Estimating Mast Production: An Evaluation of Visual Surveys and Comparison with Seed Traps using White Oaks

Roger W. Perry, *USDA Forest Service, Southern Research Station, Hot Springs, AR 71902, and* **Ronald E. Thill**, *USDA Forest Service, Southern Research Station, Nacogdoches, TX 75962.*

ABSTRACT: *We compared five types of visual mast surveys with seed trap data from 105 white oaks* (Quercus alba *L.*) *during 1996–1997 in the Ouachita Mountains of Arkansas. We also evaluated these visual survey methods for their usefulness in detecting differences in acorn density among areas. Indices derived from all five methods were highly correlated with acorn densities derived from traps, and the Koenig method had the highest r-values. Categorical surveys using fewer than six categories yielded significantly different acorn densities among all categories, whereas surveys using nine or ten categories did not. All survey methods detected moderate to large acorn density differences among four study areas. We found no difference in the effectiveness of visual surveys in dense versus open-forested conditions. Visual surveys are an effective method for evaluating acorn production and may be superior to seed traps for comparisons of acorn production in tree canopies since they are not affected as greatly by wildlife removal. However, visual surveys can be biased by observer differences, whereas trap data are not. South. J. Appl. For. 16(3):164–169.*

Acorns are used extensively by wildlife and are essential for oak regeneration. Because of their importance, land managers and researchers have attempted to estimate acorn crops for decades. However, direct measures of acorn production are difficult given the height, canopy size, and density of leafy vegetation of oaks, especially in the southeastern United States. Accurately counting all acorns in a tree, or in a fixed portion of the canopy, cannot be done from the ground, and doing it in the canopy is impractical.

Acorn traps, plots located on the ground, and visual surveys are three commonly used methods for estimating acorn crops. Acorn traps, which catch acorns as they fall from the tree, have been used in the majority of studies on acorn production (e.g., Downs and McQuilkin 1944, Christisen and Korschgen 1955, Goodrum et al. 1971) and in most studies relating acorn production with wildlife parameters (e.g., Nixon et al. 1975, McShea and Schwede 1993). Many types of acorn traps have been developed (Thompson and McGinnes 1963). However, traps are labor intensive and costly because they must be built, placed on site, maintained, and checked periodically. Moreover, acorn traps and ground plots only estimate the density of acorns that reach the ground, although arboreal acorn consumption by wildlife can sometimes be estimated when acorn fragments fall into traps. Nevertheless, a reliable estimate of complete arboreal removal of acorns by wildlife cannot be assessed using acorn traps or ground plots.

Visual surveys are commonly used to estimate acorn crops. These surveys are much less labor intensive because they can be completed rapidly, require only a single visit to each tree, and require little equipment. Although visual surveys do not yield quantitative estimates of acorn biomass, they provide indices that can be compared among trees, sites, or years.

Various visual survey methods have been used. Koenig et al. (1994) used a method (henceforth the Koenig method) whereby observers count acorns in the tree canopy within a given period of time (30 sec in their case). Most other visual surveys use categorical ranks to evaluate production. The Whitehead method (Whitehead 1969) has been used in many wildlife studies (e.g., Wentworth et al. 1990, Ford et al. 1997) and has been used extensively by state wildlife agencies in the southeastern United States to evaluate yearly trends and differences in acorn production among areas. This method involves estimating the percentage of a tree's canopy containing mast, the percentage of twigs containing mast, and the average number of nuts per twig to derive a rank of 0 to 10.

Other categorical ranking methods use subjective assessments such as "poor," "good," or "bumper" to describe mast production. Christisen and Kearby (1984) used a rating system ranging from 1 (few to no acorns) to

Note: R.W. Perry is the corresponding author—Phone: (501) 321-9825; Fax: (501) 623-0186; E-mail: rperry/R8_ouachita@fs.fed.us. Manuscript received May 15, 1998, accepted November 13, 1998.

9 (a bumper crop). Sharp (1958) used a rating system of 0 (no acorns detected) to 5 (a bumper crop). Other state wildlife agencies, including California (Graves 1980) and Missouri (Christisen 1980) have used an index comprised of four levels. This method has also been used in studies comparing wildlife parameters with mast production (e.g., Smith and Scarlet 1987).

Visual surveys provide useful indices of relative acorn production (Graves 1980, Koenig et al. 1994, Garrison et al 1998). However, few studies have tested whether categorical surveys provide accurate estimates of mast production and no thorough studies have been conducted on southeastern tree species. Land managers and researchers typically use mean index values derived from visual surveys for year-to-year and between-area comparisons of mast production, but whether visual surveys accurately detect mean density differences among areas is not known. Also, since many categorical scales have been used for visual surveys, it would be useful to know if increasing the number of categories increases accuracy.

In this study, we compared the estimated acorn production derived from traps with five visual survey methods to determine the usefulness of these techniques in estimating acorn density in white oaks (*Quercus alba* L.), a common oak of the southeastern United States. We also evaluated the usefulness of visual surveys in determining differences in mean acorn densities among areas and whether differences in forest stand density affect survey accuracy.

Materials and Methods

Study Areas

The study was conducted during 1996 and 1997 in four late-rotation mixed pine-hardwood stands in the Ouachita and Ozark National Forests of west-central Arkansas. An unharvested forest stand and a partially harvested stand were selected in both the northern and southern portions of the Ouachita Mountains. The Ouachita Mountains are a series of east-west ridges and valleys where elevations range from 152 to 853 m, mean annual precipitation ranges from 112 to 137 cm, and mean annual temperatures range from 13.9°C to 16.1°C (Skiles 1981).

Unharvested stands were naturally regenerated, approximately 80 yr old, were previously unmanaged, and occupied about 18 ha on predominately southern aspects with slopes of 5–20%. Total basal area in unharvested stands was 29.9 m^2/ha, with hardwoods comprising 7.1 m^2/ha. Partially harvested stands were similar in size, age, and aspect to unharvested stands but were harvested in 1993 using pine-hardwood single tree selection (Baker 1994). Residual overstory hardwood basal areas in these stands was 2.8 to 5.1 m^2/ha and total basal area was 15.4 to 16.1 m^2/ha. The most abundant tree species within study stands were shortleaf pine (*Pinus echinata* Mill.), white oak, post oak (*Quercus stellata* Wang.), sweetgum (*Liquidambar styraciflua* L.), and hickories (*Carya* spp.).

Visual Surveys Methods

We surveyed 15 white oaks in each stand during 1996 and 12–15 different white oaks in each stand in 1997. Trees selected were larger than 20 cm in dbh, dominant or codominant in crown position, and had visible acorn production. Because acorns can be difficult to see in white oaks when densities are low, an additional five trees in unharvested stands with no visible acorn production were selected to test the accuracy of visual surveys in detecting absence of acorns. Thus, 120 trees were surveyed during the 2-yr period, although only 105 were included in analysis (see the Acorn Density Estimates section below). We surveyed trees in early September, just prior to acorn fall.

Each tree was surveyed using five different visual survey methods. A single observer completed all surveys to eliminate observer biases. We first used the Koenig method on each tree (Koenig et al. 1994). For this survey, the observer randomly selected a portion of the crown and counted all mature acorns seen through binoculars during a 15 sec period. The observer then moved to another side of the tree and counted acorns for an additional 15 sec period. Both counts were combined, and the total number of acorns counted in 30 sec was used as the index value.

We then evaluated each tree using the Whitehead method (Whitehead 1969). First, the entire tree canopy was scanned using binoculars, the percent of the crown containing acorns was categorized as 1 of 4 percentage classes (column 1, Table 1), and the score for that percentage class was noted. Next, the percent of twigs within the portion of the crown containing acorns was estimated, categorized as 1 of 4 percentage classes (column 3, Table 1), and the score for twigs was noted. Finally, the average number of acorns on producing twigs was estimated, and the score for that number was noted. The overall production index for each tree was derived by summing the scores for each of the three measures (percent of crown, percent of twigs, and average number of nuts). For example, a tree in which 50% of the crown had acorns (score = 2), 30% of the twigs within that portion of the crown had acorns (score = 1), and the average number of acorns per twig was 2 (score =1), would have a Whitehead index of 4. This method results in a number between 0 (little or no mast) and 10 (a bumper crop).

Table 1. Classes and corresponding score used to determine Whitehead's (1969) oak mast index.

Percent of crown with acorns		Percent of twigs with acorns		Ave. no. of acorns/twig	
% class	Score	% class	Score	Ave. no.	Score
0–5	0	0–5	0	0	0
6–33	1	6–33	1	1–2	1
34–66	2	34–66	2	3–4	2
67–100	3	67–100	3	5–6	3
				7+	4

We then observed the crown of each tree for several minutes with binoculars and ranked the overall acorn crop using three other categorical scales. The first scale was Graves' modified scale (Graves 1980, Koenig et al. 1994), which uses five levels; 0 = no nuts observed, 1 = a few nuts seen under close scrutiny, 2 = a fair number of nuts, 3 = a good crop, and 4 = a bumper crop. The second was Sharp's (1958) 6-category scale where 0 = none, 1 = trace, 2 = poor, 3 = fair, 4 = good, and 5 = bumper. The third was Christisen and Kearby's (1984) 9-category scale where 1 = few to none, 2 = poor (sparsely scattered acorns), 3 = poor+ or fair–, 4 = fair, 5 = fair+ or good–, 6 = good (evenly distributed acorns with numerous small and medium-sized clusters), 7 = good+ or heavy–, 8 = heavy (numerous medium and large-sized clusters throughout the crown), 9 = bumper (very high acorn density over a large percentage of the crown).

Acorn Density Estimates

Acorn density was estimated using acorn traps. Two trap types were used under each tree: metal trash cans (37 cm tall with a 0.33 m diameter opening) and wooden peach baskets (30 cm tall with a 0.43 m diameter opening). Traps had poultry wire covers to prevent wildlife from removing acorns. Traps were placed under each tree half-way between the trunk and canopy edge and in random orientation to the trunk. The number of acorn traps used varied depending on the estimated number of acorns observed in individual tree canopies. Trees with numerous acorns were sampled with four acorn traps; those with relatively few acorns were sampled with 5–6 traps. Average sample area per tree was 0.543 m^2. Acorn density (number of acorns/m^2) for each tree was estimated using the total number of acorns collected in traps divided by the trap sampling area. Acorn traps were placed under trees in early August, prior to acorn fall, and acorns were removed every 14 days until all acorns had fallen (typically early December). This technique was possible because there was little or no crown overlap among oaks in our study areas.

Because the goal of our study was to test whether visual surveys accurately estimate acorn production, steps were taken to account for wildlife consumption in study tree canopies. Partially consumed and/or fragmented acorn husks collected in traps were combined to estimate the number of whole acorns consumed in tree canopies. The density of these partially consumed or fragmented acorns was added to densities of undamaged, mature acorns collected in traps to better reflect total acorn production. However, to reduce errors in the density estimates that may have occurred from extreme wildlife removal, 13 trees with acorn damage rates greater than 85% were deleted from the data set. Two additional trees that had abundant acorns in their canopies but yielded no acorns in traps were also deleted, leaving a total of 105 of the original 120 sample trees.

Data Analysis

The five visual surveys methods were compared with acorn densities using Pearson correlation coefficients (SAS Institute, Inc. 1988). Density data and Koenig index data were log-transformed [$\ln(x + 1)$] to increase the linearity of the index-density relationship. Indices derived using the Koenig method were regressed with acorn density estimates using linear regression (SAS Institute, Inc. 1988).

Mean acorn density was determined for each value of the four categorical visual survey methods (Whitehead, Sharp, Christisen-Kearby, and modified Graves). Density data from traps were log transformed to reduce the correlation between the mean and variance (Sokal and Rohlf 1969). Differences in acorn density were tested among categorical index levels using analysis of variance and Tukey's studentized range tests at the 0.10 probability level (SAS Institute, Inc. 1988).

To determine if visual surveys were useful in determining differences in acorn density among areas, we first compared the mean acorn density among our four study stands. We then compared the mean index values among the four stands using the five visual survey methods. Differences in mean acorn density and mean index values among stands were tested using analysis of variance and Tukey's studentized range test at the 0.10 probability level.

To compare the general accuracy of visual surveys in dense canopy conditions versus relatively open forest stands, we compared the Pearson's correlation coefficients (log-transformed density estimates correlated with the survey values of producing trees) of the two unharvested stands with the two partially harvested stands using a homogeneity of correlation coefficients test (Steel and Torrie 1960).

Results and Discussion

All five visual survey methods were highly correlated with acorn densities (Table 2). The Koenig method had the highest r value, although r values were similar for the five methods. These results suggest that all five visual survey methods are roughly comparable for estimating acorn densities.

There was a strong ($r^2 = 0.76$), highly significant ($F = 334.7$, $n = 105$, $P = 0.0001$) linear relationship between the Koenig acorn counts and corresponding acorn densities as expressed by the following equation: $y = 1.13x + 0.05$, where x = number of acorns counted in 30 sec and y = acorn density. These results are similar to what both Koenig et al. (1994) and Garrison et al. (1998) found when evaluating this method on oak species in California. Thus, these data suggest the Koenig method is highly effective in predicting acorn densities in white oaks.

Index values coincided with significantly different mean acorn densities at all categorical levels using the modified Graves and the Sharp methods (Table 3). All four categorical

Table 2. Pearson correlation coefficients between five visual surveys and log-transformed ($\ln[x+1]$) acorn density (number of acorns/m^2) under 105 white oaks in the Ouachita Mountains, Arkansas.

Visual survey method	r	$P > \lvert r \rvert$
Koenig[1]	0.87	0.0001
Whitehead	0.85	0.0001
Christisen-Kearby	0.81	0.0001
Sharp	0.85	0.0001
Modified Graves	0.85	0.0001

[1] Values of the Koenig index were log-transformed.

Table 3. Mean (± SE) white oak acorn density (number of acorns/m²) collected in traps for each categorical value of the Whitehead, Christisen-Kearby, Sharp, and modified Graves visual mast survey methods in the Ouachita Mountains, Arkansas.

Index	Whitehead		Christisen-Kearby		Sharp		Modified Graves	
value	*n*	Mean	*n*	Mean	*n*	Mean	*n*	Mean
0	5	0.0 a[1] ± 0.0			5	0.0 a ± 0.0	5	0.0 a ± 0.0
1	6	9.9 b ± 2.7	9	3.0 a ± 1.4	10	11.6 b ± 2.1	26	15.6 b ± 2.2
2	7	15.0 bc ± 2.1	16	15.8 b ± 1.8	24	24.4 c ± 4.2	24	40.2 c ± 4.8
3	13	20.3 bc ± 3.9	12	27.4 b ± 7.5	25	53.9 d ± 6.4	32	81.8 d ± 7.6
4	13	32.6 c ± 6.6	19	44.4 c ± 4.4	26	84.9 e ± 8.4	18	143.0 e ± 15.3
5	22	56.7 d ± 6.5	9	58.8 cd ± 11.0	15	153.8 f ± 16.9		
6	18	93.7 de ± 10.7	14	85.0 de ± 9.9				
7	9	111.1 e ± 19.1	12	113.4 de ± 16.5				
8	10	153.0 e ± 24.5	7	124.9 de ± 21.6				
9	2	124.3 de ± 8.2	7	165.4 e ± 29.5				
10	0	— —						

[1] Within columns, means followed by the same letter are not different ($P > 0.10$) using Tukey's studentized range test on log-transformed ($\ln[x + 1]$) density data.

surveys were effective in distinguishing large differences in acorn density, although minor differences in index values did not always represent differences in acorn density using the Christisen-Kearby and Whitehead methods. Among these latter two survey methods, the ranges in acorn density associated with each categorical level commonly overlapped. Because of this and their relatively large standard errors, we suggest these two survey methods not be used to estimate differences among individual trees with relatively similar production.

Although the Whitehead method scores trees from 0 to 10, we had no trees that scored a 10 and only two trees that scored a 9. The small sample size of trees scoring 9 is probably why their mean acorn density was less than trees scoring 8. The index value derived using the Whitehead method is partially based on the number of acorns per twig (the size of acorn clusters). White oaks in this study rarely had more than four acorns/twig, making values of 9 rare and values of 10 nonexistent. Since the maximum possible index level obtained using the Whitehead method is controlled by the number of fruits/twig, mast species such as mockernut hickory (*Carya tomentosa* Nutt.), which rarely have more than three nuts/cluster (personal observation), would have a maximum potential index of 8. Species like post oak, which frequently have more than seven acorns/cluster, would have a maximum index value of 10. The difference in maximum obtainable index of the Whitehead method complicates comparisons among different masting species. However, unlike other categorical surveys, this method better represents the differences in total number of fruits produced by different species (although fruit size is not accounted for).

All five visual survey methods were effective in distinguishing large differences in acorn production among areas when compared with trap densities (Table 4). All visual methods detected an acorn density difference between the highest acorn density stand (harvested south) and the two lower density stands (unharvested south and north). However, the effectiveness of the visual surveys in determining differences among the intermediate-density areas was equivocal. The Whitehead method detected no difference between the harvested north and harvested south stands and the Christisen-Kearby method detected no difference between the unharvested north and south stands, whereas the Sharp and modified Graves methods indicated differences in these pairs. These data suggest that the Koenig, Christisen-Kearby, and Whitehead surveys may be similar in their effectiveness when determining density differences among areas.

Correlations among index levels and acorn densities were good, but arboreal acorn consumption was high in some trees, and this may have reduced our ability to discern the full effectiveness of the visual surveys. The mean percentage of acorns collected in traps that were either partially consumed or fragmented by wildlife was 33.3% (SE = 3.1%) for all 115 producing trees. These acorns represent those that were at least partially consumed in the canopy. Two sample trees had abundant acorn crops when viewed during surveys, but no acorns were collected in their traps and no nuts were observed on the ground under the canopy, suggesting complete arbo-

Table 4. Comparison of white oak acorn density (number of acorns/m², collected in seed traps) among two partially harvested and two unharvested stands and comparisons among these stands using five visual survey methods in the Ouachita Mountains, Arkansas.

	Harvested		Unharvested	
Variable	South (n = 30)	North (n = 27)	South (n = 29)	North (n = 19)
Trap density	95.2 a[1] ± 8.9	69.2 ab ± 4.0	47.0 bc ± 9.0	19.0 c ± 4.0
Koenig index	43.8 a ± 2.3	31.8 b ± 3.4	25.2 bc ± 3.1	15.3 c ± 2.9
Whitehead index	6.0 a ± 0.3	4.9 ab ± 0.3	4.4 b ± 0.4	2.7 c ± 0.4
Christisen-Kearby index	6.2 a ± 0.3	4.6 b ± 0.5	4.1 bc ± 0.4	2.8 c ± 0.4
Sharp index	3.9 a ± 0.2	3.1 b ± 0.2	2.7 b ± 0.3	1.7 c ± 0.2
Modified Graves	3.1 a ± 0.1	2.2 b ± 0.2	2.1 b ± 0.2	1.4 c ± 0.2

[1] Within rows, means followed by the same letter are not different ($P > 0.10$).

real removal of acorns. Thus, visual surveys may yield better estimates of acorn production for wildlife, whereas traps provide better estimates of acorn production for regeneration.

Koenig et al. (1994) suggested counting acorn caps collected in traps as a way to estimate arboreal predation. However, in a concurrent study we collected more than 5000 acorns from the canopies of five oak species and found acorns were difficult to detach from caps unless the acorns were ready to fall (personal observation). Thus, arboreal predators would probably remove caps along with the nuts. Fragmented caps were as common as nut fragments in traps, suggesting wildlife were picking caps and nuts together prior to consumption. We found no difference in numbers of caps and numbers of acorns collected in traps using a matched-pairs t-test on all producing trees (mean difference = 0.61, SE = 0.89, n = 100, t = 0.69, P = 0.49). Thus, we obtained no reliable estimates of complete arboreal removal.

The density of trees surrounding sample trees made seeing acorns difficult at times. However, we found no difference in the reliability of the surveys in the densely forested, unharvested areas versus the more open, partially harvested areas (Table 5). Although the correlation coefficients appeared to be higher in the dense stands, these differences were not significant.

Our data suggest most visual surveys are effective in determining relative acorn production in tree canopies, whereas seed traps are effective in determining acorn biomass reaching the forest floor. Although seed traps are best for estimating the seed fall available for regeneration, studies comparing mast production among areas or years using seed traps or ground plots may suffer from inherent problems when used to estimate total production available for wildlife. Besides the problem of wildlife removal and consumption of mast in the tree canopy, seed traps can also be unreliable if a sufficient portion of the area under a tree's canopy is not sampled. One trap is not sufficient to estimate a tree's production given the variance observed beneath individual trees. Koenig et al. (1994) estimated that an average of only 0.3 % of the total canopy area was sampled using 3, 0.2 m^2 acorn traps, whereas the Koenig visual survey sampled approximately 13% of the tree canopy. The four categorical surveys discussed here involve observing nearly the entire tree canopy.

Table 5. Correlation coefficient comparison between white oak acorn density (log-transformed number of acorns/m²) and visual surveys in partially harvested (open) stands and unharvested (dense) stands in the Ouachita Mountains, Arkansas.

	r			
Visual survey	Open (n = 57)[2]	Dense (n = 43)[2]	z	$P > \mid z \mid$
Koenig[1]	0.68	0.75	0.66	0.51
Whitehead	0.76	0.81	0.63	0.53
Christisen-Kearby	0.80	0.82	0.28	0.78
Sharp	0.79	0.76	0.31	0.76
Modified Graves	0.80	0.83	0.31	0.75

1 Koenig survey values were log-transformed.
2 Only trees producing mast were included in analysis.

Various factors can affect an observer's ability to see mast during visual surveys, especially in tall (>18 m) trees. Extreme sun angles, position of the observer in relation to the sun, cloud cover, and canopy leaf density can affect one's ability to accurately see mast in trees. Mast can be difficult to count on windy days because of branch and leaf movement, causing errors in counting with the Koenig method, whereas moving leaves reveal mast that would otherwise not be seen and increases the accuracy of the categorical survey methods. For mast species other than white oak, acorn placement in relation to leaves can complicate surveys if differences in acorn growth among species are not recognized (Sharp 1958). Thus, an observer's viewing angle must be adjusted for the species studied. Contrasts in color or texture between mast and leaves can affect accuracy. White oak acorns, which are typically green prior to falling, are more difficult to see among the leaves than northern red oak (*Quercus rubra*) acorns, which are red. The size of the mast also affects the accuracy of the mast surveys. Hickories, with nuts that average about 6 cm in diameter, are much easier to see than post oak acorns, which average only about 1 cm in diameter

Our results substantiate findings by Graves (1980), Koenig et al. (1994), and Garrison et al. (1998) that visual surveys are a legitimate means for quantifying relative mast production in tree canopies. Our results also suggest that all five of these visual surveys can be used effectively in determining moderate to large mast production differences among study areas Visual surveys may be superior to seed traps in their simplicity, low cost, and possible accuracy in describing total acorn production in tree canopies, but there are shortfalls associated with visual surveys. Because visual surveys result in an index, estimates of density or mass of mast produced cannot be made without developing conversion factors. Conversion factors are typically created using seed traps which are affected by wildlife removal in the tree canopies. Thus, accurate conversion factors are difficult to obtain. Whitehead (1969) developed conversion factors for his visual surveys by surveying trees prior to harvest and counting all nuts after felling. In addition, visual surveys take into consideration only mast numbers, not mass. Acorn size among individual oaks of the same or different species can vary greatly, and these differences are not considered in any of the visual surveys we evaluated.

Another shortfall of visual surveys are their susceptibility to observer differences. When more than one observer is used to conduct surveys, it is imperative that all procedures are standardized prior to conducting surveys. Different observers may count acorns at different speeds using the Koenig method or interpret what is considered a twig or branch differently using the Whitehead method. When using categorical surveys with subjective measures such as fair, good, or bumper, all observers should have prior exposure to trees with varying levels of acorn production so they know what constitutes a fair, good, or bumper mast crop. Graves (1980) demonstrated that 3 observers classified 150 trees the same only 73% of the time when using a 4-category classification survey. Thus, variation among observers can be high, especially when numerous category levels are used such as in the Christisen-Kearby method.

The five visual survey methods differed only slightly in their difficulty and accuracy. The Graves, Sharp, and Christisen-Kearby methods were the simplest to perform and took the least amount of time to complete, whereas the Whitehead and Koenig methods took slightly longer (usually less than 3 minutes per tree). The Koenig method is probably less affected by observer biases than the other methods. No relative knowledge of acorn production (e.g., poor, average, or bumper) is required, making it less subjective than other methods. Furthermore, there are no ambiguous terms such as "branch" or "twig" with this method. Thus, we preferred the Koenig method over the other visual survey methods.

Visual surveys provide a quick and inexpensive method for evaluating relative acorn production and may be superior to traps for estimating production in tree canopies if done early enough to avoid substantial wildlife removal. However, visual surveys may not be useful in detecting small differences among individual trees or areas. Likewise, traps are probably no more useful than visual surveys in detecting these small differences given the confounding factors associated with trapping. Furthermore, visual surveys can be biased by observers if methods are not standardized, whereas trap data are independent of observer influences. Thus, visual surveys may be used for estimating moderate to large differences in mast production among trees or areas if the aforementioned safeguards are applied.

Literature Cited

BAKER, J.B. 1994. An overview of stand-level ecosystem management research in the Ouachita/Ozark National Forests. P. 18–28 *in* Ecosystem management research in the Ouachita Mountains: Pretreatment conditions and preliminary findings. USDA For. Serv. Gen. Tech. Rep. SO-112.

CHRISTISEN, D.M. 1980. Mast yields in Missouri. Preformance Rep. Surveys Invest. Proj. Mo. Dep. Conserv. 10 p.

CHRISTISEN, D.M., AND W.H. KEARBY. 1984. Mast measurement and production in Missouri (with special reference to acorns). Missouri Dep. Conserv., Terrestrial Series 13. Jefferson City. 35 p.

CHRISTISEN, D.M., AND L.J. KORSCHGEN. 1955. Acorn yields and wildlife usage in Missouri. Trans. N. Am. Wildl. Conf. 20:337–357.

DOWNS, A.A., AND W.E. MCQUILKIN. 1944. Seed production of southern Appalachian oaks. J. For. 42:913–920.

FORD, W.M., A.S. JOHNSON, AND P.E. HALE. 1997. Influences of forest type, stand age, and weather on deer weights and antler size in the southern Appalachians. South. J. Appl. For. 21:11–18.

GARRISON, B.A. , R.L. WACHS, J.S. JONES, AND M.L. TRIGGS. 1998. Visual counts of acorns of California black oak (*Quercus kelloggii*) as an indicator of mast production. West. J. Appl. For. 13:27–31.

GOODRUM, P.D., V.H. REID, AND C.E. BOYD. 1971. Acorn yields, characteristics, and management criteria of oaks for wildlife. J. Wildl. Manage. 35:520–532.

GRAVES, W.C. 1980. Annual oak mast yields from visual estimates. P. 270-274 *in* Proc. of the symp. on the ecology, management, and utilization of California Oaks, Plumb, T.R. (tech.coord.).USDA For. Serv. Gen. Tech. Rep. PSW-44.

KOENIG, W.D., J.M.H. KNOPS, W.J. CARMEN, M.T. STANBACK, AND R.L. MUMME. 1994. Estimating acorn crops using visual surveys. Can. J. For. Res. 24:2105–2112.

MCSHEA, W.J., AND G. SCHWEDE. 1993. Variable acorn crops: responses of white-tailed deer and other mast consumers. J. Mammal. 74:999–1006.

NIXON, C.M., M.W. MCCLAIN, AND R.W. DONOHOE. 1975. Effects of hunting and mast crops on a squirrel population. J. Wildl. Manage. 39:1–25.

SAS INSTITUTE, INC. 1988. SAS/STAT user's guide, Version 6.03 Edition. SAS Institute, Cary, NC. 1028 p.

SHARP, W.M. 1958. Evaluating mast yields in the oaks. Penn. State Univ. Agric. Exp. Sta. Bull. 635. University Park. 22 p.

SKILES, A. 1981. Arkansas climate atlas. Arkansas Energy Office, Arkansas Indus. Dev. Comm., Little Rock, AR. 93 p.

SMITH, K.G., AND T. SCARLETT. 1987. Mast production and winter populations of red-headed woodpeckers and bluejays. J. Wildl. Manage. 51:459–467.

SOKAL, R.R., AND F.J. ROHLF. 1969. Biometry. W.H. Freeman, San Francisco, CA. 776 p.

STEEL, R.G.D., AND J.H. TORRIE. 1960. Principles and procedures of statistics, with special reference to the biological sciences. McGraw-Hill, New York. 481 p.

THOMPSON, R.L., AND B.S. MCGINNES. 1963. A comparison of 8 types of mast traps. J. For. 61:678–680.

WENTWORTH, J.M., A.S. JOHNSON, AND P.E. HALE. 1990. Influence of acorn use on nutritional status and reproduction of deer in the Southern Appalachians. Proc. Annu. Conf. Southeast. Assoc. Fish and Wildl. Agencies 44:142–154.

WHITEHEAD, C.J. 1969. Oak mast yields on wildlife management areas in Tennessee. Tenn. Wildl. Resour. Agency, Nashville, TN. 11 p.