Estimating Snag and Large Tree Densities and Distributions on a Landscape for Wildlife Management

Lisa J. Bate, Edward O. Garton, and Michael J. Wisdom

Authors

LISA J. BATE is a wildlife biologist, and EDWARD O. GARTON is a professor, Fish and Wildlife Resources Department, University of Idaho, Moscow, ID 83844; and MICHAEL J. WISDOM is a regional wildlife ecologist, U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, Forestry and Range Sciences Laboratory, 1401 Gekeler Lane, La Grande, OR 97850.

Abstract

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We provide efficient and accurate methods for sampling snags and large trees on a landscape to conduct compliance and effectiveness monitoring for wildlife in relation to the habitat standards and guidelines on National Forests. Included online are the necessary spreadsheets, macros, and instructions to conduct all surveys and analyses pertaining to estimation of snag and large tree densities and distributions at the subwatershed scale. The methods focus on optimizing sampling effort by choosing a plot size appropriate for the specific forest conditions encountered. Two methods are available for density analysis. Method one requires sampling until a desired precision level is obtained for a density estimate. Method two is intended for use in areas that have low snag densities compared to Forest plan targeted densities. After taking a minimum of 60 samples, one may test for a significant difference between the estimated and targeted densities. In addition, data can be used to calculate a distribution index. The value obtained from the distribution index indicates whether the current distribution of target snags and large trees across a subwatershed is adequate to meet the habitat needs of territorial cavity-nesters and other wildlife species. Wildlife use also may be evaluated.

Keywords: Density, distribution, foraging, nesting, monitoring, sampling technique, snag, large tree, woodpecker, wildlife management, wildlife use.

Contents

Introduction

A wide variety of wildlife depend on snags and large trees for survival and reproduction. In the Blue Mountains of Oregon and Washington, for example, 62 species of birds and mammals use snags or large trees for roosting, denning, feeding, or related life functions (Thomas and others 1979). Woodpeckers are an especially important group of species that depends on snags and large trees, and whose role in forested ecosystems is integral to the continued health of such systems. As primary cavity-nesters, woodpeckers excavate nest and roost sites for themselves and many other species. An absence of viable woodpecker populations in fact, means an uncertain future for secondary cavity-nesters, or nonexcavators. Woodpeckers often are referred to as indicator species because it has been assumed that if woodpecker populations are maintained at viable levels, secondary cavity-nesting populations also will be present at viable levels (Thomas and others 1979).

Currently, the nesting and roosting needs of woodpeckers and other cavity-nesters are assumed to be met by controlling only the density of snags, standing dead trees, on public lands. This is based on a snag model developed by Thomas and others (1979); this model assumed a positive, linear relation between woodpecker and snag abundance in the Blue Mountains of Oregon. This relation was confirmed by Mannan and others (1980) for forests in western Oregon (as stated in Nietro and others 1985). The model, however, did not account for the foraging needs of woodpeckers and other cavity-nesters, and more recent studies have shown that foraging structures can differ from nesting and roosting structures for woodpeckers (Bate 1995, Bull and Holthausen 1993, Dixon 1995). For example, large trees (>20 inches [51 cm] diameter at breast height [d.b.h]) are also critical for woodpecker populations; large trees develop deep furrows that harbor increased arthropod densities (Bull and others 1986, Mariani and Manuwal 1990). Some species, such as the white-headed woodpecker (*Picoides albolarvatus*), depend on the seeds produced by mature ponderosa pine (*Pinus ponderosa* Dougl. ex Laws.) for autumn foraging (Dixon 1995). In addition, other species such as the pileated woodpecker (*Dryocopus pileatus*) select large hollow trees for roosting (Bull and others 1992). Finally, retaining large trees across a landscape provides a continual source of large snags, even in areas managed primarily for timber resources.

Although most resource specialists recognize the need to retain adequate densities of snags and large trees across a landscape, these structures have declined in abundance for various reasons (Hann and others 1997). Large trees are targeted for removal during timber harvesting. Snags also have been systematically removed from public lands. Historically, snags have been reduced because of even-age management techniques (Titus 1983), fuelwood cutting, and the elimination of snags as a source of disease and insect pests (Dickson and others 1983, Ffolliot 1983, Styskel 1983). In addition, Hope and McComb (1994) found that snag retention programs on National Forests are hampered by problems with safety, funds, and inconsistent standards and guidelines. Consequently, density, size, and condition of snags on National Forests often fail to meet the snag (Morrison and others 1986) and woodpecker guidelines outlined in Forest plans (Bate 1995).

Cavity-nesting birds are not the only species affected by reduced snag densities. Commodity values of timber can be reduced by insect damage. Most cavity-nesters are insectivores, and have proven instrumental in preventing, or retarding, local insect outbreaks (Beebe 1974, Otvos 1979). Some species of woodpeckers will aggregate in areas where insect outbreaks are occurring, thus accelerating the decline of the insect population (Otvos 1979). In addition, as foraging woodpeckers remove the bark of beetle-infested trees by chipping and probing, the microenvironment of the remaining beetle eggs and larvae is altered. The remaining eggs and larvae may be more susceptible to mortality caused by parasites and extreme temperature fluctuations (Otvos 1979). Thomas and others (1979) provided additional compelling arguments and evidence in support of maintaining viable populations of woodpeckers and other insectivores for their benefits to forest-based economies.

National Forests are required to maintain viable levels of native wildlife populations on public lands. This was the objective in 1974 when the Forest and Rangeland Renewable Resources Planning Act (RPA) became law (Forest and Rangeland Renewable Resources Planning Act 1974). Then in 1976, the National Forest Management Act was passed as an amendment to the RPA. This second law requires the preparation of forest plans that include periodic evaluation and monitoring of management objectives, standards, and guidelines for National Forest Service lands and its resources (U.S. Laws, National Forest Management Act 1976). Woodpeckers, an important wildlife resource because of their role as indicator species and controlling agents of forest insect pests, are a primary focus of the Forest Service's monitoring efforts.

To help ensure that viability requirements are met, targeted woodpecker and snag densities are set by each National Forest based on land use allocation and the forest community type. Many National Forests use the findings from the Blue Mountains for their target guidelines (Thomas and others 1979). For example, at the Deschutes National Forest, old-growth and riparian areas are managed for 100 percent of the woodpecker potential maximum population (PMP)(Thomas and others 1979), whereas in even-aged ponderosa pine harvest units, visual corridors, and deer management areas, 40 percent of the PMP is the objective (Deschutes National Forest plan 1992).[1] In contrast, forests west of the Cascade Range such as the Willamette National Forest aim to maintain habitat capability at the 40 percent PMP (Nietro and others 1985) level on all subwatersheds (Willamette National Forest plan 1992).[2]

There are three types of monitoring in National Forests: implementation, effectiveness, and validation. Implementation, or compliance, monitoring determines whether a National Forest complies with the objectives, standards, and guidelines outlined in their Forest plan. For example, Were a minimum of 0.9 snags per acre (2.2 snags per ha) left in a stand after timber harvest? Effectiveness monitoring refers to periodically collecting the necessary data to determine whether management actions are producing the desired effect. For example, Are woodpeckers present at 40 percent of their PMP (Thomas and others 1979) level when 0.9 snags per acre (2.2 snags per ha) are left?

[1] Deschutes National Forest, Bend and Fort Rock Ranger Districts, 1230 NE 3d, Suite A-262, Bend, OR 97701.
[2] Willamette National Forest, Blue River Ranger District, Blue River, OR 97413.

Validation monitoring collects information to support, or refute, the assumptions of the guidelines and objectives stated in the Forest plan for a particular species. For example, Does woodpecker abundance respond in a positive, linear fashion to increasing snag densities? (Wisdom and others, in prep.).

Monitoring requires both time and money. If resource specialists are to monitor woodpecker habitat, therefore, they need efficient and statistically valid methods to achieve monitoring objectives. Key decisions managers must make before sampling snags and large trees are the shape and size of plot that statistically is most efficient. Bull and others (1990) tested the efficiency and accuracy of both fixed- and variable-radius circular plots to determine snag densities. They found that 1-acre and variable plots, with a factor-5 prism, worked best for areas with snag densities ranging from 0.7 to 2 snags per acre (1.7 to 4.9 snags per ha). In areas obscured by vegetation, or in steep, difficult terrain, however, it may be difficult to accurately count all snags in these plot sizes. In addition, Krebs (1989) states that most ecologists have found that long, thin or rectangular plots work better than circular or square plots in the same area. The habitat components of a forest are never uniformly distributed; rather, there are often clumps, or patches, of habitat components such as snags and trees. Consequently, rectangular plots are better for sampling because they cross more clumps of snags or trees, rather than encircling, or missing, them completely. This results in a lowered variance, which translates into smaller sample sizes. Rectangular plots therefore are recognized as the optimal plot shape for sampling in patchy habitats. For the optimal plot size, however, each forest situation needs to be analyzed independently (Krebs 1989).

This report provides resource specialists with efficient and accurate methods to sample snags and large trees with the use of rectangular plots. This report also was written in response to the concern that many National Forest subwatersheds fail to provide the necessary densities of snags and large trees to maintain viable populations of cavity-nesters (Bate 1995, Morrison and others 1986). Currently, most National Forests east of the Cascade Range use the snag densities recommended by Thomas and others (1979) for woodpecker management. Bull and Holthausen (1993), however, found that pileated woodpecker densities were less than what this model would have predicted by snag numbers alone. In addition, recent studies suggest that current snag density guidelines may be too low to produce the desired levels of woodpecker abundance because the guidelines focus only on their nesting needs (Bull and others 1997). The primary purpose of these methods is therefore to conduct compliance and effectiveness monitoring for woodpeckers in relation to the habitat standards and guidelines of National Forests.

The necessary spreadsheets and macros (Excel Version 5.0)[3] to conduct all analyses pertaining to snag and large tree densities and distributions on a landscape can be found online at http://www.fs.fed.us/pnw/snags. Guidelines for stratification are included to reduce sampling effort and to increase precision of an estimate (Krebs 1989). Methods presented will help resource specialists to optimize their sampling effort by choosing a plot size that minimizes the number of samples required for their specific forest conditions.

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[3] The use of trade or firm names in this publication is for reader information and does not imply endorsement by the U.S. Department of Agriculture of any product or service.

Two methods are available for density analysis. Method one requires sampling until a desired level of precision is obtained for a density estimate, for example, a density estimate that could be within 20 percent of the true mean, 90 percent of the time. The second density analysis method was developed for sampling in areas that have low snag densities compared to targeted densities. After taking a minimum of 60 samples, a resource specialist may test for a significant difference between the estimated and targeted densities. In addition, resource specialists can use their data to calculate a distribution index. The Distribution Index will estimate how evenly distributed target snags or large trees are across a landscape; this index is based on the proportion of the sampled landscape supporting target snags or large trees.

General Information

Files Online

Four files will accompany each report. They can be found online at http://www.fs.fed.us/pnw/snags. Both English and metric versions are available. The file names for the English versions are (1) Estimate.xls, (2) Single.xls, (3) Strate.xls, and (4) Append2.doc. The file names for the metric version equivalents are (1) Estimatm.xls, (2) Singlem.xls, (3) Stratm.xls, and (4) Append2.doc. Within these files are the data forms, data sets, macros, and spreadsheets necessary for snag and large tree density and distribution analyses on landscapes. The files named *.xls were created and are intended for use in Microsoft Excel Version 5.0. The Append2.doc is a Microsoft Word Version 6.0c document. It contains detailed explanations of each item on the field form and has been made available on disk for modification for specific forest conditions. Please make back-up copies of all files before beginning any data entry or analyses.

The file Estimate.xls (Estimatm.xls) contains no data; this is where your own data should be entered.

Two files containing data sets are provided for tutorial purposes: (1) Single.xls (Singlem.xls) and (2) Strate.xls (Stratm.xls). The file Single.xls (Singlem.xls) contains a subset of the data collected from a 900-acre (364-ha) old-growth ponderosa pine forest. It represents an example of a landscape area smaller than the typical subwatershed. The file Strate.xls (Stratm.xls) contains a subset of the data collected from a 4,347-acre (1760-ha) Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco)/western hemlock (*Tsuga heterophylla* (Raf.) Sarg.) subwatershed. This subwatershed was delineated into three strata (Bate 1995). These two files are identical in every way except for the data sets they contain.

All working spreadsheets are protected with the exception of the Optimal sheet. Only the shaded areas on each of these spreadsheets therefore can accept alphanumeric information from you. This protects the formulas and format necessary to conduct all analyses. In the "Computer Analysis" section of this report, users will find the background, statistics and discussion of each macro and spreadsheet. In the "Tutorial" sections, detailed operating instructions are given for using the two sample data sets provided.

Sampling Applications

Although these sampling techniques were designed to address objectives for the management of woodpeckers, these techniques may be used for any wildlife species associated with snags and large trees. For example, a manager may want to determine the

difference in large, hollow tree densities between two subwatershed areas for black bears (*Ursus americanus*).   These sampling techniques would be appropriate for this objective.

In addition, these techniques may be used to complement the information collected in other monitoring projects. For example, the USDA Forest Service's current vegetation survey (USDA Forest Service 1993) collects Forest habitat data from the same perma-nently established plots every 8 years. These plots are located on a 1.7-mile (2.7-km) grid across Oregon and Washington on National Forest Service lands. The final pro-duct of both of these monitoring techniques could be converted to similar units of measurement (e.g., no. per acre [no. per ha]) to provide additional baseline data for resource specialists.

General Snag and Large Tree Sampling Guidelines

A condensed outline of the guidelines for sampling snag and large trees can be found in appendix 1. A more detailed discussion of the topics in the outline follows.

Landscape Definition and Selection

The first step in sampling snags and large trees is to select the area to be surveyed. Our snag and large tree sampling methods were developed to be compatible with the intended sampling unit for the Forest Service's woodpecker monitoring program, which was defined as a landscape ranging from 3,000 to 7,000 acres (1215 to 2834 ha) (Bull and others 1991). Our sampling methods also are intended for use on a subwatershed scale with some slight modifications. See the "Establishing Transects" and "Compare to Target" sections for details. Subwatersheds average nearly 20,000 acres (8097 ha) within the interior Columbia basin (Quigley and others 1996) but can be as small as 1,000 acres (405 ha).

The area to be sampled, however, need not be a delineated subwatershed. For exam-ple, a manager may want to know the estimated snag and large tree density within an old-growth Research Natural Area that comprises only 900 acres (364 ha). These methods will work for this situation as well. Our sampling methods, however, are not intended for small-scale sampling such as an individual stand (<100 acres [40 ha]); complete counts are more appropriate in individual stands.

Sampling Objectives

After a landscape area has been selected for sampling, the next step is to specify the sampling objectives. Doing this will dictate the stratification process and can aid in the decisionmaking process for optimal plot size. The following questions should be answered before sampling begins: (1) What size class of snags or large trees will be surveyed (e.g., what d.b.h. and height)? (2) What condition of snags and large trees will be surveyed? (e.g., both hard and soft snags? Hollow trees? All trees?) (3) Should any species be excluded (e.g., if a particular tree species is known to provide little, if any, wildlife value, should it be excluded from your sampling program)? and (4) Should signs of wildlife use be recorded (e.g., woodpecker foraging and nesting signs)? Your choices will ultimately determine the amount of time and resources needed to obtain a density estimate with a desired level of precision. In addition, several of these choices will affect the outcome of the Compare to Target density estimate test and the Distribution Index found in the "Computer Analysis" section of this paper.

Landscape Stratification

Perhaps the most critical step in any snag or large tree sampling program is deciding on the stratification process. Although the initial investment of time spent in the stratification process can be large, if done correctly, this process should reduce the final requirement of resources and provide a more precise density estimate (Krebs 1989). Before stratification of a landscape begins, however, we recommend checking with local foresters. Field-level foresters often stratify for other sampling needs, and their delineations may work well for purposes outlined here.

If the landscape is homogeneous throughout in regard to snag or large tree densities, there is probably little to be gained by stratifying. Whether a landscape should be stratified before sampling begins, however, depends on several factors. Cochran (1977) presents the three most common reasons:

1. Stratification may produce a gain in precision of the estimate. If the landscape is heterogeneous in regard to its snag or tree densities, creating individual strata, which are homogeneous within themselves, can improve the precision of an estimate.

2. Sampling problems can differ for different parts of the landscape because of forest community type, timber harvest method, or seral stage.

3. Resource specialists may want to obtain separate estimates for certain subdivisions of the landscape. For example, if part of a subwatershed is managed for 40 percent PMP, compared to another, which is managed for 100 percent PMP, stratification can provide separate estimates for each stratum.

If one or more of the above reasons applies to your situation, it would probably be beneficial to stratify. The spreadsheets contained within this report can accommodate up to four strata.

To stratify your survey area, use the following steps:

1. Visit the area if you are unfamiliar with it. Landscape patterns unclear on maps may become apparent from an initial ground survey. What differences are visible in the vegetative structure across the landscape? What similarities exist? Begin to think about strata that are homogeneous in regard to snag and large tree densities or forest structure.

2. Obtain reference maps for use in the field. Use whatever maps are available. For example, either geographical information system (GIS), or orthoquad maps, or both, can contain the following necessary information: (a) current road system with all detectable roads drawn, (b) stand units and their unique numeric identifier for each stand, and (c) current seral stage of vegetation. We recommend using maps scaled to 1:31,680 or less. This information may be contained on one or several maps. Make several copies of a map with the stand units delineated.

3. Obtain the most current aerial photographs of the survey area.

4. Run a query by using either the GIS or any stand exam database available. Because each local area (district) has its own approach to the storage of stand data, we recommend first checking with the data specialist to develop the most efficient approach to obtaining this information if you are unfamiliar with its recovery. You are interested in what each stand supports in regard to (a) the current community type, (b) the management history, (c) seral stage, and (d) snag and large tree densities. For example, Has the stand ever been harvested? Was regeneration successful? Has it been thinned? If harvested, what method was used? Were snags retained? Were large trees retained? Use the aerial photographs to confirm the database information.

5. Visit the area with the above information.

6. Assign each stand to a stratum. Plan on spending at least one day in the field to validate the information you have received from the GIS or stand exam database. Generally, the amount of time spent in the field for stratification purposes will be directly related to the quality of the information collected from the GIS or stand exam database. Additional field days may be required to complete the stratification work. This is case-specific and depends on the resource specialist's knowledge of the area.

7. Estimate the number of acres (ha) within each stand or stratum.

We assume that most landscapes surveyed for snags and large trees will have undergone some amount of timber harvest. Consequently, depending on the primary method of timber harvesting, the placement of each stand unit within a stratum may or may not be straightforward. For example, on the west side of the central Oregon Cascade Range where clearcutting has been the primary method of timber harvest, the delineation of strata for a snag survey should be relatively apparent.

For this situation, combine all unharvested, old-growth stands into a single stratum. Then consult the silviculturist, and conduct a groundcheck to determine at what age tree and shrub growth are great enough to interfere with the sightability of snags within the harvested stands. Separate all harvested stands with overgrown vegetation from those that remain visually open. These overgrown stands would be your second-growth stands. Finally, combine all stands that have been harvested more recently where the line of vision still extends out to at least 66 feet (20 m). This should give you three strata: (1) recent clearcut stands, (2) second-growth stands, and (3) old-growth stands. Then generate a map with each stand assigned to one of the three strata for use in the field.

By contrast, in areas where selective logging has occurred, the designation of individual strata takes more time, especially where no GIS layers are available. In this situation, first place stands into strata based on ocular estimation. This can usually be done from

stationary viewpoints within or near the edge of stands, oftentimes without having to venture far from roads. For example, in a subwatershed composed of a mix of ponderosa pine and lodgepole pine (*Pinus contorta* Dougl. ex Loud.) stands, three strata might be possible, based on various tree composition and varying snag densities: (1) stands dominated by ponderosa pine with few snags observed; (2) stands represented by codominance of ponderosa and lodgepole pine trees, with usually one or two snags per acre observed; and (3) stands dominated by lodgepole pine tree with two or more snags per acre observed.

Remember, the main criteria in making the decision to stratify a subwatershed are the sampling objectives. For example, if the sample is designed exclusively for estimating the density of large trees, the stratification can be dictated solely by this variable. If both large trees and snags are of interest, stratification should be done based on which of the two (trees or snags) appears to be more variable. In areas where clearcutting is the common method of timber harvest, the density of snags and large trees often is highly correlated, and stratification can be done reliably by using either variable.

The second criterion should be either seral stage or timber harvest technique. Do you expect that certain stands will be more difficult to survey than others? If so, separate these out. The final criterion should be forest community. This is especially important for snags in areas undergoing insect or disease events. Certain tree species are more susceptible to insects or diseases; therefore, where these trees are located, you can expect higher densities of snags. This may be the situation where lodgepole pine trees intersperse with ponderosa pine.

Methods

General Surveying Procedures

Field equipment—Surveyors will require some or all of the field equipment in the list following:

Item	Use
1. Accurate map showing stand units with stratum number	Record correct stratum number
2. Road map	Determine location and access
3. Aerial photographs	Determine stratum and locations
4. Orthophoto quads	Determine stratum and locations
5. Field data forms	Record survey information
6. Hip-chain	Measure transect distances; mark center line of transect
7. Biodegradable hip-chain line	Same as above
8. Diameter or Biltmore stick	Measure diameter of snags or trees
9. Clinometer	Measure heights of snags or trees
10. Compass	Determine bearings
11. Meter tape >66 feet (20 m) long	Measure perpendicular distances from the center line
12. Pocket knife	Determine species and decay class of snags
13. Flagging	Mark ends of subsegments, if necessary
14. Stake	Secure end of tape measurer if only one observer

Field forms—Standardized field forms are provided to record the necessary snag and large tree information for density and distribution analyses. If both snag and large tree data are recorded simultaneously, these data should be entered into separate files. All data entered into the spreadsheet should be numeric, following the format shown on the sample sheet (fig. 1). If available, hand-held computers can be used for data entry in the field. The spreadsheets were created with this purpose in mind and data can be entered directly onto Sheet 1. This eliminates the need to enter the data from the field forms.

If hand-held computers are not used, however, field forms can be produced by using the macro **Dataform**. It will create data forms on a blank worksheet for use in the field. To create a data form (1) open the Estimate.xls (Estimatm.xls) file; (2) select any blank sheet in the file (e.g., Sheet 4); (3) select Macro from the Tools menu; (4) highlight **Dataform**; (5) choose Run; (6) highlight entire page with mouse; and (7) then choose Selection, instead of Sheet, under the Print options. This will create data forms with grid lines (fig. 1).

Establishing Transects   Appendix 2 provides detailed explanations for the correct input of snag and large tree habitat information. It is also online (filename: Append2.doc) so that it can be customized for different areas; each forest will most likely have different snag and tree species encountered. Resource specialists also have the option to alter the requirements for each field variable to meet their objectives. For example, should heights be recorded to the nearest foot or meter? What wildlife signs should be recorded?

Option 1: landscape method—Use the following steps to establish transects by using the entire landscape: (1) randomly place a grid over the subwatershed map; (2) randomly select five grid points within each stratum that will be used to establish starting points for each transect; (3) randomly select compass bearings for each of the five transect starting points; and (4) determine if each of the five transects within each stratum fall within sufficient area of the stratum to allow four sample subsegments (one subsegment = 164 feet [50 m]) to be placed; if not, select additional transects and starting points until a total of 20 samples (subsegment lengths), from a minimum of five stands, have been located within each stratum (fig. 2).

Use a random numbers table for any of the selections above, or generate random numbers using the second hand of a watch. If a watch is used to generate random starting direction, multiply the number of seconds by six to obtain any of 360 random numbers that can be used as compass bearings for the starting point.

Option 2: stand method—In areas composed of highly fragmented small stands, it may be more efficient to dispense with the grid method for establishing transects. For example, some clearcut stands in western Oregon are just large enough to accommodate 654 feet (200 m), or four subsegments of randomly established transect. To establish transects in highly fragmented areas (1) select stands for sampling by randomly picking stand unit numbers from the complete list of stands within that stratum; (2) select a random point along the road bordering the stand as an entry point into the stand; and

STRATUM	LOCATION	SEGMENT	SUBSEGMENT	WIDTH33(10)	WIDTH66(20)	WIDTH99(30)	WIDTH132(40)	DISTANCE	SPECIES	CLASS	DBH	HEIGHT	CAVITY	FORAGING
1	2345	1	1.1					66	2	5	18	33	5	2
1	2345	1	1.1					7	2	1	25	107	1	3
1	2345	1	1.1					16	2	5	16	9	2	4
1	2345	1	1.1					43	2	2	29	87	1	1
1	2345	1	1.1					23	2	3	30	58	5	4
1	2345	1	1.1					36	2	2	27	85	4	3
1	2345	1	1.1					56	2	2	35	95	4	4
1	2345	1	1.1					26	2	2	24	78	3	4
1	2345	1	1.2					66	2	1	15	56	1	4
1	2345	2	2.1					20	2	2	13	63	4	4
1	2345	2	2.1					10	2	5	11	8	4	3
1	2345	2	2.1					49	2	4	35	50	4	4
1	2345	2	2.2					33	2	4	16	50	4	4
1	2345	2	2.2					26	2	4	15	45	4	2
1	4567	3	3.1					39	2	4	19	63	5	2
1	4567	3	3.1					30	2	3	22	116	5	3
1	4567	3	3.1					3	2	1	37	125	5	4
1	4567	3	3.2					66	2	3	34	63	3	1
1	4567	3	3.2					33	2	1	13	86	4	3
1	4567	4	4.1					30	2	4	30	95	3	3
1	4567	4	4.2					10	2	3	40	101	2	4
1	4567	4	4.2					59	2	4	28	99	3	4
1	6789	5	5.1					13	2	2	13	41	4	3
1	6789	5	5.1					16	2	3	25	122	4	4
1	6789	5	5.2					9999						
1	6789	6	6.1					0	2	2	24	77	4	2
1	6789	6	6.1					30	2	2	25	53	5	2
1	6789	6	6.1					49	2	3	17	51	4	2
1	6789	6	6.1					66	2	3	24	60	4	2
1	6789	6	6.1					26	2	2	28	105	3	4

Figure 1–Sample data form.

(3) from the point along the road, randomly select a starting point from which to establish a transect within 164 feet (50 m) of the road. In this way, you can usually sample at least four subsegments within each clearcut stand.
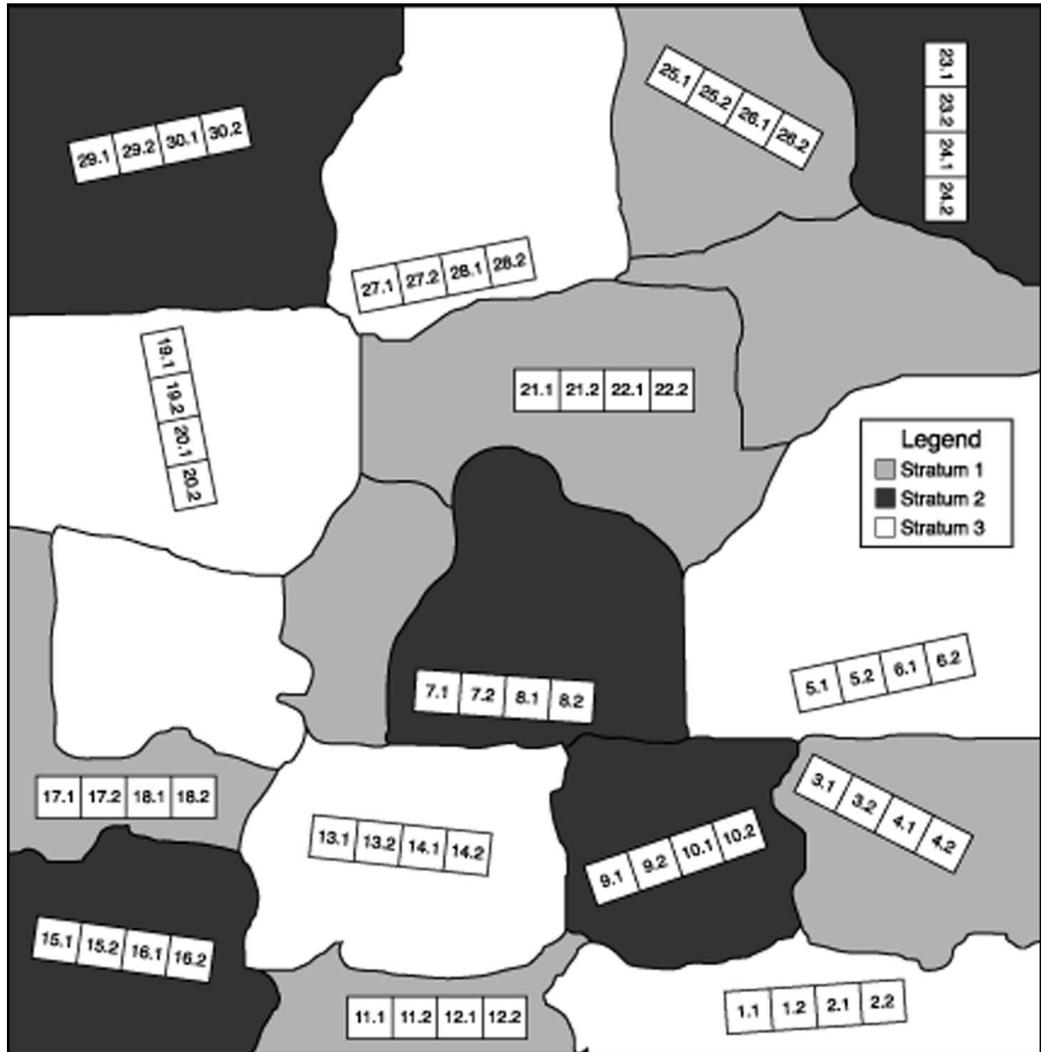

Figure 2—Example of pilot survey transect establishment on landscape with three strata. A maximum of four subsegments should be surveyed along each transect within each stand. A minimum of 20 subsegment samples should be taken within each stratum for the pilot survey. Each subsegment is given a unique numeric identifier (e.g., 1.1, 1.2, 2.1, and 2.2). Two subsegments comprise one segment. Segments are identified by the whole number associated with the subsegment number.

The pilot survey should include a minimum of 20 samples taken within each stratum. For nonstratified landscapes, 20 total samples are needed for the pilot survey. Subsegment plots are 164 feet (50 m) long. One subsegment is considered one sample for the pilot survey. Segment plots are 328 feet (100 m) long. Two consecutive subsegments constitute one segment (fig. 3). The 20 samples should be taken from at least five different stands for each stratum, or four subsegments (656 feet [200 m]) within each stand (fig. 2). This is necessary to ensure that the variability within each stratum is adequately represented and will provide a better estimate of the sample size required for your objectives.

On large subwatersheds, the stands in which the pilot samples are taken should not be near each other. This is especially important on subwatersheds that encompass several plant communities because of an elevational gradient. In this situation, divide the sub-watershed into three sections and equally divide your samples throughout these sections.

Once the requirements of the pilot survey have been met and the optimal plot size within each stratum has been selected, transects longer than four subsegments in length (656 feet [200 m]) may be established. Transects within a stand should not exceed 12 subsegment lengths (1,968 feet [600 m]). If the transect crosses through many stands (and consequently different strata), however, this distance may be increased up to 24 subsegment lengths (3,936 feet [1200 m]) if large samples are required. Use your best judgment in how long a transect should be to ensure that you adequately sample the natural variability of the landscape. For landscapes >7,000 acres (2834 ha), it would be best to continue to establish short transects (four subsegment lengths) after the pilot survey if your only objective is to compare the estimated density to the targeted density of snags or trees. See the "Compare to Target Density" section for details.

Plot Size Selection

Presampling selection–In some situations, it may be more practical to preselect a plot size for sampling, rather than conducting the Optimal Plot Size analysis (see "Optimal Plot Size" in the "Computer Analysis" section). This can often be determined based on information gathered during the stratification process. For example, in low-density (<1 snags per acre [0.4 snags per ha]) clearcut strata where travel is easy, a statistical review of the data reveals little about the optimal plot size. Rather, wider plots should be used to collect data on as many snags or large trees as possible.

In steep, rugged terrain, or in densely overgrown forest, the wider plots should not be used because they are inefficient and prone to inaccuracies in these conditions. By contrast, the narrower plots make it easier to detect snags and large trees within the plot boundaries and to measure their distances. Then, in areas where snag numbers tend to be low, but clumps of snags are present because of disease or insect events, the longer, narrower plots work best to minimize the variance. See appendix 3 for additional information on presampling plot size selection in various forest conditions.

Postsampling selection–In most forested conditions, the optimal plot size to use for sampling is unknown until a pilot sample has been collected. Then you have estimates of the density and distribution of the snags or trees in the area. Then use the pilot-sample
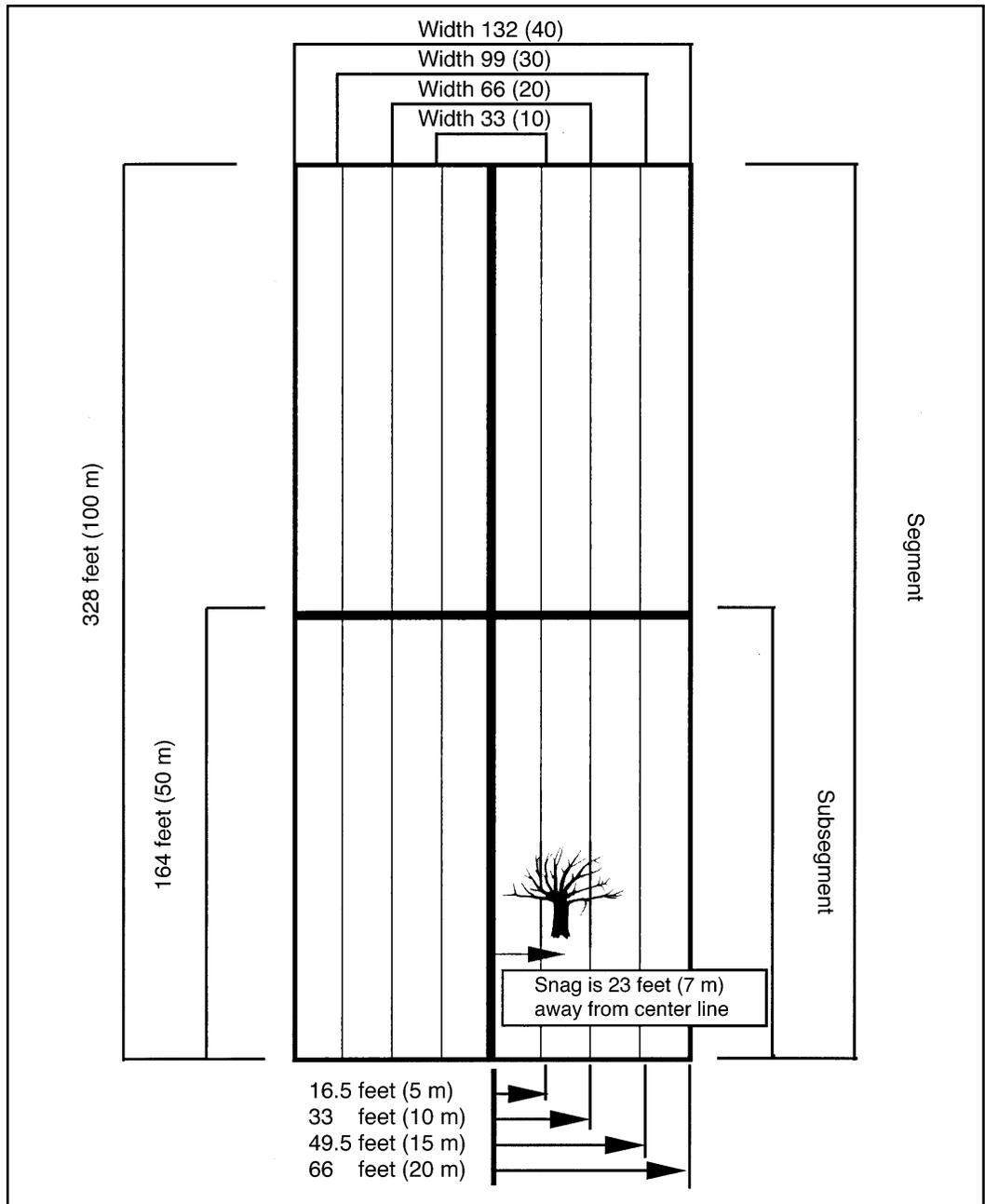
Figure 3—The eight plot sizes available for sampling snags and large trees: two possible lengths and four possible widths. During the pilot survey, the smallest plot size is nested within the larger plots until an optimal plot size is selected. Then the optimal plot size is used for the remainder of the survey. The Width33(10) - Width132(40) plots refer to the entire width (feet [m]) of the plot. Therefore, only snags or trees whose measured distance from the center line is ≤ half of the width qualify for a specific plot size when determining the optimal plot size. For example, a snag that is 23 feet (7 m) away from the center line qualifies for the Width66(20), Width99(30), and Width132(40) plot sizes. It does not qualify, however, for the Width33(10) plot because its measured distance is not ≤16.5 feet (5m), which is half-width of the Width33(10) plot.

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data to determine which plot size minimizes your sampling effort to obtain your desired objectives. See the "Optimal Plot Size" analysis section for details. Then the Optimal plot size can be used for the remainder of the survey.

Snag and Large Tree Survey Techniques

One of the most critical steps of any snag and large tree survey is to conduct a **pilot survey.** The two main objectives in conducting a pilot survey are to (1) collect preliminary data by which to identify the optimal plot size and (2) obtain an estimate of the total number of samples required to meet your objectives. It is important to recognize that pilot data are not extraneous data to be discarded. Rather, they are the first samples collected and to be included in the density and distribution estimates for the entire sub-watershed. In areas where snag and large tree densities are high, the pilot survey in itself may provide an adequate number of samples to meet objectives. By contrast, in areas where snag and large tree densities are low, analyzing pilot data for the optimal plot size can greatly reduce the number of samples needed to obtain a desired level of precision. The optimal plot size can then be used to collect the remainder of the data.

Follow these steps to conduct the pilot survey: (1) use a hip-chain to establish transects; start transects from the randomly selected points described above, (2) delineate sub-segment lengths (164 feet [50 m]) and segment lengths (328 feet [100 m]) along the transect as you walk, (3) assign a unique numeric identifier to each segment and sub-segment as you establish them, and (4) conduct a complete count of all qualifying snags or trees out to 66 feet (20 m) from the center line. The hip-chain line functions as the center line. A snag or tree is considered "in" if its midpoint is <66 feet (20 m) from the center line.

Exceptions to this procedure occur when the stratum to be surveyed has reduced visibility (<33 feet [10 m]) or high densities (>15 snags or trees per plot are consistently counted). In these conditions, snags and trees should be counted to 33 feet (10 m) either side of the center line. See "Presampling Selection" for selecting plot size for other exceptions to this procedure. After the pilot survey is completed, snags and trees should be counted to the boundary of the plot size selected rather than 66 feet (20 m) either side of the center line.

Samples are taken along the transects you have established as described above. During sampling, it will always be necessary to survey subsegments (164 feet [50 m]) in sets of two so that combined, they equal one segment (328 feet [100 m]). If at any time it is not possible to survey two consecutive subsegments, because of stratum changes, discard the single subsegment plot from the data set. This is critical for the analyses. Otherwise the spreadsheets will yield erroneous results about optimal transect sizes, densities, and distributions.

There are four possible widths for both subsegments and segments resulting in a total of eight possible plot sizes (fig. 3). The four widths available are 33, 66, 99, and 132 feet (10, 20, 30, and 40 m, respectively). These are the whole widths of the plots. These are referred to as Width33, Width66, Width99, and Width132 plots, respectively,

in the English version of these spreadsheets. In the metric version, these plots are referred to as the Width10, Width20, Width30, and Width40 plots, respectively. The half width of each of these plots is then 16.5, 33, 49.5, and 66 feet (5, 10, 15, and 20 m, respectively). The half width is the distance out from the center line to which all snags or trees are counted for each chosen plot width size (fig. 3). All snags and trees should be measured to their midpoints.

A snag or tree qualifies if it meets stipulated criteria. For each snag or tree encountered, record the following information: (1) stratum number, (2) segment number, (3) subsegment number, (4) perpendicular distance of the midpoint of the snag or tree in feet (m) from the center line, (5) species, (6) decay, (snags) or structural (large tree) class, (7) d.b.h., and (8) height (fig. 1). These fields must be entered for the spreadsheets to operate correctly. Refer to appendix 2 for details about each field variable. The location, cavity and forage fields are optional. The location field can correspond to (1) the stand number from which the transect originates, (2) the transect starting position determined by a global positioning system (GPS), or (3) the Universal Transverse Meridian (UTM) coordinates of the transect starting point. The Width33(10)-Width132(40) fields are to be left blank while in the field. These will be automatically filled in by the spreadsheets during the computer analysis (fig. 1).

Other field variables also may be recorded during surveys. For example, the seral stage of the stand, distance to the nearest edge, and immediate habitat surrounding a snag or tree can influence whether it is used by wildlife species. Resource specialists therefore, may want to include additional habitat variables to measure. Note, however, that spreadsheet columns to record additional habitat information should be placed at least four columns to the right of the foraging field before any cavity or foraging analyses occur. Columns "A-S" should not be altered if the macros are to properly operate.

In addition to the field variables listed above, several header row variables must be filled in for each snag or tree encountered: (1) forest, (2) district, (3) subwatershed, (4) observer, (5) date, and (6) pages. Because the information recorded for each of these variables may be the same for each row, data columns are set to the far right of the data entry spreadsheet. This allows for easy viewing of the data while providing a permanent record of each of these variables for future referencing. Note that field names for these header variables begin in column "T." The columns for these header rows can be moved.

The numbering system for segments and subsegments is important to follow to maintain accuracy in all analyses. Each new segment should be given a unique whole number even if it is a new segment within a different stratum, e.g., 1, 2, 3, etc. Two subsegments are nested within a segment. The subsegments therefore should have the same whole number as the segment, plus a decimal number indicating whether it is the first or second subsegment. For example, for Segment 1, there should be a Subsegment 1.1 and a Subsegment 1.2. On each new day in the field, numbering of segments and subsegments should follow consecutively from the previous day (fig. 2). If several

groups of observers are conducting surveys simultaneously, however, the numbering sequence does not have to be consecutive; again, what is important is that each segment and subsegment plot has a unique numeric identifier. For example, if three groups are surveying on the same day, one group can number plots in the single digits; another can number plots in the 100 series, and so on.

Of all the fields found on the data sheet, Distance is the most important variable to record accurately. In cases where no snags or trees are encountered, it is critical to record a "9999" in the distance column. This allows the macros to distinguish between plots without snags or trees versus plots that have snags or trees with a distance of "0" because they are located directly on the center line. Periodically, supervisors should calibrate measurements of the distance variable to ensure accurate collection of data. Even small but consistent, overestimation or underestimation of this variable will yield different results. Attention especially should be given to borderline cases. A borderline case is one in which the distance of the snag or tree being surveyed falls on the edge between two width intervals. For example, if a tree is estimated to be 33 feet (10 m) away from the line, it is important to measure this distance exactly. To record 33 feet (10 m) when the actual distance is 36 feet (11 m) will bias the accuracy of the data. We found that we could consistently pace the distance accurately in open, flat areas, but borderline cases still should be measured. When vegetation or steep terrain make pacing difficult, distances need to be measured with a tape to maintain accuracy.

Computer Analysis

In this section, we provide the background, statistics and discussion of each macro and spreadsheet. Refer to the "Tutorial" section for detailed operating instructions. Appendix 4 contains frequently used Excel commands. No two data sets will be the same size, and all macros have been written to accommodate this variation. Data set lengths will differ depending on the overall densities of qualifying snags and trees, the number of strata, and the total number of samples taken in a pilot survey.

Data Entry

Users should enter data into the file Estimate.xls (Estimatm.xls). To prepare for data entry and analysis follow these steps: (1) open the Estimate.xls (Estimatm.xls) file; (2) rename the Estimate.xls (Estimatm.xls) file with the subwatershed name or another filename; (3) use the newly named file for your own data entry and analysis; this preserves the file Estimate.xls (Estimatm.xls) in its original format for analysis of other landscapes; (4) make backup copies of the Tutorial files, Single.xls (Singlem.xls) and Strate.xls (Stratm.xls); this will preserve the original files for reference and tutorial purposes; (5) enter your data onto Sheet 1; several of the macros need to reference Sheet 1 to work properly; and (6) double check here to ensure that the number "9999" has been entered in each subsegment where no snags or trees were encountered; failing to enter the number "9999" in these rows will cause miscalculations to occur.

Consecutive Plots

Run the macro Consecutive before beginning any computer analysis. It will sort your data set by segments and subsegments. This is important because data from the same subsegment plots, entered accidentally or out of sequence, will be analyzed as a separate plot. After running this macro, it is extremely important to scroll through the entire

data set to ensure that two subsegment plots are entered for each segment. For example, segment 13 should contain subsegments 13.1 and 13.2. If segment 13 only has subsegment 13.1 listed but no subsegment 13.2, this entire segment and subsegment should be deleted. Otherwise, the analyses for optimal plot size and a distribution index will be inaccurate.

Formulas

Filling the width columns, Width33(10)-Width132(40), with the appropriate formulas is the first step performed by the computer analysis. You do not have to write the formulas in the Width columns yourself. Rather, the macros Formula (Formmulti and Formsingle) will create the appropriate formulas based on the information you supply in each of four input boxes. These boxes will appear once the macro has begun running. Refer to the "Tutorial" section for detailed operating instructions.

There are five criteria for which each snag or large tree is evaluated before a formula is placed in each of the width columns: (1) d.b.h., (2) height, (3) decay (snags) or structural (trees) class, (4) species, and (5) distance. The first four criteria are relative fields; the values accepted are those entered by the user. By contrast, the distance criterion is an absolute field; the macro truncates the distances for each snag or tree in 16.5-foot (5-m) intervals. Thus, four plot widths are created: 33, 66, 99, and 132 feet (10, 20, 30, and 40 m, respectively). Again, these four plot widths correspond to the four blank width columns: (1) Width33(10), (2) Width66(20), (3) Width99(30), and (4) Width132(40), respectively.

The formulas are "If, then" statements. Therefore, if the snag or tree meets all the target criteria specified by the user, plus meets the distance requirement, then a "1" is placed in the column by the macro. By contrast, if the snag or tree fails to meet all the target criteria, then a "0" is placed in the column. Only those snags or trees that meet all the requirements of the formula created by the user are given the value "1." Consequently, these are the only snags or trees that will be included for the statistical analysis for each plot size. For example, if the perpendicular distance of a snag from the center line was measured at 23 feet (7 m), it will qualify in the Width66(20), Width99(30), and Width132(40) columns if it meets all other criteria. It will not be considered, however, for the Width33(10) column. This is because the Width33(10) column represents a plot with a 33-foot (10-m) total width, or a 16.5-foot (5-m) half width. Therefore, only snags or trees <16.5 feet (5 m) away from the center line, in either direction, will be accepted within the Width33(10) column. See figure 3 for an example.

Two macros are available for entering the formulas for snag analyses. The macro **Formmulti** can evaluate several species of snags. It also has the option of excluding a single species from the analysis.   For example, if a manager is interested in the snag replacement potential provided by large trees, and knows that a species in the area is not used for nesting purposes, this species may be excluded from the analysis by entering its numeric code when the species input box appears. By contrast, if a manager is only interested in the density of a single large tree species, the macro **Formsingle** allows for this narrowed focus in an analysis. **Formsingle** is identical to **Formmulti** (we refer to both of these as the **Formula** macros) in every way except that it will evaluate only a single snag or tree species at a time.

The **Formula** macros will evaluate d.b.h. and height characteristics based on a minimum value you provide. By contrast, decay or structural classes are evaluated based on a maximum value that you want considered for analysis. For example, in the "Tutorials" provided, decay classes I-III are considered hard snags, and decay classes IV-V are considered soft snags. This is based on the five-decay class system developed by Cline and others (1980). By entering the number three as the maximum decay class value, therefore, only hard snags are included in the analysis.

Parks and others (1997) have simplified this system by reducing the number of decay classes to three. This has been done by combining Cline and other's (1980) decay classes II and III together, and classes IV and V together. Both systems are compatible. The division between hard and soft snags therefore remains the same. We recommend using the new system developed by Parks and others (1997) for future subwatershed surveys for its simplicity to new users.

Bull and others (1997) also provide descriptions of large tree structural variations important to wildlife. For example, hollow trees, trees with partial decay, and trees with brooms provide a valuable wildlife resource. We recommend referring to Bull and others (1997) therefore before beginning a large tree survey to ensure that large tree structural classes are designed to meet your objectives. Refer to appendix 2 for an example. Large tree numeric values should be arranged so that with increasing values, the tree is increasingly sound. This is the opposite of the decay class values for snags.

It is important that the width formulas are entered precisely because the macro uses these columns to calculate the means and standard deviations of the data. When the **Formula** macro is finished running, therefore, scroll down throughout each of the width columns to ensure that they contain an "If, then" statement that looks like the following:

=IF(AND(I2<=16.5, K2<=5, L2>=10, M2>=6, J2<>9999),1,0)   formula 1 (English).

=IF(AND(I2<=5, K2<=5, L2>=25, M2>=1.8, J2<>9999),1,0)   formula 1 (metric).

This is the proper syntax for the formula in the Width33(10) column, for snags <16.5 feet (5 m) away from the line (cell range = I2), in all decay classes (cell range = K2), with a d.b.h. >10 inch (25 cm [cell range = L2]), height >6 feet (1.8 m [cell range = M2]), and all species (cell range = J2). If some cells are missing a formula, rerun the macro. In addition, this macro must be run every time new data are added to the data sheet. The macro should be run before the strata are separated to avoid having to run it multiple times. Double check that a "9999" is placed in the distance cell whenever a subsegment does not register any snags or trees. This will allow the macro to distinguish between subsegments with zero snags or trees versus subsegments with a snag or a tree on the line and a resulting distance of zero feet (m).

The **Formula** macros can take only maximums and minimums. If, however, you want to determine the density of snags in a particular size class, these formulas can be edited. For example, to determine the density of snags that are ≥10 inches (25 cm) d.b.h. and <12 inches (31 cm) d.b.h., follow these steps: (1) run one of the **Formula** macros if they

have not been run already to create the proper syntax (see Formula 1) for the "If, then" formula; (2) highlight the cell E2; (3) press the function key F2. This will allow you to edit the formula; (4) insert **L2<12** to the "If, then" statement (Formula 2); and (5) press Enter. This will create the formula:

=IF(AND(I2<5, K2<=5, **L2>=10, L2<12,** M2>=6, J2<>9999),1,0)   formula 2.

(6) Copy the formula in cell range E2; (7) paste this newly edited formula throughout the E column; and (8) repeat this procedure for each Width column so that the macro maintains the distance requirement within each Width column. Similarly, if you are interested in only one decay class of snags, or one structural class of large trees, run one of the formula macros and edit it to conduct this narrower analysis. For example, if you are interested in the density of hollow trees within a stratum, and hollow trees are identified by the numeric code = 1, edit the "K" column in formula 1 shown above to the following:

=IF(AND(I2<=5, **K2=1,** L2>=10, M2>=6, J2<>9999),1,0)   formula 3.

Next, copy and paste this formula throughout the Width33(10) column. Then repeat this procedure for all width columns before running further analyses.

Cavity and Foraging Signs

Depending on the objectives of your snag and large tree surveys, you may want to take your analysis beyond densities and distributions. For example, if you want to determine what snag species most of the cavities were found in, use the macro **Cavity**. Or, if you are interested in what tree species exhibit the most foraging signs, you can analyze this situation by using the macro **Forage**. Each of these macros can evaluate every snag or large tree for five factors: (1) d.b.h., (2) height, (3) decay (snag) or structural (tree) class, (4) species, and (5) cavity or foraging use. The main function of both of these macros is to provide the user with a percent use value. This is calculated by taking the number of snags or trees with cavities or foraging signs and then dividing this by the total number of snags or trees encountered:

$$P_u = \frac{S_s}{S_t - U} \, , \qquad (1)$$

where

P_u = percent use;
S_s = number of snags or trees with nesting or foraging signs;
S_t = total number of snags or trees encountered; and
U = unknowns: entire snag or tree could not be examined or unknown whether foraging or nesting signs were present.

A separate column to the right of the cavity and forage columns is created for these analyses (labeled "QUALIFYING"). Here you will find the formulas that are created and placed into the spreadsheet by the macros. These formulas are also "If, then" statements. They evaluate each snag or tree for the target criteria you stipulate. Similar to

the **Formula** macros, these macros accept only one value for each input box. These formulas, however, also can be edited to obtain the precise information on cavities or foraging you desire. Please refer to the "Cavity" section in "Example I" of the "Tutorial" for detailed instructions on operating the **Cavity** macro.

Before conducting any cavity or foraging analyses, check to make sure that no zeros are found in rows under the Cavity or Forage columns where no snags or trees were encountered. The value zero is not acceptable here because the macros will view these as data values in the analysis.

Sorting Data Sets

Few subwatersheds will be homogeneous enough to forgo stratification. In addition, the optimal plot size likely will differ among heterogeneous strata, as will the means and variances. Consequently, first separate the strata to analyze each stratum individually. For nonstratified landscapes, proceed to the "Analysis by Segment" section.

The macro **Sort** will first sort the data set by stratum in ascending order. Then you will be prompted to enter the ranges of each stratum. Use the scroll bar to determine the ranges. Using the mouse to highlight the range will cause the macro to abort. The macro will place each stratum on a separate sheet. These can be found by clicking on the tabs labeled Stratum1, Stratum2, etc. If the names of these sheets are not in view, use the arrows in the bottom left hand corner to tab left, or right, until they appear.

As additional data are collected, they should be entered directly onto Sheet 1 of your file. Then rerun the **Consecutive**, **Formula**, and **Sort** macros. If for some reason you have fewer rows of data for a stratum the second time you run the **Sort** macro, you should first activate that stratum's sheet and clear or delete all data on that page. The macro will then place the correct number of rows of data on the sheet.

When the macro moves the data for each stratum, it takes with it the necessary format and formulas to conduct all analyses. Simultaneously, it keeps the entire data set in its original format on Sheet 1.

Analysis by Segment

The macro **Segment** will compute averages, standard deviations, and sample sizes based on plot lengths of 328 feet (100 m) or segments for each of the four plot widths. When initiated, this macro will first sum the number of qualifying snags or trees within each segment. The macro will then condense the spreadsheet and show only the number of trees or snags within each segment. These will be labeled as Totals but are also referred to as Subtotals by Excel. We refer to these condensed rows as Subtotals. After condensing the Subtotals, the macro will move them to a new area. This is necessary or else the macros will calculate averages and standard deviations by using the original data rows and the Subtotals.

If at any time the **Segment** macro stops with an error message, restore the sheet to its original state before running the macro again. To restore the sheet to its original format, (1) press End within the Error message box if macro stops, (2) highlight all rows below

the Grand Total Row, (3) select Delete from the Edit menu, and (4) click on Entire Row. Then to remove the subtotals, (1) click on the field name SEGMENT, (2) from the Data menu, select Subtotals, and (3) choose Remove All. With the exception of the first step, these same steps must be performed whenever a new analysis is run using a different macro.

There are several ways to determine the range of subtotals to be copied but only one correct way to enter it into the input box. The proper syntax for a cell range is: "E2:E213." The range can be determined either by using the scroll bar or the arrow keys and visually noting the end cell in the column. If you try to determine the range by dragging the mouse, the cell range will look like this: =$E$2:$E$213. The "dollar" and "equal" signs, however, need to be removed or the macro will abort; the macros work on relative cell ranges to accommodate data sets of different lengths and the "$" refers to an absolute cell range. If an input box ever blocks the view of the cell ranges, you can move it by clicking on the title bar and dragging it to a new position.

Once the subtotals have been moved, you will then be prompted to enter the ranges of each of the newly pasted columns. The macro will then calculate averages and standard deviations for each segment plot width size:

Averages in Excel Version 5.0 are calculated by using the equation:

$$x = \frac{\sum x_i}{n} \, , \qquad (2)$$

where

$\bar{x}$ = sample mean,
x_i = value of x observed in sample i, and
n = total number of samples.

Excel standard deviations are obtained by the equation:

$$s = \frac{n \sum x_i{}^2 - (\sum x_i)^2}{n(n-1)} \, , \qquad (3)$$

where

s = sample standard deviation.

The results will be placed both below the condensed rows of information at the cell address you give, and in the appropriate columns on the Optimal sheet. Always direct the macro to place the table of results at least three rows below the newly pasted data. The macro also will provide you with the sample size (N) for this data set. This value is not, however, automatically transferred to any other spreadsheet. It is good practice to print out your results before continuing. At the end of this macro, you will be asked if you want to be transferred to the Optimal sheet. Choosing "No" will keep you on the active sheet.

Analysis by Subsegment

To compute averages and standard deviations for subsegments, use the macro **Subsegment**. Operation of this macro is identical to the **Segment** macro, but sums on plot lengths of 164 feet (50 m) rather than 328 feet (100 m). To remove the Subtotals, however, highlight the field name SUBSEGMENT rather than SEGMENT before selecting Subtotals from the Data menu.

Optimal Plot Size

To begin analysis to determine the optimal plot size within a stratum, bring up the Optimal sheet by clicking on the tab with this label in the lower left screen. Any gray boxes on this sheet require input from the user. (Note: This sheet could not be protected; please make backup copies in case of accidental entries.) The Stratum box in the upper left portion of the sheet allows for a written description of the stratum. This is useful in situations where resource specialists want to determine what the optimal transect is for both hard snags and large trees. We recommend running the optimal plot size analysis several times if more than one habitat variable is the focus of the survey. The Minimum Sample Size Required box just below should contain one of two numbers, 60 or 20. These numbers correspond to the minimum sample size required for a simple-random, or stratified-random sampling design, respectively, within each stratum. See the "Compare to Target" section for an exception to the minimum sample size required.

There are two options to determine the optimal plot size for a stratum or area. The first option, the sample size option, examines the number of plots required for sampling in comparison to the number of acres that would be sampled for the same plot size. The second option is based on Wiegert's (1962) method, which incorporates a cost factor into the analysis. Both methods evaluate the estimated number of samples needed to obtain a density estimate that is within 20 percent of the true mean, 90 percent of the time.

The sample size option considers three factors: (1) the sample size required in plots (2) the sample size required in acres (ha), and (3) whether the estimated sample size (n) meets the minimum requirements. The required sample size is determined by (Cochran 1977):

$$ n = \left(\frac{t_a s}{d} \right)^2 , \tag{4} $$

where

n = sample size required to estimate the mean density,
s = standard deviation of the mean within each plot size,
t_a = Student's *t*-value for a 90 percent confidence interval ($a = 0.10$), and
d = desired absolute error (calculated as 20 percent of the pilot mean).

First look at the number of sample plots required for each size. Then look at the estimated number of acres (ha) required for each specific plot size to obtain the same level of precision. The optimal plot size is often that which requires the minimal number of

plots and acres (ha) to be sampled, once the minimum sample size requirements have been met. Often, several plot sizes will be appropriate. This is where the person who has conducted the pilot sample needs to examine numbers given on the Optimal sheet and consider, Would it be more efficient and accurate to use a wider or a narrower plot width, given the forest conditions of this stratum? For example, the results on the Optimal sheet may estimate that a Subsegment132(40) plot requires 20 more acres (49 ha) than a Subsegment66(20) plot to obtain the same level of precision. This seems like a large difference, but what really matters is whether it will take a considerable amount of extra time to survey to 66 feet (20 m) in a Subsegment132(40) plot, as opposed to sampling only 33 feet (10 m) out from the line in a Subsegment66(20) plot. In areas where snags or trees are present in low densities, and visibility is open to 66 feet (20 m) from the center line, the Subsegment132(40) plots would probably be the best choice. In contrast, if snag or tree densities are moderate or high, narrower plots are likely the better choice. This will reduce sampling effort by decreasing the amount of time it takes to complete each plot. In addition, users need to consider how easy or difficult it is to see and reach snags or trees out to a specified distance. In steep terrain where shorter snags may be obscured by vegetation, it is important to select a narrower plot size to maintain accuracy.

The second option, which incorporates Wiegert's (1962) method, can aid the decision-making process. Wiegert demonstrates that the optimal plot size is that which minimizes the product of the relative cost and the relative variance. Given that you have the data necessary to determine both relative costs and variances, Wiegert's method is considered preferable (Krebs 1989). It would be the most accurate to conduct time trials (to estimate costs) to measure the amount of time it takes to survey each plot size within your area. Then assuming that costs are directly related to time, relative costs could be incorporated into the optimal plot analysis. There are, however, some logistical difficulties with conducting time trials because only one plot size can be surveyed at a time. In addition, time trials cannot be conducted simultaneously while conducting the pilot survey, which requires surveying snags or large trees to 66 feet (20 m) from the center line. Consequently, the time (and costs) to conduct time trials may quickly offset any benefits gained by acquiring this information because of the separate field efforts required beyond the pilot survey.

We therefore recommend that resource specialists not conduct time trials. Rather, we suggest that if a manager wants to include a cost factor, it is reasonable to use the general costs-per-sample guidelines that we developed. These costs are all built on a relative scale. We have outlined our methods for developing cost estimates, however, so that resource specialists may understand how the costs were derived. Subsequently, resource specialists may adjust these costs for their survey areas, or conduct their own time trials, if they believe their surveys would benefit from the effort.

If resource specialists prefer to incorporate a cost factor into the analysis, six costs per plot scenarios are listed at the bottom of the Optimal sheet under the General Cost per Sample Guidelines based on the conditions listed in table 1. These have been made

available for demonstration. To understand how the relative cost affects the outcome of your decision about the optimal plot size, pick the category that best describes the forest situation within the current stratum. Then copy and paste the information within this column into the Cost per Sample above it. We encourage resource specialists to try several Cost per Sample categories if their forest conditions fall between the categories described.

Table 1—Cost estimates based on time trials to conduct snag (>10-inch [25-cm] d.b.h.) surveys in different forest conditions

Plot dimensions	Time to walk plot length (no snags)[a]	Average number of snags per plot	Time per snag[a]	Total time[a]	Total cost[b]
High visibility (>66 feet [20 m]); easy terrain (<30% slope); low (2 snags/acre [0.8/ha]) density					
Subsegment33(10)	2	0.25	2	2.50	0.43
Subsegment66(20)	2	.50	2	3.00	.51
Subsegment99(30)	2	.75	2	3.50	.60
Subsegment132(40)	2	1.00	2	4.00	.68
High visibility (>66 feet [20 m]); easy terrain (<30% slope); high (8 snags/acre [3.2/ha]) density					
Subsegment33(10)	2	1.00	2	4.00	.68
Subsegment66(20)	2	2.00	2	6.00	1.02
Subsegment99(30)	2	3.00	2	8.00	1.36
Subsegment132(40)	2	4.00	2	10.00	1.70
Medium visibility ([a]16.5 yards [15 m]); moderate terrain (<50% slope); low (2 snags/acre [0.8/ha]) density					
Subsegment33(10)	3	.25	3	3.75	.64
Subsegment66(20)	3	.50	3	4.50	.77
Subsegment99(30)	4.5	.75	3	6.75	1.15
Subsegment132(40)	6.75	1.00	3	9.75	1.66
Medium visibility ([a]16.5 yards [15 m]); moderate terrain (<50% slope); high (8 snags/acre [3.2/ha]) density					
Subsegment33(10)	3	1.00	3	5.00	.85
Subsegment66(20)	3	2.00	3	8.00	1.36
Subsegment99(30)	4.5	3.00	3	13.50	2.30
Subsegment132(40)	6.75	4.00	3	18.75	3.19

Table 1—Cost estimates based on time trials to conduct snag (>10-inch [25-cm] d.b.h.) surveys in different forest conditions (continued)

Plot dimensions	Time to walk plot length (no snags)[a]	Average number of snags per plot	Time per snag[a]	Total time[a]	Total cost[b]
Low visibility (<33 feet [10 m]); difficult terrain (>50% slope); low (2 snags/acre [0.8/ha]) density					
Subsegment33(10)	6	0.25	4	7.0	1.19
Subsegment66(20)	6	.50	4	8.0	1.36
Subsegment99(30)	24	.75	4	27.0	4.59
Subsegment132(40)	30	1.00	4	34.0	5.78
Low visibility (<33 feet [10 m]); difficult terrain (>50% slope); high (8 snags/acre [3.2/ha]) density					
Subsegment33(10)	6	1.00	4	10.0	1.70
Subsegment66(20)	6	2.00	4	14.0	2.38
Subsegment99(30)	24	3.00	4	36.0	6.12
Subsegment132(40)	30	4.00	4	46.0	7.82

[a] Time in minutes.
[b] Cost calculated at $10 per (hour*person). Units in dollars.

In addition, we have taken Wiegert's method one step further by calculating the Total Cost a resource specialist might expect for each plot size selected. We have found this to be the most valuable piece of information, because all costs are relative to each other within the same area.The Total Cost also incorporates the Minimum Sample Size required. Although, the actual cost for sampling may be more or less in a particular area, selecting the plot size that demonstrates the lowest Total Cost will likely result in selection of the Optimal plot size for your current forest conditions.

Estimating Costs

The cost per plot, or time, seems to be a function of three factors: (1) visibility, (2) terrain, and (3) density. Visibility refers to the unobstructed viewing distance within a stratum; visibility is most strongly affected by the seral stage, or amount of shrub cover, within a stand. Terrain includes such things as the slope, shrub cover, and the amount of downed woody debris. All of these factors affect how easy or difficult it is to walk through an area. Density is dictated by the target criteria of the snags or trees being censused and the natural occurrence of these target snags or trees.

Cost estimates per plot were calculated at $10 per observer-hour. In addition to costs per plot, each survey will have associated fixed cost. Fixed cost is the time spent selecting and locating each beginning transect point and then returning to a vehicle after the surveying has been completed. This cost can be minimal in clearcut areas or quite high in areas with difficult terrain. We therefore calculated a fixed cost based on a moderate situation with a low snag density, which averages the cost per plot in this category for Subsegments and Segments. This assumes that observers choose the quickest route to the beginning point of a transect.

Out cost estimates were based on time trials conducted in forests in northern Idaho and then adjusted based on cost estimates from a snag study in the central Oregon Cascade Range. During the time trials, all snags >10 inches (25 cm) d.b.h. were surveyed. For each, we recorded the following information: (1) species, (2) d.b.h. (measured by using a Biltmore diameter stick), (3) decay class, (4) height (ocular estimate), (5) distance of the midpoint of the snag from the center line, (6) nesting evidence (ocular), and (7) foraging signs (ocular).

In flat, open areas, distances for each snag were either paced or determined by using a measuring tape. Paced distances were accepted only after accuracy and consistency in the estimation of distances of snags not considered to be marginal could be demonstrated. A snag was considered marginal, for example, if its distance of 16.5 or 18 feet (5 or 5.5 m) away from the line was uncertain. For these cases, all distances were measured. In addition, periodic calibration of pacing was conducted. In steep areas, all distances >12 feet (3.5 m) were measured.

We developed six hypothetical situations based on our experience surveying snags. "Easy" refers to an area that is relatively flat (<30 percent slope) and where snags or trees are easily observed out to 66 feet (20 m) in both directions. "Moderate" refers to situations where the slope is <50 percent and visibility of snags or trees averages 50 feet (15 m). "Difficult" describes situations in which a combination of factors makes travel difficult and slow, and visibility is low. For example, in dense regeneration stands, it is not possible to accurately detect snags beyond a particular distance. Travel could be difficult as a result of slope (>50 percent), type of seral stage, or the amount of shrub cover or downed woody debris. Cost estimates were developed for each forest situation given two densities: (1) two snags per acre (0.8 snags per ha) and (2) eight snags per acre (3.2 snags per ha) as shown in table 1.

To develop the costs, we first determined the average amount of time required for an observer to walk a 164-foot (50-m) line looking for snags in the various forest conditions but without encountering any target snags. Then we estimated the average amount of time per snag in the different forest conditions required to record the snag characteristics listed above. Next we summed the time required to walk a transect without snags, with the time per snag given the two densities. Total time was then multiplied by $10 per hour to obtain the cost (table 1). Costs for all Segment plots were derived by simply doubling the cost of a Subsegment plot with the same width.

Within the moderate and difficult categories, costs jump considerably for the Width99(30) and Width132(40) plot sizes. This is a result of the observer having to periodically leave the center line to survey beyond the point of visibility.

Sample Size Determination

For unstratified subwatersheds, the estimated sample size is given on the optimal sheet under "Sample Size (plots)." For stratified subwatersheds, go to the sheet Sample Size. This sheet provides two methods for estimating the total sample size required on a stratified subwatershed: (1) optimal and (2) proportional allocation. It also breaks down the total sample size required into the number of plots required for sampling within each stratum.

Proportional allocation of the sample size allocates the samples among the strata based on the proportion of the total area in each stratum (weight W_i). In contrast, optimal allocation incorporates both the stratum proportional area (W_i) and variance (s_i^2) to determine how many samples are required within each stratum (Krebs 1989). Both methods calculate the number of samples required to obtain a density estimate that is within 20 percent of the true mean, 90 percent of the time.

The sample size (Krebs 1989) required by the proportional allocation method is determined by the equation:

$$n = \frac{t_a^2 \sum W_i s_i^2}{B^2} \, , \tag{5}$$

Then the number of samples within each stratum (n_i) is determined by multiplying the total number of samples needed (n) by the weight (W_i) of each stratum.

$$n_i = nW_i \, , \tag{6}$$

Sample size for the optimal allocation method (Krebs 1989) is found by the following equation:

$$n = \frac{(\sum W_i s_i)^2}{\left(\frac{B^2}{t_a}\right) + \left(\frac{1}{A}\right)(\sum W_i s_i^2)} \, , \tag{7}$$

Then the number of samples needed within each stratum is estimated by:

$$n_i = n \left(\frac{A_i s_i}{\sum A_i s_i}\right) \, , \tag{8}$$

where

B = desired bound for 1 - a (x_{st} * 20 percent),[4]
t_a = Student's t-value for 90 percent confidence limits (1 - a),
n = total sample size required in stratified sampling,
W_i = stratum weight (A_i/A),
s_i = standard deviation in stratum i,
s_i^2 = variance in stratum i,
A = total number of acres (ha) in subwatershed,
A_i = number of acres (ha) in stratum I, and
n_i = total sample size required in stratum i.

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[4] We have substituted the symbol B (to denote bound) for the d listed in Krebs' (1989) equations.

There are advantages and disadvantages to each of the allocation methods. Proportional allocation offers the advantage of dropping the strata and combining all samples after the sampling is done. You would do this in cases where you found little or no difference in densities between strata. This will yield both a larger sample size (n) and a smaller variance (s²). By contrast, this option is not available if the optimal allocation method is used. The optimal allocation method, however, provides the best estimate for the least cost in situations where large differences in density exist between strata. With this method, sampling is concentrated in the stratum that has the highest variance. By contrast, proportional allocation concentrates sampling effort in the largest stratum, regardless of the variance within each stratum.

It is important to remember that the sample sizes given are only estimates of the number required to obtain a desired level of precision. Consequently, we recommend that data be analyzed in the macros periodically to gauge the precision of estimates.

Estimating Densities   After a minimum of 60 samples (See the "Establishing Transects" section for an exception to the minimum number of samples required.) have been collected (or 20 samples per stratum), the mean density of snags or trees can be estimated; resource specialists may then decide whether enough samples have been collected to achieve their objectives. The two density options provided are (1) Estimate Average Density and (2) Compare to Target Density. These allow the user to either obtain an average snag or tree density that is within 20 percent of the true mean at a desired confidence level or determine whether the estimated density is significantly different from the targeted density, respectively. Users can choose both options. For the Estimate Average Density option, use the Densities sheet. For the Compare to Target Density option, you must first obtain a density estimate from the Densities sheet, and then use this information on the Statistical Test sheet.

Estimate average density—To meet the requirements of the Estimate Average Density option, two equations are available on the Density sheet based on two sampling methods: (1) simple and (2) stratified random sampling. For the simple random sampling method, the average is calculated in the normal way (equation 1). Then the variance is calculated by:

$$s^2 = \frac{\sum (x_i - \bar{x})^2}{n-1} \; ,$$

(9)

and the standard error of the mean is then determined by:

$$s_{\bar{x}} = \sqrt{\frac{s^2}{n}} \; ,$$

(10)

where

$\bar{x}$ = population mean,
x_i = observed x value in sample i,
n = sample size,
s^2 = variance of the measurements,
$s_{\bar{x}}$ = standard error of the mean $\bar{x}$, and
t_a = Student's t-value for 90 percent confidence limits (1 - a).

The confidence interval is then calculated by using a normal approximation (Krebs 1989) :

$$\bar{x} \pm t_a s_{\bar{x}} \quad , \tag{11}$$

As in the previous sheets, all shaded boxes require input from the user. The t-value is preset at 1.67 for a sample size equal to 60 to obtain a 90-percent confidence interval. If a different level of confidence is desired, however, the t-value may be changed. In the first section of the Densities sheet, an estimated mean is given based on simple random sampling methods.

In the second section, a density estimate with a bound is calculated based on stratified random sampling methods. The stratified mean density is computed by the following equation:

$$\bar{x}_{st} = \frac{\sum_{i=1}^{L} A_i \bar{x}_i}{A} \quad , \tag{12}$$

To calculate a confidence interval, the stratified variance must first be determined:

$$\text{Variance of } (\bar{x}_{st}) = \sum_{i=1}^{L} \left(\frac{W_i^2 s_i^2}{n_i} \right) , \tag{13}$$

Then the confidence interval is calculated by the normal approximation:

$$\bar{x}_{st} \pm t_a \left(\sqrt{\text{var}(\bar{x}_{st})} \right) , \tag{14}$$

where

$\bar{x}_{st}$ = stratified population mean (number per acres [ha]),
$\bar{x}_i$ = observed mean in stratum i,
A_i = number of acres (ha) in stratum i,
A = total number of acres (ha) in subwatershed,
n_i = number of samples in stratum i,
i = stratum number,
L = number of strata,
s_i^2 = variance in stratum i, and
W_i = stratum weight or proportion of area in stratum i (A_i/A).

Because this section is designed to accommodate landscapes with different numbers of strata, the user must enter the correct number of strata in the column Stratum Number. The macro counts the number of rows within this column that contain a value corresponding to the number of strata within the landscape. It then selects the appropriate equation for the given number of strata. For example, for a subwatershed with four strata, enter the numbers 1, 2, 3, and 4 in each of the rows under the column heading Stratum Number.

Compare to target density test—The second density option is an informal statistical test that allows resource specialists to determine whether the estimated snag or tree density is significantly different from the targeted density identified as part of their standards and guidelines. A minimum of 60 samples for the landscape, or 20 samples from each stratum (whichever is higher), are required. For subwatersheds >7,000 acres (2834 ha) increasing your sampling effort may be necessary to compensate for the natural variability of snags and trees because of an elevational gradient. For example, a 20,000-acre (8097-ha) subwatershed, which encompasses three distinct forest community types, may require about 100 samples to adequately conduct the Compare to Target Density test. This translates into an increase of about three sample plots for every 1,000 acres (405 ha) surveyed above 7,000 acres (2834 ha). See the "Establishing Transects" section for details in plot establishment. This option is especially useful in situations where densities are low and the sampling effort to obtain an estimate within 20 percent of the true mean (90 percent of the time) is extremely high. It is intended for surveys where the main objective is determining whether the subwatershed meets the targeted guidelines for snags or large trees. Note here that recent data suggest that snag targets set in National Forest plans are too low (Bull and others 1997).

The most common way to test for a significant difference between two means is to conduct a t-test that compares the mean within each plot to the target mean. Although this would work for our purposes, in single-stratum landscapes, there are some problems with this approach on stratified landscapes. Consequently, we chose to use the confidence interval statistical test. This test determines whether the targeted density value falls within the confidence interval of the estimated density. Because the bound on the density estimate is calculated by using a t-statistic, it is essentially the same as a t-test. This t-statistic has the same distribution as the Student's t-test statistic. In addition, this approach simplified the process and made it possible to use with stratified landscapes.

Resource specialists can use this same statistical comparison after the minimum number of samples has been met. The spreadsheet labeled Statistical Test then allows resource specialists to visually assess whether the estimated and targeted densities of a survey are significantly different from each other (fig. 4). Users need only enter the targeted density and the estimated density and its bounds from snag or tree survey; the resulting graph is automatically plotted. For example, on a homogeneous 6,044-acre (2447-ha) study site in ponderosa pine forest in the Oregon Cascade Range, one objective was to determine whether the study area met the targeted hard snag densities listed in the Forest plan. The Forest plan guidelines (Deschutes National Forest plan 1992; see footnote 1) for this area stipulated it support at least 0.9 hard snags per acre (2.2 hard snags per ha). On this site, the estimated (n = 175) hard snag density was 0.11 + 0.04 snags per acre (0.3 + 0.1 snags per ha [Bate 1995]). It was obvious that the study area did not meet the targeted snag densities listed in the Forest plan; this could be demonstrated statistically. The null hypothesis for this test was:

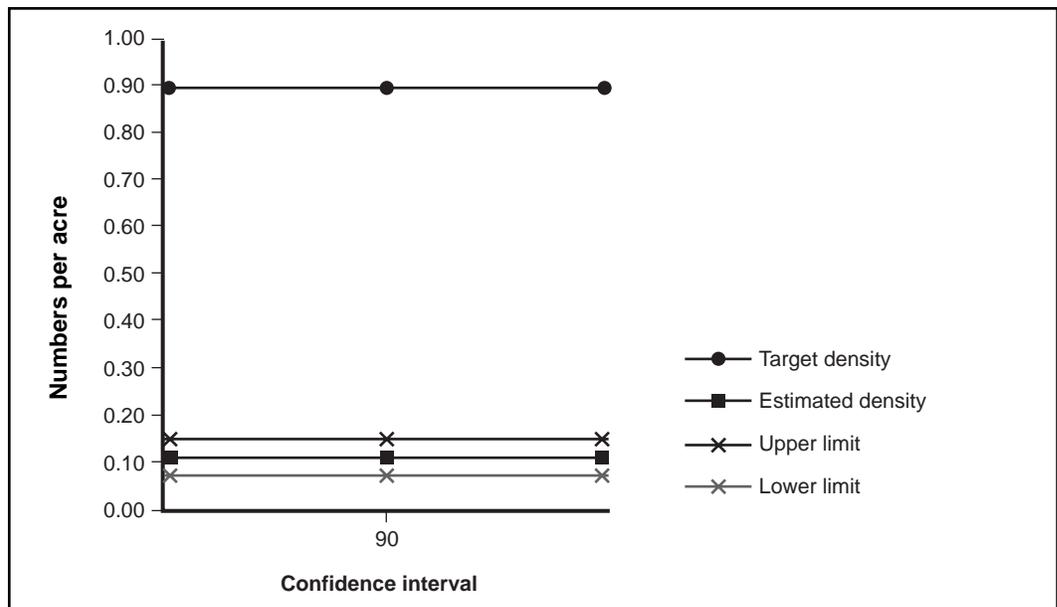H_o: There is no difference between the targeted and estimated hard snag densities.

Figure 4—Statistical Test sheet. Results of the statistical test found a difference between the targeted density of 0.9 snags per acre (2.2 snags per ha) and the estimated density of 0.11 snags per acre (0.3 snags per ha). Data from intensively harvested landscape in ponderosa pine forest on the Deschutes National Forest.

To evaluate the results, we checked whether the target value (0.9 hard snags per acre [2.2 snags per ha]), fell between the values 0.07 and 0.15. These values are the upper and lower limits on the density estimate 0.11 hard snags per acre (0.27 hard snags per ha). If so, we could fail to reject the null hypothesis. In this case, however, the targeted density did not fall within the confidence interval of the estimate (fig. 4). We therefore rejected the null hypothesis. These are the results when a 90 percent confidence interval is used. If there is any uncertainty at the 90 percent confidence level as to whether there is a difference between the targeted and estimated densities, resource specialists may select a narrower confidence interval to decrease the possibility of a type I error. If after this step, a manager still questions the results, more samples should be taken before repeating this test. By contrast, resource specialists should be aware that the biological consequences of having a type II error occur may be more serious. We therefore recommend consulting with a statistician so that you are aware of the biological consequences of each of these types of errors before implementing any major management actions as a result of this test.

Distribution Analysis

The Distribution Index sheet estimates how evenly distributed target snags or large trees are across a landscape; this is based on the percentage of the sampled landscape supporting target snags or large trees. To obtain a distribution index, users must first obtain two values: (1) present value and (2) count value. These are calculated by using

the macro **Pres_Abs**. These values are the number of Segment33(10) plots supporting a target snag or tree, and the total number of plots sampled, respectively. These values are then entered onto the Distribution Index sheet. The macro **Pres_Abs** runs similarly to the Segment and Subsegment macros in that it will sum the number of target snags or trees within each row. It will only do this, however, for the Width33(10) column. It will then condense the information into rows of Subtotals. Next, the condensed Subtotals will be pasted to another area for analysis. As with the Segment macro, it is necessary to enter the range by using the following format:

C1:F334

Symbols within the range will cause the macro to abort.

For single stratum landscapes, use the first section on this sheet. For stratified sub-watersheds, use the second section and run the macro **Pres_Abs** on each stratum. In addition, you will need to know the total number of acres (ha) within each stratum. Subsequently, a stratified distribution index is produced. Follow the directions given in the "Tutorial" for complete details about proper cell entries.

While calculating a stratified Distribution Index, it is critical to enter the correct number of strata by deleting the empty cells. This is similar to the Densities sheet where the equation used is driven by the numbers in the Stratum column. Otherwise, the macro selects the wrong equation. Highlight the unused stratum cells under Stratum and press Delete.

As the name of the macro **Pres_Abs** suggests, the Distribution Index is a presence-absence analysis. It determines the proportion of plots with a qualifying snag or tree, divided by the total number of plots sampled. The proportion of plots containing a quali-fying snag or tree is then adjusted to compensate for the small amount of area sampled relative to the critical area of 10 acres (4 ha). This result can then be extrapolated across the entire landscape.

We chose 10 acres (4 ha) as the critical area to evaluate for the distribution analysis, because it approximates the average home range size of the red-breasted nuthatch (*Sitta canadensis*) (Raphael and White 1986). This primary cavity-nester has the small-est home range of the primary cavity-nesters. In addition, 10 acres (4 ha) is often recommended as an appropriate size area on which to evaluate the distribution of snags for cavity-nesters (Raphael 1997). In choosing this size area, we assume that if snags and large trees are adequately distributed to meet the needs of red-breasted nuthatches, this distribution will also meet the needs of cavity-nesters that have larger home ranges.

We theorized that if snags are adequately distributed on a landscape, we should find a hard snag present within nearly every 10-acre (4-ha) circular area. To test our theory, we used snag data collected from three old-growth strata in the central Oregon Cascade Range (Bate 1995). Then we approximated the diameter of an area of this size by joining

two Segments (656 feet [200 m]) together. The diameter of a 10-acre (4-ha) circle is 738 feet (225 m). Combined with a 66-foot (20-m) width we were sampling about 10 percent of a 10-acre (4-ha) area. In the two old-growth stands of Douglas-fir/western hemlock forests, target snags (>18 inch [46 cm] d.b.h., >20 foot [6 m] height, decay classes I-III [Cline and others 1980]) were present in an average of 88 percent of these two Segment66(20) plots joined together. On a landscape with old-growth ponderosa pine forest present, we found that 90 percent of these double Segment66(20) plots had a target snag (>10 inch [25 cm] d.b.h., >6-foot [1.8-m] height, decay classes I-III [Cline and others 1980]) present. When all decay classes were included, the proportion increased to nearly 100 percent in both forest types. We then used these results as the baseline from which the proportions from smaller plot sizes were adjusted.

We wanted to conduct the distribution analyses by using the narrowest plot size (33 feet [10 m]) so that a distribution index could be calculated regardless of the optimal plot size selected for density analyses. We also wanted to avoid having to collect informa- tion with plots 656 feet (200 m) in length. To do this, we looked at the relation between the proportion of larger plots with a snag present compared to the proportion of the smaller plots with a snag present (1 minus proportion of plots with snags absent). We then used a fractal dimension to adjust for the change in the proportions because of the change in the scale (Milne 1991). The proportions found in each of the plot sizes are related by:

$$P_{abs} = p^n \quad ,$$ (15)

where

P_{abs} = proportion of larger plots with snag or tree absent,
p = proportion of smaller plots with snag or tree absent, and
n = fractal dimension.

Next, we calculated the value "$1 - p$" (proportion of plots with a target snag present) by using the old-growth sites described above. We used this as a baseline value. Then we divided the proportion of smaller plot sizes supporting a target snag for sites in various conditions: lightly, moderately, and intensively harvested. This gave us what we termed the Distribution Index. We found that old-growth areas had an index of 1.00 or greater. This translated into about 90 percent of the larger plot sizes supporting a hard target snag. In contrast, intensively harvested areas, where large areas were devoid of snags, had a Distribution Index of 0.40 or less. Given that woodpeckers are territorial, we questioned the level at which these areas could support breeding popula- tions of woodpeckers. Realize that the Distribution Index for both hard and soft snags would be higher.

The need for a Distribution Index became apparent after a study done on a subwater- shed in the Willamette National Forest found that only about 28 percent of the land- scape supported any qualifying snags (Bate 1995). This subwatershed had a stratified Distribution Index of 0.39. Although clearcut and second-growth areas did have some

large, soft remnant snags and smaller diameter hard snags, most snags that met the target criteria were encountered only in the remaining old-growth forest. In a situation like this, the stratified snag density becomes irrelevant because of the poor distribution of snags.

Tutorials

Example I: Density and Distribution Analysis for Single-Stratum Landscape

Background information—You are the manager of a stand of old-growth ponderosa pine located on the east side of the central Oregon Cascade Range. The entire old-growth area comprises 900 acres (364 ha). You need to estimate the density of hard snags to determine whether the area meets the targeted densities listed in the Forest plan. Only hard snags (decay classes I-III [Cline and others 1980]) that are ≥10 inch (25 cm) d.b.h. and ≥6 feet (1.8 m) tall qualify. You are also interested, however, in determining the density of soft snags in this same size class to provide baseline data for resource specialists in adjacent areas. They are interested in mimicking old-growth characteristics in this region. You therefore plan on sampling all decay classes but with hard snags as the primary objective. In addition, you want to assess how evenly qualifying hard snags are distributed across the landscape. Finally, you would like to obtain some information on the percentage of snags that are used for nesting.

Stratification—To start the snag surveying project you use aerial photographs and stand maps to determine whether any apparent strata can be delineated. The area appears patchy in regards to the seral stage because of management actions; some areas have undergone controlled burns, whereas others have not. You think therefore that this may mean very different snag densities. A more thorough ground check, however, reveals a relatively homogeneous forest in regard to snag densities based on 1-acre (0.4-ha) ocular estimates. Consequently, the area was not stratified. Visibility averages about 49 feet (15 m), and the area is flat and easy to traverse.

Pilot survey—Five transects were established within the area. Placement was determined by randomly placing a grid over a map and then randomly selecting five grid intersection points for the starting point of each transect. The compass direction was then also chosen randomly. Each transect was delineated into two segments or four subsegments. Two consecutive subsegments constitute one segment. A hip-chain was used to delineate each 164-foot (50-m) subsegment plot.

Field forms were created by using the macro **Dataform** (fig. 1) to record all information gathered in the field. (See "Field Forms" under "General Surveying Procedures" for complete details.) To explain to observers what information was required under each field heading, you customized the file called Append2.doc. This file contains the basic field descriptions and the numeric codes for each habitat variable.

Once in the field, all qualifying snags within each subsegment were counted out to 66 feet (20 m) from the center line. Snags were measured to their midpoints. The d.b.h. and height of each snag were measured. Diameters were measured in inches (cm) and heights in feet (m). In addition, for each snag encountered, you recorded the perpendicular distance of the midpoint of the snag in feet (m) away from the center line, the numeric code for species, its decay class (Cline and others 1980), and the numeric code to indicate evidence of nesting or foraging.

Data entry—To enter your own data, you open the file Estimate.xls (Estimatm.xls) and go to Sheet1. For this example, however, the data are already entered and can be found in the file Single.xls (Singlem.xls). Open this file in the spreadsheet program Excel for Windows, Version 5.0. On Sheet 1 you will find the data from the pilot survey described above. Twenty subsegments, nested within 10 segments, of data have been entered. Note that the data have been entered into the spreadsheet following the same format provided on the field form and are always entered on Sheet 1 (fig. 1). If these were your own data, you would need to run the macro **Consecutive** before beginning computer analyses. For this example, it is not necessary. Please refer to the "Computer Analysis" section for information on this macro.

You now want to run the analyses to determine which of the eight available plot sizes minimizes your sampling effort for snags that meet the target criteria. However, you have two objectives: (1) hard snag density and (2) the density for snags in all decay classes. First, run the analysis on qualifying hard snags. The first step is to run the **Formula** macros.

Formula entry—The first step in the computer analysis is to place the appropriate formulas within each of the Width columns. This is done by the macro **Formmulti** using the distances you recorded in the field. To activate the macro, (1) click on Macro from the Tools menu, (2) highlight **Formmulti**, and (3) press Run.

To create the correct formula for each of the Width columns follow these steps: (1) When an input box appears with the message, "Please enter the minimum d.b.h. you want to consider for this analysis," enter the number 10 (25). This is because target snags are ≥10 inch (25 cm) d.b.h. For the metric version, the correct entry is in the parentheses: (2) Then press the OK button when a message box appears to confirm that this is the correct value; (3) When the height input box appears, enter 6 (1.8) to specify that only snags with heights ≥6 feet (1.8 m) tall should be considered; (4) Press OK after the message box appears to confirm your entry; (5) For the Class input box, enter "3." This is based on the decay class descriptions of Cline and others (1980), where hard snags were those in the Decay Classes I-III; and (6) Finally, when the macro asks if you want to exclude any species from the analysis, enter "9999" to specify that you want all species of snags to be considered in the analysis.

To have these formulas entered throughout the Width columns, (1) enter E2:E50 for the range of the Width33(10) column. Use the scroll bar on the right side of the screen to determine the last cell row in the Width33(10) column; then (2) enter F2:F50, G2:G50, and H2:H50 for the ranges of the Width66(20), Width99(30), and Width132(40) columns, respectively; and (3) check to ensure that each row in the width columns contains either a "0" or a "1."

Analyzing by segment for single stratum—The next step is to calculate averages and standard deviations for each plot size. The macro **Segment** will do part of this; first, it will sum the total number of qualifying snags within the segment plot sizes that are

328 feet (100 m) in length. To obtain these statistics, follow these steps: (1) select Macro from the Tools menu; (2) highlight the **Segment** macro; (3) press Run. You will see the macro create rows of Totals. Excel refers to these as Subtotals; for clarity, we also refer to these as Subtotal rows. Then the spreadsheet is condensed so that only the Subtotals are shown.

The next step is to move only the visible Subtotals rows to a new area for analysis. Otherwise, the macro will calculate averages and standard deviations on both the individual data rows and the Subtotal rows. To transfer these Subtotal rows, (1) enter C1:H60, when an input box appears with the message "Please enter the range which includes the Segment and Width columns, but excludes the Grand Total row (C1:H?)." If the input box interferes with the range determination, just click on the title bar Copy Range and drag it out of the way. Then use the scroll bar to determine the range. Do not use the mouse because it will include absolute range symbols in the value, which will cause the macro to abort. Refer to the directions given below to restore the sheet back to its original format if an error occurs. (2) Then a message box will appear to verify that the range you entered is correct; click OK, and then Yes if the range is accurate. If not, click No and a second input box will appear for the correct range; and (3) enter the cell range C64 for the input box labeled Paste Range. The table of results should always be at least three rows below the newly pasted data.

The next steps will build the table of SEGMENT Results and place it below the newly pasted data. To do this, (1) enter the cell range E65:E74 when asked for the "range of the newly pasted Width33(10) column"; (2) direct the macro to place the table at the cell range E77 by entering this value into the input box labeled Segment Results. Here is where the macro will insert the averages, standard deviations, and sample size into a table for the various widths of the segment plots; and (3) enter the ranges of the newly pasted Width66(20), Width99(30), and Width132(40) columns. The correct ranges for this sample data set are F65:F74, G65:G74, and H65:H74, respectively. After the ranges have been entered a message box will appear with each value you have given. Click OK or enter to proceed.

Finally, the macro presents you with another input box: "Do you want to switch to the Optimal sheet to see your results? Please record your current results for use in further analyses. Remember, to analyze by Subsegment, you must first restore the data set to its original format." Click on No. This will keep you on Sheet 1. Now scroll down below the newly pasted Subtotals. There you will find a table with the segment averages, standard deviations, and number of samples for this data set (table 2). The row labeled Segment33(10) gives you the average snag density and standard deviation for plots that are 328 feet (100 m) long by 33 feet (10 m) wide. Segment66(20), Segment99(30), and Segment132(40) rows refer to plots that are also 328 feet (100 m) long, but either 66 feet (20 m), 99 feet (30 m), or 132 feet (40 m) wide, respectively. These results are based on the pilot sample of 20 samples. The "N" is "10," however, because the macro lumped two consecutive subsegments together to determine whether longer plots would be more efficient than shorter (164-feet [50-m]) plots. The averages and standard

Table 2—Segment plot statistics[a]

Plot dimensions	Average	Standard deviation
Segment33(10)	0.8	0.789
Segment66(20)	1.8	1.874
Segment99(30)	2.4	3.098
Segment132(40)	2.8	3.615
N	10	

[a] Averages and standard deviations for each segment plot size, along with total sample size, using the Single.xls (Singlem.xls) data set. Values calculated by the macro **Segment**. Analysis for hard snags from old-growth ponderosa pine landscape.

deviations from this analysis also will be placed in the appropriate cells on the Optimal sheet for analysis. You may want to print these results for your own records. To print the results, (1) highlight the range with the mouse by clicking and dragging; (2) select Print from the File menu; and (3) Choose Selection. Also note that the "N" is not recorded elsewhere.

After recording or printing the results of this analysis, you need to restore Sheet 1 back to its original format so that you can run an analysis based on Subsegment plots. To restore the sheet to its original format, (1) select all rows containing data beneath the Grand Total row, (2) select Delete from the Edit menu, (3) press on Entire Row, (4) activate the cell with the field name SEGMENT, (5) choose Subtotals from the Data menu, and (6) select Remove All. This will return the data set to its original format. If the macro ever stops because of a cell range entered incorrectly, you will receive an error message box. Click End within the message box and proceed with the steps listed above to restore the sheet to its original format.

Analyzing by subsegment for single stratum—The next step is to estimate the averages and standard deviations for the subsegment plot sizes that are 164 feet (50 m) long. Refer to the directions given above to restore the sheet to its original format, if Subtotals or results remain from any other analyses. To start the **Subsegment** macro, (1) select Macro from the Tools menu, (2) highlight **Subsegment**, and (3) press Run. Similar to the **Segment** macro, the macro will first sum the number of qualifying snags in each plot and then present these results in condensed Subtotal rows.

The next steps involve transferring the Subtotals to a new area for analysis. Enter D1:H70 into the input box titled Copy Range. A message box will appear with this range value. If correct, click on Yes. If not, click No and a second input box requesting the same range will appear and you can enter it correctly this time. Enter D73 into the input box titled Paste Range. This is where the Subtotals will be pasted.

To have the macro create the Subsegment statistics table, (1) enter E74:E93 into the input box labeled Width33(10) Statistics; (2) enter the value E96 into the input box titled SUBSEGMENT Results. The Subsegment Statistics table will be placed here; and (3) enter the ranges of each of the newly pasted Width66(20), Width99(30), and Width132(40) columns when you are prompted. The correct entries for these input boxes are F74:F93, G74:G93, and H74:H93, respectively.

Finally, the macro will bring up an input box with "Do you want to switch to the Optimal sheet to see your results? Please record your current results for use in further analyses. Remember, to analyze by Segment you must first restore the data set to its original format." Choose Yes. This will transfer you to the Optimal sheet. On Sheet 1 below the newly pasted data, however, you will still find a table of Subsegment results. Table 3 shows the correct averages and standard deviations for each of the 164-foot (50-m) subsegment plots. For example, Subsegment33(10) refers to a plot that is 164 feet (50 m) long by 33 feet (10 m) and its estimated average and standard deviation for the 20 pilot samples. In addition, the table gives you "N" which is the number of subsegments for this data set.

Table 3—Subsegment plot statistics[a]

Plot dimensions	Average	Standard deviation
Subsegment33(10)	0.4	0.681
Subsegment66(20)	.9	1.21
Subsegment99(30)	1.2	1.795
Subsegment132(40)	1.4	2.01
N	20	

[a] Averages and standard deviations for each subsegment plot size, along with total sample size, using the Single.xls (Singlem.xls) data set. Values calculated by the macro **Subsegment**. Analysis for hard snags from old-growth ponderosa pine landscape.

Optimal plot size—The next step is to determine which plot size optimizes sampling in the current forest conditions. This is done on the Optimal sheet. (If you chose not to be transferred to the Optimal sheet after running the Subsegment analysis, you can switch to it now by clicking on the Optimal tab in the lower left hand corner of the screen.) The shaded boxes on this sheet are those requiring input from you. First, write a brief description of the study area in the shaded box labeled Stratum. For example, for this analysis you might write:

"Stratum: Old-growth P.Pine; ≥10 in (25 cm) d.b.h.; ≥6 ft (1.8 m) tall; Hard snags."

Then look under the column heading Mean Density (no. per plot). Here you will find the estimated average for each of the eight plot sizes. These values were automatically transferred when you ran the Segment and Subsegment macros. Similarly, you will find the appropriate standard deviation values under the column heading Standard Deviation (no. per plot). Table 4 shows the correct entries and resulting calculations.

In the first section of the Optimal sheet, you will find that the Mean Density (no. per plot) has been converted to the number of snags per acre (ha) under the column heading Mean Density (no. per acre [no. per ha]). Similarly, the standard deviation of each plot has been squared to get the variance, and then converted to the no. per acre (no. per ha) under the Variance column. Then, beneath the Variance column you will find a value with the label Lowest Variance = 10.08 (62.22). The Optimal spreadsheet uses the lowest variance calculated among the eight plot sizes as the divisor for all the variances. These values are used to calculate the relative variances; they are then used to fill the Relative Variance column. The next two columns of this section, Sample Size (plots), Sample Size (acres [ha]), calculate the total number of plots and acres (ha), respectively, needed to obtain a density estimate that is within 20 percent of the true mean 90 percent of the time. Finally, the last column, Number of Acres (ha) Required, gives the minimum number of acres (ha) required for sampling (table 4). This value includes the pilot sample data. This is based on the value entered into the cell labeled "Minimum Sample Size Required." For a single stratum landscape, a minimum of 60 samples are required. For landscapes with two or more strata, the minimum sample size within each stratum is 20. See the "Establishing Transects" section for exceptions to the minimum number of samples required. For this data set, enter "60" into the box labeled "Minimum Sample Size Required" in the upper left corner of the sheet.

To select the optimal plot size, first look at the number of plots required for each plot size. Which plot sizes require the smallest number of samples? Then consider the plot size in terms of area (acres or ha). Segment33(10) plots require both the lowest number of plots (68) and acres (17) to be sampled. (For the metric version, 6.8 ha are required.) It is important, however, to remember that a minimum of 60 samples are required for these methods regardless of the plot size used.

Table 4—Optimal plot size analysis for hard snags in single-stratum ponderosa pine landscape[a]

Plot dimensions	Plot size	Mean density	Standard deviation	Mean density	Variance	Relative variance(RV)=	Sample Size	Sample Size	Number required
	Feet² (m²)	---- No./plot ----		-- No./acre (no./ha)--			No. of plots	---- Acres (ha) ----	
Subsegment33(10)	5,412 (500)	0.4	0.681	3.22 (8)	30 (185.3)	2.98	202	25 (10.1)	7.4 (3)
Subsegment66(20)	10,824 (1000)	.9	1.21	3.62 (9)	23.7 (146.3)	2.35	126	31 (12.6)	14.8 (6)
Subsegment99(30)	16,236 (1500)	1.2	1.795	3.22 (8)	23.2 (143.2)	2.3	156	58 (23.4)	22.2 (9)
Subsegment132(40)	21,648 (2000)	1.4	2.01	2.82 (7)	16.4 (101.1)	1.62	144	71 (28.8)	29.6 (12)
Segment33(10)	10,824 (1000)	.8	.789	3.22 (8)	10.1 (62.2)	1	68	17 (6.8)	14.8 (6)
Segment66(20)	21,648 (2000)	1.8	1.874	3.62 (9)	14.2 (87.8)	1.41	76	38 (15.1)	29.6 (12)
Segment99(30)	32,472 (3000)	2.4	3.098	3.22 (8)	17.3 (106.7)	1.71	116	87 (34.9)	44.5 (18)
Segment132(4)	43,296 (4000)	2.8	3.615	2.82 (7)	13.2 (81.7)	1.31	116	115 (46.5)	59.3 (24)
				Lowest variance	10.08 (62.22)				

Plot dimensions	Plot size	Relative variance	Fixed cost	Cost per sample	Total cost per plot unit	Relative cost	Product	Total cost
	Feet² (m²)			------- Dollars -------				Dollars
Subsegment33(10)	5,412 (500)	2.98	1.06	.64	1.7	1.00	2.98	343
Subsegment66(20)	10,824 (1000)	2.35	1.06	.77	1.8	1.08	2.53	230
Subsegment99(30)	16,236 (1500)	2.3	1.06	1.15	2.2	1.30	2.99	345
Subsegment132(40)	21,648 (2000)	1.62	1.06	1.66	2.7	1.60	2.6	391
Segment33(10)	10,824 (1000)	1	2.11	1.28	3.4	1.99	1.99	230
Segment66(20)	21,648 (2000)	1.41	2.11	1.54	3.7	2.15	3.03	276
Segment99(30)	32,472 (3000)	1.71	2.11	2.30	4.4	2.59	4.45	512
Segment132(40)	43,296 (4000)	1.31	2.11	3.32	5.4	3.19	4.19	631
				Lowest total cost	1.70			

[a] Cost estimates taken from the General Cost per Sample Guidelines. A minimum of 60 samples is required.

This is where consideration of a cost factor can aid the decisionmaking process. On the Optimal sheet are six estimated costs for conducting surveys. These are listed under the General Cost per Sample Guidelines lower on the Optimal sheet. (See "Estimating Costs" in the "Computer Analysis" section for additional details). We decided that the survey area could be easily walked, but visibility averaged 49 feet (15 m). This puts us in a moderate situation because of the visibility restrictions. Two density options are provided. Select the low density because our means appear to be closer to two snags per acre (0.8 snags per ha) then to eight snags per acre (3.2 snags per ha). Now, copy the column values under Moderate; Low Density. Then paste these values into the column titled Cost per Sample in the row above. Table 4 demonstrates the results when these values have been entered correctly. Refer to appendix 4 for Copy and Paste instructions.

The spreadsheet then calculates a relative cost for each of the eight plot sizes by dividing the cost for each plot size by the lowest cost among them, which is 1.70. Then, following Wiegert's method (1962), we multiply the relative variance by the relative cost. The plot size that minimizes the product of these two factors is considered to be the optimal plot size. Once again, Segment33(10) plots appear to be Optimal because they have the lowest relative variance and relative cost product (1.99). Now, however, look at the column labeled Total Cost. This column calculates the cost based on the minimum number of samples required; this is the lowest of either the recommended number of samples (Sample Size [plots]), or the cost to meet the minimum sample size requirement of "60." The spreadsheet bases the cost on the lowest of these two values. For Segment33(10) plots, you could expect to spend about $230. If Subsegment66(20) plots were used, however, the estimated total cost also is $230. Subsequently, it is not clear which of these two plots would be optimal. We are also interested in snags of all decay classes, however, and running the optimal plot analysis on both hard and soft snags may aid in the decisionmaking process.

To run the analysis for snags in all decay classes, first return to Sheet 1. If necessary, restore the data sheet to its original format by following the instructions given above in the "Analyzing by Segment" section. Then you will need to rerun the **Formmulti** macro. Refer to the "Formula" section above and enter everything exactly the same with the exception of the decay class. When the input box asking for the maximum decay class to consider appears, enter "5" instead of "3" this time. This will include both hard and soft snags in the analysis. Then rerun the **Segment** and **Subsegment** macros exactly as you did above. Make copies of both results' tables and then transfer over to the Optimal sheet. Then copy and paste the values under the Moderate; High Density column in the General Cost per Sample Guidelines into the Cost per Sample column. Use the High Density column this time. This high density choice will help to compensate for additional time spent sampling because of more snags encountered. Table 5 shows the results for both hard and soft snags.

In the analysis for both hard and soft snags, Segment33(10) plots again seem to be the best choice in regards to the number of plots required for sampling. They require the lowest sample size in plots (19) and in acres (5). (For the metric version, 1.9 ha are required.) If this was one of multiple strata, this plot size would be the best. This is best demonstrated by entering "20" in the box labeled Minimum Sample Size Required to simulate this as one of three strata within a landscape, instead of a single stratum.

Table 5—Optimal plot size analysis for both hard and soft snags in single stratum ponderosa pine landscape[a]

Plot dimensions	Plot size	Mean density	Standard deviation	Mean density	Variance	Relative variance(RV)=	Sample size	Sample size	Number required
	Feet² (m²)	--- No./plot ---		--- No./acre (no./ha)---			Plots	---Acres (ha) ---	
Subsegment33(10)	5,412 (500)	0.6	0.754	4.83 (12)	36.8 (227.4)	5.68	110	14 (5.5)	7.4 (3)
Subsegment66(20)	10,824 (1000)	1.4	1.188	5.63 (14)	22.8 (141.1)	3.53	50	12 (5)	14.8 (6)
Subsegment99(30)	16,236 (1500)	1.85	1.814	4.96 (12.33)	23.7 (146.3)	3.66	67	25 (10.1)	22.2 (9)
Subsegment132(40)	21,648 (2000)	2.25	2.124	4.53 (11.25)	18.3 (112.8)	2.82	62	31 (12.4)	29.6 (12)
Segment33(10)	10,824 (1000)	1.2	.632	4.83 (12)	6.5 (40)	1	19	5 (1.9)	14.8 (6)
Segment66(20)	21,648 (2000)	2.8	1.549	5.63 (14)	9.7 (60)	1.5	21	11 (4.3)	29.6 (12)
Segment99(30)	32,472 (3000)	3.7	2.791	4.96 (12.33)	14 (86.5)	2.16	40	30 (11.9)	44.5 (18)
Segment132(40)	43,296 (4000)	4.5	3.274	4.53 (11.25)	10.9 (67)	1.68	37	37 (14.8)	59.3 (24)
				Lowest variance	6.48 (40)				

Plot dimensions	Plot size	Relative variance	Fixed cost	Cost per sample	Total cost per plot unit	Relative cost	Product	Total cost
	Feet² (m²)		-------- Dollars --------					Dollars
Subsegment33(10)	5,412 (500)	5.68	1.06	0.85	1.9	1.00	5.68	210
Subsegment66(20)	10,824 (1000)	3.53	1.06	1.36	2.4	1.27	4.47	145
Subsegment99(30)	16,236 (1500)	3.66	1.06	2.30	3.4	1.76	6.43	225
Subsegment132(40)	21,648 (2000)	2.82	1.06	3.19	4.3	2.23	6.28	264
Segment33(10)	10,824 (1000)	1	2.11	1.70	3.8	1.99	1.99	229
Segment66(20)	21,648 (2000)	1.5	2.11	2.72	4.8	2.53	3.79	290
Segment99(30)	32472 (3000)	2.16	2.11	4.60	6.7	3.51	7.6	403
Segment132(40)	43296 (4000)	1.68	2.11	6.38	8.5	4.45	7.45	509
			Lowest total cost	1.91				

[a] Cost estimates taken from the General Cost per Sample Guidelines. A minimum of 60 samples are required.

Nevertheless, a minimum of 60 samples is recommended to ensure that the assumptions of normality are met and the variability of the study area is adequately represented. In situations like these, therefore, it is important to consider alternative plot sizes that may require less sampling effort. Examine the Total Cost column to see that this time Subsegment66(20) plots seem to be the optimal plot size because they are the least expensive ($145). This result corroborates the results of the optimal plot analysis for hard snags alone, which found that either Subsegment66(20) or Segment33(10) plots would be optimal based on the estimated Total Cost. Consequently, Subsegment66(20) plots seem to be the best plot size for sampling snags in this area; we will use this plot size for the remainder of our analyses.

Density analysis—Now switch to the spreadsheet Densities by clicking on the tab with this label in the Single.xls (Singlem.xls) file. Here a density estimate is calculated. Begin with hard snags. Again, the shaded boxes are those that require input from you. Leave the t-value at 1.67 even though this is the value that provides a 90 percent confidence level with 60 samples. Next enter 900 acres (364 ha) into the box labeled Landscape Area. To obtain a density estimate and its bound, use the "Simple Random Sampling Equation" section. Enter Subsegment66(20) in the gray box under the column heading Plot Dimensions (name). The spreadsheet will then give you "10824" under Plot Size (feet^2). (For the metric version, under Plot Size (meters^2) you will get "1000.") This will then convert the Plot Size into "Plot Area (acres [ha])." Then input the estimated average density and standard deviation in snags per plot into the appropriate locations: "0.9 and 1.21" snags per plot, respectively. Finally, enter the number 20 into the shaded box under the column heading "Sample Size." The results are shown immediately below your entered values (fig. 5).

Landscape area in acres (ha)=	900 (364)						
Plot dimensions (name)	Plot size in feet^2 (m^2)	Plot area in acres (ha)	Average density (No./plot)	Standard deviation (No./plot)	Average (No./acre [ha])	Variance in (No./acre [ha])	Sample size (n)
Subsegment66(20)	10,824 (1000)	0.25 (0.10)	0.9	1.21	3.62 (9)	23.71 (146.41)	20

$$\mathbf{X} \text{ in acres (ha)} = 3.62 \quad {}^{(9)}$$
$$\text{Bound} = 1.81 \quad (4.51)$$
$$\text{Upper limit} = 5.44 \quad (13.51)$$
$$\text{Lower limit} = 1.81 \quad (4.49)$$
$$\text{Current level of precision (\%)} = 50$$

Figure 5—Density sheet. Estimated density results for single-stratum ponderosa pine landscape by using optimal plot size: Subsegment66(20) plots. Results for qualifying hard snags in the Single.xls (Singlem.xls) data set.

The landscape supports 3.62 $\pm$ 1.81 hard snags per acre (9.00 $\pm$ 4.51 hard snags per ha). To determine the precision of your estimate, the bound is divided by the mean. For this example, the bound 1.81 is divided by the mean of 3.62 and the result is 50. This says that you are 90 percent confident that your density estimate is within 50 percent of the true mean. After obtaining the density results for hard snags, enter the average and standard deviation of the Subsegment66(20) plots for both hard and soft snags. These values are "1.4" and "1.188," respectively. This results in a density estimate of 5.63 $\pm$ 1.78 snags per acre (14 $\pm$ 4.42 snags per ha).

Distribution analysis—The final objective for this snag survey is to determine whether hard snags are adequately distributed to meet the needs of territorial cavity-nesters. The Distribution spreadsheet bases its calculations on the percentage of the sampled landscape with at least one qualifying snag present. The presence or absence of a qualifying snag is evaluated on plots that are a subsample of an area about 10 acres (4 ha) in size. Details about this index are given in the "Computer Analysis" section under "Distribution Analysis."

To begin (1) switch to Sheet 1; (2) make sure the data set is in its original state by deleting any results from the **Segment** or **Subsegment** macros and removing all Subtotals following the instructions given above; (3) click on the width columns to ensure that the formulas within these cells are for hard snags only (e.g., within the formula you should find K<=3). If not, rerun the **Formmulti** so that only snags with the maximum decay class III are counted following the instructions given above in the Formula section; (4) then choose Macro from the Tools menu; (5) select **Pres_Abs**; and (6) click on Run.

Once the macro begins, (1) Enter: C1:E60 into the first input box labeled Copy Range. (2) Press OK when the message box appears with this cell range. (3) For the next input box, labeled Paste Range, enter the cell range C64. This will place the Subtotals below the condensed rows. Then the macro will count how many segments were counted with at least one qualifying hard snag present. (4) Another input box labeled Width33(10) Range will come to the screen requesting the range of the newly pasted Width33(10) column. Enter E65:E74. (5) Then you will notice that two additional column headings are added to the right of the Width33(10) column. These are the Present and Count fields. They should have the values "6" and "10," respectively. Record these values to enter onto the Distribution Index sheet.

Now bring up the Distribution Index sheet by clicking on the tab with this title. If this sheet is not readily visible, use the right arrow keys at bottom left until it appears. Enter the values for the Present and the Count shaded boxes (6 and 10, respectively). Once adjusted, the Distribution Index for this example is 1.37 (table 6). Values of 1.00 or greater reflect a hard snag distribution similar to that found in old-growth forested areas. This index value suggests, therefore, that the distribution of snags in this area is adequate to meet the needs of territorial cavity-nesters.

Table 6—Distribution spreadsheet: the distribution index for qualifying snags for the single-stratum ponderosa pine landscape[a]

Present	Count(N)	Proportion of with snag/tree	Proportion of plots with snag/tree present (adjusted)
6	10	0.6	1.37
Distribution Index	DI =	1.37	

[a] Data from the Single.xls (Singlem.xls) file. Distribution Index values of 1.00 or greater reflect a snag distribution similar to that found in old-growth forested areas.

Cavity analysis—To conduct cavity analyses, first return to Sheet 1 and restore the data set to its original format by removing all results below the Grand Total row and the Subtotals. Refer to directions given in the "Analyzing by Segment" section above for complete details. The data in the Single.xls (Singlem.xls) file have been given codes for cavity and forage use based on definitions described in appendix 2 (note: the cavity and forage data have been created for demonstration purposes). To create the correct formula to determine the percentage of snags sampled that have been used for nesting (either recently or in the past), (1) select Cavity from the Tools menu under Macro; (2) then select Run; (3) enter 10 inches (25 cm) when an input box appears asking for the minimum d.b.h. to consider for the analysis; (4) then enter 6 feet (1.8 m) when asked for the minimum height; (5) for the maximum decay or structural class, enter "5"—this will evaluate snags in all decay classes; (6) then when prompted for any species to exclude enter "9999"—this will allow all species of snags to be included in the analysis; and (7) finally, you will be asked for a cavity code: enter "1," the code for any snag with a new cavity (see appendix 2).

After building the correct formula, complete the following steps: (1) enter P2:P50 when asked for the range of the Qualifying column; (2) when asked for the range of the Cavity column, enter N2:N50; (3) then enter the range of the Qualifying column again. Enter P2:P50 once more.

Now scroll to the top of the spreadsheet. There you will find three additional column headings: (1) TOTAL, (2) UNKNOWNS, and (3) CAVSIGNS. You should find the values "45," "8," and "4," in these columns, respectively. In addition, just below these field names will be a row labeled Percent Use (Cavity) =. This will divide CAVSIGNS by the (TOTALS-UNKNOWNS) to get the percent use. You should find the value "10.8." This means that 10.8 percent of the snags surveyed showed new signs of nesting.

Now to determine what percentage of the snags show both new and old cavity signs, (1) first activate the cell P2 by clicking on it; (2) press the function key F2 at the top of your keyboard. This allows you to edit the formula within this cell; (3) change the portion of this formula that says N2=1 to N2<=3;

=IF(AND(K2<=16.5, L2>=10, M2>=6, J2<>9999, N2<=3),1,0)   (English version)
=IF(AND(K2<=5, L2>=25, M2>=1.8, J2<>9999, N2<=3),1,0)   (metric version)

(4) then press Enter. This will cause the macro to include snags that have either new or old cavities, or both (codes 1-3); and (5) copy and paste (see the Excel Commands sheet [appendix 4] if necessary) this revised formula in cell P2 throughout the P column under QUALIFYING (P3:P50). Notice that values in both the TOTAL column and in the UNKNOWN column stay the same. The CAVSIGNS column, however, has changed to "14." Now your results should show that about 37.8 percent of the snags surveyed showed some kind of nesting activity, at some point in time.

Conclusions for single stratum—Based on the 20 samples collected thus far, the results are inconclusive as to whether the estimated density of hard snags (3.62 $\pm$ 1.81 snags per acre [9.00 $\pm$ 4.51 snags per ha]) on this landscape meets, or exceeds, the targeted densities (2.2 snags per acre [5.4 snags per ha]) listed in the Forest plan. More sampling is required, therefore, using the optimal plot size selected, Subsegment66(20) plots, before any conclusions about density can be drawn. Results from the distribution analysis suggest that hard snags are distributed evenly enough across the landscape to meet the needs of cavity-nesters, but again are inconclusive until 60 samples have been collected.

Example II: Density and Distribution Analysis for Subwatershed with Multiple Strata

Background information—You are required to conduct a snag survey on one representative subwatershed to determine how effective management actions have been in maintaining the desired snag densities. This is part of the compliance monitoring project taking place forest-wide. The stands are dominated by Douglas-fir/western hemlock forest communities. Because of limited resources, you are mainly interested in determining whether the subwatershed meets the guidelines for hard snags outlined in the Forest plan. In addition, you would like to assess the distribution of the qualifying snags encountered, and judge whether or not this distribution addresses the territorial needs of cavity-nesters.

Subwatershed stratification—Aerial photographs show that the subwatershed is highly fragmented. Information from the Forest's GIS informs you that clearcutting has been the primary method of timber harvesting. In addition, a snag-retention program was initiated only 6 years ago. For a snag to meet the target criteria on this subwatershed, it must have a d.b.h. $\geq$18 inches (46 cm), be $\geq$20 feet (6.1 m) tall, and be in the decay classes I-III (Cline and others 1980). Because of the timber harvesting techniques used within this area, and recent initiation of the snag retention program, you expect snag densities to be low in second-growth and most clearcut stands. In the old-growth stands, you expect to find high densities of target snags.

Based on snag densities alone, you think that two strata may be appropriate: (1) old-growth stands and (2) second-growth and clearcut stands combined. A thorough ground check, however, reveals that although all old-growth stands may be combined into one stratum, lumping the second-growth and clearcut stands would not be ideal. It seems that once the clearcut stands reach a certain age, mobility and visibility away from a center transect line are greatly decreased. You therefore decide to place all clearcut stands that have been harvested in the past 10 years into their own stratum, and to lump all older cut stands into another stratum labeled second growth.

You now have three strata delineated: (1) clearcut, (2) second-growth, and (3) old-growth stands. You use the GIS to print out a map with all stands designated into one of the three strata. These are color coded for quick, easy referencing. In addition, the GIS output gives you the number of acres (ha) within each stand, and within the entire subwatershed.   Strata one, two, and three, have 1,759 acres (712 ha), 1,381 acres (559 ha), and 1,243 acres (503 ha), respectively, for a total of 4,383 acres (1775 ha). You then spend a day in the field, validating that each stand has been placed in the proper stratum.

Pilot survey—The topography of the subwatershed differs from flat benches to steep (>100 percent) slopes. Clearcutting has occurred predominantly on the flat areas. Visibility within the clearcut stratum is unobstructed, travel is easy, and snag densities seem low. You therefore preselect a plot size for sampling within this stratum to meet your objectives. Subsegment132 (40) plots are the best choice to increase the probability of detecting a target snag, while minimizing the amount of sampling effort resulting from the shorter plot size selected.

A preliminary review of the second-growth stands reveals difficult travel conditions and low visibility. In addition, few, if any, target snags are expected because of a zero snag retention policy when these stands were harvested. You therefore also preselect a plot size for use within this stratum. Subsegment66 (20) plots are narrow enough to ensure that any target snags out to 33 feet (10 m) from the center line are detected. Again, the shorter plots will meet the requirement of a minimum sample size more quickly.

By contrast, it is not clear what plot size would be the best choice within the old-growth stratum where snag densities appear highly variable. Visibility averages about 49.5 feet (15 m), and mobility varies from moderate to difficult, because of large volumes of downed woody debris and dense tree and shrub regeneration in places.   Consequently, you will conduct a formal Optimal Plot Size analysis within this stratum.

Five stands within each stratum were randomly selected for the establishment of transects across the subwatershed. Random starting points for each transect were selected by placing a grid over each stand and then randomly selecting a grid intersection for the starting point. The compass direction was also randomly determined. Each transect was then delineated into four subsegment plots for a total of 20 samples within each stratum. As described above in "Example I," two consecutive subsegments make up one segment. A hip-chain was used to measure the 164-foot (50-m) plot lengths and to function as the center line of the plots.

All qualifying snags within each subsegment were counted out to 66 feet (20 m) from the center line in strata 1 and 3, following the methods described in "Example I" of the "Tutorial."   By contrast, target snags were only counted out to 33 feet (10 m) within stratum 2.

Data entry—Data for all strata within this subwatershed were entered onto Sheet 1 of the file named Strate.xls (Stratm.xls). It may be accessed in the spreadsheet program Excel for Windows, Version 5.0. Open this file and you will find that 20 subsegments, nested within 10 segments, of data have been entered for each stratum. There are a total of 60 subsegment samples. (If these were your own data, you would run the macro **Consecutive** before beginning any computer analyses. Please refer to the "Computer Analysis" section for information on this macro.) You now want to run the analyses necessary to determine which of the eight available plot sizes minimizes your sampling effort for snags within each stratum.

Formula entry—As in the single stratum example, the first step in the computer analysis is to fill in the appropriate formulas for each of the Width columns. This is done by the macro **Formmulti**. To activate the macro, (1) find Macro under the Tools menu, (2) highlight **Formmulti**, and (3) press Run.

To create the correct formula for a target snag analysis, (1) enter 18 inches (45 cm) into the DBH input box; (2) press OK to continue; (3) next, enter 20 feet (6.1 m) into the height input box; (4) the next input box will ask for the maximum decay class to consider in the analysis. Enter the number "3." This is based on the decay class descriptions of Cline and others (1980), where hard snags were those in Decay Classes I-III; and (5) enter "9999" into the species input box to specify that you want all snag species considered in the analysis.

Now to paste the correct formula for target snags into the Width columns, enter E2:E116 when asked for range of the Width33(10) column. Use the scroll bar on the right side of the screen to determine the last row in the Width33(10) column. You will be prompted to enter the individual ranges of the Width66(20), Width99(30), and Width132(40) columns. Your entries should be F2:F116, G2:G116, and H2:H116, respectively. The spreadsheet will then enter "1s" and "0s" into each cell within these columns. A "0" is given if the snag within that row fails to meet all of the target qualifications. A "1" is given if the snag meets all the specifications you entered into the **Formmulti** macro above.

Sorting strata—The next step is to sort, and then to separate, the main data set on Sheet 1 into the three individual strata. This is necessary to obtain estimates of the averages and standard deviations for each stratum. To begin, (1) select Macro from the Tools menu; (2) click on Sort; and (3) click on Run. This macro will first sort the data, in ascending order, by stratum number.

The macro will then copy each stratum's data rows onto a separate sheet. Follow these steps to complete this process. First, enter A2:O21 into the input box requesting the "range of Stratum 1." Use the scroll bar to determine the range. As stated above, using the mouse will cause the macro to abort. Then another input box will come up asking for the "range of Stratum 2 (A?:O?)." Enter A22:O41. The next input box will ask Do you need to move another stratum? Click on Yes. Enter A42:O116 into the input box requesting the "range of Stratum 3." Finally, when the message box asking Do you need to move another stratum? appears, press No. Now the data rows for each stratum have been copied and pasted onto three individual sheets within this same file: (1) Stratum1, (2) Stratum2, and (3) Stratum3.

Analyzing by segment and subsegment with multiple strata—When working with multiple strata, it is important to run both the **Segment** and **Subsegment** macros on each stratum to obtain averages and standard deviations before proceeding to the next stratum, unless a plot size was chosen before sampling began. This is necessary because both macros transfer results directly to the "Optimal" sheet on completion. If you switch to a different stratum before running both the **Segment** and **Subsegment** macros on one stratum, you will get mixed results from two different strata. To ensure that the correct values are transferred to the "Optimal," always print out the Segment and Subsegment plot statistics on completion. See tables 7 and 8 for examples of these results.

Table 7—Segment plot statistics[a]

Plot dimensions	Average	Standard deviation
Segment33(10)	0.7	0.675
Segment66(20)	1.6	1.174
Segment99(30)	2.2	1.476
Segment132(40)	2.7	1.889
N	10	

[a] Averages and standard deviations for each plot size in stratum three, along with total sample size, using the Strate.xls (Stratm.xls) data set. Analysis for hard snags from old-growth Douglas-fir/ western hemlock forest subwatershed.

Table 8—Subsegment plot statistics[a]

Plot Dimensions	Average	Standard deviation
Subsegment33(10)	0.35	0.489
Subsegment66(20)	.8	.894
Subsegment99(30)	1.1	1.021
Subsegment132(40)	1.35	1.387
N	20	

[a] Averages and standard deviations for each plot size in stratum three, along with total sample size, using the Strate.xls (Stratm.xls) data set. Analysis for hard snags from old-growth Douglas-fir/ western hemlock forest subwatershed.

Stratum 1 analysis—Using the arrow keys in the bottom left corner of the screen, click several times in the right direction until you see a sheet labeled Stratum1. Click on this tab. Here are the 20 subsegment samples taken during the pilot survey from Stratum 1, composed of the clearcut stands. Scrolling down through the data you will quickly notice that only one qualifying snag was encountered during the pilot survey. You still need to run, however, the **Subsegment** macro to get a snag average and standard deviation for the Subsegment132(40) plot size.

To begin, (1) click on Macro from the Tools menu, (2) select **Subsegment,** and (3) Click on Run. Next, follow these steps for the correct entries into each of the input boxes: (1) For the first input box, Copy Range, enter D1:H41. Press OK when each of the message boxes throughout this section appear with the correct cell addresses for confirmation. (2) Enter D45 into the second input box titled Paste Range. The summed rows will be pasted here. (3) The next input box, Width33(10) Statistics asks for the "range of the newly pasted Width33(10) column." Enter E46:E65. (4) Then, enter E68 into the input box labeled SUBSEGMENT Results. The table of results will be placed here. (5) Three additional input boxes will appear asking for the ranges of the newly pasted Width66(20), Width99(30), and Width132(40) column ranges. Enter F46:F65, G46:G65, and H46:H65, respectively. And (6) finally, a message box labeled "More Analysis" will appear. Click on No. Clicking Yes will transfer you to the Optimal sheet. The Optimal Plot Size analysis, however, is not necessary because we preselected the plot size to use within this stratum.

Now scroll down to find a table with the Subsegment results. Only the Subsegment99(30) and Subsegment132(40) plot sizes have values other than "0." Both of these plot sizes will have 0.05 (snags per plot) for their averages and 0.224 (snags per plot) for their standard deviations. Because the center of the single snag encountered had a distance greater than 33 feet (10 m) from the center line, it did not qualify for the Width33(10) or Width66(20) plot sizes. Therefore, each of these plot sizes have the value 0.0 for both their averages and standard deviations. Print, or record these values for further analysis. To print the results, (1) highlight the range with the mouse, (2) select Print from the File menu, and (3) choose Selection.

If the macro ever stops because a cell range was entered incorrectly, you will see an error message box. Click End within the message box and then proceed with the following steps to restore the sheet to its original format: (1) select all rows containing data beneath the Grand Total row (2) select Delete from the Edit menu (3) click on Entire Row (4) then activate the cell with the field name SUBSEGMENT (5) from the Data menu choose Subtotals; and (6) select Remove all. This will return the data set to its original format.

Stratum 2 analysis—Click on the tab labeled Stratum2; this contains data from the second-growth stratum.   Scroll down through the data set. Note that no target snags were encountered during the pilot survey within this stratum. Subsequently, it is not necessary to run either the **Segment** or **Subsegment** macros for this stratum.

Stratum 3 analysis—Now click on the tab labeled Stratum3 in the lower left corner of the screen. These are the data from the old-growth stratum. Begin your analysis by obtaining averages and standard deviations for each 328-foot (100-m) long Segment plot within this stratum. To begin this process, (1) choose Macro from the Tools menu, (2) click on **Segment**, and (3) highlight Run. After the macro sums and condenses the rows, a series of input boxes will appear. Follow these steps for the correct entries: (1) For the Copy Range input box enter C1:H86. Then the macro double checks to see that you entered the correct range. Click on Yes if correct, otherwise click No and re-enter the range. (2) Then the Paste Range will come up. Enter C90 as the location to paste the data rows. (3) For the Width33(10) Statistics input box, enter E91:E100. (4) For the SEGMENT Results input box, enter the cell range E103. Your table of results will be placed here. (5) Then for the ranges of the Width66(20), Width99(30), and Width132(40) newly pasted columns, enter F91:F100, G91:G100, and H91:H100, respectively. (6) When asked whether you want to switch to the Optimal sheet, click on No. Now scroll down to examine, and record the results (table 7). Follow the directions given above to print your results. You will find that an average of 0.7 snags per plot were found in the Segment33(10) plot size. This is for a plot size 328 by 33 feet (100 by 10 m). The standard deviation was 0.675 snags per plot. Segment66(20), Segment99(30), and Segment132(40) plots each had an average of 1.6, 2.2, and 2.7 snags per plot, respectively. The column to the right of the averages lists the corresponding standard deviation for each plot size (table 7).

The next step in the Stratum 3 analysis is to obtain the averages and standard deviations for each Subsegment plot 164 feet (50 m) in length. To begin this process: (1) Remove any results from the **Segment** macro analysis following the directions given above with the exception of "Step 4." Here you should highlight the field name SEGMENT, rather than SUBSEGMENT. (2) Then select Macro from the Tools menu. (3) Highlight **Subsegment**. And (4) Click on Run.

Follow these steps so that correct cell ranges are entered within each of the input boxes. Enter D1:H96 into the input box labeled Copy Range. When asked by the next input box whether the range you entered was correct, press Yes if it was, No if not. Reenter the correct range if necessary. The Paste Range input box should appear. Enter D100 to have the newly pasted data rows copied here. For the Width33(10) Statistics input box type in E101:E120. Then direct the macro to place the SUBSEGMENT Results table in the cell E123. Next, for the ranges of the newly pasted Width66(20), Width99(30), and Width132(40) columns, enter F101:F120, G101:G120, and H101:H120, respectively. Finally, a More Analysis? input box will appear. Choose No to first print the results from your Subsegment analysis before transferring to the Optimal sheet. Table 8 shows the correct averages and standard deviations for each of the Subsegment plot sizes.

Optimal plot size—For this example, only the old-growth stratum is available for the Optimal plot size analysis because plot sizes were preselected for the clearcut and second-growth strata. To begin the Optimal Plot Size, first transfer to the Optimal sheet

if you have not already. Use the tabs in the lower left corner of the screen to activate the Optimal sheet. The averages and standard deviations for the old-growth stratum for each of the eight plot sizes available should have already been transferred by the Segment and Subsegment macros (table 9).

Now follow these steps to furnish the necessary information to aid in the decisionmaking process: (1) Enter the number "20" into the box labeled Minimum Sample Size Required. You enter "20" because you have three strata and need a minimum of 20 samples within each stratum for stratified landscapes. (2) Next, examine the values in the Mean Density (no. per acre) column. Are they closer to two snags per acre (0.8 snags per ha) or eight snags per acre (3.2 snags per ha)? They are closer to two snags per acre (0.8 snags per ha). Therefore, copy the estimated prices for a difficult, low snag density situation and then paste these into the Cost per Sample column above (table 9). (Note: If both hard and soft snags were included, the density would be high). Select the difficult category because of large amounts of downed woody debris and dense shrub cover in mainly steep areas.

To choose the Optimal plot size, consider these factors: (1) Segment99(30) plots require the lowest number of plots (31) to be sampled, whereas Segment33(10) plots require the smallest amount of acreage (16 acres [6.5 ha]) to be sampled. (2) Now look at the values listed in the Product column. When the relative costs have been multiplied by the relative variances, we find the Segment66(20) plots have the lowest product (3.32) of the eight plot sizes. Therefore, based on Wiegert's (1962) method, this is the optimal plot size to use to sample for snags in this forest stratum. (3) Now look at the column Total Cost. Do the results within this column support what we found in the Product column? Yes, they do. If we use this plot size, we would minimize our costs ($181) to obtain the desired level of precision. In addition, we would not be jeopardizing our accuracy by trying to sample beyond the point of clear visibility from the center line. Segment66(20) plots therefore seem to be the optimal plot size to use within stratum three, and we will use this plot size for the remainder of the analyses.

Stratified density analysis—Your next objective in this process is to obtain an estimate of the required sample size for this subwatershed. To accomplish this, however, we must first have an estimate of the stratified mean density to enter into the Sample Size equation. To obtain the stratified density estimate follow these steps: (1) Click on the tab labeled Densities. (2) Go to the section titled Stratified Random Sampling Equation. (3) Enter the number of strata within the subwatershed in the shaded box labeled Stratum. For this example, there are three strata so enter the numbers 1, 2, and 3. (4) Enter the name of each plot size selected for sampling within each stratum under Plot Dimensions (name). Stratum one used Subsegment132(40) plots, stratum two used Subsegment66(20) plots, and three used Segment66(20) plots. The spreadsheet will then provide the area in square feet (m) under the Plot Size column. This translates into 21,648 feet^2 (2000 m^2) for the Subsegment132(40) and Segment66(20) plots and 10,824 feet^2 (1000 m^2) for the Subsegment66(20) plots, respectively. Notice that the default area here is 5,412 feet^2 (500 m^2). Double-check to ensure that the correct area

Table 9—Optimal spreadsheet[a]

Plot Dimensions	Plot size	Mean density	Standard deviation	Mean density	Variance	Relative variance(RV)=	Sample size	Sample size	Number required
	Feet² (m²)	----No./plot ----		--- No./acre (no./ha) ---			Plots	---- Acres (ha) -----	
Subsegment33(10)	5,412 (500)	0.35	0.489	2.82 (7)	15.5 (95.8)	4.3	136	17 (6.8)	2.2 (0.9)
Subsegment66(20)	10,824 (1000)	.8	.894	3.22 (8)	13 (80)	3.59	87	22 (8.7)	4.4 (1.8)
Subsegment99(30)	16,236 (1500)	1.1	1.021	2.95 (7.33)	7.5 (46.3)	2.08	60	22 (9)	6.7 (2.7)
Subsegment132(40)	21,648 (2000)	1.35	1.387	2.72 (6.75)	7.8 (48.1)	2.16	74	37 (14.7)	8.9 (3.6)
Segment33(10)	10,824 (1000)	0.7	0.675	2.82 (7)	7.4 (45.6)	2.04	65	16 (6.5)	4.4 (1.8)
Segment66(20)	21,648 (2000)	1.6	1.174	3.22 (8)	5.6 (34.4)	1.55	38	19 (7.5)	8.9 (3.6)
Segment99(30)	32,472 (3000)	2.2	1.476	2.95 (7.33)	3.9 (24.2)	1.09	31	23 (9.4)	13.3 (5.4)
Segment132(40)	43,296 (4000)	2.7	1.889	2.72 (6.75)	3.6 (22.3)	1.00	34	34 (13.6)	17.8 (7.2)
				Lowest variance	3.61 (22.29)				

Plot dimensions	Plot size	Relative variance	Fixed cost	Cost per sample	Total cost per plot unit	Relative cost	Product	Total cost
	Feet² (m²)		-------- Dollars --------					Dollars
Subsegment33(10)	5,412 (500)	4.3	1.06	1.19	2.3	1.00	4.3	307
Subsegment66(20)	10,824 (1000)	3.59	1.06	1.36	2.4	1.08	3.86	211
Subsegment99(30)	16,236 (1500)	2.08	1.06	4.59	5.7	2.51	5.22	339
Subsegment132(40)	21,648 (2000)	2.16	1.06	5.78	6.8	3.04	6.56	503
Segment33(10)	10,824 (1000)	2.04	2.11	2.38	4.5	2.00	4.08	291
Segment66(20)	21,648 (2000)	1.55	2.11	2.72	4.8	2.15	3.32	181
Segment99(30)	32,472 (3000)	1.09	2.11	9.18	11.3	5.02	5.45	354
Segment132(40)	43,296(4000)	1.00	2.11	11.56	13.7	6.08	6.08	466
				Lowest total cost =	2.25			

[a] Optimal plot size analysis for hard snags in stratum three of the Douglas-fir/western hemlock forest subwatershed. Data from the Strate.xls (Stratm.xls) file. Cost estimates taken from the Optimal spreadsheet in the General Cost per Sample Guidelines section.

size is being used. Also make sure you use the appropriate Plot Size name depending on if you are using the metric or English spreadsheet. (5) Enter the number of acres (ha) found within each stratum under Stratum Size (acres [ha]). There were 1,759, 1,381, and 1,243 acres (712.1, 559.1, and 503.2 ha, respectively), for strata one, two, and three, respectively. (6) Enter the estimated densities and standard deviations for each plot size within each stratum under Average Density (no. per plot) and Standard Deviation (no. per plot), respectively. For stratum one, enter 0.05 for the average density and 0.224 for the standard deviation. For stratum two, enter 0.00 for both of these values. For stratum three, enter 1.6 and 1.174 for the average and standard deviation, respectively. (7) Finally, enter the number of samples you have for each stratum in the column Sample Size. This should be "20" for strata one and two. You should enter "10" for stratum three. The results from the Densities spreadsheet, shown in figure 6, estimate the average density on this subwatershed to be 0.953 + 0.359 target snags per acres (2.37 + 0.89 snags/ha).

Sample size determination—The next step in the analysis for multiple strata is to obtain an estimate of the required sample size to obtain your desired level of precision. The sample sizes required for stratified subwatersheds are calculated on the sheet labeled "Sample Size." Click on the tab in the lower left of the screen to bring up this spreadsheet. Again, all shaded boxes require values to be entered. Notice that one of the first pieces of information required is an estimate of the stratified mean. This was estimated for you on the spreadsheet labeled Densities (fig. 6). Enter this value (0.953 snags per acre [2.37 snags per ha]) into the Pilot Sample Mean box.

Next, follow these steps to supply the correct information to the sample size spreadsheet: (1) Enter the number of strata you have under Stratum Number. For this example, there are three strata, so enter the numbers 1, 2, and 3. (2) Highlight the box where the number "4" would go if there were four strata and press Delete. This is to ensure that the spreadsheet uses the appropriate sample size equation. (3) Enter the number of acres found within each stratum under Stratum Size (acres [ha]). There were 1,759, 1,381, and 1,243 acres (712.1, 559.1, and 503.2 ha), for strata one, two, and three, respectively. (4) Enter the name of each of the plot sizes selected for sampling within each stratum under Plot Dimensions (name). Stratum one used Subsegment132(40) plots, stratum two used Subsegment66(20) plots, and stratum three used Segment66(20) plots. (5) Finally, enter the estimated average densities and standard deviations for each plot size within each stratum under Average Density (no. per unit) and Standard Deviation (no. per unit). These should be 0.05 and 0.224, 0.00 and 0.00, and 1.6 and 1.174 for strata one, two, and three, respectively.

For the results, scroll to the bottom of the Sample Size page (fig. 7). First, look in the section under the heading Optimal Allocation. This method, which incorporates the stratum variances into its calculations, estimates that only 54 (52) samples will be required to obtain a stratified mean that is within 20 percent of the true mean, 90 percent of the time. These 54 (52) samples are then divided among the three strata. It estimates that only 11 plots are needed in stratum one (clearcuts), none in stratum two (second growth), and 43 (41) are required in stratum three (old growth).

Now look in the section under the heading Proportional Allocation. This method uses the overall variance of the subwatershed and then allocates the samples based on the size of each stratum. Here it is estimated that 128 samples must be taken to obtain the same level of precision. This translates into 51, 40, and 36 plots, of the appropriate size, to be sampled within each stratum.

Stratum	Plot dimensions (names)	Plot size in feet² (m²)	Plot area in acres (ha)	Stratum size acres (ha)	Average density (no. per plot)	Standard deviation (no. per plot)	Average in acres (ha)
1	Subsegment132(40)	21,648 (2000)	0.5 (0.2)	1,759 (712.1)	0.05	0.22	0.1 (0.25)
2	Subsegment66(20)	10,824 (1000)	0.25 (.1)	1,381 (559.1)	0	0	0
3	Segment66(20)	21,648 (2000)	.5 (.2)	1,243 (503.2)	1.6	1.17	3.22 (8)
		5,412 (500)	.12 (.05)		0	0	0

Total acres (ha) = 4,383 (1774.4)

Variance in acres (ha)	Stratum weight	Sample size (n)	Stratified mean equations	Stratified variance equations			
0.2 (1.25)	0.40	20					
0	0.32	20	0.04 (0.1)	0.0020 (0.01)			
5.58 (34.46)	0.28	10	0.996 (2.369)	0.0466 (0.2861)			
0	0		0	0			

Total samples = 50

$$\overline{X}_{st\ in\ Acres\ (ha)} = \quad 0.953 \ (2.37)$$

$$Var_{st} = \quad 0.046 \ (0.29)$$

$$S_e = \quad 0.215 \ (0.53)$$

$$Bound = \quad 0.359 \ (0.89)$$

$$Upper\ limit = \quad 1.313 \ (3.26)$$

$$Lower\ limit = \quad 0.594 \ (1.48)$$

$$Current\ level\ of\ precision\ (\%) = \quad 38$$

Figure 6—Densities spreadsheet. Stratified mean density estimate with a 90 percent confidence interval for qualifying hard snags for the Douglas-fir/western hemlock forest watershed. Data from Strate.xls (Stratm.xls) file.

Pilot					t-values	Confidence level
sample mean X_{st}=		0.953 (2.37)			1.67	90%
in acres (ha)					2	95%
					2.66	99%

Stratum number	Stratum size in acres (ha)	Stratum weight (W_i)	Plot dimensions (name)	Plot size in feet² (m²)	Plot area in acres (ha)	Average density (no./plot)	Standard deviation (no./plot)
1	1,759 (712.1)	0.40	Subsegment132(40)	21,648 (2000)	0.5 (0.2)	0.05	0.22
2	1,381 (559.1)	0.32	Subsegment66(20)	10,824 (1000)	0.25 (0.1)	0	0
3	1,243 (503.2)	0.28	Segment66(20)	21,648 (2000)	0.5 (0.2)	1.6	1.17
		0.00		5,412 (500)	0.12 (.05)		
	4,383 (1774.4)						

Average density (no./acre [ha])	Standard deviation (no./acre [ha])	Variance (no./acre [ha])		Desired absolute variance	t-value	Optimal equations (see below)	Proportional equations (see below)
0.1 (0.25)	0.45 (1.12)	0.2 (1.25)		0.013 (0.0806)	1.67		
0	0	0				2.5	6.3 (6.2)
3.22 (8)	2.36 (5.87)	5.58 (34.46)				54 (51.8)	127.8 (127.5)
0	0	0				0	0

Optimal Allocation			
Total number of samples required	Stratum number	Number of samples per stratum	Sample size (acres [ha])
54 (52)	1	11 (11)	5.7 (2.2)
	2	0	0
	3	43 (41)	21.1 (8.2)
	4	0	0.0

Proportional Allocation			
Total number of samples required	Stratum number	Number of samples per stratum	Sample size (acres [ha])
128	1	51	25.5 (10.2)
	2	40	10 (4)
	3	36	18 (7.2)
	4	0	0.0

Figure 7—Sample Size spreadsheet. Optimal and proportional sample size calculations for sampling hard snags in each of the three strata on the Douglas-fir/western hemlock subwatershed. Data from the Strate.xls (Stratm.xls) file.

You will notice that the two sample size equations are close in agreement about the number of samples to take in stratum three. Within strata one and two, however, there are large discrepancies. The optimal method suggests focusing most of the sampling effort in stratum three (n = 43), which has the largest variance relative to the other strata. The optimal method recommends no samples should be taken in stratum two, whereas the proportional method suggests 40 sample plots.

The results of the optimal allocation method recommending zero samples in stratum two is a problem. Although on subwatersheds where clearcutting has been the primary method of timber harvesting, and target snags within cut stands may be rare or non-existent, it is still necessary to sample stands within these strata. Small values for both the average and standard deviation within this stratum therefore should be entered. For example, enter 0.01 for the average and 0.05 for the standard deviation. Examine figure 8 for the results. Now the optimal method requires four samples within stratum two. We still recommend, however, that a minimum of 20 samples (from a minimum of five stands) be taken within every stratum regardless of the estimated sample size required. In this example, we would recommend not sampling within strata one and two anymore, unless you think that encountering zero snags within these stands for the pilot sample was an inaccurate representation of the conditions within these strata. Rather, focus your sampling effort in stratum three by surveying 10 additional Segment66(20) plots. These would best be distributed among three different stands. After these 10 plots have been sampled, you will have met your minimum sample size requirement of 60. You can then reanalyze the data to determine whether you want to continue sampling to increase the precision of your estimate, or stop sampling because the estimate is precise enough to meet your objectives. It is important to remember that the most any sample size equation can give you is an estimate of the number of samples required. As additional data are collected, entered, and analyzed, therefore, you may find the variances, and consequently the required sample size, changing within a stratum. This possibility increases if the pilot sample data turn out to be a poor representation of the variation within a stratum. Consequently, the best way to avoid oversampling (where large sample sizes are required) is to continually enter your data and periodically calculate a mean density and its bound to determine the current level of precision.
Also, please refer to the discussion of Sample Size Determination in the "Computer Analysis" section for a discussion of the advantages and disadvantages of optimal and proportional allocation methods for determining your sample size.

Compare to target density—Let us now assume that 60 samples have been taken and, therefore, it is possible to test whether the estimated density of qualifying snags meets the targeted density listed in the Forest plan. You already have the bound on the density estimate for the 90 percent confidence interval. See the Densities sheet. This is 0.953 + 0.36 target snags per acre (2.47 $\pm$ 0.90 snags per ha). Now bring up the sheet labeled Statistical Test by clicking on this tab. To conduct the test, follow these steps: (1) Create your null hypothesis: Ho: There is no difference between the estimated and the targeted hard snag densities. (2) Let us assume that the target density for hard snags on this subwatershed is 1.51 snags per acre (3.73 snags per ha). Enter this value into the shaded box labeled Target Density. (3) Enter the estimated snag density of 0.953 snags per acre (2.37 snags per ha) into the shaded box labeled Estimated Density. (4) Enter the estimated bound for a 90 percent confidence interval: 0.36 (0.89). See table 10 for the correct entries.

					t-values	Confidence level	
Pilot							
sample mean	$X_{st}=$	0.953 (2.37)			1.67	90%	
in acres (ha)					2	95%	
					2.66	99%	

Stratum number	Stratum size in acres (ha)	Stratum weight (W_i)	Plot dimensions (name)	Plot size in feet^2 (m^2)	Plot area in acres (ha)	Average density (no./plot)	Standard deviation (no./plot)
1	1,759 (712.1)	0.40	Subsegment132(40)	21,648 (2000)	0.5 (0.2)	0.05	0.22
2	1,381 (559.1)	0.32	Subsegment66(20)	10,824 (1000)	0.25 (0.1)	0.01	0.05
3	1,243 (503.2)	0.28	Segment66(20)	21,648 (2000)	0.5 (0.2)	1.6	1.17
		0.00		5412	0.12 (.05)		
	4,383 (1774.4)						

Average density no./acre (no./ha)	Standard deviation no./acre (no./ha)	Variance no./acre (no./ha)		Desired absolute variance	t-value	Optimal equations (see below)	Proportional equations (see below)
0.1 (0.25)	0.45 (1.12)	0.2 (1.25)		0.013 (0.0806)	1.67		
0.04 (0.1)	0.2 (0.5)	0.04 (0.25)				4.6	7.2
3.22 (8)	2.36 (5.87)	5.58 (34.46)				62.3 (59.7)	128.7 (128.5)
0	0	0				0	0

Optimal Allocation			
Total number of samples required	Stratum number	Number of samples per stratum	Sample size (acres)
62 (60)	1	12	6.1 (2.4)
	2	4	1.1 (.4)
	3	46 (44)	22.7 (8.8)
	4	0	0

Proportional Allocation			
Total number of samples required	Stratum number	Number of samples per stratum	Sample size (acres)
129	1	52	25.7 (10.3)
	2	41 (40)	10.1 (4)
	3	37 (36)	18.1 (7.3)
	4	0	0

Figure 8—Sample Size spreadsheet. Optimal and proportional sample size calculations for sampling hard snags in each of the three strata on the Douglas-fir/western hemlock forest subwatershed. Stratum two average density and standard deviation have been adjusted to compensate for zero snags encountered. Data from the Strate.xls (Stratm.xls) file.
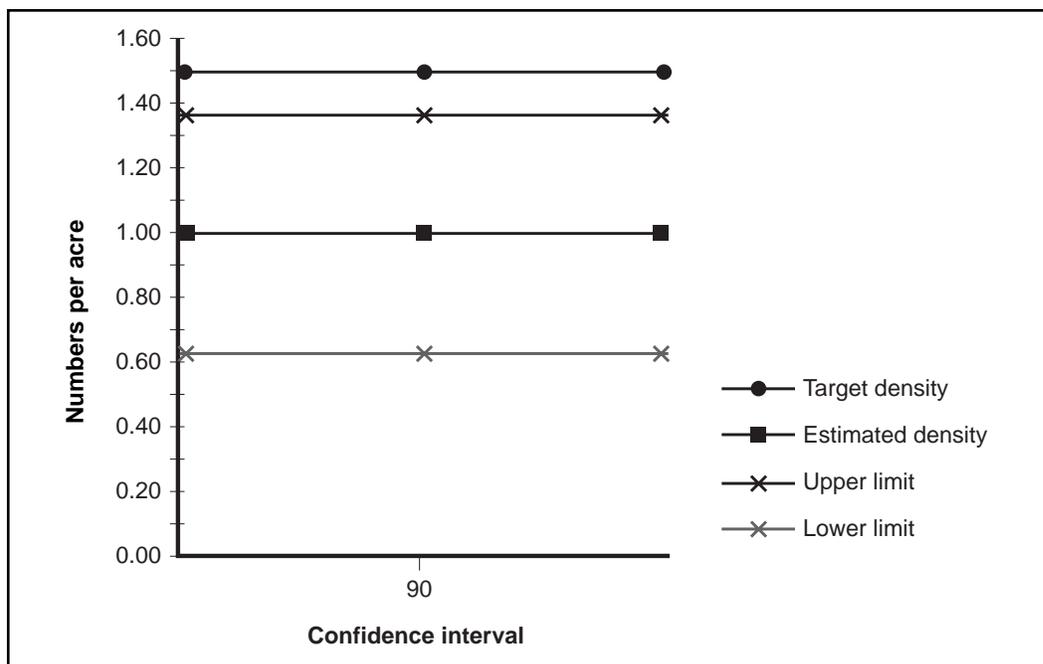
58

Figure 9—Statistical Test spreadsheet. Graph depicting test for significant difference between estimated and targeted densities of qualifying snags on Douglas-fir/western hemlock subwatershed. Input data from table 10.

Table 10—Statistical Test spreadsheet. The target density and the estimated snag density and its bounds for qualifying hard snags for the Douglas-fir/western hemlock forest subwatershed. Data from the Stratify.xls file used to create figure 5.

Percent confidence interval	Target density acre (no./ha)	Estimated density acre (no./ha)	Upper limit	Lower limit	Bound
	1.51 (3.73)	.996 (2.47)	1.356 (3.37)	.636 (1.57)	.36 (.90)
90	1.51 (3.73)	.996 (2.47)	1.356 (3.37)	.636 (1.57)	.36 (.90)
	1.51 (3.73)	.996 (2.47)	1.356 (3.37)	.636 (1.57)	.36 (.90)

Once the necessary information has been entered into the spreadsheet portion of the Statistical Test sheet, a graph depicting the results is automatically created (fig. 9). Looking at the graph, you can see that the line representing the target density for snags does not enter within the upper and lower limits of the estimated density. You can therefore reject the null hypothesis, which states that "there is no difference between the estimated and targeted snag densities." This test suggests that you can be 90-percent confident that the snag density on this subwatershed fails to reach the targeted density. Now you have satisfied the requirements of your first objective: to determine whether or not the subwatershed met the targeted hard snag density. Subsequently, you can decide whether or not to continue sampling to obtain a more precise density estimate.

Stratified distribution analysis—To obtain the necessary information to conduct a distribution assessment for this subwatershed, you will need to run the macro **Pres_Abs** for each stratum with snags present. Details for this index are given in the "Computer Analysis" section under "Distribution Analysis."

Start with stratum one and complete these steps: (1) click on the Stratum1 tab to activate the sheet; (2) remove any subtotals that may be present (for detailed instructions see "Restoring Sheet to Original Format" in appendix 4); (3) once the sheet is returned to its original format, select Macro from the Tools menu; (4) click on **Pres_Abs**; (5) then highlight Run. The macro will sum and condense the data rows for each Segment33(10) plot; (6) then enter C1:E31 into the input box labeled Copy Range; (7) for the Paste Range input box enter C34; (8) enter E35:E44 into the input box labeled Width33(10) Range for the range of the newly pasted Width33(10) column; and (9) record the Present and Count field values to enter onto the Distribution Index sheet. They should have the values "0" and "10," respectively. These fields are added to the right of the Width33(10) column.

Skip the process for stratum two, because no target snags were encountered there. Then repeat the above procedure for stratum three. For example: (1) click on the Stratum3 tab to activate the sheet; (2) remove any subtotals that may be present (for detailed instructions see "Restoring Sheet to Original Format" in appendix 4); (3) once the sheet is returned to its original format, select Macro from the Tools menu; (4) click on **Pres_Abs**; and (5) then highlight Run. The macro will sum and condense the data rows for each Segment33 (10) plot. (6) When asked to enter the Copy Range, enter C1:E86; (7) for the Paste Range enter C89; (8) enter E90:E99 for the newly pasted Width33(10) Range; and (9) record Present and Count field values. They should be "6" and "10," respectively.

Now, to correctly enter the correct values onto the Distribution Index sheet follow these steps: (1) activate the Distribution Index sheet by clicking on the tab with this title; (2) go to Multiple-Strata Distribution Index section; (3) under Stratum enter the numbers 1, 2, and 3 to indicate that there were three strata on this subwatershed; (4) in the cell where the number 4 would go if there were four strata, press Delete; and (5) then enter the number of acres of each stratum under Stratum Size (ac). These were 1,759, 1,381, and 1,243 acres (712.1, 559.1, and 503.2 ha), for strata one, two, and three, respectively. (6) Next, enter the values "0" and "10" for the Present and the Count fields, respectively, for both strata one and two. (7) For stratum three enter "6" and "10" for the Present and Count fields, respectively. Results show the distribution index for this subwatershed to be 0.39 (fig. 10). This means that it is questionable whether the habitat needs of territorial cavity-nesters are being met on this subwatershed (see details in the "Computer Analysis" section under "Distribution Analysis").

Conclusions for multiple strata—The density and distribution results of this analysis suggest that the necessary snag resources to sustain woodpecker populations may be inadequate on this subwatershed. Based on the results of the Compare to Target analysis, estimated snag densities were less than the targeted snag densities listed in the Forest plan. In addition, results from the distribution analysis indicate that large portions of the landscape do not support any snags at all. This can be a problem because woodpeckers are territorial. These tests are not conclusive, however, unless a minimum of 60 samples has been taken on a subwatershed of this size.

Stratum	Stratum size in acres (h/a)	Present	Count (N)	Proportion of plots with snag/tree present	Proportion of plots with snag/tree present (adjusted)	Distribution Index equations
1	1,759 (712.1)	0	10	0	0	
2	1,381 (559.1)	0	10	0	0	0.00
3	1,243 (503.2)	6	10	0.6	1.37	0.36
			0	0	0.36	
Total acres 4,383 (1,774.4)						
Distribution Index: DI_{st} = 0.39						

Figure 10—Distribution Index spreadsheet. The distribution index for qualifying snags for the Douglas-fir/ western hemlock subwatershed. Data from the Strate.xls (Stratm.xls) file. Distribution Index values of 0.40 or less indicate a poor snag distribution.

At this point, you have several management options. First, you may want to continue sampling to increase the precision of your estimates and to determine whether this changes the results of your analyses. Second, you may want to examine recent clearcut areas for the number, and quality, of the retention snags. Third, you may want to work with foresters to increase snag retention efforts. Finally, you may want to initiate snag creation programs to increase the density and improve the distribution of snags on this subwatershed.

Acknowledgments

English Equivalents

When you know:	Multiply by:	To find:
Centimeters (cm)	0.394	Inches
Meters (m)	3.281	Feet
Hectares (ha)	2.471	Acres

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**Appendix 1:
General Snag
and Large Tree
Sampling
Guidelines**

I. Landscape definition and selection (these snag and large tree sampling methods are intended for use on a landscape, or subwatershed, scale; they are not intended for sampling on the individual stand (<100 acres [40 ha]) where complete counts are more appropriate).

    A. Select landscape.

    B. Delineate boundaries if necessary.

II. Sampling objectives
    A. Size and condition of snags and large trees to be surveyed

        1. Decide what diameter of snags or large trees will be surveyed.

        2. Decide what height of snags will be surveyed.

        3. What condition of snags and large trees will be surveyed?

            a. Both hard and soft snags?

            b. All trees? Just hollow trees?

        4. Should any species be excluded? For example, if a particular tree species is known to provide little, if any, wildlife value, should it be excluded from your sampling program?

        5. Should wildlife use signs be recorded (e.g., woodpecker foraging and nesting signs)?

    B. Density estimate objectives

        1. Estimate average density.

        2. Compare to target density.

    C. Obtain a distribution index.

III. Landscape stratification

    A. Visit the area if you are unfamiliar with it. Landscape patterns unclear on maps may become apparent from an initial ground survey. What are the obvious differences visible across the landscape? What are the similarities? Would combining stands into strata that are homogenous in regards to snag or large tree densities, or forest structure, increase your precision? Decrease your sampling effort? If so, begin the stratification process.

B. Obtain several reference maps of landscape for use in the field: geo-graphical information system (GIS) or Orthoquad maps, or both, containing the following information:

   1. Current road system (use maps scaled to 1:31,680 or less)

   2. Stand units and their unique numeric identifier

   3. Current seral stage of vegetation

   4. Aerial photographs of the survey area.

C. Run a query by using either the GIS or any stand exam database available. Obtain any, or all, of the following information for each stand if it will aid in the stratification process:

   1. Forest community type

   2. Management history (i.e., harvest information, prescribed burns)

   3. Seral stage

   4. Predicted snag and large tree densities.

D. Visit area with above information.

E. Assign each stand to a stratum.

F. Obtain number of acres (ha) within each stand or stratum.

IV. Surveying procedures

   A. Establishing transects

      1. Option 1: randomly place transects across landscape.

         a. Randomly place a grid over the subwatershed map.

         b. Select five grid points within each stratum that will be used to establish starting points for each transect.

         c. Randomly select five compass bearings for each of the transect starting points.

         d. Determine if each of the five transects within each stratum fall within suffi-cient area of the stratum to allow four sample subsegments (164 feet [50 m]) to be placed; if not, select additional transects and starting points until a total of 20 samples (subsegment lengths), from a minimum of five stands, have been located within each stratum.

2. Option 2: Randomly select stands. For use in highly fragmented landscapes with many small stands.

   a. Randomly pick stand unit numbers from the complete list of stands within that stratum for sampling.

   b. Select a random point along the road bordering the stand to use for entry into the stand.

   c. Then from the point along the road selected above, randomly select a starting point from which to establish a transect perpendicular to the road within 164 feet (50 m) of the edge of the stand.

   d. Continue stand selection until a total of 20 samples (subsegment lengths), from a minimum of five stands, have been located within each stratum.

B. Plot size selection

   1. Prepilot sampling plot size selection, for example:
      Based on information gathered during the stratification process, it may be beneficial to preselect a plot size for sampling. For example:

      a. In open, clearcut strata supporting low densities (<1per acre [0.4 per ha]) of snags or trees, use Subsegment132(40) plots.

      b. In dense (visibility <33 feet [10 m]) strata supporting low densities (<1 per acre [0.4 per ha]) of snags or trees, use Subsegment66(20) plots.

      c. See appendix 3 for other situations where plot sizes may be preselected.

   2. Postpilot sampling plot size selection

      In most forested conditions, the optimal plot size to use for sampling is unknown until the density and distribution of the snags or trees can be evaluated. In these situations therefore:

      a. Use pilot sample data to determine which plot sizes minimize sampling effort to obtain your desired objectives. See "Optimal Plot Size Analysis" section for details.

      b. Use Optimal plot size for remainder of survey.

C. Field surveying techniques

   1. Establish transects by using a hip-chain starting from the points selected above. The hip-chain line also marks the center of the strip transect.

2. Delineate subsegment lengths (164 feet [50 m]) along the transect. Assign a unique numeric identifier to each subsegment as you sample (see appendix 2 for details).

3. Always sample subsegment lengths in sets of two. Two subsegments equal one segment. This will allow macros to help you determine whether shorter or longer plots are more efficient for your specific forest conditions. This is a function of the density and distribution of snags or trees in the area. This also allows you to obtain a Distribution Index.

4. For each subsegment length during the pilot survey, conduct a complete count of all qualifying snags or trees out to 66 feet (20 m) from the center line.

5. Record the perpendicular distance from the center line to the midpoint of each snag or tree. This information will aid in the decision making process for the optimal plot width.

6. Note: If after the survey begins, you realize visibility in stand is limited (<33 feet [10 m]), count only snags and trees out to 33 feet (10 m) from the line. Wider plots may be inaccurate in these conditions.

7. Note: If after the survey begins, you realize snag or tree densities are consistently high (>15 snags or trees/plot), count only snags and trees out to 33 feet (10 m) from the line. Wider plots may be inefficient in these conditions.

8. Refer to appendix 2 for details on other information collected for each snag or tree.

9. After pilot survey, count only snags and trees within the boundaries of the chosen plot size.

V. Data Entry

A. Make backup copies of all files before entering own data.

1. Open the Estimate.xls (Estimatm.xls) file.

2. Rename the Estimate.xls (Estimatm.xls) file with the subwatershed name or another file name.

3. Enter your data into the newly named file on Sheet 1.

4. Double check data to ensure that the number "9999" has been entered in each subsegment where no snags or trees were encountered.

VI.   Computer analysis for stratified landscapes

   A. Run **Consecutive** macro.

      1. This sorts data sets by consecutive Segments and Subsegments.

      2. Scroll through the entire data set to ensure that two Subsegment plots are entered for each Segment. For example, Segment 13 should contain Subsegments 13.1 and Subsegments 13.2

   B. Run **Formula** macro to have "If, then" formulas entered into Width columns. If a snag or tree meets the criteria that you specify, it will then be included in the analysis.

      1. Specify minimum d.b.h. of snags or trees.

      2. Specify minimum height of snags or trees.

      3. Specify maximum decay (snags) or structural (trees) class.

      4. Specify species of snags or trees.

   C. Run **Sort** macro to separate strata for individual analysis.

   D. Run **Segment** macro to obtain averages, standard deviations, and sample sizes for each of the four segment (328 feet [100 m]) plots widths based on the criteria you provided to the Formula macro.

   E. Run **Subsegment** macro to obtain averages, standard deviations, and sample sizes for each of the four subsegment (164 feet [50 m]) plot widths based on the criteria you provided to the Formula macro.

VII. Optimal Plot Size Analysis

   A. Given mean and variance of each plot size, which one of the eight possible plot sizes minimizes the number of samples required? Note that if snags or trees were counted only out to 33 feet (10 m) from the center line, only four possible plot sizes are available.

   B. Given mean and variance of each plot size, which one minimizes the number of acres (ha) required?

   C. Which plot size minimizes the product of the relative variance and relative cost?

   D. Which plot size predicts the lowest Total Cost?

   E. Select plot size which seems Optimal given your specific forest conditions.

VIII. Sample Size Determination

    A. Use Sample Size spreadsheet to obtain estimate of total sample size required by using plot sizes selected above.

    B. Collect remaining number of samples, after pilot survey samples, to meet your objectives.

    C. Continue to enter additional data on Sheet 1 as collected.

IX. Density Analysis

    A. Use Density spreadsheet to obtain density estimate and its bound.

    B. Use Statistical Test spreadsheet to compare estimated density to targeted density (optional).

X. Distribution Analysis

    A. Use Distribution Index spreadsheet to assess the distribution of snags and trees across the landscape.

Appendix 2: Field Form Explanations

1. Stratum: Enter the stratum number: 1, 2, 3, or 4.

2. Location: Enter the stand number in which the plot is contained.

3. Segment: Enter a single whole number to indicate which 328-foot (100-m) transect length is being surveyed (e.g., 1, 2, 3, or 4). No two numbers within a survey area should be the same.

4. Subsegment: Enter the corresponding whole number of the Segment that this 164-foot (50-m) transect length is nested within. Then give the Subsegment an additional number after a decimal point to indicate whether the Subsegment is the first, or second, within this Segment. For example, the two Subsegments nested within Segment 1 should be identified as Subsegment 1.1 and 1.2.

5. Width33(10): This column will be filled in by the macro for all snags or trees that meet the target criteria and are <16.5 feet (5 m) away from the center line.

6. Width66(20): This column will be filled in by the macro for all snags or trees that meet the target criteria and are <33 feet (10 m) away from the center line.

7. Width99(30): This column will be filled in by the macro for all snags or trees that meet the target criteria and are <49 feet (15 m) away from the center line.

8. Width132(40): This column will be filled in by the macro for all snags or trees that meet the target criteria and are <66 feet (20 m) away from the center line.

9. Distance: Enter the perpendicular distance between the midpoint of the qualifying snag or tree and the center of the transect line to the nearest foot (nearest halfmeter). If no snag is encountered within the entire Subsegment, enter "9999" under distance. It is critical to measure distances precisely. If the midpoint of a snag or tree falls directly on the boundary, include the first one, exclude the second one, and so on.

10. Species: Enter the corresponding numeric code of the snag or tree species encountered (standardized species codes taken from Stand Exam Program in the Pacific Northwest Region [USDA Forest Service 1991]).

Douglas-fir/redwoods:

Douglas-fir *(Pseudotsuga menziesii)*	202
Redwood *(Sequoia sempervirens)*	211

True firs:

Pacific silver fir *(Abies amabilis)*	011
White fir *(A. concolor)*	015
Grand fir *(A. grandis)*	017
Subalpine fir *(A. lasiocarpa)*	019
California red fir *(A. magnifica* var. *magnifica)*	020
Shasta red fir *(A. magnifica* var. *shastensis)*	021
Noble fir *(A. procera)*	022

Cedars:

Port-Orford-cedar *(Chamaecyparis lawsoniana)*	041
Alaska cedar *(C. nootkatensis)*	042
Incense-cedar *(Calocedrus decurrens)*	081
Western redcedar *(Thuja plicata)*	242

Larch:

Western larch *(Larix occidentalis)* 073

Spruce:

Brewer spruce *(P. breweriana)* 092
Engelmann spruce *(Picea engelmannii)* 093
Sitka spruce *(P. sitchensis)* 098

Pines:

Lodgepole pine *(Pinus contorta)* 108
Jeffrey pine *(P. jeffreyi)* 116
Sugar pine *(P. lambertiana)* 117
Western white pine *(P. monticola)* 119
Ponderosa pine *(P. ponderosa)* 122

Hemlock:

Western hemlock *(Tsuga heterophylla)* 263
Mountain hemlock *(T. mertensiana)* 264

Hardwoods:

Bigleaf maple *(Acer macrophyllum)* 312
Red alder *(Alnus rubra)* 351
Western paper birch *(Betula papyrifera)* 376
Pacific madrone *(Arbutus menziessii)* 361
Golden chinkapin *(Castanopsis
  chrysophylla)* 431
Oregon ash *(Fraxinus latifolia)* 542
Tanoak *(Lithocarpus densiflorus)* 631
Quaking aspen *(Populus tremuloides)* 746
Black cottonwood *(P. trichocarpa)* 747
Oregon white oak *(Quercus garryana)* 815
California black oak *(Q.. kelloggii)* 818
Oregon myrtle *(Umbellularia californica)* 981

Other conifers:

Subalpine larch *(Larix lyallii)* 072
Cypress *(Cupressus)* 050
All junipers *(Juniperus)* 060
Pacific yew *(Taxus brevifolia)* 231
Knobcone pine *(P. attenuata)* 103
Limber pine *(P. flexilis)* 113
Whitebark pine *(P. albicaulis)* 101

11. Class: Enter the numeric value for the appropriate decay or structural class of the snag or tree encountered. Snag data should be collected on a data form separate from large trees. For snags, the numeric value should increase with increasing amounts of decay. For example, Parks and others (1997) categorized snags into three structural classes.

A. Snag structural classes
  1. Snags that have recently died.
  2. Snags that have been dead several years and have lost some branches and bark.
  3. Snags that have been dead a long time and lack branches and bark (except grand fir and Douglas-fir, which tend to retain bark).

In contrast, numeric values for the structural class of trees should decrease with increasing amounts of decay. For example:

Tree structural classes
  1. Hollow
  2. Some decay evidence (broken branch or top, fungi, wildlife signs)
  3. Broomed trees
  4. Sound

Refer to Bull and others (1997) for detailed information on delineating categories and identifying trees useful to wildlife in the field.

12. D.b.h.: Enter the diameter at breast height of the snag or tree encountered using a d.b.h., stick or tape, to the nearest inch (cm).

13. Height: Enter the height of the snag or tree to the nearest foot (m).

14. Cavity: Enter the appropriate numer-
ic code to indicate any nesting use of the
snag or tree under consideration.

> 1. New cavity indicated by one
> or all of following: fresh wood
> chips on ground below hole, light
> colored wood around entrance,
> bird occupying cavity (excavated
> or natural).
> 2. Old cavity: Gray colored chips
> on ground below hole, gray col-
> ored wood around entrance, no
> sign of bird occupying cavity
> (excavated or natural).
> 3. Both old and new cavities
> 4. Other wildlife use.
> 5. Unknown. It is not possible to
> determine whether any cavities
> are present.
> 6. No cavities found.

15. Foraging: Enter the appropriate
numeric code to indicate any foraging use
of the snag or tree under consideration.

> 1. New foraging indicated
> by light colored wood around
> foraging sign, recent scaling.
> 2. Old foraging indicated by
> gray colored wood around
> foraging sign.
> 3. Both old and new foraging.
> 4. No foraging signs.

Appendix 3: Recommended Plot Sizes for Presampling

Table 11—Recommeded plot sizes for presampling plot size[a]

Recommended plot size	Forest conditions[b]	Density	Distribution	Examples
Subsegment132(4)[c]	Easy	Low (<1 snag/acre [0.4/ha])	Evenly scattered	Recent clearcuts
Segment66(20)	Moderate	Medium (5 snags per acre [2/ha])	Clumped	Pockets of beetle kill
Subsegment66(20)[d]	Moderate	High (>8 snags per acre[3.2/ha])	Evenly scattered	Widespread beetle kill or stand replacement burns
Segment66(20)	Easy-moderate	Low (<2 snags per acre [0.8/ha])	Clumped	Open grass areas with treed draws
Subsegment66(20)	Difficult	Low (<1 snag/acre [0.4/ha])	Scattered	Dense regeneration stands

[a] In most forested areas, however, the optimal plot size should be determined by evaluating the density and distribution of snags or trees within the areas and then conducting an Optimal Plot Size Analysis

[b] Easy forest conditions refer to high visibility (>66 feet [20 m]), easy travel, little slope; moderate refers to medium visibility (approx. 49.5 feet [15m]), moderate travel conditions due to downed woody debris, high shrub cover, or moderate slope (≤50 percent slope); difficult refers to low visibility (<33 feet [10 m]), difficult travel due to large amounts of downed woody debris, high shrub cover, or high slope (≥50 percent).

[c] If interested in foraging and nesting use in clearcuts, use Segment132(40) plots to encounter more snags.

[d] If densities are extremely high such that >15 snags per plot are consistently encountered, Subsegment33(10) plots may be more appropriate.

Appendix 4: Frequently Used Excel Commands in Computer Analysis

I. To start a macro over:
    1. Press Enter or OK until message box with Error appears.
    2. Select End.
    3. Follow directions to restore sheet to its original format.

II. To restore a sheet to its original format:
    1. Select all rows containing data beneath the Grand Total row.
    2. Select Delete from the Edit menu.
    3. Click on Entire Row.
    4. Then activate the cell with the field name SEGMENT (SUBSEGMENT if you are running the SUBSEGMENT macro).
    5. From the Data menu choose Subtotals.
    6. Select Remove all.

III. To print out results:
    1. Use mouse to highlight area to be printed (Click and drag with mouse).
    2. Select Print from the File menu.
    3. Click on Selection.
    4. Choose OK.

IV. To edit a formula:
    1. Activate top cell in column with formula to edit.
    2. Press the function key "F2" at the top of the keyboard.
    3. Change formula to meet your criteria.
    4. Press Enter. (Arrow keys do not work in Edit mode.)
    5. Copy and paste top cell throughout the column.

V. To copy and paste:
    1. Highlight range to copy using the mouse. Click and drag for large areas.
    2. Select Copy from the Edit menu.
    3. Highlight area where formula is to be pasted.
    4. Choose Paste from Edit menu.

VI. To reverse out of a process:
    1. Press Escape.

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We provide efficient and accurate methods for sampling snags and large trees on a landscape to conduct compliance and effectiveness monitoring for wildlife in relation to the habitat standards and guidelines on National Forests. Included online are the necessary spreadsheets, macros, and instructions to conduct all surveys and analyses pertaining to estimation of snag and large tree densities and distributions at the subwatershed scale. The methods focus on optimizing sampling effort by choosing a plot size appropriate for the specific forest conditions encountered. Two methods are available for density analysis. Method one requires sampling until a desired precision level is obtained for a density estimate. Method two is intended for use in areas that have low snag densities compared to Forest plan targeted densities. After taking a minimum of 60 samples, one may test for a significant difference between the estimated and targeted densities. In addition, data can be used to calculate a distribution index. The value obtained from the distribution index indicates whether the current distribution of target snags and large trees across a subwatershed is adequate to meet the habitat needs of territorial cavity-nesters and other wildlife species. Wildlife use also may be evaluated.

Keywords: Density, distribution, foraging, nesting, monitoring, sampling technique, snag, large tree, woodpecker, wildlife management, wildlife use.