Designing a Sampling System for Concurrently Measuring Outdoor Recreation Visitation and Describing Visitor Characteristics

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Abstract: Two primary information needs for managing recreation areas and the visitors to those areas are: (1) good estimates of visitation volume, and (2) accurate descriptions of visitor characteristics, such as length of stay, frequency of visit, and primary activity. For National Forests in the United States of America with large undeveloped areas, efficient sampling for the two types of information may be to a large extent incompatible. Sampling plans that address visitation volume issues allocate most of the sample days to the largest and most internally variable strata. Sampling plans for studies of visitor characteristics allocate sampling effort to locations that most efficiently provide visitor information, such as at developed sites. Additionally, sampling plans for studies of visitor characteristics may need to ensure spatial or temporal dispersion of the sample, in order to ensure adequate representation of different visitor sub-groups. A method is demonstrated for allocating days into sampling strata which balances the contribution of sample days in improving the accuracy of the total visitation estimate with the contribution of the sample day to maximizing the quantity and dispersion of visitor information. The resulting sampling allocation provides an optimal solution to address both of the information needs through a single data collection effort. A second phase of the method addresses how to ensure spatial and temporal dispersion of sampling effort. Examples of applications on National Forests in the United States are provided.
Key Words: National Visitor Use Monitoring, onsite sampling, sampling plan, use estimation, visitor characteristics, sample allocation.

Introduction

Managers of recreation and Wilderness areas need information about both the volume of visitation and some salient characteristics about those users. Accurate measures of visitation volume are critical in estimating the social and economic benefits of recreation. Accurate estimates of the characteristics of recreation visitors are needed in all aspects of a customer-focused management strategy such as prioritizing facility development and maintenance or timing management activities. Obtaining good estimates for both these types of information is more difficult and expensive if there are many uncontrolled access points, or if much of the visitation occurs in relatively low use, dispersed settings. Both situations occur on lands managed by the USDA Forest Service.

Typical approaches for jointly estimating these two sets of information on Forest Service lands involve calibrating mechanical counts of traffic, combined with some form of visitor observation or surveying (English et al. 2002, Gregoire and Buhyoff 1999, Watson et al. 2000). Sampling frames for estimating visitation and interviewing visitors almost always incorporate both spatial and temporal dimensions. Sampling strata are usually defined by the expected volume and variability of visitation levels. Sampling strata may also be defined by the existence of certain types of visitation-related information that can be used to improve visitation estimates.

A difficulty comes in choosing how to allocate sample days across the strata. Optimal allocation of sample effort when the goal is estimating total visitation volume is unlikely to coincide with optimal allocation when the objective focuses on obtaining visitor characteristics. For estimating total visitation, many sample days are allocated to low-use dispersed settings because of the stratum's size. However, few visitor contacts are likely to result from sampling in those settings. Sampling for visitor characteristics could put more emphasis on sampling in locations that coincide with greater visitor volume in order to minimize the cost per visitor survey obtained, or allocate sampling effort such that either the number or proportion of visitors in each stratum are sampled.

This paper demonstrates a method for allocating days of sampling effort into strata in a manner that accounts for the need to obtain accurate visitation volume estimates, as well as attempting to maximize both the number and representativeness of the visitors who are contacted. The method is a refinement to the Forest Service's National Visitor Use Monitoring (NVUM) project. The initial design of the NVUM project focused on estimating visitation volume. However, it has become clear that accurate estimates of visit characteristics are of equal importance for many policy decisions. Presented first is a review of the method used for allocating sample days into strata for the first cycle of NVUM sampling. Then, the rationale and computation process for the proposed model are discussed. Empirical examples for allocation of sample effort for a national forest are provided. Results for the proposed allocation model are also compared to those obtained under several other allocation algorithms.

Background

The NVUM sampling design divides developed sites on each national forest into two types based on the nature of their intended use. Access points to undeveloped areas of the forest were divided into two types; undeveloped areas that are part of the National Wilderness Preservation System and those that are not. These four mutually exclusive site types provided the spatial stratification for the sample frame. These sites types are defined as:

1. Day-Use Developed Sites (DUDS) – developed sites intended mostly for day use such as ski areas, picnic sites, wildlife viewing areas, visitor centers, and swimming areas.
2. Overnight-Use Developed Sites (OUDS) – developed sites that primarily provide overnight accommodations such as campgrounds, cabins, lodges, resorts, or horse camps.
3. Wilderness Sites (WILD) – sites or access points for designated Wilderness areas.
4. General Forest Area (GFA) – access points to any other areas in the national forest that are not DUDS, OUDS or WILD.

The basic temporal unit was a calendar day at each site or access point. A second level of stratification focused on the level of last exiting visitation for the day[1]. Every day of the sample year was classified according to the expected level of last exiting recreation visitation, as High, Medium, Low, or Closed. Stratifying days by visitation volume should yield the most precise (i.e., minimum variance) estimate of visitation. Unfortunately, intervening factors such as fire, unusual weather, or re-scheduling events can greatly affect the actual visitation for any given day, and will introduce unanticipated variability into the system. Sample days were not assigned to the closed stratum, as it was assumed that visitation levels equaled zero. Money was transferred to forests to accomplish sampling on a flat rate per day. Allocation of sample days into the strata followed an optimal allocation formula (Cochran 1977, p. 98):

$$n_h = n \frac{N_h S_h}{\sum N_h S_h} \qquad (1)$$

Where:
n = number of sample days for the forest
n_h = number of sample days in stratum h
N_h = number of site days in stratum h
S_h = standard deviation of visitation in stratum h

From this formula, more sampling effort is expended in strata with larger populations and/or higher within stratum variance. The average number of sample days per forest was a little less than 200. There was a concern that a strict adherence to the optimal allocation of days would not yield an adequate sample size for estimating either a mean or variance in some strata. For example, GFA site days accounted for well over 60% of all of the site days on the forest. Consequently, an initial allocation of 8 sample days was made to each stratum. The remaining available sample days were allocated across the strata according to the formula given in (1). In the initial sampling cycle, no reliable estimates of the standard deviations were available. It was assumed that the relative ratios of standard deviations for all site types would be Low=1, Medium=10, and High=20. To illustrate the results of this allocation method, the size of the site day population and resulting allocation of sample days are presented for the Cherokee NF in Table 1.

Single Dimension Allocation Alternatives

For determining a sample day allocation in the second round of sampling, a number of alternative algorithms that focus on one dimension were considered. Expected results for any of these can be based on information obtained in the first round of sampling. Three of these algorithms were considered.

The first was a fixed minimum allocation and optimal allocation thereafter as defined in (1) using standard deviations estimated from the first cycle. Minimum allocation was assumed to be 8 days. This method should yield the minimum variance visitation estimate. A common result is that both the number and proportion of days and interviews are unequal across strata. The exact formula would be:

$$OPTn_h = m + (n - mH)\frac{N_h S_h}{\sum N_h S_h} \quad (2)$$

Where:
m = minimum allocation per stratum
H = total number of strata

The second algorithm was a fixed minimum allocation (8 days) and thereafter allocation proportional to total visitation. More days are allocated to strata with greater visitation. This is similar to the optimal method, but weights according to visitation level rather than variance of the visitation estimate. The formula for allocating days beyond the minimum would be:

$$VISn_h = m + (n - mH)\frac{V_h}{\sum V_h} \quad (3)$$

Where:
V_h = total visitation estimate for stratum h

The third algorithm involved equalizing the sampling ratio of recreation visits across strata. This method allocates days so that about the same ratio of visits is sampled in each stratum. This method has the greatest benefits in analyzing the information obtained from the individuals surveyed to describe the visitor population, because each interview has approximately equal weight in representing the total visitor population. In the other methods, the sampling rate of the recreation visits is quite disparate. This method does not address variance in the visitation estimate. Here the allocation algorithm is:

$$SRVn_h = n * \frac{V_h / I_h}{\sum V_h / I_h} \quad (4)$$

Where:
I_h = Average number of recreation interviews per day obtained in stratum h

Multi-criterion Algorithm

The goal was to determine the sample size for any stratum, balancing between minimizing the variance of the overall visitation estimate and maximizing the amount and representation of the individual visitors surveyed. Designing sampling schemes to serve multiple purposes is not uncommon in biophysical forest monitoring efforts (Schreuder et al. 1993). The process followed initially allocates a minimum sample size to each stratum, as in equation (1). The minimum number of days can be set by the user, but for these examples it is assumed to be 8 days. The remaining sample days are assigned to strata iteratively. The algorithm computes the expected benefits for each of the objective criteria of placing the next sample day in each stratum. The values are compared, and the day is assigned to the stratum with the 'best' result. The algorithm is recomputed with the new number of sampling days, and the process continues until all available days are assigned.

The first objective criterion (O1) evaluates the marginal contribution of one more sample day to reduction in the variability of the visitation estimate. All else equal, increased sampled size in a stratum will reduce the standard deviation of the estimated visit total. Variance is reduced directly by increasing the number of sample days from which an estimate of

Table 1. Population and Allocation of Sample Days by Stratum for Cherokee National Forest.

Site type/Stratum	Site-day Population	Sample Days	Total Visits (000's)	Standard Deviation (000's)	Recreation Interviews per day
Day Use Developed:					
High	607	13	80	17	7.85
Medium	837	12	91	40	4.58
Low	5017	10	136	49	2.20
Overnight Use Developed					
High	121	9	22	4	12.33
Medium	1469	14	67	18	2.14
Low	3760	10	146	42	2.00
General Forest Area:					
High	3115	30	597	133	8.67
Medium	6179	30	262	60	3.17
Low	53182	27	978	283	1.11
Wilderness:					
High	559	11	5	2	1.91
Medium	1176	13	7	2	0.67
Low	5076	11	25	10	1.21

average daily visitation is made, and indirectly by increasing the number of visitor contacts used to calibrate traffic counts. To determine the contribution of a sample day to variance reduction, a regression equation was estimated for each stratum, using sampling results from 87 national forests. A double-log specification fit the data best, and ensured declining marginal contribution of additional sample days to expected variance. The model was:

$$\text{Log}(S_h) = f(\text{LOGVIS, LOGSIZE, LOGNH, LOGINT}) \qquad (5)$$

Where:
LOGVIS = log(visitation estimate for stratum)
LOGSIZE=log(number of days in the stratum)
LOGNH = log(sample days in the stratum)
LOGINT = log(sample days * interviews/day)

Regression results for each of the twelve sampling strata showed R-square measures over 0.92, positive coefficients on visitation and stratum size, and negative coefficients on sample days and interviews obtained. Given the values for visitation, sample size, and average interviews per day, for any expected sample size (n_h) a fitted value can be obtained for the standard deviation (SDHAT(n_h)) The contribution of the (n_{h+1}) day to reducing the standard deviation of the visitation estimate for that stratum is equal to:

(SDHAT(n_h)) - (SDHAT(n_{h+1})).

The second objective criterion (O2) is the contribution of the sample day to the number of interviews of recreation visitors. The expected gain in interviews equals the average interviews per sample day from the initial round of sampling. The range of responses is shown in the last column of Table 1. The lowest return is for Wilderness Medium (0.67 per day), and the highest in Overnight High (12.33 per day). This gain is constant regardless of how many days are allocated to any stratum, and favors strata with the highest average interviews per day.

Clearly, the units and scale for the two criteria are quite different. Converting each into a standardized measure (subtracting the mean taken over all strata and dividing by the standard deviation) allows summation into a composite score (Zarnoch et al. 2002). The stratum with the highest composite score indicates the ‘best’ choice of allocation for the next sample day. The algorithm weights the two elements equally, although a different user-defined weighting can be incorporated.

Several controls are built into the algorithm to ensure that neither criterion dominates too greatly and so that some dispersion of sample days across strata results. These controls affect the composite score, and thus the allocation of days to sampling strata. The first control computes a standardized measure of the relative concentration of sample days in each stratum. Those strata with the most sample days (highest concentration of the allocated sample) get the lowest values. The effect is to dampen the attractiveness of putting days in strata that are already over the average sample size. In each iteration, the control value for the stratum ($C1_h$) is computed as:

$$C1_h = -\left(\frac{n_h - \overline{n_h}}{Sn_h}\right) \qquad (6)$$

Where:
Sn_h = standard deviation of n_h over h strata

The second control functions as an override that is activated for any stratum that samples over a user-specified percentage of its site-days. The initial level was set at 15 percent. The override decrements the value of the composite score by a standardized measure of the proportion of unsampled days in the stratum. The effect is to limit the maximum sampling rate of site days in a stratum to about 15 percent. The computation for this control ($C2_h$) is

$$C2_h = (I2) * \left(\frac{UN_h - \overline{UN_h}}{S(UN_h)}\right) \qquad (7)$$

Where:
I2 = 1 if (UN_h) < 0.85, and 0 otherwise
$UN_h = (N_h - n_h)/N_h$
$S(UN_h)$ = standard deviation of UN_h across the h strata

A second override control (C3) computes the expected sampling rate of visits in each stratum, and decrements the composite value by a standardized measure if the sampling rate in that stratum exceeds the minimum rate in all strata by a user-defined threshold factor. Our initial setting for this factor was fairly unrestrictive, at 400. This control reduces the likelihood of allocating any more days to a stratum that already samples a very high proportion of visits, until some days are allocated to strata where the sampling ratio of visits is over 400 times less. The data in Table 1 show that there were about 101 recreation interviews obtained in the OUDS High stratum, and the total estimated visitation for that stratum is about 22,000. Thus each of the 101 interviews represents about 218 visits. In the GFA Low stratum, only 30 interviews were obtained from a total visitation estimate of 978,000. Each of these represents about 32,600 visits. In other words, each one carries about 150 times the weight of each individual survey obtained in OUDS High sampling. The computation for this control is:

$$C3_h = I3_h * 100(\frac{1}{(1+n_h)}) \quad (8)$$

Where:
$I3 = 1$ if $(V_h/(n_h*I_h)) / MIN(V_h/(n_h*I_h)) > 400$,
$= 0$ otherwise

Computation of the value of the algorithm at any iteration is simply the sum of the two objective criteria and the three controls.

Results

Results for these allocation methods for the Cherokee National Forest are presented in Table 2. The equal sampling rate for visits (SRV) allocates too few days to several of the strata to obtain accurate estimates of visitation, and yields the fewest number of interviews (361), or an average of less than 2 per day. The optimal method assigns about half the sampling days to GFA Low stratum, and yields only 508 interviews, only about 2/3 the number obtained in the first cycle of sampling (773). The proportional-to-visits method yields a sample allocation that is fairly similar to the allocation used in the initial sampling cycle. The biggest difference is 19 more days (10 percent of total sampling effort) in the GFA Low stratum. Because few interviews per day are obtained in that stratum, the number of total interviews is slightly lower. This method allocates only one more than the minimum number of days to any of the Wilderness strata, because total visitation is very small when compared to the developed site strata or general forest areas. If there is strong interest in obtaining a relatively large sample of Wilderness visitors, this allocation method may not be best.

The multiple-criterion method provides the greatest number of expected individual interviews (824), about 8% higher than that obtained in the first sampling cycle. The 80% confidence interval width for the first cycle was 17.5% of the total visitation estimate. The fitted values for variance for both the initial cycle and the multiple-criterion allocations were essentially equal. In other words, the multiple criterion method allocates a sample for this forest that could be expected to yield just about as precise a visitation estimate as the initial cycle allocation, but with 8% more information about recreation visitors. Given the equal importance of visitor information and precision of visitation estimates, this method appears to be worthwhile. However, the allocation of days to Wilderness sampling is not incremented beyond the minimum assigned level. Wilderness strata have low levels of visitor contacts per day, and make relatively little contribution to the precision of the overall visitation estimate.

These results indicate that a multiple-criterion algorithm can provide an allocation of sampling effort that is better than single-purpose allocation methods. Flexibility exists in designing minimum allocations, thresholds for triggering overrides, and weighting the relative importance of visitor contacts versus the algorithm. Given the increased need for information on recreation visitation, maximizing the total usefulness of data collection is essential. Standardizing units of the response variables for the criteria enables composite measures to be developed, and allows for compatible controls to regulate the allocation mechanism in unusual situations. Further refinements of the method presented here could come in the form of additional or more specific optimization criteria, improved estimation of the effect of sample allocation to the project objectives, or testing the sensitivity of the sample allocation to threshold levels for the override controls.

Table 2. Allocation of Sample Days by Stratum for Single Dimension Algorithms.

Site type/Stratum	OPTn	VISn	SRVn	Multi-Criteria
Day Developed:				
High	8	11	2	19
Medium	8	12	3	17
Low	9	13	9	14
Overnight Developed:				
High	8	9	1	12
Medium	8	11	5	15
Low	9	14	11	15
General Forest Area:				
High	10	31	10	27
Medium	10	18	12	18
Low	94	46	132	29
Wilderness:				
High	8	8	1	8
Medium	8	8	1	8
Low	8	9	3	8
Total Recreation Interviews	508	742	361	824

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End Notes[1]

Another portion of this stratification level focused on the existence and type of other information (such as fee envelopes, permanent traffic counts, skier visits, or mandatory wilderness permits) that could be used as a proxy for actual visitation for some set of the days of operation for any given site. To simplify the description of the model, we ignore those strata in this paper, although the process described can readily be expanded to include them.