Use of Capture-recapture Techniques to Estimate Public Use on the Clarks Hill WMA

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Abstract: License plates were used as markers for capture-recapture estimates of vehicle numbers on a 12,547-ha study area. License plate numbers were recorded during random surveys. An attempt to estimate vehicle numbers, using open-population model JOLLY, failed due to problems with equal catchability caused by users leaving the area, then returning. Chapman's Lincoln-Peterson index provided acceptable estimates of vehicle numbers. Numbers of vehicles were calculated for each sample day, then extrapolated to the entire study period. Average number of people per vehicle, area of use, and use activity were calculated using information obtained from mail and personal interview questionnaires.

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Quantifying public use on large areas which have unlimited access and numerous landowners can be difficult, especially for resource management agencies with limited manpower and budgets. The needs of public agencies to justify the costs of acquiring and maintaining Wildlife Management Areas (WMAs) and increasing pressure on management agencies to become more responsive to diverse user groups require better estimates of public use and the demographics of those users.

Long hunting seasons with liberal regulations further compound the task of

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estimating public use. We conducted a pilot study to develop a technique which would estimate user/days during hunting seasons, be reasonably simple to administer and not require budgets or manpower beyond existing project levels.

Mark and recapture techniques have been used for many years to estimate animal numbers. In 1783 Laplace (in Seber 1982) used mark-recapture techniques to estimate the human population of France. Lincoln (1930) provided 1 of the first modern papers on the subject. Otis et al. (1978), Seber (1982), and Pollock et al. (1990) provided summations of such techniques for use with numerous animal species. Our concept of using mark-recapture techniques on vehicles was inspired by the pioneering work of Carothers (1973) who used observations of license plates to test capture-recapture techniques on a known population of taxicabs. His observations, however, were of moving vehicles made from a fixed point, while we observed parked vehicles while driving on the study area.

We reasoned that most resource users drove to the study area and therefore their numbers could be estimated with standard capture-recapture methods, using license plates as the identifying mark. Our objectives were to 1) estimate numbers of vehicles present, 2) estimate average number of individuals per vehicle, 3) determine their area (i.e., land ownership) of use and 4) gather pertinent data concerning demographics of these individuals.

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Methods

Our study area was a portion of the Clarks Hill Wildlife Management Area (CHWMA) located adjacent to J. Strom Thurmond (formerly Clarks Hill) Lake in McCormick County, South Carolina. The 12,547-ha study area included 3,227 ha of U.S. Army Corps of Engineers (COE), 1,163 ha of U.S. Forest Service (USFS), and 735 ha of Champion International Corporation (CIC) lands leased or licensed for public hunting to SCWMRD. The study area included an additional 7,422 ha of private or other corporate lands, most of which were leased to private hunt clubs. The area contained about 65.7 km of paved roads, including a 34.8-km perimeter road around the study area, 45.4 km of maintained unpaved state, county or USFS roads, and an unknown length of non-maintained roads (Fig. 1).

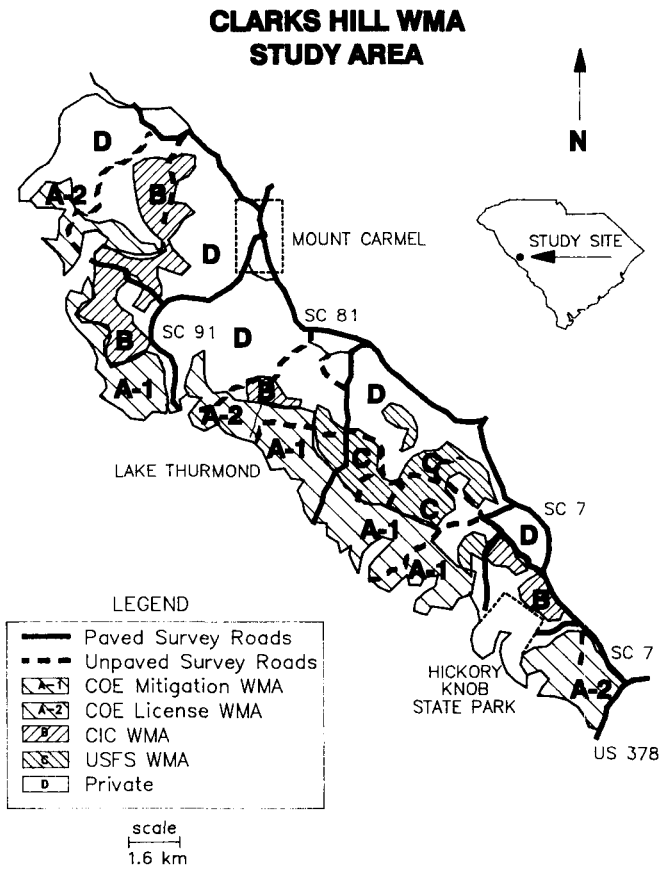

Figure 1. Map of study area showing survey roads, multiple access points, and varied landowner pattern.

Geography of the study area is typical of the Piedmont. For a more complete description of the habitat, refer to Shelford (1963), Camp and Herren (1980), and Godfrey (1980). The area is open for public hunting as part of the Western Piedmont Hunt Unit (Anon. 1991), with gun hunts for deer occurring from 11 October through 1 January with a bag limit of 2 per day, 7 per season. Spring turkey season is the month of April with a bag limit of 2 per day, 5 per season. Hunting on Sunday was not allowed. Fishing and other resource use occur throughout the year.

Data were collected during 11 December 1989–1 January 1990 (late deer season), 1 April–1 May 1990 (Spring turkey season) and 11 October 1990–1 January 1991 (deer and fall turkey season).

We experimented with 2 separate designs to attempt to determine the number of vehicles on the area. Both designs relied on license plate numbers to identify individual vehicles. Survey dates and starting points were randomized. Only parked vehicles obviously involved in resource use on the area were recorded. License plate numbers of moving vehicles, logging trucks, or vehicles parked at residences were

not recorded. Observers tried to cover all drivable roads on the study area. If necessary, observers left their vehicle to facilitate reading license numbers.

Surveys started shortly after daylight and usually lasted about 3 hours. Mail questionnaires were placed on a systematic random sample of vehicles to determine the number of people traveling in the vehicle, specific area being used, type of use activity, number of trips to the area, and other demographic information. The same questionnaire was used for personal interviews with people encountered during the survey. A map on the back of the questionnaire was used to identify the specific area of use.

Design I, used during the period 11 December 1989–1 January 1990, employed 2 observers on the study area. In this design the study area was divided in half and each observer recorded the vehicle license plates in their half of the study area each sample day. Surveys were conducted each Saturday and 3 randomly-selected week days of the period. Observers alternated between sample areas to reduce possible observer-related bias. Mail questionnaires were placed on the windshield of every second vehicle.

Results were analyzed using open population models described by Pollock et al. (1990) and program JOLLY described in that publication. Initial observation of a license plate was considered the "capture," and later observation of the same license plate on any subsequent survey during the study period the "recapture".

Design II was used during the second and third study periods due to problems with "non-permanent" emigration during the first study period. Both observers independently sampled the entire study area each sample day. Starting points were randomized, and observers started in opposite directions to reduce problems associated with following each other.

We used Chapman's modification of the Lincoln-Peterson Index (Seber 1982), to compute the estimate of N and its variance by slightly changing the notations so that:

N_1 = number vehicles seen by 1st observer;

N_2 = number vehicles seen by 2nd observer; and

M = number vehicles mutually seen.

Estimates of N were made for each day of the survey, then post-stratified into 3 periods; 1) opening week, 2) weekends or either-sex days, and 3) all other week days because, for management purposes, we needed to know the relative numbers of users for each time period. The average number of people per vehicle, obtained by questionnaire, was used as the multiplier to arrive at the total people using the area. Questionnaire responses were similarly used to determine the percent of people using various landholdings and the number engaged in hunting, fishing, or other resource use.

On the first day of the second study segment, a separate survey was done by 2 additional observers to try to count all vehicles on the area. Comparison with the regular observers showed that some vehicles were missed by all observers, and thus a simple census of vehicles would lead to underestimation of total use (Hallett et al. 1991).

During the third segment of the study the same mail questionnaire was placed on every 5th vehicle and the personal interview questionnaire was expanded to include additional demographic information. Most of these interviews were obtained while observers were performing their routine duties on the area, rather than while conducting the survey.

Results

Design I

One hundred ninety-one cars were observed on 15 surveys during the 19-day study period. Four of these were the same car on the same day, therefore the number of different vehicles was 187. By extrapolation we estimated the total number of vehicle use days at 236.74 (i.e., 12.46 = average number of vehicles seen per day and 19 total days in the study period). The average number of people per vehicle was 2.12. Therefore the total "use days" was 523.2. This clearly is a minimum estimate because some vehicles were missed during the inventory attempts.

We attempted to estimate the total number of vehicles present by employing open population mark-recapture models (Pollock et al. 1990) using license plate numbers as our markers. Our estimate of the average number of cars using the area per day was 77.1 or a total of 1,464.9 vehicles. At the above average number of people per vehicle, our estimated "use days" for the 19-day late deer season was 3,105.59. This estimate is larger due to the greater number of vehicles estimated to be present on a daily basis. We believe that the estimate is higher than the actual use, due to "non-permanent" emigration, which violates the equal catchability assumption of the Jolly-Seber model (Pollock et al. 1990). "Non-permanent" emigration occurred when resource users (primarily hunters) visited the area once, but did not return for some period of time. This resulted in a lower recapture probability estimate which inflated the estimate of vehicle numbers.

Design II

Estimates for the 2nd study period were post-stratified into 3 periods: opening week, Fridays and Saturdays, and all other week days. We found an average of 43.1 vehicles per day used the area during the first week, 16.7 used each of the remaining Fridays and Saturdays, and 5.9 used each of the remaining week days (Table 1).

Eighty-one (67 mail, 14 personal interview) questionnaires were distributed, with 41 (50.6%) returned. Respondents averaged 1.63 people per vehicle; 85.4% had been hunting and 14.6% fishing.

Third Study Period

The only change in procedures for the 3rd study period (11 Oct 1990–1 Jan 1991) was an expansion of the personal interview questionnaire. This period included the gun season for deer and a 1 week either-sex hunt for wild turkeys. Post-sample strata used were opening week; Fridays, Saturdays, and other either-sex days; and

Table 1. Estimated vehicle use on the Clarks Hill Wildlife Management Area, South Carolina, April 1990, using Chapman's Lincoln Index, by post-stratified period.

Survey		*N* cars seen			Estimated	
Day	Date	N_1[a]	N_2[b]	M[c]	cars present	SE
Opening week						
Sat	31 Mar	11	10	2	43.0	16.2
Tue	03 Apr	12	9	3	31.5	9.4
Wed	04 Apr	17	10	2	65.0	25.7
Sat	07 Apr	7	16	3	33.0	9.4
Total					172.5	33.2
$\bar{x}$					43.1	
Fridays and Saturdays						
Sat	14 Apr	6	16	5	18.8	2.3
Fri	20 Apr	5	7	2	15.0	4.5
Sat	21 Apr	6	7	1	27.0	11.8
Fri	27 Apr	5	8	3	12.5	2.6
Sat	28 Apr	6	10	6	10.0	0.0
Total					83.3	13.1
$\bar{x}$					16.7	

[a] N_1 seen by 1st observer.
[b] N_2 seen by 2nd observer.
[c] M mutually seen.

all other days. We found an average of 33.5 vehicles used the area during the first week; 72.2 used each of the remaining Fridays, Saturdays, and either-sex days; and 9.6 used each of the remaining week days (Table 2), which extrapolates to 2,139.7 vehicles for the period.

Responses were received from 126 personal interviews and 37 mail questionnaires. Mail questionnaires indicated an average of 1.7 (SE 0.5) people per vehicle, while personal interviews averaged 2.0 (SE 0.8) people per vehicle. Personal interviews were all done with hunters, while some mail questionnaires involved fishermen or other resource users. Mail respondents reported that 96.3% were hunting and 3.7% fishing (Tables 3, 4).

Two surveys were conducted during the fall either-sex wild turkey season. An estimated 8 vehicles were present on 1 day, but no vehicles were seen on the 2nd survey.

Cost of the surveys was minimal. Paper and postage for the questionnaires was about $150. Observers' time was the main expense. The first observer spent an average of 2 hours and 50 minutes and the second observer spent 3 hours and 21 minutes conducting each survey.

Discussion

Sampling only during the morning hours could bias the study. However, we believe that our technique provided a reasonable minimum estimate of resource

Table 2. Summary of vehicle survey on Clarks Hill Wildlife Management Area, South Carolina, Deer Season 1990–91, using Chapmans's Lincoln Index, by post-stratified period.

Survey		*N* cars seen			Estimated	
Day	Date	N_1[a]	N_2[b]	M[c]	cars present	SE
Opening week						
Thu	11 Oct	30	27	15	53.3	6.0
Wed	17 Oct	12	8	7	13.6	1.0
Total					66.9	6.1
$\bar{x}$					33.5	
Fridays, Saturdays and either-sex days						
Fri	19 Oct	52	58	25	161.3	12.7
Thu	25 Oct	41	38	20	70.2	6.3
Fri	26 Oct	51	50	30	84.6	6.0
Sat	03 Nov	23	15	8	41.6	7.1
Sat	09 Nov	36	21	8	89.4	19.4
Fri	16 Nov	36	36	22	58.3	4.6
Sat	24 Nov	22	17	1	206.0	107.7
Fri	30 Nov	0	0	0	0.0	0.0
Fri	17 Dec	21	21	10	43.0	6.4
Sat	22 Dec	15	9	8	16.8	1.2
Fri	28 Dec	7	4	1	19.0	7.7
Total					793.8	111.9
$\bar{x}$					72.2	
All other days						
Thu	01 Nov	4	5	2	9.0	2.2
Wed	07 Nov	4	3	2	5.7	1.1
Tue	13 Nov	8	3	3	8.0	0.0
Mon	19 Nov	4	3	2	5.7	1.1
Tue	27 Nov	6	8	6	8.0	0.0
Tue	11 Dec	6	7	2	17.7	5.6
Thu	20 Dec	5	3	2	7.0	1.4
Thu	27 Dec	9	9	5	15.7	2.5
Total					76.8	6.9
$\bar{x}$					9.6	

[a] N_1 seen by 1st observer.
[b] N_2 seen by 2nd observer.
[c] M mutually seen.

users, since deer and turkey hunting were the main use activities and most hunting occurs in the mornings (D. Shipes, unpubl. data).

Area users who stayed on the area for longer periods of time were more likely to be sampled. However, the effect of this bias on the total estimate should be minimal.

The technique only estimates "vehicle days" or "user days" and one should be careful not to interpret the data as indicating the total number of individual resource users. The same individuals may return to the area many times, but at present we lack a suitable method of quantifying them given present budget and manpower constraints.

The technique was not tested against a known population of vehicles. However,

Table 3. Estimated number of vehicles and extrapolation of number of people and area of use derived from 126 responses to personal interview questionnaires with hunters, Clarks Hill Wildlife Management Area, South Carolina, deer season 11 October 1990–1 January 1991 (standard errors in parentheses).

Stratum	$\bar{X}$ N cars/ day	N days	Estimated Total cars	Estimated Total people[a]	Estimated N cars by area A1[b] 32.5%	A2[c] 16.7%	B[d] 18.3%	C[e] 24.6%	D[f] 7.9%
First week	33.5	7	234.5	469.0	76.2	39.2	42.9	57.7	18.5
			(21.3)	(191.6)	(13.0)	(9.7)	(10.1)	(11.7)	(6.6)
Fri.–Sat.	72.2	22	1588.4	3176.8	516.2	265.3	290.7	390.7	125.5
			(222.6)	(1334.6)	(105.7)	(71.8)	(74.9)	(58.3)	(43.9)
All other days	9.6	33	316.8	633.6	103.0	52.9	58.0	77.9	25.0
			(13.8)	(254.7)	(16.0)	(14.3)	(12.9)	(14.6)	(9.1)
Totals			2139.7	4279.4	695.4	357.4	391.6	526.1	169.0
			(224.0)	(1372.2)	(107.7)	(265.8)	(76.7)	(61.2)	(45.3)

[a]Calculated from $\bar{X}$ = 2.0 (SE = 0.8) people per vehicle (N = 91).
[b]U.S. Army Corps of Engineers Mitigation.
[c]COE license
[d]Champion International Corp.
[e]U.S. Forest Service.
[f]Private.

the results using Chapman's Lincoln Index seems to provide realistic estimates, given existing knowledge of the study area.

Data from demographic information collected from questionnaires could be analyzed in a number of ways. Since the intent of this paper is to discuss the survey method, only that information needed to calculate the average number of people per vehicle and the areas they used was treated.

Table 4. Estimated number of vehicles and extrapolation of number of people, type, and area of activity derived from 37 responses to mail questionnaires. Clarks Hill Wildlife Management Area, South Carolina, deer season, 11 October 1990–1 January 1991 (standard errors in parentheses).

Stratum	$\bar{X}$ N cars/ day	N days	Estimated Total cars	Estimated Total people[a]	N people by activity Hunt 96.3%	Fish 3.7%	Estimated N cars by area A1[b] 51.4%	A2[c] 18.9%	B[d] 8.1%	C[e] 18.9%	D[f] 2.7%
First week	33.5	7	234.5	398.6	383.8	14.8	120.5	44.3	19.0	44.3	6.3
			(21.3)	(122.3)	(21.8)	(7.1)	(22.3)	(15.8)	(1.5)	(15.8)	(6.3)
Fri–Sat.	72.2	22	1588.4	2700.3	2600.4	99.9	816.4	300.2	128.7	300.2	42.9
			(222.6)	(872.7)	(223.9)	(50.1)	(113.0)	(110.9)	(73.6)	(110.9)	(42.8)
Other days	9.6	33	316.8	538.6	518.7	19.9	162.8	59.9	25.8	59.9	8.4
			(13.8)	(159.9)	(16.6)	(9.8)	(7.1)	(20.8)	(14.4)	(20.8)	(8.4)
Totals			2139.7	3637.5	3502.9	134.6	1099.8	404.4	173.5	404.4	57.6
			(224.0)	(895.6)	(225.6)	(51.6)	(115.5)	(113.9)	(75.0)	(113.9)	(44.2)

[a]Calculated from $\bar{X}$ = 1.7 (SE = 0.5) people per vehicle (N = 37).
[b]U.S. Army Corps of Engineers Mitigation.
[c]COE license.
[d]Champion International Corp.
[e]U.S. Forest Service.
[f]Private.

Management Implications

Our technique using Chapman's Lincoln-Peterson Index (Seber 1982) provides a reliable means of estimating resource use on large tracts of land. We believe that a team effort could be employed to sample larger areas. Efficiency could be improved by designating a permanent route on sample roads throughout the area. Surveys would provide an index to resource user numbers.

Information on resource user numbers can be obtained with relatively little cost. Demographic information on user activities, expenditures, and preferences, obtained concurrently with the vehicle survey, can provide managers with useful information for making decisions that effect resource use. A collateral benefit is the one-to-one contact between resource users and managers provided during the interview process.

Summary

The Lincoln-Peterson Index procedure gave plausible estimates of the total number of vehicles present on the area. The total number of people was then obtained by using the average number of people per vehicle as a multiplier. Pertinent demographic information could be calculated based on the responses to questionnaires.

The study was simple to administer, costs were within existing budgets, and relatively little manpower was required.

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