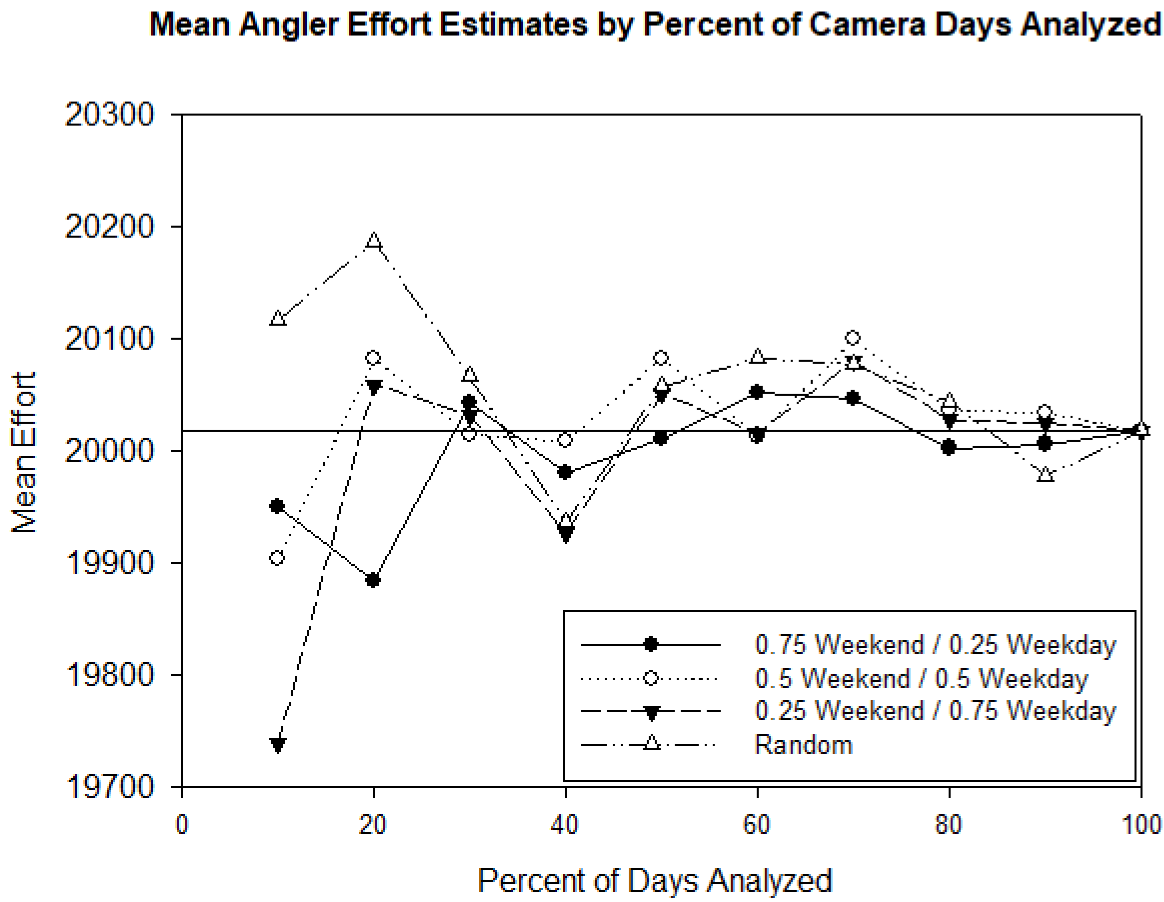

Figure 2.4. Mean angler effort estimates of four trail camera image sampling scenarios in terms of the probabilities of sampling weekday and weekend days. The solid horizontal line corresponds to the number of effort hours from the 2020 angler effort census.

Chapter 3. Estimating the economic damages of fish kills through angler effort estimation and use valuation on three mid-size Alabama Rivers

Introduction

Major fish kills can lead to significant economic losses as well as declines in ecological health (Olmstead 1974; Bryson et al. 1975; Meade 2004; La and Cooke 2011; King 2015). Economic losses relative to fish kills can include loss of fish biomass, investigative and restocking costs, habitat restoration costs, and losses due to decline in angler use and expenditures (Cowx et al. 2004; Nuhfer et al. 2009; Southwick and Loftus 2017). At the national and global scale, fish kills that occur in commercial and recreational fisheries have major economic implications. The US Environmental Protection Agency estimated economic loss resulting from fish kills in the United States to be approximately $240 million annually from 1977 to 1987, or a total of $2.4 billion (Pimentel et al. 1993; La and Cooke 2011). A similar nationwide summary of fish kill losses today would likely produce an even higher figure due to inflation and potential increases in the frequency of fish kills as anthropogenic activity continues to increase due to a growing human population (Olmstead and Cloutman 1974; La and Cooke 2011; Fey et al. 2015; King 2015; Til et al. 2019).

Local and regional economies are often highly reliant on economic input from a nearby fishery or fisheries (Driscoll and Meyers 2014; Plauger 2018; Phelps et al. 2019). Although of lesser economic magnitude than at the national scale, fish kills can have a detrimental effect on local and regional economies (Phelps et al. 2019). An economic assessment of a single fish-kill event on a popular Michigan trout fishery deemed total damages to be $668,236 based on replacement costs, staff salaries for investigating and managing the kill, and user loss (Nuhfer et al. 2009). King (2015) estimated that a single chemical spill in an Ireland river containing brown trout *Salmo trutta* and Atlantic salmon *Salmo salar* caused $240,815 worth of damage, based on replacement costs and user loss values alone. In extreme cases requiring prolonged closure of a fishery, estimates of cost of recovery can balloon into the millions of dollars and take many years for the fishery to return to its pre-kill state (Koehn 2004). While repopulation of the original species assemblage occurs quickly, larger and older individuals, often comprising significant fisheries, are much slower to return (Meade 2004). Furthermore, the efficacy of restocking as a management strategy in responding to fish kills can be limited because fingerling or "catchable" stocked fish may not be immediately available and still need years of growth to replace lost trophy individuals (Bryson et al. 1975). Whether a management agency relies upon immigration of large individuals, restocks new fish, or both, loss of large fish often reduces the appeal of a fishery to anglers for years and, in turn, can lead to drastic decreases in angler use and expenditures for years to come (Teirney and Richardson 1992; Fisher 1997; Meade 2004; Hunt et al. 2019).

Following a fish-kill event in which the party responsible can be identified, state fisheries or pollution control agencies of the water body usually seek financial restitution for economic damages (Bryson et al. 1975; Southwick and Loftus 2017). These fines usually comprise investigative agency staff costs, replacement costs, biological interim loss value, user loss value, and, at times, nonuse value (Southwick and Loftus 2017). All are allowable expenses but not all are always utilized by government entities when levying fines for fish-kill events (King 2015; Southwick and Loftus 2017). Replacement and staff costs are readily used due to the availability of this data, and biological interim loss value, or the quantification of the biological losses to a fishery from the fish kill relative to the pre-kill state, is often used in fish-kill loss valuations (Southwick and Loftus 2017). However, costs due to user loss are more difficult to derive because prior data on the economic value of a water body are necessary in order to estimate damages due to user loss (Connelly and Brown 1991; King 2015; Southwick and Loftus 2017). Lacking user value data, therefore, impedes a state agency from including a user loss metric in their fish-kill loss valuations and, in turn, leads to state agencies underestimating the economic damages of fish kills (Southwick and Loftus 2017).

Two recent fish kills on the Mulberry Fork, Alabama, have shown that fish kill loss assessments in Alabama suffer from this lack. These fish kills resulted in the estimated combined loss of 176,000 fish. This kill and a smaller kill, which saw a total of 508 fish killed, were valued by Alabama Department of Environmental Management (ADEM) and Alabama Department of Conservation and Natural Resources (ADCNR) at $869,464.31 in replacement, investigative, and biological interim loss costs (ADEM 2019 a; Floyd and McKee 2019). Although this is a conservative estimate as it was unlikely that all dead fish were counted, lacking the ability to include user loss value likely far underestimated the actual economic damage. The ADCNR has a good understanding of economic use and angler effort occurring on reservoirs in the state (Hanson et al. 2002; McKee 2013; Lothrop et al. 2014; Gratz 2017; Plauger 2018). Conversely, little information on angler use and economic impact is available for mid-sized rivers in Alabama, as these systems are sampled infrequently. Before ADCNR can integrate user loss metrics into fish-kill valuations on mid-size rivers, data on angler effort, expenditures, and contingent behavior following a fish kill of varying severity are necessary.

Angler Surveys

Traditionally, angler surveys have been used to estimate angler effort, catch, and harvest of a fishery and to evaluate effectiveness of prior management decisions on a waterbody (Pollock et al. 1994). However, the scope of angler surveys was broadened over time to gather socioeconomic information, allowing fisheries managers to better understand their user base and manage resources accordingly (Pollock et al. 1994). This is of obvious importance when considering the dependence of state agency revenue on license sales and angler retention (Long and Melstrom 2016).

Two main creel survey methods are used to sample recreational fisheries: access-point surveys and roving creel surveys (Pollock et al. 1994). Access-point surveys consist of a creel clerk intercepting anglers returning from fishing trips at an access point. Interviewing the angler upon the close of their trip is a strength of the access-point survey because it allows the creel clerk to obtain completed trip information, in lieu of having to supplement the data collected on-site with a follow-up telephone survey or mail survey (Pollock et al. 1994). Access-point surveys are usually a cheaper means of conducting an angler survey because a boat is not necessary and usually fewer employee hours are required. However, it has limitations in many circumstances. For example, a waterbody with many access points or where angling primarily originates from private land would be difficult to sample with access-point surveys alone (Pollock et al. 1994). Under these circumstances, a roving survey is more appropriate.

Roving creel surveys operate under similar principles as the access-point method albeit with a few notable differences. A roving survey requires the creel clerk to actively seek out interviews on the water body, usually via boat (Rohrer 1986; Pollock et al. 1994). The creel clerk covers a predetermined area and interviews anglers while they are still engaged in angling; thus, usually incomplete trip data are collected, in contrast to access-point surveys (Pollock et al. 1994). Therefore, it is often necessary to supplement on-site data collected by roving creel with a follow-up survey to collect completed trip information. Because anglers are interviewed while they are fishing and the probability of encountering them is proportional to the duration of their fishing trip, roving creels are also susceptible to a "length-of-stay" bias, where anglers who fish longer are more likely to be interviewed (Malvestuto 1983; Wade et al. 1991). Similarly, follow-up surveys conducted subsequent to roving surveys are susceptible to recall bias, where anglers are less likely to properly remember the trip in question as duration between the surveys increases (Pollock et al. 1994). Thus, follow-up surveys should be conducted as soon as possible after the initial on-site survey.

Both of these survey methods are usually conducted using a stratified, random design of some form, especially when they take place on large reservoirs or rivers with many access points that may be long distances apart (Malvestuto et al. 1978; Pollock et al. 1994). This study design involves dividing a large sampling area into subareas or sections with individual sampling sites within. Sampling sites are assigned at random based on weighted probabilities of the subarea and access points within each subarea; these probabilities are a product of a known or expected use scale (Pollock et al. 1994). This allows the frequency at which an area is sampled to be determined by the amount of expected angling activity in that area, in hopes of increasing the number of anglers encountered in the study. It is also common to divide the sample day into multiple time periods, usually morning and afternoon, and stratify sampling as described above. Stratification, in general, reduces variability in estimates by accounting for varying spatial and temporal patterns in angling effort (Malvestuto et al. 1978; Pollock et al. 1994; Lockwood 2000).

Another benefit of a roving creel survey is the ability to obtain an instantaneous count of anglers in the sample area. Usually this is accomplished by the creel clerk traversing the entire sample area via boat and counting all active fishing vessels at the start of each survey period (Pollock et al. 1994). The instantaneous count allows for a more accurate estimation of angler effort, catch, and harvest than simply immediately seeking out interviews since some anglers may leave the designated area while the creel clerk is in the midst of interviewing other anglers (Malvestuto et al. 1978). While the instantaneous count is the most commonly used method for obtaining an estimate of angler effort, some systems may require other methods for estimating angler effort, such as heavily forested rivers and streams that may lack the appropriate water depth for navigation of a section.

Over the last decade, there has been an increase in the use of trail cameras as a tool for monitoring angler effort and recreational use in situations where an instantaneous count is not feasible or at least difficult to perform (Smallwood et al. 2012; van Poorten et al. 2015; Hartill et al. 2016; Stahr and Knudsen 2018). Even in systems that could be sampled using traditional methods, trail cameras have been found to provide long term cost savings and passively monitor angling effort while requiring little on-site staff time (Hining and Rash 2016; Eckelbecker 2019; Hartill et al. 2020; Dorsey 2020; Unger et al. 2020). Trail cameras have proven useful in monitoring angler use and effort at times when staff are not working (i.e. nights, holidays, etc.), or when continuous monitoring of angler effort is desired (Olsen and Wagner 2014; Hartill et al. 2016). Olsen and Wagner (2014) found angler effort to be 22% higher at four Texas boat ramps than previously estimated due to the continuous monitoring capabilities of trail cameras. Trail cameras are also useful in weighting access points based on observed angler use and how to allocate sampling effort relative to the spatial distribution of angler effort (Hartill et al. 2016; Eckelbecker 2019; Afrifa-Yamoah et al. 2020).

Trail cameras can be employed using either a time-lapse or motion-detection setting. The appropriate mode of capture is dependent upon the layout and expected level of use of the access points to be monitored. A high use area where a camera can be placed so its field of view encompasses the entire area is best suited for time-lapse captures are best suited, whereas motion-detection capture is a better option for a low use or sporadically used area with a narrow entry and exit point (Hining and Rash 2016; Hartill et al. 2020). Using the wrong image capture method can lead to unnecessary staff hours sorting through photos containing no angling activity (Afrifa-Yamoah et al. 2020). Images are time stamped so that effort can be estimated for any angler who triggered the camera. The time stamp also allows for subsampling of images if so desired or comparison with other effort data gathered while a roving creel is being performed.

One drawback of monitoring angler effort via trail cameras is the vast amount of time needed to sort and analyze images, but this can still be less than the effort expended monitoring effort via more conventional means (Kristine 2012; Smallwood et al. 2012; Hartill et al. 2020). For example, Wise and Fletcher (2013) compared the cost efficiency of multiple instantaneous count methods and found that trail camera boat counts were the most cost-efficient method. Processing time of camera images is likely to decline in the future as more technology on the automation of image analysis is developed (Morrow et al. 2022). Another challenge of using trail cameras is continuity and accounting for missing photos as a result of a stolen or vandalized camera or loss of power (van Poorten et al. 2015; Hartill et al. 2020). Hartill et al. (2020) suggested using image data collected concurrently by other cameras in the study to fill in data gaps caused by a malfunctioning or lost camera. Angler effort is usually dictated by factors such as weather patterns, holidays, days of the week, and seasons; all factors that can be assumed to be consistent among access points in a fishery (van Poorten et al. 2015; Hartill et al. 2020). Thus, data collected across camera stations should be related and be able to predict missing data from an affected station. Overall, proper implementation of trail cameras could effectively change the way in which angler surveys are designed in the future (Wise and Fletcher 2013; Hartill et al. 2016; Eckelbecker 2019; Afrifa-Yamoah et al. 2020).

Combining multiple survey techniques when conducting angler surveys increases accuracy and precision of estimates (Pollock et al. 1994). Common combinations of techniques include roving creel surveys and telephone surveys, access-point surveys and aerial surveys, and access-point surveys and trail camera time-lapse photos (Pollock et al. 1994; Eckelbecker 2019; Hartill et al. 2020). While all of these multi-survey designs have their limitations, many studies have demonstrated their effectiveness in cost efficiency and accuracy of estimates relative to single survey techniques (Pollock et al. 1994; Viega et al. 2010; Smallwood et al. 2012). Trail cameras have been found to be an adequate supplement to measuring angler effort on days when access-point surveys were not conducted (Stahr and Knudson 2018). Estimated effort, harvest, and catch from traditional intercept surveys can be scaled up with effort data collected via non-intercept surveys, allowing for more complete and accurate estimates of effort, harvest, and catch in a more cost-effective manner (Pollock et al. 1994; Smallwood et al. 2012).

Economic Valuation

Often management of large multi-use systems such as southeastern U.S. reservoirs is dictated by competing economic considerations, yet economic value of inland recreational fisheries is rarely known (Pollock et al. 1994; Schorr et al. 1995). Demonstrating the worth of a fishery enables fisheries managers to justify program budgets, seek out further funding, and is a critical prerequisite to economic loss assessments (Pollock et al. 1994). Economic impact studies are usually the methodology of choice to determine potential changes to regional economies due to sudden declines in a fishery (Propst and Gavrilis 1987). Economic impacts are separated into two categories. Expenditures such as gas, food, lodging, fishing equipment, etc. are known as direct impacts; whereas, indirect impacts are income added to the region such as taxes and retail sales of local businesses, resulting from direct impact expenditures (Chen et al. 2003).

The Travel Cost Method (TCM) is commonly used to estimate economic value and impact of a recreational fishery through estimating the travel costs of the anglers using the resource (Weithmann & Haas 1982; Parsons 2003). Because TCM estimates use values based on observed angler behavior, it is commonly used in natural resource damage assessments like fish-kill loss valuations. As a demand-based model, it relates the number of trips taken to the cost per trip. Therefore, it assumes that as trip cost increases, the number of trips taken decreases. Generally, anglers living in close proximity to a fishery spend less per trip, while the price is higher for those living further away (Parsons 2003). Direct expenditures within the local economy are estimated from data gathered from surveys or targeted questionnaires and then tax revenue from these expenditures can be calculated and added to the estimated value of the fishery.

Once the relation between number of trips and travel costs for a fishery is established, a demand curve is created, and a consumer surplus can be calculated (Hunt and Grado 2010). Consumer surplus is an estimate of the benefit consumers gain from consuming goods and services at prices below what they would be willing to pay for those same goods and services (Leftwich and Eckert 1985). This is important because non-market goods like an angler's experience on a river or reservoir has no market price to indicate its value. Therefore, angler willingness-to-pay (WTP) multiplied by the total angler population yields the total consumer surplus or gross economic value of a fishery (McKean and Taylor 2000).

The Contingent Valuation Method (CVM) is a survey-based technique in which a sample of the angling population is asked hypothetical questions concerning changes to a fishery or resource in order to understand how their behavior or WTP would be altered due to the resource change (Binger et al. 1995; Loomis and White 1996; Hunt and Grado 2010). Decreases in spending or use of the resource following the change allow for the quantification of loss due to the change in the fishery. Thus, the CVM is commonly used when estimates of economic loss are a desired product of a study. Survey questions can be designed as open or close-ended based upon angler knowledge and the needs of the specific project. However, a key assumption in the CVM is that the angling population is not only capable and willing to answer the proposed questions, but also has sufficient knowledge of the fishery to allow them to answer questions accurately (Hunt and Grado 2010). This can be manipulated by respondents in certain circumstances, such as in hotly debated fisheries or when resource users have reason to falsify responses to pursue personal agendas (Pollock et al. 1994). Despite this, CVM is a good approach to resource and resource-loss valuation as long as appropriate survey methods are used (Pollock et al. 1994; Loomis and Walsh 1997; Carson 2000).

Study Objectives

Using a roving creel survey, bus-route surveys, trail cameras, TCM, and CVM of fish kills, this study aimed to obtain data on angling effort (trips) use value (cost per trip), and calculation of total expenditures and demand on the Cahaba River, Locust Fork River, and the tailwater of the Coosa River below Jordan Dam. These data will allow ADCNR to more thoroughly value fish kills that occur on Alabama rivers by including angler/user-days lost in their fish kill assessments and also aid in ADCNR policy development concerning fish kills. The study objectives, in specific, were to:

1. Quantify recreational fishing effort on these rivers.
2. Quantify expenditures and consumer surplus values (using TCM) associated with mid-size river recreational anglers and kayakers using these three rivers.
3. Determine tax revenues generated from angling and kayaking activities on these rivers.
4. Use CVM to elicit changes in expenditures and consumer surplus values due to changes in angler and kayaker trips due to fish kills and time of fish population recovery.

Methods

Angler Survey

For details on the study areas please refer to Chapter 1. General Introduction.

Rivers were initially intended to be sampled from February through October, but complications related to Covid-19 resulted in the sampling timeframe being May through October in 2020. This timeframe was chosen because the majority of angling on rivers occur from late spring to early fall, with lower activity outside these seasons (Ebert et al. 2012; Hining and Rash 2016; Fink 2017). Higher precipitation and lower evapotranspiration rates during the winter in the southeastern U.S. often results in high flows and water levels that also decrease effort.

Due to the proximity of the drainages, the Cahaba and Locust Fork rivers were sampled for angler interviews together on two 5-day trips each month in 2020. On each trip, the Cahaba and Locust Fork rivers were sampled on two week days, and one week day respectively; each river was sampled on one weekend day per trip. Due to a trend of low weekday and high weekend angler effort observed on these rivers in 2020, in 2021 the sampling scheme was changed to three three-day trips (Friday through Sunday) each month. Sample days were divided into morning (sunrise to 12:00 PM) and afternoon (1:00 PM to sunset) shifts. When time permitted, one reach was sampled each shift for a total of two reaches sampled per day. The sampling schedule on each river was determined using a stratified random non-uniform sampling design (Malvestuto et al. 1978).

Study sections served as the main stratum and sample reach (segment between access points) was the second stratum. Sample reaches were chosen through weighted probabilities based on expected use at the section and reach scales in 2020 and known probabilities from the trail camera data in 2021 (Table 3.2). Weighting these factors based on expected and known use allowed for the creel clerks to maximize the number of angler interviews by sampling areas with higher angler activity more often (Pollock et al. 1994). The Coosa River below Jordan Dam (hereafter, Jordan tailwater) was sampled four times a month on 2 week days and 2 weekend days each year. While still randomly determined, these sampling trip dates were modified if needed so they were scheduled to occur in between sampling trips on the Cahaba and Locust Fork rivers.

All access points in the section sampled were visited sequentially at the beginning of each shift using a modified bus-route design, starting from one of the access points of the specific reach determined to be sampled (Pollock et al. 1994; Kinloch et al. 1997; Table 3.1). For specifics on sections and reaches (i.e., numbers, lengths, weights, etc.), refer to the Study Areas section in Chapter 1. Creel clerks spent 10 minutes at each access point, counted all vehicles that appeared to be that of an angler or kayaker (i.e., having canoe racks, trailers, or identifying gear present), and attempted to interview any anglers and kayakers that were present. All non-anglers/non-kayakers utilizing the access point for other recreational purposes (i.e. swimming, picnicking, tubing, etc.) were tallied separately. The creel clerks then proceeded to the next access point and repeated this process until all access points within the section were visited.

After the bus-route survey was completed, creel clerks traversed the river between the access points in the designated sample reach using canoes or kayaks and interviewed any individual that was angling or otherwise recreating, whether by wading, kayak, canoe, boat, or on the bank (Pollock et al. 1994; Fink 2017). Anglers contacted during the BRS or roving survey that refused the interview or could not be interviewed for various reasons were simply counted and tallied. The survey schedule was followed under all conditions unless exceptionally high water levels or other inclement weather events made navigation too hazardous. All anglers interviewed were asked the same series of questions (Appendix A.2). Recreational kayakers and rafters were also asked the same questions excluding those questions pertaining directly to angling. Near the close of the interview, participants were asked if they were willing to participate in a more detailed, follow-up telephone interview. Upon receiving their consent to participate, creel clerks collected contact information. In an attempt to minimize recall bias, creel clerks called the participant within 14 days of the on-river survey in order to conduct the telephone interview and gather completed trip data (Tarrant et al. 1993).

Each telephone interview generally took 15-20 minutes to complete. Survey questions were posed to gather information on trip cost, trip frequency, angler effort, species specific catch and harvest, and trip origin. There was also a contingent valuation question pertaining to angler behavior in the event of a hypothetical fish kill in which the degree of severity of the kill was varied randomly from 10% to 90% (Appendix A.2). Anglers were asked how long it would be before they returned to fish following a fish kill. Trip expenditures normally include vehicle and/or boat gas, food and drink, fishing equipment and bait, whitewater equipment, lodging, license fees, and recent canoe/kayak purchases (Chen et al. 2003; Gratz 2017; Plauger 2018). Further information was gathered concerning where these purchases were made to calculate sales tax for the appropriate cities and counties near each study area (Hanson et al. 2002; Plauger 2018). Because the on-river angler surveys only provided incomplete trip data, each interview was augmented and completed with a follow-up telephone interview. Along with providing completed trip information on angler effort hours and catch and harvest, the follow-up interview was designed to gather information such as angler perception of fishing quality, visit length (days), riverfront property ownership, alternate riverine fisheries in which the angler may fish, distance to the alternate site, and general demographic information such as household income and profession (Appendix A.3).

Camera Placement and Image Analysis

Unlike reservoirs and lakes, angling effort on rivers tends to be spread out over a wide geographical area, making estimation of angling effort difficult using traditional methods (Smucker et al. 2011; Volstad et al. 2011). Further, the rivers in this study were too narrow and densely canopied to allow aerial surveys that have been successfully used in other studies (Soupir et al 2006; Smucker et al. 2011; Plauger 2018). Remote trail cameras were installed at each of the 38 access points on the three study rivers to derive a more accurate estimate of angler use and effort (Hining and Rash 2016; Unger et al. 2020). Trail cameras images served as a substitute for the instantaneous count customarily employed on many roving creels done on reservoirs (Hanson et al. 2002; McKee 2013; Gratz 2017; Plauger 2018).

Spypoint Force-Dark (GG Telecom, Victoriaville, Quebec, Canada) trail cameras were mounted approximately 3m up trees near access points in discrete locations that still allowed for a field of view that fully included entry and exit points. All cameras were locked and secured in a steel security box to deter theft and vandalism (Hining and Rash 2016). At access points where theft was a recurring problem, we employed “dummy” cameras (i.e., previously battered security boxes locked and secured to a tree) in conspicuous sites to convey the belief that the camera in the area had already been stolen. All cameras were active from May through December 2020 and February through December 2021. Images were taken using the motion detection function utilizing a 10-second delay between captures. Creel clerks conducted camera maintenance monthly during the on-site survey period to ensure proper functioning, battery life, and to exchange memory cards. At the close of each month, images were downloaded to a computer, sorted by day and month the images were taken, and stored for processing. Image processing occurred from November to January each year.

Only individuals in possession of a fishing rod in at least one image were considered to be anglers, all others were considered non-anglers (kayakers, etc.) An individual angler’s daily bank/wading angling effort was calculated by subtracting the entry image timestamp from the exit image timestamp. This only required image data from one camera. Some boat anglers remained in the vicinity of an access point and therefore effort was calculated similar to bank/wading anglers. However, most traversed between access points, requiring effort to be calculated using images and timestamps from two cameras, upstream and downstream; one in which the angler or angler party can be seen launching and one in which they can be seen taking out.

Although relatively uncommon, missing image data due to theft, vandalism, memory card corruption, flooding, etc. was imputed from neighboring cameras by multiplying a daily angler count from the downstream (take-out) camera by the mean trip length for that reach, according to the suggestions of van Poorten et al (2015) and Hartill et al (2020).

Effort, Catch, and Harvest Rates

Effort, catch, and harvest rates for each river were calculated for black bass anglers and catfish anglers; and all other species targeted were combined into an “Other” category, due to small numbers of interviews for many species. However, Striped Bass *Morone saxatilis* was a popular target species on the Jordan tailwater and was included as a third target species. For the Cahaba and Locust Fork rivers, “Other” species targeted consisted of sunfish *Lepomis* spp. and crappie *Pomoxis negromaculatus*, while it included Skipjack Herring *Alosa chrysochloris*, sunfish, and crappie on the Jordan tailwater. Total angler effort, catch, and harvest rates for each river were also calculated by combining all species. In 2020, total effort was estimated via a census in which every angler and angler hour from the trail camera images were counted and then the totals multiplied by the proportion of angler interviews for each species targeted group. Boat and bank angling hours were counted separately by section and access point and then summed for each section and river to yield total annual effort. Wading anglers were included with bank anglers in both years.

The 2020 census data was used to perform a bootstrap analysis of angler use and effort in order to determine the number of days of images that must be sampled to estimate use and effort with acceptable levels of precision (Chapter 2). From this, we determined sampling 30 – 40% of the available sample days and weighting day type so that all weekend days were sampled produced estimates with CVs between 0.12 and 0.07. Therefore, images from 125 days, 35% of the available 365 days, were analyzed in 2021. All images from weekend days were analyzed, so those daily effort hours were summed for a total annual weekend effort, while 36 random weekdays of the 125 sample days were analyzed. Weekday annual boat effort for each river section was calculated using the following equation:

$$E = \bar{e} / \rho_1 \qquad (1)$$

Where $\bar{e}$ is mean weekday boat angler hours for a section of river, ρ_1 is the probability of a boat angler fishing within that section (Pollock et al. 1994). This value was then multiplied by the total number of weekdays in a year (260), producing an annual weekday boat effort value. Summation of the total weekday boat effort and total weekend boat effort yielded total annual boat effort for each river section, which then summed to produce total annual boat effort for each river. Similar analyses were conducted to find annual bank and kayak effort (refer to Chapter 2).

Catch-per-effort (CPE; fish/h) and harvest-per-effort (HPE; fish/h) were estimated for anglers targeting particular species and other species on each river. Catch includes fish reported by anglers as harvested or released back to the river, whereas harvest was any fish reported as kept or harvested. CPE was the amount of fish caught per angler effort hour. Annual CPE and HPE were estimated by dividing the total catch ($\hat{C}_{species}$) or harvest ($\hat{H}_{species}$) reported during the on-site roving and follow-up telephone surveys by the total angler effort for each target species ($\hat{E}_{species}$) (Pollock et al. 1994).

$$CPE_{species} = \hat{C}_{species} / \hat{E}_{species} \qquad (2)$$

Angler Socioeconomic Characteristics

For each river, socioeconomic data gathered during the on-site roving and follow-up telephone surveys were compared for all target species groups. This included mean party size, mean expenditures, mean roundtrip distance traveled, mean distance to an alternate site, mean years of fishing experience, mean trip quality, mean angler age, mean household income, and mean percent of trips in which fish were harvested.

A one-way Analysis of Variance (ANOVA) with a Tukey's Post-Hoc test was conducted to determine if there were any significant differences between target species groups and expenditures per angler trip. Significance for all statistical tests were set at $P \leq 0.05$.

Expenditures and Tax Revenue

Using the calculations described in Pollock et al. (1994) and Malvestuto et al. (1978), trail camera, telephone survey, and on-site roving survey data were combined in order to estimate trip expenditures and economic impacts of angling and kayaking on these rivers. Each angler and recreational kayaker encountered during the on-site roving creel survey was asked to provide the direct cost of their trip. Anglers and recreational kayakers that participated in the follow-up telephone survey were then asked to break down their total trip expenditures into groups. This included boat gas costs (if any), equipment and bait costs, restaurant costs, grocery costs, and lodging costs. Anglers and kayakers then related each expenditure group to an Alabama county or city. Round trip mileage to and from the river was used to calculate vehicle gas expenditures by multiplying the round trip mileage by 58 cents per mile, in accordance with standard mileage rate (Internal Revenue Service 2022). Although anglers were asked to include gas cost in their estimate of their trip cost, this calculated gas cost, or adjusted gas cost, was used instead since an angler may purchase *X* amount of gas but only use a portion of it on the actual trip and Internal Revenue Service rate includes depreciation.

Daily expenditures were calculated for bass anglers, catfish anglers, other anglers on the Cahaba and Locust Fork rivers and bass anglers, catfish anglers, striped bass anglers, and other anglers on the Coosa River. Daily expenditures were also calculated for recreational kayakers on each river. Anglers who made a day trip and stayed overnight were analyzed together. Expenditures per day for overnight anglers were calculated by dividing the costs in each expenditure group by the number of days the angler was at the river, yielding an average cost per day. Summing all daily costs by target species group and by trip type (day or overnight) resulted in total cost per day of fishing on each river. Average daily expenditures for each target species group were then multiplied by the total number of trips by that species group on each river. The summation of these values yielded the total annual direct expenditures of angling and kayaking on each river.

Tax revenue in Alabama counties from direct expenditure groups were estimated from annual extrapolated expenditures. Alabama counties that gained tax dollars due to angling or kayaking on each river were mainly those that bordered each river. Gas taxes were estimated for vehicle and boat gas by dividing each angler or kayaker’s annual gas cost by the average price per gallon of gas ($2.51) to calculate the total gallons of gas. This was then multiplied by the Alabama state gasoline tax rate ($0.28). When summed, this produced the total amount of tax revenue from gasoline for each river. For groceries, equipment, restaurant food and drink, and lodging, general tax rates were applied. This was the state sales tax rate of 4% along with any corresponding county or city tax rate. A lodging tax was also applied on top of this for hotel stays.

Travel Cost Model

Parsing out trip costs for multipurpose trips in past studies has proven difficult, as trip expenses no longer account for the angling or kayaking experience alone (Loomis 2006; Martinez-Espineira and Amoako-Tuffour 2009). Because of this multipurpose trips do not fit the TCM well (Parsons 2003). Therefore, anglers who did not participate in the follow-up telephone survey or list fishing as their sole purpose for visiting the river were excluded from all travel cost analyses. This was also the case for TCM analyses for recreational kayakers on the three rivers; kayakers needed to designate floating or kayaking as their sole purpose for visiting the site to be included in the analyses. Regression analyses were used to describe the relationship between the total number of angling or kayaking visits over the year and independent variables such as travel costs, household income, years of fishing experience, trip quality, CPE, ethnicity, alternative site distance, opportunity cost of visiting an alternative site, and other sociodemographic variables. Inclusion of these independent variables varied in the models dependent on the river being analyzed, target species group, and model fit. Travel costs, household income, opportunity cost of visiting an alternative site, and years of fishing experience were included throughout most of the models due to the first three variables being requirements for travel cost models and years of experience being a shifter variable that was usually present in the best fit model according to Quasi-Aikaike Information Criterion (QAICc) (Parsons 2003).

Opportunity cost (O_a), or a fraction of an angler or kayaker's wage rate applied to round trip travel time to the river, is an important component of the TCM and was calculated as such:

$$O_a = ((H_a / 2{,}000) * 0.33) * (D_a / 55 \text{ mph}) \quad (3)$$

Where H_a was the annual household income for an angler or kayaker divided by 2000 hours worked per year to estimate an hourly wage rate for each individual. Annual household income (H_a) was asked of anglers or kayakers during the follow-up telephone survey. If an individual did not wish to respond, mean household income of other anglers or kayakers from that particular region was used. 0.33 serves as the value of an individual's per hour travel time and was multiplied by the hourly wage rate. Round-trip distance to an angler or kayaker's respective river (D_a) was divided by 55 mph (average speed to the destination) to estimate travel hours (Prado 2006). A similar equation was applied to estimate opportunity cost of travel to the alternative site (O_{alt}), or the river that an angler or kayaker designated as their likely destination if the original river experienced a fish kill. This was calculated by replacing D_a from the original equation with D_{alt}, which was the roundtrip distance to the alternative site.

Angler or kayaker total expenditures have to be included in the TCM (Parsons 2003), and individual angler or kayaker's travel cost (T_c) was calculated using the following equation:

$$T_c = O_a + X_a \quad (4)$$

Where X_a was the sum of an angler or kayaker's gas, restaurant meals, groceries, equipment, and lodging expenditures and O_a was the opportunity cost of the angler or kayaker's time spent traveling to the site.

Prior to running TCM regressions of angler and kayaker visits, outliers, which constituted less than 10% of the angler data and 13% of the kayaker data, were identified using Cook's Distance Versus Leverage Statitsic tests in R and then removed from the dataset. Count models with Poisson or negative binomial distributions are commonly used to account for overdispersion that often occurs in count sampling when applying the TCM to angler visitation (Parson 2003; Lothrop et al. 2014). However, underdispersion was present following the removal of outliers, likely due to small sample sizes across the rivers and the regional nature of these riverine fisheries. A count model with a negative binomial distribution accounts for overdispersion, or variance that exceeds the mean, but it is not suited for underdispersion. One of the assumptions of Poisson regression models is that variance is equal to the mean. Although underdispersion has often been ignored in the past, modeling underdispersed data with a standard Poisson distribution can lead to underestimated standard errors and inaccurate conclusions (Sellers and Morris 2017). Quasi-Poisson regression models and other variants of the Poisson regression model can account for underdispersion of a dependent variable (Harris et al. 2012; Sellers and Morris 2017; Istiana et al. 2020; Toledo et al. 2022). Thus, all TCMs for angler visitation and kayaker visitation were run using a Quasi-Poisson regression model, following model fit comparisons with a general Poisson regression model. Since quasi-models in program R do not produce a likelihood, model fit was assessed according to the suggestions of Bolker (2017), where models were run twice using a general Poisson and then a quasi-Poisson distribution. The likelihood was extracted from the general Poisson and the dispersion parameter from the quasi-Poisson to compute a quasi-AICc.

Avidity bias or endogenous stratification, a bias that occurs because individuals who make more trips are more likely to be surveyed than those who make less, was corrected by using a non-uniform probability sampling strategy (Table 3.2; Englin and Shonkwiler 1995). All observations were weighted prior to model fitting by multiplying each individual's proportion of the total annual visits by the effort estimated from the trail cameras. Although these riverine fisheries were primarily used by local residents and numbers of anglers unique to the fishery were low, we did not interview anglers or kayakers who had already been interviewed before.

Quantity of angling and kayaking trips (Q) for each river was estimated using the following equation:

$$Q = \beta_0 + \beta_1 T + \beta_2 A + \beta_3 H + \beta_4 V + \varepsilon_i \qquad (5)$$

Where β_0 was the intercept, $\beta_1 T$ was the total travel cost coefficient estimate, $\beta_2 A$ was the opportunity cost of travelling to an alternative site coefficient estimate, $\beta_3 H$ was the angler or kayaker's household income coefficient estimate, $\beta_4 V$ was coefficient estimates for a matrix of sociodemographic variables including years of experience, ethnicity, CPE, perceived trip quality, and other variables, and ε_i was random error in the model (Ojumu et al. 2009). Variables demonstrating collinearity were removed prior to the model selection process and TCM models for each river were selected using a QAICc model selection process. Variables were considered statistically significant at P values ≤ 0.05.

Consumer Surplus

Consumer surplus (CS), or the difference between the price actually paid for an angling or kayaking trip and the maximum WTP, was estimated from the travel cost coefficient from the TCMs (Parsons 2003; Figure 3.1). Consumer surplus per angler visit (*CSv*) was calculated for each river and all angler species targeted groups combined. It was also calculated for bass anglers alone for each river. Due to small sample sizes of telephone surveys of anglers targeting species other than bass, CS was estimated separately for bass anglers and for all anglers targeting all other species. CS per kayaker visit was also calculated for recreational kayakers on each river, and CS for all user groups was calculated using the following equation:

$$CSv = \frac{(\hat{\lambda}/-\hat{\beta}1)}{\hat{\lambda}} = \frac{1}{-\hat{\beta}_1} \quad (6)$$

Where $\hat{\lambda}$ was the estimated number of angler or kayaker trips and $\hat{\beta}_1$ was the estimated travel cost coefficient from the TCM (Parsons 2003).

In order to estimate consumer surplus per trip or day (*CSt*), *CSv* was divided by the average length of visits with the following equation:

$$CSt = \frac{(\hat{\lambda}/-\hat{\beta}1)}{\hat{\lambda}} = \frac{1}{-\hat{\beta}_1} / AT \quad (7)$$

Where $\hat{\lambda}$ was the estimated number of angler or kayaker trips, $\hat{\beta}_1$ was the estimated travel cost coefficient from the TCM, and *AT* was the average visit length of the angler or kayaker (Parson 2003). *CSt* values were aggregated and multiplied by the total number of annual trips on each river to produce total annual consumer surplus per river for both anglers and kayakers. The summation of aggregate consumer surplus values and aggregate direct expenditures yielded total WTP for each activity for each river. Summing angler WTP and kayaker WTP produced total annual WTP for each river.

Contingent Valuation

Each angler and kayaker interviewed during the on-site roving survey was asked a question concerning the amount of time, if any, needed to elapse following a fish kill of *X*% target species lost or, in the case of kayakers *X*% of fish abundance lost, before they would return to the river (Appendix A.2). Percentage of target species lost was varied randomly for each interviewee from 10% to 90% in increments of ten. The mean for each percentage category was calculated separately for angler and kayaker responses (Table 3.3). Multiplying these values by the estimated total number of annual trips for each river produced total number of lost trips for each level of fish kill severity. Trips lost was then multiplied by the average trip cost for each river, yielding total annual direct expenditures lost at each level of fish kill severity. Lost CS was also calculated in this manner. The summation of total annual direct expenditures lost and total annual consumer surplus lost yielded a total angler WTP lost and a total kayaker WTP lost. Finally, summing these economic loss values produced a total WTP lost for each river at the corresponding fish-kill severity categories.

Results

Descriptive Survey Statistics

Cahaba River

Sixty-seven on-site roving surveys were performed on the Cahaba River from May through December 2020 and February through December 2021, resulting in 55 angler parties and 24 recreational kayaker parties being interviewed (Table 3.2). Twenty-five angler parties were interviewed in 2020 and 30 angler parties were interviewed in 2021. Seven kayaker parties were interviewed in 2020 and 17 kayaker parties were interviewed in 2021. Mean angler party size was 1.8 and mean recreational kayaker party size was 2.8.

Bass anglers accounted for 60% of angler parties interviewed across all seasons. Thirteen percent of angler parties interviewed were targeting catfish, 7% sunfish, and 20% anything. Boat angler parties composed 56% of the angler parties interviewed. Most angler interviews came from the upper section (64%); 31% of the angler interviews came from the middle section and 5% from the lower section. Fifty-four percent of the kayaker interviews came from the upper section, 41% came from the middle section, and 4% from the lower section. More angler parties were interviewed in the summer months (50%), followed by spring (32%), and fall (18%) (Table 3.3). Sixty-two percent of the kayaker parties interviewed were interviewed in the summer, 26% in the spring, and the remaining 12% of kayaker party interviews came from the fall.

Jordan Dam Tailwater of the Coosa River

Thirty-five on-site roving surveys were conducted on the Coosa River; 17 sampling events from in 2020 and 18 sampling events from in 2021 (Table 3.2). This resulted in 135 total angler interviews and 21 kayaker interviews. Sixty-nine anglers were interviewed in 2020 and 66 anglers in 2021. Thirteen kayakers were interviewed in 2020 and 8 were interviewed in 2021. Mean angler party size was 1.7 and mean kayaker party size was 3.0.

Anything/Other angler parties comprised the most angler party interviews (37%). Following anything/other angler parties, was bass (23%), catfish (22%), striped bass (12%), and sunfish (5%) (Table 3.3). 67% of angling parties interviewed were fishing from the bank or wading with the remaining 33% made up by boat angling parties. More angler parties were interviewed during the summer (45%) months than in spring (28%) and fall (27%). Recreational kayaking interviews were highest in the summer (67%), while 24% of the interviews came from the spring and 9% from the fall.

Locust Fork River

Forty-three on-site roving surveys were conducted on the Locust Fork River; 19 in 2020 and 24 in 2021. Forty-one angler interviews and 16 kayaker interviews resulted from these surveys (Table 3.2). Eleven anglers and 4 recreational kayakers were interviewed in the 2020 field season and 30 anglers and 12 kayakers in the 2021 field season. Mean angler party size was 2.1 and mean kayaker party size was 5.0.

Interviews from black bass and catfish anglers accounted for 54% and 22% of the total interviews, respectively. The remainder of angler parties were either targeting anything (22%) or sunfish (2%). All 41 angler interviews occurred in the upper section of the Locust Fork River (Table 3.3). Despite sampling the lower section on six occasions, no angling or kayaker parties were encountered. Of the 41 angler party interviews, 68% were bank/wade fishing and 32% were fishing from boats (i.e., kayaks or canoes). Forty-four percent of the angler party interviews occurred during the spring, followed by summer (31%) and fall (24%). Fifty percent of kayaker interviews occurred in the spring. Of the remaining kayaker party interviews, 31% occurred in the summer and 19% in the fall.

Effort, Catch, and Harvest Rates

Cahaba River

Estimated total angling effort in 2021, boat and bank angling hours combined on the Cahaba River, was 23,057 h (95% CI = ± 2,038 h), over an estimated 6,202 angler trips (Table 3.4). Most of the effort came from boat angling (17,963 h; 95% CI = ± 1,570 h), whereas bank/wade angling accounted for 5,094 h (95% CI = ± 468 h) of the total angling effort. Black bass anglers fished an estimated 13,373 h (95% CI = ± 1,183 h), by far the most hours fished by any angler group on the Cahaba River (Table 3.4). Most black bass angling effort was by boat anglers, with an estimated 10,430 h (95% CI = ± 923 h), compared to only 2,942 h (95% CI = ± 260 h) by bank anglers. Black bass anglers fished for an average of 4 h per trip and took an estimated 3,343 trips in 2021. Mean CPE for bass anglers was 1.5 fish/h, resulting in an estimated 20,059 bass caught. Bass harvest was rare on the Cahaba River, as none of the black bass anglers interviewed harvested bass on their trip and all bass anglers reported having released their catch.

Catfish anglers fished an estimated 2,766 h (95% CI = ± 244 h) on an estimated 553 angler trips in 2021 (Table 3.4). On average, catfish anglers fished for 5 h per trip. As with black bass, catfish angling generally occurred using a boat (2,158 h; 95% CI = 190 h), with only an estimated 608 h (95% CI = ± 53 h) occurring from the bank. Catfish angler CPE was 0.9 fish/h and HPE was 0.7 fish/h for an estimated total of 1,932 catfish harvested in 2021.

Anglers targeting all other species fished for an estimated 6,917 h (95% = ± 611 h) on an estimated 2,305 trips (Table 3.4). Boat angling effort (5,395 h; 95% CI = 476 h) was 3.5 times higher than bank angling effort (1,521 h; 95% CI = 134 h). Anglers in this group had a mean CPE of 1.7 fish/h and HPE of 0.2 fish/h for an estimated annual 2021 total of 1,384 fish harvested.

Recreational kayakers spent on average 3.1 h per trip with an estimated total effort of 25,869 h (95% CI = ± 2,346 h) on the Cahaba River in 2021. This occurred over an estimated 8,623 trips.

Jordan Dam Tailwater of the Coosa River

Estimated total angling effort in 2021, boat and bank angling combined, in the Coosa River was 16,504 h (95% CI = ± 3,109 h), over an estimated 3,936 trips (Table 3.4). More than two-thirds of this effort was from boat angling (11,161 h; 95% CI = ± 2334 h), with only 5,343 h (95% CI = ± 775 h) occurring from the bank. Unlike the other two rivers, black bass angler hours did not account for the majority of angling effort on the Coosa River. This angler group fished for an estimated 3,795 h (95% CI = ± 715 h), averaging 5 h/trip over an estimated 759 trips (Table 3.4). Most of these angler hours (2,543; 95% CI = ± 479 h) of these angler hours were by boat, with bank angling accounting for the remaining 1,252 h (95% CI = ± 235 h). Mean black bass angler CPE was 1.3 fish/h and HPE was 0.09 fish/h for an estimated 4,933 bass caught and an estimated 341 bass harvested in 2021.

Over an estimated 907 trips, catfish anglers fished an estimated 3,632 h (95% CI = ± 638 h) in 2021. Anglers fishing from boats accounted for an estimated 2,434 h (95% CI = ± 458 h), whereas bank anglers fished for an estimated 1198 h (95% CI = ± 225 h) (Table 3.4). Mean catfish angler CPE was 0.8 fish/h and HPE was 0.4 fish/h, resulting in an estimated 1,452 catfish harvested in 2021.

Striped Bass anglers (i.e., hybrid Striped Bass and Striped Bass) fished an estimated 1,981 h (95% CI = ± 373 h) over an estimated 495 trips (Table 3.4). Boat anglers fished for an estimated 1,326 h (95% CI = ± 249 h) and bank anglers fished for an estimated 653 h (95% CI = ± 123). Mean Striped Bass angler CPE was 1.8 fish/h and HPE was 0.6 fish/h for an estimated total of 1,188 striped bass harvested in 2021.

The majority of angling effort on the Coosa River tailrace came from anglers targeting other species, who fished for an estimated 7,096 h (95% CI = ± 1,336 h) in 2021; 4,754 h (95% CI = ± 895 h) came from boat angling and 2,341 h (95% CI = ± 1,336 h) from bank angling (Table 3.4). Average daily trip length was 4 h and other anglers made an estimated 1,774 trips to the Coosa River in 2021. These anglers had a mean CPE of 1.6 fish/h and a HPE of 1.2 fish/h for an estimated total of 8,052 fish of other species harvested.

Recreational kayakers spent an estimated 19,597 h (95% CI = ± 7,972 h) on the Coosa River tailrace over 6,532 trips in 2021. Mean trip length was 3.2 h.

Locust Fork River

Estimated annual angling effort on the Locust Fork River was 10,731 h (95% CI = ± 1,408 h) in 2021, with 8,494 h (95% CI = ± 999) of that coming from boat angling and 2,237 h (95% CI = ± 409) from bank angling (Table 3.4). Anglers took an estimated 3,102 total trips to the Locust Fork River in 2021. Black bass angling accounted for nearly half of the annual effort (5,689 h; 95% CI = ± 746 h; Table 3.4). Anglers targeting black bass from boats fished 4,495 h (95% CI = ± 589) and those from the bank or wading fished for 1,194 h (95% CI = ± 156). Average black bass angler trip length was 4 h, resulting in 1,421 angling trips. Mean black bass angler CPE was the highest of all rivers at 2.5 fish/h but HPE was only 0.08 fish/h for an estimated total of 455 bass harvested.

Catfish anglers fished an estimated 2,360 h (95% CI = ± 309 h) over an estimated 786 trips (Table 3.4). Boat anglers accounted for most of this effort (1,864 h; 95% CI = ± 244 h) with bank anglers only estimated 495 h (95% CI = ± 65 h) in 2021. Mean catfish angler trip length was 3 h. Mean catfish angler CPE was 0.8 fish/h and HPE was 0.7 fish/h for an estimated total of 1,652 catfish harvested in 2021.

Anglers targeting other species on the Locust Fork River fished for an estimated 2,682 h (95% CI = ± 352 h) over an estimated 894 trips (Table 3.4). The most effort came from boat angling at 2,119 h (95% CI = ± 278 h), with bank/wading anglers only fishing for an estimated 563 h (95% CI = 73 h). Mean trip length for anglers targeting other species was 3 h. Mean other angler CPE was 1.7 fish/h and HPE was 0.3 fish/h for an estimated total of 804 other species harvested.

Recreational kayakers spent 7,868 h (95% CI = ± 1,376 h) on the Locust Fork River over an estimated 2,622 trips in 2021. Mean trip length was 3.3 h.

Angler Socioeconomic Characteristics

Cahaba River

Mean party size across all angling species target groups was 1.8 anglers per party and party size was similar among target groups (F=1.812, df=31, P=0.18) (Table 3.5). Mean angler party size for those targeting black bass, catfish, and other was 1.8, 2.3, and 1.4, respectively. Mean expenditures per angler trip for all anglers was $115 (Table 3.5). Mean expenditures by anglers for target species were $146 for black bass, $106 for catfish, and $25 for other species, but these were similar across groups (F=0.711, df=50, P=0.499). Mean party size of the kayakers interviewed was 2.8 kayakers per trip who spent on average $169 on a trip (Table 3.6).

All 77 anglers and recreational kayakers surveyed on the Cahaba River were residents of Alabama, and 56 resided in counties contiguous to the river (Bibb, Jefferson, or Shelby counties) (Figure 3.2). In total, anglers and kayakers surveyed were from 11 Alabama counties.

Average round trip distance for anglers across target species was 58 km. Bass anglers, on average, traveled the farthest roundtrip distance (73 km) and sunfish anglers traveled the least (19 km). Catfish anglers traveled an average roundtrip distance of 55 km per trip and anglers who responded as targeting anything traveled 32 km on average (Table 3.7). Kayakers traveled an average of 72 km roundtrip. Across all target species groups, average roundtrip distance to an alternative site was 83 km. Anglers cited various tributaries of the Cahaba River, Mulberry Fork River, and Locust Fork River as alternative sites most frequently. Black bass angler alternative site roundtrip distance was the furthest at 94 km and anything anglers alternative distance the least at 57 km (Table 3.7). Catfish angler alternative site distance was 65 kilometers and sunfish angler alternative site distance was 91 km. Roundtrip distance to the alternative site for kayakers was 53 km.

The average angler surveyed fished 28 days per year. Black bass anglers fished an average of 22 days a year, catfish anglers 18 days a year, sunfish anglers 30 days a year, and anglers who responded as targeting anything fished 35 days per year (Table 3.7). Conversely, kayakers only visited the Cahaba River eight times per year. There were very few overnight stays on the Cahaba River; mean visit length across target species groups was 1.1 per trip. Of the two angler parties that did stay overnight, one stayed in a hotel and the other camped along the river.

Across all anglers, average age was 37 years old. Average age of bass anglers was 34, catfish anglers was 33, and sunfish anglers was 27, but the average age of anglers targeting other species was 60 years old. Angler had been fishing for 26 years on average. Black bass anglers, on average, had 22 years of fishing experience, catfish anglers 26, sunfish anglers 21, and anglers targeting other species 44 (Table 3.7). Kayakers were, on average, 32 years old and had an average of 24 years of experience floating rivers. Mean household income for all anglers was $82,490. Black bass anglers had the highest annual household income at $85,062 and catfish anglers the lowest at $54,600. Average sunfish angler household income was $60,666 and anything angler household income was $80,181. Mean household income of kayakers was $72,625.

Female anglers made up only 2% of the anglers who participated in the telephone survey. The vast majority (98%) were male anglers. African Americans comprised 8% of all anglers interviewed; the remainder were Caucasians. All kayakers surveyed on the Cahaba River were Caucasian. The vast majority of the kayakers that participated in the telephone interview were male (77%).

Jordan Dam Tailwater of the Coosa River

Mean party size ranged from 1.3 to 1.8 across target species groups and was 1.5 anglers per party across all groups (Table 3.5). Mean party size was similar across target species groups (F=1.4, df=53, P=0.253). Mean party size for kayakers was 3.0. Mean expenditures ranged from $16 to $73 across target species groups, but was similar among groups (F=1.899, df=53, P=0.141). (Table 3.5). Conversely, kayakers on the Coosa River spent an average $118 on each trip (Table 3.6).

Of the 156 anglers and kayakers surveyed, all resided in Alabama. Most (134) of these were from counties containing the Coosa River (i.e., Montgomery and Elmore counties). The remainder lived in Autauga, Bibb, Etowah, Fulton, Jefferson, Lee, Mobile, Talladega, and Tallapoosa counties (Figure 3.2).

Mean roundtrip distance traveled for all anglers was 73 km and ranged from 62 km (catfish anglers) to 123 km (sunfish anglers). Sunfish anglers traveled the furthest distance on average (123 km), while catfish anglers traveled the least distance for a trip (62 km). Second longest average roundtrip was made by anything anglers (72 km) and striped bass anglers drove an average 65 km per trip. Average roundtrip distance for Coosa River kayakers was 117 km and their mean alternative site distance 55 km. The average alternative site roundtrip distance for anglers was 47 km. The Tallapoosa and Alabama rivers were the most common alternative sites. Roundtrip distance to the alternative site was highest for bass anglers (64 km) and lowest for sunfish anglers (31 km). Average roundtrip distance driven by Coosa River kayakers was 117 km and their mean alternative site distance was 55 km.

Mean number of days fished per year for all anglers was 37 and ranged from 9 to 38 among target species groups (Table 3.7). Kayakers, on average, made 5 trips a year on the Coosa River. There were no overnight stays reported by any party surveyed using the Coosa River for recreational purposes. Mean age and years of fishing experience for all anglers was 43 and 27, respectively. Mean age of bass, catfish, and sunfish anglers was 41 years old; and black bass anglers had fished for 29 years, catfish anglers for 26, and sunfish anglers for 25 years. Anglers targeting other species averaged 45 years of age and had 26 years of fishing experience. Mean age and years of fishing experience for Striped Bass anglers were 47 years and 25 years, respectively (Table 3.7). Conversely, the average kayaker surveyed had recreated for 13 years and was 34 years old.

Mean household income for all anglers was $75,014 and varied from $63,857 (sunfish anglers) to $85,806 (black bass anglers) (Table 3.7). Kayakers had a mean annual household income of $75,512. Ninety-one percent of the anglers surveyed were males, whereas female anglers made up the remaining 9%. The racial demographics of the Coosa River were far more diverse than the other two rivers. Fifty-one percent of the anglers interviewed identified as African American, 39% identified as Caucasian, 7% Hispanic, and the remaining 3% of anglers identified as Asian. Of the kayakers interviewed on the Coosa River, 75% were male and 25% female. All kayakers surveyed were Caucasian.

Locust Fork River

Mean party size of all anglers on the Locust Fork River was 2.1, and ranged from 1.9 to 2.8 across target species groups, but was similar across groups (F=0.881, df=25, P=0.427; Table 3.5). Mean expenditures of all anglers was $81 per trip and ranged from $11 to $231 per trip, but were similar across groups (F=1.14, df=25, P=0.336). Mean kayaker party size was 5.0, higher than the other two rivers in the study. Kayakers spent an average $157 on each trip and they spent an average $157 per trip (Table 3.6).

Of the 57 angler and kayaker parties surveyed on the Locust Fork River, all anglers and kayakers interviewed resided in the state of Alabama. Anglers and kayakers from Blount (28), Jefferson (12), and Cullman (6) counties, all of which the Locust Fork River flows through, comprised the majority of the interviews. Otherwise, anglers and kayakers traveled to the Locust Fork River from Calhoun, Etowah, Lee, Limestone, Madison, Marshall, Shelby, and St. Clair counties (Figure 3.2).

Average roundtrip distance traveled by all anglers visiting the Locust Fork River was 59 km. At 81 km, bass anglers averaged a longer roundtrip distance than anything (31 km) or catfish anglers (38 km). Roundtrip distance of the alternate site was also the largest for bass anglers (75 km) compared to the other two angler groups. Catfish angler mean roundtrip distance was 44 km and anything angler mean roundtrip distance was 54 km. Average alternate site distance for all anglers was 62 km (Table 3.7). Kayakers traveled 64 km roundtrip to float the Locust Fork River and an average 39 km to float their alternate site.

Mean number of days fished per year was 44 for all anglers. Bass anglers averaged 62 days fished per year, far more than the other two angler groups surveyed. Catfish anglers fished an average 40 days each year and anything anglers only 8 days per year. Mean kayaker trips per year was 16. Overnight stays were uncommon for both anglers and kayakers on the Locust Fork River. Mean visit length per trip was 1.2 for anglers and 1.1 for kayakers. Those that did overnight on or near the river either camped along the river, stayed in a hotel or at a friend’s home nearby.

Locust Fork River anglers were on average 39 years old and had fished for 26 years. Catfish angler age was on average 36, anything anglers (40), and bass angler mean age was 39. Bass anglers had 25 years of fishing experience, catfish anglers had fished for 22 years, and anything anglers 29 years (Table 3.7). Mean age of kayakers was 41 and they averaged 19 years of experience floating rivers.

Mean annual household income for catfish anglers was lowest ($73,000) and highest for bass anglers ($80,363). Anything angler’s average annual household income ($78,777) was right below the mean for all anglers ($79,073) (Table 3.7). Locust Fork River kayaker mean annual household income was comparable to that of the angler groups at $79,666.

12% of the anglers that participated in the telephone survey were female and 88% male. Anglers interviewed were 97% Caucasian and the remaining 3% identified as Hispanic. All kayakers that participated in the telephone survey were Caucasian and primarily males (92%). Female kayakers made up 8% of the kayakers interviewed.

Expenditures and Tax Revenue

Cahaba River

Total extrapolated direct expenditures from angling trips on the Cahaba River amounted to $725,634 in 2021. Anglers spent more on equipment (61%) and vehicle gas (20%) than anything else. 14% of the direct expenditures came from grocery expenses and 3% from restaurant meals. As anglers who participated in the survey did not take many overnight trips, lodging expenses accounted for less than 1% of the extrapolated direct expenditures (Table 3.8).

All of the anglers interviewed resided in Alabama, nearly all of these expenditures occurred within the state.

Over an estimated 8,623 trips, extrapolated total kayaker direct expenditures amounted to $1,457,289 in 2021. Fuel expenditures (40%) and grocery expenses (42%) accounted for most of the direct kayaker expenditures, followed by 9% each from lodging and restaurant meals (Table 3.9). With angling direct expenditures combined with kayaker expenditures, the total direct expenditures accrued on the Cahaba River in 2021 was an estimated $2.1 million.

Total Alabama state tax revenue from these estimated expenditures was $261,840, $63,859 from angling expenditures and $197,981 from kayaking expenditures. Tax revenue generated from sales related to angling came primarily from vehicle gas (64%). 36% of the tax revenue came from general sales. Of the general sales, taxes from equipment sales (77%) accounted for the majority, while tax revenue from grocery sales (18%), restaurant sales (4%), and lodging (<1%) made up the rest (Table 3.10). Fuel sales brought in the most tax revenue (82%) from kayakers too, while tax revenue from general sales accounted for 28% of the revenue. More specifically, the sources of tax revenue were as follows: grocery sales (70%), restaurant sales (16%), and lodging sales (14%) (Table 3.11).

Jordan Dam Tailwater of the Coosa River

Total extrapolated direct expenditures from angling on the Coosa River in 2021 amounted to $200,737. Nearly half of this came from vehicle gas expenditures (46%). Equipment expenditures accounted for 34%, and the rest came from grocery (13%) and restaurant (7%) expenditures (Table 3.8). No surveyed anglers reported staying overnight.

Kayaker expenditures, in total, amounted to $770,776 in 2021. Grocery (36%), vehicle gas (31%), and equipment (29%) expenditures accounted for the majority of Coosa River kayaker direct expenditures (Table 3.9). The remaining 4% came from restaurant expenditures. Like anglers on the Coosa River, no surveyed kayakers reported staying overnight, so there were no lodging costs related to kayaking trips. The total summation of extrapolated direct expenditures related to angling and kayaking was $971,513 in 2021.

Expenditures related to angling generated $30,590 and kayaking $88,016 in tax revenue, totaling $118,606 in state taxes accrued from the estimated direct expenditures described above. 86% of the tax revenue from angling expenditures was from vehicle gas sales. Of the tax revenue generated from general sales related to angling, equipment sales accounted for 63%, followed by grocery (25%) and restaurant sales (12%). Vehicle gas made up most of the tax revenue (75%) generated from sales related to kayaking, while tax revenue from general sales the remaining 25%. A breakdown of the tax revenue from general sales by category was as follows: grocery (51%), equipment (42%), and restaurant (6%).

Locust Fork River

In total, annual extrapolated direct expenditures from angling on the Locust Fork River was slightly more than the Coosa River and far less than the Cahaba River at $272, 976. Accounting for 51% of total extrapolated expenditures, far more was spent on equipment than the other categories. Vehicle gas (23%) and grocery (21%) expenditures also made up a large portion of the total. Restaurant (3%) and lodging (2%) expenditures accounted for the rest of the total extrapolated expenditures related to angling (Table 3.8).

As with the other two rivers, total extrapolated kayaker expenditures was higher than total angling expenditures on the Locust Fork River. Kayakers spent an estimated $411,654 in direct expenditures in 2021. Kayakers rarely stayed overnight, therefore lodging made up less than 1% of this total, while vehicle gas (39%) and grocery (29%) expenditures accounted for the vast majority of the total. The rest of the expenditures came from equipment (21%) and restaurant meals (10%) (Table 3.9). Angling and kayaking, together, was worth $684,630 in extrapolated direct expenditures in 2021.

Total tax revenue accumulated from angling and kayaking expenditures on the Locust Fork River was $81,079. Tax revenue generated from sales related to angling was $26,357 and $54,772 from sales related to kayaking. Of that from angling, 67% came from vehicle gas sales and 33% from other general sales. Of the tax revenue generated from general sales, grocery (27%) and equipment (66%) sales made up the majority, the remaining portion came from restaurant (4%) and lodging (3%) (Table 3.10). 81% of the tax revenue related to kayaking trips came from vehicle gas sales and 19% from general sales. Tax revenue from equipment (35%) and grocery (47%) sales made up most of the tax revenue from general sales. The rest came from restaurant (17%) and lodging (<1%) sales (Table 3.11).

Travel Cost Model and Consumer Surplus

Cahaba River

Due to TCM requirements, all models included travel cost, alternative site opportunity cost, and household income. The best-fit model used to explain visitation for all anglers on the Cahaba River included CPE also (Table 3.12). Although CPE and household income were not statistically significant in explaining angler visitation, an increase in these variables would result in an increase in angler visitation. Variables that were statistically significant in explaining visitation were travel cost and opportunity cost of travel to the alternative site. An increase in alternative site opportunity cost would result in an increase in angler visitation. Travel cost had a negative influence on angler visitation; as travel cost increased, angler visitation decreased. Consumer surplus for all Cahaba River anglers was $204 per angler visit. Dividing this value by the average visit length (1.1 days), yielded the consumer surplus per angler trip ($185). The summation of this value with the estimated direct expenditures per trip yielded angler WTP per trip ($302). Total aggregated angler WTP was $1,873,004, $725,634 from aggregated direct angler expenditures and $1,147,370 in aggregated angler consumer surplus.

The bass angler TCM variables included travel cost, opportunity cost of travel to the alternative site, household income, bass CPE, and years of fishing experience (Appendix A.5). Although this was the best-fit model, none of the variables were statistically significant in explaining bass angler visitation to the Cahaba River. It's likely that the small sample size of Cahaba River bass anglers (n=24) that participated in the follow-up telephone survey influenced this. Years of fishing experience, bass CPE, and household income all positively influenced bass angler visitation, while increases in travel cost and opportunity cost of travel to the alternative site resulted in decreased bass angler visitation. Dividing consumer surplus per visit ($245) by the average visit length (1.2 days), provided consumer surplus per bass angler trip ($204). Combining this value with the average bass angler expenditures per trip ($146) produced a bass angler WTP of $350. Therefore, consumer surplus made up 58% of bass angler WTP.

Variables included in the TCM regression for other species anglers included travel cost, opportunity cost of travel to the alternative site, household income, and years of fishing experience (Appendix A.6). None of the variables were statistically significant in explaining other species angler visitation at the $P < 0.05$ confidence level. It should be noted that sample size of other anglers who participated in the follow-up telephone interview was small (n=11). Years of experience and household income positively influenced other species angler visitation, while other species angler visitation decreased as travel cost increased. After dividing consumer surplus per angler visit by average visit length (1.1 days), other species angler consumer surplus per trip was $161. Other species angler WTP was $186, therefore consumer surplus made up 86% of other species angler WTP.

Variables included in the TCM to explain kayaker visitation on the Cahaba River were travel cost, opportunity cost of travel to the alternative site, and household income (Table 3.13). In the best-fit model, the variables were only statistically significant in explaining kayaker visitation at the $P < 0.10$ level. Visitation would increase with household income and decrease as opportunity cost of travel to the alternative site increased. Kayaker visitation would also decrease as travel cost to the Cahaba River increased. Consumer surplus per visit was $287 per visit and $239 per trip. Consumer surplus per trip combined with average kayaker expenditures ($169), yielded a kayaker WTP of $408 per trip. Aggregate consumer surplus of all Cahaba River kayakers was $2,060,897. This combined with aggregate kayaker expenditures yields an aggregate kayaker WTP of $3,518,186, the highest of any of the rivers in the study.

Jordan Dam Tailwater of the Coosa River

Variables included in the TCM regression for all anglers on the Coosa River were travel cost, opportunity cost of travel to the alternate site, household income, years of fishing experience, and ethnicity (Table 3.14). None of the variables were statistically significant in explaining angler visitation at the $P < 0.05$ level, however an increase in household income led to an increase in angler visitation. Years of fishing experience had a negative influence on the number of visits an angler made. Visitation decreased with the probability of not being Caucasian. Visitation also decreased with increased travel cost. Consumer surplus per angler trip was $246. Anglers averaged $51 in direct expenditures per trip, therefore consumer surplus made up 82% of an angler's WTP per trip. Over 3,936 trips, aggregate consumer surplus for all anglers was $968,256. This combined with the aggregate expenditures from anglers on the Coosa River provided an aggregate angler WTP of $1,168,992.

The best-fit model for Coosa River bass anglers included the following variables: travel cost, opportunity cost of travel to the alternate site, household income, years of fishing experience, and ethnicity (Appendix A.7). Variables that were statistically significant in explaining bass angler visitation were years of fishing experience and travel cost; an increase in both led to a decrease in visits. As opportunity cost to the alternative site and household income increased, visitation increased. Visitation decreased with the probability of not being Caucasian. Bass anglers had a consumer surplus per trip of $121, 62% of angler WTP per trip. Coosa River bass anglers spent an average $73 per trip, therefore bass angler WTP per trip was $194.

None of the variables were statistically significant in the other species TCM model (Appendix A.8). Other species anglers included people fishing for striped bass, sunfish, catfish, skipjack herring, and anything. The independent variables in this model were travel cost, years of experience, opportunity cost of travel to the alternate site, and household income. Visitation decreased as travel cost, household income, and years of fishing experience increased. Consumer surplus per trip for other species anglers was $164 and their average trip expenditures $41, resulting in a WTP per trip value of $205. Consumer surplus represented 80% of other species angler WTP per trip.

The sample size of Coosa River kayakers that participated in the follow-up telephone survey was small (n=11), as with the other kayaker TCMs. As such this model, had low explanatory power also. All of the variables required by TCM were included in the model along with years of floating experience (Table 3.15). Years of floating experience and opportunity cost of travel to the alternate site both positively influenced visitation, while increases in household income and travel cost led to decreases in kayaker visits. Coosa River kayaker consumer surplus per trip was $228 and average expenditures per trip was $118, therefore kayaker WTP per trip was $346. Aggregate consumer surplus across 6,532 kayaking trips was $1,489,296. This combined with aggregate kayaker expenditures ($770,776) yielded an aggregate kayaker WTP of $2,260,072.

Locust Fork River

As with the other rivers, all models included travel cost, alternative site opportunity cost, and household income, as these variables are requirements of the TCM (Parsons 2003). The best-fit model used to explain angler visitation for all anglers on the Locust Fork River also included years of angling experience and trip quality. Higher angler trip quality led to an increase in angler visitation, while angler visitation decreased as an angler's years of fishing experience increased (Table 3.16). Although not statistically significant at any confidence level, as expected angler visitation increased with higher income and decreased as opportunity cost of the alternative site increased. As economic theory surrounding TCMs suggests, the number of trips declined with an increase in travel cost. Although this was statistically significant at the $P < 0.10$, it was not at $P < 0.05$ level (Table 3.16). Consumer surplus per angler visit was $153. This was divided by mean visit length (1.21 days) to yield the consumer surplus per trip value, which was $126 (Table 3.16). The summation of travel cost per day of all anglers ($88) and consumer surplus per trip ($126) yielded angler WTP per trip ($214). Therefore, consumer surplus accounted for 59% of angler WTP. Aggregate consumer surplus of all Locust Fork River anglers was $390,852. Adding this aggregate value to aggregate angler direct expenditures resulted in a total aggregate angler WTP of $663,828.

Despite the small sample size, a TCM regression was run for bass anglers on the Locust Fork River. Independent variables included in the model were travel cost, opportunity cost to the alternative site, household income, years of fishing experience, and trip quality (Appendix A.9). Although neither were statistically significant in explaining bass angler visitation, bass angler visitation decreased with an increase in opportunity cost of the alternative site and increased with higher household. With a parameter estimate of 0.39614 ($P = 0.0217$), trip quality was statistically significant in explaining angler visitation. Bass anglers with more years of fishing experience, made less visits to the Locust Fork River. Bass had a consumer surplus per angler visit of $126 and a consumer surplus per angler trip of $105. Total bass angler WTP was $238, therefore bass angler consumer surplus accounted for 44% of total bass angler WTP.

The TCM for other species anglers included all of the required variables and years of fishing experience and trip quality. Other species anglers included those fishing for catfish, sunfish, or anything on the Locust Fork River. None of the parameter estimates were statistically significant in explaining other species angler visitation, likely due to small sample size. Consumer surplus per angler visit was $106 and consumer surplus per angler trip was $88. Total angler WTP was $114. Other species consumer surplus per trip made up 77% of other species angler WTP.

Variables included in the TCM model for kayakers on the Locust Fork River were travel cost, opportunity cost, household income, and years of experience (Table 3.17). None of the parameter estimates were statistically significant in explaining kayaker visitation. An increase in years of floating experience and household income resulted in an increase in kayaker visits. Consumer surplus per visit was $284. This converted to consumer surplus per trip was $246. Kayaker WTP was $403 per trip. Aggregate kayaker consumer surplus on the Locust Fork River was $645,012. This summed with the total extrapolated kayaker expenditures yielded an aggregate kayaker WTP of $1,056,739.

Contingent Valuation and Economic Loss

At the lowest percent target species lost (10%), mean angler return time was 0.09 years, and mean kayaker return time was 0.35 years. For anglers, there was a commensurate increase in return time with increase in the percentage of target species lost. At 50% target species lost, mean angler return time was 1.15 years, and at 90% target species lost, mean angler return time increased to 2.9 years (Table 3.18). Although mean kayaker return time also increased with the severity of fish kill, it did so at a much slower rate than mean angler return time. At 50% fish abundance lost, mean kayaker return time was 0.5 years and at the extreme, 90% fish abundance lost, mean kayaker return time was 1.7 years (Table 3.19).

Cahaba River

At the least severe target species lost level (10%), an estimated 558 angling trips and 3,018 kayaking trips to the Cahaba River would be forgone. This would result in an estimated $65,311 lost in direct angler expenditures and $510,050 lost in kayaker direct expenditures, totaling $575,361 lost (Table 3.20). When angler ($103,269) and kayaker ($721,314) consumer surplus loss are added to direct expenditures lost to produce total willingness-to-pay (WTP) lost, $1,399,944 was estimated to be lost. At more moderate severity levels, 50% target species lost for example, the number of estimated angling trips lost increased to 7,133 and kayaking trips lost increased to 3,191. This resulted in an estimated $834,524 loss in direct expenditures related to angling and $539,196 loss in direct expenditures related to kayaking, totaling $1,373,720 in direct expenditures lost. When consumer surplus lost from both recreational activities was added in to yield total WTP lost, this figure nearly tripled and $3,455,798 was lost, due to a 50% decline in targeted species (Table 3.20). At 90% target species lost, an estimated 17,987 angling trips and 14,659 kayaking trips were lost, resulting in an estimated $4,581,839 total loss in direct expenditures. Again, when consumer surplus lost is added to produce total WTP lost, this estimated loss ballooned to over $11 million (Table 3.20).

Jordan Dam Tailwater of the Coosa River

In general, potential angler and kayaker use loss due to fish kills on the Coosa River were of lesser economic magnitude than on the Cahaba. At 10% targeted species lost, there was an estimated 354 foregone angler trips and 2,286 kayaker trips, resulting in the loss of $287,852 in total direct expenditures. Consumer surplus loss at the 10% level was $87,148 for angling and $521,280 for kayaking. Therefore, angler WTP lost was $105,215 and kayaker WTP lost was $896,280, for a total WTP loss of $896,280 for the least severe fish kill scenario (Table 3.21). When the severity was increased to 50%, there was an estimated loss of 4,527 angling trips and 2,417 kayaking trips. This resulted in an estimated $516,060 in direct expenditures not being spent on angling or kayaking the Coosa River. When consumer surplus for both recreational types were added to this, there was a total WTP loss of $2,180,680 (Table 3.21). If there was a 90% loss of target species, economic losses would be severe; an estimated 11,415 angling trips and 11,105 kayaking trips were lost that otherwise would have been taken on the Coosa River. Lost direct expenditures related to these trips totaled $1,892,551. This figure along with angler and kayaker consumer surplus loss resulted in a total WTP loss of $7,232,571 (Table 3.21).

Locust Fork River

Due to lower angler and kayaker use, economic losses due to fish kills were lower on the Locust Fork River than the other two study rivers. At the lowest percentage of targeted species lost (10%), it was estimated that 279 angling trips and 918 kayaking trips were lost, resulting in $168,690 of direct expenditures that would not be spent in the communities nearby the Locust Fork River. There was a $35,185 loss in angler consumer surplus and a $260,693 loss in kayaker consumer surplus also. Between direct expenditure lost and consumer surplus lost, total WTP lost in this scenario was $464,568 (Table 3.22). If there were a 50% loss of a target species, there were 3,567 forgone angling trips and 970 forgone kayaking trips, resulting in a loss of $313,932 in direct expenditures related to angling and $152,351 related to kayaking. If lost consumer surplus for each recreation type was included there was a total WTP loss of $1,191,367 (Table 3.22). At a 90% decline in targeted species, total WTP loss would be an estimated $3,891,785. This resulted from the loss of 8,998 angling trips and 4,459 kayaking trips (Table 3.22).

Discussion

On-site Survey and Follow-up Telephone Survey

In general, anglers and kayakers encountered during the roving survey were more than willing to participate in the on-site survey, especially those that were aware of the recent fish kills on the Mulberry Fork. The Cahaba River was sampled on 67 days, which produced 55 angler interviews and 24 kayaker interviews for an average of 0.82 angler parties and 0.36 kayaker parties interviewed per survey period (Table 3.2). 135 angler interviews and 21 kayaker interviews were collected over 35 sampling events on the Jordan Dam tailwater of the Coosa River (Table 3.2). On average, 3.9 angler parties were interviewed per sampling period and 0.6 kayaker parties were interviewed per sampling period. Over 43 sampling events on the Locust Fork River, 41 angler parties were interviewed and 16 kayaker parties were interviewed, resulting in an average interview per sampling period of 0.95 for anglers and 0.4 for kayakers.

Actual on-site sampling effort was nearly equal to the weights developed from expected use and known angler use from the 2020 trail camera data. The Upper section of the Cahaba River was sampled exactly 45% of the time, the Middle section made up 25% of the effort, and the Lower section was sampled 21% of the time (Table 3.2). Eighty-six percent of the sampling effort went to the Upper section of the Locust Fork River and 14% to the Lower section of the Locust Fork River(Table 3.2).

The causes of disparity between the number of interviews acquired on the Coosa River and the other two rivers was likely twofold. First, angler use was thoroughly concentrated below Jordan dam on a 12 km reach at one boat ramp making it relatively easy for the creel clerks to intercept nearly all active anglers during a sampling period. This was not the case on the Cahaba and Locust Fork rivers, as the study areas were 221 km and 145 km in length with angler use spread over these large geographic areas, making it difficult to be truly efficient in angler interception on some days. While stratification via a weighting system of river sections and reaches helped greatly with this issue, in an anecdotal sense, trail cameras verified this. It was not uncommon during photo analysis, for the creel clerk to see a random boon in angler use at a low use access point, on the same day that the creel clerk was elsewhere seeking out interviews. For example, only three angler interviews were obtained from the lower Cahaba River, however from trail camera count extrapolation, it is estimated that 1,400 anglers (95% C.I. = 67 anglers) fished the section in 2021. Second, although the particular reach of the Coosa River sampled still had characteristics of piedmont rivers (i.e., rocky shoal complexes, etc.) like the other two rivers, minimum flow and water depth was always high enough that a small 3.5 hp outboard could be used. This afforded the creel clerks an advantage that was lacking on most of the higher use reaches on the other two rivers in that most angler parties who began fishing downstream before the survey period began could still be interviewed because creel clerks could proceed downstream at a faster rate than anglers who were paddling for mobility. Most of the Cahaba and Locust Fork rivers' reaches were extremely shallow and rocky for many miles at a time, which required creel clerks to rely on paddling solely for mobility. On each sampling trip, every effort was made to paddle faster than a comfortable rate in an attempt to intercept anglers that had started their trip before the clerks. However, there is little doubt that interviews were missed due to this issue.

The small sample sizes of kayaker interviews on each of the rivers was likely due to a number of factors. First and foremost, seeking out angler interviews was of primary concern, so there were times when a creel clerk was interviewing an angler and potential kayaker interviews were missed. There were also times in which kayaker interviews were bypassed in pursuit of anglers downstream. Kayakers were also often in large parties, especially on the Locust Fork River, in the interest of time, one individual from the group was interviewed and their expenditures extrapolated out to party expenditures. Interviewing recreational kayakers also posed potential issues with the ability to consent to participation in the survey, as many kayakers floated the rivers while consuming alcohol. If a kayaker in possession of alcohol was encountered near the beginning of their trip or while they were unloading their boats, they were interviewed. However, if it was readily clear that an individual was under the influence of alcohol and may lack the ability to consent to an interview, creel clerks bypassed the interview and simply tallied the kayakers.

While anglers and kayakers demonstrated willingness to participate in the on-site survey, the percentage of those that agreed to a follow-up telephone interview or answered the phone within the three call limit was lower than that seen in similar studies on reservoirs but still higher than other follow-up methods like mail-in surveys (Snellings 2015; Gratz 2017; Plauger 2018). Follow-up telephone survey participation rate was highest on the Locust Fork River (68%), followed by the Cahaba River (64%), and the Coosa River (42%). This was with calling each angler from a phone with a local area code, which theoretically should have increased response rates (Plauger 2018). Although the recent major fish kills were highly publicized, it is possible that response rates were higher on the Locust Fork and Cahaba rivers due to their close proximity to the Mulberry Fork, the site of the most recent major fish kill. The Locust Fork River is an adjacent tributary of the Mulberry Fork River, so Locust Fork River anglers were well aware of the issues on the Mulberry Fork River and were generally the most enthusiastic of all the participants to take part in the survey. Similarly, many Cahaba River anglers have, at some point over their angling careers, made a trip to fish the Locust or Mulberry Forks, so they were likely somewhat familiar with the issues. The Mulberry Fork River is also under a 35-minute drive from Birmingham, therefore it is in relative close proximity to the Cahaba River. Coosa River anglers rarely reported being aware of the Mulberry Fork River kills and often listed alternate sites of the Alabama River, Tallapoosa River, or Coosa River reservoirs, so many of their angling trips were occurring a significantly south of the Black Warrior River drainage.

For kayakers, 75% of the individuals that participated in the on-site survey also participated in the corresponding follow-up telephone survey on the Locust Fork River. Cahaba River kayaker response rate to the follow-up telephone survey was extremely low at 21% and Coosa River kayaker response rate was 57%.

Surveying three rivers concurrently likely had a negative influence on the number of interviews obtained on each river, especially when the lengths of the study areas are considered. However, a roving survey of this scope, in which the goal was to assess angler use and economics of entire mainstem river systems, has rarely, if at all, been attempted. It is far more common and manageable to focus sampling effort on specific reaches, which has been commonplace in the past (Rohrer 1986; Choi 1993; Heggenes 1987; Prado 2006). If a study of this nature were to be planned in the future, researchers should either consider focusing sampling efforts on either one or two rivers or designating a substantial number of employees to the study. In this study, 1 or 2 employees covered the entirety of the sampling on all three rivers. It would be advisable to have 1 or 2 employees' time dedicated to each river. However, at their simplest, in terms of design, creel surveys can be cost-prohibitive to begin with, so it is unlikely that most managing agencies have the necessary funds and available staff to implement such a strategy.

Effort, Catch, and Harvest

It is not surprising that angler effort for the three rivers in this study was far lower than that estimated for any of the reservoirs in Alabama, considering the popularity of tournament fishing and bass fishing, in general, on Southeastern U.S. reservoirs. Of all the recent reservoir angler use and effort studies, Gratz’s (2019) estimate of 97,257 annual effort hours on Millers Ferry Reservoir was the lowest, which is still over 70,000 h more than the highest effort estimate of these study rivers. Effort estimates for these rivers were, however, consistent with estimates for other low-use riverine fisheries. Heggenes (1987) estimated angler effort for three riverine grayling *Thymallus thymallus* and brown trout *Salmo trutta* fisheries to have a range between 6,756 h and 18,576 h annually. Similarly, a roving creel survey of 24 rural trout streams in Southeastern Minnesota, found each stream to receive on average 1,861 angler effort hours, the highest being 7,353 h, annually (Snook and Dieterman 2013). While both of these examples involve coldwater fisheries, they demonstrate that angler effort patterns are much different for smaller to mid-size streams and rivers than effort is for larger rivers and reservoirs. Unfortunately, this type of information is difficult to come by for rivers and streams in the Southeastern U.S., due to the focus of management and funding dedicated to reservoirs. One study on a coastal river in South Alabama, where largemouth bass and hybrid striped bass were commonly targeted, found low annual angler effort during the survey period also (Armstrong 2003).

When compared to other small to mid-size river effort estimates, the annual angler effort estimate of 23,057 h on the Cahaba River places it at the higher end of the range based on the sparse amount of comparative examples available. The Coosa (16,504 h) and Locust Fork (10,731 h) rivers’ effort estimates are well within the range of commonality for rivers of this size. It is also important to consider that riverine angler effort in Alabama and across the Southeast is likely to increase further in the near future, as the popularity of fly fishing, ultra-light angling, and awareness of and desire to target endemic riverine black basses and other riverine fishes increases (Thomas 2015; Taylor and Sammons 2019; Cooke et al. 2020).

Another thing that differentiates these riverine fisheries from reservoir fisheries in Alabama is the proportions of bank and boat angling use (i.e., angler counts). Many of the past reservoir studies found bank angling use to be almost insignificant when compared to boat angling use. Bank angling made up 5% of the total use on Lake Eufaula, 10% on Millers Ferry Reservoir, and 13% on Lake Guntersville (McKee 2013; Gratz 2017; Plauger 2018). On these study rivers, bank angling made up a significant proportion of the total estimated use. At its lowest, bank angling made up 33% of the total angling population, while boat angling accounted for 67% of the use. However, on the Cahaba and Locust Fork Rivers, proportional use for bank and boat angling was nearly equal. 44% of the total angling use on the Cahaba came from bank angling and 48% came from bank angling on the Locust Fork River. Ease of access to river fisheries compared to reservoirs may be one explanation for this, as lack of access to bank fishing sites on reservoirs has been documented in the past (Schramm et al. 2003; Plauger 2018; Kane et al. 2020). As mentioned previously, wading and bank anglers were combined for the purposes of this study. This likely explains the high number of bank anglers on these rivers, as there are many shallow shoals on the Upper and Middle sections of the Cahaba River and Upper section of the Locust Fork River that are conducive to effective wade fishing. Although, wade fishing is not possible on much of the Jordan Dam tailwater on the Coosa river, bank angling has been found to be a popular activity on many tailwaters in the past (Schramm et al. 2003; Kane et al. 2020). Finally, the disparity could be due to sampling efficiency, as trail cameras may have been better suited to documenting bank anglers. Since a photo was taken of anglers as they entered and exited the fishing site, accuracy and precision of total angler counts would be expected to be fairly high, while estimating bank angler numbers from an instantaneous count or aerial flight understandably has limitations.

Bass angler CPE on all three rivers was higher than on any of the Alabama reservoirs studied in the past. Average bass angler catch rates from the reservoir studies was 0.78 fish/h, while Cahaba River bass angler CPE was 1.5 fish/h, Coosa River CPE was 1.3 fish/h, and the Locust Fork River the highest at 2.5 fish/h (Lothrop 2012; McKee 2013; Snellings 2015; Gratz 2017; Plauger 2018; Table 3.4). There are a number of possible reasons, none of them mutually exclusive, for angler CPE being higher on rivers than reservoirs. For one, it's likely that lower angler use and effort on the rivers allows anglers that do fish the rivers to take advantage of bass naivety (Hessenauer et al. 2016). In other words, riverine bass may lack learned lure avoidance that bass in high-effort reservoir systems develop under heavy fishing pressure. It's also possible that bass habitat on these rivers is simply easier for anglers to identify and effectively fish than on reservoirs. Bass angling on these rivers consists of casting to current seams adjacent to the thalweg, eddies, emergent boulders, and rocky outcroppings, while reservoir bass angling can require knowledge of submerged habitat, etc. that bass are suspended near, which can sometimes be hard to identify without advanced sonar equipment and/or prior knowledge. Another factor may be the regional nature of these fisheries in that these are local anglers fishing their home river, who primarily fish at the given site, and as such are more effective on their home waters than an angler population comprised of many non-locals fishing a reservoir once in a given year like on Lake Eufaula or Guntersville (McKee; Plauger 2018). Lant et al. (2022) saw higher catch rates for local anglers than non-local anglers in a Yellow Perch *Perca flavescens* fishery in Wisconsin. Indeed, although anglers unique to each riverine fishery was not a metric this study was concerned with, it was apparent from the trail camera image analysis that many of the trips taken on each river were largely from repeat anglers.

Seasonally, angler effort on the study rivers was similar to that seen on Alabama reservoirs. Very little effort occurred in the winter months, less than 6% on each river. The majority of the angling effort occurred during the spring and summer months, which is consistent with reservoir angling also. Spring (48%) and summer (35%) seasons saw 83% of the total effort on the Cahaba River with just 12% coming from the fall. On the Coosa River, 37% of the angling effort was in the spring and 36% in the summer with 21% coming in the fall. Higher fall effort on the Coosa River is likely related to the sustained presence of striped bass, hybrid striped bass, and white bass *Morone chrysops*, which remain in the high velocity tailwaters below Jordan dam through the late fall and early winter months. Eighty percent of the total effort on the Locust Fork River came from the spring (42%) and summer (38%) months and 17% from the fall. This same seasonal trend persists for kayakers also, albeit with more kayaking hours occurring in the summer than the spring on the Coosa and Locust Fork rivers.

Kayaking hours on the Cahaba River were highest in the spring (46%) and summer (40%) months, followed by the fall (11%) and winter (3%) months. No kayakers were seen on the Coosa River trail cameras during the winter months. Heavy rain events from late fall through the winter in 2021 forced Alabama Power, the managing authority of Jordan Dam, to generate with three turbines and open up many of the gates for the majority of this time period. When water levels and flow are this high in the tailwater, the 12 km float can be completed in less than two hours and many of the whitewater obstacles that are a major draw for whitewater kayakers are completely submerged. Therefore, it’s probable that potential kayakers pursued other recreational activities or kayaked elsewhere during this time period. Most of the kayaking hours were in the summer (61%) months, followed by the spring (22%), and fall (17%) months. On the Locust Fork River, 6% of the kayaking effort occurred during the winter months, 34% in the spring, nearly half (48%) in the summer, and 13% in the fall.

These seasonal effort patterns make sense when the different types of kayakers are considered. Kayakers on these rivers can categorically be separated into two user groups: whitewater kayakers, those seeking out rapids and high velocity waters, and pleasure kayakers, those seeking relaxation, moderate velocity waters, and respite from high temperatures. Whitewater kayakers are somewhat of a niche, although growing group of recreationalists in Alabama, who kayak year round, while pleasure kayakers are usually using rivers in the spring and summer months when flows are manageable for the novice and the hazards that accompany the presence of class II-IV rapids are at a minimum. This explains overall high kayaker effort hours in the spring and summer months because both of these groups are active. However, as rainfall and discharge increases on free-flowing rivers (i.e., Cahaba River and Locust Fork River) in the fall and winter months, rapids become more intense, logjams and deadfalls shift location, and water temperatures decrease. All factors that increase the already inherent danger of navigating flowing waters drastically. Therefore, the skill, experience, and gear required to float these rivers in the late fall and winter months, relegate kayaker use to the whitewater group alone, explaining the low kayaker effort seen at these times.

Angler Socioeconomic Characteristics

River anglers in Alabama demonstrated some characteristics that differentiate them from reservoir anglers in the state. A lot of these characteristics seem to stem from the regional nature of these river fisheries. Of the use and effort that occurs on these rivers, the vast majority comes from anglers living in close proximity to the system. Eighty-five percent of anglers interviewed on the Cahaba River resided in contiguous counties, specifically Jefferson, Bibb, Dallas, Perry, Shelby, and St. Clair counties. Coosa River anglers residing in contiguous counties (i.e., Elmore and Montgomery counties) accounted for 86% of the interviews and 82% of anglers interviewed on the Locust Fork River were residents of contiguous counties, specifically Blount, Cullman, Etowah, and Jefferson counties (Figure 3.2). From similar studies done on Alabama reservoirs, the range in percentages of local anglers was from 27% to 63%, therefore local river anglers in this study made up a far larger proportion of the anglers encountered than they did in the reservoir studies (McKee 2013; Snellings 2015; Gratz 2017; Plauger 2018). Furthermore, Plauger (2018) reported 57% of anglers interviewed claimed Alabama state residency; the rest were from Georgia or other states. Not one out-of-state angler was encountered on these rivers throughout the study. One recent resident of Alaska and one recent resident of Georgia were interviewed, each targeting Cahaba Bass *Micropterus cahabae,* but they both had established Alabama residency at the time of the interview.

Mean one-way distance anglers traveled to these rivers was also far less than not only what reservoir anglers customarily drive but also less than mean angler travel distance from similar studies on riverine fisheries, although these studies focused on coldwater trout fisheries (Choi 1993; Prado 2006). Mean one-way trip distance for the Cahaba River was 29 km, the Coosa River 37 km, and the Locust Fork River 30 km, compared to a range of mean values of 77 to 268 km for the fisheries mentioned above (Choi 1993; Prado 2006; Lothrop 2012; McKee 2013; Gratz 2017; Plauger 2018).

Racial and gender demographics of anglers on the Cahaba and Locust Fork rivers, however, were similar to that observed on many other fisheries. Gratz (2017) and Plauger (2018) reported over 88% of the anglers that participated in the on-site surveys for their reservoir studies identified as Caucasian and predominantly male (98%). Ninety-eight percent of anglers interviewed on the Cahaba River identified as male and 92% identified as Caucasian and 88% of anglers interviewed on the Locust Fork River identified as male and 97% identified as Caucasian. Although the Coosa River showed this same pattern, concerning gender (91% male), angler racial diversity was higher than what is commonly seen on many fisheries in the U.S. Fifty-one percent of anglers interviewed identified as African American, 39% identified as Caucasian, and the remaining 10% Asian or Hispanic. This percentage of angling participation by African Americans was 44% higher than the estimated 7% found in a recent report produced by the Outdoor Foundation and Recreational Boating and Fishing Foundation (2020).

Expenditures and Tax Revenue

Anglers spent $725,634 fishing the Cahaba River in 2021, more than double the total expenditures on angling trips on each of the other two study rivers (Table 3.8). Anglers spent more per trip ($117) over nearly twice as many trips, which explains why annual expenditure totals on the Cahaba River were so much higher than on the Coosa River and Locust Fork River. Total angler annual expenditures on the Coosa River was $200,737 and $272,976 on the Locust Fork River. The Cahaba River's proximity to the Birmingham metro area probably has a lot to do with this, as it flows directly through Birmingham and its suburbs. While the Coosa River flows near Montgomery, Alabama's third largest city center, it does not flow directly through the metro area as the Cahaba River does Birmingham. Anglers in the Montgomery area also have more alternative options nearby than Cahaba River anglers, in terms of other nearby rivers and reservoirs to fish. The Tallapoosa River, Alabama River, and Lake Jordan, a Coosa River impoundment are all within a 40 km drive from Montgomery. In fact, many Coosa River anglers listed all three of the abovementioned sites as common places they traveled to fish. While there are plenty of tributaries of the Cahaba River available for anglers to fish near Birmingham, river and reservoir fishing opportunities require driving further, therefore Birmingham metro anglers may choose to fish the Cahaba River more often, in lieu of incurring the expense of driving elsewhere. The Locust Fork River flows through a fairly rural area that lies between Tuscaloosa and Birmingham, so it is not surprising that the annual expenditures on the Cahaba River would be much higher. There are also notorious rapids on a number of reaches of the Locust Fork River that may decrease angler use on this system.

Although Millers Ferry Reservoir had the lowest annual economic value ($2.5 million), it still brings in $1.7 million more than the highest of the study rivers (Gratz 2017). Despite the Cahaba River's high economic value compared to the other study rivers, it is still worth $1.7 million less annually than Miller's Ferry Reservoir, the least valuable reservoir of the prior studies (Gratz 2017). This speaks volumes about the popularity of reservoir angling in Alabama.

Similar to that found on reservoirs, bass angling was the major economic driver, in terms of angling, on the Cahaba River and Locust Fork River fisheries (McKee 2013, Gratz 2017, Plauger 2018). Of the annual expenditures on each river, bass angling accounted for the vast majority of the dollars spent; 66% on the Cahaba River and 69% on the Locust Fork River. This was not the case, however, on the Coosa River. While bass angling expenditures still made up a sizeable portion of the total annual expenditures (28%), anglers targeting other species (i.e., sunfish, crappie, skipjack herring, etc.) accounted for a larger portion of the annual expenditures (40%). This was most likely because of the greater number of annual trips that anglers targeting other species made.

Among anglers on all the rivers, equipment and fuel expenditures accounted for the majority of the annual total expenditures. Anglers spent far more on equipment on the Cahaba River than they did on the other two rivers (Table 3.8). Fuel made up the majority of expenditures on the Coosa River, while more was spent on equipment on the Cahaba and Locust Fork rivers. Lodging expenditures were minimal, as there were very few overnight trips made on any of the rivers. Past studies found a relationship between anglers making overnight trips and anglers spending more money at restaurants (McKee 2013; Gratz 2017; Plauger 2018). This would explain the low restaurant expenditures on these rivers, compared to the larger amounts spent on groceries. Anglers may be more likely to buy groceries in preparation for a day trip and return home for dinner. Most of these expenditure trends are, again, likely related to the regional nature of these fisheries. Since most of these anglers lived nearby, a mean range of 29 – 36 km away from their respective site, far less was spent on expenditures associated with longer travel distances than on reservoirs where anglers traveled long distances and overnight stays of 2 to 3 days were common (Table 3.7). 70% of the total expenditures on the Cahaba River were incurred locally, according to the follow-up telephone surveys. Local expenditures on the Coosa River were high also; 75% occurred in contiguous counties. Local expenditures on the Locust Fork River was the lowest, making up 54% of the total. This is likely due to the Locust Fork River's distance from city centers in which equipment (i.e., fishing rods, canoes, kayaks, etc.) could be purchased. Many Locust Fork River anglers made the drive to Birmingham for larger equipment purchases.

Estimated annual kayaker expenditures were higher than angling expenditures on all three rivers. This may be, at least in part, due to small sample sizes of kayakers who participated in the follow-up telephone survey. However, mean kayaking expenditures per trip on an Ireland River were similar. Hynes (2007) reported a mean trip cost of £83, which after the foreign exchange rate and an average inflation rate increase of 2.07% per year, from 2005 – 2021, are applied, yields a mean trip cost of $138. Another explanatory factor may be that kayakers, on average, traveled further on their trips than anglers. Locust Fork River kayakers had a mean roundtrip distance of 102 km. Kayakers on the Coosa River traveled 117 km roundtrip and Cahaba River kayakers had a mean roundtrip distance of 70 km. Finally, many kayakers rented their vessels from local outfitters. This understandably increases equipment cost per trip. Mean individual expenditures per trip on the Coosa River was $118, $169 on the Cahaba River, and $157 on the Locust Fork River. In 2021, kayakers spent $1,457,289 on the Cahaba River, $770,776 on the Coosa River, and $411,654 on the Locust Fork River (Table 3.9).

While local taxes (i.e., county and city taxes) were estimated for each river from, both, angling and kayaking expenditures, they were not reported because the local benefit to each respective county and city was minimal. State taxes generated from angling and kayaking were highest on the Cahaba River and totaled $261,840 (Table 3.10; Table 3.11). At $0.28 per gallon, revenue from vehicle gas made up the majority of this. This was true for the Coosa and Locust Fork rivers also. State tax revenue gained from angling and kayaking on the Coosa River was $118,606 and $80,714 on the Locust Fork River(Table 3.10; Table 3.11).

Travel Cost Models and Consumer Surplus

Many studies in which the TCM was used to explain angler visitation included multiple independent variables, however due to small sample sizes, only one or, at most, two independent variables were included in these models beyond those that the TCM theory requires (Lothrop 2012; Plauger 2018). These variables changed depending on the river and model fit. The quality of an angler's trip proved to be one of the important explanatory variables on the Locust Fork River, as anglers who ranked their trip higher made more trips to the Locust Fork River(Table 3.16). This was true for bass anglers on the Locust Fork River too. This was one of the only shifter variables not required by the TCM that was statistically significant at the $P < 0.05$ level (Parsons 2003). Although Bass CPE proved important in explaining bass angler visitation on the Cahaba River (Appendix A.5).

In all models, angler visitation declined with increased travel costs. Of the all angler models for each river, travel cost was statistically significant at the $P < 0.05$ level for the Cahaba River and at the $P < 0.10$ level for the Coosa and Locust Fork Rivers. This was the case for a TCM study on striped bass angler visitation on Lewis Smith Reservoir in which angler visits was regressed on travel cost with a small number of observations (n=56) (Lothrop 2012). These all-angler models performed adequately in predicting angler consumer surplus values on these rivers, when the negative slope and statistical significance of the travel cost coefficients are considered. The consumer surplus per trip values for these rivers were $185 for Cahaba River anglers, $246 for the Coosa River, and $126 for the Locust Fork River. These values were comparable to those found in other studies. Plauger (2018) estimated consumer surplus per trip for Lake Eufaula anglers to be $189. Average consumer surplus per angler trip from past studies have commonly ranged from $100-$250 in the Southeast. A few examples include: Lower Illinois River ($112; Prado 2006), Lake Guntersville ($156; McKee 2013), and Sam Rayburn Reservoir ($259; Driscoll et al. 2012).

Average aggregate consumer surplus from all of the Alabama reservoir studies was $15.4 million, annually, ranging from $0.6 million to $31.8 million (Lothrop 2012; McKee 2013; Plauger 2018). It should be noted that Lothrop (2012) was a fishery-specific study in which the consumer surplus of the striped bass fishery, alone, was estimated; aggregate consumer surplus would have been higher if the study was concerned with the entire fishery. As aggregate consumer surplus for Cahaba River anglers was ($1.1 million), Coosa River anglers ($0.9 million), and Locust Fork River anglers nearly ($0.4 million), these fisheries have far less annual value than the average reservoir fishery in Alabama. This is likely explained by the higher angler effort on reservoirs compared to rivers in Alabama.

Once outliers were removed, sample sizes for kayakers that participated in the follow-up telephone survey on these rivers were small (Cahaba River, n=5; Coosa River, n=12; Locust Fork River, n=12), therefore caution should be observed in applying the current kayaker consumer surplus values to loss valuations (Table 3.13; Table 3.15; Table 3.17). If kayaker consumer surplus values are included in loss valuations on Alabama Rivers in the future, it is likely that total annual economic value will double in most cases. In all kayaker TCM models, visitation did decrease with an increase in travel costs as economic theory would suggest (Parson 2003). However, this was at low significance levels across the rivers. Travel cost was only statistically significant at the $P < 0.10$ level on the Cahaba River.

Consumer surplus for kayakers on all three rivers was higher than that of anglers. This seems irrational initially, but when it is considered that many kayakers paid a rental fee as part of their daily trip cost that anglers only rarely paid on the Coosa River, it is understandable. Kayaker consumer surplus per trip was $239 on the Cahaba River, $228 on the Coosa River, and $246 on the Locust Fork River. Studies on the economic value of whitewater recreation are rare. However, when compared to the available estimates from the literature, these estimated consumer surplus values are similar to those estimated for kayaking and whitewater rafting recreationalists on other river systems. For example, Hynes and Hanley (2006) estimated consumer surplus of kayakers to be $245 on the Roughty River in Ireland. After adjusting for inflation between 1996 and 2021, kayaker and rafter consumer surplus per trip was found to be $260 on a river in North Georgia and $162 on the Gauley River in West Virginia (English and Bowker 1996; Ready and Kemlage 1998). Although comparisons across studies can be difficult to interpret, due to the differences in study sites and methodology, it seems that the estimated kayaker consumer surplus values for these Alabama Rivers are, at least, consistent with those found elsewhere despite small sample sizes.

Economic Loss and Contingent Valuation

Economic loss due to fish kills of varying percentages of target species lost was presented in such a way that a managing body tasked with valuing economic loss post fish kill could choose which values they wish to include in the valuation process. Loss estimates vary greatly dependent upon what is included in the loss valuation (i.e., angling expenditures, kayaking expenditures, angler WTP, kayaker WTP, etc.) and the river in question (Table 3.20; Table 3.21; Table 3.22). For example, if, theoretically, 30% of a targeted species were lost on the Cahaba River, leading to 5,086 angling trips lost and lost direct angling expenditures, alone, were used as the user value loss metric, then $595,052 in economic loss results. If, however, angler WTP lost, which is the sum of angler direct expenditures lost and angler consumer surplus lost, was used as the user value loss metric, then $1,535,496 is lost. It may also be desirable to only include direct expenditures, but to do so with the summation of angler and kayaker direct expenditures, which results in an estimated $1,250,831 in economic losses. Finally, if angler WTP lost and kayaker WTP lost was used as the user value loss metric, then over $3 million is lost due to the fish kill (Table 3.20).

As stated above, loss values vary significantly by river. However, one goal of this valuation and loss valuation estimation was to develop lists of other Alabama Rivers on which these values can be applied in the event of a fish kill in the future. Survey questions asked to each angler and kayaker that have gone, heretofore, unmentioned were (Appendix A.2):

1. What other rivers have you fished/floated in Alabama over the last 12 months?
2. What river would you fish/float in Alabama if *X* River had experienced a major fish kill?

While the local knowledge and discretion of a district fisheries manager is of the utmost importance when selecting rivers on which to apply the loss values from these study rivers, patterns did emerge from these responses that may inform decision making in the future. All anglers surveyed on the Locust Fork River, who fished other rivers in the last year, fished only rivers in the North-Central to Northern regions of the state. Sixty-seven percent had fished the Black Warrior River drainage, 11% the mainstem Black Warrior River, 6% the Sipsey Fork, and 50% the Mulberry Fork. Twenty-two percent had fished the Tennessee River drainage, either the Flint River (11%) or the mainstem Tennessee River (11%). The remaining 11% came from anglers fishing the Sipsey River above Lewis Smith Reservoir.

Kayakers surveyed on the Locust Fork River had similar use patterns as anglers on the Locust Fork River in that many of them had floated other rivers in the North, North-Central region of the state. However, 25% made the trip to float the Coosa River below Jordan Dam, which none of the anglers fished in 2021. Another 25% had floated a Tennessee River tributary, mainly the Flint River. Nineteen percent floated through Little River Canyon. Nineteen percent floated the Mulberry Fork or other Black Warrior River tributaries (i.e., Blackburn Fork, Calvert Prong) and 12% of kayakers floated the mainstem Cahaba and its tributaries, such as the Little Cahaba River and Shades Creek.

Cahaba River anglers fished a wider breadth of rivers, however 69% of the anglers had fished rivers in the north to north-central parts of the state. These included: Mulberry Fork River (25%), Locust Fork River (16%), Black Warrior River (3%), Tennessee River (6%), Duck River (3%), Little River (6%), and the upper Coosa River (10%). The remaining rivers that Cahaba River anglers fished were the Coosa River (Jordan Dam tailwater) (9%), upper Tallapoosa River (3%), Chattahoochee River (3%), Choctawhatchee River (6%), and Alabama River (9%).

Cahaba River kayakers did not use the same wide range of rivers as anglers on the Cahaba River. The Mulberry Fork and Locust Fork Rivers accounted for 40% of the rivers visited and 40% other Black Warrior tributaries, the Little Warrior River and Sipsey River. Twenty percent made the trip down to float the Coosa River below Jordan Dam.

Anglers surveyed on the Coosa River rarely fished north of Horseshoe Bend National Military Park on the Tallapoosa River. Eighty-three percent had fished either the Tallapoosa (22%) or Alabama (61%) rivers over the last year. Of the anglers interviewed that fished the Tallapoosa River, 28% had fished near Horseshoe Bend and the remaining 72% fished the reach below Thurlow Dam. Six percent fished the Chattahoochee River and 1 angler reported having fished the Cahaba, Locust Fork, Mulberry, Little, and Choctawhatchee rivers last year.

Thirty percent of the kayakers surveyed on the Coosa River floated other Coosa River tributaries, like Autauga Creek, Hatchet Creek, and Socapatoy Creek. Forty percent had floated either the Cahaba River or Locust Fork River, 10% floated Tennessee River tributaries, and the remaining 20% had floated the mainstem Tallapoosa River.

Since anglers and kayakers that use the Jordan dam tailwater seem to demonstrate different characteristics, in terms of species targeted, etc., than the other two rivers in this study, it may be appropriate to use Coosa River values on other tailwaters in the state.

It seems clear that loss values from the Locust Fork River could be applied to much of the Black Warrior drainage, as there seems to be high levels of angler crossover on the Mulberry Fork and Locust Fork rivers. Further, it may be worth considering applying values from the Locust Fork River for rural mid-size rivers that lack large population centers, like the Choctawhatchee River, Duck River, etc. For mid-size rivers, nearer to larger population bases, the Cahaba River use values should be considered. If it's thought that a river demonstrates properties that fall in between two rivers in this study, it may be appropriate to use a mean loss value from two of the rivers.

In all likelihood, the majority of fish kills that occur due to point source or non-point source pollution events will fall somewhere in the 10-30% abundance lost range (La and Cooke 2011). These user loss values are of the most applicability to loss valuations on Alabama Rivers, while the higher end (40-90%) will likely serve as a reference point in most cases (La and Cooke 2011). However, fish kills that have affected over 90% of a population have been documented (Cooke et al. 2004). In the rare cases in which fish kills cause massive die-offs and extreme levels of lost biomass, user loss values from the 40-90% abundance lost range would be of use.

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Tables

Table 3.1. Access points, reach distance, and estimated angler use for three sections on the Cahaba River, one section on the Coosa River, and two sections on the Locust Fork.

River	Section	Access Points		Reach Distance (km)	Estimated Use
		Put in	Take out		
Cahaba	Upper				
		White’s Chapel Parkway	Moon River	14.8	Moderate (2)
		Moon River	Grant’s Mill	8.2	High (3)
		Grant’s Mill	Old Overton Rd	11.1	Very High (4)
		Old Overton Rd	Hwy 280	10.4	High (3)
		Hwy 280	Sportsplex	9.8	Moderate (2)
		Sportsplex	Lorna Rd	8.3	Moderate (2)
		Lorna Rd	CR 52	15.7	Low (1)
	Middle				
		Old Slab	Lebron Launch	3.21	Low (1)
		Lebron Laucnch	CR 24/NWR	13.4	Very High (4)
		CR 24/NWR	Caffee Creek/NWR	2.4	Very High (4)
		Caffee Creek/NWR	Pratt’s Ferry	8.4	Moderate (2)
		Pratt’s Ferry	Walnut Street	13.5	Moderate (2)
	Lower				
		Harrisburg Rd	Onrow Tubbs Rd	18.2	Low (1)
		Onrow Tubbs Rd	Sprott Bridge	19.3	Moderate (2)
		Sprott Bridge	Radford Rd	12.4	Moderate (2)
		Radford Rd	CR 6	14.7	Low (1)
		CR 6	Hwy 80	15.7	Low (1)
		Hwy 80	Hwy 22	19.9	Moderate (2)
		Hwy 22	Old Cahawba Park	14.4	Low (1)
Locust Fork	Upper				
		Lurleen Dr	Cold Branch Rd	16.1	Low (1)
		Cold Branch Rd	Taylor Ford Rd	5.3	Moderate (2)
		Taylor Ford Rd	King’s Bend	11.1	Moderate (2)
		King’s Bend	Swann Bridge	6.7	High (3)
		Swann Bridge	Nectar Bridge	6.7	High (3)
		Nectar Bridge	CR 13	8.0	High (3)
		CR 13	Center Springs Rd	16.1	Moderate (2)
		Center Springs Rd	Warrior-Trafford Rd	13.6	Moderate (2)
		Warrior-Trafford Rd	Warrior-Kimberly Rd	12.7	Moderate (2)
	Lower				

River	Section	Access Points		Reach Distance (km)	Estimated Use
		Put in	Take out		
		Warrior-Kimberly Rd	Mt. Olive Rd	26.8	Low (1)
		Mt. Olive Rd	Old Jasper Hwy	14.8	Low (1)
		Old Jasper Hwy	Porter Rd	19.9	Low (1)
Coosa					
		Jordan Dam Rapids	Wetumpka City Ramp	11.4	Very High (4)

Table 3.2. Sections weighted by ADCNR biologists and anglers, sections weighted by known use from 2020 trail camera data, actual percentage of sampling by section, number of times sections, and actual interviews by section on the Cahaba, Coosa, and Locust Fork Rivers, AL.

River	Section	ADCNR/angler weight (%)	Trail camera weight (%)	Actual (%)	Sampling events	Interviews	
						Angler	Kayaker
Cahaba	Upper	41	42	45	30	35	13
	Middle	43	37	34	23	17	10
	Lower	16	21	21	14	3	1
	Total	-	-	-	67	55	24
Locust Fork	Upper	80	0.78	86	37	41	16
	Lower	20	0.23	14	6	0	0
	Total	-	-	-	43	41	16
Coosa	Tailwater	-	-	-	35	135	21

Table 3.3. Anglers targeting specific species by season for anglers who participated in the angler survey on Cahaba, Locust Fork, and Coosa Rivers, AL.

		Spring		Summer		Fall		Total	
River	Angler Type	N	%	N	%	N	%	N	%
Cahaba	Bass	12	67	15	54	5	63	32	60
	Catfish	1	5	4	14	2	25	7	13
	Sunfish	0	0	4	14	0	0	4	7
	Anything	5	28	5	18	1	12	11	20
	Total	18	100	28	100	8	100	54	100
Coosa	Bass	2	5	17	28	12	33	31	23
	Catfish	8	21	14	23	8	22	30	22
	Sunfish	2	5	5	8	0	0	7	5
	Striped Bass	8	21	4	7	4	11	16	12
	Anything	13	35	21	34	11	31	45	33
	Other	5	13	0	0	1	3	6	4
	Total	38	100	61	100	36	100	135	100
Locust Fork	Bass	14	78	5	38	3	30	22	54
	Catfish	3	17	5	38	1	10	9	22
	Sunfish	1	5	0	0	0	0	1	2
	Anything	0	0	3	24	6	60	9	22
	Total	18	100	13	100	10	100	41	100

Table 3.4. Angling effort, trips, catch rate, and harvest rate by species for both boat and bank anglers on the Cahaba, Coosa, Locust Fork Rivers from the on-site survey and trail camera effort estimation from February through December 2021.

River	Angler Type	Effort (h)	95% Confidence Interval	Average Effort Hours	Trips	CPE	HPE
Cahaba	Bass (32)	13,373	1,183	4	3,343	1.5	0.0
	Catfish (5)	2,766	244	5	553	0.9	0.7
	Other (16)	6,917	611	3	2,305	1.7	0.2
	Total (53)	23,057	2,038	4	6,202	-	-
Coosa	Bass (31)	3,795	715	5	759	1.3	0.1
	Catfish (30)	3,632	638	4	907	0.8	0.4
	Striped Bass (16)	1,981	373	4	495	1.8	0.6
	Other (58)	7,096	1,336	4	1,774	1.6	1.2
	Total (135)	16,504	3,109	4.25	3,936	-	-
Locust Fork	Bass (22)	5,689	746	4	1,421	2.5	0.08
	Catfish (9)	2,360	309	3	786	0.8	0.7
	Other (10)	2,682	352	3	894	1.7	0.3
	Total (41)	10,731	1,408	3.3	3,102	-	-

Table 3.5. Mean party size and expenditures by target species per angler trip and per kayaker trip obtained during the follow-up telephone survey on the Cahaba, Coosa, and Locust Fork Rivers from the follow-up telephone survey from May through December 2020 and February through December 2021.

River	Target	N	Party Size	Party Size (SD)	Expenditures ($)	Expenditures (SD)
Cahaba	Bass	24	1.8	1.2	146	287
	Catfish	2	2.3	1.4	106	85
	Other	9	1.4	0.5	25	28
	All Anglers	35	1.8	1.1	115	245
	Kayakers	5	2.8	2.1	169	243
Coosa	Bass	19	1.3	0.6	73	73
	Catfish	11	1.8	0.7	43	28
	Striped Bass	6	1.3	0.5	37	16
	Other	20	1.6	0.7	41	25
	All Anglers	56	1.5	0.7	51	48
	Kayakers	12	3.0	1.8	118	85
Locust Fork	Bass	16	1.9	0.9	133	231
	Catfish	5	2.8	1.3	31	11
	Other	7	2.0	1.8	26	17
	All Anglers	28	2.1	1.3	88	181
	Kayakers	12	5.0	7.5	157	229

Table 3.6. Summary of recreational kayaker expenditures ($), and standard deviation in parenthesis, obtained from follow-up telephone interview on the Cahaba, Coosa, and Locust Fork Rivers, AL in 2020 and 2021.

River	Category	Mean Expenditures
Cahaba (N=5)		
	Fuel	61 (90)
	Lodging	32 (72)
	Grocery	42 (35)
	Restaurant	34 (71)
	Equipment	0
	Total	169 (253)
Coosa (N=12)		
	Fuel	49 (42)
	Lodging	0
	Grocery	33 (35)
	Restaurant	11 (19)
	Equipment	25 (34)
	Total	118 (85)
Locust Fork (N=12)		
	Fuel	42 (23)
	Lodging	23 (81)
	Grocery	30 (42)
	Restaurant	12 (39)
	Equipment	51 (172)
	Total	157 (229)

Table 3.7. Summary of angler variable means (SD in parenthesis) by species targeted, collected on the roving creel and follow-up telephone surveys on Cahaba, Coosa, and Locust Fork Rivers, Alabama from May – December 2020 and March – December 2021. Variables include: Roundtrip distance - origination site to access point site to origination site, Days Fished - number of days fished on the river in the 12 months before the interview, Quality- perceived quality of fishing (1 = poor, 5 = excellent), Alt. Site Distance – roundtrip distance from place of residence to alternative access site, Age – age of angler in years, Years Fished – number of years angler has fished, Household Income – annual household income ($), Percent of Trips Harvesting Fish (%) – percentage of angler trips in which fish are harvested.

River	Variable	Bass	Catfish	Sunfish	Striped Bass	Anything	All
Cahaba	Distance (km.)	73 (108)	55 (27)	19 (17)	-	32 (39)	58 (86)
	Days Fished	22 (22)	18 (13)	30 (5)	-	35 (48)	28 (37)
	Quality	3.5 (1.1)	4.5 (0.7)	4 (0)	-	2.8 (0.8)	3.3 (1.2)
	Alt. Site Distance (km.)	94 (67)	65 (65)	91 (60)	-	57 (30)	83 (60)
	Age	34 (10)	33 (18)	27 (8)	-	60 (21)	37 (15)
	Years Fished	22 (11)	26 (12)	21 (6)	-	44 (28)	26 (16)
	Household Income ($)	85,062 (39,665)	54,600 (27,982)	60,666 (35,232)	-	80,181 (35,810)	82,490 (37,498)
	Percent of Trips Harvesting Fish (%)	5 (8)	40 (14)	38 (18)	-	27 (23)	15 (20)

River	Variable	Bass	Catfish	Sunfish	Striped Bass	Anything	All
Coosa	Distance (km.)	79 (105)	62 (23)	123 (176)	65 (18)	72 (59)	73 (73)
	Days Fished	38 (70)	38 (58)	9 (8)	35(62)	37 (68)	37 (64)
	Quality	3.3 (1.2)	3.4 (1.1)	4.5 (0.7)	3.4 (1.5)	3.4 (1.1)	3.4 (1.2)
	Alt. Site Distance (km.)	64 (110)	38 (31)	31 (8)	38 (15)	48 (70)	47 (69)
	Age	41 (12)	41 (10)	41 (14)	47 (5)	45 (12)	43 (11)
	Years Fished	29 (15)	26 (8)	25 (7)	25 (15)	26 (10)	27 (11)
	Household Income ($)	85,806 (57,243)	72,166 (18,056)	63,857 (19,342)	76,250 (31,160)	71,555 (26,606)	75,014 (31,433)
	Percent of Trips Harvesting Fish (%)	18 (26)	82 (19)	53 (32)	56 (29)	65 (37)	52 (37)
Locust Fork	Distance (km.)	81 (99)	38 (25)	-	-	31 (17)	59 (77)
	Days Fished	62 (92)	40 (63)	-	-	8 (9)	44 (76)
	Quality	3.8 (1.1)	2.6 (1.5)	-	-	3 (0.8)	3.3 (1.2)

River	Variable	Bass	Catfish	Sunfish	Striped Bass	Anything	All
Locust Fork	Alt. Site Distance (km.)	75 (60)	44 (27)	-	-	54 (38)	62 (51)
	Age	39 (12)	36 (9.4)	-	-	40 (8)	39 (11)
	Years Fished	25 (11)	22 (11)	-	-	29 (15)	26 (11)
	Household Income ($)	80,363 (18,648)	73,000 (17,388)	-	-	78,777 (6,300)	79,073 (19,259)
	Percent of Trips Harvesting Fish (%)	14 (12)	70 (20)	-	-	30 (20)	26 (26)

Table 3.8. Total extrapolated angler expenditures ($) obtained from the follow-up telephone survey and trail camera effort estimates for the Cahaba, Coosa, and Locust Fork Rivers, AL, 2021.

	Cahaba River	Coosa River	Locust Fork
Fuel	145,229	94,006	63,994
Lodging	831	-	5,822
Restaurant	24,933	13,464	7,166
Grocery	104,885	25,757	58,935
Equipment	449,229	67,509	139,066
Total	725,634	200,737	272,976

Table 3.9. Total extrapolated recreational kayaker expenditures ($) obtained from the follow-up telephone survey and trail camera effort estimates for the Cahaba, Coosa, and Locust Fork Rivers, AL 2021.

	Cahaba	Coosa	Locust Fork
Fuel	582,040	238,271	159,403
Lodging	125,035	-	2,210
Restaurant	140,665	33,119	41,963
Grocery	609,548	274,045	120,056
Equipment	-	225,340	88,020
Total	1,457,289	770,776	411,654

Table 3.10. Alabama state tax revenue ($) generated from estimated angling expenditures on the Cahaba, Coosa, and Locust Fork Rivers in 2021.

	Cahaba	Coosa	Locust Fork
Fuel	40,664	26,321	17,918
Lodging	33	-	232
Restaurant	997	538	286
Grocery	4,195	1030	2,357
Equipment	17,969	2,700	5,562
Total	63,859	30,590	26,357

Table 3.11. Alabama state tax revenue ($) generated from estimated kayaking expenditures on the Cahaba, Coosa, and Locust Fork Rivers in 2021.

	Cahaba	Coosa	Locust Fork
Fuel	162,971	66,715	44,632
Lodging	5,001	-	88
Restaurant	5,626	1,324	1,678
Grocery	24,381	10,961	4,802
Equipment	-	9,013	3,520
Total	197,981	88,016	54,722

Table 3.12. Results from the travel cost model regression for all anglers on the Cahaba River, AL from the on-site and telephone surveys from May through December 2020 and February through December 2021. Dependent variable was annual visits.

Variable	Parameter Estimate	Standard Error	Pr(>|t|)
Intercept	3.211716	1.264850	0.016532
Travel cost per visit	-0.004897	0.001531	0.003242
Alternative site opportunity cost	0.017476	0.004219	0.000258
Log of household income	-0.166484	0.116550	0.163495
CPE	0.058382	0.035895	0.114305
DF (Error)	34		
DF (Model)	4		
Residual Deviance	15.137		
Consumer Surplus per angler visit	$204		
Consumer Surplus per angler trip	$185		
Log-likelihood	64		
Scaled Pearson X^2	14		

Table 3.13. Results from the travel cost model regression for recreational kayakers on the Cahaba River, AL from the on-site and telephone surveys from May to December 2020 and February through December 2021. Dependent variable was the natural log of annual visits.

Variable	Parameter Estimate	Standard Error	Pr(>|t|)
Intercept	-1.2309418	0.5457309	0.2657
Travel cost per visit	-0.0034807	0.0004471	0.0813
Alternative site opportunity cost	-0.0260768	0.0027741	0.0675
Log of household income	0.3212581	0.0504543	0.0992
DF (Error)	4		
DF (Model)	3		
Residual Deviance	0.024		
Consumer Surplus per visit	$287		
Consumer Surplus per trip	$239		
Log-likelihood	9		
Scaled Pearson X^2	1		

Table 3.14. Results from the travel cost model regression for all anglers on the Coosa River, AL from the on-site and telephone surveys from May through December 2020 and February through December 2021. Dependent variable was annual visits.

Variable	Parameter Estimate	Standard Error	Pr(>|t|)
Intercept	0.038976	1.233610	0.9749
Travel cost per visit	-0.003371	0.001881	0.0792
Alternative site opportunity cost	-0.004616	0.006845	0.5032
Log of household income	0.164099	0.115815	0.1627
Years of experience	-0.009077	0.005953	0.1336
Ethnicity	-0.107636	0.085970	0.2164
DF (Error)	55		
DF (Model)	5		
Residual Deviance	36.455		
Consumer Surplus per angler visit	$296		
Consumer Surplus per angler trip	$246		
Log-likelihood	101		
Scaled Pearson X^2	31		

Table 3.15. Results from the travel cost model regression for recreational kayakers on the Coosa River, AL from the on-site and telephone surveys from May to December 2020 and February through December 2021. Dependent variable was the natural log of annual visits.

Variable	Parameter Estimate	Standard Error	Pr(>|t|)
Intercept	2.210142	2.099936	0.328
Travel cost per visit	-0.003363	0.002637	0.243
Alternative site opportunity cost	0.008515	0.012787	0.527
Log of household income	-0.032204	0.196522	0.874
Years of experience	0.004736	0.006172	0.468
DF (Error)	11		
DF (Model)	4		
Residual Deviance	1.905		
Consumer Surplus per visit	$297		
Consumer Surplus per trip	$228		
Log-likelihood	21		
Scaled Pearson X^2	2		

Table 3.16. Results from the travel cost model regression for all anglers on the Locust Fork, AL from the on-site and telephone surveys from May through December 2020 and February through December 2021. Dependent variable was annual visits.

Variable	Parameter Estimate	Standard Error	Pr(>|t|)
Intercept	2.484076	2.711116	0.3695
Travel cost per visit	-0.006534	0.003557	0.0797
Alternative site opportunity cost	-0.008492	0.009727	0.3921
Log of household income	-0.134383	0.249411	0.5954
Years of experience	-0.006213	0.008049	0.4484
Trip Quality	0.248928	0.097066	0.0177
DF (Error)	27		
DF (Model)	5		
Residual Deviance	13.673		
Consumer Surplus per angler visit	$153		
Consumer Surplus per angler trip	$126		
Log-likelihood	49		
Scaled Pearson X^2	14		

Table 3.17. Results from the travel cost model regression for recreational kayakers on the Locust Fork, AL from the on-site and telephone surveys from May to December 2020 and February through December 2021. Dependent variable was the natural log of annual visits.

Variable	Parameter Estimate	Standard Error	Pr(>|t|)
Intercept	5.548206	2.703403	0.0793
Travel cost per visit	-0.003513	0.002867	0.2600
Alternative site opportunity cost	0.016746	0.011557	0.1906
Log of household income	-0.405645	0.263886	0.1681
Years of experience	0.031872	0.014175	0.0593
DF (Error)	11		
DF (Model)	4		
Residual Deviance	3.042		
Consumer Surplus per visit	$284		
Consumer Surplus per trip	$246		
Log-likelihood	22		
Scaled Pearson X^2	3		

Table 3.18. Average angler use loss time from angler responses to fish kill contingent valuation question from the on-site survey on the Cahaba, Coosa, and Locust Fork Rivers, AL from May through December 2020 and February through December 2021. Survey question elicited angler response concerning the duration of time that would have to elapse before they returned to the fishery at varying severities of target species lost due to a fish kill.

	Percent of preferred target species abundance lost (%)								
	10	20	30	40	50	60	70	80	90
Angler use loss duration (months)	1	3	9	9	14	22	21	26	35
Angler use loss duration (years)	0.09	0.27	0.82	0.78	1.15	1.84	1.76	2.16	2.9

Table 3.19. Average recreational kayaker loss time from kayaker responses to fish kill contingent valuation question from the on-site survey on the Cahaba, Coosa, and Locust Fork Rivers, AL from May through December 2020 and February through December 2021. Survey question elicited kayaker response concerning the duration of time that would have to elapse before they returned to the river at varying severities of fish abundance lost due to a fish kill.

	Percent of fish abundance lost (%)								
	10	20	30	40	50	60	70	80	90
Kayaker use loss duration (months)	4	4	5	6	4	7	14	22	20
Kayaker use loss duration (years)	0.35	0.41	0.45	0.5	0.37	0.6	1.2	1.8	1.7

Table 3.20. Summary of the number of estimated trips, associated expenditures, and consumer surplus values lost due to fish kills of varying severities for the Cahaba River, AL, based upon angler and recreational kayaker contingent valuation responses.

	Percent of fish abundance lost (%)								
	10	20	30	40	50	60	70	80	90
Angler trips	558	1,675	5,086	4,838	7,133	11,142	10,916	13,397	17,987
Kayaker trips	3,018	3,535	3,880	4,312	3,191	5,174	10,348	15,521	14,659
Total	3,576	5,210	8,966	9,149	10,323	16,586	21,264	28,918	32,646
Direct angler expenditures ($)	65,311	195,932	595,052	566,025	834,524	1,335,238	1,277,184	1,567,454	2,104,452
Direct kayaker expenditures ($)	510,050	597,488	655,779	728,644	539,196	874,372	1,748,744	2,623,117	2,477,388
Total ($)	575,361	793,419	1,250,831	1,294,668	1,373,720	2,209,610	3,025,929	4,190,570	4,581,839
Angler Consumer Surplus ($)	103,269	309,807	940,894	894,997	1,319,546	2,111,274	2,019,480	2,478,452	3,327,552
Kayaker Consumer Surplus ($)	721,314	844,968	927,404	1,030,449	762,532	1,236,538	2,473,076	3,709,615	3,503,525
Total ($)	824,583	1,154,774	1,868,298	1,925,445	2,082,078	3,347,812	4,492,556	6,188,067	6,831,077

	Percent of fish abundance lost (%)								
	10	20	30	40	50	60	70	80	90
Angler WTP ($)	168,579	505,738	1,535,946	1,464,022	2,154,070	3,446,512	3,296,664	4,045,906	5,432,003
Kayaker WTP ($)	1,231,364	1,442,455	1,583,183	1,759,092	1,301,728	2,110,910	4,221,821	6,332,731	5,980,913
Total WTP ($)	1,399,944	1,948,194	3,119,129	3,220,114	3,455,798	5,557,423	7,518,485	10,378,637	11,412,916

Table 3.21. Summary of the number of estimated trips, associated expenditures, and consumer surplus values lost due to fish kills of varying severities for the Coosa River, AL, based upon angler and recreational kayaker contingent valuation responses.

	Percent of fish abundance lost (%)								
	10	20	30	40	50	60	70	80	90
Angler trips	354	1,063	3,228	3,070	4,527	7,243	6,928	8,502	11,415
Kayaker trips	2,286	2,678	2,940	3,266	2,417	3,919	7,839	11,758	11,105
Total	2,640	3,741	6,168	6,336	6,944	11,162	14,767	20,260	22,520
Direct angler expenditures ($)	18,067	54,202	164,612	156,582	230,858	369,373	353,314	433,612	582,165
Direct kayaker expenditures ($)	269,785	316,034	346,867	385,408	285,202	462,489	924,978	1,387,468	1,310,386
Total ($)	287,852	370,236	511,479	541,990	516,060	831,862	1,278,292	1,821,080	1,892,551
Angler Consumer Surplus ($)	87,148	261,443	794,011	755,279	1,113,552	1,781,683	1,704,219	2,091,541	2,808,088
Kayaker Consumer Surplus ($)	521,280	610,643	670,217	744,686	551,068	893,623	1,787,246	2,680,870	2,531,932
Total ($)	608,428	872,086	1,464,228	1,499,965	1,664,620	2,675,306	3,491,465	4,772,411	5,340,020

	Percent of fish abundance lost (%)								
	10	20	30	40	50	60	70	80	90
Angler WTP lost ($)	105,215	315,645	958,623	911,861	1,344,410	2,151,056	2,057,533	2,525,153	3,390,253
Kayaker WTP lost ($)	791,065	926,677	1,017,084	1,130,094	836,270	1,356,112	2,712,224	4,068,338	3,842,318
Total WTP lost ($)	896,280	1,242,322	1,975,707	2,041,955	2,180,680	3,507,168	4,769,757	6,593,491	7,232,571

Table 3.22. Summary of the number of estimated trips, associated expenditures, and consumer surplus values lost due to fish kills of varying severities for the Locust Fork, AL, based upon angler and recreational kayaker contingent valuation responses.

	Percent of fish abundance lost (%)								
	10	20	30	40	50	60	70	80	90
Angler trips	279	838	2,544	2,420	3,567	5,708	5,461	6,702	8,998
Kayaker trips	918	1,075	1,180	1,311	970	1,574	3,147	4,721	4,459
Total	1,197	1,913	3,724	3,731	4,537	7,282	8,608	11,423	13,457
Direct angler expend. ($)	24,574	73,722	223,895	212,973	313,932	502,332	480,555	589,772	791,824
Direct kayaker expend. ($)	144,116	168,821	185,291	205,879	152,351	247,055	494,006	741,166	699,990
Total ($)	168,690	242,543	409,186	418,852	466,283	749,387	974,561	1,330,938	1,491,814
Angler Consumer Surplus ($)	35,185	105,556	320,577	304,939	449,494	719,248	688,068	844,447	1,133,748
Kayaker Consumer Surplus ($)	260,693	305,383	335,177	372,419	275,590	446,902	893,615	1,340,707	1,266,223
Total ($)	295,878	410,939	655,754	677,358	725,084	1,166,150	1,581,683	2,185,154	2,399,971

	Percent of fish abundance lost (%)								
Angler WTP ($)	59,759	179,278	544,472	517,912	763,426	1,221,580	1,168,623	1,434,219	1,925,572
Kayaker WTP ($)	404,809	474,204	520,710	578,298	427,941	693,957	1,387,621	2,081,873	1,966,213
Total WTP ($)	464,568	653,482	1,065,182	1,096,210	1,191,367	1,915,537	2,556,244	3,516,092	3,891,785

Figures

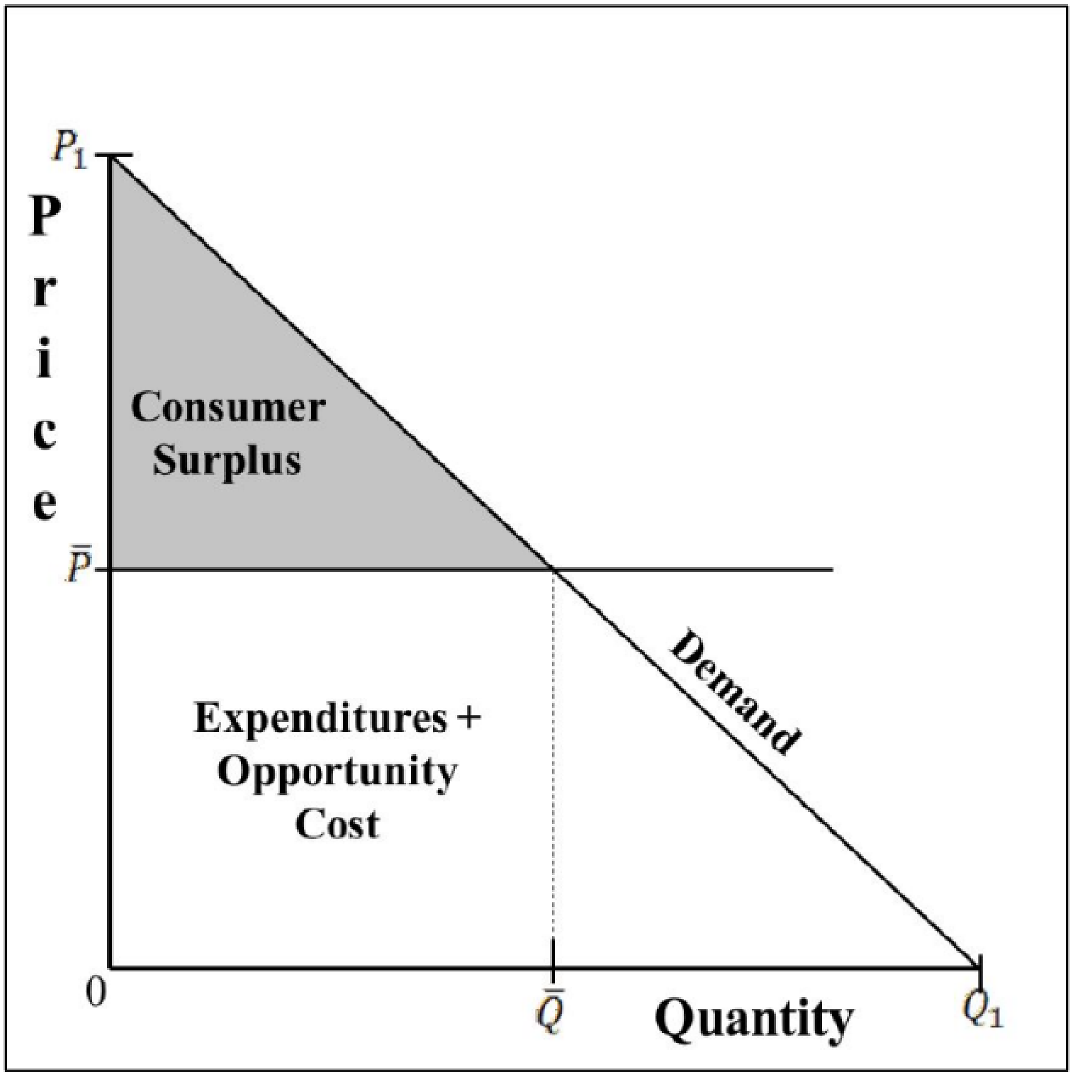


Figure 3.1. Graphical representation of a demand curve (quantity demanded) and consumer surplus. P_1 is the maximum visit price that one is willing to pay and Q_1 is the maximum number of visits a consumer will demand at a price of $0. $\bar{P}$ is the equilibrium (mean) price paid and $\bar{Q}$ is the equilibrium (mean) number of visits demanded by a typical (average) consumer. Consumer surplus is the willingness-to-pay for a recreational visit above and beyond a person's actual visit expenditures and is the area below the recreational visit demand curve and above the equilibrium visit cost ($\bar{P}$). Expenditures are actual purchases incurred by the person on the visit plus the opportunity cost of time based on the respondent's wage rate and the calculated roundtrip travel time to the site. Taken from Parsons (2003).

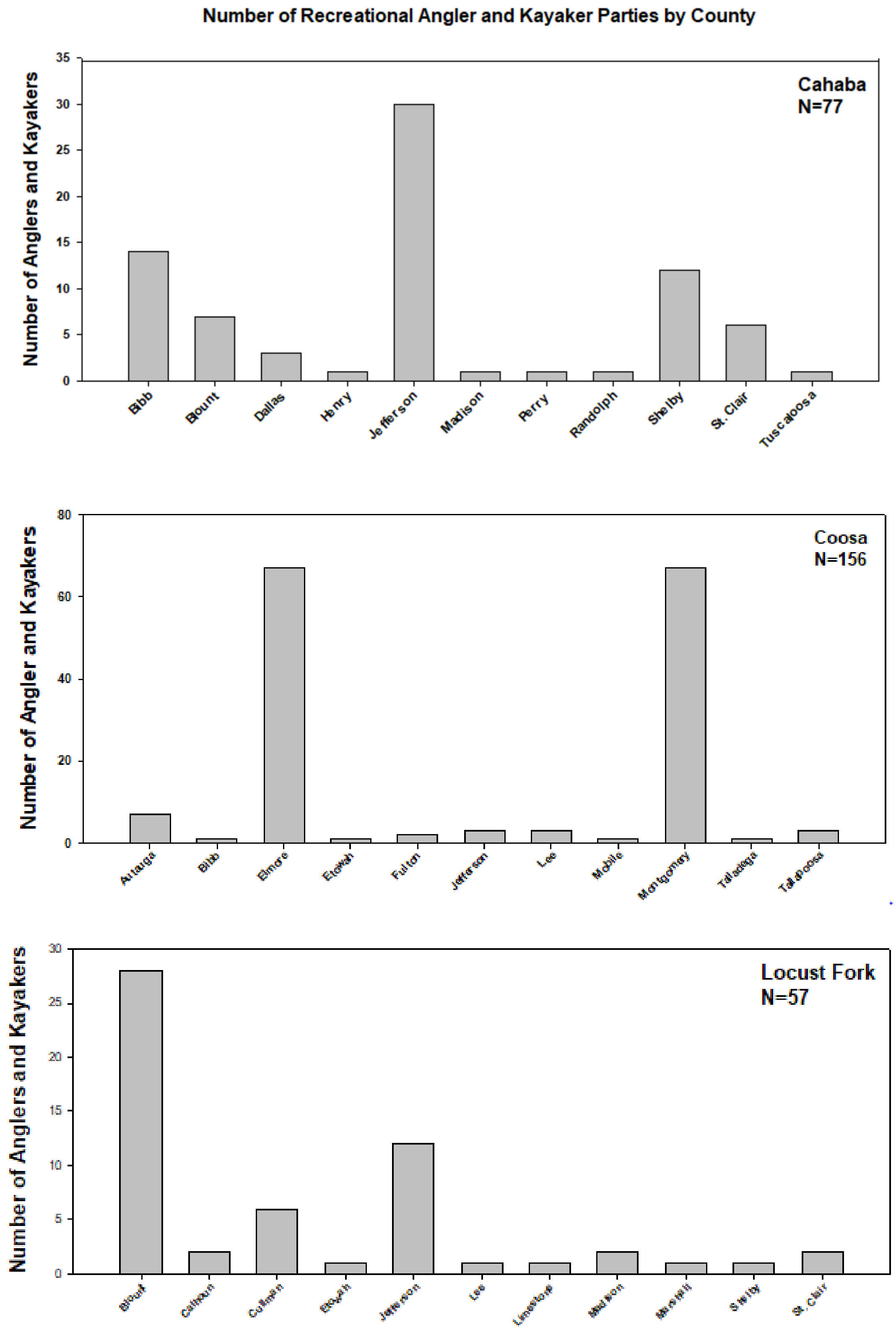
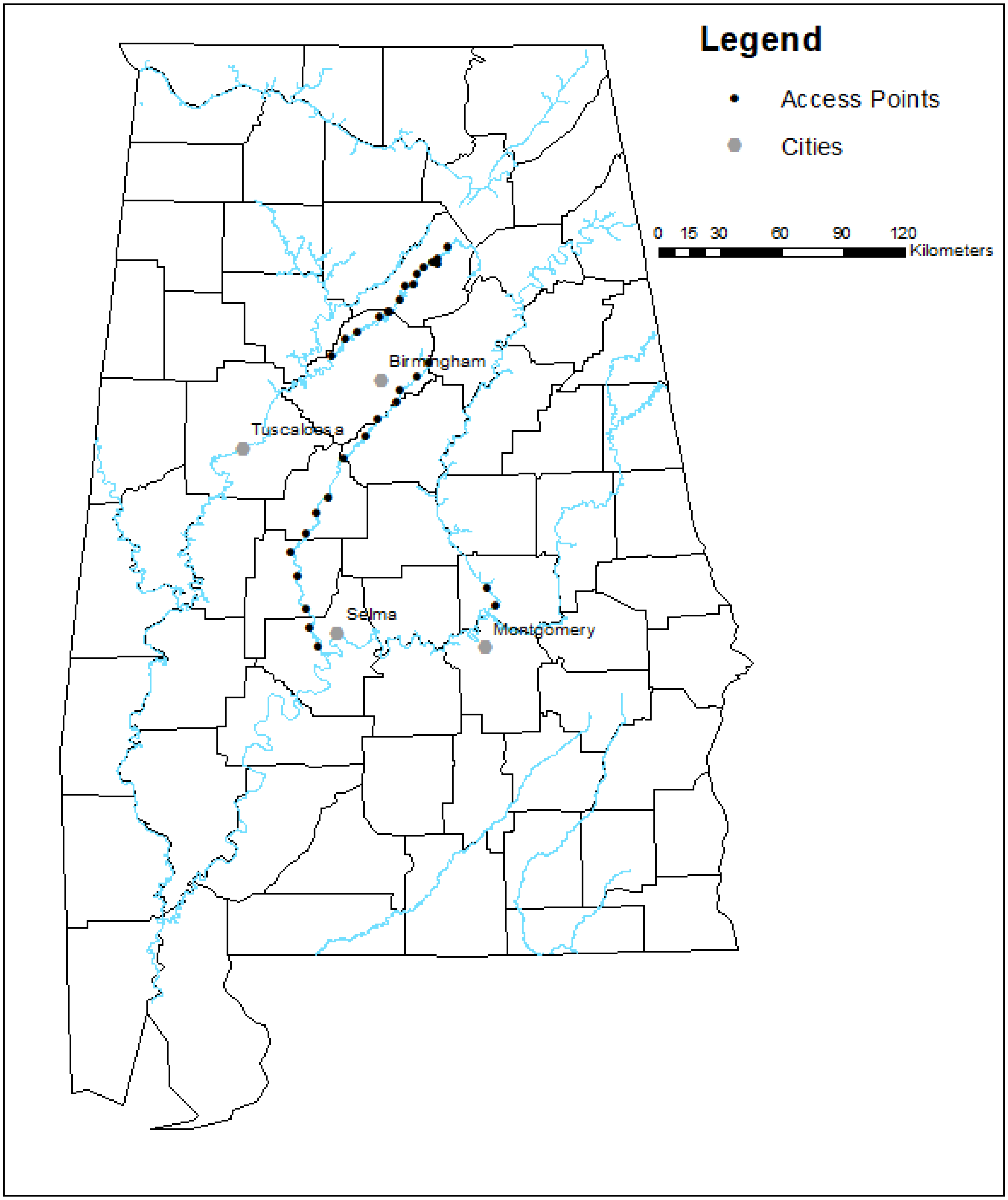


Figure 3.2. Number of angler and kayaker parties interviewed by county of residence.

Appendix

A.1. Access points on the Cahaba, Coosa, and Locust Fork Rivers



A.2. On-site Roving Creel Survey Form

AL Rivers Interview Form 2020
Date: ______ Time: ______ River: ______ Section: ______ Creel Clerks: ______ Interview #: ______
WPT: ______ Latitude: ______ Longitude: ______
Circle One: *Boat* *Canoe/Kayak* *Wading* *Other*________
Hello, we are working with Auburn University Fisheries Department…May we interview you? *Y N*

---

1. What are you primarily fishing for*? Bass / Crappie / Sunfish / Catfish / Striped Bass / Anything / Other*______
2. How many of each species have you caught today?

Bass	Crappie	Sunfish	Catfish	Striped Bass
Keep: _____	Keep: _____	Keep: _____	Keep: _____	Keep: _____
Release: _____	Release: _____	Release: _____	Release: _____	Release: _____

3. Is this a guided trip? *Y N*

4. Have we contacted you before about this survey? *Y N*
   a. If **YES**, Have we contacted you on this particular fishing trip? *Y N*

5. What time did you start fishing today? ______
   a. What time do you expect to quit fishing today? ______

6. What city do you live in?
   a. City: _______________ State: ______
   b. Trip type: *Day* *Overnight* If overnight, how many days? ______
   c. Launch Site: ______________________
   d. Riverfront Property? *Y N Cabin*

7. How many miles 1-way did you travel from your home to fish? ______

8. How much will your completed trip cost, including gas, lodging, food, drinks, ice, fishing equipment, license fees, and any other items? ________ **Circle One**: *Individual* *Boat/Party*
   a. Of the $xxx you will spend on this trip, how much will be spent within "20" miles of this river section? _______
9. How many days have you fished for *species* at this section of the river in the past 12 months? _____

10. If a fish kill were to occur on river and X% of *target species* were absent from the system, how long would it be before you return to fish? _____

11. In the case of a fish kill as described on river, how long do you think it would be until the fishery fully recovers? _____

12. Number of adult anglers in party ____m ____f :::::: Number of children <16 ____m ____f

13. Would you be willing to allow us to contact you by phone for a more detailed survey? *Y N*
Contact Information: Name: _________________ Phone Number: _______________________
M/F Age: _____ Ethnicity: ________ Occupation: ___________________

A.3. Follow-up Telephone Survey

AL River Creel Telephone Survey

Call Date: _______ *Clerk:* ____ *Call Attempts:* ____ *Interview #:* _____ *Name:* _____________________ *Target Species:* _______ *River:* _____________
Creel Telephone: __________________ *Creel Fishing Trip Total Cost (yyy):* ______ *Creel Date:* ____________ *Was the survey completed? Y N*

Hello, I am with Auburn University Fisheries Department. I contacted you on ______________ River (Locust Fork, Cahaba, or Coosa) on date. You gave me permission to conduct a follow up survey about your fishing trip that day. The interview should take only 10 minutes of your time. All the information you give me today will remain confidential, anonymous, and no one will try to sell you anything. May I interview you?

1. Was fishing for *target species* your sole purpose for visiting river? *Y N*
   - *a.* If NO what was the primary purpose of the trip? _________________________________

2. How many hours did you fish the day I interviewed you? _____________

3. For your fishing trip on date, the same trip I interviewed you when you were fishing for *target species*, would you rate the quality of that trip as poor, fair, average, good, or excellent? *Poor Fair Average Good Excellent*

4. Do you plan on returning to *river* to fish for *target species* in the future? *Y N*
   - ***a.*** ***(YES)*** How many trips do you expect you will go on within the next 12 months? ______________
   - ***b.*** ***(NO)*** Why not? ____

5. What put-in/ramp do you use the most? ________________________

6. Was this an overnight trip? *Y N*

7. How many days did you spend on *river*? ________

8. What kind of lodging did you use on the fishing trip? *Camping Home/Private Property Friends/Family Other*__________

IF Private Property:

a. Do you own, rent, or lease this property? (circle one) *Own Rent Lease*

IF they rented or leased a property:

b. How much do you pay to lease/rent? ______________per *month year*

c. Is fishing the primary reason you visit this property? *Y N*

d. What city, state is it in? _________________________

9. If fishing for *target species* was not available at river, where would you go fish for *target species* instead? _____________________________________

a. How many miles is (answer to #9) from your house one-way? ________

b. Which is better (circle one) *River* or *Answer to 9a*?

10. Do you ever fish *river* at night? Y N How many days per year? _____

11. Are you a member of any fishing clubs? Y N Name: ___________________________

12. Approximately, how many other rivers have you fished in Alabama this year? _______

a. What are the names of them? ____

b. Including *river*, which is your favorite to fish? ____

13. On how many of your fishing trips on *river* do you harvest fish? _____

14. How many years of fishing experience do you have? _____

15. Next, we'd like to break down your $xxx that you spent on the trip by what items and what town you bought it in. How much was spent and where was it bought for:

Item	Total Cost	Town/County	Cost	Town/County	Cost	Town/County	Cost
Fishing Equip/Bait							
Vehicle Gas							
Restaurant Meals							
Groceries/Ice/Drinks							
Lodging							

16. What is your household income? _________

17. Do you have any questions/comments?

A.4. Number of recreational angling and kayaking parties contacted during roving creel survey by county of Alabama residence on Cahaba, Coosa, and Locust Fork Rivers, AL in 2020 and 2021.

River	County	Total	Bass	Crappie	Sunfish	Catfish	Anything	Striped Bass	Kayaker
Cahaba	Bibb	14	5	1	1	1	1	0	5
	Blount	7	1	0	0	0	6	0	0
	Dallas	3	0	0	0	2	0	0	1
	Henry	1	1	0	0	0	0	0	0
	Jefferson	30	17	1	0	1	0	0	11
	Madison	1	0	0	0	0	0	0	1
	Perry	1	0	0	0	0	1	0	0
	Randolph	1	1	0	0	0	0	0	0
	Shelby	12	4	0	2	2	1	0	3
	St. Clair	6	2	0	0	1	0	0	3
	Tuscaloosa	1	1	0	0	0	0	0	0
	Total	77	32	2	3	7	9	0	24
Coosa	Autauga	7	1	0	1	3	0	0	2
	Bibb	1	1	0	0	0	0	0	0
	Elmore	67	19	2	4	11	20	4	7
	Etowah	1	0	0	0	0	0	0	1
	Fulton	2	0	0	1	0	1	0	0
	Jefferson	3	0	0	0	0	1	0	2
	Lee	3	2	0	0	0	1	0	0
	Mobile	1	1	0	0	0	0	0	0
	Montgomery	67	7	1	1	14	25	12	7
	Talladega	1	0	0	0	0	0	0	1
	Tallapoosa	3	0	0	0	2	0	0	1
	Total	156	31	3	7	30	48	16	21
Locust Fork	Blount	28	11	0	1	4	7	0	5

River	County	Total	Bass	Crappie	Sunfish	Catfish	Anything	Striped Bass	Kayaker
Locust Fork	Calhoun	2	0	0	0	0	0	0	2
	Cullman	6	2	0	0	1	1	0	2
	Etowah	1	1	0	0	0	0	0	0
	Jefferson	12	4	0	0	3	1	0	4
	Lee	1	1	0	0	0	0	0	0
	Limestone	1	0	0	0	0	0	0	1
	Madison	2	1	0	0	0	0	0	1
	Marshall	1	1	0	0	0	0	0	0
	Shelby	1	0	0	0	1	0	0	0
	St. Clair	2	1	0	0	0	0	0	1
	Total	57	22	0	1	9	9	0	16

A.5. Results from the travel cost model regression for anglers targeting bass on the Cahaba River, AL from the on-site and telephone surveys from May through December 2020 and February through December 2021. Dependent variable was annual *visits*.

Variable	Parameter Estimate	Standard Error	Pr(>|t|)
Intercept	1.027576	2.254809	0.6540
Travel cost per visit	-0.004072	0.003424	0.2498
Alternative site opportunity cost	-0.006699	0.005888	0.2701
Log of household income	0.026916	0.209970	0.8994
Bass CPE	0.075329	0.040225	0.0774
Years of experience	0.013294	0.009869	0.1947
DF (Error)	23		
DF (Model)	5		
Residual Deviance	10.630		
Consumer Surplus per angler visit	$245		
Consumer Surplus per angler trip	$204		
Log-likelihood	44		
Scaled Pearson X^2	10		

A.6. Results from the travel cost model regression of anglers targeting other species (Sunfish, Catfish, Anything) on the Cahaba River, AL from the on-site and telephone surveys from May through December 2020 and February through December 2021. Dependent variable was annual *visits*.

Variable	Parameter Estimate	Standard Error	Pr(>|t|)
Intercept	4.104408	1.414871	0.0273
Travel cost per visit	-0.005597	0.003040	0.1152
Alternative site opportunity cost	0.002440	0.013094	0.8583
Log of household income	-0.243877	0.140893	0.1342
Years of experience	0.008676	0.004507	0.1025
DF (Error)	10		
DF (Model)	4		
Residual Deviance	1.791		
Consumer Surplus per angler visit	$178		
Consumer Surplus per angler trip	$161		
Log-likelihood	19		
Scaled Pearson X^2	2		

A.7. Results from the travel cost model regression for anglers targeting bass on the Coosa River, AL from the on-site and telephone surveys from May through December 2020 and February through December 2021. Dependent variable was annual *visits*.

Variable	Parameter Estimate	Standard Error	Pr(>|t|)
Intercept	-2.290083	2.744332	0.4040
Travel cost per visit	-0.008258	0.002935	0.0049
Alternative site opportunity cost	0.007044	0.015423	0.6479
Log of household income	0.518713	0.272262	0.0568
Years of experience	-0.033579	0.016744	0.0449
Ethnicity	-0.839731	0.473419	0.0761
DF (Error)	18		
DF (Model)	5		
Residual Deviance	18.206		
Consumer Surplus per angler visit	$121		
Consumer Surplus per trip	$121		
Log-likelihood	31		
Scaled Pearson X^2	15		

A.8. Results from the travel cost model regression for anglers targeting other species (Sunfish, Catfish, Striped Bass, Skipjack Herring, Anything) on the Coosa River, AL from the on-site and telephone surveys from May through December 2020 and February through December 2021. Dependent variable was annual *visits*.

Variable	Parameter Estimate	Standard Error	Pr(>|t|)
Intercept	1.919960	1.6582258	0.255
Travel cost per visit	-0.005058	0.004709	0.290
Alternative site opportunity cost	0.006249	0.020848	0.766
Log of household income	-0.021129	0.152106	0.890
Years of experience	-0.008284	0.006660	0.222
DF (Error)	37		
DF (Model)	4		
Residual Deviance	18.106		
Consumer Surplus per angler visit	$197		
Consumer Surplus per trip	$164		
Log-likelihood	67		
Scaled Pearson X^2	18		

A.9. Results from the travel cost model regression for anglers targeting bass on the Locust Fork, AL from the on-site and telephone surveys from May through December 2020 and February through December 2021. Dependent variable was annual *visits*.

Variable	Parameter Estimate	Standard Error	Pr(>|t|)
Intercept	0.715863	4.491522	0.8704
Travel cost per visit	-0.007898	0.003467	0.0459
Alternative site opportunity cost	-0.011634	0.010770	0.3054
Log of household income	0.037807	0.414032	0.9290
Years of experience	-0.024051	0.010286	0.0415
Trip Quality	0.349614	0.128749	0.0217
DF (Error)	15		
DF (Model)	4		
Residual Deviance	4.443		
Consumer Surplus per angler visit	$126		
Consumer Surplus per angler trip	$105		
Log-likelihood	26		
Scaled Pearson X^2	4		

A.10. Results from the travel cost model regression for anglers targeting other species (Sunfish, Catfish, Anything) on the Locust Fork, AL from the on-site and telephone surveys from May through December 2020 and February through December 2021. Dependent variable was annual *visits*.

Variable	Parameter Estimate	Standard Error	Pr(>|t|)
Intercept	2.649801	3.46125	0.473
Travel cost per visit	-0.009391	0.011643	0.451
Alternative site opportunity cost	0.007091	0.030689	0.825
Log of household income	-0.121556	0.307343	0.706
Years of experience	0.001080	0.018239	0.955
Trip Quality	0.100717	0.143284	0.508
DF (Error)	11		
DF (Model)	5		
Residual Deviance	4.2625		
Consumer Surplus per angler visit	$106		
Consumer Surplus per angler trip	$88		
Log-likelihood	21		
Scaled Pearson X^2	5		