SAMPLING CHARACTERISTICS OF THE BUS ROUTE SURVEY TECHNIQUE IN THE JAMES RIVER, VIRGINIA

by

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(ABSTRACT)

The bus route survey technique is a new on-site angler survey technique that was developed for small rivers, with remote access points and low angler use. The technique employs vehicle counts to collect angler effort information. Interviews are conducted at access points to collect user characteristic and catch data from arriving, mid-trip, or departing anglers. This technique was modified to sample total recreational use on 306 km of the James River from Glen Wilton to Richmond, Virginia. The river was spatially stratified into 6 areas, two urban areas (Areas 5 and 6), and four rural areas (Areas 1-4). The two-year study was conducted from March through November, in 1988 and 1989.

In order to compare the bus route technique in a large riverine system, I conducted four 4-day intensive sampling days, two weekend and two week days, in Areas 1 and 4 during each year. During these periods a complete as possible access-point survey was conducted simultaneously with the bus route survey. Surveyors for both techniques collected effort, user characteristic, and catch data from several user groups. Aerial flights were also conducted to estimate effort during the 4-day intensive sampling periods. Effort estimates of the bus route and complete access-point surveys were similar in both areas, however aerial surveys collected 205 (29%) more hours of effort per sample because it included users accessing the river

through undefined or private access points. Data collected on most user characteristics were not significantly different among methods. In three of four sampling periods catch was not significantly different between the bus route and complete access-point techniques, but in 1988, Area 4, catch was statistically higher for the complete access-point surveys. To solve this problem of underestimating case with the bus route survey more afternoon samples must be conducted to intercept departing anglers.

In areas with more than 15 access points or driving time between access points is longer than half the survey day, the bus route can be extended over a two-day period, or a sub-sample of a number of access points can be surveyed. A 4-day intensive sampling period was conducted in 1989, Area 1 during the summer season to compare effort, user characteristics, and catch data between two-day, sub-sampling, and complete access-point surveys. Also, 26 sampling days were conducted in 1989, Area 1 during the summer season to compare effort, user characteristics, and catch between two-day and sub-sampling bus route techniques. No significant difference in effort, and certain (9) user characteristics, or angler catch data was detected between bus route modifications or the complete access-point survey. Also, no significant differences in effort, user characteristics (11), and angler catch variables (2) were detected between the two-day and sub-sampling methods that were conducted throughout the entire summer period.

The bus route survey was designed to have equal daily probabilities. When unequal daily probabilities are used, the daily effort formula becomes complex. Daily effort, user characteristics, and catch data were compared from interviews conducted in morning and afternoon samples in 1989, Area 4 during the summer season. Results showed no statistical difference in effort although a mean of 72 (52%) more hours of effort were collected per afternoon sampling period. Most user characteristics were not significantly different, but a larger proportion of departing users were interviewed in the afternoon period (54%) then the morning period (22%). Because only two departing interviews in the early sampling period were anglers, catch estimates could not be compared between the two periods. If collecting catch data is an important survey objective, then more afternoon bus route sampling periods must be conducted.

Acknowledgements

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CHAPTER 1: INTRODUCTION

Since the early 1940s, fisheries managers have used creel surveys to collect information on angler effort, harvest, and fishing success. Traditionally, surveys have helped evaluate: tailwater fisheries (Fry 1962; Boles 1968; Aggus et al. 1977; Hanson 1977); effects of species introductions at power plants (Hanson 1974; Schneider et al. 1977); general species introductions (Hanson and Dillard 1975; Campbell et al. 1978; Crandall 1978); size limit changes (Surber 1968; England and Fatora 1974; Kauffman 1983); standing timber benefits (Burress 1961); angler traits (Jarmen et al. 1968; Von Geldern 1972; Lingerfelter and Summerfelt 1973; Palm and Malvestuto 1983; McGurrin 1986); and total recreational use (Hanson and Dillard 1978, Fleener 1974, 1976, 1982, 1988 1989; Hess and Ober 1981; Haverland 1990; Missouri Department of Conservation 1990). Managers and researchers also have used surveys to assess economic benefits (Weithman and Haas 1982; Palm and Malvestuto 1983).

Even with such widespread applications, most angler surveys have not traditionally received statistical and theoretical evaluation. Many surveys are simply results-oriented management tools without statistical testing either before or after data collection. Effort, catch, and harvest results are often reported without variability estimates such as confidence limits.

Carlander et al. (1958) emphasized that many survey designs were inadequate and imprecise and that survey methodology needed to address the statistical framework, so representative data could be collected without biases. He stated that the sampling scheme should consider hourly, daily, and seasonal differences in fishing effort as well as the difference in angler distribution throughout the resource.

Recently, these concerns have been addressed at angler survey symposia, held in Destin, Florida in 1988 and Houston, Texas in 1990 (Guthrie et al. 1991). Through these symposia, fisheries professionals stressed that creel surveys are important sampling tools to collect angler information and they allow researchers and managers to check on fish populations and other sampling techniques. These symposia allowed participants to share statistical techniques to make surveys more accurate and precise and help eliminate common biases associated with surveys. Finally, these symposia have generated new approaches for designing surveys for difficult systems such as riverine environments.

Survey Design Considerations

Angler surveys measure angler effort (pressure), catch or harvest, and user characteristics. For roving surveys, angler effort is determined by angler counts at randomly selected times throughout the survey period. For access-point surveys, angler effort is calculated by expanding the number of angling hours of each departing angler interviewed. Angler effort estimates mean resource use for an average day. Angler catch and user characteristics are measured by interviewing anglers. Angler catch includes the species and numbers of fish caught, whereas harvest includes only the species and numbers of fish kept. User characteristics may include species preference, attitudes and comments about the trip or the resource, daily expenditures (gas, bait, food, lodging), distance traveled to the resource, and demographic information (town and county of residence).

Complete censuses rarely are used because of expansive study areas, prohibitive cost, and multiple access points; partial sampling is the only efficient means to effectively sample large survey areas. Old studies showed that by sampling 20-25 percent of the possible angling time yielded accurate estimates of angler effort when compared to a complete census (Best and Boles 1956; Johnson and Wroblewski 1962; Pfeiffer 1966; Van Den Avlye 1986).

Two standard design features are temporal and spatial stratification. Temporal stratification occurs when the survey period is divided into weeks, months, or other seasonal sampling periods. Seasonal strata can be further divided into weekend (and major holidays) and weekday sampling strata. Each sampling day can be partitioned further into morning, afternoon, and night periods. Stratification guarantees sampling of a predetermined number of units in each stratum (Van Den Avyle 1986). Also, temporal stratification improves precision and reduces variability when all strata are combined (Malvestuto 1983). A stratified design must allocate at least two samples per stratum to estimate precision and allow comparisons among strata (Van Den Avyle 1986).

Spatial stratification occurs when the study area is partitioned into smaller geographic units by dividing the area into separate physiographic or angler usage areas. Ecological division is achieved by placing different ecotypes (e.g. tributary arms, pelagic areas of reservoirs) into separate sampling areas. Angler effort division is achieved by separating study areas based on amounts or kinds of fishing effort. Therefore, spatial stratification gives more precise data than an unstratified design. Malvestuto (1983) stated that most survey designs use stratified two-stage sampling designs. Primary sampling units such as days are chosen first. Secondary sampling units, such as lake areas or diel time periods, are then chosen.

Allocation of sampling effort among strata is achieved by uniform or nonuniform probability sampling. Uniform probability sampling, or simple random sampling, means that every area has an equal chance of being sampled. The major advantage of this technique is that no prior study area knowledge is required; the major disadvantage is low survey efficiency because few anglers are contacted in low-use sampling units.

Nonuniform probability sampling assigns unequal weights to sampling units based on the "expected" fishing effort (from previous field studies) or time distribution in each stratum (Lambou 1961; Malvestuto et al. 1978). This method improves survey efficiency by increasing the number of anglers contacted per sampling day because sampling is concentrated in heavily fished areas. This approach is unbiased if each sampling unit is allotted a non-zero weight and the sum of all sampling units equals one (Malvestuto et al. 1978; Malvestuto 1983; Van Den Avyle 1986). The major disadvantage is the need for prior information to assign probabilities.

Two widely used effort allocation techniques are stratified random sampling, in which every sampling unit is assigned the same probability of selection (Abramson and Tolladay 1959), and stratified nonuniform probability sampling, in which each unit is given a sampling probability based on use (Malvestuto et al. 1978). General aspects of choosing stratified versus unstratified or uniform verses nonuniform probability sampling are described by Cochran (1977).

Angler Interception Methods

Three traditional data collection methods and one new data collection method will be discussed: access point and roving surveys, instantaneous aerial flights, and the bus route survey. Discussion of survey methodology will include the advantages and disadvantages of each method. Each of these methods collects data in two major areas: 1) effort information, estimated by angler or car counts, and 2) harvest and user characteristic data, gathered from angler interviews.

Access-point survey

The access-point survey stations a surveyor at a particular access point based on previously described methodology; information on angler catch and hours spent fishing is collected from all departing anglers. Total angler effort in hours is estimated by extrapolating the number of angler hours spent by the probability of picking that sampling unit (Van Den Avyle 1986). For example, if 10 hours of angler effort is collected at an access point with a probability of selection of 0.5, then a total 20 hours of angler effort will be calculated for the entire area. Total angler trips are estimated by dividing total hours by the average length of an angler trip. One advantage to access-point surveys is reliable harvest and effort information is collected. A major disadvantage is the potential inefficiency, in terms of angler interview numbers, collected at only one access point. Furthermore, access-point surveys may not sample certain users (e.g. bank anglers) who do not use specified access points.

Roving survey

The roving survey uses a surveyor who moves around an area (usually by boat) to intercept anglers. In small study areas, angler effort is collected by making a separate instantaneous angler count at a randomly selected time (Lambou 1961; Malvestuto et al. 1978). This instantaneous count provides an unbiased estimate of the average number of anglers for the survey day (Lambou 1961). Multiplying this count by the length of the recreational day (usually designated as sunrise to sunset) gives total daily effort (Lambou 1961). In large study areas where an instantaneous count can not be taken in less than one hour, a progressive count is used. The surveyor counts all users as he/she moves through the survey area. Extrapolation of use to a daily estimate is similar to instantaneous counts.

An advantage of the roving survey is the increased numbers of angler contacts per sampling day. In addition, roving clerks can sample bank anglers not using access points. A disadvantage is estimating catch per unit of effort from incomplete trip data (Carlander et al. 1958; Malvestuto et al. 1978). Robson (1960, 1961) stated that incomplete trip information is biased because of schooling behavior of some fish species and because different angling strategies and different fishing success rates exist throughout the day. Brown (1970) and Malvestuto et al. (1978), however, found that incompleted trip information provided a reliable estimator of catch per unit effort when compared to completed-trip catch per unit effort. Malvestuto's study was conducted on a large mainstem Alabama reservoir. Therefore, his findings are more applicable to large-scale survey areas.

Instantaneous aerial counts

Instantaneous aerial counts to estimate angler effort can also be used in conjunction with either an access point or roving survey. Angler effort is estimated by multiplying the length of the recreational day by the aerial count (Van Den Avyle 1986). User information is gathered via a separate on-site survey in conjunction with the aerial flight. Aerial flights, however, are expensive and subject to cancellation due to bad weather. Furthermore, distinctions among different user groups are difficult (Malvestuto 1983). Finally, underestimates of use can be substantial if visibility of users is blocked by overhanging trees.

Bus route survey technique

This access-point survey was developed for situations where low angling pressure among many access points exists, thus making angler counts and interviews difficult (Robson and Jones 1989). This method employs a surveyor who drives to each access point within a survey area each sampling day. Angler effort is related to the time the surveyor waits at the access point to the time the angler's car is parked there (Robson and Jones 1989). Thus, this method assumes that the angler's car is representative of the angler party fishing time. Although this technique has been shown to be unbiased for total party hours when simulated for a riverine angling population (Jones et al. 1990), no field validity tests have been done. Also, no field or simulation experiments have been performed on user characteristics or catch data.

The survey technique is analogous to a circular bus route (Robson and Jones 1989). Upon arriving at the access point, the surveyor counts all vehicles at the access point and interviews any arriving or departing anglers in order to collect information on catch and user characteristics. After waiting a specified time period, the surveyor drives to the next access point, counts vehicles and conducts interviews. This exact procedure is repeated for each access point along the route until the surveyor completes the entire route. A complete discussion on the process of setting up a survey route is found in the study area section (Chapter 2) or Nielsen et al. (1988).

This method has several advantages. First is randomness in design because a surveyor can start the sampling day at any point along the route and travel in either direction allowing for large area coverage in a single day, not just one access point. Second, departing anglers give completed trip information. Third, this method allows efficient data collection because interview and effort data are generated each sampling day. Finally, surveyor interest is maintained as they travel to several access points during the day, rather than remaining stationary for long time periods. Disadvantages include this method must be used with well defined and limited numbers of access points. Also, access points should be single purpose (e.g. angling only). Ways to minimize these problems can be found in Chapter 2.

This dissertation is organized into chapters. Chapter 2 describes the study area and gives an overview and a detailed example of the bus route survey technique. The first objective in Chapter 3 is to compare daily effort estimates between the bus route survey, a complete access-point survey, and aerial flights. The null hypothesis is that daily effort estimates between each pair of techniques will not be significantly different. The second objective, also in Chapter 3, is to compare user characteristics and catch data between the bus route survey and the complete access-point survey. The null hypothesis is that user characteristics and catch data of the two techniques will not significantly differ. The objective of Chapter 4 is to compare daily effort estimates, user characteristics, and catch data between a bus route survey that takes two days to complete and a sub-sampling bus route survey that samples a certain proportion of access points each day. The null hypothesis is that daily effort, user characteristics, and catch data will not be significantly different between the two techniques. The objective of Chapter 5 is to compare daily effort, user characteristics, and catch data between morning and afternoon sampling periods using a bus route survey with no overlapping time periods in the middle of the day. The null hypothesis is that daily effort, user characteristics, and catch data between the morning and afternoon time periods will not be significantly different. Finally, Chapter 6 compares applicability of the access-point, roving, aerial, and bus route survey methods based on eight survey criteria (e.g. type of survey, type of waterbody, cost per sampling day, etc).

CHAPTER 2: STUDY AREA AND BUS ROUTE TECHNIQUE

The James River originates in western Virginia at the confluence of the Cowpasture and Jackson Rivers below Iron Gate, Virginia. It flows southeasterly to Hampton Roads where it empties into the Chesapeake Bay. The James River basin encompasses 26,265 square kilometers and includes 39 counties and 18 cities while draining one-fourth of the state's land area (Sevebeck et al. 1986). The river discharges an average of 18,510 million liters per day (Sevebeck et al. 1986). Commercial navigation occurs below the fall line at Richmond where two major inland ports, Richmond and Hopewell, are found. The James River serves recreational and commercial purposes throughout the year. Major industry dependent on the river includes transportation, lumbering, and the manufacturing of chemicals, furniture, textiles, and apparel (Sevebeck et al. 1986).

The James River Recreational Survey study area extended from the confluence of the Cowpasture and Jackson Rivers to the I-95 bridge in Richmond, below which the river becomes tidal. This two-year project was conducted from March through November in 1988 and 1989. Each year was stratified into five sampling seasons including: early spring (March 1- April 14), late spring (April 15 - June 9), summer (June 10 - September 5), early fall September 6 - October 18), and late fall (October 19 - November 30). Each season was further stratified into weekend and weekday samples. Each sampling day was divided into an early (a.m.) start or a late (p.m.) start. For example, in the summer season a morning sampling period was conducted from 0700 to 1500 and an afternoon period was conducted from 1200 to

2000. The length of the recreational day was adjusted seasonally. For example, during the summer season when daylight was the longest the recreational day was from 0700 to 2000. During the late fall season when daylight was the shortest, the recreational day was from 0800 to 1700.

The 306-km study region was also stratified spatially based on ecological and angler-usage perspectives. I divided the river into four rural areas (one mountain and three piedmont sections) and two major urban areas (Lynchburg and Richmond), Figure 1. Area 1 was a 96-km mountainous region that encompassed the Glen Wilton access point to the access point above Snowden Dam. Area 2 was a 48-km piedmont region that encompassed Monocan Park to the access point at Bent Creek. Area 3 was a 80-km piedmont region that encompassed the Norwood access point to the Bremo Bluff access point. Area 4 was a 64-km piedmont region that encompassed the Columbia access point to the Watkins access point. Area 5 was a 16-km region that encompassed Richmond city from Bosher's Dam to the I-95 Bridge. Area 6 was 1.6 km long and encompassed Lynchburg City. Area 6 was sampled on the same days as Area 2. These six areas covered all major access points along the river. River reaches between the six areas were not covered but these regions were generally remote and for the most part inaccessible to river users. Users floating between areas could be interviewed as an arriving party at the lowest access part in one area and as a departing party at the upper most access point in the downstream area.

Use differed among areas and seasons. Area 1 had a muskellunge fishery in early spring and late fall and float-fishing for smallmouth bass throughout the year. Also, kayaking and canoeing were common recreational activities, especially through the 4.8-km gorge from

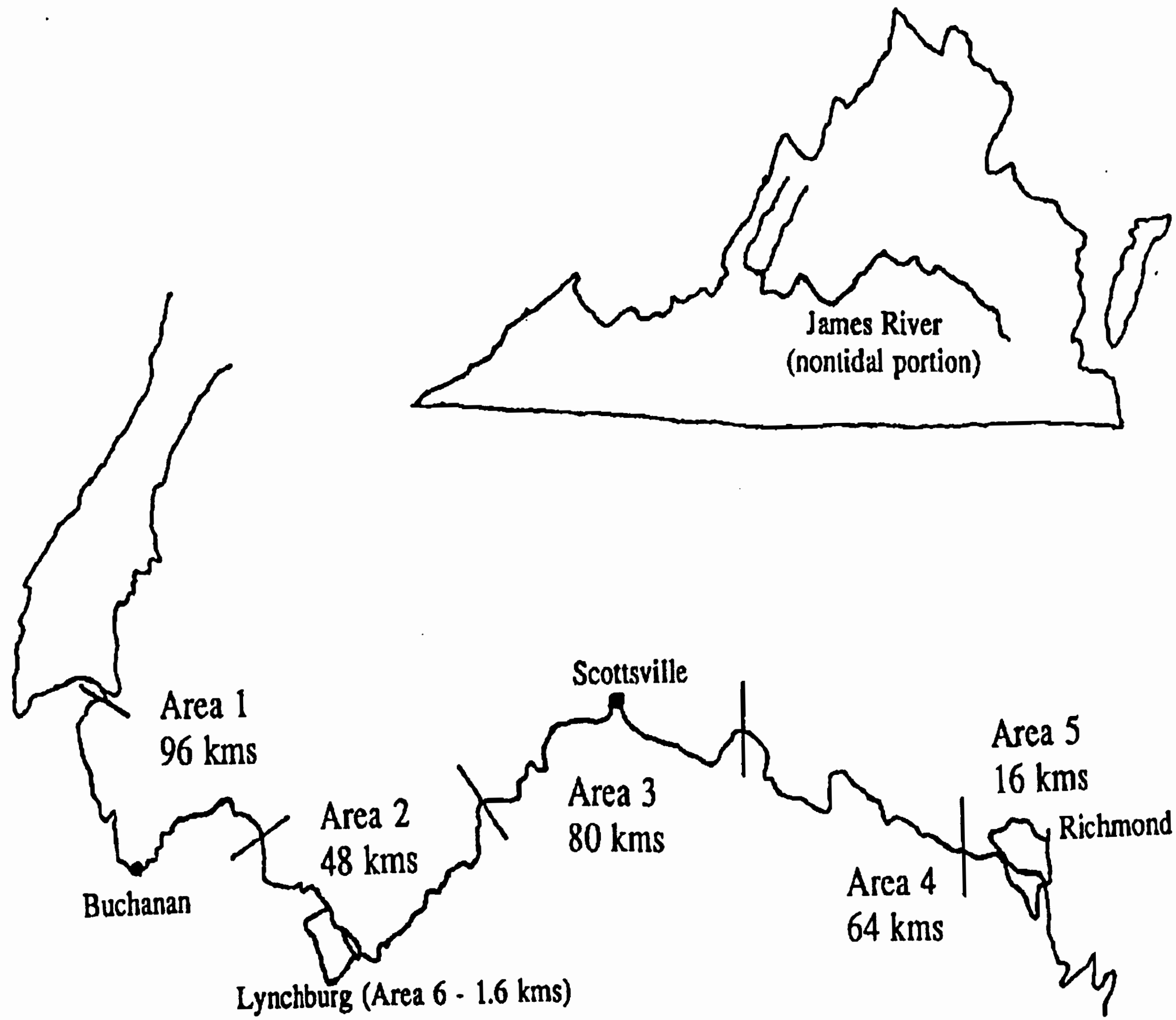

Figure 1. Pictorial representation of the James River and study area.

Glasgow to Snowden. Area 2 had some localized bank fisheries in spring and summer and float-fishing for smallmouth bass in the summer months. Also, recreational boating (boats with engines greater than 25 h.p.) was a frequent summer activity above Scot's Mill and Ruesens Dam. Area 3 had float-fishing for smallmouth bass throughout the year with swimming, canoeing, and tubing (i.e. floating in a tire or innertube) common in the summer months. Area 4 had float-fishing for smallmouth bass throughout the year with swimmers and tubers common in the summer months. Furthermore, recreational boating was a common activity from late spring through early fall above Bosher's Dam. Area 5 had an early spring American shad, white perch, and striped bass fishery with swimming, tubing, and kayaking common throughout the summer months. Area 6 had light bank fishing, mostly during the spring and summer months. A copy of the questionnaire can be found in the appendix.

The Bus Route Survey Technique

This section deals with the steps involved in setting up and designing a survey route. Procedural examples are shown for Area 4. Some figures in this section are from Nielsen et al. (1988).

Bus Route Design Criteria

A bus route should have several characteristics. First, the survey area should be homogeneous with respect to physiographic characteristics (Robson and Jones 1989) and recreational use types. Area 4 fits this criterion , since this 64-km river reach was relatively flat throughout the entire length while passing through pastoral land. The stretch was rural with angling, tubing, canoeing, and recreational boating being the dominant user activities throughout.

Second, the survey route should be designed so that less than one-half of the survey day is spent traveling between access points ensuring enough waiting time at each access point. In Area 4, only 31 percent of the eight-hour survey day was allotted to driving between access points. This amounted to 150 minutes of driving time between access points and 330 minutes during which the surveyor was stationed at access points collecting effort and user data.

Third, the route must be a circuit so that a random starting point and direction of travel around the circuit can be chosen. A schematic representation of Area 4 is shown in Figure 2. This route follows sampling sites along the river from Columbia to Cartersville to Westview to Maidens to Watkins and back to Columbia.

Creating the Bus Route

The first step in setting up the survey route was determining travel time between access points. We drove between access points and recorded the number of driving minutes. To account for delays in travel time (e.g., getting behind a farm vehicle or being detained by a train), extra travel time between access points was added to the schedule. If the actual driving time was less than 20 minutes, then the scheduled travel time was rounded up to the nearest five minutes. For example, the actual driving time between Columbia and Cartersville was 17 minutes; therefore the scheduled travel time was 20 minutes. If the actual driving time was greater than 20 minutes, then the travel time was rounded up to the nearest 10 minutes. For example, the actual driving time was 36 minutes between Watkins and Columbia; therefore the scheduled travel time was 45 minutes.

The second step was determining the surveyor's waiting time, that is, the number of minutes actually spent waiting at each access point. Subtracting total travel minutes (150) from the total sampling day minutes (480) left 330 minutes to be allocated to the five access points. Waiting time distribution was based on unequal usage probabilities. I used subjective judgements from fishery biologists and other knowledgeable river users to obtain these probabilities for the five access points (Stanovick and Nielsen 1991). Five biologists and 22 other river users were telephoned. I asked each user to rate the usage at a particular access point on a scale of 1 to 5 (1 being an access point with low use). The mean ratings for all respondents are found in Table 1. I then divided each individual access point rating by the total area rating (16.5) for Area 4, yielding a proportion of use for each access point. Finally,

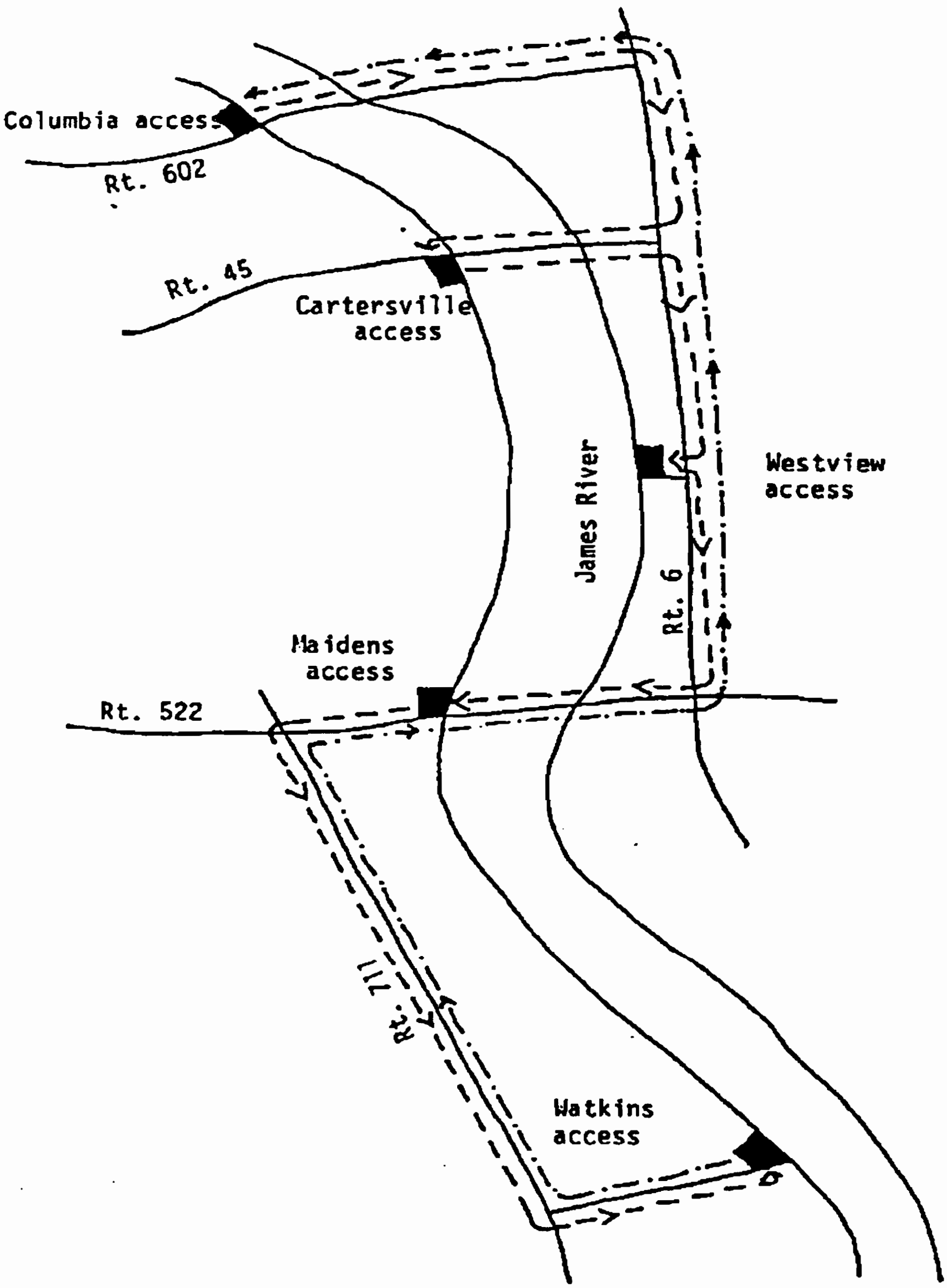

Figure 2. View of the Area-4 bus route.

these proportions were applied to the 330 minutes of available waiting time, yielding waiting times (in minutes) for the five access points.

This process completed, the route and the schedule can be created (Figure 3). The access point column lists the access points in route order. The wait/travel column gives the precise amount of scheduled waiting time at each access point or driving time between access points. The "start time" column (route time) was used along with a random number table to determine the random starting minute and where the surveyor would start the route. Finally, the clock time column was used for recording the scheduled driving and waiting times for a particular sampling day.

Scheduling a Survey Day

Two choices were needed before the survey schedule could be completed. First, a morning or afternoon sampling period was chosen. A morning sampling period began at the beginning of the recreational day and ran eight hours, while a late sampling period finished at the end of the recreational day and began eight hours prior to the recreational day's end. For example, in the summer season the length of the recreational day was 0700 to 2000. The morning period was conducted from 0700 to 1500 while the afternoon sampling period was conducted from 1200 to 2000. Notice that from 1200 to 1500, there was an overlap between the two time periods. I used a 50 percent late to 50 percent early sampling scheme. For example, if Area 4 was allotted four sampling days within a certain time stratum, and the first two days were randomly chosen as morning starts, then I fixed the other two sampling days as afternoon starts. The second choice was to chose the surveyor's travel direction either up or down the survey route. No restrictions were made on this random choice with direction

Table 1. Subjective judgement usage scores, proportion of use, and waiting time (minutes) for the five access points in Area 4. Five users rated this area.

Access Point	Subjective Usage Score	Proportional Use Score	Waiting Time
Columbia	2.50	.15	50
Cartersville	2.25	.14	45
Westview	3.75	.23	75
Maidens	4.00	.24	80
Watkins	4.00	.24	80
Total	16.50	1.00	330

(5-24-88) James River Study - Access Point Survey

Daily Sampling Schedule - Area 4

Date: 8/4/88 Random Starting Minute 250 Early/Late Up/Down

Access Point	Wait/Travel Time	Start Time	Clock Time
Columbia	50	0	1050
Travel	20	50	1140
Cartersville	45	70	1200
Travel	25	115	1245
Westview	75	140	1310
Travel	30	215	1425
Maidens	80	245	1455 - 1500 END 700 START
Travel	30	325	815
Watkin's (Vests)	80	355	845
Travel	45	435	1005

Notes:

Figure 3. Hypothetical daily sampling schedule for Area 4 in 1988.

determined by flip of a coin. In Figure 3, an early sampling period and a downstream direction were chosen.

The starting point on the route was determined by choosing a number from 0 to 480 from a random number table. For this example, 250 was chosen as the random starting minute (Figure 3). This number corresponds to 5 minutes into the waiting time at Maidens and was set equal to the survey day start (in the case 0700 a.m.). The remainder of the schedule was set by adding the appropriate minutes from the wait/travel time column. Thus, from 0700 to 0815 the surveyor waited at Maidens, counting vehicles and conducting interviews. From 0815 to 0845 the surveyor drove to Watkins. From 0845 to 1005 the surveyor waited at Watkins, counting vehicles and conducting interviews. This procedure was followed until the surveyor arrived at Maidens at 1455, surveyed for 5 minutes, and finished the survey day at 1500.

To avoid splitting the survey period at an access point into two separate sampling periods at the beginning and end of the survey day, I modified the technique so that all of the survey time fell at the beginning or end of the day. If the random starting minute fell in the first half of an access point's waiting time, the surveyor started that many minutes before the stated start time. In this example, the random starting minute was 5 minutes into the wait time of 80 minutes at Maidens. Instead of starting at Maidens at 0700 (the regular start time), the surveyor started at 0655 and finished at 1425 (Figure 4). I did this to eliminate long travels and short wait times at the end of the day. This eliminated needless traveling expenses. The remainder of the schedule was set by adding the appropriate minutes from the wait/travel time column. Thus, from 0655 to 0815 the surveyor waited at Maidens, counting vehicles and conducting interviews. From 0815 to 0845 the surveyor drove to Watkins. From 0845 to 1005 the surveyor waited at Watkins, counting vehicles and conducting interviews. This procedure was followed until the surveyor arrived finished the survey day at 1425 at Westview. In this example, the 30-minute drive time is eliminated at the end of the day, thus saving on driving expenses.

If the random starting minute fell in the second half of the waiting time, however, I assigned all the waiting time at the end of the day. The start of the day, therefore, was set at the scheduled start time for next access point. For example, if the random starting minute had been 320, this would have been in the second half of the waiting time, with only five minutes of waiting time scheduled for the start of the day. Therefore, I would start the day at Watkins at 0735. After a day of sampling, the surveyor would arrive at Maidens at 1335 and collect data for 80 minutes, ending at 1505.

If the random starting minute fell in the driving time between access points, I started the survey day at the scheduled beginning of the first waiting time. For example, if the random starting minute was 330 (5 minutes into the driving time to Watkins), I would start the survey day at Watkins at 0725. Using this process meant the starting and ending times were often outside the stated eight-hour survey day. However, on average the starting and ending times were equal to always starting and ending at specific times.

(5-24-88) James River Study - Access Point Survey

Daily Sampling Schedule - Area 4

Date: 8/4/88 Random Starting Minute 260 Early/Late Up/Down

Access Point	Wait/Travel Time	Start Time	Clock Time
Columbia	50	0	1050
Travel	20	50	1140
Cartersville	45	70	1200
Travel	25	115	1245
Westview	75	140	1310
Travel	30	215	1425 End
Maidens	80	245	0655 Start
Travel	30	325	0815
Watkin's (Vests)	80	355	0845
Travel	45	435	1005

Notes:
ACTUAL TIME ADJUSTED TO 0655 AT MAIDEN

Figure 4. Adjusted daily sampling schedule for Area 4 in 1988.

Collecting and Recording Effort Data

The bus route technique was developed to record the length of time a vehicle was parked at an access point in relation to the time the surveyor was stationed at an access point. Vehicle minutes accrued by calculating the number of minutes a recreational vehicle was in the surveyor's sight relative to the time the surveyor was stationed at an access point. Recording and keeping track of vehicles was a painstaking process that required simultaneous recording of various data. Therefore, surveyors had to be attentive and responsible. The data collection form is shown in Figure 5, with data corresponding to the Figure-4 route example.

Parking lots along the river were used for other purposes than river recreation and, therefore, vehicles of recreationists had to be separated from non-recreationists. To solve this problem, I divided vehicles into "known" and "unknown" vehicles based on appearance. A "known" vehicle was one with a canoe rack or a boat trailer. An "unknown" vehicle was one without either of the above attachments. "Unknown" vehicles were proportioned as river users or nonusers based on interviews of arriving or departing persons who were driving vehicles originally classified as "unknown". In this example, drivers of three "unknown" vehicles were interviewed at Maidens; two of these were river users while one was not (Figure 5, box in bottom left corner). The proportion of nonusers to users was used to adjust seasonal vehicle hours for unknown vehicles.

Vehicle minutes observed by a surveyor during a waiting interval were the basic statistics collected. Vehicle minutes for known and unknown vehicles were accumulated in three ways (Figure 5). First, some vehicles remained at the access point throughout the

James River Study - Access Point Survey - Vehicle Count Form

Date: 8/29/88 Area: 4 Initials: JSS Page 1 of 1

Access Point	Time		Known Vehicles				Unknown Vehicles			
	Start	End	No. Pres.	Arriv. Time	Depar. Time	Total Min.	No. Pres.	Arriv. Time	Depar. Time	Total Min.
Maid	0655	0815	6			480	10			720
				0711		64		0721		54
									0756	61
								0807		08
Vest	0845	1005	14			720	7			400
					0848	03			0905	20
					0859	14			0913	28
					0902	17				
					0912	27				
					0956	71				
Colu	1050	1140	4			200	1			50
Cart	1200	1245	4			135	7			315
					1223	23				
West	1310	1425	3			225	5			375
				1348		37		1330		55

Access Point	Unknown Veh.	
	River User	Non User
Maid	11	1
Vest	11	
Colu	—	—
Cart	—	—
West	1	

Notes:

Figure 5. 1988 example of vehicle count data for Area 4.

surveyor's wait time. All vehicles were recorded in the numbers present column when the surveyor arrived at the access point. Upon leaving, the surveyor subtracted all departing vehicles from the number present at the beginning of the interval; the difference represented vehicles that were present throughout the entire waiting time. Total minutes for these vehicles were the number of vehicles multiplied by the interval length. For Maidens access point, six known vehicles were present when the surveyor arrived and all remained at the end of the 80-minute interval; this generated 480 vehicle minutes. Ten unknown vehicles were present when the surveyor arrived at Maidens, but one of these departed at 0756. Because nine vehicles remained the whole interval, 720 vehicle minutes were accrued.

Second, some vehicles arrived during a sampling interval. These times were recorded and minutes were accumulated to the end of the interval. For example at Maidens, one known vehicle arrived at 0711 accumulating 64 minutes, and two unknown vehicles arrived, one at 0721 accumulating 54 minutes and one at 0807 accumulating 8 minutes.

Third, some vehicles departed during the interval. These vehicle departure times accumulated minutes from the beginning of the interval to the departure time. At Maidens one unknown vehicle departed at 0756 accumulating 61 vehicle minutes.

The eight-hour routes produced an overlap between early and late starts during the middle of a sampling day. For example, during the summer season when the recreational day was 0700 to 2000, the overlap period occurred from 1200 to 1500. All vehicle minutes that are accumulated from 0700 to 1200, and from 1500 to 2000 are doubled. Notice these are sampling hours where no overlap exists. Doubling vehicle minutes outside the overlap period from 1200 to 1500 allows daily estimation of vehicle hours to be calculated. All vehicle minutes observed at access points were adjusted to account for the overlap period using the following formula (Robson and Jones 1989):

$$V_i = (2 * (V_i)_{nonoverlap}) + (V_i)_{overlap}$$

where: V_i = Vehicle minutes for vehicle i

Therefore, vehicle minutes had to be adjusted in three different ways depending on when in the sampling day an access point was visited (Figure 5). First, if the wait time at an access point fell completely outside the overlap period, all vehicle minutes observed were doubled. In this example, this situation occurred at Maidens, Watkins (Vests), and Columbia. For example, at Maidens, 720 unknown vehicle minutes were accrued for the nine cars that remained throughout the entire waiting period. Doubling this amount gave a total of 1440 unknown vehicle minutes for the nine vehicles.

Second, the waiting time at an access point could fall completely within the overlap period. In this situation, no vehicle minute adjustments were necessary. For example, at Westview, five unknown vehicles remained throughout the entire interval accumulating 375 vehicle minutes (5 cars x 75 minute waiting period).

Third, the waiting time at an access point could occur partly in both the overlap and nonoverlap periods. In this situation, only vehicle minutes outside the overlap period were doubled. For this example, no access points fell in this category.

Total daily vehicle hours was calculated based on the following formula from Robson and Jones (1989):

$$TVH = T\sum_{i=1}^{n}\left(\frac{v_i}{t_i}\right)$$

where: TVH = Total daily vehicle hours
T = Route time (8 hours)
v_i = Total vehicle minutes observed at access point i
t_i = Waiting time at access point i (minutes)
n = Number of access points on the route

Along with collecting vehicle minutes, the surveyor interviewed arriving, mid-trip, and departing recreational users to collect other survey information (e.g., type of user group, economic variables, and user attitude information). User groups were categorized as boat anglers, bank anglers, canoeists, kayakers, power boaters, swimmers, or hunters.

The above example was taken from an actual sampling day. In order to clarify the concepts associated with the bus route technique, I will explain a simplified sampling day. The first step before collecting the survey data is setting up the survey schedule. To do this, I pick a day to sample, random starting minute, morning or afternoon starting time and a direction of travel. For this example, I chose August 30, 1888, with a random starting minute of 260, an early starting time, and finally a downward direction of travel (Figure 6). Since the random number 260 falls 15 minutes into the wait time at Maidens, I start the survey day at 0645. Figure 6 shows the start and drive times for the other four access points.

After finishing the survey day at 1415, I notice that I did not interview a single user party but did encounter one "known" vehicle at each access point. Each vehicle remained at the access point throughout the length of the wait time at each access point. Several steps are performed before the actual calculation of the number of vehicle hours that were accumulated for the entire recreational day. First, I calculate vehicle minutes for each access point. Because Maidens, Watkins, and Columbia had wait times outside the overlap period from 1200 to 1500 all vehicle minutes are doubled (remember that one vehicle remained the entire wait time at each access point). Before doubling vehicle minutes, Columbia had 50 vehicle minutes, Maidens had 80 vehicle minutes, and Watkin's had 80 vehicle minutes. After doubling vehicle minutes, Columbia had 100 vehicle minutes, Maidens had 80 vehicle minutes, and Watkin's had 80 vehicle minutes. Next, Westview accumulated 75 vehicle minutes. No doubling or adjustment was necessary because the entire wait time was in the period with no overlap. Finally, Cartersville, had 10 minutes outside the overlap period and 35 minutes within the overlap period. Since one vehicle remained at the access point the entire time 45 vehicle minutes were accrued. Because 10 vehicle minutes were outside the overlap period they are doubled, while the 35 minutes within the overlap period remains the same. Therefore, total vehicle minutes at Cartersville is 55 (10 * 2 + 35). The adjusted vehicle minutes are as follows: Columbia 100 vehicle minutes, Carterville 55 vehicle minutes, Westview 75 vehicle minutes, Maidens 160 vehicle minutes, and Watkin's 160 vehicle minutes.

Adjusted vehicle minutes for each access point are divided by the wait time at each access point based on using the total vehicle hours formula. For example, 100 vehicle minutes were accrued at Columbia. Columbia had 50 minutes of wait time. Therefore, 100 divided by

(5-24-88) James River Study - Access Point Survey

Daily Sampling Schedule - Area 4

Date: 8/30/88 Random Starting Minute 260 Early/Late Up/Down

Access Point	Wait/Travel Time	Start Time	Clock Time
Columbia	50	0	1040
Travel	20	50	1130
Cartersville	45	70	1150
Travel	25	115	1235
Westview	75	140	1300
Travel	30	215	1415
Maidens	80	245	0645
Travel	30	325	805
Watkin's (Vests)	80	355	835
Travel	45	435	955

Notes:

Figure 6. Daily sampling schedule for August 30, 1888, Area 4.

50 equals 2. Notice at this point there are no units associated with the value of 2. The same procedure is followed for every access point along the route. The values are summed. Finally, the value is multiplied by the length of the survey period (8 hours in this example). The result is total vehicle hours for entire recreational day. Below is the calculation of vehicle hours for this example.

$$TVH=8*\left(\frac{100}{50}+\frac{55}{45}+\frac{75}{75}+\frac{160}{80}+\frac{160}{80}\right)$$

TVH = 65.8 vehicle hours

If I had not doubled vehicle minutes for the access points which had wait times outside the overlap period, then I would have an estimate for vehicle hours only for the eight-hour sampling period. For example, one vehicle remained at each access point the entire waiting time. Without the doubling procedure, this yields a value of 1 for each access point or a value of five for all access points. Therefore, 40 (8 * 5) vehicle hours were accrued the eight-hour period. Also, notice that vehicle hours may not be a meaningful number by itself. I had to convert vehicle hours to users by multiplying the number of vehicle hours by the average number of people per vehicle. This yields number of user hours. Finally, dividing the number of user hours by the average number of hours per trip yields number of trips. Numbers of trips or user hours are the standard estimates reported in most recreational surveys.

CHAPTER 3: COMPARISON OF THE BUS ROUTE, AERIAL, AND COMPLETE ACCESS-POINT SURVEYS

INTRODUCTION

The bus route survey technique is a new use-intensity method designed for low participant use areas with dispersed access points (Robson and Jones 1989). Although this technique has been shown to be unbiased for daily party hour estimates when simulated for a riverine angling population (Jones et al. 1990), no field validity tests have been done. Also, no testing from either field or simulation experiments have been performed on user characteristic or catch data.

Validation of recreational survey techniques is rare for several reasons. First, surveys are conducted because complete censuses are usually difficult or expensive to perform. Second, most study areas are large, creating complex designs. Validation in these circumstances is expensive. Finally, most use surveys are performed for management purposes and institutional desires to validate their accuracy are not common. Therefore, on-site validation has been conducted on small areas with limited access (Best and Boles 1956; Johnson and Wrolewski 1962; Pfeiffer 1966).

The James River study gave a unique opportunity to compare the bus route, aerial, and "complete" access-point survey techniques in a large riverine system. Through help from Virginia Polytechnic Institute and State University faculty and graduate students, Virginia Department of Game and Inland Fisheries personnel, and Virginia Commonwealth University personnel, I was able to perform a nearly complete census of two study areas and conduct aerial surveys.

Bus route, aerial, and complete access-point surveys were conducted simultaneously in Areas 1 and 4 in 1988 and 1989 during the summer season. In this chapter, I compare daily vehicle hours between bus route, aerial, and complete access-point surveys. Also, I compare user characteristics and catch information between the bus route and complete access-point techniques.

METHODS

Survey Methods

Aerial counts, complete access-point surveys, and bus route surveys were conducted concurrently in Areas 1 and 4 in 1988 and 1989 during the summer season. All user groups were represented in the daily effort estimates. In each area and year, sampling occurred on 4 consecutive sampling days consisting of 2 weekdays and 2 weekend days producing a total of 16 sampling days. Area 1 was a medium-use area; it had 12 access points in 1988 and 16 access points in 1989. Area 4 was the highest-use area; it had 5 access points in 1988 and 6 access points in 1989.

Also, two aerial surveys were conducted per day during either the morning or afternoon sampling period.

Bus route technique -- Two drivers were used on each intensive sampling day. One driver drove an early route (0700 to 1500) and the other driver drove a late route (1200 to 2000). For the original bus route technique, only one driver worked per sampling day. I choose to use two drivers for the intensive sampling periods so that the entire 13-hour recreational day would be covered. Routes in Area 1 and Area 4, in 1988 and in Area 4 in 1989 were designed for completion in one day. In Area 1 in 1989, the route was designed for completion in two days (see chapter 4). A detailed discussion on designing a survey route and conducting a sampling day is described in chapter 2.

Daily vehicle effort was estimated using a two-step process. First, because driving an eight-hour route produced an overlap in the morning and afternoon sampling periods, vehicle minutes were adjusted based on the waiting time being in the overlap period or not. All vehicle minutes observed at access points were adjusted using the following formula (Robson and Jones 1989):

$$V_i = 2(V_i)_{nonoverlap} + (V_i)_{overlap}$$

where: V_i = Vehicle minutes for vehicle i

During the summer sampling season, the overlap period was from 1200 to 1500. Therefore, during an morning sampling period, vehicle minutes counted before 1200 were doubled. Similarly, during a afternoon sampling period, vehicle minutes counted after 1500 were doubled.

The second step for calculating daily vehicle effort is dividing the adjusted minutes for each access point by the wait time at each access point. These values are summed for all access points and multiplied by the length of the survey period using the following formula:

$$TVH=T\sum_{i=1}^{n}\left(\frac{v_i}{t_i}\right)$$

where: TVH = Total daily vehicle hours
T = Route time (8 hours)
v_i = Total vehicle minutes observed at access point i
t_i = Waiting time at access point i (minutes)
n = Number of access points on the route

Since both an early and late driver drove an eight-hour route during the 16 sampling days, mean daily vehicle effort estimates were calculated by averaging the two individual daily vehicle effort estimates. However, in 1989 Area 1, where a two-day, 16-hour route was employed, daily vehicle effort estimates were calculated by summing effort per access point over the two-day period and using each driver's estimate as an individual sample (thus yielding four estimates).

Complete access-point survey -- Surveyors were stationed at access points from 1000 to 2000 each sampling day. In Area 4, which had few access points, all access points were sampled each day.

In Area 1, which had too many access points to be censused, I selected access points to be sampled based on usage probabilities. In 1988, I categorized access points as high, medium, or low use based on observed summer effort prior to the 4-day sampling period. Access points in 1989 were categorized as high, medium-high, medium, or low-use based on 1988 summer effort estimates. All access points with high or medium-high use were censused in all four days in both years. Medium and low-use access points were censused based on the number of surveyors available. This was accomplished by randomly selecting access points based on probabilities related to relative-use within the medium and low use categories (Tables 2 and 3). At each access point, the surveyor recorded the amount of time vehicles were parked, noting the arrival and departure time of each vehicle. For vehicles present when the surveyor arrived (1000), the surveyor estimated arrival time by interviewing the driver as she/he was leaving. An arrival time of 0700 was assigned to any vehicle that was present when the surveyor arrived at 1000 and remained to the end of the day (2000). All vehicles remaining when the surveyor left (2000) were assigned a departure time of 2000. Therefore, the length of the recreational day was set at 13 hours, equaling the length of the recreational day for the bus route and aerial surveys. Users that departed before 1000 were not incorporated into the daily vehicle hours because the surveyor had not yet arrived at the access point. In order to assess this underestimate of effort, I used the 1988 data to calculate the percentage of users that departed before 1000. For the 1988 sampling season, only 13 of 594 (2.2%) departing user parties left before 1000. Therefore, daily effort estimates that were collected by complete access-point surveyors were almost identical to the true estimate of daily effort.

Surveyors were also responsible for interviewing arriving, mid-trip, or departing users to collect selected user characteristic and catch information. These responses were averaged

Table 2. Three use categories, random number range, and probability of selection for the 12 access points for Area 1, 1888 as used to pick complete access-point survey locations.

Access Point Categories	Random Number Range	Probability of Selection
Low Use Access Points		
Glen Wilton	000-099	.10
Gala	100-399	.30
Saltpetre Cave	400-549	.15
Springwood	550-799	.25
Alpine Farms (meat house)	800-999	.20
Medium Use Access Points		
Eagle Rock	000-204	.204
Horseshoe Bend	205-429	.225
Buchanan	430-639	.210
Arcadia	640-799	.161
Alpine Farms	800-999	.200
High Use Access Points		
Glasgow		1.00
Snowden		1.00

Table 3. Four usage categories, random number range and probability of selection for the 16 access points for 1989, Area 1 as used to select access point surveyors.

Access Point Categories	Random Number Range	Probability of Selection
Low use Access Points		
Glen Wilton	000-099	0.10
Gala	100-249	0.15
Saltpetre Cave	250-374	0.125
Springwood	375-549	0.175
Alpine Farms (meat house)	550-724	0.175
Dirt Road Junction	725-824	0.10
Bedford Dam	825-999	0.175
Medium Use Access Points		
Eagle Rock	000-199	0.20
Arcadia	200-429	0.23
Alpine Farms (dirt ramp)	430-619	0.18
Cave Mountain	620-799	0.18
Picnic Area	800-999	0.20
Medium-High Use Access Points		
Horseshoe Bend		1.00
Buchanan		1.00
High Use Access Points		
Glasgow		1.00
Snowden		1.00

over the four-day validation period in each area and year for comparison to the bus route method.

Total daily effort was generated by two different methods. First, in Area 4 where all access points were sampled, daily effort equalled the sum of observed effort over all access points for each day, as follows:

$$TVH=\sum_{i=1}^{n} VH_i$$

Where: TVH = Total daily vehicle hours
VH_i = Vehicle hours observed at access point i

Second, in Area 1 daily effort was estimated as follows:

$$TVH=\left(\sum_{i=1}^{n} VH_i\right)_{(high)}+\left(\sum_{i=1}^{n} VH_i\right)_{(med\ high)}+\left(\sum_{i=1}^{n}\left(\frac{VH_i}{P_i}\right)/n\right)_{(med)}+\left(\sum_{i=1}^{n}\left(\frac{VH_i}{P_i}\right)/n\right)_{(low)}$$

where: TVH = Total daily vehicle hours
VH_i = Vehicle hours observed for access point i
p_i = Probability of selecting access point i
n = Number of access points surveyed

Aerial surveys -- Two aerial surveys were flown in the morning or afternoon periods each day. During each flight, the surveyor counted the number of people using the river and assigned them to specific user types, if possible.

I used Lambou's (1961) effort estimation formula to estimate total user effort in hours for each sampling day. Daily effort had to be converted to daily vehicle hours so comparisons of effort between aerial, complete access-point, and bus route surveys could be conducted. The formula was as follows:

$$TVH = C\sum_{i=1}^{n}\left(\frac{X_i + X_i}{2}\right)\left(\frac{\overline{V}_i}{\overline{P}_i}\right)$$

where: TVH = Total vehicle hours
C = Length of recreational day (13 hours)
X_i and X_i = Aerial count for each use type (people)
$\overline{V}_i$ = Average number of vehicles per party in use type $_i$ (from access-point survey)
$\overline{P}_i$ = Average number of people per party in each use type $_i$ (from access-point survey)
n = Number of use types

Statistical Analyses

Wilcoxon's sign-rank tests were employed to compare daily vehicle effort between each pair of techniques. I choose this test because the data were not normally distributed. Also, I set up the design to get paired estimates for effort each intensive sampling day. Paired samples eliminated the variability associated between sampling days. Comparisons included testing all days (15-16 days), each area (7-8 days), and each day-type (7-8 days). Because three tests were performed on the same data set, I had to adjust the alpha level so that there was only a 5 percent chance of making a Type 1 error (rejecting the null hypothesis when it is actually true) for all three tests. Therefore, instead of an alpha of 0.05, I used the experimentwise error rate of 0.017. The null hypothesis was that daily vehicle effort was not significantly different between the three techniques.

Power analysis (Dixon and Massey 1957) using the paired t-test formula was conducted for comparisons of daily vehicle effort estimates in this chapter, and Chapters 4 and 5, because of the large variability in effort estimates and low sample sizes. Peterman (1989, 1990) defines statistical power (1-beta), where beta (Type II error) is the probability of failing to reject the null hypothesis when it is false. Therefore, power reflects the probability of correctly rejecting the null hypothesis (Peterman 1990). Power is a function of sample size (N), variability (Variance), effect size (minimal detectable difference), and the alpha level (Peterman 1990). Power of a test is increased with larger sample sizes, large effect sizes, low variability in estimates, and higher alpha values. Ideally, experiments should have high power (0.80 or higher) of detecting an effect if one exists (Peterman 1990). Therefore, decision makers should accept the null hypothesis only if the probability of making a Type II error is low and the power is high. This is an important concept to this study because I will be making recommendations about the applicability of the bus route survey and bus route modifications in different management situations.

User characteristics were averaged for both bus route and complete access-point surveys for each four-day sampling period. All users arriving at the river, in mid-trip, and departing were used in the analyses. Continuous variables, such as number of people per party, number of vehicles per party, days fished in the last thirty days, and economic expenditures (gas, food, bait) were analyzed using Wilcoxon's rank-sum test. The null hypothesis was user characteristics between complete access-point and bus route surveys were not significantly different over the 4-day intensive sampling period. Categorical variables, such as distribution of interviews among user groups and access points, were analyzed using Chi-square tests. In order to have a sample size of five or more in each contingency cell in Area 1, I grouped access points into high, medium-high, medium, or low usage categories. Also, if Chi-square tests showed statistical differences in interview distribution in user group between complete access-point and bus route methods, user groups were categorized as angling or recreational groups and Fisher's exact test was performed.

Catch information was collected from departing anglers and pooled for each method and sampling period. Total numbers of smallmouth bass caught and released per party were analyzed using Wilcoxon's rank-sum test. The null hypothesis was catch was not significantly different between complete access-point and bus route surveys over the 4-day intensive periods.

RESULTS

Effort

Analysis of all 16 sampling days together showed no statistical differences in daily estimated vehicle effort between bus route and complete access-point surveys (Table 4). Mean difference between the techniques averaged only 2% of the lower average estimated effort (access point in this case), and on no day was the difference greater than 46% of the lower. On 9 of the 16 days, estimated effort was higher using the bus route technique (Table 5).

Analysis of 15 sampling days showed no statistical differences in daily estimated vehicle effort between bus route and aerial surveys (Table 4). Mean difference between the techniques averaged 29% of the lower average estimated effort (bus route), but on one day the

Table 4. Wilcoxon sign-rank tests of daily vehicle effort (hours) for all sampling days for bus route (BR), complete access-point (AP), and aerial surveys (AS) by three sampling frames: all sampling days, by area, and by day-type (weekend days and weekdays).

Sampling Frame	Comparison	N	First Technique Mean	Second Technique Mean	Mean Difference	SE of Difference	P
All sampling days	BR[a]-AP	16	690.4	677.4	13.0	31.3	0.50
	AS[b]-BR	15	911.8	705.3	206.5	97.3	0.10
	AS[b]-AP	15	911.8	700.3	211.5	114.1	0.09
Area 1 1988-1989	BR[a]-AP	8	565.1	512.2	52.8	35.30	0.38
	AS[b]-BR	7	908.2	579.2	329.1	127.21	0.05
	AS[b]-AP	7	908.2	537.7	370.5	144.18	0.05
Area 4 1988-1989	BR-AP	8	815.5	842.6	-27.0	49.86	0.99
	AS-BR	8	927.5	815.6	118.8	142.15	0.84
	AS-AP	8	927.5	842.6	84.83	166.59	0.95
Weekdays 1988-1989	BR[a]-AP	8	270.0	245.4	24.6	21.57	0.46
	AS-BR	8	278.6	270.0	8.6	45.04	0.99
	AS-AP	8	278.6	245.4	33.2	38.22	0.84
Weekend days 1988-1989	BR-AP	8	1110.7	1109.5	1.3	60.69	0.99
	AS[b]-BR	7	1649.8	1202.8	447.0	165.93	0.05
	AS[b]-AP	7	1649.8	1220.3	429.5	221.67	0.11

[a]Weekday effort calculated from high, medium high, and medium use access points only
[b]Due to inclement weather on 7-23-88, no aerial counts were taken

Table 5. Daily vehicle effort estimates (vehicle hours) for bus route (BR), complete access-point (AP), and aerial surveys (AS) by date, area (1 and 4), day-type (weekend days and weekdays), and year for the 16 intensive sampling days.

Date	Year	Area	Day-type	BR	AP	AS
7-21	88	1	wd	44.4	49.2	160.3
7-22	88	1	wd	47.8	57.5	275.2
7-23	88	1	we	466.4	333.8	.[a]
7-24	88	1	we	435.5	531.0	1036.9
8-05	88	4	wd	560.4	618.7	585.3
8-06	88	4	we	1326.5	1553.2	1345.0
8-07	88	4	we	1364.2	1281.6	2339.9
8-08	88	4	wd	458.9	337.9	297.3
6-29	89	1	wd	291.0	215.4	191.4
6-30	89	1	wd	191.2	210.1	216.3
7-01	89	1	we	1543.5	1357.2	1963.4
7-02	89	1	we	1500.7	1343.9	2413.8
8-03	89	4	wd	257.0	176.3	239.8
8-04	89	4	wd	309.0	298.1	163.0
8-05	89	4	we	1336.6	1314.6	1761.5
8-06	89	4	we	912.4	1160.8	688.0

[a]No aerial counts due to inclement weather

difference was 476% of the lower. On 11 of the 15 days, estimated effort was higher using the aerial survey technique (Table 5).

Analysis of 15 sampling days showed no statistical differences in daily estimated vehicle effort between complete access-point and aerial surveys (Table 4). Mean difference between the techniques averaged 31% of the lower average estimated effort (access point), but on one day the difference was 379% of the lower (the same day on which the aerial survey greatly exceeded the bus route estimate). On 9 of the 15 days, estimated effort was higher using the aerial survey technique (Table 5).

Analysis of eight Area-1 sampling days showed no differences in daily estimated effort between bus route and complete access-point surveys (Table 4). Mean difference between the techniques averaged only 10% of the lower average estimated effort (access point), and on noday was the difference greater than 40% of the lower. On 4 of the 8 days, estimated effort was higher using the bus route technique (Table 5).

Analysis of seven Area-1 sampling days showed no significant difference in daily estimated vehicle effort between bus route and aerial surveys (Table 4). Mean difference between the techniques averaged 69% of the lower average estimated effort (bus route), but on one day the difference was 476% of the lower. On 6 of the 7 days, estimated effort was higher using the aerial survey technique (Table 5).

Analysis of seven Area-1 sampling days showed no significant difference in daily estimated vehicle effort between access-point and aerial surveys (Table 4). Mean difference between the techniques averaged 54% of the lower average estimated effort (access point), but on one day the difference was 379% of the lower. On 6 of the 7 days, estimated effort was higher using the aerial survey technique (Table 5).

Analysis of eight Area 4 sampling days showed no significant differences in daily estimated vehicle effort between bus route and complete access-point surveys (Table 4). Mean difference between the techniques averaged only 3% of the lower average estimated effort (bus route), and on no day was the difference greater than 46% of the lower. On 5 of the 8 days, estimated effort was higher using the bus route technique (Table 5).

Analysis of eight Area-4 sampling days showed no significant differences in daily estimated vehicle effort between bus route and aerial surveys (Table 4). Mean difference between the techniques averaged only 14% of the lower average estimated effort (bus route), and on no day was the difference greater than 90% of the lower. On 4 of the 8 days, estimated effort was higher using the bus route technique (Table 5).

Analysis of eight Area-4 sampling days showed no significant differences in daily estimated vehicle effort between complete access-point and aerial surveys (Table 4). Mean difference between the techniques averaged only 10% of the lower average estimated effort (access point), and on no day was the difference greater than 83% of the lower. On 5 of the 8 days, estimated effort was higher using the complete access point technique (Table 5).

Results from using all weekdays were statistically identical to those using all sampling days. In all comparisons differences were not significant (Table 4). Differences in mean estimated effort ranged from less than 1% to 14% of the lower of each pair.

Results from using all weekend days were identical to those using all sampling days. In all comparisons differences in mean estimated vehicle effort were not significant and ranged from less than 1% to 37% of the lower pair (Table 4).

Power analysis indicated that my ability to reject the null hypothesis that there was no difference between daily vehicle hours, if the null hypothesis was actually false, was low (1-

beta<0.10 in all cases). Low power was primarily due to large variability in daily vehicle effort estimates and small sample sizes. For example, the bus route survey, on average, estimated 690.4 vehicle hours for the 16 sampling days. However, one standard deviation about the mean was 545.5 vehicle hours. The large variability was due to dramatic differences in vehicle hours collected for weekend days and weekdays. For example, weekend vehicle estimates were approximately 4 times more than weekday vehicle estimates. However, when I conducted the analysis by weekend days and weekdays I only had half the sample size.

User Characteristics

User characteristics and economic expenditures for the complete access-point and bus route surveys were pooled for each four-day validation period. Thus, four comparisons were possible (Area 1 and 4 in 1988 and 1989). Economic data were analyzed for 1989 only because complete access-point surveyors in 1988 did not ask any economic questions. Wilcoxon rank-sum tests between the two techniques showed no differences in any of the nine continuous variables (Tables 6 and 7).

Differences between complete access-point and bus route surveys by year and area for two categorical user characteristics were analyzed using Chi-square analysis or Fisher's exact test when there was a 2 x 2 contingency table. The first variable described the distribution of interviews among two user groups (Anglers and other recreationists) in Area 1, 1988 or six user groups (users were not grouped into recreationists or anglers (Table 8). Analysis between complete access-point and bus route surveys showed no differences in the proportion of user groups interviewed in 3 out of 4 cases (Table 9). A significant difference (P=0.03) was detected in 1989 Area 1 between the two techniques. Further analysis revealed no differences between these two techniques in the distribution of the two angling groups, but a significant

Table 6. Wilcoxon rank-sum tests between bus route (BR) and complete access-point interviews (AP) for four user characteristic and two catch variables for Area 1 and 4 in 1988 and 1989.

			BR			AP			
Variable	Year	Area	N	Mean	SE	N	Mean	SE	P
Mean number of people per party	88	1	40	4.6	0.85	173	3.7	0.28	0.54
	89	1	90	3.1	0.25	526	3.2	0.10	0.78
	88	4	199	3.6	0.24	573	3.5	0.12	0.44
	89	4	151	3.5	0.23	517	3.8	0.18	0.52
Mean number of vehicles per party	88	1	40	1.7	0.20	173	1.6	0.08	0.92
	89	1	90	1.5	0.07	511	1.6	0.04	0.25
	88	4	195	1.3	0.04	576	1.4	0.03	0.09
	89	4	151	1.5	0.07	515	1.4	0.04	0.16
Mean number of days fished in last month	88	1	30	6.5	0.91	151	5.8	0.53	0.12
	89	1	83	5.4	0.74	442	6.0	0.32	0.37
	88	4	103	6.0	0.60	314	5.7	0.32	0.92
	89	4	143	5.7	0.55	484	5.7	0.30	0.64
Mean number of days fished in last month on James River	88	1	35	3.3	0.53	152	3.2	0.34	0.27
	89	1	88	2.4	0.49	478	2.4	0.18	0.42
	88	4	196	3.9	0.36	463	4.1	0.23	0.45
	89	4	149	3.1	0.36	496	3.0	0.20	0.53
Mean number of bass caught per party	88	1	19	12.3	2.90	52	9.7	2.00	0.13
	89	1	29	22.0	5.60	161	16.8	1.70	0.77
	88	4	48	5.0	0.90	150	9.6	1.00	0.01
	89	4	34	7.5	1.87	99	7.6	1.00	0.52
Mean number of bass released per party	88	1	19	9.2	2.60	52	8.0	1.80	0.24
	89	1	29	21.3	5.60	161	16.0	1.60	0.78
	88	4	48	4.7	0.90	150	8.8	0.90	0.02
	89	4	34	6.7	1.80	99	7.2	0.95	0.53

Table 7. Wilcoxon rank-sum tests between bus route (BR) and complete access-point (AP) interviews for five economic user characteristics for 1989 Area 1 and Area 4.

		BR			AP			
Variable	Area	N	Mean	SE	N	Mean	SE	P
Mean three-month tackle expenditure ($)	1	59	189.61	46.19	372	189.31	22.41	0.55
	4	57	311.40	76.40	219	344.86	42.52	0.97
Mean daily bait expenditure ($)	1	60	2.18	0.50	363	3.36	0.32	0.11
	4	57	2.22	0.57	229	2.73	0.40	0.98
Mean daily gasoline expenditure ($)	1	89	11.57	1.57	500	11.11	0.57	0.80
	4	151	11.71	1.16	512	10.86	0.52	0.23
Mean daily food expenditure ($)	1	90	16.24	2.28	482	18.15	1.67	0.99
	4	151	10.14	1.07	510	11.72	0.71	0.46
Mean round trip miles to James River	1	90	101.0	11.76	513	115.9	8.31	0.64
	4	150	45.4	3.69	512	49.0	2.15	0.20

Table 8. Numbers of interviews for the six user groups and the distribution of interviews by four access point usage categories for bus route (BR) and complete access-point (AP) surveys for the 1989, Area 1 intensive survey period.

		Number of Interviews							
Access Point Category	Survey Type	Bank Angler	Boat Angler	Canoeist	Kayaker	Swimmer	Tuber	Total	Percent
High Use	BR	5	9	9	8	0	6	37	41
	AP	30	50	41	9	3	14	147	28
Medium High Use	BR	5	11	3	0	0	0	19	21
	AP	21	87	13	1	2	2	126	24
Medium Use	BR	5	12	2	1	2	0	22	24
	AP	48	93	16	4	6	22	189	36
Low Use	BR	5	6	0	0	1	0	12	13
	AP	11	42	7	0	3	2	65	12
Total	BR	20	38	14	9	3	6	90	100
	AP	110	272	77	14	14	40	527	100
Percent	BR	22	42	16	10	3	7	100	
	AP	21	52	15	3	3	8	100	

Table 9. Chi-square analysis or Fisher's exact test between complete access-point, and bus route surveys for two categorical user characteristics (distribution of user groups interviewed and distribution of interview location) for intensive samples in Area 1 and 4, in 1988 and 1989.

Variable	Year	Area	DF	Chi-square value	P
Distribution of two groups[a] (angling and recreational)	88	1	1	0.73	0.44
Distribution of six user groups	88	4	5	3.65	0.60
	89	1	5	12.80	0.03
Distribution of two angler groups[b]	89	1	1	0.78	0.38
Distribution of four recreational groups[c]	89	1	3	8.12	0.04
Distribution of six user groups	89	4	5	7.98	0.16
Access point interview distribution	88	1	2[d]	1.74	0.42
	88	4	4	6.50	0.17
	89	1	3[e]	7.53	0.06
	89	4	5	14.64	0.01

[a]Fisher's exact test for angling and recreational categories only
[b]Chi-square test for angling categories only
[c]Chi-square test for recreational categories only
[d]Access points grouped into high, medium, or low use
[e]Access points grouped into high, medium high, medium, or low use

difference (P=0.04) in the distribution of the four non-angling recreational groups (Table 9).

The second categorical user characteristic was the distribution of all interviews among access points. Because Area 1 had 12 and 16 access points in 1988 and 1989, respectively, grouping of access points into usage categories was necessary, as described earlier. Distribution of interviews (i.e. recorded number of interviews at an access point compared to total number of interviews for the area) using the two techniques were not significant for both areas in 1988 and for Area 1 1989. The difference was significant for Area 4 in 1989 (P=0.01).

Catch

Wilcoxon rank-sum tests showed no differences in the number of smallmouth caught and released per angling party between techniques in both areas for 1989, and for Area 1, in 1988 (Table 6). A significant difference in numbers of smallmouth bass caught and released was detected in Area 4 in 1988. During that 4-day sampling period, the complete access-point surveyors recorded 4.6 more smallmouth bass caught and 4.1 more released per departing angling party than did bus route surveyors. Underrepresentation of successful parties (ones that caught more than 15 fish) was the reason the bus route survey had lower mean catch per party. Underrepresentation of successful parties did not occur in the other three sampling periods. For example, in 1988 Area 1, 4 of 19 (21%) of bus route interviews were angling parties who caught 15 or more fish while 13 of 52 (23%) of complete access-point angling parties caught 15 or more fish. Similar percentages of successful angling parties were seen in 1989 for both areas. For 1989, Area 1, bus route surveyors interviewed 9 of 29 (31%) of successful angling parties which caught 15 or more fish while, 56 of 161 (35%) of departing angling parties caught 15 or more fish in the complete access-point survey. Finally, for 1989, Area 4, 6 of 34 or (18%) of bus route interviews were angling parties which caught 15 or more fish while, 17 of 99 or (17%) of complete access-point angling interviews were angling parties who caught 15 or more fish.

DISCUSSION

Effort -- The bus route and complete access-point techniques gave statistically similar effort estimates in all analyses, but the power of the test was low in all cases. The bus route technique performed equally well in Area 1, which had many access points, some of which were only pull-offs parallelling the river, and Area 4, which had only a few well-developed access points. The bus route and access-point techniques generated similar effort estimates in a high-use area (Area 4) with diverse recreational activity at most access points, and in a medium-use area (Area 1) with diverse recreational use at a few access points only.

Aerial surveys produced consistently higher vehicle effort estimates than the other two techniques, especially in Area 1 and on weekends. This probably occurred because Area 1 had a sizeable "bank fishery" between access points that neither the complete access-point nor the bus route survey could sample. For example, during the 1989 intensive sampling period, 527.8 hours or 11% of the total aerial effort was attributed to between access-point bank angling effort. This was a minimum estimate for two reasons. First, not all anglers fishing between access-points would be counted due to limited visibility from overhanging trees (Malvestuto 1983). Second, I interpreted user locations conservatively; for any anglers counted adjacent to an access-point, I assumed the party entered the river through the access point. Also, any other recreationists who did not enter the river through a sampled access point (e.g. canoeists entering the river from private property) would be included in the aerial effort estimation but not in the complete access-point or bus route survey effort estimates.

Therefore, aerial effort estimates may be the most accurate estimates of total effort especially where widespread access is possible. In Area 1 for example, a dirt road parallels several segments of the river, affording users easy entry.

Aerial surveys, however, have several disadvantages. Adverse weather conditions can ground randomly scheduled flights and make low altitude flight dangerous. Also, overhanging trees can make bank anglers hard to spot and count. Finally, flying is expensive. In this study flights were 2.5 times as expensive as the ground surveys conducted.

User Characteristics -- Bus route and complete access-point surveys produced statistically similar estimates for most user characteristics. This was expected because the accuracy of user characteristic data (the exception being angler catch data) is not dependent on time of interview. Therefore, even though early bus route drivers intercepted mostly arriving parties, they still recorded representative data about miles driven, frequency of fishing, and economic expenditures. Answers to these types of questions will not change throughout the survey day. Additionally, because all interviews (arriving, mid-trip, and departing) can be used in generating mean estimates for each variable, the precision of estimates is maintained with the bus route survey. Although designed to estimate effort, the bus route technique yields valid user characteristic data when compared to the complete access-point survey.

A significant difference was detected in proportions of user group types interviewed in 1989, Area 1. Bus route surveyors were stationed by chance at Glasgow and Snowden access points, the two access points with the highest recreational use of kayakers, swimmers, and tubers, in the afternoon periods, which corresponded to the peak usage time of recreational users; consequently, they collected more nonconsumptive user interviews (36% of total) in proportion to those collected by complete access-point surveyors throughout the entire 10-hour sampling day (29% of total). The major difference between the two techniques was for the percentage of kayakers and canoeists interviewed. Bus route surveyors interviewed 10 kayaking parties, comprising 10% of the total number interviewed; complete access-point surveyors interviewed 14 kayaking parties, which comprised only 3% of the total number of interviews. Bus route surveyors interviewed 8 kayaking parties at Glasgow and Snowden, while the complete access-point surveyors interviewed 9 kayaking parties at Glasgow and Snowden. All of the bus route interviews for kayakers were conducted between 1200 and 1700. In contrast, canoeists had longer trip lengths and were not abundant in the afternoon. Of the 41 canoeists interviewed by access-point surveyors in the high-use areas, 22 (54%) were interviewed between 10 a.m. and noon when bus route surveyors were not present. Because of their longer trip length, these users were still on the river when the bus route interviewers were at the two high-use access points. Therefore, bus route surveyors interviewed a lower percentage of canoeists (39%) than the access-point surveyors (62%). Increasing the number of samples, on weekend days, in Area 1, would have distributed the wait times at high-use access points more evenly throughout the recreational day. Therefore, the statistical difference that was detected was probably due to low sample sizes in 1989, Area 1, weekend day samples. Anglers were more evenly distributed at access points in Area 1. Therefore, the problem of sampling both high-use access points in the afternoon period did not affect proportions of interviews collected with the bus route technique. The bus route survey yielded similar numbers of angling parties when compared to the complete access-point survey.

In Area 4 in 1989, a significant difference occurred in distribution of interviews among access points. This difference occurred because access-point surveyors were stationed at all access points for ten consecutive hours, giving equal weight to each access point, whereas bus route drivers waited at access points a predetermined time length. Wait times were not equal. Therefore, bus route drivers had a greater chance of interviewing more parties at high-use (longer wait time) access points than at low-use (shorter wait time) access points. For example, bus route surveyors conducted only one interview at Erwin access point, an extremely low-use access point, which was less than 1% of all bus route interviews conducted. Complete access-point surveyors conducted 32 interviews at Erwin access point which was 6% of all complete access-point interviews. Furthermore, bus route surveyors conducted 78 out of 151 interviews (52%) for the four-day sampling period at Watkins access point, a high-use access point, whereas complete access-point surveyors conducted 203 out of 519 (39%) interviews for the four-day sampling period.

This suggests that setting use probabilities based on sampling rather then censuses may be a problem because low-use access points get underrepresented and undersampled. In this study, that meant a larger proportion of recreational users may have been interviewed because they used access points where the surveyors were stationed the longest. Researchers should be concerned about interviewing user groups in proportion to their use. This could be accomplished by setting lower probabilities on access points where the predominant uses are general recreation rather than angling. Increasing wait times for bus route surveys at low-use access points that are primarily angling would yield more angling interviews and, hopefully, more precise catch information.

In this study, use was very different among access points within an area. High-use access points typically were used by different recreational groups. Longer waiting times at these access points resulted in sampling a larger percentage of use other than angling. Because of increased numbers of interviews, the bus route technique may be biased towards recreational use at high-use access points.

Catch -- One possible explanation for differences in angler catch between access points and bus route surveys is the distribution of catch is negatively skewed. Most angling parties catch few fish while a small proportion of anglers catch many fish. Under representation of these successful parties in the bus route method can lead to an underestimation of average catch per party. In Area 4, in 1988 this situation was very apparent. Only 3 of 48 interviews (6.2%) of departing anglers from the bus route survey stated they caught 15 or more fish, while 35 of 150 interviews (23.4%) of the departing anglers from the complete access-point survey stated they caught 15 or more fish. Underrepresentation of successful anglers did not occur in the other three intensive sampling periods.

The significant difference in catch in 1988, Area 4 was observed because only 1 departing angler party that caught 15 or more fish was interviewed after 1600 by the bus route surveyor, while 20 departing angler parties were interviewed after 1600 by the complete access point surveyors. Therefore, bus route surveyors interviewed only 5% of the successful angling parties that departed after 1600. This large underrepresentation of successful anglers was not apparent in the other three intensive sampling periods. For example, in 1989, Area 4, the bus route surveyors interviewed four angling parties after 1600 that caught 15 fish or more while the complete access point surveyors interviewed 10 angling parties after 1600 that caught 15 or more fish. Therefore, in 1989, Area 4, the bus route surveyors interviewed 40% of the departing anglers which left after 1600.

To eliminate this possible negative bias in catch, survey designs should employ a larger proportion of afternoon sampling periods, thus increasing sample sizes of departing anglers and allowing greater opportunities for the bus route drivers to intercept the few successful angling parties. For example, if 60% of departing anglers exit the river after the morning sampling period then afternoon samples should be given a probability of selection of at least 60%. Also, I would increase the afternoon probability if low numbers of really successful anglers are interviewed. Proportioning more afternoon samples into the survey design is especially important in riverine systems such as the James River because anglers floating between access points routinely made all day float trips and did not exit the lower access point until after 1600 or 1700 in the afternoon.

CHAPTER 4: SUB-SAMPLING-1-DAY BUS ROUTE SURVEYS COMPARED TO TWO-DAY BUS ROUTE SURVEYS

INTRODUCTION

The bus route technique accumulates information only when the surveyor is waiting at access points. Therefore, the relationship between waiting and driving times is an important criterion of survey efficiency. At least half of the daily route time in the bus route survey should be spent waiting at access points (Cynthia Jones, personal communication). The bus route survey is of limited use in areas with many access points because of a high driving to waiting ratio. Also, areas with many access points require partitioning fewer waiting minutes per access point, reducing the probability of interviewing users.

Four sampling options exist for increasing waiting times at access points in areas that have many access points. First, sampling low-use access points can be omitted in the survey design, presuming that the use is inconsequential, allowing longer waiting times at high-use access points. For example, in many cases low-use access points contribute little to daily vehicle effort. Eliminating these access points from the design would produce an overall underestimate of total area effort because no low-use access points would be sampled.

Second, an area with many access points can be stratified into two separate areas. This option would allow longer wait times at each access point because fewer access points are sampled along the route. Also, because the areas are stratified, separate effort estimates will be made for each area. Because two areas exist, only half the original number of sampling days would be allocated to each area. For example, 16 sampling days were allocated to Area 1, in 1989, in the summer sampling season. If I had stratified Area 1 into Area 1A and Area 1B then only eight samples would be allocated to each area.

Third, a longer 16-hour two-day bus route survey can be created, instead of completing the route in the standard eight-hour period. In this case the surveyor starts at a randomly selected access point and samples for eight hours on the first day. On the second day, the surveyor starts where she/he finished the previous day and proceeds along the route for eight more hours, covering all access points in two days. This approach allows longer waiting times at each access point. However, because the route takes 16 hours to complete only half the number of samples can be conducted. Thus, between-day variance estimates for daily effort would be greater because the route takes two days to complete. This option differs from option two because estimates are made for the entire area, whereas in option two estimates are made for each area separately. This approach is recommended by Robson and Jones (1989, 1991).

Fourth, a subset of access points can be sampled, maintaining the one-day bus route. Daily effort estimates are made by expanding the data based on use probabilities. This method is called the sub-sampling-one-day bus route survey. This method will simply be referred to as the sub-sampling method. A standard number of access points are chosen for sampling, and before each sampling day a customized route is designed for the specific set of waiting and driving times. For example, in 1989, Area 1 had 16 access points. For the two-day route (option 3) approximately eight access points were sampled in consecutive order on the first day, and the final eight access points were sampled on the second day. For the sub-sampling bus route survey seven access points (1 high-use, 1 medium-high-use, 2 medium-use, and 3 low-use) were sampled each day regardless of where they were along the route. This method allows longer waiting times at individual access points, because not all access points are sampled each day. However, within-day variance estimates for daily effort are greater because all access points are not sampled every day. This method may be desirable because the allocation of samples will not be reduced, as in options 2 and 3.

The hypothesis that sub-sampling and two-day bus route surveys produce representative effort, user characteristic, and catch data has not been tested. Testing these approaches against a complete access-point survey would make the bus route technique more widely applicable to survey areas with many access points within one area.

I compared the last two methods in 1989, Area 1, to determine differences in daily effort, user characteristics, and catch data. In this chapter, I report two different field testing procedures. First, I compare sub-sampling 1-day and two-day bus route surveys against a nearly complete access-point survey and aerial counts over a four-day intensive sampling period. Second, I compare sub-sampling and two-day bus route surveys on 26 sampling days and assess the magnitude changes in variance when using either technique.

METHODS

Sub-sampling and two-day bus route validation

Aerial, complete access-point, sub-sampling bus route, and two-day bus route surveys were conducted concurrently in Area 1 from June 29 to July 2, 1989. This four-day sampling period included two weekdays and two weekend days. Sixteen access points were sampled during the period, including 7 low-use, 5 medium-use, 2 medium-high-use, and 2 high-use access points. Daily effort estimates between techniques were compared using Wilcoxon's sign-rank tests. User characteristics and catch data were generated by pooling all interviews for the four-day period. Analysis of these data consisted of Chi-square analyses or Fisher's exact tests for categorical variables and Wilcoxon rank-sum tests for discrete variables.

Aerial and complete access-point surveys -- The procedures for collecting effort data for both techniques along with methods for collecting user characteristics and catch data from the complete access-point survey are described in the methods section in Chapter 3. The only difference in sampling methodology was the omission of low-use access points from the access-point survey on weekdays, because effort was characteristically zero and personnel was limited.

Two-day bus route surveys -- Two surveyors were used on each validation sampling day. One driver drove an morning route (0700 to 1500) and the other drove an afternoon route (1200 to 2000).

A two-day route was established for Area 1 (Figure 7), using the methods described in chapter 2, except waiting times and driving times were based on a 16-hour total route time (960 minutes). The surveyor's schedule for a two-day bus route was completed using the following steps. For the first sampling day a random starting minute from 0-960 was chosen using a random number table. Next, the sampling period (morning/afternoon) and direction of travel (up or down the survey route) were chosen by flipping a coin. For the example in Figure 7, a random starting minute of 280 was chosen along with an early sampling period and a downward direction of travel. This corresponded to starting at Buchanan at 0710. To

(6-7-89) James River Study-Access Point Survey

Daily Sampling Schedule - Area 1

Date 7/1/89 Random Stating Minute: 280 Early/Late Up/Down

Access Point	Wait/Travel Time	Start Time	Clock Time
Glen Wilton	20	0	1515
Travel	10	20	1535
Gala	30	30	1545
Travel	10	60	1615
Eagle Rock	45	70	1625
Travel	10	115	1710
Saltpetre Cave	25	125	1720
Travel	5	150	1745
Horseshoe Bend	80	155	1750
Travel	10	235	1910
Springwood	35	245	1920
Travel	10	280	1955
Buchanan	70	290	0710
Travel	10	360	0820
Arcadia	50	370	0830
Travel	15	420	0920
Alpine Farms (Meat)	35	435	0935
Travel	5	470	1010
Alpine Farms (Dirt)	40	475	1015
Travel	5	515	1055
Dirt Road Junction	20	520	1100
Travel	10	540	1120
Cave Mountain	40	550	1130
Travel	5	590	1210
Glasgow	100	595	1215
Travel	10	695	1355
Picnic Area	45	705	1400
Travel	5	750	1445 end 1st Day
Snowden	95	755	1150
Travel	5	850	1325
Bedford Dam	35	855	1330
Travel	70	890	1405
Notes:			

Figure 7. Two-day bus route survey for 7/1/89 and 7/2/89

complete the first sampling day, waiting times and driving times were assigned specific clock times based on the general schedule and the specific starting time. In this example, the surveyor finished the first sampling day at the Picnic Area access point at 1445.

On the second day the surveyor worked the opposite sampling period (morning or afternoon) as the first day; in this example, because the first day was a morning route, the second day was an afternoon route. The surveyor's direction of travel remained the same so that all 16 access points were sampled by the end of the second day. The starting access point on the second day was the next access point after the access point at which the first sampling day stopped. Thus, the surveyor for second day in this example started at Snowden. Following the procedures described in Chapter 2, that the entire waiting time for an access point was scheduled at the beginning or the end of a route, a waiting time that was split between the end of the first day and the beginning of the second day was assigned completely to one day. For this example, the first day would have ended 10 minutes into the 95-minute Snowden waiting time. Therefore, the first day route was ended 10 minutes early and the second day was started at Snowden at 1150. The remaining schedule could then be completed as shown in Figure 7.

Effort estimates were generated by summing the vehicle hours at each access point, for the morning or afternoon driver on the first day and the opposite period driver for the second day. Subsequent calculations were analogous to those described in Chapter 3. The resulting effort estimate for a two-day route represents the average total daily effort for the two days covered. Since the route took two days to complete, only one effort estimate was generated from the two drivers instead of the two separate effort estimates that were generated from a one-day route. For example, vehicle hours from the morning surveyor on day one were added to the vehicle hours collected from the afternoon surveyor on day two.

<u>Sub-sampling bus route survey</u> -- Two drivers were used on each validation sampling day. One driver drove a morning route (0700 to 1500) and the other drove an afternoon route (1200 to 2000). For sub-sampling routes, both the route and the schedule were customized for each sampling day, because different combinations of access points were sampled each day.

The first step in designing the sub-sampling route was choosing starting access point, sampling period, and direction of travel. A random number between 0-960 was chosen to determine where the surveyor started, based on the two-day bus route schedule; sampling period and direction of travel were chosen by flipping a coin. For the example shown in Figure 8, a random starting minute of 360 was chosen along with an early sampling period and a downward direction of travel. This corresponded to starting at Arcadia at 0710.

The second step was choosing six other access points to sample. A surveyor waited at seven access points each day, because this produced an average route time of approximately eight hours. Access points were divided into four-use-categories, as described in Chapter 3 (Table 10). One high use access point (waiting times longer than 80 minutes), one medium-high use access point (waiting times between 70 and 80 minutes), two medium use access points (waiting times between 40 and 50 minutes), and three low-use access points (waiting times shorter than 35 minutes) were chosen per sampling day. Access points within each category were chosen in proportion to their waiting times, using a random number table. In the example shown in Figure 8, because Arcadia (a medium use access point) was already selected as the starting access point, one high (Snowden), one medium-high (Horseshoe Bend), one medium (Alpine Farms-Dirt Ramp), and three low use (Glen Wilton, Gala, and Alpine Farms-Meat House) access points were chosen.

(6-7-89) James River Study-Access Point Survey

Daily Sampling Schedule - Area 1

Date: 7/2/89 Random Stating Minute: 360 Early/Late Up/Down

Access Point	Wait/Travel Time	Start Time	Clock Time
Glen Wilton LOW	20	0	1235
Travel	10	20	1255
Gala LOW	30	30	1305
Travel	10	60	1335
Eagle Rock	20 45	70	
Travel	10	115	
Saltpetre Cave	25	125	
Travel	5	150	
Horseshoe Bend mH	80	155	1355
Travel	10	235	1515
Springwood	35	245	
Travel	25 10	280	
Buchanan	70	290	
Travel	10	360	
Arcadia Med	50	370	0710
Travel	15	420	0800
Alpine Farms (Meat) LOW	35	435	0815
Travel	5	470	0840
Alpine Farms (Dirt) Med	40	475	0925
Travel	5	515	
Dirt Road Junction	20	520	
Travel	30 10	540	
Cave Mountain	40	550	
Travel	5	590	
Glasgow	100	595	
Travel	10	695	
Picnic Area	45	705	
Travel	5	750	
Snowden H	95	755	0955
Travel	5	850	1130
Bedford Dam	35	855	
Travel	65 ~~70~~	890	
Notes:			

Figure 8. Sub-sampling bus route schedule for 7/2/89.

Table 10. Number of access points picked per sampling day, access points in the four usage categories, waiting time at each access point, and random number range for the 16 access points for Area 1 as used to design sub-sampling bus routes.

Number of Access Points Picked	Access Point Categories	Waiting Time (minutes)	Random Number Range	Probability of Selection
3	Low use Access Points			
	Glen Wilton	20	001-020	0.10
	Gala	30	031-050	0.15
	Saltpetre Cave	25	051-075	0.125
	Springwood	35	076-110	0.175
	Alpine Farms (meat house)	35	111-145	0.175
	Dirt Road Junction	20	146-165	0.10
	Bedford Dam	35	166-200	0.175
2	Medium Use Access Points			
	Eagle Rock	45	201-245	0.20
	Arcadia	50	246-295	0.23
	Alpine Farms (dirt ramp)	40	296-335	0.18
	Cave Mountain	40	336-375	0.18
	Picnic Area	45	376-420	0.20
1	Medium-High Use Access Points			
	Horseshoe Bend	80	421-500	0.53
	Buchanan	70	501-570	0.47
1	High Use Access Points			
	Glasgow	100	571-670	0.52
	Snowden	95	671-765	0.49

The third step was adjusting the travel times for each particular sampling day to match the chosen access points. In particular, travel times for access points that were not adjacent were often reduced. For the example in Figure 8, the travel time from Gala to Horseshoe Bend was reduced five minutes from 25 to 20 minutes because the intermediate access points (Eagle Rock and Saltpetre Cave) that would be visited on a regular route were not along the main route of travel and required additional travel time to reach them.

The final step was to assign the actual driving time between access points and the waiting times at access points. For the example in Figure 8, the surveyor was stationed at Arcadia for 50 minutes from 0710 to 0800, collecting effort information and interviewing any users. From 0800 to 0815, the surveyor drove to Alpine Farms (meat house). This procedure continued throughout the sampling day until the surveyor finished the route at 1515 at Horseshoe Bend. Because of the adjustments in travel time and the slight differences in waiting times among access points within usage categories, the total route time did not always equal eight hours. For computational ease, however, all sub-sampling surveys were treated equally, as eight-hour routes.

Daily effort estimates were generated by summing vehicle hours over the four use categories as follows:

$$TVH=\left(\frac{VH_i}{P_i}\right)_{(high)}+\left(\frac{VH_i}{P_i}\right)_{(medium\ high)}+\left(\sum_{i=1}^{2}\left(\frac{VH_i}{P_i}\right)/2\right)_{(medium)}+\left(\sum_{i=1}^{3}\left(\frac{VH_i}{P_i}\right)/3\right)_{(low)}$$

where: TVH = Total daily vehicle hours
VH_i = Vehicle hours for access point i
P_i = Probability of selecting access point i

Sub-sampling daily effort estimates for weekdays during the 4-day sampling period did not include low-use access points because no surveyors were stationed at the low-use access points in the complete access-point survey.

Because two drivers (one early and one late) drove routes per sampling day, an average for the two drivers was calculated as the daily effort estimate.

Sub-sampling and two-day bus route survey comparison

Twenty-six sub-sampling and 13 two-day bus route sampling surveys were conducted in Area 1 from May 4 to August 22, in 1989. Dates were chosen randomly as pairs of either weekdays or weekend days. The same procedures for designing sub-sampling and two-day routes described earlier were used, with the exception that only surveyor drove per sampling day for both techniques. The same sampling dates and time periods were used for both techniques, to allow paired comparisons. For example, both techniques were used on May 4 and May 5. On May 4, the two-day bus route surveyor and the sub-sampling-1-day bus route surveyor both drove in the morning period. On May 5, the two-day bus route surveyor and the sub-sampling surveyor both drove an afternoon route. Therefore, on any given sampling day, it was possible for both drivers to be waiting at the same access point.

Effort estimates also were calculated using the methods described earlier. Because a complete two-day route took two days, the 26 sampling days yielded 13 two-day effort estimates. Daily effort estimates for the sub-sampling bus route method were averaged for each pair of sampling days, for comparison with the concurrent two-day route estimates. Thus, 13 paired samples were available for Wilcoxon sign-rank tests.

User characteristics and catch data were averaged for each technique over all sampling days and analyzed using Chi-square analyses or Fisher's exact tests for categorical variables and Wilcoxon rank-sum tests for discrete variables.

RESULTS

Sub-sampling and two-day bus route validation

Effort -- Analysis of the four sampling days showed no difference in daily estimated effort between two-day bus route and the complete access-point surveys (Table 11). Mean difference between the techniques averaged only 13% of the lower average estimated effort (access-point in this case), and on no day was the difference greater than 35% of the lower. On three of four days, estimated effort was higher using the two-day bus route technique (Table 12). Because these data are a subset of those used in similar comparisons in Chapter 3, the same results occurred.

Table 11. Wilcoxon's sign-rank tests of effort for all 4 intensive sampling days for two-day bus route (TW), sub-sampling bus route (SU), complete access-point (AP), and aerial surveys (AS).

Comparison	N	First Technique Mean	Second Technique Mean	Mean Difference	SE	P
TW[a]-AP	4	881.6	781.6	100.0	46.0	0.25
SU[a]-AP	4	770.7	781.6	-11.1	22.1	0.88
TW-AS	4	897.6	1196.2	-298.6	228.3	0.38
SU-AS	4	783.9	1196.2	-412.3	279.1	0.63
AP-AS	4	781.6	1196.2	-414.6	226.2	0.38

[a]Weekday effort calculated from high, medium-high, and medium use access points only

Table 12. Daily effort estimates for two-day bus route (TW), sub-sampling bus route (SU), complete access-point (AP), and aerial surveys (AS) by date and day-type (weekend day and weekday) for the 1989, Area 1, 4-day sampling period.

Date	Day-type	TW	SU	AP	AS
6-29	wd	291.0	225.1	215.4	191.4
6-30	wd	192.2	283.1	210.1	216.3
7-01	we	1543.5	1286.2	1357.2	1963.4
7-02	we	1500.7	1341.1	1343.9	2413.8

No difference in daily estimated effort occurred between sub-sampling-one-day bus route and the complete access-point surveys (Table 11). Mean difference between the techniques averaged only 1% of the lower average estimated effort (sub-sampling), and on no day was the difference greater than 35% of the lower. On two of four days, estimated effort was higher using the sub-sampling bus route technique (Table 12).

No difference in daily estimated effort occurred between aerial surveys and two-day bus route surveys (Table 11). Mean difference between the techniques averaged 36% of lower average estimated effort (two-day), and on no day was the difference greater than 61% of the lower. On three of four days, estimated effort was higher using the aerial survey technique (Table 12). Because these data are a subset of those used in similar comparisons in Chapter 3, the same results occurred.

No difference in daily estimated effort occurred between aerial surveys and sub-sampling-one-day bus route surveys (Table 11). Mean difference between the techniques averaged 56% of lower average estimated effort (sub-sampling), and on no day was the difference greater than 80% of the lower. On three of four days, estimated effort was higher using the aerial survey technique (Table 12).

No difference in daily estimated effort occurred between aerial surveys and complete access-point surveys (Table 11). Mean difference between the techniques averaged 56 % of lower average estimated effort (access-point), and on no day was the difference greater than 80% of the lower. On all four days, estimated effort was higher using the aerial survey technique (Table 12). Because these data are a subset of those used in similar comparisons in Chapter 1, the same results occurred.

Results from using weekend days were identical to those using all sampling days. In all comparisons between two techniques, differences were non-significant (Table 13). Differences in mean estimated daily effort ranged from 3% to 62% of the lower of each pair. The difference in estimated effort in two-day bus route and complete access-point surveys was nearly significant (P= 0.06), even though the actual difference in mean estimates was only 13% of the lower estimate.

Results from using weekdays were identical to those using all sampling days. In all comparisons between two techniques, differences were non-significant (Table 13). Differences in mean estimated efforts ranged from 1% to 20% of the lower of each pair. The difference in estimated effort was less than 10% of the lower estimate in 4 of 6 comparisons.

Power analysis indicated that my ability to reject the null hypothesis that there was no difference between daily vehicle hours, if the null hypothesis was actually false, was low (1-beta<0.10 in all cases). Low power was primarily due to large variability in daily vehicle effort estimates and small sample sizes.

User characteristics -- User characteristics and economic expenditures for the complete access-point, two-day bus route, and sub-sampling bus route were compared over the four-day validation period. Wilcoxon rank-sum tests between two-day bus route and complete access-point surveys and between sub-sampling bus route and complete access-point surveys showed no differences in any of nine discrete variables (Tables 14 and 15).

Differences between complete access-point, sub-sampling, and two-day bus route surveys for two categorical user characteristics were analyzed using Chi-square tests. The first variable described the distribution of interviews among six different user groups. Analysis between sub-sampling bus route and complete access-point surveys showed no differences in

Table 13. Wilcoxon's sign-rank test of daily effort for all 4 sampling days by day-type (weekend day and weekday) for two-day bus route (TW), sub-sampling bus route (SU), complete access-point (AP), and aerial surveys (AS).

Technique Comparisons	N	Day-type	First Technique Mean	Second Technique Mean	Mean Difference	SE	P
TW[a]-AP	2	wd	241.6	212.8	28.8	47.2	0.50
	2	we	1521.1	1350.6	171.6	14.7	0.50
SU[a]-AP	2	wd	227.7	212.7	14.9	20.8	0.50
	2	we	1313.7	1350.6	-36.9	34.1	0.50
TW-SU	2	wd	273.1	254.1	19.0	78.4	0.99
	2	we	1522.1	1313.7	208.5	48.8	0.50
TW-AS	2	wd	273.1	203.9	69.2	28.3	0.50
	2	we	1522.1	2188.6	-665.5	246.6	0.50
SU-AS	2	wd	254.1	203.9	50.2	16.6	0.50
	2	we	1313.7	2188.6	-875.0	197.8	0.50
AP-AS	2	wd	212.8	203.9	-8.9	15.1	0.99
	2	we	1350.6	2188.6	-838.1	231.8	0.50

[a]Weekday effort calculated from high, medium-high, and medium use access points only

Table 14. Wilcoxon rank-sum tests between complete access-point (AP) and two-day bus route (TW) interviews for four user characteristics, five economic variables, and two catch estimates for 1989, Area 1.

Variable	AP			TW			P
	N	Mean	SE	N	Mean	SE	
Mean number of people per party	526	3.2	0.09	90	3.1	0.20	0.78
Mean number of vehicles per party	511	1.6	0.04	90	1.5	0.07	0.25
Mean number of days fished in last month	442	6.0	0.32	83	5.4	0.74	0.37
Mean number of days fished in last month on James River	478	2.4	0.18	88	2.4	0.49	0.42
Mean tackle expenditure ($)	372	189.31	22.41	59	189.61	46.19	0.55
Mean daily bait expenditure ($)	363	3.36	0.32	60	2.18	0.50	0.11
Mean daily gasoline expenditure ($)	500	11.11	0.57	89	11.57	1.57	0.80
Mean daily food expenditure ($)	482	18.15	1.67	90	16.24	2.88	0.99
Round trip mileage to James River	513	115.88	8.31	90	100.98	11.76	0.64
Mean number of bass caught per party	161	16.7	1.67	29	22.0	5.64	0.36
Mean number of bass released per party	161	16.0	1.64	29	21.3	5.64	0.80

Table 15. Wilcoxon rank-sum tests between complete access-point (AP) and sub-sampling bus route (SU) interviews for four user characteristics, five economic variables, and two catch estimates for 1989, Area 1 intensive survey.

Variable	AP			SU			P
	N	Mean	SE	N	Mean	SE	
Mean number of people per party	526	3.2	0.09	85	3.2	0.09	0.75
Mean number of vehicles per party	511	1.6	0.04	85	1.5	0.09	0.64
Mean number of days fished in last month	442	6.0	0.32	72	7.4	0.96	0.36
Mean number of days fished in last month on James River	478	2.4	0.18	81	2.6	0.50	0.93
Mean tackle expenditure ($)	372	189.31	22.41	61	257.30	64.04	0.86
Mean daily bait expenditure ($)	363	3.36	0.32	64	2.86	0.75	0.29
Mean daily gasoline expenditure ($)	500	11.11	0.57	84	11.39	1.20	0.39
Mean daily food expenditure ($)	482	18.15	1.67	85	18.39	3.29	0.92
Round trip mileage to James River	513	115.88	8.31	84	111.75	22.75	0.58
Mean number of bass caught per party	161	16.7	1.67	27	20.0	4.15	0.44
Mean number of bass released per party	161	16.0	1.64	27	20.0	4.15	0.36

the proportion of six different types of user groups interviewed over the four-day period (Table 16). Analysis between two-day bus route and complete access-point surveys, however, showed a significant difference between the two techniques (Table 16). Further analysis between these two techniques revealed no difference in the distribution of the two angling groups, but a significant difference in the distribution of the four non-angling recreational groups wasdetected (Table 16). The data and analysis were identical to the Chapter 3 user characteristic data and analysis.

The second categorical user characteristic was the distribution of interviews among four categories of access points based on frequency of use. Categories were the same as described for sub-sampling bus route surveys (Table 17). Differences between access-point and sub-sampling bus route surveys and between complete access-point and two-day bus route surveys were both nearly significant (P=.05 and P=.06 respectively) (Table 16). For the two-day comparison with the complete access-point, these are the same data as reported in Chapter 3.

Catch -- Mean numbers of smallmouth bass caught and released per departing angler party were compared over the four-day period for complete access-point, two-day bus route, and sub-sampling bus route techniques. Wilcoxon rank-sum tests between complete access-point and sub-sampling bus route surveys showed no differences (Table 15). Furthermore, tests between complete-access point and two-day bus route surveys showed no significant differences (Table 14).

Table 16. Chi-square analyses or Fisher's exact tests between complete access-point (AP) and sub-sampling bus route (SU) or two-day bus route (TW) surveys for user group type interviewed and distribution of interview location, Area 1, 1989.

Variable	Comparison	DF	Chi-square value	P
Distribution of six user groups	SU-AP	5	3.98	0.55
	TW-AP	5	12.80	0.03
Distribution of two groups (angling and recreation)				
Distribution of two angler groups[a]	TW-AP	1	0.78	0.38
Distribution of five recreational groups[b]	TW-AP	4	8.12	0.04
Access point Interview Distribution[c]	SU-AP	3	7.74	0.05
	TW-AP	3	7.53	0.06

[a]Fisher's exact test for angling categories only
[b]Chi-square test for recreational categories only
[c]Access points grouped into high, medium-high, medium, or low use

Table 17. Numbers of interviews for the six user groups and the distribution of interviews by four access point usage categories for sub-sampling bus route (SU), two-day bus route (TW), and complete access point (AP) surveys for 1989 Area 1.

Access Point Category	Survey Type	Number of Interviews						Total	Percent
		Bank Angler	Boat Angler	Canoeist	Kayaker	Swimmer	Tuber		
High Use	SU	3	6	5	4	1	2	21	25
	TW	5	9	9	8	0	6	37	41
	AP	30	50	41	9	3	14	147	28
Medium High Use	SU	5	19	2	1	0	2	29	34
	TW	5	11	3	0	0	0	19	21
	AP	21	87	13	1	2	2	126	24
Medium Use	SU	6	9	1	0	0	4	20	24
	TW	5	12	2	1	2	0	22	24
	AP	48	93	16	4	6	22	189	36
Low Use	SU	5	8	2	0	0	0	15	18
	TW	5	6	0	0	1	0	12	13
	AP	11	42	7	0	3	2	65	12
Total	SU	19	42	10	5	1	8	85	100
	TW	20	38	14	9	3	6	90	100
	AP	110	272	77	14	14	40	527	100
Percent	SU	22	50	12	6	1	9	100	
	TW	22	42	16	10	3	7	100	
	AP	21	52	15	3	3	8	100	

Sub-sampling and Two-day bus route survey comparison

Effort -- Analysis of the 13 two-day samples (Wilcoxon's sign-rank test) showed no difference in daily estimated effort between two-day bus route and sub-sampling bus route surveys (Table 18). Mean difference between the techniques averaged only 7% of lower mean estimated effort (sub-sampling), but for one pair (June 5-6) the difference was 265% of the lower. For 8 of the 13 paired samples, estimated daily effort was higher using the two-day bus route technique (Table 18).

Analysis of the seven weekday two-day samples showed no difference in daily estimated effort between two-day bus route and sub-sampling bus route surveys (Table 18). Mean difference between the techniques averaged only 12% of lower mean estimated effort (sub-sampling), but for one pair (June 5-6) the difference was 265% of the lower. For 3 of the 7 paired samples, estimated daily effort was higher using the two-day bus route technique.

Analysis of the six weekend two-day samples also showed no difference in estimated daily effort between two-day bus route and sub-sampling bus route surveys (Table 18). Mean difference between the techniques averaged only 7% of lower mean estimated effort (sub-sampling), and for no pair was the difference greater than 65% of the lower. For 5 of the 6 paired samples, daily estimated effort was higher using the two-day bus route technique.

Power analysis indicated that my ability to reject the null hypothesis that there was no difference between vehicle hours, if the null hypothesis was actually false, was low (1-beta<0.10 in all cases). Low power was primarily due to large variability in vehicle effort, mall effect sizes (especially when comparing weekday samples) and small sample sizes. No significant differences were found when variance estimates were compared for all combinations of samples (Table 19). However, when the samples were analyzed as a set of replicates within each technique (similar to the way they would be used in effort estimation),

Table 18. Effort estimates for two-day bus route (TW) and sub-sampling bus route (SU) techniques for 1989 Area 1 and Wilcoxon's sign-Rank test of estimated daily effort for all thirteen sampling pairs and for weekday and weekend day periods.

Sampling Dates	Day-type	Estimated Effort (vehicle hours)			SE	P
		TW	SU	Diff.		
May 04-05	wd	22.6	41.2	-18.6		
May 27-28	we	1622.8	1409.1	213.7		
Jun 03-04	we	1175.8	1151.2	24.6		
Jun 05-06	wd	104.2	28.6	75.6		
Jun 17-18	we	383.4	631.4	-248.0		
Jun 29-30	wd	323.8	213.7	110.1		
Jun 29-30	wd	199.1	260.6	-61.5		
Jul 01-02	we	1490.6	1211.5	279.1		
Jul 01-02	we	1414.9	1217.3	197.6		
Jul 10-11	wd	75.0	116.0	-41.0		
Jul 15-16	we	406.1	398.6	7.5		
Jul 25-26	wd	142.9	211.2	-68.3		
Aug 21-22	wd	167.9	52.5	115.4		
Mean	all	579.2	534.3	45.1	39.22	0.27
	we	1082.3	1003.2	79.1	79.00	0.36
	wd	148.0	132.0	16.0	30.80	0.62

Table 19. Number of sampling days (N), mean daily effort, standard deviation (STD), relative standard error (SE), F statistic, and P-value for various sampling frames for sub-sampling (SU) and two-day bus route (TW) surveys from May through August 1989, Area 1.

	SU				TW					
Sampling Frame	N	Mean	STD	SE	N	Mean	STD	SE	F	P
13 two-day samples	13	540.3	535.0	148.4	13	579.2	605.6	168.0	1.28	0.67
26 sub-sampling/ 13 two-day bus route	26	540.3	537.0	105.6	13	579.2	605.6	168.0	1.27	0.59
6 weekend two-day samples	6	1016.7	412.5	168.4	6	1082.3	552.1	225.4	1.79	0.54
12 sub-sampling/ 6 two-day bus route (weekend days)	12	1016.7	429.0	123.8	6	1082.3	552.1	225.4	1.66	0.45
7 weekday two-day samples	7	132.0	95.7	36.2	7	148.0	97.4	36.8	1.03	0.96
14 sub-sampling/ 7 two-day bus route (Weekdays)	14	132.0	98.1	26.2	7	148.0	97.4	36.8	1.02	0.99

the standard error was always lower using the sub-sampling technique (Table 19). The lowest percent difference in standard errors for the two techniques was in weekday samples (2% difference). The highest percent difference occurred when the 26 sub-sampling days were compared to the 13 two-day samples (37% difference).

User and catch characteristics -- Four user characteristics, five economic, and two angler catch variables for sub-sampling and two-day bus route surveys were compared over the 26 days of sampling. Wilcoxon rank-sum tests comparing the two techniques showed no differences in any of the 11 discrete variables (Table 20).

Mean differences between two categorical variables for sub-sampling and two-day bus route surveys were analyzed using Chi-square analysis (Table 21). No differences occurred in the proportion of each user group interviewed or in the distribution of interviews among access points. Distribution of interviews among user groups and access point categories are found in Table 22.

Table 20. Wilcoxon rank-sum tests between sub-sampling bus route (SU) and two-day bus route (TW) interviews for four user characteristics, five economic variables, and two catch estimates for 26 sampling dates, May through August 1989, Area 1.

Variable	SU			TW			P
	N	Mean	SE	N	Mean	SE	
Mean number of people per party	211	3.9	0.27	202	3.9	0.25	0.76
Mean number of vehicles per party	211	1.7	0.09	200	1.7	0.10	0.96
Mean number of days fished in last month	182	5.3	0.50	192	4.8	0.41	0.91
Mean number of days fished in last month on James River	205	2.0	0.25	199	1.9	0.28	0.73
Mean tackle expenditure	148	188.67	28.72	138	170.74	23.45	0.57
Mean daily bait expenditure	151	2.80	0.39	140	3.50	0.41	0.41
Mean daily gasoline expenditure	209	11.71	1.03	199	12.69	1.34	0.56
Mean daily food expenditure	209	19.02	2.48	200	20.13	2.77	0.91
Round trip mileage to James River	208	106.48	10.92	201	99.84	7.77	0.84
Mean number of bass caught per party	64	16.5	2.90	58	19.5	3.84	0.87
Mean number of bass released per party	64	16.3	2.92	58	18.7	3.81	0.83

Table 21. Chi-square analysis between sub-sampling bus route (SU) and two-day bus route (TW) surveys for two categorical user characteristics (distribution of user groups interviewed and distribution of interview locations) on 26 sampling days, May through August 1989, Area 1.

Variable	DF	Chi-square value	P
User group distribution	5	3.90	0.57
Access point interview[a] distribution	3	3.93	0.27

[a]Access points grouped into high, medium-high, medium, or low use categories

Table 22. Numbers of interviews for six user groups and distribution of interviews by four access point usage categories for sub-sampling bus route (SU) and two-day bus route (TW) surveys for the 26 sampling days, May through August, 1989, Area 1.

		Number of Interviews							
Access Point Category	Survey Type	Bank Angler	Boat Angler	Canoeist	Kayaker	Swimmer	Tuber	Total	Percent
High Use	SU	14	22	20	8	1	3	68	32
	TW	17	17	22	9	0	9	74	36
Medium High Use	SU	5	34	9	1	0	3	52	25
	TW	7	22	5	0	0	1	35	17
Medium Use	SU	21	16	6	0	0	4	47	22
	TW	21	21	8	1	2	1	54	27
Low Use	SU	15	25	3	0	0	1	44	21
	TW	19	17	3	0	1	0	40	20
Total	SU	55	97	38	9	1	11	211	100
	TW	64	77	38	10	3	11	203	100
Percent	SU	26	46	18	4	1	5	100	
	TW	32	38	19	5	2	5	100	

DISCUSSION

Sub-sampling, two-day bus route, access-point, and aerial survey comparison

Effort -- The two-day bus route, sub-sampling bus route and complete access-point techniques gave similar effort estimates in all analyses. These results using a subset of the data presented in Chapter 3 for aerial, access-point, and two-day samples, were explained in detail in Chapter 3. The further verification that sub-sampling also produces similar effort estimates when compared to aerial and complete access-point techniques indicates that the bus route technique and modifications may be applicable to large riverine systems.

User and catch Characteristics -- Two-day bus route, sub-sampling bus route, and complete access-point surveys had similar means for most user characteristic variables. This was expected because both arriving and departing users provide representative user characteristic data which are not dependent on if the user is arriving, in mid-trip, or departing from the river. Therefore, even though morning two-day and sub-sampling bus route surveyors intercepted mostly arriving parties, they still recorded representative user characteristic data. Although designed to estimate effort, the two-day and sub-sampling bus route techniques yielded similar user characteristics when compared with a complete access-point survey.

No differences in the mean number of smallmouth bass caught or released per party were detected between two-day bus route and complete access-point surveys or between sub-sampling bus route and complete access-point surveys, suggesting that certain modifications of the original bus route technique, primarily two-day and sub-sampling techniques, offer viable alternatives for estimating catch statistics for a riverine system.

However, as described in Chapter 3, researchers should be cautious about distributing sampling effort early within a sampling day. It is important that bus route surveyors interview anglers ending their fishing trip because more of the few really successful anglers will be contacted and a better representation of total catch collected.

A significant difference was detected between two-day bus route and complete access-point surveys for proportions of user groups interviewed in 1989, in Area 1. As described in Chapter 3, bus route surveyors were stationed by chance at Glasgow and Snowden access points, the two access points with the highest recreational use of kayakers, swimmers, and tubers, in the afternoon periods, which corresponded to the peak usage time of recreational users. Therefore, they collected more recreational interviews (36%) in proportion to what the complete access-point surveyors collected throughout the entire 10-hour sampling day (29%).

Although not significant, a low P-value was detected between two-day bus route and complete access-point surveys for distribution of interview location for four frequency-of-use categories (high to low-use access points) using Chi-square analysis. As described in Chapter 3, two-day bus route surveyors were stationed at a high-use access point between 1200 and 1700 and interviewed more recreational users who typically started and ended their trip between 1200 and 1700.

A low P-value, that was nearly significant, was detected between sub-sampling bus route and complete access-point surveys for distribution of interview location. Sub-sampling surveyors collected 10% more interviews at medium-high use access points and 12% fewer interviews at medium use access points then complete access-point surveyors collected. These trends arise because sub-sampling surveyors were randomly stationed at medium use access points during the two weekend sampling days during low usage periods (0700 to 1200). This phenomenon did not affect the proportion of types of user groups interviewed, however, because medium-high and medium use access points had similar proportional usage by all six user groups.

Because total effort estimates for the bus route method are made from car counts and not by departing angler interviews (access-point method) or instantaneous counts (roving surveys), the significant differences in user characteristics detected in the 4-day sampling period will not affect overall effort estimates. However, effort estimates of individual user groups will be affected because all unknown vehicles are proportioned to user groups based on the percentage of interviews collected for each user group. Therefore, effort estimates for recreational user groups in Area 1 will be overestimated because bus route surveyors were stationed for longer time periods at high-use access points that were very diverse in use; thus they collected a larger proportion of interviews from recreational users groups than were actually using the river. This bias cannot be assessed in this study. I felt it was important to expend more sampling time at these access points to increase the sample size of non-consumptive recreational users interviewed, yielding more precise user characteristic and economic data for these groups. Depending on the objectives of a recreational survey, researchers must decide whether to collect unbiased effort estimates for all user groups or intentionally spend additional waiting times at access points that are mostly used by nonconsumptive users so that more precise user characteristic data are collected. For example, in Area 1, only two access points were used by kayaking parties. I decided to increase the wait times at these two access points in the late spring and summer seasons when kayaking was a prevalent activity. This additional wait time allowed me to interview more kayaking parties resulting in more precise user characteristic data for this particular user group.

Sub-sampling and two-day bus route survey comparisons

Effort -- The two-day and sub-sampling surveys gave similar effort estimates in all analyses. Therefore, either technique seems to be an acceptable alternative in systems with more access points then the original one-day bus route technique can accommodate.

Even though both techniques gave similar effort estimates, sub-sampling may be preferable for two reasons. First, sub-sampling bus route surveys have lower relative standard error estimates in all cases. The greatest standard error difference (about 50% higher) was between the 26 one-day, sub-sampling effort estimates and the set of 13 two-day samples. Variability around effort estimates decreases with larger sample sizes. Because high variance estimates are a constant problem in user surveys, a technique that gives valid means with lower variance estimates is highly desirable.

Second, no sampling day restrictions exist when using the sub-sampling technique. When sampling with the two-day bus route technique, pairs of consecutive sampling days must be used to keep the between-day sampling variance as low as possible. Fishing tournaments, river festivals, and other recreational events are often held on consecutive days, and weather patterns are likely to be similar on consecutive days. Therefore, conducting a two-day route will probably increase seasonal variance estimates for effort because fewer samples will be conducted within a season. Sub-sampling allows twice as many random choices in overall survey design, producing a more statistically valid and accurate estimator.

User and catch characteristics -- Estimates of user characteristics and catch for two-day and sub-sampling bus route surveys were similar for all data. This was expected because both techniques had the same design. For example, both survey techniques were conducted in the same time period during the sampling day. Also, both techniques collected user characteristic data from arriving, mid-trip, and departing users. Over the course of 26 sampling days, both strategies are likely to collect representative data regardless of the anomalies noted earlier for smaller sets of data. Therefore, both survey techniques are viable alternatives when user characteristics and catch are important objectives in the survey design.

CHAPTER 5: COMPARING MORNING AND AFTERNOON BUS ROUTE DAILY SAMPLING PERIODS

INTRODUCTION

Daily stratification or daily nonuniform probability sampling are common survey design features (Malvestuto et al. 1978, Fleener 1974, 1976, Van Den Avyle 1986, Haverland 1990, and many others). Distributing sampling within a 24-hour period can yield more efficient designs for increasing user contacts. Higher sampling probabilities in afternoon or evening periods can increase departing angler interviews and catch information.

One feature inherent in the bus route survey method is equally distributed sampling probabilities for morning and afternoon sampling periods in a day (Robson and Jones 1989). When equal probabilities exist, the computation of effort estimates is simple. With unequal sampling periods, the effort formula becomes extremely complex, and to date no associated variance formula has been developed. Equal within-day sampling periods may be satisfactory for effort estimates, but less optimal for angler interviews because contacting arriving users in the morning period provides less information than departing interviews in the afternoon period. Adjusting within-day sampling probabilities would give researchers a more efficient sampling design. The purpose of this study was to test the hypothesis that morning and afternoon sampling periods produce equivalent effort, user characteristic, and catch information.

METHODS

Both morning and afternoon bus route surveys were conducted on each of seven weekdays in 1989, in Area 4. Area 4 was chosen because it had the fewest access points. This was important because I had to reduce the wait time at each access point to accommodate a 6.5-hour route instead of the original eight-hour route. This sampling regime avoided overlapping time periods and allowed estimates to be independent. The morning route was driven from 0700 to 1330 and the afternoon route was driven from 1330 to 2000. The same surveyor drove both routes. No bias in surveyor accuracy was detected from working a 13-hour day. The route was conducted like an 8-hour bus route survey except the surveyor's waiting times at some access points were decreased due to reduced sampling time. In addition, on sampling days when the driving distance from the last morning access point to the first afternoon access point was long, waiting times for the last morning access point and the first afternoon access point were reduced to accommodate the extra driving time. The revised route schedule is found in Figure 9.

(7-18-91) James River Study - Access Point Survey

Daily Sampling Schedule - Area 4

Objective 3 - 6-1/2 Hour Days

Date: 8/23/89 Random Starting Minute 005 Early/Afternoon Up/Down

Access Point	Wait/Travel Time	Start Time	Clock Time
Columbia	25	0	0655
Travel	20	25	0720
Cartersville	25	45	0740
Travel	25	70	0805
Westview	45	95	0830
Travel	20	140	0915
Erwin	5	160	0935
Travel	10	165	0940
Maidens	70	175	0950
Travel	30	245	1100
Watkin's Landing	70	275	1130
Travel	45	345	1240

Notes:

Actual Start at 0655 at Columbia

Another Early morning!

Figure 9. 6-1/2 hour sampling schedule for 8-23-89.

Daily effort estimates for each route were generated by modifying the effort formula found in Chapter 3 as follows:

$$TVH = 2 * T \sum_{i=1}^{n} \left(\frac{v_i}{t_i} \right)$$

where: TVH = Total daily vehicle hours
T = Route time (6.5 hours)
v_i = Total vehicle minutes observed at access point i
t_i = Wait time at access point i
n = Number of access points on the route

Because there was no overlap between the two sampling periods, all vehicle minutes were doubled.

Daily effort estimates for each morning and afternoon bus route survey for the seven sampling days were analyzed using Wilcoxon's sign-rank test.

Interviews were conducted during both sampling periods, to generate user characteristic data. As in earlier chapters, Wilcoxon-rank sum tests were used to analyze nine continuous user characteristics. Chi-square analyses and Fisher's exact tests were used to analyze three categorical variables. Because only two morning sampling interviews were departing anglers, analysis of catch data was not appropriate.

RESULTS

Effort

Analysis of the seven sampling days showed no differences in daily effort estimates between morning and afternoon bus route surveys (P=0.09, SE=35.83; Table 23). Mean difference between the sampling periods averaged 53% of the lower total estimated daily effort (morning bus route), but on one day the difference was greater than 236% of the lower totaleffort. On 5 of the 7 sampling days, estimated daily effort was higher in the afternoon bus route survey. Most of the additional effort was attributed to nonangling parties. Only 5 of 23 (22%) of morning sample interviews were nonangling parties, whereas 32 of 63 (51%) of afternoon sample interviews were nonangling parties. Most nonangling parties concentrated their usage between 1200 and 1700. For example, in the 1989 summer season, in Area 4, 55% of all interviews were conducted between 1200 and 1700 and 89 of 127 (70%) of nonangling interviews occurred in this period. Only 1.5 hours or 23% of an morning 6.5-hour route fell in this period, whereas 5 hours or 77% of the afternoon 6.5-hour route fell there.

Power analysis indicated that my ability to reject the null hypothesis that there was no difference between daily vehicle hours, if the null hypothesis was actually false, was low (1-beta=0.23). Low power was primarily due a small sample size.

On August 25, one large tubing party, consisting of 8 vehicles and 13 people, contributed 104 hours (39%) of the total effort in the morning route. Eliminating this one party changed the statistical outcome, producing a significant difference in estimated daily effort between morning and afternoon sampling periods (P=0.03, SE=30.15). Mean difference between the sampling periods averaged 64% of the lowest total estimated effort (morning bus

Table 23 Daily and mean effort estimates for morning and afternoon bus route surveys for seven weekdays in 1989, Area 4.

Date	Morning	Afternoon	Difference
8-18	97.1	116.4	-19.3
8-23	213.1	420.6	-207.5
8-25	268.5	220.0	48.5
8-28	67.7	125.5	-57.8
8-29	66.8	224.4	-157.6
8-30	140.7	265.9	-125.2
9-06	108.4	91.5	17.3
Mean	137.5	209.2	-71.7

route). On 6 of the 7 sampling days, estimated effort was higher in the afternoon bus route survey. Because effort was substantially affected by this one large tubing party, all analyses of user characteristics and economic data that follow evaluate differences with and without this party.

Power analysis indicated that my ability to reject the null hypothesis that there was no difference between daily vehicle hours, if the null hypothesis was actually false, was fairly high (1-beta=.63). Higher power of the test was primarily due to the large difference in effect size.

User characteristics and economic variables

Four continuous user characteristics and five continuous economic variables for morning and afternoon bus route surveys were summed over the seven sampling days (Table 24). Wilcoxon rank-sum tests between the two sampling periods showed no mean differences between any of the variables. However, when the one tubing party was eliminated, significant differences occurred for mean number of people per party and mean daily food expenditures (Table 25).

Differences between the two sampling periods for three categorical variables were analyzed using Chi-square analysis and Fisher's exact test. The first variable was distribution of interviews among the six user groups. Because low interview numbers were collected for several user groups in the morning sampling period, I combined user groups into angling (bank and boat anglers) and nonangling (kayakers, canoeists, power boaters, and tubers) user groups (Table 26). Analysis of the two user groups showed no difference between the two sampling

Table 24. Wilcoxon rank-sum tests between morning bus route (AM) and afternoon bus route (PM) interviews or four user characteristics, and five economic variables, for seven weekdays, in 1989, Area 4.

Variable	AM			PM			P
	N	Mean	SE	N	Mean	SE	
Mean number of people per party	23	2.4	0.46	63	2.6	0.16	0.09
Mean number of vehicles per party	23	1.4	0.33	61	1.3	0.10	0.49
Mean number of days fished in last month	23	5.4	1.56	62	5.7	0.75	0.30
Mean number of days fished in last month on James River	23	3.4	1.25	62	3.5	0.60	0.52
Mean three month tackle expenditure ($)	17	140.00	31.03	61	257.30	64.04	0.86
Mean daily bait expenditure ($)	17	2.86	1.11	32	3.35	1.19	0.88
Mean daily gasoline expenditure ($)	23	6.35	1.85	63	9.01	1.26	0.10
Mean daily food expenditure ($)	23	10.39	3.03	63	8.94	1.66	0.81
Round trip mileage to James River	23	38.52	5.56	62	43.06	4.90	0.91

Table 25. Wilcoxon rank-sum tests between morning bus route (AM) and afternoon bus route (PM) interviews for four user characteristics, and five economic variables, for 1989 Area 4 without the one tubing party on 8/25.

Variable	AM			PM			P
	N	Mean	SE	N	Mean	SE	
Mean number of people per party	22	2.1	0.31	63	2.6	0.16	0.03
Mean number of vehicles per party	22	1.1	0.15	61	1.3	0.10	0.29
Mean number of days fished in last month	22	5.7	1.61	62	5.7	0.75	0.43
Mean number of days fished in last month on James River	22	3.6	1.29	62	3.5	0.60	0.65
Mean three month tackle expenditure ($)	17	140.00	31.03	61	257.30	64.04	0.86
Mean daily bait expenditure ($)	17	2.86	1.11	32	3.35	1.19	0.88
Mean daily gasoline expenditure ($)	22	8.60	2.55	63	9.01	1.26	0.96
Mean daily food expenditure ($)	22	5.91	1.89	63	8.94	1.66	0.05
Round trip mileage to James River	22	37.09	5.62	62	43.06	4.90	0.74

Table 26. Numbers of interviews for the six user groups, distribution of interviews at the six access points, and distribution of interview type for morning (AM) and afternoon bus route surveys for 1989, Area 4.

Data type	Categories	Number of Interviews	
		AM	PM
Distribution of user groups	Bank Angler	5	9
	Boat Angler	12	24
	Canoeist	2	7
	Power boater	1	17
	Swimmer	1	2
	Tuber	2	4
Distribution of interviews at access points	Cartersville	1	6
	Columbia	1	5
	Erwin	1	0
	Maidens	12	20
	Watkins	6	27
	Westview	2	5
Distribution of interview type	Arriving	16	22
	Mid-trip	2	7
	Departing	5	34

periods using Fisher's exact test with all data, but a nearly significant ($P=0.05$) difference was detected between the two sampling periods when the one tubing party was excluded (Table 27).

The second categorical variable was distribution of interviews conducted at each access point. Because of low interview rates at several access points in the morning sampling period, access points were grouped into low (Columbia, Cartersville, and Erwin) and high (Westview, Maidens, Watkins) use categories based on 1988 effort information (Table 26). Analysis using Fisher's exact test showed no differences in the two sampling periods with or without the one tubing party (Table 27).

The third categorical variable was distribution of time of interview. The three categories were arriving at the river, in mid-trip, or departing from the river (Table 26). Mid-trip parties were mainly bank anglers that were present the entire time period at an access point and were interviewed prior to the surveyor's departure. Chi-square analysis between the two sampling periods showed a significant difference for numbers of interviews of arriving, mid-trip, and departing users (Table 27). Morning routes interviewed 70% arriving and 22% departing users, while afternoon routes interviewed 35% arriving and 54% departing users. Mid-trip interviews were nearly equal (9 and 11%, respectively). A significant difference for this categorical variable also was detected between the two sampling periods without the tubing party (Table 27).

Table 27. Chi-square analysis and Fisher's exact tests between morning (AM) and afternoon (PM) bus route surveys for two categorical user characteristics for seven, 1989 area 4, weekdays.

Variable	DF	All data		Data without Large Tubing Party	
		Chi-square Value	P	Chi-square value	P
User group distribution[a]	1	3.21	0.09	4.17	0.05
Access point Interview[b] Distribution	1	0.12	0.99	0.47	0.57
Number of arriving, mid-trip, or departing users	2	8.53	0.01	9.95	0.01

[a]Fisher's exact test for user types grouped into angling or recreational use
[b]Fisher's exact test for access points grouped into high or low use categories

DISCUSSION

Effort

Effort between the two sampling periods did not differ when all data were included. However, when the one large tubing party was eliminated from the data set, effort for the two sampling periods was significantly different. On average, 72 (34%) more hours of effort were collected per sampling period, but most of the extra effort recorded was by non-anglers. Future recreational use studies should weight afternoon sampling periods more heavily than morning sampling to collect more interviews from nonanglers and more completed interviews from anglers.

User Characteristics

Lack of differences between morning and afternoon sampling periods for the continuous user characteristic and economic variables suggests that similar data were collected. However, when the large tubing party was eliminated, the average number of people per party and average food expenditure per party were significantly different. Because there were 13 people in the one tubing party, they raised overall mean daily food expenditures by $4.48 (57%) per party and raised the mean number of people per party by 0.3 (13%) people for the morning sampling period interviews. In general, nonanglers used the river more in the afternoon sampling period in larger user groups and had higher expenditures per party.

Even though different numbers of anglers and nonanglers were interviewed in the two time periods, arriving and departing users reported similar economic and user characteristics, regardless of interview time. Answers to these types of questions do not change throughout the day. If economic information or user characteristics are important aspects of a recreational survey and large numbers of interviews of all groups are needed, then evenly allocated sampling periods may be justified. However, if user characteristics and economic estimates are greatly different among the different recreational groups and the number of interviews will be used to proportionally allocate effort data to unknown vehicles, then weighting afternoon sampling periods heavier may give better estimates for overall mean expenditures.

The number of interviews of each type of use was not significantly different with all the data; however, when the one tubing party was eliminated, a significant difference occurred. About half of the afternoon-route interviews were nonangling parties, while only about 20% of the morning sampling interviews were nonanglers. Therefore, if the survey is designed to sample total recreational use, then more afternoon samples should be incorporated into the survey design to collect additional nonangling party information. If, however, the main survey objective is to gather effort information on angling parties only, the bus route method with equal morning and afternoon sampling periods may be applicable.

As expected, a significant difference in numbers of interviews of arriving, mid-trip, and departing users was detected. Morning surveyors interviewed mostly arriving users while, afternoon surveyors interviewed mostly departing users. Also, because nonangling user groups used the river mostly in the afternoon sampling period, almost three times as many interviews were conducted in the afternoon sampling period.

Combining all interviews from both sampling periods showed that 44% of all interviews conducted were users arriving to the river and 45% were departing from the river. Designing a bus route survey with equal morning and afternoon sampling periods limits the numbers of departing users and reduces completed trip interviews. This was especially true for anglers; only two departing angler parties were interviewed during the morning sampling period. If collecting precise catch information is an important survey objective, then more afternoon samples or additional sampling periods should be incorporated into the design to reduce the large variance in catch estimates from low sample sizes of completed angler trips. Otherwise, such extreme variability in catch estimates would mask any statistical significance or reliability in estimates.

Two options exist for modifying the bus route method to collect more information from departing user groups. First, afternoon sampling periods can be sampled more than morning sampling periods. Second, because the bus route survey allows for overlapping time periods, the length of the sampling periods can be increased. This would allow greater sampling in the heavily used afternoon hours, 1200 to 1700.

CHAPTER 6: CONCLUSIONS

The four major survey techniques used in fisheries today are: Access Point, Roving, Bus Route, and Aerial Surveys. A description of each technique if found in Chapter 1. Each was developed to resolve sampling problems in a variety of resource situations, each has advantages and disadvantages. Before employing any of these techniques, the researcher must consider the objectives of the survey and the type of water body surveyed. The purpose of this chapter is to discuss which survey methods are applicable based on eight survey criteria: survey type, water body type, type of use, spatial stratification, temporal stratification, established variance formulas, cost per sampling day, and surveyor factors (Table 33).

Angler survey objectives

Effort - All four survey methods work well when estimating angler effort. Access-point and bus route surveys are the two techniques for collecting angler effort information at access points, while roving and aerial surveys are the two sampling methods to collect angler effort between access points. Robson (1991) suggested that the roving survey may yield biased effort estimates in situations where effort is estimated from the count-as-you-go method because interviewing anglers interrupts roving time. However, Wade et al. (1991) showed through simulations that this bias was < 1 percent when landmarks are used to keep the surveyor on schedule. Therefore, if use between access points is a large component of total use, aerial surveys or roving surveys should be conducted. If, however, use is concentrated at remote access points, then either the access-point or bus route surveys would be the best sampling methods.

Table 28. Applicability of 4 survey techniques based on 8 survey criteria. A rating of G = a good survey choice, a rating of F = a fair choice, a rating of P = is a poor choice, and a rating of N/A = not applicable.

Survey Criteria	Access Point Survey	Roving Survey	Bus Route Survey	Aerial Survey
Type of Survey				
Angler survey	G	G	G	G
Effort at access points	G	P	G	P
Effort between access points	P	G	P	G
User Characteristics	G	G	G	N/A
Catch	G	F	F	N/A
Total recreational survey				
Effort	G	P	F	F
User characteristics	G	F	G	N/A
Waterbody				
Large Rivers	G	F-P	G	F
Large Reservoirs	P	G	P	G
Small streams	G	P	G	P
Small lakes (reservoirs)	G	G	F	P-F
Intensity and uniformity of use				
Uniform high use	G	G	F	F
Nonuniform high use	G	G	F	F
Uniform low use	P	F	G	F
Nonuniform low use	F	F	G	F
Spatial Stratification				
Many access points	P	G	F	G
Few access points	G	G	F	G
Urban areas	F	F	P	F
Large survey areas	F-P	G	F	G
Temporal Stratification				
Seasonal strata	G	G	G	G
Within day strata/probabilities	G	G	P	G
Established Effort Variance Formulas	G	G	F	G
Bus route modifications				
Sub-sampling	N/A	N/A	P	N/A
Two-day	N/A	N/A	P	N/A
Cost per sampling day	G	F	F	P
Surveyor factors				
Complexity of survey	G	F	P	G
Boredom	P	G	G	G

User characteristics - Access-point, roving, and bus route survey methods are good tools for sampling user characteristics while aerial surveys only gather effort information. If user characteristic or catch data are important survey objectives, then an on-site survey must be employed in conjunction with the aerial survey. The three on-site methods collect representative user characteristic data because anglers can answer these types of questions at anytime during their trip. However, Kokel et al. (1991) found that mid-trip interviews from a roving survey were statistically different from the bus route survey because of "length-of-stay" bias of anglers. Therefore, it is important that researchers take this bias into account when comparing user characteristics between survey methods.

Catch - Access-point surveys are a good choice for obtaining unbiased catch and harvest estimates because anglers are interviewed when they are departing. This holds true for areas that have well-defined and concentrated use at access points. Robson (1960,1961), Malvestuto et al (1978), Phippen and Bergerson (1991), and many other authors have discussed the biases associated with using a roving survey to collect catch information from anglers that are still actively fishing. In my opinion, this bias is common in many fisheries because the chance of catching certain fishes is not an independent event because once a school (or breeding area) is located many fish can be caught in a short time span. The roving survey is a good survey technique in fisheries where harvest or catch of certain species of fish is not clumped. The original bus route survey is only a fair sampling choice for collecting angler catch and harvest data because 50% of sampling effort is allocated to morning periods where mostly arriving anglers are interviewed. In this study, equal morning and afternoon sampling dramatically reduced the number of departing angler interviews. Therefore, large standard errors for catch and harvest estimates were typical. In mostly catch-and-release fisheries it is important that the few anglers harvesting fish are interviewed. Incorporating modifications such as doubling the number of afternoon sampling periods (thus interviewing more departing anglers) would yield more precise catch and harvest estimates and enhance the applicability of the bus route technique.

Total recreational survey objectives

Effort - Recently, there has been a dramatic increase of nonconsumptive recreational use. Of the four survey techniques discussed, the access-point survey is the method that is best adapted to estimate total recreational use. The bus route technique is a fair survey choice. Jones and Robson (1991) showed that the precision of estimates of the bus route technique are lower than the access-point technique when use has to be partitioned between anglers and other river users. The aerial survey is also only a fair choice because of the difficulty in determining the type of recreational user from the air (Malvestuto 1983). In my opinion, the roving survey is a poor choice because of the difficulty in making instantaneous counts of mobile recreational boats.

User characteristics - The access-point and bus route survey methods are both good choices for collecting user characteristic data because accurate information can be collected from arriving or departing users. The roving survey is only a fair choice because of the difficulty in interviewing some user groups. For example in Area 4 there was a large proportion of power boaters in the area above Bosher's Dam. It was difficult to interview these people because they were never stationary long enough to conduct an interview. The problem is magnified on large mainstem reservoirs where hundreds to thousands of users may be encountered on weekends making it impossible to interview even a small proportion of their use.

Because most existing surveys provide a poor estimate of total recreational effort, the seven remaining criteria will be evaluated for angler surveys only.

Waterbody

Large rivers - For large rivers, such as the James River, the access-point and bus route surveys would be good choices because the surveyor is stationed at access points, eliminating the problem of interviewing anglers during high flows. The roving survey is a fair to poor choice depending on flow. For example, on a large river like the Mississippi, which has many locks and dams, the river is essentially several small reservoirs. In this case, the surveyor can perform a circular route. The roving survey is a poor choice, however, in rivers that lack dams. For example, most of the James River is free flowing with riffles and rapids, making motoring upstream extremely difficult. This leads to designs that are not random because the surveyor is limited to starting at one access point and floating or motoring downstream. Aerial surveys are a fair choice in large rivers if most of the use is from boats. If a substantial number of anglers fish from the bank they are often underrepresented in aerial surveys because of overhanging trees (Malvestuto 1983).

Large reservoirs - Roving and aerial surveys are good choices for large reservoirs because these techniques allow a large area to be covered (Malvestuto 1983). The access-point and bus route surveys are poor survey choices for large reservoirs because they are typically too large to sample efficiently because of lengthy driving times to access points or between access points. This design would yield imprecise estimates from areas that have many access points (Malvestuto 1983; Robson and Jones 1989). Moreover, heavy use at private docks can underestimate effort since anglers are interviewed at randomly selected access points only (Malvestuto 1983; Van den Avyle 1986; Robson and Jones 1989; Jones and Robson 1991).

Small streams - The access-point and bus route surveys both work well in small streams because anglers typically have to enter and exit the river through access points. The bus route survey was developed for small remote streams that have low use (Robson and Jones 1989). Also, partitioning effort between several user groups is minimized because use is predominantly angling. Roving and aerial surveys are poor sampling choices for small streams. First, small streams flow in one direction making it difficult to use a roving survey because going upstream through riffles and rapids is almost impossible. Second, overhanging trees can make counting anglers difficult in aerial surveys (Malvestuto 1983).

Small lakes - Access-point surveys and roving surveys are good survey tools for sampling small lakes (less than 200 hectares) because typically these resources only have a few access points or can be surveyed quickly by boat. For example, the majority of small Department of Conservation lakes in Missouri use one of the these two methods on lakes, especially lakes with few access points. A roving survey is used on lakes with more than two access points or where anglers can enter the lake from undefined access points. The bus route survey is a fair survey choice. Jones and Robson (1991) found that the access-point survey was superior to the bus route survey when three or fewer access points made up a survey route. In this situation, the access-point survey was cheaper to conduct because of the reduced cost of driving. Economically, aerial surveys are a fair to poor choice on small lakes. However, if many small lakes can be covered in one aerial route, then efficiency increases.

Intensity and uniformity of use

Uniform and nonuniform high use - Access-point and roving surveys are good sampling choices in fisheries that have high uniform use. The advantage to both these methods is that large numbers of contacts will be made each sampling day. They are also good choices when nonuniform high-use is encountered, because weighting can be incorporated into the survey design. For example, nonuniform probability sampling is used extensively on many of the high-use reservoir systems (Malvestuto 1983; Van den Avyle 1986).

The bus route survey would only be a fair choice because interviewing arriving and departing anglers and recording effort information from vehicles is difficult when extremely high-use is encountered. Usually, a surveyor discontinues interviews and only records vehicle information. Aerial surveys are also a fair sampling choice in high-use situations because it is difficult for the person recording large numbers of users to be accurate while traveling at a high plane speed.

Uniform and nonuniform low use - The bus route survey is a good survey method when there is uniform or nonuniform low use. These conditions exist in riverine situations where the access points are well developed but in remote regions (Jones and Robson 1991). To further enhance the applicability of this method in this situation, Robson and Jones (1989) developed the effort estimation procedure based on the number of vehicles at the access point. The roving and aerial surveys are only fair techniques because they are expensive to conduct and the cost may be prohibitive when assessing effort in low use areas. Access-point surveys received a poor rating for uniform low and a fair rating for nonuniform low use. The major disadvantage with this method is that surveyors will be placed at low-use access points where they will collect little angler information (Malvestuto 1983) resulting in inefficient sampling and boredom. Reducing sampling effort at access points of low-use will result in more efficient sampling and angler information.

Spatial stratification

Access points - Roving and aerial surveys are appropriate in areas regardless of how many access points exist because aerial and roving surveys take angler counts independent of access points by locating anglers while they are fishing.

Access-point surveys are a poor sampling choice in areas with many access points and a good sampling choice in areas with few access points. The access-point survey is the best method for sampling areas with a few access points (Van den Avyle 1986). With a large number of access points, however, the allocation of sampling effort becomes increasing small for each access point. Thus access points will be sampled only occasionally leading to larger variability in area estimates.

Bus route surveys are a fair choice when sampling areas with many (greater than 12) or few (less than 5) access points, but a good sampling technique for areas with a medium number of access points. Sampling approximately 8 to 10 access points per day provided a good balance between waiting at access points and driving between access points. However, this number can change depending on the driving time between access points. Jones and Robson (1991) found that bus routes with few access points in the route generated similar estimates to access-point surveys. In this case, an access-point survey is more economical than the bus route survey. If more than 10 access points existed, the surveyor spent too little time at each access point, lowering the chance of contacting any arriving or departing anglers.

Urban areas - Urbanization adjacent to rivers and reservoirs is increasing annually. Access-point and aerial surveys each have problems in the urban environment. The access-point survey misses anglers that enter the fishery from areas other than established access points. I found this to be the case within Lynchburg City limits where we abandoned sampling at access points in favor of a roving survey (Stanovick et al. 1991). Aerial surveys have trouble distinguishing between user groups and bank anglers under overhanging trees (Malvestuto 1983). The roving survey probably is the best method in urban areas because it incorporates anglers that enter the fishery from outside the access points and also allows private docks to be incorporated into the estimates.

The bus route survey received a poor rating because it uses cars to generate daily effort estimates, which leads to several biases in an urban setting. First, many users can simply walk, hitchhike or bike from their homes to the resource. The bus route technique has no methods for incorporating these users into the daily effort estimates (Jones and Robson 1991). Second, use is extremely diverse in large cities. This compromises methodology of the original design because effort has to be proportionally allocated to several user groups. Finally, the large numbers of users and vehicles can make recording effort and doing interviews extremely difficult. This was the case at Pony Pasture, an access point in Richmond, where it was difficult to keep track of all the vehicles, users, and non-users (Stanovick et al. 1991). Therefore, the bus route survey may not be applicable in urban areas that have heavy use concentrated at a few access points.

Large survey areas - Roving and aerial surveys are good sampling choices for large survey areas because they both can efficiently sample vast areas every sampling day. Access-point surveys are a fair to poor choice depending on the number of access points in the survey area. Most likely, a large survey area would probably have enough access points to make sampling difficult. Bus route surveys were also rated fair because large survey areas mean longer driving distances between access points and reduced waiting times at access points. This reduced waiting time at access points means a reduced chance of collecting angler information.

The ratio between driving and waiting time was an important criterion when setting up survey routes for the James River survey. With 306 kms of the James River to survey I stratified the river into six distinct areas (two city and four rural) in order to yield estimates of greater precision within an area. More river areas with fewer access points would have allowed longer waiting times and more interviews at each access point. The problem with further stratifying the river is that more sampling days are required. With limited budget and personnel it would have been difficult to add additional areas.

In my opinion, only Area 1 should have been divided into two areas. 96 kms with 16 access points was too long to sample effectively in one day. Therefore, we used sub-sampling and two-day routes in this area. Area 1 could have been stratified into two areas and sampled each the same number of times as the original design. Lower variance estimates would have been generated because the lower half of Area 1 had different user groups (kayakers and canoeists) due to the 4.8-km gorge between the Blue Ridge Mountains.

Temporal stratification

Seasonal strata - All four survey methods allow for seasonal stratification and therefore would be good survey choices. The cost of aerial and bus route surveys could make them cost prohibitive in the morning spring and fall when more sampling effort needs to be allocated to reduce variability in estimates. For example, on the James River survey during the morning spring and both fall seasons, I only sampled 4 days (2 weekend and 2 week days) in a 40-50 day season. Because weekend and weekday samples were stratified, we estimated weekend and weekday effort based on only two samples. Not surprisingly, effort estimates in these seasons are not very precise. Malvestuto and Knight (1991) suggested that to optimally allocate sampling effort requires more sampling days in the spring and fall to reduce variance estimates. Therefore, future research with the bus route technique or another survey technique on the James River should have more sampling effort allocated to the spring and fall seasons to generate effort estimates with narrower confidence limits. Also, sampling more years would help minimize variations as a result of environmental factors such as high flows (Stanovick et al. 1991).

The problem of small sample sizes was magnified during the intensive sampling periods. Consequently, it was almost impossible to show a statistical difference in daily estimated effort. For example, weekend aerial surveys, on average, collected over 400 hours of effort more per sampling day than bus route or complete access-point surveys, yet no significant differences in effort were detected. Also, the power of the tests were very low because of the small sample sizes. In future experiment, it is important that more sampling be done. I would recommend testing the technique for an area that had high-use of all user groups and sample either all weekend or week day samples. This would bolster the sample size and yield smaller variance estimates around mean effort estimates.

Within day strata/probabilities - Access-point, roving, and aerial surveys allow for sampling strata or weighted probabilities, because time periods within the sampling day are distinct nonoverlapping periods (Malvestuto 1983). These methods would be good sampling choices in situations where angler use within a sampling day was not uniform. The bus route survey received a poor rating for this criterion. As Chapter 5 showed, modifications that incorporate more afternoon sampling periods within a survey design would increase the interview rate of departing anglers and yield catch estimates with lower variance estimates. Catch estimates are often an important survey objective. Jones has been working on developing variance formulas for the situation where within day sampling probabilities are weighted according to use (C.J. Jones, Personal communication, 1989). To date nothing has been published. Unfortunately, the variance formula becomes very complex in this situation. If these formulas can be developed, it would greatly enhance the applicability of this survey technique. During the intensive sampling periods, I found that having clerks perform equal numbers of morning and afternoon sampling periods dramatically reduced the number of departing angler interviews because the morning surveyor interviewed mostly arriving anglers. Therefore, large standard errors were calculated around catch estimates. Variances of harvest estimates were even larger than catch estimates because most of the anglers released their fish. In fisheries that are mostly catch-and-release, it is important that the few anglers that harvest fish are interviewed. Incorporating modifications such as doubling the number of afternoon sampling periods and thus interviewing more departing anglers would yield more precise catch and harvest estimates. This would greatly enhance the applicability of the bus route technique.

Established effort variance Formulas

Access-point, roving, and aerial surveys have variance formulas that were developed for each survey method (Hayne 1991; Lambou 1961). These formulas have been used for the past 30 years with only minor modifications. The bus route survey received only a fair rating because a variance formula has not been specifically developed for this technique. The co-developers of the technique, Robson and Jones (1989, 1991) suggest using the Horowitz-Thompson Estimator for calculating variances for effort estimates. Unfortunately, this estimator is conservative and yields a larger variance estimate than would a variance estimator that was developed specifically for this technique. Therefore, the enhanced precision that is potentially gained by using this technique may be reduced by using the conservative estimator.

Bus route modifications- The bus route survey received a poor rating for established variance formulas when testing sub-sampling and two-day bus route surveys because no exact variance formulas have been developed for these two techniques. In Chapter 4, I compared these two techniques against the complete access-point survey and against each other. Even though no variance formulas exist for these techniques, there are still advantages and disadvantages to using either technique. The advantage of using the sub-sampling technique is that a daily effort estimate is generated each sampling day. By picking several access points along the entire route to sample, the surveyor has a greater chance to interview large parties of river users such as fishing tournaments and recreational parties that floated between two or three access points. This was not the case with the two-day route where consecutive access points were sampled. In the two-day design, large amounts of user effort from unusual events would either severely overestimate area effort, when the surveyor waited at all access points where the party had vehicles, or severely underestimate daily effort if the surveyor missed the access points where the large party was floating. Furthermore, because sub-sampling surveys sampled a fixed number of access points from each usage category, lower estimated variance estimates were generated. A problem of the two-day route was that access points were sampled in consecutive order. In Area 1, this meant usually sampling both high-use access points in one sampling day. Sampling all high use access points on the same day would be a disadvantage if between-day variance among access points is a large component of the total variance. Furthermore, to complete a two-day route the same route must be sampled on consecutive days, whereas sub-sampling surveys have no constrictions on selecting sampling days.

The problem with both techniques is that larger within-day variances will be generated because not all access points are surveyed each sampling day. Jones and Robson (1991) in simulation trials found that variance estimates for effort were lower when a completed route was run each survey day. Another disadvantage with the sub-sampling technique is that it is more expensive to conduct because the surveyor skips access points along the route but has to drive the whole route. Finally, the driving form has to be modified for every sampling day with this technique. Variance formulas are needed for both techniques. Without variance formulas neither of these techniques will be very useful in future surveys.

Cost per sampling day

Access-point surveys received a good rating for cost per sampling day. The primary cost is the surveyor's pay and paid mileage to and from the access point. Roving and bus route surveys received fair ratings. For roving surveys the cost per sampling day includes above expenses plus boat and motor expenses to make circuits around the area. This charge can be significant depending on the size of the area and the number of counts taken within a survey period. For bus route surveys, the cost per sampling day includes the access-point expenditures plus mileage to drive to each access point within the sampling period. In the James River Survey, this meant an additional 100 to 200 miles of travel per day ($20.5 to $41) depending on the area. If I had used the traditional access-point survey instead of the bus route surveys I could have hired an additional clerk to work in the spring and fall seasons when I was only able to allocate 4 samples per area. Additional samples in these seasons with high variances in effort may have reduced overall variance estimates within a season. Jones and Robson (1991) showed that the bus route technique is superior to the access-point survey when there are unpredictable changes in effort between days and when within-day use of access points differs. If lower variance estimates can be generated by increasing the samples of traditional access-point surveys for seasons with high effort variances, then this design may be more appropriate. However, if fewer bus route samples within a season can generate equivalent or lower variance estimates with the same cost, then this technique may be more appropriate.

Aerial surveys received a poor rating in terms of cost per sampling day. Our aerial flights cost approximately $400 dollars per sample. This is an extremely high cost for effort information only.

Surveyor factors

Complexity of survey- Access-point and aerial surveys received good ratings because the surveyors essentially only have to learn to administer and fill out the interview or aerial count form. Roving surveys received a fair rating because in addition to the above responsibilities the surveyor is responsible for boat maintenance, driving, and safety. Finally, the bus route survey received a poor rating. Precise routes must be driven, on time with no breaks. Also, survey and driving forms must be impeccable. I do not know if all surveyors hired for a state agency could perform these tasks. In my opinion, the bus route technique is a method more applicable to surveys conducted by researchers in an academic setting where surveyors are undergraduate or graduate students in fisheries and wildlife disciplines.

Boredom - Aerial, roving, and bus route surveys received good ratings for this category. All three methods keep the surveyor constantly moving. Therefore, they have little time to get bored. Access-point surveys received a poor rating. Surveyors are stationed at one access point for the entire sampling period. Often they lose interest in the job after a short time.

Summary

When developing a sampling design and selecting a survey method for a particular resource researchers should keep in mind the above criteria framework. It should be pointed out that the framework is simple compared to real world decisions. Ideally, a person would weigh the pluses and minuses of each method against each criterion to come up with the best survey method to meet survey objectives.

The bus route survey is a new technique that has disadvantages and advantages over other survey methods. To be more widely applicable research in several areas is needed. First, testing of the bus route survey techniques need to be conducted in other systems such as lakes and small streams. Second, modifications such as the two-day bus route and sub-sampling bus route must be tested with more samples. It is hard to assess the attributes and estimates generated with either method using only one four-day period. Third, unequal daily sampling probabilities need to be further explored. Fourth, exact variance estimators need to be created for the original method and all the modifications discussed. Fifth, the technique must be made more amendable to use by state agencies including more attention to design documentation that describes how to develop a sampling scheme. Sixth, more field testing to existing fisheries is needed. Seventh, biases in proportioning unknown vehicle effort among user groups need to be addressed. Finally, biases must be assessed in extremely high-use areas where the ability to interview users and record arriving and departing vehicles is difficult.

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Appendix

James River Study - Interview Form

Date______________Area_________Section/Access_______________Initials____________

Interview type___________Interview no.________Start time________End time________

Use type: bank-fish boat-fish canoe swim other_____________________________
Number in party______Interviewed today: Y N (if yes, stop interview)

"Hello. I'm doing a survey for the Commission of Game and Inland Fisheries. Do you mind if I ask you some questions about your trip on the river today? (approach) "First, I want you to know that all of your answers will be anonymous."

Where did you start fishing_____________________When did you start____________
Where do you plan to stop___________________When do you plan to stop__________
How many vehicles do you have parked at access points____________

What kind of fish are you after: any SMB LMB RBR RKB MUS ___ ___ ___
How many have you caught today: ___ ___ ___ ___ ___ ___ ___ ___ ___
How many have you released: ___ ___ ___ ___ ___ ___ ___ ___ ___

How often have you fished in the last month: 0-5 6-10 11-15 over 15_____
How many of those have been on the James: 0-5 6-10 11-15 over 15_____

"Now we'd like to ask you some questions about how much money you've spent for your fishing trip."

How many days is your fishing trip: 1 2 3 over 3 ______
How many miles did you drive one-way: 0-25 25-50 50-75 75-100 over 100_____
How much did you spend for bait: 0-2 2-5 5-7 8-10 over 10______
How much will you spend on food: 0-5 6-10 11-15 16-20 21-25 over 25______
Did you stay in a motel: Y N How many nights______
What major items have you bought for fishing in the last year:
Boat Canoe Motor(_____hp) Rod(no_____) Reel(no_____) Trailer
other____

Where do you live: State______County/City_______________Town____________
How old are you: 0-9 10-19 20-29 30-39 40-49 50-59 60-69 over 70______

How successful was your day today: Excellent Good Fair Poor
Why____

Is there anything you would like us to tell the Game Commission about the condition of the river or their management?

"This fall, we will be asking anglers their ideas about fishing on the river. Would you be willing to participate in a mail survey?" Thank you.

"Do you mind if we weigh and measure the fish you have kept today?"

Vita

John Stuart Stanovick was born on 4 August 1961 in Rochester, New York, to Suzanne (Royce) Stanovick and Richard Paul Stanovick. He spent two years at Broad Run High School. In 1980, he earned his high school diploma from Fort Defiance High School in Fort Defiance, Virginia. In 1984, he earned his Bachelor of Science Degree in Biology from James Madison University in Harrisonburg, Virginia. After spending two summers working in Yellowstone National Park, he entered a masters degree program at Auburn University in the fall of 1985. In 1987, he received his Masters of Science degree in Fisheries Science from Auburn University in Auburn, Alabama. In 1987, following the completion of his Masters of Science degree in Fisheries Science, he entered a graduate program at Virginia Polytechnic Institute and State University to pursue a Doctor of Philosophy degree in Fisheries and Wildlife Sciences.

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