Studies in Avian Biology No. 6:139–145, 1981.

THE DETERMINATION OF AVIAN DENSITIES USING THE VARIABLE-STRIP AND FIXED-WIDTH TRANSECT SURVEYING METHODS

KATHLEEN E. FRANZREB[1]

ABSTRACT.—This study assesses the extent to which the variable-strip and fixed-strip transect methods satisfy the assumptions upon which they are based. Mathematical as well as verbal descriptions of both sampling methods are provided.

The variable-strip transect method involves the observer traversing a transect of predetermined length and recording the lateral distance from the transect of each bird observed. Avian densities are calculated by counting the number of individuals found in strips on both sides of the transect from the base to the point of inflection on the distribution curve of the results. This transect method can be used at any time of the year and enables an observer to quickly census relatively large areas for all birds including breeding birds, non-breeding birds, and fledglings.

Several modifications in the variable-strip transect method are suggested including using the additional category of "all observations" in the density calculation. It is also suggested that measurements be recorded as precisely as possible and pooled at a later time into smaller increments than those recommended by J. T. Emlen (1971).

In the fixed-strip or belt transect method, a transect of known length and width are sampled. Species may be assigned belts of different widths depending upon each species' detectability characteristics.

This study computed avian densities in a mixed-coniferous forest in the White Mountains, Arizona, using the variable-strip transect method. Data were also segregated on the basis of strips of fixed-widths (15 m, 30 m, 60 m, and 125 m wide belts located on both sides of the transect).

The variable-strip transect data indicated a total avian community density of 835.4 birds per 40 ha. Of the four fixed-widths, the highest density was calculated for the 60 m strip on either side of the trail (519.3 birds per 40 ha).

Until relatively recently probably the most widely used sampling technique to estimate population size of breeding birds was the spot-map (or territorial mapping) method (Williams 1936). This approach has several limitations, namely, it is time-consuming, and is only applicable during the breeding season, since it is only then that most avian species maintain territories. A number of innovative approaches have been proposed which offer alternatives to the spot-map technique.

One such alternative is the variable-strip transect method developed by J. T. Emlen (1971) which is now a widely used censusing technique and has provided a rapid, relatively easy way to sample large areas during any season of the year. The objectives of this investigation were to: (1) explore the theory of line sampling more fully by examining the assumptions upon which the variable-strip and fixed-width transect methods are based, (2) discuss the shortcomings and advantages of both these techniques, (3) compare the results of the variable-strip transect method to those of transects of fixed-widths, and (4) suggest modifications of the variable-strip transect method to enhance its reliability.

[1] U.S. Fish and Wildlife Service, Endangered Species Office, 1230 N Street, 14th Floor, Sacramento, California 95814.

MATERIALS AND METHODS

STUDY AREA

The study was conducted in the Willow Creek watershed, a mixed-coniferous forest located in the Apache-Sitgreaves National Forest, White Mountains, Arizona, during the summer of 1974. Elevation ranged from 2682 m to 2805 m. The vegetation is dominated by Douglas fir (*Pseudotsuga menziesii*), ponderosa pine (*Pinus ponderosa*), and southwestern white pine (*Pinus strobiformis*). A total of eight tree species were present, of which only quaking aspen (*Populus tremuloides*) was deciduous. A detailed description of the study area derived from the plotless point-quarter sampling method (Cottam and Curtis 1956) is provided in Franzreb and Ohmart (1978).

AVIAN SPECIES DENSITIES

Assumptions

Line transect methods, in general, employ a variety of assumptions which include the following (the accuracy and validity of the variable-strip and fixed-width sampling methods depend on the degree to which the assumptions are satisfied and will be addressed later in the Discussion): (1) birds are uniformly and randomly distributed; (2) the probability of observing a bird decreases with distance from the transect, or remains constant to a given distance and then declines rapidly; (3) the behavior of birds in one portion of the band width does not influence those in another; (4) the probability that a bird is observed if it is at right angles from the transect at a distance (w) is given by the simple function $g(x)$ such that $g(0) = 1$ (Burnham et al. 1980, Seber 1973) (This simply means that birds directly on the line will never be overlooked); (5) the bird does not move in response to the observer's presence prior to being detected; (6) no bird is counted more than once; (7) there are no measurement errors; (8) the response behavior of the avian community does not change appreciably throughout the sampling period; and (9) the response behavior of individuals of a species is similar regardless of sex or age.

In this study a transect line 1.6 km long was established using plastic flagging, a steel tape, and compass. Sampling began ½ hr after sunrise and was completed within two hours. This line consisted of four individual parallel transects each extending 400 m in length. The starting point of the first transect was randomly located. Six surveys concentrated at the beginning of each month were conducted beginning 1 June and ending 9 August 1974. The weather during each survey was either clear or with less than 30% overcast and with little, or no wind. Results are represented in terms of the mean of the monthly values. The results of each month's six surveys were pooled and the density values then calculated to provide a monthly figure. The overall density value was computed by averaging the June, July, and August values.

Data analysis

The accumulated data for each species are plotted on a graph with distance on the abscissa and number of observations on the ordinate. The density value for each species is calculated by counting the number of individuals encountered in strips located on both sides of the transect from the base to the point of inflection on the distribution curve of the results. Given that detectability declines with distance from the transect, if the area in these particular strips is multiplied by the appropriate value, the resulting figure will be the number estimated to occur within the 125.6 m (412 ft) or another appropriate value, on both sides of the transect line. The procedure and computation are more fully described in J. T. Emlen (1971).

According to the established technique, data are generally tabulated separately for singing males and for all other observations (J. T. Emlen 1971). Results from the singing male data are multiplied by two (assuming each male is paired) and compared to those from all other observations, with the adoption of the larger value. Instead, I utilized the highest number of observations encountered in either twice the singing male data, or all other observations, or all total observations (male data plus all other observations). Data are expressed as density per 40 ha as this is a standard size in avian studies.

J. T. Emlen (1977) proposed refinements in his variable-strip transect method as described in 1971. During the breeding season, he suggests that locality specific cue frequency values based on song frequency be determined for each species which are then used to calculate breeding density. A further explanation regarding the data collection and analysis process involved in the derivation of cue frequency values and the computation of avian densities appears in J. T. Emlen (1977). Results of this study were analyzed following the procedures as outlined in J. T. Emlen's 1971 paper.

Mathematical representation

The variable-strip transect method as described by J. T. Emlen (1971, 1977a) was not mathematical in its development but is similar to the method developed by Anderson and Pospahala (1970). Mathematically the model is represented as follows (Burnham and Anderson 1976): if W is the fixed strip width, a characteristic proportion of birds of a given species will be detected within $2LW$ where L is the length of the transect. It is assumed that $g(0) = 1$ which indicates that all birds on the actual transect line will be observed (probability of 1); then the coefficient of detectability $(\widehat{CD}_w) = n/(W\hat{h}(0)) = 1/W\hat{f}(0)$ where $\hat{h}(0)$ is the estimator of $n\hat{f}(0)$ which was determined for a smoothed frequency histogram; and finally the density estimator $(\hat{D})$ is: $\hat{D} = n/2LW\widehat{CD}_w) = (n\hat{f}(0))/(2L)$.

A similar method to the variable-strip technique as developed by Emlen was described by Kelker (1945). Both methods rely upon density estimates for bands within which it is assumed there is 100% coverage. Kelker discards observations falling beyond the distance from the transect at which observations begin to decline, whereas Emlen uses all the data (though the actual density calculation is similar). Anderson and Pospahala (1970) developed an elaboration of Kelker's method which involves fitting a regression curve for the frequency distribution data to allow calculation of an estimate of the objects observed in the belt of attempted coverage. Robinette et al. (1974) compared 10 census methods including those of Kelker and Anderson and Pospahala and found the results were within 15% of the correct density.

Data analysis fixed-width method

The fixed-strip survey method (Kendeigh 1944, Emlen 1974, and others), whereby belts of given widths are sampled on either side of the established transect, was applied to the data collected using the variable-strip transect data for the month of July. Data were segregated according to 15.2 m (50 ft), 30.5 m (100 ft), 61.0 m (200 ft), and 125.6 m (412 ft) wide belts of strips extending on either side of the transect.

Mathematical representation fixed-width method

Mathematically the fixed-width technique's density estimate $(\hat{D})$ is indicated by $\hat{D} = n/(2LW)$ where n is the number of observations within the strip of width W and transect of length L.

Other models

Numerous models representing the distribution curve of the sampling results have been proposed which graphically and mathematically portray the relationship of the number of observations versus distance from the transect line. For a detailed discussion of such models the reader is referred to the monograph by Burnham et al. (1980).

RESULTS

Analysis of data derived from the variable-strip transect sampling method indicated an avian community density of 835.4 birds per 40 ha (Table 1). Among the most abundant species

TABLE 1
AVIAN SPECIES DENSITIES (NUMBER PER 40 HA) DERIVED USING THE VARIABLE-STRIP AND FIXED-STRIP CENSUSING METHODS

	Density				
	Variable-strip	Fixed-strip width			
Species	transect	15 m	30 m	60 m	125 m
Goshawk (*Accipiter gentilis*)	1.8	0.0	1.4	0.7	0.3
Broad-tailed Hummingbird (*Selasphorus platycercus*)	20.8	2.7	9.6	4.8	2.4
Common Flicker (*Colaptes auratus*)	18.3	8.2	11.0	13.8	7.5
Yellow-bellied Sapsucker (*Sphyrapicus varius*)	5.2	0.0	2.7	2.1	1.0
Williamson's Sapsucker (*S. thyroideus*)	5.5	2.7	2.7	2.1	1.0
Hairy Woodpecker (*Picoides villosus*)	6.7	0.0	4.1	3.5	1.7
Downy Woodpecker (*P. pubescens*)	4.2	2.7	2.7	2.1	1.4
Northern Three-toed Woodpecker (*P. tridactylus*)	12.8	5.5	5.5	4.8	2.4
Western Flycatcher (*Empidonax difficilis*)	71.6	21.9	32.9	21.4	10.5
Olive-sided Flycatcher (*Nuttallornis borealis*)	0.6	0.0	0.0	0.7	0.3
Violet-green Swallow (*Tachycineta thalassina*)	8.6	0.0	0.0	1.4	0.7
Steller's Jay (*Cyanocitta stelleri*)	16.5	5.5	9.6	7.6	5.1
Common Raven (*Corvus corax*)	3.4	2.7	1.4	0.7	0.3
Clark's Nutcracker (*Nucifraga columbiana*)	2.4	0.0	2.7	1.4	0.7
Mountain Chickadee (*Parus gambeli*)	64.8	43.8	37.0	26.2	13.9
White-breasted Nuthatch (*Sitta carolinensis*)	5.2	2.7	2.7	1.4	0.7
Red-breasted Nuthatch (*S. canadensis*)	23.8	2.7	6.9	6.2	3.4
Pigmy Nuthatch (*S. pygmaea*)	27.2	0.0	20.6	16.6	8.2
Brown Creeper (*Certhia familiaris*)	46.4	35.6	34.3	23.5	11.6
House Wren (*Troglodytes aedon*)	5.7	0.0	2.7	2.1	1.4
American Robin (*Turdus migratorius*)	3.0	0.0	0.0	1.4	1.0
Hermit Thrush (*Catharus guttatus*)	42.8	30.1	48.0	43.5	34.0
Golden-crowned Kinglet (*Regulus satrapa*)	51.4	30.1	45.2	23.5	11.6
Ruby-crowned Kinglet (*R. calendula*)	88.6	38.4	49.3	33.8	18.4
Warbling Vireo (*Vireo gilvus*)	17.7	8.2	8.2	6.2	3.4
Olive Warbler (*Peucedramus taeniatus*)	3.7	8.2	5.5	2.8	1.4
Yellow-rumped Warbler (*Dendroica coronata*)	136.5	82.2	87.7	57.3	28.2
Grace's Warbler (*D. graciae*)	4.9	8.2	5.5	2.8	1.4
Red-faced Warbler (*Cardellina rubrifrons*)	40.3	13.7	15.1	8.3	4.1
Western Tanager (*Piranga ludoviciana*)	3.6	2.7	1.4	1.4	0.7
Black-headed Grosbeak (*Pheucticus melanocephalus*)	3.7	8.2	4.1	2.1	1.0
Pine Siskin (*Carduelis pinus*)	14.0	2.7	9.6	5.5	2.7
Green-tailed Towhee (*Pipilo chlorurus*)	1.8	0.0	2.4	1.4	0.7
Gray-headed Junco (*Junco caniceps*)	66.6	35.6	43.8	29.7	15.0
Chipping Sparrow (*Spizella passerina*)	5.5	0.0	2.7	2.1	1.4
TOTAL	835.6	405.0	519.3	364.9	199.5
Species richness	35	24	32	35	35

were the Yellow-rumped Warbler (136.5 birds/40 ha), Ruby-crowned Kinglet (88.6 birds/40 ha), and Gray-headed Junco (66.6 birds/40 ha).

Of the four fixed-width surveys the 30.5 m strip on each side of the transect yielded the highest density (519.3 birds/40 ha) (Table 1). By widening the effective width of the strip to 61.0 m the maximum number of species (35) was included. Fixed-strip width data indicated the Yellow-rumped Warbler, Mountain Chickadee, Ruby-crowned Kinglet, and Gray-headed Junco were the most abundant species.

The majority of species were most numerous within the 15.2 m and 30.5 m wide strips on either side of the transect. Observations declined rapidly within the 61.0 m and 125.6 m strips.

Relative results were similar between the fixed-width and variable-strip sampling methods. However, none of the various belt widths approached either the overall density of the majority of individual species' densities derived from the variable-strip transect method. In assessing the similarity in results from these two techniques, it was assumed that a species' density value, determined for any of the four fixed-strip widths was similar to that of the variable-strip transect results if the two values were within 10 percent (an arbitrarily selected value). Using this criterion, in this study eight species had approximately similar dentities, whereas 27 did not. Of those which did not, the density values computed from the variable-strip transect data were higher for 24 of the 27 species.

DISCUSSION

Various techniques have been devised to enable investigators to compute avian species' densities. An acceptable method must provide relatively reliable results, be reasonably efficient to use in the field, and rely upon as few assumptions as possible. The following discussion focuses on the various assumptions of the variable-strip and fixed-strip sampling methods (as previously stated in the Assumptions section) and the extent to which each satisfies the assumptions. Transect methods of variable as well as fixed-width strips are advantageous in that they embrace all individuals, not just breeding birds, and can be utilized during any season of the year. Yet do these methods provide reasonably good predictions of the actual absolute densities of members of the avian community?

The design of the transect route should consider the size and shape of the area to be sampled, the terrain, the type of habitat, and most importantly, biological features of the avian community (e.g., a species with a large territory may require a longer transect(s) to obtain a sufficient sample size than for a numerous species and/or one with a small territory).

A single long transect or a series of parallel transects may be established. If the latter approach is utilized then care should be taken to assure that lines are sufficiently far apart as to preclude counting the same individual from more than one line. Several lines can be combined into one sampling unit (Eberhardt 1978). Transects may be of various configurations as necessitated by terrain and do not have to be parallel.

Gates et al. (1968), Eberhardt (1978), and Seber (1973) noted that animals should be distributed uniformly and independently (assumption 1) but that this was rarely the case under natural circumstances. In view of this, Eberhardt (1978) believes that establishment of randomly placed transect lines is needed. A systematic design will satisfy this requirement in some cases as long as the beginning of the first transect is randomly located (Anderson et al. 1979). The study should also be designed so that the transect is sufficiently long and wide to provide (if possible) at least 40 observations for each species (Burnham et al. 1980).

Assumption 2 (pertaining to the decrease in probability of observing a bird as the distance from the transect line increases) is generally no problem nor is assumption 3 (relating to the behavior of birds in one transect band not influencing the behavior of birds in another), at least not in this study. However, situations could arise where, for example, an alarm call issued close to the transect could silence the other singing birds in the vicinity, and thereby affect the results.

In addressing assumption 4 (a bird on the transect has a probability of 1 of being observed) and assumption 5 (the bird does not move in response to the observer prior to being detected), J. T. Emlen (1971) noted on the distribution curve of the results that the number of observations increases with distance from the transect to a maximum point and then declines. Even though the observer's ability to detect a species should be maximal in the strips immediately adjacent to the transect, the birds' response to the observer may effectively preclude this. If a bird is attracted to the observer, shies away, or "drives" in front of the observer, assumptions 4 and 5 will not be satisfied. In other work it has been noted that only approximately 20 percent of the total observations occurred within 25 m of the transect (Järvinen and Väisänen 1975). It is therefore not surprising that in the fixed-width survey results the highest densities for most avian species did not occur in the 15 m wide belt on either side of the transect.

In other animal surveys, short lateral movements caused by the observer's approach have been observed or suspected (Eberhardt 1978, Hirst 1969, and Dassmann and Mossman 1962). Eberhardt (1978) suggested a modification of the variable-strip method by using a width sufficiently wide as to include at least two-thirds of the total observations. If so, then shifts in movement of this sort may not influence the results. However, this modification may make the width measurement used for density computation purposes unnecessarily wide and thereby reduce the density value. Emlen (1977a) suggested that birds be counted if they are first detected within a distance of 61.0 m (200 ft) before and behind the advancing observer which may minimize this problem (although double-counting may then be a consideration). In this study some lateral movement was observed in response to the observer, but it was limited to short distance changes in position to nearby trees. Movement itself is not critical if it is independent of the observer and slow with respect to the observer's speed (Anderson et al. 1979).

Another problem is the potential for double-counting the more mobile individuals (assumption 6) and hence, overestimating such species' densities. Some individuals may be attracted to the observer while others may move ahead ("drive") of the observer along the transect. Either situation may result in counting the individual more than once. If this situation is not detected and recognized, an erroneously high density estimate will be obtained. This difficulty is alleviated, to a certain extent, by the observer moving along the transect at a moderately-fast, constant pace. Recording only those birds at approximately right angles to the observer traversing the transect line also aids in reducing the probability of double-counting. In most cases transboundary movement should even out if enough tranverses of the transect are conducted.

With either the variable-strip or fixed-width transect methods, the quality of the results depends, in part, upon the degree to which the observer accurately determines the distance measurements (assumption 7). Some investigators have argued that strip surveys do not permit density calculations because an observer can not estimate distance measurement by eye with enough accuracy (Enemar and Sjöstrand 1967). However, with experience and the use of a properly calibrated range-finder or steel tape, distance measurement in most habitats should not pose an insurmountable obstacle. Pacing, since it tends to be quite variable, especially in rough terrain, should be avoided. In densely forested situations when one is attempting to gauge the distance of singing, non-visual males, estimation of distance becomes more difficult and more susceptible to error.

Results may be biased in that distance measurements may be rounded off to convenient numbers (e.g., 0, 5, 10 m). This phenomenon has been noted by Gates et al. (1968), Anderson and Pospahala (1970), and Robinette et al. (1974). Judicious selection of distance class intervals and more thorough instructions to field personnel may alleviate this problem.

The extent to which assumption 8 (similar avian behavior throughout the course of the study) is satisfied is difficult to assess; however, with the exception of perhaps a limited degree of habituation to the observer's presence, it probably holds for both of these sampling methods. Further, the degree of detectability will vary between individuals, sexes, and season. This is directly contradictory to assumption 9. In some species males become less conspicuous and ardent in territorial advertisement as the breeding season progresses. Since females are generally considerably less obvious than the males, owing to their lack of song, usually drab coloration, and larger proportion of the maternal duties such as incubation, the likelihood of detecting them is substantially less than for the males. Such problems are inherent in any transect method and in part, are ameliorated by concentrating on sampling an area during a short, carefully specified time frame.

In analyzing the nine basic line transect assumptions to satisfy objective 1, there appears to be basically little difference in the degree to which these assumptions are met by the variable-strip and fixed-width sampling methods. However, it should be noted that although both rely upon estimating distances, a distance error is considerably more critical (and more likely) with the variable-strip method. This is because each observation needs an accurate distance measurement, whereas with the fixed-width, all one must do is accurately decide if the bird is within the belt (a significantly easier undertaking). Also short lateral movements (assumptions 4 and 5) are less meaningful to the precise calculation of the fixed-width results than is the case with the variable-strip method. Other than these two differences the methods are similar in their assumptions and the degree to which they meet them (objective 1).

At least four major factors influence the success of transect censusing methods and include the competence of the observer, weather conditions, habitat type, and inherent nature of the avian species being sampled. If we assume the observer is experienced and the weather is propitious, the type of habitat greatly impacts the level of censusing accuracy in that a dense heavily-vegetated forest situation will present more detectability problems than will, say, an open, sparsely-vegetated habitat. The last, and probably most important, factor is the species' inherent behavior, which in concert with the sparseness or denseness of the vegetation determines the detectability of the species. If a species is conspicuous either because of its foraging behavior (e.g., flycatching from a clearly visible branch), frequent and or readily audible songs or calls, striking plumage coloration, limited fear of the observer, or other behavioral characteristics (such as drumming, wing-flashing, tail-bobbing, or aerial courtship displays), then the probability of encountering the individual is enhanced and the computed density will more closely approach reality. In this study species with high probabilities of detection included the Mountain Chickadee (frequent call, little apparent shyness toward the observer), Yellow-rumped Warbler (frequent call and song, prefers relatively open tree foliage in which to forage), Ruby-crowned Kinglet (frequent and strident song), and Gray-headed Junco (ground forager using more open areas).

There are various advantages and adverse aspects of each of these two sampling methods (objective 2). With the variable-strip transect method it is assumed that all individuals are detected within the strips on either side of the transect line bounded by the point of inflection on each species' distribution curve of the results. In this study's dense mixed-coniferous forest, this assumption was probably not valid. Therefore, the actual density was undoubtedly higher, at least for some species. As degree of conspicuousness of a species decreases, an even larger disparity between the results and the real density will be realized. Recognizing this dilemma, J. T. Emlen (1971) suggested that a basal detectability adjustment factor be applied to the results to take into consideration the incompleteness of the surveys. However, the adjustment value must be obtained by using another sampling method which itself is subject to limitations and increases the amount of time necessary to sample the plot.

Coefficient of detectability (CD) values as described by J. T. Emlen (1971) are designed to enable similar habitats to be sampled quickly. However, they are not necessary in order to calculate avian density. CD values may vary as the season progresses and degree of conspicuousness declines, and also on a yearly basis as densities change.

A highly conspicuous species will be observed more frequently than a less readily observable species. Thus the density computation for the latter species once the transect results are averaged will be far below its actual value. The same argument applies to sparsely distributed species in that the probability of encountering them is reduced. Hence, results for the less conspicuous and/or uncommon species are probably not as reliable as are those of more conspicuous and/or densely distributed species.

Fixed-width strip transects present similar problems to those encountered with the variable-strip transect method. The results are susceptible to detectability difficulties and errors in distance estimations.

As evidenced in this study, since some species will have highest densities in the narrowest belt width, whereas others may only be observed in the furthest belts, it is best to choose the strip width wisely, keeping in mind each species' detectability characteristics.

In comparing the variable-strip transect results to those of the various fixed-strip surveys (objective 3), it becomes apparent that they will be in full accord only in those instances whereby the peak (point of inflection) on the distribution curve corresponds to the exact width of the fixed-width strip survey. Otherwise the transect method should provide higher densities than those of the fixed-width transect survey because the data increments are so much smaller (i.e., 3 m belts vs 15 m or larger belts). In the variable-strip transect technique the density calculation depends on the curve's point of inflection. In constrast, with the fixed-strip method, even though the number of observations may reach a peak and then decline to the far edge of the belt, the entire area encompassed by the belt is used in the final density calculation, thus reducing the density value from what it would have been had only the area from the transect to the peak of observations been considered.

The main asset of a fixed-width survey is its simplicity in recording observations and analyzing data which allows for a rapid density computation. However, because the variable-strip transect method provides a more reliable estimate of species and population densities, at least on theoretical grounds, it is preferable except in cases of narrow habitat strips which lend themselves more readily to a fixed-width analysis.

I recommend several modifications in the data collection and analysis process for the variable-strip transect method (objective 4). Instead of comparing male data times two to all other observations and selecting the higher figure as proposed by J. T. Emlen (1971), I suggest that a third category encompassing "total observations" be included in the comparison. This is because the total observations may equal a higher value than either the male data times two, or all the other non-male data. If so, then the total observations category represents a more accurate reflection of the population density than would either of the other two groups.

Another possible modification of the variable-strip method involves the determination of a more precise distance measurement for observations beyond 30.5 m (100 ft) of the transect instead of lumping all observations lying within the 30.5 m–61.0 m (100–200 ft) strip on either side of the transect and all those from 61.0 m–125.6 m (200–412 ft) as described by J. T. Emlen (1971). I recommend recording each bird's distance as accurately as possible and then grouping results according to 6 m substrips from 30–60 m from the transect, and 12 m intervals for substrips out to 126 m of the transect. For observations within 30 m of the transect, the use of 3 m substrip intervals is suggested in a similar fashion to that indicated by J. T. Emlen (1971). The consideration of additional substrips for distances beyond 30.5 m of the transect allows for the demarcation of the point of inflection of the curve for those species whose peak lies within the 30–60 m range, and the albeit few species displaying an inflection point beyong 60 m. Without such a modification in the prescribed procedures, it is difficult to obtain a reliable estimate of densities for those species peaking at the relatively greater distances from the transect. Furthermore, at a later date the actual measurements can be segregated into a prescribed number of intervals with particular interval widths. The number of intervals and their widths will depend upon the width of the transect, the number of observations obtained, and the accuracy of the measurements (Anderson and Paspahala 1970).

It has been recommended that when analyzing data from intervals, it is best to use the average of all the exact measurements falling within the interval rather than using the interval midpoint for the estimation, as it provides a more precise value (Pollock 1978).

ACKNOWLEDGMENTS

I wish to thank R. D. Ohmart, J. T. Emlen, J. Verner, W. F. Laudenslayer, and others for providing insight and ideas for analyzing avian species densities and communities. I am especially grateful to D. R. Anderson for his valuable suggestions on improving the manuscript. This study was supported through cooperative aid agreements from the U.S. Forest Service, Rocky Mountain Forest and Range Experiment Station, Tempe, Arizona (No. 16-402-CA and 16-382-CA).