United States
Department of
Agriculture

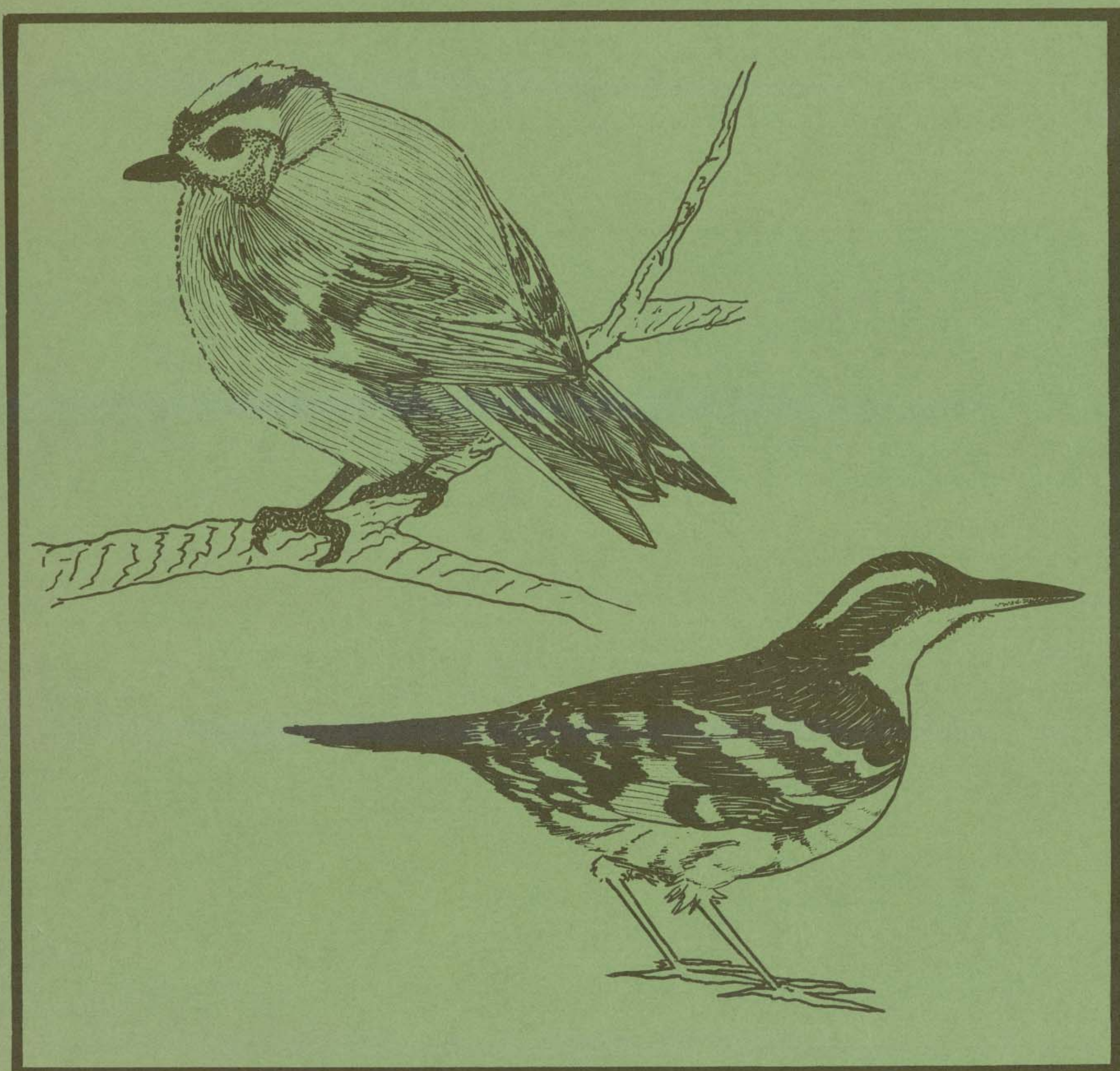
Forest Service

Pacific Northwest
Research Station

General Technical
Report
PNW-GTR-278
November 1991

Methods for Measuring Populations of Small, Diurnal Forest Birds

David A. Manuwal and Andrew B. Carey



Wildlife-Habitat Relationships: Sampling Procedures for Pacific Northwest Vertebrates

Andrew B. Carey and Leonard F. Ruggiero, Technical Editors

Methods for Measuring Populations of Small, Diurnal Forest Birds

David A. Manuwal
Professor
Wildlife Science Group
College of Forest Resources
University of Washington
Seattle, Washington 98195

Andrew B. Carey
Principal Research Biologist
U.S. Department of Agriculture
Forest Service
Pacific Northwest Research Station
Forestry Sciences Laboratory
Olympia, Washington 98502

USDA Forest Service
Pacific Northwest Research Station
Portland, Oregon
General Technical Report PNW-GTR-278
1991

Preface

Concern about the value of old-growth Douglas-fir forests to wildlife in the Pacific Northwest began escalating in the late 1970s. The available information on wildlife-habitat relationships suggested that as many as 75 species, including amphibians, birds, and mammals, could be dependent on old-growth forests. The USDA Forest Service chartered the Old-Growth Forest Wildlife Habitat Program to investigate the role old growth plays in maintaining viable populations of wildlife. It was apparent that broad surveys of vertebrate communities would be necessary to determine which species were truly closely associated with old-growth forests. Insufficient guidance on techniques, procedures, and sample size was available in the existing literature. We assembled a team of researchers from universities and Federal agencies to conduct pilot studies to develop sampling protocols and to test the basic experimental design for contrasting the wildlife values of young, mature, and old-growth forests. The sampling protocols resulting from the pilot studies were implemented in 1984-86 across broad areas of the Cascade Range in southwestern Washington and Oregon, the Oregon Coast Ranges, and the Klamath Mountains of southwestern Oregon and northern California. Naturally, improvements were made to the protocols as time passed. A tremendous amount of experience in sampling was gained.

Our goal in this series is to compile the extensive experiences of our collaborators into a collection of methodology papers providing biologists with pilot study-type information for planning research or monitoring populations. The series will include papers on sampling bats, aquatic amphibians, terrestrial amphibians, forest-floor mammals, small forest birds, and arboreal rodents, as well as papers on using telemetry for spotted owl studies and a guide to bird calls.

Andrew B. Carey
Leonard F. Ruggiero

Abstract

Manuwal, David A.; Carey, Andrew B. 1991. Methods for measuring populations of small, diurnal forest birds. Gen. Tech. Rep. PNW-GTR-278. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 23 p. (Carey, Andrew B.; Ruggiero, Leonard F., tech. eds.; Wildlife-habitat relationships: sampling procedures for Pacific Northwest vertebrates).

Before a bird population is measured, the objectives of the study should be clearly defined. Important factors to be considered in designing a study are study site selection, plot size or transect length, distance between sampling points, duration of counts, and frequency and timing of sampling. Qualified field personnel are especially important. Assumptions applying to all bird-counting techniques are discussed. The following techniques and their applications are discussed; simple line transect, fixed-width transect, variable-width transect, simple point count, fixed-radius point count, variable-radius circular plot, spot mapping, and total mapping. For determining species richness and presence, the simple line transect and simple point count methods are recommended. Measures of relative abundance can be obtained by using the simple line transect, simple point count, fixed-width line transect, and fixed-radius point count methods. Population trends during the same season each year can be detected by using the same trends as those used for relative abundance. If more than one season is involved, however, the variable-distance transect or variable-radius point count are necessary to account for differences in bird detectability. Habitat-use patterns can be determined best by using the spot-map method to elucidate territory locations. More precise information can be obtained for larger birds by using radio transmitters.

Keywords: Birds, populations, sampling methods, surveys.

Contents

Introduction

During the last few years, many ornithologists have devoted much time to assessing techniques and developing new approaches for determining avian abundance. Because no one technique provides adequate results for all situations, our objective is to describe and provide examples of the best available techniques for measuring populations of small, diurnal forest birds. Also, because techniques require assumptions, we point out critical assumptions for each technique and describe the extent to which violations can be expected. The biologist interpreting the data must therefore consider the severity and consequences of violations when reporting results and making recommendations. Forest bird survey techniques, generally fall into one of three categories: line transects, point counts, or mapping. Ralph and Scott (1981), Shields (1979), and Verner (1985) should be consulted for more indepth coverage and examples of bird-sampling theories and techniques.

Study Design

The design should directly reflect the objectives of the study, otherwise objectives will not be met, and serious biases will arise. The following factors should be considered when designing a study.

Study site selection—The study site is important. Study stands must be large enough to contain the number of sampling points required for an adequate sample size without being located too near a forest edge (usually within 75 meters). Yet, if statistical comparisons are to be made and if the results are to be generalized to other sites, then the stands must be randomly selected from the population to which the results will be applied. From a statistical perspective, sampling points can be arranged in a random, stratified random, or regular pattern without incurring the risk of detecting differences that do not exist, failing to detect real differences, or obtaining badly biased estimates of abundance.

Plot size or transect length—The plot or transect length should be of a sufficient size and at a location representative of the kind of habitat being sampled. Because few forest habitats are truly homogeneous, variation within a plot or along a transect should be minimized. A homogeneous group of trees (generally located in a particular topographic position and arising from a single regenerative disturbance) is called a stand. Stand size can be quite variable, and average size differs with physiographic province in the Pacific Northwest, thereby reflecting differences in geology, topography, fire, and logging history. Stands in the Coast Range of Oregon are usually much smaller (29 hectares on average) (Carey and others 1991) than stands in the Cascade Range of Washington. If several plots or transects are used, they should all be the same size because plot size or transect length changes estimates of abundance (for example, Engstrom and James 1981, Granholm 1983, Morrison and others 1981).

Distance between sampling points—For distance between sampling points, there are two considerations. First, point-count stations, transects, or grids should adequately sample the avian population of the stand; second, when point counts are used, the distance between points should be great enough to ensure that the stand is fully sampled and the spacing of points is large enough to encompass territories of the target species. The effect of detecting the same birds at different points is minimized by using the point-count technique because the population estimate is derived by averaging the detections at each point. The range of sampling must reflect the range of bird distribution in the landscape. Because territory sizes differ, any distance used will not be equally suitable for all bird species. Birds with large territories, such as woodpeckers, present special problems because one territory may include several point-count stations or entire transects. The probability of counting one bird several times is great.

Duration of counts—Standardizing the length of the sampling period is important. When estimates of actual numbers or density are desired, duration at any one point should be short (8 minutes or less) to avoid the problem of birds continuously moving in and out of the detection range and thus being counted more than once. We conducted pilot studies to determine an optional sampling time. Count time ranged from 2 to 24 minutes per station. Number of species detected did not differ between 8-minute and longer counts. At 2 minutes, an observer detects only about 54 percent of the birds detected during an 8-minute count in Douglas-fir *(Pseudotsuga menziesii* (Mirb.) Franco) forests of the west slope of the southern Washington Cascade Range. Eight minutes is also longer than the average pause between song bouts of most species. Our data indicate that 8 minutes is an efficient count period; almost 90 percent of all detected birds are detected during the first 8 minutes. If the counting period is less than 8 minutes, a substantially lower percentage of the birds will be detected (fig.1, table 1). For more open habitats, such as ponderosa pine (*Pinus ponderosa* Dougl. ex Laws.), a shorter time may be adequate. A simple species accumulation curve should be calculated for field data collected in that habitat to verify the appropriate count duration.

Frequency of sampling—The number of times a stand is sampled often depends on logistical constraints and available personnel. Sufficient experiments have been done on individual techniques to demonstrate that minimum sampling frequencies are necessary. In general, sampling frequency depends on the objectives of the study. For example, if a complete species list or relative abundance for a particular habitat type or stand is needed, an area must be visited throughout the breeding season, migration periods, or winter season. During the breeding season, in particular, sampling frequency is important because of differing breeding phenologies among the various species in the avifauna. Three samples well-spaced in time (>1 week apart) will be necessary. Six to eight samples are necessary when measuring diversity is important or when densities are to be estimated. There is a tradeoff between frequency of sampling and number of stands sampled. Objectives must be carefully considered to optimize the sample sizes within and among stands.

Timing of sampling—Knowledge of bird nesting seasons and migration phenology is important when deciding on sampling time. If breeding-season abundance is the objective, early counts may not include late breeders, and thus negatively bias the estimates. Late counts, however, may include young birds and thus positively bias the estimates.

Some Characteristics of Forest Birds

Most forest birds are insectivorous and strongly territorial during spring and early summer. Detections of birds usually depend on certain attributes of singing and calling and on the level of feeding activity; for example, characteristics of songs and calls such as the type, frequency, duration, volume, and pitch can affect bird detectability. Birds that forage high in the canopy may be less detectable than those that forage lower in the canopy or on the ground. Species-specific detectability and decline in detectability due to distance from observer, weather, or season are the principal sources of difficulty in accurately estimating relative density. These characteristics for some species or groups are briefly discussed.

The Vaux's swift (*Chaetura vauxi* Townsend) nests colonially in large snags. It forages over the forest canopy and open areas such as rivers or lakes. It is usually detected as it forages overhead or en route to a nest site. Reliable density or abundance estimates are difficult to obtain for this species because of its mobile foraging behavior. When feeding, it calls frequently and thus can be heard by the observer from within 100-200 meters away.

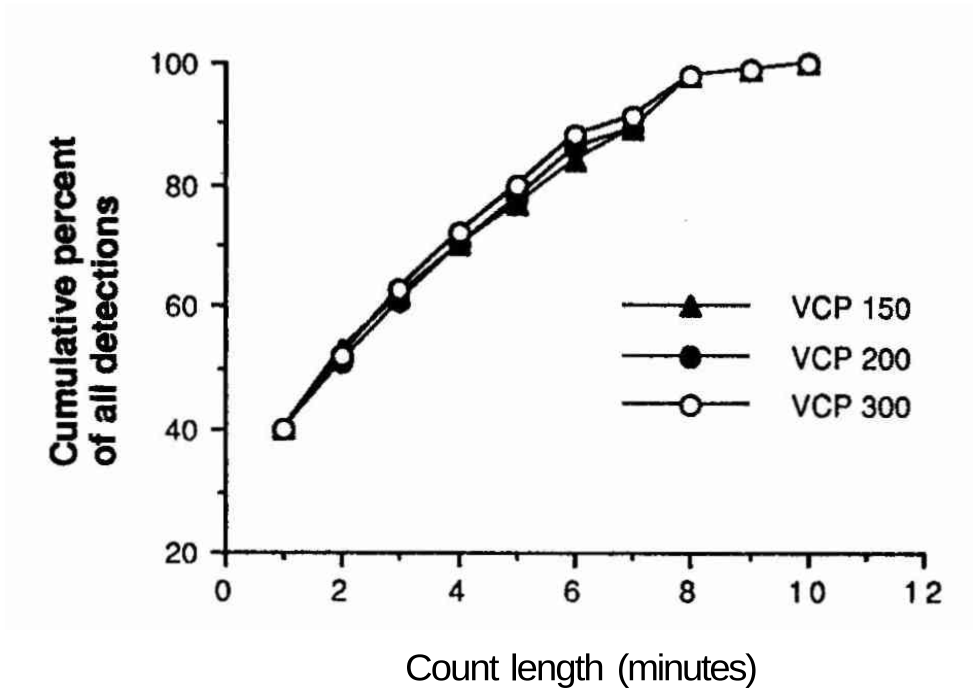


Figure 1—Relation between length of bird count and percentage of bird detections. Variable-radius circular plots (VCP) with interstation distances of 150 meters, 200 meters, and 300 meters.

Table 1—Important characteristics of 6 different bird-counting methods

Method	Number of transects or points	Space between (m)	Count duration (minimum) or walking speed (kilometers/hour)	Minimum number of visits
Simple line transect		200	0.5-1.0 kilometers for rugged terrain, 1.0-2.0 for level easy terrain	3-6
Fixed-width transect		200	as above	3-6
Variable-width transect				
Simple point count	6	200	10	3
Fixed-radius point count	12	150	8	6
Variable-radius point count	12	150	8	6
Spot-map	grid	15-20 between points on grid	60-120 depends on grid size and terrain	8

Hummingbirds are small, active birds that are detectable only at short distances from an observer. Call notes and the sound of wing flapping are usually the only indications of the presence of a hummingbird. Individuals tend to return to the same flowering plants, so repeated detections are possible over a 1- to 2-week period. The apparent short nesting season makes an accurate assessment of the breeding population difficult because nonbreeders may intrude in the habitat at almost any time.

Woodpeckers are difficult to detect because they have large home ranges in which they call relatively infrequently. Auditory communication is by calls or mechanical sounds such as drumming and ritual tapping (Short 1979). The red-breasted sapsucker *(Sphyrapicus varius* Gmelin) is especially silent, with vocalizations and drumming being infrequent even during the peak of the nesting cycle. The pileated woodpecker *(Dryocopus pileatus* Linnaeus) can be detected from great distances because of its size and ability to call, tap, or drum loudly. Detection distances of 300-400 meters or more are possible. Nest sites of woodpeckers often can be located by the loud calls of nestlings during feeding.

Of all the forest birds in the Pacific Northwest, flycatchers present the most difficult identification problems. Most coniferous forest habitats typically have two to three species of flycatchers. The small four species in the genus *Empidonax* found in Douglas-fir forests are the willow (*E. traillii* Audubon), Hammond's (E. *hammondii* Xantus de Vesey), dusky (*E. oberholseri* Phillips), and western (E *difficilis* Baird). They all have eye rings and wing bars. The coloration varies from the greenish western to the more brownish Hammond's and dusky. The only sure way to identify these birds is to hear them sing. Observers should become very familiar with these songs before surveying these species; they should listen to taped calls of these species in the field until they feel confident they can correctly identify the encountered species.

The *Empidonax* flycatchers are mostly lower canopy to midcanopy dwellers. They are difficult to see, although they call frequently during the nesting cycle. They typically stay at a perch for long periods, moving only to catch a passing insect or to chase an intruding flycatcher.

Two other species may be encountered: the western wood pewee *(Contopus sordidulus* Sclater) and the olive-sided flycatcher (C. *borealis* Swainson). The pewee is larger and lacks the prominent eye ring and wing bars of the *Empidonax* group. Its behavior, however, is similar to that of the smaller flycatchers. The olive-sided flycatcher is often found at the forest edge or near larger forest openings or in burns or clearcuts where it usually calls or perches from large dominant snags that have been retained.

Jays present special detectability problems. Both species call infrequently and may mimic the sounds of other birds. Because gray jays *{Perisoreus canadensis* Linnaeus) seem to be attracted to observers, these birds should be detected as soon as possible and their movements mentally followed to avoid counting them more than once. Gray jays often travel in pairs or family groups, which makes counting them more difficult. Steller's jays *(Cyanocitta stelleri* Gmelin), on the other hand, are not particularly attracted to observers and are usually solitary. Their infrequent calls can be heard from a considerable distance (200 meters or farther).

Chickadees and golden-crowned kinglets *{Regulus satrapa* Lichtenstein) are vocal throughout the year. They often forage in either single or mixed-species feeding flocks, depending on season. Golden-crowned kinglets are difficult to see because they usually forage in the upper levels of the forest canopy. Their high-pitched calls are difficult to locate, and some people may not be able to hear them at all.

The red-breasted nuthatch *(Sitta canadensis* Linnaeus) gives an unmistakable call that may be difficult to locate. Because this species does not call frequently, it often may be undetected. Foraging can occur at any location in the canopy, but when conifer seeds are available, nuthatches will feed either on the seeds or on insects attracted to the cones. During postbreeding or winter periods, nuthatches may occur in mixed-species flocks, which change their detectability.

Brown creepers *(Certhia americana* Bonaparte) are small cryptically colored birds that elicit ventriloquistic calls and songs. Creepers typically forage on the bark of tree trunks and branches. Extra time is required to locate creepers if exact location is desired. These birds often feed on the side of a trunk or branch opposite the observer and so are not observable for a short time.

Determining exact locations of thrushes and winter wrens *(Troglodytes troglodytes* Linnaeus) is difficult because the songs of both have a ventriloquistic quality. Winter wrens have a very loud call note they give in all seasons. Additionally, winter wrens forage on the ground but may sing from snags or low branches or as high as 15 meters aboveground. Thrushes, however, are usually silent during the postbreeding season and may sing from any height.

Vireos are uncommon in Douglas-fir forests except in the early stages of succession where the warbling vireo *(Vireo gilvus* Vieillot) and Mutton's vireo *(V. huttoni Cass\n)* (low elevation only) may be common. The solitary vireo *(V. solitarius* Wilson) may be found uncommonly in Douglas-fir forests. Vireos tend to be relatively slow-moving birds and so may be difficult to detect despite usually being found in the lower canopy. The warbling vireo apparently sings more frequently than do the other two species. Mutton's vireo nests very early and may not be detected by field observers if surveys start late in the breeding season. Warbling and solitary vireos are later migrants and so begin nesting later than the Mutton's.

Warblers are relatively easy to detect during the breeding season because most species sing vigorously and frequently. Upper canopy dwellers such as the Townsend's *(Dendroica* townsendi Townsend), hermit *(D.* occidentalis Townsend), and black-throated gray *(D. nigrescens* Townsend) are often difficult to locate, especially because their songs are easily confused. In the southern Washington Cascades, songs of the Townsend's and hermits are impossible to distinguish because of extensive interbreeding. Hybrids are commonly detected and do not sing a predictable song type.

The Nashville *(Vermivora ruficapilla* Wilson), orange-crowned *(V. celata* Say), MacGillivray's *(Oporornis tolmei* Townsend), and Wilson's *(Wilsonia pusilla* Wilson) warblers typically feed and sing in the understory or low canopy of Douglas-fir forests (see Morrison 1981). The MacGillivray's warbler, however, is secretive, and its singing posts are often obscured by small trees, branches, and shrubs.

During the postbreeding or nonbreeding periods, warblers may be difficult to detect because they do not sing then. Observers should listen for call notes given by these birds. They often gather in mixed-species flocks during migration.

Despite its brilliant plumage, the western tanager {*Piranga ludoviciana* Wilson) is not easy to detect. It forages slowly, usually in the upper canopy (Manuwal 1983) and sings relatively infrequently. When it sings, however, the bird can be heard for several hundred meters.

The dark-eyed junco (Junco *hyemalis* Linnaeus) is a common bird in Douglas-fir forests. Juncos sing frequently and for several weeks. Singing posts can be at any height. In more open stands in the Rocky Mountains (Manuwal 1983) or eastern Cascade Range, singing often occurs on the forest floor but may occur in the tree canopy if there is an outbreak of insects such as the spruce budworm *(Choristoneura occidentalis* Freeman).

The red crossbill *(Loxia curvirostra* Linnaeus) is a flocking species that typically feeds on conifer seeds in the uppermost portions of the canopy. Their almost constant call notes make detection easy, but counting the number of birds in a flock can be most difficult. When the birds are feeding quietly, observers should look or listen for seed coats and bits of cones falling from the upper canopy. The breeding cycle is erratic, apparently occurring only during years when production of conifer seeds is high (Gabrielson and Jewett 1970).

The detectabilities of pine siskins {*Carduelis pinus* Wilson) and evening grosbeaks *(Coccothraustes vespertinus* Cooper) are similar to that described for the red crossbill. Two differences are that siskins and grosbeaks apparently nest every year and are territorial and, thus, are probably more detectable, at least during the nesting cycle.

Several authors have documented changes in detectability due to either season or time of day (for example, Best 1981, Best and Peterson 1982, Kessler and Milne 1982, Ralph 1981, Robbins 1981 b, Skirvin 1981). The presence of bird flocks may influence estimates of abundance (Quinn 1981).

Selection of Personnel

Accurate monitoring of small forest birds will be successful only if the field personnel are competent. Competence in bird identification and in conducting sampling should be demonstrated before any data are collected. Periodic testing may be appropriate. Virtually all recognized techniques for counting birds are subject to observer bias, which results from differences in the attitude, field experience, and abilities of observers. In most forest habitats, birds are much more often heard than seen; for example, in our study of birds in the Douglas-fir forests of western Washington, we saw only 3-4 percent of the birds we heard. Field personnel therefore must be able to correctly identify birds by both calls and songs. Field personnel should be given hearing tests if possible. Emien and DeJong (1981) found that observers with slight hearing losses in the high-frequency ranges detected some species at only 25-90 percent of the distances at which observers with normal hearing detected them. Ramsey and Scott (1981) found that hearing thresholds of people over 40 years of age usually did not meet the minimum required to hear frequencies typical of the songs of many passerine birds. If people with different aural abilities are used as bird surveyors, special techniques will have to be used to analyze the data. Other important observer attributes include alertness, field experience, knowledge of ornithology, and good physical condition. Observers should be systematically rotated among the stands being sampled to compensate for any between-observer bias in ability to detect birds among the stands.

Principles of Identification

Forest birds are often difficult to see, so observers should become adept at identifying them by calls and songs. People differ in the speed at which they learn bird identification. Tape recordings of bird songs and calls are important aides that can speed the learning process. An inexperienced person may need 2-4 weeks with the assistance of an experienced birder to become competent in identifying birds by song and call. It is therefore important to recruit experienced field biologists and to maximize field time early in the season to allow mastery of the indigenous bird species in a short time. In spring, birds are active early in the morning from just before sunrise to about 5 hours after sunrise, with another short burst of activity occurring in early evening.

Field training, testing, and surveying should be done early in the morning. Field guides, checklists, tapes, and discussion should be emphasized later in the day. In winter, birds are generally active most of the day, so there is little advantage to surveying them early in the morning.

A biologist learning to identify birds without assistance can identify a bird by a process of elimination: first, note the general outline and size of the bird; next, notice the shapes of specific body parts such as the bill, neck, wings, and tail. These features will indicate the general bird group. Some field guides incorporate silhouettes as an aide to identification. Color and patterns of color are especially important in the identification of species. Note whether the bird has an eye ring, eye stripe, wing bars, or a spotted or streaked breast. There are only a few potentially difficult identification problems with birds in Douglas-fir forests (table 2).

Other nonmorphological or behavioral traits can be helpful in the identification process. Some knowledge of the normal seasonal occurrence, distribution, and preferred habitat of birds can greatly assist the field biologist in determining the identity of a bird. These kinds of information are readily available in field guides and in local publications on birds. It is important to realize that birds vary regionally in vocalization and repertory of vocalizations. Teaching tapes are available for some locales. Finally, the learning process can be greatly facilitated by a few field trips with experienced birders.

Seasonality Considerations

Bird populations are usually sampled during either the breeding season or winter. The season chosen should reflect objectives or hypotheses. The annual cycle of birds usually manifests itself by dramatic changes in behavior and habitat use. Choice of sampling method must consider season and bird biology. During the nesting season, males, and the females of some species, are strongly territorial. During the territory-establishment phase of the nesting cycle, males spend much time singing and are easily detected. Later, males sing less and do so primarily in the morning and late afternoon (Kessler and Milne 1982). Females of most species of songbirds tend to be secretive during the nesting season and are detected less often than males. These behavioral traits result in the differential detectability of males and females during the nesting season. When interpreting count data, the timing of bird sampling should be considered. Counts should be made when most birds are in the territory-establishment phase of the nesting cycle. If the survey occurs after a species nests, abundance estimates will underestimate the numbers present.

During the nonbreeding periods, such as fall or winter, birds are usually less detectable because males are not in well-established territories and thus are not singing. All birds give calls, however, particularly when they are feeding, flocked, or alarmed. These calls, which are given throughout the year, are usually much different than the songs given by males in territories. Observers need to identify these calls to correctly identify many of the birds that will be heard during the survey.

Weather

Inclement weather conditions can preclude sampling or bias the survey results (Anderson and Ohmart 1977, Dawson 1981, Emlen and DeJong 1981, O'Connor and Hicks 1980, Bobbins 1981 a, Verner 1985). Before surveys are made, minimum standards for weather

Table 2—Potentially difficult bird species to identify in Douglas-fir forests

Species/group	Comments
Woodpeckers	Need visual contact or use calls and drumming characteristics. Refer to field guide and tape of calls.
Flycatchers	Visual contact will only separate *Empidonax* from other species. Songs are critical for species identification. Refer to tape.
Chestnut-backed chickadee and golden-crowned kinglet	Some call notes of these species are similar. The two species are often mixed-species flocks during the non-breeding seasons. Field personnel should refer to tapes and field guides, and they should attempt to identify the birds as often as possible and note the calls being given by each species.
Mutton's vireo and ruby-crowned kinglet	Both species have eye rings and wing bars but the Hutton's vireo is larger and has a thicker bill than does the ruby-crowned kinglet. The kinglet forages rapidly and has a characteristic habit of flicking its wings frequently. The vireo is relatively slow-moving and does not flick its wings. The calls and songs are not at all similar.
Black-throated gray, Townsend's, hermit and hybrid warblers	This is a difficult group, especially where the Townsend's Townsend's and hermit warblers interbreed (see Morrison and Hardy 1983). Except for hybrid warblers that show a mix of plumage traits of the parental types, the warblers are easily distinguish able when they are observed. Unfortunately, they are found in the upper most parts of the forest canopy. The major problem lies in their vocalizations which are impossible to distinguish in some parts of their range, particularly in the southern Washington Cascades.

should be established. Observers should avoid periods of moderate to heavy rain. The noise of rain coming through the canopy significantly reduces a person's ability to hear birds. It may also cause birds to sing with less intensity or call less often. Rain also interferes with visibility in the forest because binoculars and eyeglasses get wet. Strong wind (>10 kilometers/hour) also reduces our ability to hear and see birds because of the sound of wind itself and of moving tree branches. Fog certainly reduces our ability to see birds. Periods of moderate to heavy snow obviously reduce visibility and may affect both bird and observer behavior. Extreme temperatures (<7 °C or >24 °C) affect both observers and birds. If observers are uncomfortable, they may be less able to detect birds. Bird activity, and consequently our ability to detect them, also may be affected by extreme temperatures.

Equipment

Unless large-scale sampling is planned, most techniques used for assessing bird populations require relatively little equipment and supplies. For field work, the major items are good binoculars (usually 7 x 50 or 9 x 36). materials for making bird sampling locations, compass, meter tape, stopwatch or wristwatch, clipboard, data sheets, pencils, and stand maps. Observers should wear clothing of subdued colors (that is, green, brown, and blue). For methods requiring distance estimation, rangefinders can be very useful. An equipment checklist should be reviewed before leaving for the field.

General Assumptions of All Techniques

Although each survey technique may have its own unique assumptions, the following apply to all techniques:

1. Birds are accurately identified.
2. Sampling effort was adequate to detect species present. This applies to objectives that require measures of species richness or presence or absence.
3. Sampling effort is adequate to obtain estimates with the desired precision.
4. Differences among observers are insignificant or can be accounted for.
5. Differences among species detectability are insignificant or can be accounted for, or do not matter.
6. Differences in detectability among habitats are insignificant or can be accounted for.
7. Differences in detectability among years are insignificant or can be accounted for.

Discussion of Techniques

Line Transects

Simple line transects—The assumptions of the simple line transect are as follows:

1. There are no differences among observers in their ability to detect birds.
2. There is no difference in detectability among stands.
3. If within-stand relative abundance is calculated, then there are no differences among birds.
4. No individual bird is counted more than once.

The observer walks along a predetermined (and well-marked) line recording all birds detected (fig. 2). The speed of travel must be controlled to make counts comparable among stands. The observer's speed should be fast relative to the rate of bird movement to prevent individual birds from being counted more than once but not so fast as to pass a bird before it calls or sings (0.5 -1.0 kilometers/hour is reasonable for rugged terrain; 1.0-2.0 kilometers/hour for terrain easy to traverse). Sampling effort for the simple line transect should be a total transect length of at least 1.0 kilometer. This could be accomplished by two parallel 500-meter-long lines spaced at least 300 meters apart. The observer does not measure or estimate distance from birds to the transect. Instead, he or she concentrates on detecting as many birds as possible, regardless of distance as long as the birds are in the stand. Data are summarized into species lists and birds-of-a-species per unit effort (number of kilometers). It is not suitable for density estimates. Three to six visits are required to obtain adequate data.

Fixed-width transect—The assumptions associated with the fixed-width technique are as follows (from Verner 1985:278-279):

1. All birds within the strip (or belt) are detected.
2. No bird moves into or out of the strip in response to the observer's presence before being detected.
3. No bird is counted more than once.
4. No errors are made in assigning a detected bird to the belt.
5. Detections are independent events so that results from more than one transect can be pooled.

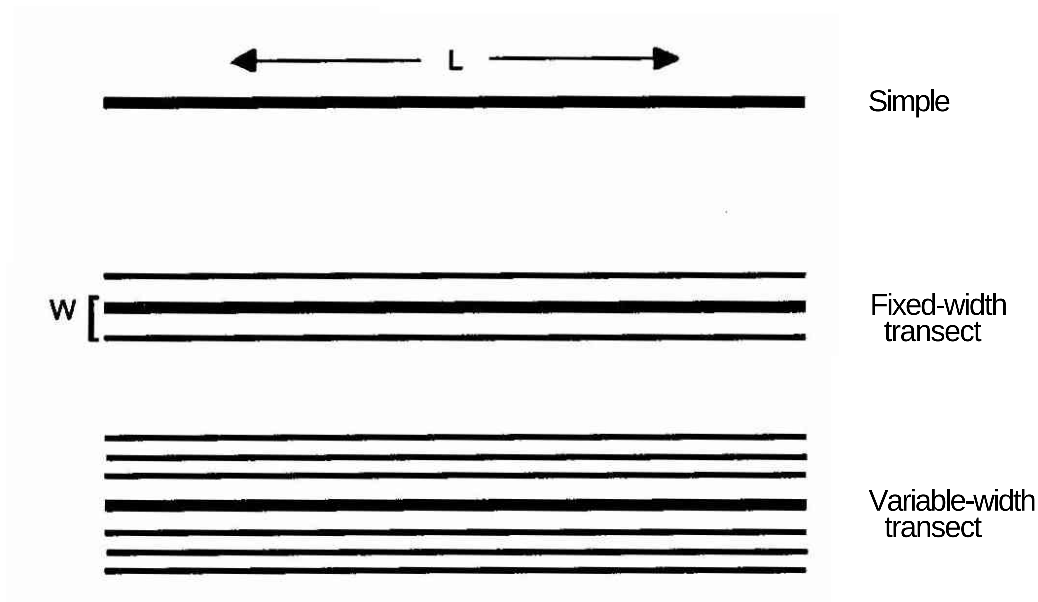


Figure 2—Schematic representation of the simple, fixed-width, and variable-width transect techniques.

There are two basic approaches to sampling by the fixed-width transect method. First, record all birds detected along a single strip of predetermined width (Franzreb 1981, Merikallio 1958). No other birds are recorded for estimating abundance (they may be recorded to obtain a complete species list). The usual width of the strip is 25-30 meters along each side of the travel route (fig. 2). Second, record all birds in the main belt (the strip) and those more than 25 meters on either side of the main belt (this is often referred to as the "Finnish method"). Jarvinen (1976), Jarvinen and Vaisanen (1975,1976). and Jarvinen and others (1976) have developed approaches to increase the accuracy of density estimates by using bird detections outside the main belt. The principal objective of the fixed-width transect is to estimate density or to estimate relative abundance by controlling for marked differences in detectability, through the following formula:

$$D = n / (2LW).$$

where n is the number of observations within the strip of width w and of length L (fig. 1). If the Finnish method is used, the following formula can be used (Jarvinen and Vaisanen 1976b):

$$D = \frac{1000\ kyN,}{L}$$

where: L = transect length;

N = number of pairs or individual birds observed in census;

k = a species-specific correction factor (it is calculated from p where MB is the ratio of main belt observations to all observations; MB is always between 0 and 1; readers should refer to Jarvinen and Vaisanen [1975,1976a] for the appropriate derivation and application of MB);

x = the number of pairs or individuals of all species observed in the main belt; and

y = a general correction factor, also derived from the total line transect data (it is calculated from y = 0.0346X + 0.6963).

The following example illustrates how to calculate the density of a species:

Given: L = 4 kilometers,
N = 62 pairs,
k = 0.00475,
x = 10.5 pairs, and
y = 0.0346 x 10.5 + 0.6963 = 1.0596 .

$$\text{Density } (D) = \frac{1000kvN}{L}.$$

Therefore: $$D = \frac{1000 \times 0.00475 \times 1.0596 \times 62}{4} = 78.0 \text{ pairs / km}^2.$$

Variable-width transects–Variable-width transects are used when the objective is to estimate densities and when it is necessary to account for differences in the detectabilities of birds due to differences among species, observers, or habitats (Emlen 1977). A review of line-transect theory is provided by Burnham and others (1980); Ralph and Scott (1981) provide examples and additional discussion. Variable-width transects differ from fixed-width transects in that exact distance measurements are used to determine the effective area samples either by choosing a distance within which all birds of a species were detected or by modeling the decline in detectability with a mathematical function. Many functions can be used including the Fourier series, the negative exponential, and the exponential power series (Burnham and others 1980, Ramsey and others 1987). Assumptions are as follows:

1. All birds on the transect line are detected.
2. Distances are measured accurately.
3. Detections of birds are independent events.
4. Birds do not move before being detected; none are counted more than once.

Variable-width transects have worked well in many areas (see Carey 1983 for an example). But field biologists in the Pacific Northwest have difficulty in negotiating rugged terrain and brush and listening for birds at the same time. Detections per minute during transect sampling were only 30-40 percent of the detections per minute using point counts. Because we do not think line transects work well here, we do not present detailed examples.

Point Counts

Simple point counts—Simple counts are used when information is needed on species presence, richness, and total bird counts (Reynolds and others 1980, Verner 1985, Verner and Ritter 1985, Webb and others 1977). This method is easy to conduct in the field, and data analysis is straightforward. The assumptions are essentially the same as those listed for the line transect.

At least six point-count stations should be placed in the habitat being sampled. Stations should be at least 75 meters from the edge of the habitat and 200 meters apart. It is convenient to use plastic flagging to mark the travel route (selected by compass direction) between stations. A count consists of recording all birds seen or heard for 8 minutes at a time. Avoid counting the same birds more than once. Also record birds detected between stations if they were not previously recorded. This allows a more complete species list to be obtained. Habitats should be visited at least five times during a particular season, giving at least 30 point counts. Fewer than 30 point counts may result in low counts, which relegate analyses to species presence and absence. Even with 84 counts per stand.

almost 25 percent of the species present will be recorded in such low numbers as to preclude analysis of relative abundance. Species richness is obtained by totalling all species seen or heard in the habitat. If more stations or replicate study sites are used, a general picture of relative abundance can be obtained. This is accomplished by using either total counts of birds or by calculating a detection rate (number of birds detected per visit). This is useful for interstand comparisons.

Fixed-radius point count—Although this method has not been widely used (Verner 1985), Hutto and others (1986) provide strong arguments for its applicability for use in examining differences in bird community composition and relative abundance among sites. Its advantages are that it has fewer assumptions than do variable distance transects and point counts, it is easy to conduct in the field, and the data are easy to analyze. The guidelines established by Hutto and others (1986) are generally followed. The assumptions for the fixed-radius point count are as follows:

1. All birds inside the fixed-radius circle are counted.
2. No birds move into or out of the circle in response to the observer before being detected.
3. Birds are not counted more than once.
4. Observers accurately recognize the limits of the fixed-radius circle.

Point-count stations are established in the same manner as that described for simple point counts. For Douglas-fir forests, 12 stations spaced 150 meters apart are adequate. Counts should last 8-10 minutes at each station (point). A median effective detection distance of 50 meters is reported by Carey and others (1991) for closed-canopy Douglas-fir forests. The fixed radius should be 50 meters unless the vegetation in the habitat is so dense that it significantly prevents detection of birds (that is, clearcuts with high density of trees 5-10 meters tall). In such cases, a 25-meter radius may be more appropriate. During a station count, the observer records the following information: (1) the number of birds of each species detected inside the 50-meter circle, (2) the number of birds of each species detected beyond the 50-meter radius, and (3) the number of birds detected while the observer walked between stations. Birds originally detected outside the 50-meter radius but that moved inside the circle during the count period are recorded as being inside the 50-meter radius.

Several indices of abundance can be calculated from fixed-radius point-count data. These are (1) a detection rate that is the mean number of birds detected per point count multiplied by 100, (2) the frequency of occurrence within the fixed-radius point-count, and (3) the frequency of occurrence of all birds detected from point counts. A frequency of occurrence is the percentage of point-counts at which a species is detected. A ranking of species according to abundance is possible by using detection rates from fixed-radius point counts only if the radius is short enough to ensure that all birds are detected (Hutto and others 1986).

Rare species or species with long detection distances (for example, pileated woodpecker) may be underrepresented in the count data. Our data from Washington indicate that mean detection distances were 50 meters or less for 20 of 23 common species found in Douglas-fir forests. Only four species (brown creeper, rufous hummingbird *(Selasphorous rufus* Gmelin), .golden-crowned kinglet, and chestnut-backed chickadee *(Parus rufescens* Townsend) have mean detection distances of 25 meters or less, however. This seems to indicate that for typical Douglas-fir forests west of the crest of the Cascade Range, a 50-meter radius circle is adequate for most species.

Variable-radius circular plots—Variable-radius plots were developed specifically for estimating the densities of birds in areas of tall, dense forest and uneven terrain (Reynolds and others 1980). Points are systematically placed along a transect through the study stand. We used 12 points 100 or 150 meters apart (100-meter spacing was used in landscapes where stand size was small. 40 hectares; 150-meter spacing was used where stand size was large). Distances are measured to all birds recorded at a station during an 8-minute count period. Assumptions are similar to those for variable-width transects:

1. Distances are measured accurately.
2. Individual birds are not counted more than once from each point.
3. The counting period is short enough to preclude birds moving into the area of detection.
4. Detections are independent events.

One should keep in mind the other assumptions of counting techniques; Verner (1985) and Hutto (1986) review and discuss the problems associated with violations of assumptions dealing with movements of birds, differences in bird behavior among species, change in behavior with time within a day, nonsinging birds, evasive birds, and other problems. Analysis of the data should be conducted with these biases and biases due to differences in detectability among observers and among habitats in mind. Proper design and training of field crews is essential to minimizing biases from the outset (see Carey and others 1991, for an example in Douglas-fir forests). As with variable-width transects, there are many options in modeling the decline in detectability with distance, including adjusting for covariates such as observers, habitat types, and time of day (Burnham and others 1980, Ramsey and others 1987). However, analysis of bird data collected in Pacific Northwest forests was not simple (Carey and others 1991).

We conducted pilot studies in the southern Washington Cascades and along the west side of the Cascades of Oregon to develop methods for counting birds; we applied these methods in the southern Washington Cascades (Manuwal 1991) and in the Oregon Coast Range (Carey and others 1991). We found marked differences in detectability skills among observers, habitat types, and years and differences in the pattern of decline in detectability among species. Observers differed in how well they could estimate distances and in how far they could detect birds of a particular species. Old-growth forests were more structurally complex and taller than young forests with attendant differences in the distances to which birds could be detected. Patterns of detectability not only differed among species, but also differed among species of like songs and calls. A common feature was the "donut": a few birds detected near the observer, an increase in detections with distance, and then, a decrease in detections with distance. Some species showed spikes: high detections near the observer after which a constant rate of detections occurs, and eventually a drop in detections. Some species exhibited both spikes and donuts. And some exhibited more classical detection curves: highest detections nearest the observer, then gradually decreasing detections with distance or constant detections out to a distance marked by sharp declines in detections. This variety of patterns makes it difficult to choose one or a few models of declining detectability that could estimate effective area sampled. Carey and others (1991) use the following approach:

1. Examination of detection curves by each species-observer-habitat type combination. The effort and counts of observers who were especially insensitive to particular bird species were deleted from the data.

2. Deletion of all observations more than 75 meters from the observer to reduce error in distance estimates.

3. Deletion of calls and other nonsong observations for species whose records consisted primarily (>75 percent) of songs; this helped to reduce spikes; for species in which only males sing, densities were doubled.

4. Deletion of the most distant 25 percent of observations for each species. This helped to reduce among-observers differences. The third quartile distance (the radius encompassing 75 percent of the observations) was used as the effective detection radius and seemed to encompass the bulk of the donuts and the areas of relatively constant detectability while eliminating observations in areas of markedly declining detectability.

5. Conversion of species-effective detection radii to areas sampled; counts within the area sampled were divided by the area to obtain densities.

This procedure is time consuming and laborious. Forty percent of the data was discarded. Coefficient of variation (CV, precision of the estimates) was not affected by the discarding. For the 15 common species, CV averaged 44 $\pm$ 7 percent for 75-meter-radius counts, and 39 ^ 7 percent for total counts. Within species, total counts and 75-meter counts were highly correlated ($r = 0.99$); 75-meter counts and densities also were highly correlated ($r = 0.97$). But across species, the correlations between densities and 75-meter counts was only 0.74. Thus, reduction in sample size did not reduce the precision of the estimates or lead to a loss of information about within-species abundance. But calculating densities did provide additional information on among-species abundances because it effectively reduced the differences among observers and the differences in detectability among habitat types. It also accounted for differences in detectability among species by using species-specific radii of effective detection. Examination of detection curves is the only way to determine what procedure would be best for a particular set of data.

Our pilot study found that VCP using all distances resulted in biases in bird densities (as measured against spot mapping) of 14-36 percent, due to counting individuals of some species more than once and to the short effective detection radii of other birds. Using short (25-50 meter) radii helps to avoid overestimates.

Mapping

Spot mapping—Spot mapping is useful for counting territorial birds. The basic elements include the plotting of locations of individual birds on maps of gridded study areas. Earlier descriptions of this technique can be found in Kendeigh (1944), Hall (1964), and Robbins (1970). Assumptions for spot mapping are as follows:

1. Populations are stable during the time of the study, and the birds remain in territories during sampling periods.
2. Birds are correctly identified.
3. One bird per territory produces a sufficient number of songs to be recorded on successive visits.
4. An accurate estimate of the population is made of the mean number of birds represented by each cluster.
5. If total population is estimated, all territorial males are mated.
6. Observers do not differ in ability to detect and identify birds.

Once a relatively homogenous study area at least 8 hectares (20 acres) has been selected, the area should be gridded. The grid is necessary so that locations of singing males can be accurately located. The grid itself should be carefully planned and established. This is done best by using measuring tapes and a compass. The spacing between grid points depends on habitat type. In dense vegetation, grid points may be as close as 5 meters apart. Generally, in open forested habitats (for example, ponderosa pine), grid points can be 15-20 meters apart, whereas in coast Douglas-fir *(Pseudotsuga menziesii* (Mirb.) Franco var. *menziesii* 10 meters may be more appropriate. Several copies of maps of the grid should be made.

During each visit to the study area, the observer should walk slowly along the grid lines recording the location of each detected bird. Different routes through the plot should be used, with different starting and ending points for each visit. Each plot should be visited 8 to 10 times within a relatively short time, although they should be uniformly spaced through the nesting season.

The recording of each detected bird is very important to the subsequent interpretation of the field data (fig. 3). Because this technique describes bird populations in terms of territories, field observations of bird behavior may be critical in determining the number of territorial males present on the grid. For example, singing males should be distinguished from nonsinging males; observations of two males of the same species singing simultaneously or aggressive encounters between two birds of the same species will help locate territory boundaries. The location of females or nests will help determine the proportion of the male population that is mated. Standard procedures for recording bird observations on maps have been developed by the International Bird Census Committee (Svensson 1970) (fig.3).

After all visits have been completed, composite maps of each species should be made (fig. 4). Clusters of detections represent centers of territorial activity. The total number of territories (T) = (number of complete clusters) + (sum of fractional clusters on plot boundaries). The estimated population (P) is calculated by $P = C + FC \times 2$. where C = the number of complete territorial clusters, FC = sum of fractional clusters on plot boundaries.

Total mapping—This method (see Verner 1985) is fundamentally different than spot mapping because it involves mapping marked birds. Total mapping is generally used in studies in which one or a small number of species are involved and determining territory size and habitat use are primary objectives. This technique gives the most accurate estimates of density, but it is costly in terms of funding and time. Many studies in the literature report the use of marked birds to study movement, home range, or territoriality.

If typical forest songbirds are studied, the field procedures are very similar to that discussed for the spot-map method. The study plot and grid are established in the same manner. Target species, however, must be captured and marked; this is done most easily by using mist nets and applying U.S. Fish and Wildlife Service aluminum bands and colored bands to the captured birds. The Bird Banding Manual (Canadian Wildlife Service and U.S. Fish and Wildlife Service 1986) provides necessary information on bird banding techniques and band sizes.[1]

If a population estimate is desired, the clusters of marked birds can be treated in the same

[1] Permits for both aluminum and colored bands are required from the Bird Banding Laboratory, Patuxent Wildlife Research Center, Patuxent, Maryland. In addition, scientific collecting permits for capturing the birds must be obtained from state agencies.

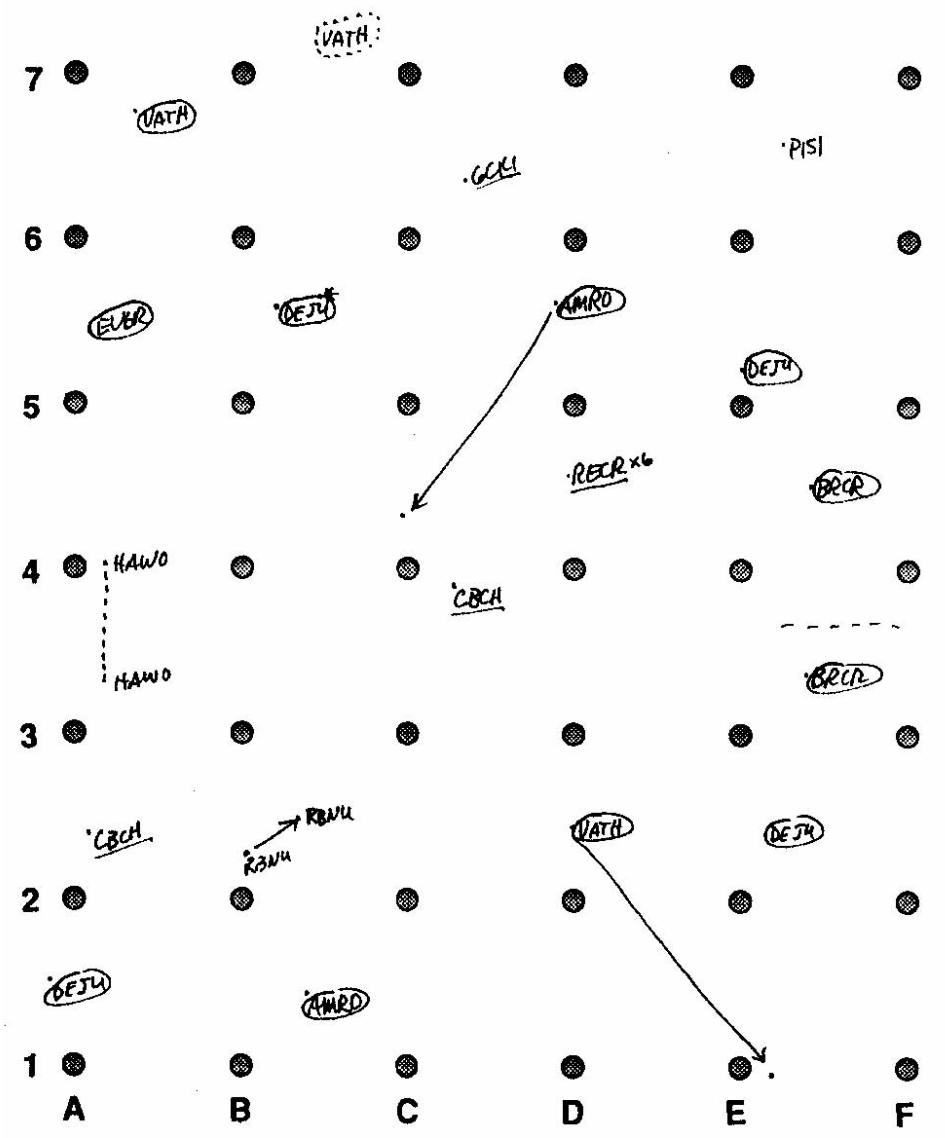


Figure 3—Example of a field map with recorded bird observations from a single visit. Symbols are adapted from Svensson (1970).

manner as that described for spot mapping. If habitat use or movements are objectives, detailed field and composite maps are needed. An accurate, comprehensive vegetation map of the gridded study area would greatly increase information content of the mapped territories. Close attention to scale would permit an estimate of territory size.

Application Of Techniques to Specific Objectives

Species Richness and Presence

Objective—The objective was to determine avian species presence and richness in a particular stand or array of stands.

Examples of questions that might be asked are as follows:

1. Does the red-breasted nuthatch occur across an array of different-aged Douglas-fir forests?

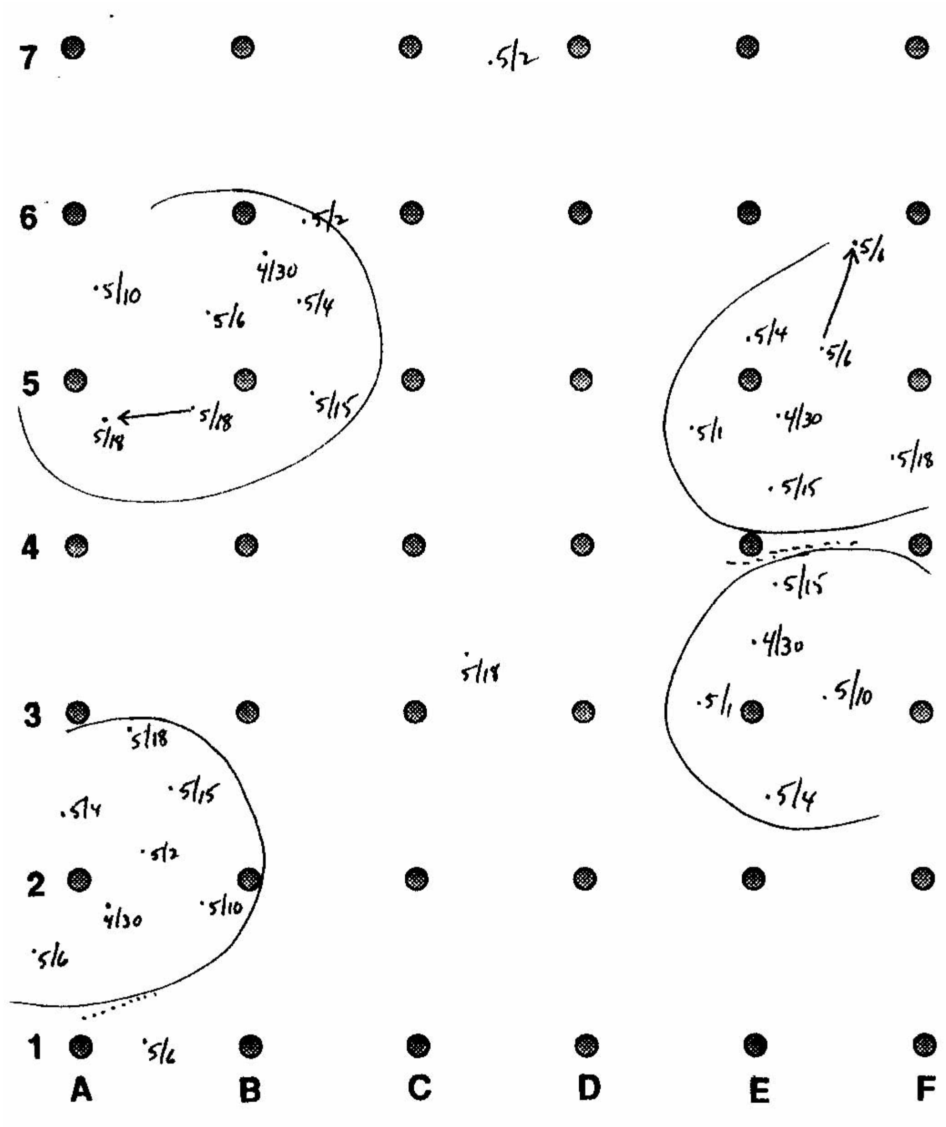


Figure 4—Example of a composite map showing locations of bird observation clusters.

2. Are willow flycatchers more likely to occur in regenerating Douglas-fir clearcuts with significant amounts of alder compared to those with little or no alder?
3. How does bird species richness change between thinned and unthinned stands?

The above questions can be answered by using a nominal scale of abundance; that is, by using only knowledge of the presence or absence of species (table 3). The most efficient techniques for assessing the presence of small forest birds are the simple line transect and the simple point count. Extensive field tests of transects and point counts were conducted in California by Verner and Ritter (1985) who concluded that point counts were preferable to transects in most cases, but it depended on study design and season. Ultimately, the method used depends on personal preference, topography, and density of vegetation. Generally, in more open habitats on level or gently sloping topography, line transects are

Table 3—Summary of applications of bird-counting techniques to specific objectives

Technique	Species presence	Relative abundance	Population trends	Density	Habitat use
Line transects:					
Simple	X	X	X		
Fixed-width	X	X	X	X	
Variable-width	X	E	X	X	
Point counts:					
Simple	R	X	R	X	
Fixed-radius		X	X	X	
Variable-radius		R	X	R	
Mapping:					
Spot-mapping		E	E	X	X
Total mapping		E	E	X	X

X = adequate.
E = more than adequate, thus inefficient.
R = recommended for Pacific Northwest Douglas-fir forests.

preferable. Field crews in the southern Washington Cascade Range and Oregon Coast Range concluded that their ability to detect birds was poor while they traversed rugged topography and stands with an abundance of brush and fallen trees. This suggests that transect approaches are not suitable for Douglas-fir forests west of the Cascade Range.

Relative Abundance

Objective—The objective is to determine relative abundance of a species or the species in a bird assemblage along an environmental gradient or among stands differing in silvicultural history. An example would be to determine the change in abundance of the chestnut-backed chickadee in stands differing in amount of precommercial thinning.

An accurate index of abundance is needed to determine relative abundance. Equal sampling effort in all study stands is a key element to any approach. Although bird species may show differences in detectability among forests that are dramatically different in structure, no data are available to indicate the magnitude of these differences. Birds occupying forests that are generally similar in structure are probably equally detectable. Given the assumption that bird detectability will not seriously affect results in stands selected for study, we can use techniques that do not require any adjustments for differential detectability. These include the simple line transect, simple point count, fixed-width line transect, and fixed-radius point count.

Population Trends

Objective–The objective was to describe population trends of a bird species. Examples of more specific objectives are:

1. Determine annual changes in abundance of the varied thrush.
2. Determine the seasonal changes in abundance of the gray jay.

To determine annual changes in abundance, we try to determine the long-term population trend of a selected species during the same season each year. In this case, we do not have to be too concerned about changes in detectability unless they are weather related. If only relative measures of abundance are needed, then the simple line transect, simple point count, and fixed-width transect or point count can be used.

For determining seasonal changes in abundance, count data must be adjusted for different detectabilities. Even though seasonal changes in detectability have been documented in only a few cases (for example, Jarvinen and others 1977, O'Connor 1980, Weber and Theberge 1977), it is a potentially serious bias that must be considered. Consequently, field techniques that allow for detectability coefficients are required. These include the variable-distance transect and variable-radius point count.

If a larger geographical area is being considered for the above examples, study sites should represent variation in the normal habitat occupied by the target species. Replication of habitat types should be considered in the design of the study.

Density

Objective—The objective is to determine if bird community structure differs between young- and old-growth stands. Examples of specific questions are as follows:

1. Does the rank-order abundance of the common birds differ between young and old-growth stands?
2. Are communities in young stands dominated by fewer species than communities in old-growth stands?
3. Are there fewer species per 100 birds (a measure of absolute diversity, Magurran 1988) in young stands than in old-growth stands?

These questions require estimates of density for each bird in the community in each of the stands in the samples of the two stand types. Spot mapping is preferable but VCP may be used. For VCP, 10-12 sampling points should be located 150 meters apart on a transect throughout the interior of each stand. Less effort could preclude modeling the decline in detections. Each point should be visited seven times, with visits spaced over the breeding season. The species of and the distance to all birds detected at each point should be recorded. Effective detection radii should be determined for each species. The counts within the radius should be divided by the area circumscribed by the radius to obtain densities. Community structure (ranked abundance) should be compiled for the species comprising 75 percent of the individuals recorded (this eliminates rare species). Rank order of species can be compared between young and old-growth stands by using Kendall's coefficient of concordance (Zar 1984). Dominance can be estimated by using the Berger-Parker Index (Magurran 1988), averaged by stand type, and tested with a t-test. Species density (number of species per number of individuals) can be estimated by using Margalefs Index (Magurran 1988), averaged by stand type and tested with a t-test. Results can be stated as follows: young stands did not differ from old-growth stands in general community structure, but young stands were dominated by a single species and had a lower species density than did the old-growth stands. Results suggest a loss of biodiversity would accompany the replacement of old-growth stands by young stands.

Habitat Use

Objective—The objective was to determine the location of territories and microhabitat use. Examples are as follows:

1. Locate the territories of songbirds in clearcuts.
2. Describe habitat use by pileated woodpeckers in selected coniferous forest types.

The spot-map method is the most efficient and least expensive way to determine the number and location of territories of most songbirds. If the territory map grid is carefully laid out and bird detections are accurately placed on the map, estimates of territory size for some species is possible. Knowledge of territory location is helpful in determining the use of specific areas in a clearcut or forest by particular bird species.

In the pileated woodpecker example, above, more precise information on bird movement is necessary to describe use. This is achievable only by plotting the visual detections and movements of marked individual birds on vegetation maps or by radio telemetry. Birds must be captured and marked with colored bands, neck bands, or patagial markers. Larger birds may also be fitted with small radio transmitters and subsequent triangulations or visual detections plotted on maps. Radio telemetry is expensive in both equipment and time needed for movement determinations, but it can be a valuable tool for studying species with large territories or home ranges and those that are difficult to observe.

Acknowledgments We thank Richard Hutto, William Mannan, and C.J. Ralph for their valuable comments on the manuscript.

Literature Cited

Anderson, B.W.; Ohmart, R.D. 1977. Climatological and physical characteristics affecting avian population estimates in southwestern riparian communities using transect counts. In: Johnson, R.R.; Jones, DA., tech. coords. Importance, preservation and management of riparian habitat: a symposium; 1977 June 19-23; Tucson, AZ. Gen. Tech. Rep. RM-43. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station: 193-200.

Best, L.B. 1981. Seasonal changes in detection of bird species. In: Ralph, C.J.; Scott, J.M., eds. Estimating numbers of terrestrial birds. Studies in Avian Biology. 6: 252-261.

Best, LB.; Peterson, K.L. 1982. Effects of stage of the breeding cycle on sage sparrow detectability. Auk. 99: 788-791.

Blondel, J.; Ferry, C.; Frochot, B. 1981. Point counts with unlimited distance. Studies in Avian Biology. 6: 414-420.

Burnham, K.P.; Anderson, D.R.; Laake, J.L. 1980. Estimation of density from line transect sampling of biological populations. Wildl. Monogr. 72. Washington, DC: The Wildlife Society. 202 p. Supplement to the Journal of Wildlife Management. 44(2): 1980 April.

Canadian Wildlife Service and U.S. Fish and Wildlife Service. 1986. North American bird banding: Volume II. Ottawa, Canada: Population and Surveys Division, Canadian Wildlife Service.

Carey, A.B. 1983. Monitoring diurnal, cavity-nesting bird populations. In: Snag habitat management: Proceedings of a symposium; 1983 June 7-9; Flagstaff, AZ. Gen. Tech. Rep. RM-99. Fort Collins, CO: U.S. Department of Agriculture. Forest Service, Rocky Mountain Forest and Range Experiment Station: 188-199.

Carey, A.B.; Hardt, M.M.; Horton, S.P. 1991. Spring bird communities—Oregon Coast Ranges. Gen. Tech. Rep. PNW-GTR-285. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 123-144.

Dawson, D.G. 1981. Counting birds for a relative measure (index) of density. Studies in Avian Biology. 6:12-16.

Emien, J.T. 1977. Estimating breeding season bird densities from transect counts. Auk. 94: 455-468.

Emien, J.T.; DeJong, M.J. 1981. The application of song detection threshold distance to census operations. Studies in Avian Biology. 6: 346-352.

Engstrom, R.T.; James, F.C. 1981. Plot size as a factor in winter bird-population studies. Condor. 83: 34-41.

Franzreb, K.E. 1981. A comparative analysis of territorial mapping and variable-strip transect censusing methods. Studies in Avian Biology. 6:164-169.

Gabrielson, I.N.; Jewett, S.G. 1970. Birds of the Pacific Northwest. New York: Dover Publications, Inc. 650 p.

Granholm, S.L 1983. Bias in density estimates due to movement of birds. Condor. 85: 243-248.

Hall, G.A. 1964. Breeding bird census—why and how. Audubon Field Notes. 18: 413-416.

Hutto, R.L.; Pletche, S.M.; Hendricks, P. 1986. A fixed-radius point count method for nonbreeding and breeding season use. Auk. 103: 593-602.

Jarvinen, O.1976. Estimating relative densities of breeding birds by the line transect method. II: Comparison between two methods. Ornis Scandinavica. 7: 43-48.

Jarvinen, O.; Vaisanen, R.A. 1975. Estimating relative densities of breeding birds by the line transect method. Oikos. 26: 316-322.

Jarvinen, O.; Vaisanen, R.A. 1976a. Estimating relative densities of breeding birds by the line transect method. IV: Geographical constancy of the proportion of main belt observations. Ornis Fennica. 53: 87-91.

Jarvinen, O.; Vaisanen, R.A. 1976b. Finnish line transect censuses. Ornis Fennica. 53; 115-118.

Jarvinen, O.; Vaisanen, R.A.; Haila, Y. 1976. Estimating relative densities of breeding birds by the line transect method. III: Temporal constancy of the proportion of main belt observations. Ornis Fennica. 53: 40-45.

Jarvinen, O.; Vaisanen, R.A.; Haila, Y. 1977. Bird census results in different years, stages of breeding seasons and times of day. Ornis Fennica. 54:108-118.

Kendeigh, S.C. 1944. Measurement of bird populations. Ecological Monograph. 14: 67-100.

Kessler, W.B.; Milne, K.A. 1982. Morning versus evening detectability of southeast Alaskan birds. Condor. 84: 447-448.

Magurran, A.E. 1988. Ecological diversity and its measurement. Princeton, NJ: Princeton University Press. 179 p.

Manuwal, D.A. 1983. Feeding locations of coniferous forest birds during a spruce budworm outbreak in western Montana. Murrelet. 64:12-17.

Manuwal, David A. 1991. Spring bird communities in the southern Washington Cascade Range. Gen. Tech. Rep. PNW-GTR-285. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 161-176.

Merikallio, E. 1958. Finnish birds: their distribution and numbers. Fauna Fennica. 5:1-181.

Morrison, M.L.; Hardy, J. 1983. Hybridization between hermit and Townsend's warblers. Murrelet. 64: 65-72.

Morrison, M.L.; Mannan, R.W.; Dorsey, G.L. 1981. Effects of number of circular plots on estimates of avian density and species richness. In: Ralph, C.J.; Scott, J.M., eds. Estimating numbers of terrestrial birds. Studies in Avian Biology. 6: 405-408.

Morrison, M.L.; Meslow, E.C. 1983. Avifauna associated with early growth vegetation on clearcuts in the Oregon Coast Ranges. Res. Pap. PNW-RP-305. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 12 p.

O'Connor, R.J. 1980. The effects of census date on the results of intensive common birds census surveys. Bird Study. 27:126-136.

O'Connor, R.J.; Hicks, R.K. 1980. The influence of weather conditions on the detection of birds during common birds census fieldwork. Bird Study. 27:137-151.

Quinn, T.J. 1981. The effect of group size on line transect estimates of abundance. In: Ralph, C.J.; Scott, J.M., eds. Estimating numbers of terrestrial birds. Studies in Avian Biology. 6: 502-508.

Ralph, C.J. 1981. An investigation of the effect of seasonal activity levels on avian censusing. In: Ralph, C.J.; Scott, J.M., eds. Estimating numbers of terrestrial birds. Studies in Avian Biology. 6: 265-270.

Ralph, C.J.; Scott, J.M., eds. 1981. Estimating numbers of terrestrial birds. Studies in Avian Biology. 6: [pages unknown].

Ramsey, F.L.; Scott, J.M. 1981. Tests of hearing ability. In: Ralph, C.J.; Scott, J.M., eds. Estimating numbers of terrestrial birds. Studies in Avian Biology. 6: 341 -345.

Ramsey, F.L.; Wildman, V.; Engbring, J. 1987. Covariate adjustment to effective area in variable-area wildlife surveys. Biometrics. 43:1-11.

Reynolds, R.T.; Scott, J.M.; Nussbaum, R.A. 1980. A variable circular-plot method for estimating bird numbers. Condor. 82: 309-313.

Robbins, C.S. 1970. Recommendations for an international standard for a mapping method on bird census work. Audubon Field Notes. 24: 723-726.

Robbins, C.S. 1981 a. Bird activity levels related to weather. In: Ralph, C.J.; Scott, J.M., eds. Estimating numbers of terrestrial birds. Studies in Avian Biology. 6: 301-310.

Robbins, C.S. 1981 b. Effect of time of day on bird activity. In: Ralph, C.J.; Scott, J.M., eds. Estimating numbers of terrestrial birds. Studies in Avian Biology. 6: 275-286.

Shields, W.M. 1979. Avian census techniques: an analytical review. In: Dickson, James G.; Conner, Richard N.; Fleet, Robert R. [and others], eds. The role of insectivorous birds in forest ecosystems. New York: Academic Press: 23-51.

Short, L.L. 1979. Burdens of the picid hole excavating habit. Wilson Bulletin. 91:16-28.

Skin/in, A.A. 1981. Effect of time of day and time of season on the number of observations and density estimates of breeding birds. In: Ralph, CJ.; Scott, J.M., eds. Estimating numbers of terrestrial birds. Studies in Avian Biology. 6: 271-274.

Svensson, S., ed. 1970. Bird census work and environmental monitoring. Bull. Ecol. Res. Comm. 9. Stockholm: Swedish National Scientific Research Council. 52 p.

Verner, J. 1981. Measuring responses of avian communities to habitat manipulation. In: Ralph, C,J.; Scott, J.M., eds. Estimating numbers of terrestrial birds. Studies in Avian Biology. 6: 543-547.

Verner, J. 1985. Assessment of counting techniques. Current Ornithology. 2:247-302.

Verner, J.; Ritter, L.V. 1985. A comparison of transects and point counts in oak-pine woodlands of California. Condor. 87: 47-68.

Weber, W.C.; Theberge, J.B. 1977. Breeding bird survey counts as related to habitat and date. Wilson Bulletin. 89: 543-561.

Zar, J.H. 1984. Biostatisical analysis. Englewood Cliffs, NJ: Prentice-Hall, Inc. 718 p.

*U.S. GOVERNMENT PRINTING OFFICE 1991-691-000/60010

Manuwal, David A.; Carey, Andrew B. 1991. Methods for measuring populations of small, diurnal forest birds. Gen. Tech. Rep. PNW-GTR-278. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 23 p. (Carey, Andrew B.; Ruggiero, Leonard F., tech. eds.; Wildlife-habitat relationships: sampling procedures for Pacific Northwest vertebrates).

Before a bird population is measured, the objectives of the study should be clearly defined. Important factors to be considered in designing a study are study site selection, plot size or transect length, distance between sampling points, duration of counts, and frequency and timing of sampling. Qualified field personnel are especially important. Assumptions applying to all bird-counting techniques are discussed. The following techniques and their applications are discussed: simple line transect, fixed-width transect, variable-width transect, simple point count, fixed-radius point count, variable-radius circular plot, spot mapping, and total mapping. For determining species richness and presence, the simple line transect and simple point count methods are recommended. Measures of relative abundance can be obtained by using the simple line transect, simple point count, fixed-width line transect, and fixed-radius point count methods. Population trends during the same season each year can be detected by using the same trends as those used for relative abundance. If more than one season is involved, however, the variable-distance transect or variable-radius point count are necessary to account for differences in bird detectability. Habitat-use patterns can be determined best by using the spot-map method to elucidate territory locations. More precise information can be obtained for larger birds by using radio transmitters.

Keywords: Birds, populations, sampling methods, surveys.

Pacific Northwest Research Station
333 S.W. First Avenue
P.O. Box 3890
Portland, Oregon 97208-3890

NATIONAL FORESTS
1891-1991

U.S. Department of Agriculture
Pacific Northwest Research Station
333 S.W. First Avenue
P.O. Box 3890
Portland, Oregon 97208