The DecAID Advisory Model: Wildlife Component[1]

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Abstract

The wildlife component of DecAID is based on a thorough review, analysis, and synthesis of the empirical literature on wildlife-dead wood relations. We developed the wildlife component by compiling data on snag and log size, snag density, and amounts of down wood related to individual species or groups of wildlife species as presented in the literature, for various habitats and types of wildlife use (breeding, feeding, roosting). The wildlife use data are arranged in three cumulative species richness curves representing means and plus or minus one standard error (or equivalent variant). The curves can be consulted to determine which species or groups are provided for snag or down wood at three statistical levels, and the amounts and sizes of snags and down wood needed to achieve a specified wildlife objective of providing for specified species, or some percent of species, at a specified statistical level. Other components of the DecAID model can then be consulted to determine hazards or mitigation for risks of fire and contribution of insects and disease to the dead wood component, and to provide for fungi and non-pest invertebrates associated with snags and down wood.

Introduction

The DecAID model is a decision-aiding advisory system being developed under the aegis of the USDA Forest Service's Pacific Northwest Region (Portland, Oregon), and the multiagency Washington-Oregon Species-Habitat Project (SHP). "DecAID" (as in "decayed" or "decay aid") will provide managers with a synthesis of all available empirical data on the relations between wildlife and wood decay elements, principally snags and down wood, in the U.S. Pacific Northwest. The model is intended to update existing regional databases and advisory models, including those of Thomas and others (1979), Marcot (1992), and others.

The DecAID model will help managers determine which wildlife species might be provided for by specific snag and down wood amounts and sizes, the amounts and

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sizes needed to meet specified species management objectives, and the amounts and sizes expected under natural and managed conditions based on inventory data. The model also will provide information about fungi associated with dead wood and insects and diseases as disturbance agents affecting recruitment of dead wood.

This paper is one of a series of four papers in this proceedings pertaining to the DecAID model (see Mellen and Marcot [2002] for an overview of the entire DecAID model structure and components). This paper discusses the wildlife component.

Methods[6]

DecAID was designed to include empirical and all currently available data; address down wood as well as snag relations; and provide a more statistical, risk-analysis basis for assessing and managing snags and down wood for wildlife.

Step 1: Literature Review

We first conducted a thorough review of literature on empirical studies of wildlife associations with snags, partially dead trees, and down wood. We focused on studies conducted within Washington and Oregon, as well as studies in adjacent states and Canadian provinces if local studies of species or habitats were not available. We included publications in journals, books, conference proceedings, theses and dissertations, and agency publications and white papers that had undergone at least some peer review. We also obtained unpublished data from scientists currently working with dead wood issues.

Step 2: Data Synthesis

We compiled all available data on species use of snags and down wood from these papers. This involved summarizing nearly 200 papers. The data from these papers were synthesized into a master spreadsheet, listing the following information:

- For snags: snag density, decay class, dbh (diameter at breast height), height, snag species.
- For down wood: amount of down wood (volume/ha, no. logs/ha, percent cover, etc.), decay class, diameter, length, and tree species.
- For both snags and down wood: user species (e.g., wildlife or fungi), type of use (breeding, feeding, resting, denning), stand age and structure, wildlife habitat type, geographic location, explanatory comments, and source citation.

Next, we abstracted data from each study by SHP wildlife habitat type and habitat structure and by individual species or species group depending on how they were reported. Habitat types constitute an array of 31 wildlife habitats (24 terrestrial and 7 coastal and marine) developed by the SHP (Trevithick and O'Neil 1999). We were able to find data for seven of the forested wildlife habitat types. Habitat structures pertain to successional and structural stages of the wildlife habitat types

[6] The data and statistics presented in this paper have been updated since this paper was presented. Specifically, methods now entail use of tolerance intervals, instead of confidence intervals, and an expanded set of research data on species. Thus, tables and figures in this paper should be viewed as examples of methods and not final analyses.

and were also developed by the SHP. We combined habitat structures into two categories, post-disturbance (i.e., post-fire or post-harvest) and forested, because most studies did not report habitats and structures in any finer resolution.[7]

Examples presented here pertain to two SHP forest habitat types in Washington and Oregon: (1) Eastside Mixed Conifer Forest, which comprises productive closed upland forests east of the Cascades, including forests of montane Douglas-fir *(Pseudotsuga menzeisii),* grand fir *(Abies grandis),* western redcedar *(Tuja plicata),* and western hemlock *(Tsuga heterophylla)* in the east Cascade Mountains, Okanogan Highlands, and Blue Mountains; and (2) Westside Lowlands Conifer/Hardwood Forest, which comprises lowland to low montane upland forests of western hemlock, western redcedar, Douglas-fir, Sitka spruce *(Picea sitchensis),* red alder *(Alnus rubra),* Port-Orford cedar *(Chamaecyparis lawsoniana),* and bigleaf maple *(Acer macrophyllum)* in western Washington, the Coast Range of Oregon, the western slopes of the Cascade Mountains in Oregon, and around the margins of the Willamette Valley in Oregon (Trevithick and O'Neil 1999). The examples presented here focus on post-fire structures in Eastside Mixed Conifer Forest, and forested structures in Westside Lowlands Conifer/Hardwood Forest, for nesting/breeding *(appendix A).*

For each combination of SHP wildlife habitat type and habitat structure, we recorded an array of data pertinent to each individual species or species group reported in each study (see below and *tables 1-4*), although data were not available for all wildlife habitat types or habitat structures. In this way, we could track the interpretation of each data point back to its source and understand the basis of its value. This would later prove essential in interpreting the resulting patterns across species.

The main data recorded from each study was the mean, mean minus 1 standard error (SE), and mean plus 1 SE, of snag density, snag dbh, down wood percent cover, or down wood diameter, for each individual species or species group, in each combination of habitat type and habitat structure. We also recorded the sampling basis for these data, the location of each study, and the statistical significance of use-availability analyses or regressions if the data were so derived and reported. We noted when studies provided multiple values from different study sites within the same habitat types and structures.

Step 3: Development of Cumulative Species Tables and Graphs into Cumulative Species Curves

We interpreted three statistical levels of data from our synthesis of the literature. We referred to mean minus 1 SE, mean, and mean plus 1 SE as low, moderate, and high statistical levels, respectively. These three levels refer to the degree to which statistical values of snag or down wood amount and size include values reported in the literature. Statistically, means minus 1 SE represent 32 percent of the reported values, means represent average values, and means plus 1 SE represent 68 percent of the reported values.

All values for each combination of wildlife species, wildlife habitat type and habitat structure, and data level (low, moderate, and high, respectively) were

[7] This was later changed to three habitat structures—small/medium trees, open canopy, and large trees—as more data became available.

averaged (further versions will include weighted averages based on sample sizes). We put this summary of data from each study into spreadsheet tables and sorted wildlife species in order of increasing values of snag density, snag dbh, down wood percent cover, and down wood diameter, for each of the three data levels. In this way, for each wildlife habitat type and structure, we graphed curves of cumulative species richness as functions of snag density, snag dbh, down wood percent cover, and down wood diameter.

The cumulative species curves summarize the findings among species from different studies often conducted in different locations, time periods, and conditions. The curves are strictly not functions or regressions. Thus, the curves should not necessarily be interpreted as representing an increase in species richness on a given site or stand, given increases in size or density of wood decay elements. Rather, the curves should be used to suggest overall potential, individual species' use of wood decay elements across broader geographical scales, such as within watersheds or larger areas.

Step 4: Interpretation of the Cumulative Species Curves into Potential Management Guidelines

The final step entailed interpreting the cumulative species curves in terms of potential management guidelines to meet objectives for snag and down wood management for wildlife. This entailed comparing the cumulative species curves and species data with data on inventory conditions of snags and down wood from unharvested stands in each wildlife habitat type and structure (Ohmann and Waddell 2002). From this comparison, we derived a reasonable set of potential management guidelines for balancing snag density and dbh and for down wood percent cover and diameter. Because local site conditions and management histories vary greatly and other people may interpret the cumulative species curves differently, we also encourage managers to do their own inspection of the data and curves to validate our interpretation or to provide their own.

Results and Examples

Some examples will help explain the process and the form of the results. The full set of cumulative species curves for all species and habitats will be presented elsewhere.

Snag Density

Example data on wildlife use, for nesting and breeding, by snag density are presented in *table 1*. Because published studies are not available on wildlife use by snag density for nesting or breeding in post-fire structures of Eastside Mixed Conifer Forest in Washington and Oregon, we deferred to a similar study in mixed-conifer forests of south-central Idaho. Data on 8 bird species were available from one study there, depicting snag densities observed at nest sites in post-fire habitat structures (Saab and Dudley 1998). For some species, multiple values of snag densities are available in different study or treatment areas; these are shown in *table 1* and are averaged for later use in the cumulative species curves.

For example, snag density data were presented by Saab and Dudley (1998) on hairy woodpecker (see *appendix A* for scientific names) from three treatment areas. Mean values of snag density minus 1 SE ("low" statistical level) in these three areas were 48, 77, and 102 snags/ha; mean values ("moderate" statistical level) were 68, 89, and 118 snags/ha; and mean values plus 1 SE ("high" statistical level) were 84, 101, and 135 snags/ha. For each statistical level, we averaged the values across the 3 treatments—that is, 76, 92, and 107 snags/ha corresponding to low, moderate, and high statistical values, respectively—to use in the cumulative species curves.

This first example is one of the simplest cases, as all data came from one study and all values represented statistically significant selection by each species for snag densities. Further, all values represented snag densities at *nest sites* instead of *stand-wide averages*, which we interpret to mean snag densities within what may have been local snag clumps that were selected by the species reported. This last point is an important distinction because it has great bearing on interpreting the literature for devising management guidelines for snag (and down wood) densities, that is, whether reported densities should be applied stand-wide or in locally dense clumps. We further address this below.

Table 1 also presents a more complex case of combining data on wildlife use, for nesting and breeding, of snag density for nesting or breeding in Westside Lowland Conifer/Hardwood Forest. In this case, the literature did not cleanly separate various forest habitat structures (successional or structural stages) but rather reported from studies conducted in various structures in mixed forest age classes. Eight studies were available, covering seven species and two species groups. Some studies, such as McComb (1991), did not report means and SEs of snag density values, but rather we interpreted values based on their regression analyses. Studies reporting variation reported either SE or standard deviation (SD); we recorded and used what was reported. Some studies reported snag density at nest sites, others were based on stand averages, and still others reported regressions across study areas (in one case based on only hard snags). We used the closest available information to populate the data tables. Dealing with data reported in disparate ways is a perennial problem in statistics when combining information across studies (e.g., Draper and others 1992). Our approach was to record the data that were presented and to footnote the specific conditions from each study (e.g., *table 2*).

The example data from *table 1* on wildlife use of snag density for our two example habitat types were then sorted by increasing value for each of the statistical levels, and plotted on curves *(figs. 1, 2).* These example cumulative species curves show the number of wildlife species or species groups as a function of, in this case, snag density.

The cumulative species curves should be interpreted with due caution because the underlying data were reported in several different ways. For example, in Eastside Mixed Conifer Forest, post-fire structures *(fig. 1),* two sets of cumulative species curves represent snag densities for different snag size classes as reported in the literature: snags > 23 cm dbh and snags > 53 cm dbh. It is important to separate snag size classes, where possible, because, in general, smaller snags tend to be more numerous than larger snags, and snag density use and selection by the same wildlife species can vary by snag size class.

Table 1—*Example data on wildlife use by snag density in two example habitats (see text for caveats and explanations).*

	No. snags/ha										
Species[1]	**Low[2]**	**Moderate[2]**	**High[2]**	**Form of data for Moderate**	**Form of data for Low, High**	**Min. dbh (cm)[3]**	**Type data[4]**	**Location**	**P value[5]**	**Plot size (ha)[6]**	**Source[7]**
Habitat type: Eastside Mixed Conifer/Ponderosa Pine Forest; Habitat structure: Post-fire; Type of use: Nesting/breeding											
BBWO	108	155	202	mean	SE	23	nest site	s-c Idaho	0.001	0.04	Saab and Dudley 1998
HAWO	48,77,102	68,89,118	84,101,135	mean	SE	23	nest site	s-c Idaho	0.001	0.04	Saab and Dudley 1998
LEWO	54,58	60, 64	66,70	mean	SE	23	nest site	s-c Idaho	0.001	0.04	Saab and Dudley 1998
LEWO	12,15	14,18	15,21	mean	SE	53	nest site	s-c Idaho	0.05	0.04	Saab and Dudley 1998
MOBL	56,58,64	70,71,76	86,82,89	mean	SE	23	nest site	s-c Idaho	0.001	0.04	Saab and Dudley 1998
MOBL	23	31	39	mean	SE	53	nest site	s-c Idaho	0.05	0.04	Saab and Dudley 1998
NOFL	36	44	52	mean	SE	53	nest site	s-c Idaho	0.05	0.04	Saab and Dudley 1998
NOFL	50,62,62	62,73,82	84,76,100	mean	SE	23	nest site	s-c Idaho	0.001	0.04	Saab and Dudley 1998
WEBL	53,61,98	71,68,125	152,81,84	mean	SE	23	nest site	s-c Idaho	0.001	0.04	Saab and Dudley 1998
WHWO	50	62	75	mean	SE	23	nest site	s-c Idaho	0.001	0.04	Saab and Dudley 1998

(*table 1* continued)

Habitat type: Westside Lowland Conifer/Hardwood Forest; Habitat structure: Various (mixed forest age classes); Type of use: Nesting/breeding

Species[1]	No. snags/ha Low[2]	Moderate[2]	High[2]	Form of data for Moderate	Form of data for Low, High	Min. dbh (cm)[3]	Type data[4]	Location	P value[5]	Plot size (ha)[6]	Source[7]
BTWO	26.29	32.45	38.61	mean	SE	25	stand avg	w OR Cascades	0.065	0.08	C. Maguire, pers. comm.
CNB	0.5	not avail.	97	n/a	range	13	regression	Olympic Peninsula	0.01	n/a	Zarnowitz and Manual 1985
CNB	18	19	20	mean	SE	50	nest site	OR Coast Range	0.001	0.2	Nelson 1988
CNB	22	24	26	mean	SE	20-49	nest site	OR Coast Range	0.001	0.2	Nelson 1988
DEMO mammals	not avail.	25.61	not avail.	mean	not given	25	stand avg	w OR Cascades	n/a	0.08	C. Maguire, pers. comm.
DOSQ	21.62	25.53	29.44	mean	SE	25	stand avg	w OR Cascades	0.8314	0.08	C. Maguire, pers. comm.
GMGS	18.21	24.03	29.85	mean	SE	25	stand avg	w OR Cascades	0.8954	0.08	C. Maguire, pers. comm.
NFSQ	9.2	not avail.	20	n/a	range	50	stand avg	OR Coast Range	0.032	n/a	Corn and Bury 1991
NFSQ	21.62	25.53	29.44	mean	SE	25	stand avg	w OR Cascades	0.8314	0.08	C. Maguire, pers. comm.
PIWO	3	16	29	mean	SD	40	nest site	OR Coast Range	n/a	0.3	Mellen 1987
PIWO	4	21	38	mean	SD	15-40	nest site	OR Coast Range	n/a	0.3	Mellen 1987
TOCH	1	not avail.	8	n/a	range	50	regression--hard snags	OR Cascades	0.002	n/a	Rosenburg and Anthony 1993
TOCH	not avail.	17	not avail.	mean	not given	50	stand avg	OR Coast Range	n/a	0.035	Carey and others 1996

[1] See *table 2* for all footnotes contained in *tables 1 and 2*.

Table 2—*Example data on wildlife use by snag size (diameter at breast height, dbh) in two example habitats.*

	Snag dbh (cm)[7]		
Species[1]	**Low[2]**	**Moderate[2]**	**High[2]**
Habitat type: Eastside Mixed Conifer/Ponderosa Pine Forest			
Habitat structure: Post-fire			
Type of use: Nesting/breeding			
AMKE	46,54	50,59	54,63
BBWO	20,22,30.35	23,28,32,40	26,35,35,45
BRCR	72	not avail.	89
CNB	20,34	35,39	36,58
EUST	30	31	32
HAWO	24,32,34,35	28,34,35,53	32,36,37,70
HOWR	28	30,30	31,32
LEWO	40,43	45,48	46,56,78
MOBL	22,29,32	31,32,34,32	36,36,40
NOFL	30,40,41,34	34,41,43,37	39,42,45,52,40
NTWO	21,30	22,31	32
RBNU	32	34	36,56
TRSW	31	32	33
WEBL	33	35	36
WHWO	33	37	42
Habitat type: Westside Lowland Conifer/Hardwood Forest			
Habitat structure: Various (mixed forest age classes)			
Type of use: Nesting/breeding			
AMMA	not avail.	81,[80][9]	not avail.
BRCR	41,75	84	92
CBCH	32,58,103	76,94,103,108	113,120,130
CNB	49,76	[50][9],83	117
HAWO	33,41,49,62	[50][9],58,72,74,80	82,83,92,107,112
NFSQ	86,65,60,39,71	[50][9],64,77,93,42,74	100,89,67,44,77
NOFL	41,46,[86][8]	53,61,78,96	65,106,109,128
PCE	[83][8]	[50][9],88	92
PIWO	44,59	67,69,78,88	75,94,100

(*table 2* continued)

Habitat type: Westside Lowland Conifer/Hardwood Forest
Habitat structure: Various (mixed forest age classes)
Type of use: Nesting/breeding

PIWO	72	78	84
PYWO	32,54	56	79
RBNU	40,75	[50][9],71,82	89,102,118
RBSA	52,[103][8],76	80,101,[113][10]	109,123
SCNB	63,94	98	103
WIWR	not avail.	93	not avail.

[1] See *appendix A* for species names and codes.
[2] Low = mean - 1 SE; Moderate = mean; High = mean + 1 SE. Multiple entries denote different study sites.
[3] Min dbh refers to the lower value of snag dbh reported in the study. This is an important factor to track because, generally, larger snags are less numerous than smaller snags.
[4] Type data refers to whether the snag densities were reported only at nest sites ("nest site"), throughout the stand ("stand avg"), or for all study sites combined ("regression").
[5] P value refers to the reported statistical outcome of use-availability analyses. P values > 0.05 pertain to studies that failed to demonstrate selection for particular snag densities; however, snag data from these studies are still useful for describing stands in which the species was observed to be present, and thus are included here.
[6] Plot size refers to the area of the sample plots in which snag density was calculated.
[7] Various sources.
[8] Value is mean - 1 SD, even though it is higher than some mean values.
[9] Preference data; redundant with utilization data, so not included in further analyses.
[10] Value is mean from 1 study, even though it is higher than some means + SD.
[11] Value is anomalously high and based on snags > 13 cm dbh, and thus not included in the cumulative species curve.

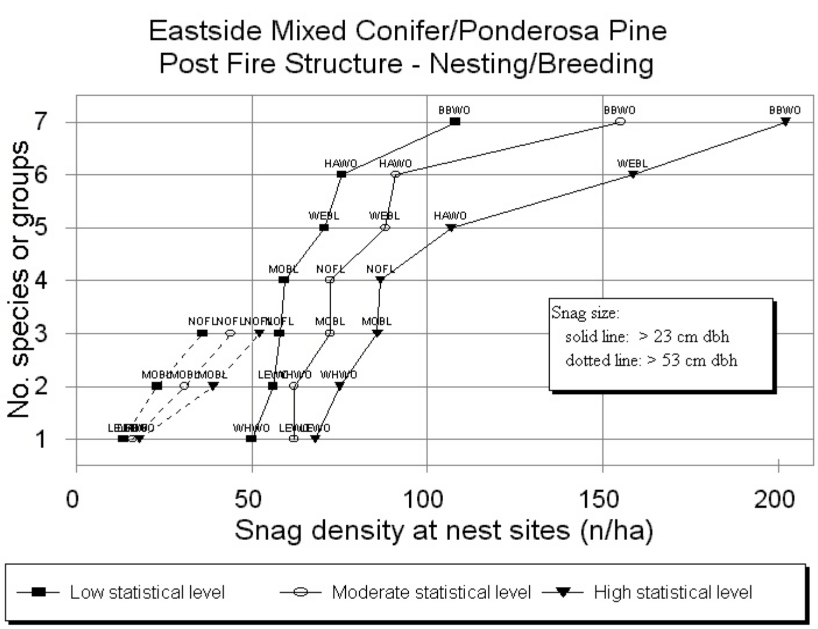

Figure 1—Example cumulative species curves of snag density in Eastside Mixed Conifer/Ponderosa Pine Forest, post-fire structural condition, for nesting/breeding use by wildlife, in eastern Washington and Oregon.

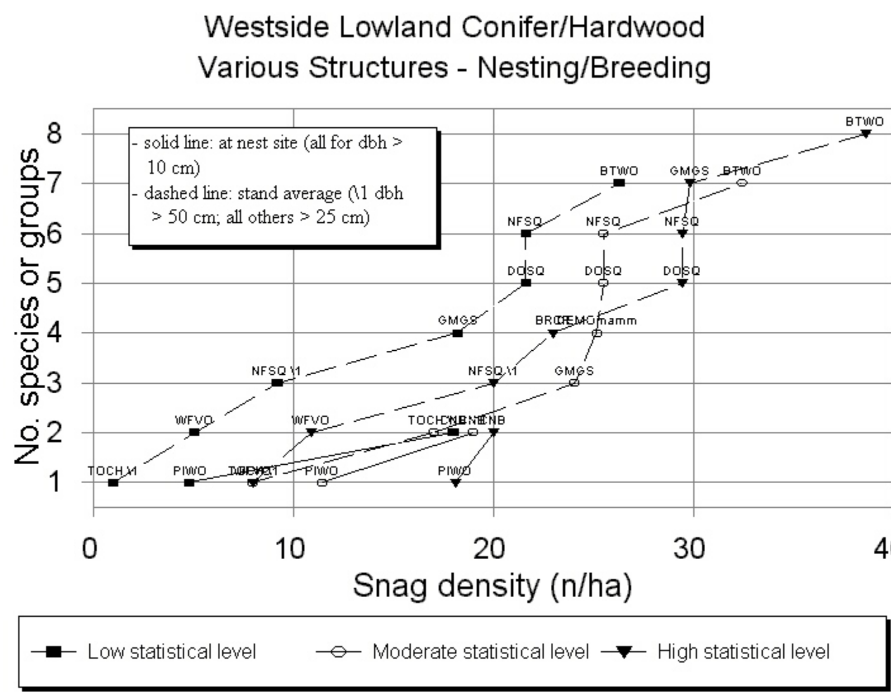

Figure 2—Example cumulative species curves of snag density in Westside Lowland Conifer/Hardwood Forest, various structural conditions, for nesting/breeding use by wildlife, in western Washington and Oregon.

Because all example data for Eastside Mixed Conifer Forest came from nest sites, so these particular cumulative species curves *(fig. 1)* could all be interpreted as representing snag densities within local snag clumps at nest sites, not necessarily as stand-wide averages. In contrast, in Westside Lowland Conifer/Hardwood Forest *(fig. 2),* the literature presented data not by snag size class, but different studies reported snag densities at nest sites (this may be in local snag clumps) or as stand-wide averages, and we show these in different sets of curves. The values of snag density are generally higher in snag clumps than for stand-wide averages *(fig. 2);* this makes intuitive sense. Another data artifact appears in *figure 2,* where the curves for moderate and high statistical levels for stand averages cross. This occurs because the data were not reported in the literature the same way for the same species at each statistical level; thus, attention needs to be given to the individual species on the data points in each curve.

The cumulative species curves can be read in two ways for management use: 1) by beginning with a known or expected snag density and reading up from the x-axis to the curves to determine which species, and what fraction of all reported species, would be provided at different levels of confidence by managing within observed values; or 2) by beginning with a specific species management target, such as for specific species or a specific fraction of all reported species, finding those target species on each cumulative species curve or along the y-axis, and reading down to the x-axis to determine what snag density would correspond to that reported in the literature at a particular statistical level (low, moderate, or high).

For example, presume that one is managing some Eastside Mixed Conifer forest stand for some purpose such as fuels reduction, and that it is expected that such silvicultural treatments will result in providing for snags > 23 cm dbh in local clumps averaging 100 snags/ha within each clump. Consulting *figure 1,* for a density of 100 snags/ha, at > 23 cm dbh, one would determine that this snag density would provide for four of the seven reported nesting or breeding species at the high statistical data level, and six of the seven nesting or breeding species at both the moderate and low levels. Further, one can determine which conditions for each species would, and which would not, match conditions reported in the literature. For example, at the high statistical level, the proposed management conditions in this scenario would fit the reported use patterns for all species except hairy woodpecker, western bluebird, and black-backed woodpecker; studies suggest that these three species use and select for higher snag densities in recent burns, although they might select for different conditions elsewhere (Bunnell, pers. comm.).

Alternatively, one could begin with a specific management goal, such as providing for all reported snag-using species at a particular statistical level. For example, in Eastside Mixed Conifer Forest *(fig. 1)* this would entail providing local clumps of snags > 23 cm dbh with densities within the clumps of at least 110 snags/ha at low statistical levels of observed species' nesting or breeding usage, 155 snags/ha at moderate levels, and 200 snags/ha at high levels. (The question of what constitutes a clump, how many clumps to provide, and how to distribute a clump is addressed below.) In Westside Lowland Conifer/Hardwood Forest *(fig. 2),* meeting the nesting or breeding use patterns of all reported species or species groups would entail providing within-clump average snag densities (the dashed lines in *fig. 2)* of about 26 to over 38 snags/ha. Also, the cumulative species curves for the two forest habitats explored here suggest that secondary cavity-using species such as northern flying squirrel and western bluebird may select for higher snag densities than many of the primary cavity-excavating species. (Values presented here and below are only examples of use of DecAID; the final model likely will have different values.)

Snag Diameter

Data on wildlife use, for nesting or breeding, by snag diameter (dbh) are far more numerous than are data on snag density. Data on 15 individual species or species groups are available for Eastside Mixed Conifer Forest and 14 species or groups for Westside Lowland Conifer/Hardwood Forest *(table 2).* However, again, the literature inconsistently reports these data. Most studies reported actual dbh of snags used by a species for a specific function (e.g., nesting, roosting, foraging). Preference studies reported snag dbh in various ways: by disparate snag dbh size classes or categories; by snags at nest sites, as averaged throughout the stands, or as regressions across study areas; by different sampling designs; and by snags generally occurring within the stand or as selected by the species (selection data).

These differences in reporting make overall interpretation of patterns of snag diameter use by nesting or breeding species difficult. However, one can use cumulative species curves *(figs. 3, 4)* for these two example habitats in the same way as with the snag density curves—that is, to determine what fits reported patterns. Comparing the curves for two habitats shows that in general, species use much larger snags in the Westside forest type than in the Eastside forest type for nesting or breeding; this makes intuitive sense, as Westside forests typically currently have larger diameter mature trees and snags, given higher rainfall and more productive tree-growing environments there. The example curves suggest that, to meet the use patterns of all reported individual species and species groups, snags of at least 72 to 89 cm dbh are needed in Eastside Mixed Conifer Forest, post-fire structures *(fig. 3)* and 92 to 121 cm dbh in Westside Lowlands Conifer/Hardwood Forest, various forest structures *(fig. 4),* for low to high statistical levels, respectively.

Also, the cumulative species curves suggest that secondary cavity-using species may select larger diameter snags than many of the primary cavity-excavating species. This is especially true with Brown Creeper and American Kestrel in the Eastside forests *(fig. 3),* and with Chestnut-backed Chickadee, Red-breasted Nuthatch (which can also excavate cavities), and other secondary cavity-nesting birds (species group "SCNB") in Westside forests *(fig. 4)*. (Note that Winter Wren also appears in *fig. 4.* This species was shown to correlate with large snags in the associated study, although the species generally does not use snag cavities per se. The correlation may pertain to use of down wood at the base of the snags or sloughing bark as nesting or hiding sites. As well, Brown Creeper often uses sloughing bark higher up on the bole of large diameter, tall snags and live trees, and does not typically use cavities per se.)

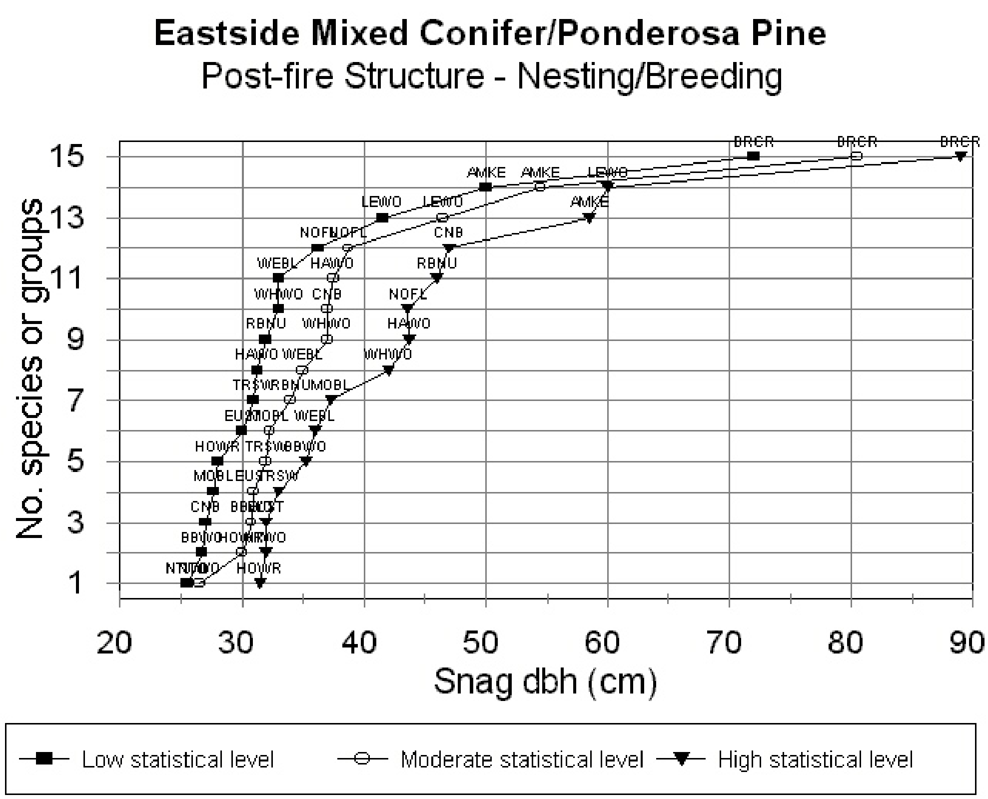

Figure 3—Example cumulative species curves of snag diameter in Eastside Mixed Conifer/Ponderosa Pine Forest, post-fire structural condition, for nesting/breeding use by wildlife, in eastern Washington and Oregon.

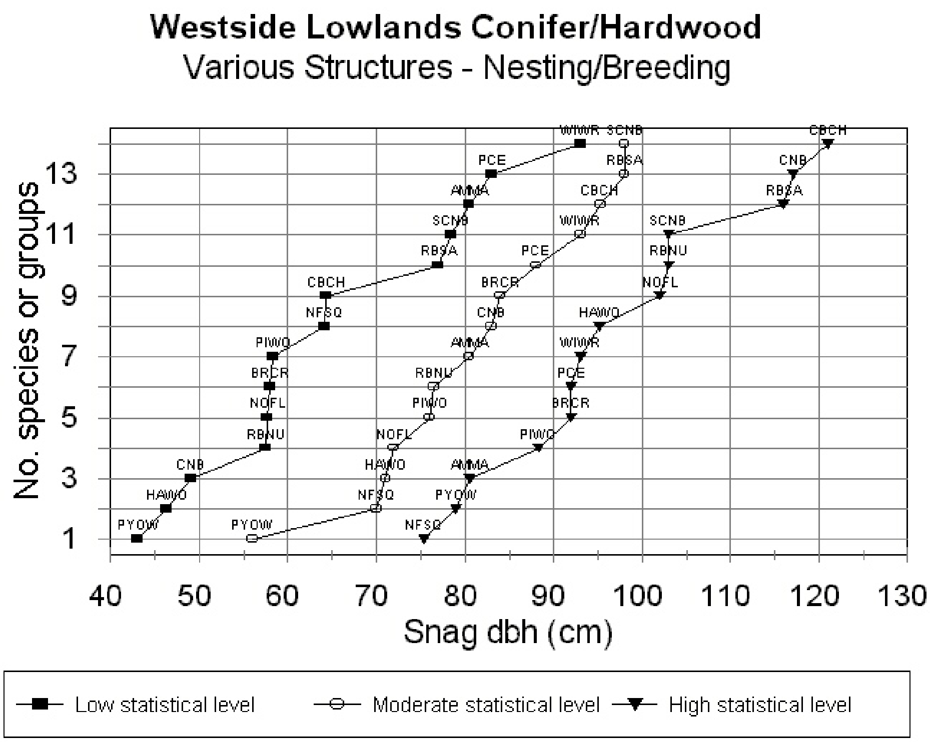

Figure 4—Example cumulative species curves of snag diameter in Westside Lowland Conifer/Hardwood Forest, various structural conditions, for nesting/breeding use by wildlife, in western Washington and Oregon.

Down Wood Percent Cover

Overall, scant data are available on wildlife use of down wood. One of the major problems is that down wood is reported in the literature in too many disparate ways: as percent ground cover, and as number of pieces, volume, density, and mass per unit area. Fuels managers prefer estimates of volume and mass, whereas for wildlife use percent ground cover may be the best single estimator (Torgersen, pers. comm.; Carey, pers. comm.). In British Columbia, down wood percent cover was a useful unit for fungi, most cryptogams, and small mammals, although down wood volume seemed more useful for Plethodon salamanders (Bunnell, pers. comm.). We used inventory data to develop regression equations to convert among these units, although such conversions introduce unknown errors in estimation.

In Eastside Mixed Conifer Forest, only two studies provided data on wildlife use of down wood cover, and one of these pertains to fungi species. The story is far better in Westside Lowland/Conifer Hardwood Forest, where 5 studies provide data on 23 species and 2 species groups *(table 3).* The example cumulative species curves *(figs. 5, 6)* suggest that, to provide for all reported species at high statistical levels, over 4 percent down wood cover in Eastside forests and 20 percent in Westside forests would be necessary to fall within observed values of species use and selection. At least for Westside forests, these values are much greater than the 0.5 to 1 percent typically specified in the Northwest Forest Plan, but, as with snag densities, they might pertain to cover within locally dense clumps of down wood, not necessarily stand-wide averages. This is a vital distinction for management.

Table 3—*Example data on wildlife use by down wood percent cover in two example habitats.*

Species[1]	Percent cover down wood			Mininum diameter (cm)[3]	How measured	P value[4]	Log decay class[5]	Plot size[6]	Data type	Source
	Low[2]	Moderate[2]	High[2]							
Habitat type: Eastside Mixed Conifer Forest; Habitat structure: Various forest structures; Type of use: Presence and density										
FUNG	0.7	1.1	1.4	7.5	not given	n/a	1-5	n/a	threshold density	Graham and others 1994
PIWO	1.6	3.2	4.7	15	not given	n/a[10]	not given[11]	0.4 ha	foraging use	Bull and Holthausen 1993
Habitat type: Westside Lowland Conifer/Hardwood Forest; Habitat structure: Various forest structures; Type of use: Presence, abundance, and nesting										
BTWO	5.54	7.35	9.16	10	transect intersection	n/a	1-5	line transect	presence	C. Maguire, pers. comm.
CLSA	2.1	not avail.	not avail.	10	not given	n/a	1-5	line transect	presence	Butts 1997
CLSA	5.92	6.97	8.02	10	transect intersection	n/a	1-5	line transect	presence	C. Maguire, pers. comm.
DEMO mamm	not avail.	6	not avail.	10	transect intersection	n/a	1-5	line transect	presence	C. Maguire, pers. comm.
DOSQ	4.5	5.3	6.1	10	transect intersection	n/a	1-5	line transect	presence	C. Maguire, pers. comm.
DUSA	8.6	10.01	11.42	10	transect intersection	n/a	1-5	line transect	presence	C. Maguire, pers. comm.
ENSA	7.2	9.2	11.1	10	not given	0.03	1-5	line transect	presence	Butts 1997
ENSA	4.83	5.76	6.69	10	transect intersection	n/a	1-5	line transect	presence	C. Maguire, pers. comm.
GMGS	4.27	4.3	4.33	10	transect intersection	n/a	1-5	line transect	presence	C. Maguire, pers. comm.
MAPG	2.69	3.12	3.55	10	transect intersection	0.0109	1-5	line transect	selection	C. Maguire, pers. comm.
MASH	6.6	8.2	9.8	10	transect intersection	0.013	1-5	line transect	selection	C. Maguire, pers. comm.
NFSQ	9.6	10	10.4	10	not given	<0.05	1-5	0.035 ha	presence	Carey and others 1999
NFSQ	5.44	6.43	8.91	10	transect intersection	0.0001	1-5	line transect	selection	C. Maguire, pers. comm.

(*table 3* continued)

	Percent cover down wood									
Species[1]	Low[2]	Moderate[2]	High[2]	Mininum diameter (cm)[3]	How measured	P value[4]	Log decay class[5]	Plot size[6]	Data type	Source
NOSA	4.64	5.36	6.08	10	transect intersection	n/a	1-5	line transect	presence	C. Maguire, pers. comm.
PCFR	1.78	2.28	2.78	10	transect intersection	n/a	1-5	line transect	presence	C. Maguire, pers. comm.
PGSA	6.9	9.06	11.22	10	transect intersection	n/a	1-5	line transect	presence	C. Maguire, pers. comm.
PIWO	4.02	4.65	5.28	20	transect intersection	0.01	1-5	line transect	foraging sites	Hartwig 1999
PJMO	6.51	8.15	9.79	10	transect intersection	0.0152	1-5	line transect	selection	C. Maguire, pers. comm.
RONE	5.69	6.9	8.11	10	transect intersection	n/a	1-5	line transect	presence	C. Maguire, pers. comm.
SHMO	5.09	6.08	7.07	10	transect intersection	n/a	1-5	line transect	presence	C. Maguire, pers. comm.
SMMA	5	12.5	20	10	not given	not given	1-5	not given	Abundance[7]	Carey and Johnson 1995
SPFR	not avail.	4.66	not avail.	10	transect intersection	0.0402	1-5	line transect	selection	C. Maguire, pers. comm.
SPSK	6.2	7.73	9.26	10	transect intersection	0.0402	1-5	line transect	selection	C. Maguire, pers. comm.
STWE	4.99	6.61	8.23	10	transect intersection	0.0402	1-5	line transect	selection	C. Maguire, pers. comm.
TOCH	8.3	8.6	8.9	10	not given	<0.05	1-5	0.035 ha	presence	Carey and others 1999
TOVO	3.76	4.68	5.6	10	transect intersection	n/a	1-5	line transect	presence	C. Maguire, pers. comm.
VASH	4.7	5.6	6.5	10	transect intersection	n/a	1-5	line transect	presence	C. Maguire, pers. comm.
WRSA	7.35	9.5	11.65	10	transect intersection	0.0154	1-5	line transect	selection	C. Maguire, pers. comm.

[1] See *table 4* for all footnotes contained in *tables 3 and 4*.

Table 4—*Example data on wildlife use by down wood diameter in two example habitats.*

	Down wood diameter (cm)							
Species[1]	Low[2]	Moderate[2]	High[2]	Selection?[8]	How measured	P value[4]	Data type	Source
Habitat type: Eastside Mixed Conifer/Ponderosa Pine Forest; Habitat structure: Various forest structures; Type of use: Presence, foraging, and denning								
ABBE	not avail.	43.3	not avail.	no	large end diam.	not given	foraging	Bull 1998
ABBE	66.51	86	105.49	no	large end diam.	not given	denning	Bull and others 1999
ABBE	91.77	108	124.23	no	large end diam.	not given	denning	Bull and others 1999
PIWO	not avail.	38	not avail.	yes	not given	0.03	foraging (preference)	Bull and Holthausen 1993
PJMO	not avail.	25	not avail.	yes	not given	<0.05	size class preference	Hallet and O'Connell 1997
SRBV	not avail.	25	not avail.	yes	not given	<0.05[9]	size class preference	Hallett and O'Connell 1997
Habitat type: Westside Lowland Conifer/Hardwood Forest; Habitat structure: Various forest structures; Type of use: Presence and selection								
BTWO	28.94	31.43	33.92	yes	transect intersection	0.0012	presence	C. Maguire, pers. comm.
CLSA	50.3	52.5	54.5	yes	not given	<0.01	used/unused	Corn and Bury 1991
CLSA	27.25	29.3	31.35	no	transect intersection	not avail.	presence	C. Maguire, pers. comm.
DEMO mamm	not avail.	26.08	not avail.	no	transect intersection	n/a	presence	C. Maguire, pers. comm.
DOSQ	23.07	24.47	25.87	no	transect intersection	0.1537	presence	C. Maguire, pers. comm.
DUSA	24.9	26.8	28.7	no	transect intersection	not avail.	presence	C. Maguire, pers. comm.
ENSA	not avail.	50	not avail.	yes	not given	<0.008[9]	presence	Butts 1997
ENSA	24.53	26.07	27.61	no	transect intersection	not avail.	presence	C. Maguire, pers. comm.
GMGS	19.27	20.26	21.25	yes	transect intersection	0.0027	presence	C. Maguire, pers. comm.
MASH	28.18	30.01	31.84	yes	transect intersection	0.0258	presence	C. Maguire, pers. comm.

(*table 4* continued)

MAPG	20.68	22.2	23.72	yes	transect intersection	0.0188	presence	C. Maguire, pers. comm.
NFSQ	25.49	27.16	28.83	yes	transect intersection	0.0005	presence	C. Maguire, pers. comm.
NOSA	24.47	25.99	27.51	no	transect intersection	not avail.	presence	C. Maguire, pers. comm.
PCFR	18.3	19.77	21.24	no	transect intersection	not avail.	presence	C. Maguire, pers. comm.
PGSA	29.71	32.39	35.07	no	transect intersection	not avail.	presence	C. Maguire, pers. comm.
PJMO	25.47	27.92	30.37	no	transect intersection	0.2951	presence	C. Maguire, pers. comm.
RONE	25.49	27.37	29.25	no	transect intersection	not avail.	presence	C. Maguire, pers. comm.
SHMO	22.94	26.4	28.02	no	transect intersection	0.8764	presence	C. Maguire, pers. comm.
SPFR	not avail.	38.7	not avail.	no	transect intersection	not avail.	presence	C. Maguire, pers. comm.
SPSK	26.24	28.17	30.1	no	transect intersection	0.2368	presence	C. Maguire, pers. comm.
STWE	22.11	25.38	28.65	no	transect intersection	not avail.	presence	C. Maguire, pers. comm.
TOVO	27.1	29.32	31.54	no	transect intersection	0.185	presence	C. Maguire, pers. comm.
VASH	24.24	25.75	27.26	no	transect intersection	>0.05	presence	C. Maguire, pers. comm.
WRSA	25.38	27.7	30.02	no	transect intersection	not avail.	presence	C. Maguire, pers. comm.

[1] See *appendix A* for species names and codes.
[2] Low = mean - 1 SE; Moderate = mean; High = mean + 1 SE.
[3] Smallest size down log included in each study.
[4] P value refers to the reported statistical outcome of use-availability analyses.
[5] Log decay class is the category of physical decay of the down wood (Maser and others 1979). 1-3 sound, 4-5 rotten.
[6] Plot size refers to the area of the sample plots in which down wood percent cover was estimated.
[7] Presence of "large populations of most small mammals" (values not given).
[8] Selection refers to statistical demonstration of preference for size class (diameter) of down wood. "No" implies that descriptive data only were presented (no statistical preference analysis was conducted).
[9] P values and preference statistics taken from regression equations: for Hallet and O'Connell (1997), these were stepwise multiple regressions where logs > 25 cm diameter were the first significant component in the regression; and for Butts (1997) where large logs (>50 cm diameter) was the only significant component in a logistic regression equation.
[10] Recommendation, no statistics given.
[11] Reported preference for "long, dead, large logs" where large means 38+ cm diameter.

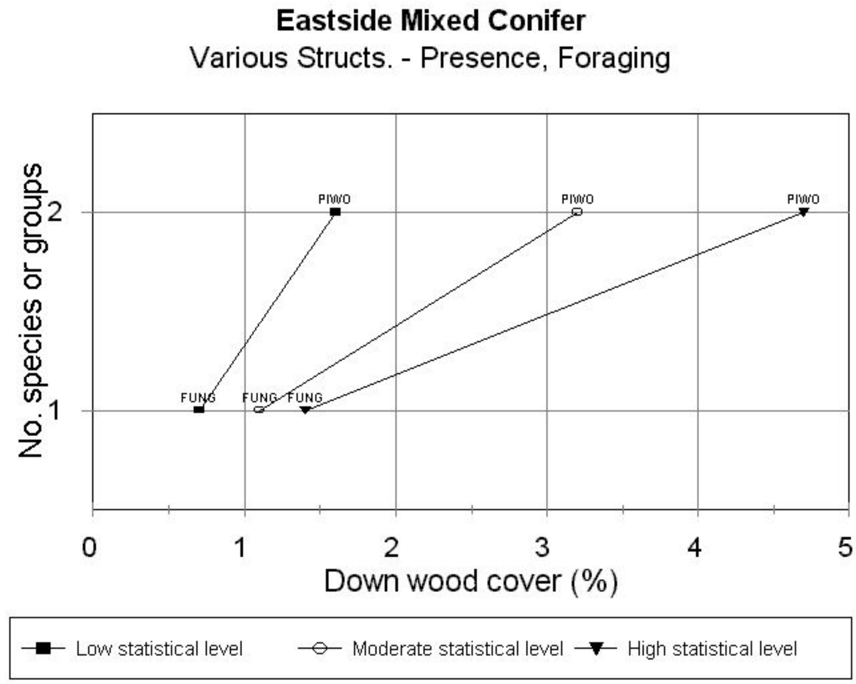

Figure 5—Example cumulative species curves of down wood percent cover in Eastside Mixed Conifer/Ponderosa Pine Forest, various structural conditions, for presence and foraging use by wildlife, in eastern Washington and Oregon. Ponderosa Pine Forest is included here and in *table 3* because the studies did not separate the two forest types.

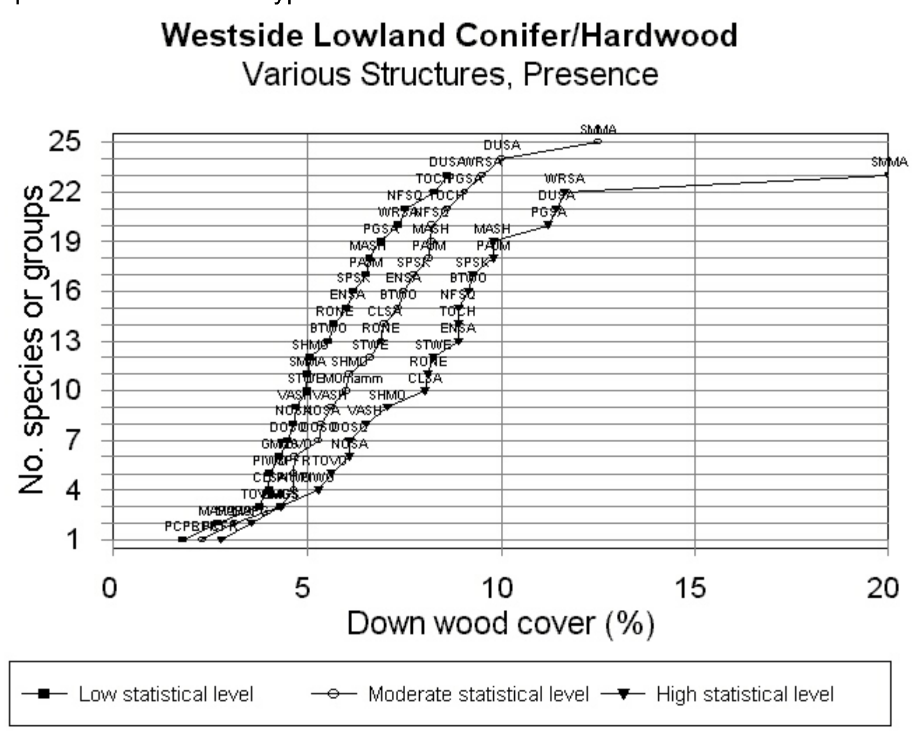

Figure 6—Example cumulative species curves of down wood percent cover in Westside Lowland Conifer/Hardwood Forest, various structural conditions, for presence and nesting/breeding use by wildlife, in western Washington and Oregon.

Down Wood Diameter

Data on wildlife use of down wood diameter also are very sparse for the Eastside Mixed Conifer Forest (3 studies, 4 species) but are somewhat better for Westside Lowland/Conifer Hardwood Forest (3 studies, 21 species and 1 species group) *(table 4)*. Diameters of Eastside down logs tend to be far larger for denning use than for foraging use *(fig. 7),* ranging up to 50 cm diameter for foraging by pileated woodpecker and over 120 cm for denning by American black bear. Diameters of Westside down logs range up to 43 cm *(fig. 8),* although data on diameter use by bears is not available there. We presume that all diameter values should be interpreted as small-end diameter, although many studies reported transect-intercept diameter or large end diameter.

Overall Interpretations

Interpreting the cumulative species data and curves for wildlife habitat management is going to be a complex process requiring knowledge of local site conditions and species' use patterns or needs. For example, interpreting the cumulative species curves independently for amounts and for sizes, of snags and down wood, may lead to incorrect estimation or conflicting projections of what is needed. Because some species select for different size classes of snags or down wood, one size does not fit all. Some combination of sizes may be needed to meet all species' use patterns.

How should one balance density and size for snag or down wood management within a stand? The overall process involves comparing and balancing snag or down wood size with snag or down wood density from the cumulative species curves, determining if this pertains to stand average values or local snag or down wood clumps, and comparing the species use data to inventory data taken in unmanaged (unharvested) stand conditions.

Here is an example with the snag data for Westside Lowland Conifer/Hardwood Forest, various forested structures. To manage for all reported nesting or breeding wildlife at high statistical levels, focusing on the species' use data representing stand averages, the stand would average about 39 snags/ha *(fig. 2)* > 25 cm dbh *(table 1, fig. 2)*. This total would include at least 20 snags/ha > 50 cm dbh for northern flying squirrel *(table 1)*. Also used are a few very large snags up to about 120 cm dbh for red-breasted sapsucker, chestnut-backed chickadee, and some cavity-nesting birds in general *(fig. 4)* scattered within and among the clumps, although chestnut-backed chickadee might use smaller snags that are well rotted (Bunnell, pers. comm.). Retaining any snags > 80 cm dbh would help meet needs of roosting bats and American marten as well (based on data for roosting and denning, not shown here). Amounts and sizes of snags at low or moderate statistical levels would be proportionately lower.

Values of snag or down wood density and size as interpreted from the cumulative species curves should be compared with forest inventory data (namely, the Continuous Vegetation Survey [CVS] and Forest Inventory and Analysis [FIA]) taken in unmanaged (unharvested) stand conditions (Ohmann and Waddell 2002). This provides a cross-check of the potential of the stand for producing snags and down wood in unharvested settings. For example, a preliminary analysis of inventory data in Westside Lowland Conifer/Hardwood Forest from reserved lands (representing unharvested conditions) suggests that natural densities of snags > 25 cm dbh average 48.4 and 40.0 snags/ha in young and mature stand structural classes, respectively, and snags > 50 cm dbh average 16.0 and 17.5 snags/ha in young and mature classes, respectively. These average values are close to the values derived from the cumulative species curves cited above, verifying that these may be appropriate stand-wide goals. In some cases, snags can be managed in clumps if the species' use data were summarized from studies focused on selected use of locally dense patches of snags or down wood, and if such values were significantly greater than stand averages as denoted in the inventory data.

The idealized cumulative species curves may not fit what is feasible on a given site, given its management history, current conditions, and expected future conditions. Disturbance such as stand-replacing fires, timber harvests, intermediate silvicultural treatments, and human safety management may result in snag and down wood conditions far different than expected or desired in a particular stand.

How does one balance all these issues and conditions? The answer may be in taking a broader view across stands and landscapes. It is imperative, however, to not average snag and down wood densities and sizes across too broad an area, such as across entire watersheds, potentially leaving large areas within watersheds with snags or down wood elements that are too scarce or too small to be of use by wildlife. An honest evaluation of watershed conditions, including the current condition and future capability of stands within, is a sound basis for devising reasonable management goals and expectations for snags and down wood on all lands.

Choosing Statistical Levels for Management Goals

How should one interpret the statistical levels represented by the low, medium, and high curves? It may be useful to interpret the three statistical levels as confidence levels and match them with overall goals for managing snags and down wood as one facet of habitat diversity for wildlife. Different landowners may have appropriately different expectations for diversity management, and thus for statistical levels to manage for, on various land use allocations.

For example, lands established or allocated mainly for conservation and protection of native ecosystems and wildlife communities, such as national parks and wilderness areas, could appropriately be operating at high statistical levels for amount and size of snags and down wood for wildlife. These lands are managed under the strictest set of regulations and laws for nature conservation. Usually, active forest management, especially timber harvesting, is not conducted on these particular lands, although one important exception is Managed Late-Successional Reserves under the Northwest Forest Plan.

It might be appropriate to allow a lower statistical level on other lands clearly designated for timber production and other intensive resource production uses. Such lands are subject to State Forestry Practices regulations and the Endangered Species Act, but not the Federal regulations for population viability and biodiversity management governing national forests. At the least, the information provided by the cumulative species curves in the DecAID advisory model will help determine the degree to which amounts and sizes of snags and down wood provided on various categories of land use, ownership, and allocation, match those reported in the wildlife literature and in inventory data from unharvested lands.

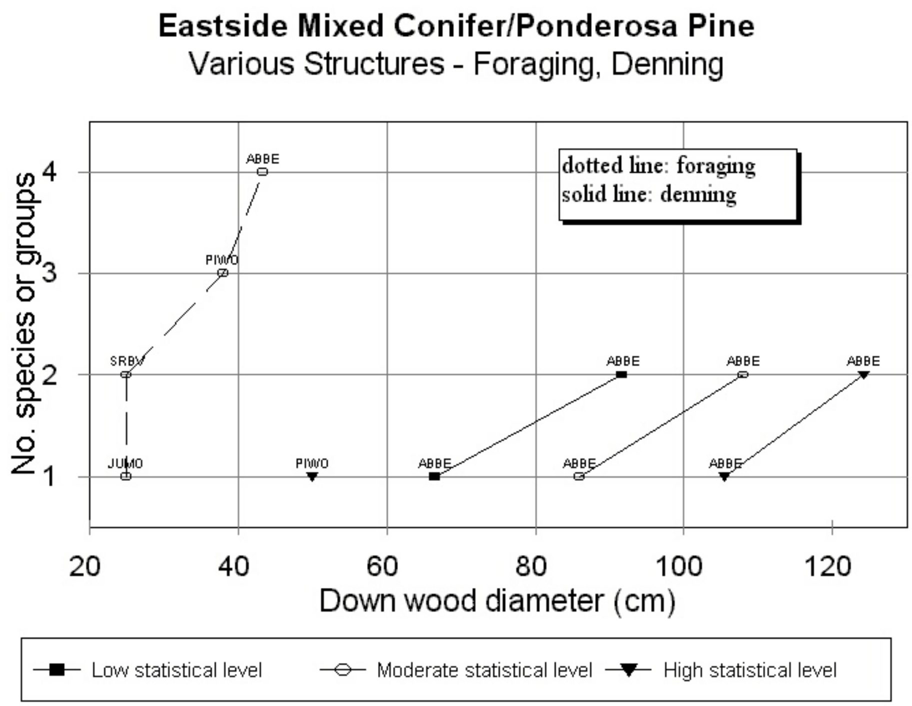

Figure 7—Example cumulative species curves of down wood diameter in Eastside Mixed Conifer/Ponderosa Pine Forest, various structural conditions, for foraging and denning use by wildlife, in eastern Washington and Oregon. Note that American black bear is represented in the denning curves twice, as data came from two different studies.

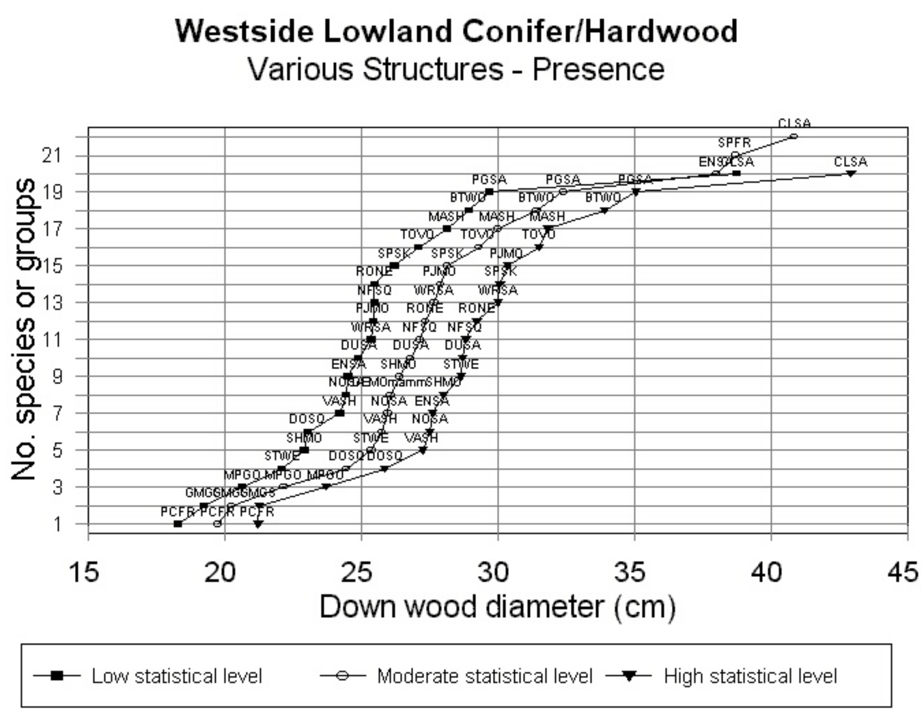

Figure 8—Example cumulative species curves of down wood diameter in Westside Lowland Conifer/Hardwood Forest, various structural conditions, for presence of wildlife, in western Washington and Oregon.

Clumping and Distribution Issues

We discussed above how we interpreted some reported snag or down wood densities as possibly occurring in local clumps instead of stand-wide averages. This interpretation seems appropriate for studies reporting densities specifically at wildlife use sites, such as nests, dens, and roosts, and especially for studies that also demonstrate selection for higher densities over stand averages.

The management question then becomes one of providing the clumps—how big, how many, and how spaced? Essentially no study has provided answers to these questions. Thus, we analyzed data on snags and down wood collected systematically in one study (Bate, pers. comm.) to determine patterns of clumping within stands. Results suggest that snags and down wood do occur in clumps, or at least nonuniformly within stands (Marcot and others 2002). In this study, observed patterns of snag and down wood distributions (number of snags or down wood pieces per line transect segment) best fit an "independent density" model. This model has fixed intervals along a line with uniform, randomly varying numbers of snags and down wood pieces, rather than a "clump-and-space" model in which uniformly randomly varying clump densities are interspersed with empty spaces that also vary randomly in size.

The better fit of empirical data on snag and down wood dispersion to the "independent density" model suggests that managers can take opportunistic advantage of site-specific occurrences of snags and down wood without having to match a particular spatial distribution pattern of clumps. This offers great flexibility to managers to provide varying local densities of snags and down wood across the ground, within and among stands. Managers would need to add the temporal dimension to this, to ensure that sufficient snag and down wood densities and sizes are provided over successional time.

In some cases, snag or down wood clumps occur because of contagious distributions of fungal rot such as *Armellaria* in conifers and *Phellinus* in aspen, or other wood decay agents. The manager may need to consider the tradeoffs and likelihoods of retaining fungal wood decay agents on further infection of sound wood.

Caveats and Cautions in Using the Cumulative Species Curves

Interpreting the Cumulative Species Curves

The cumulative species curves should not be applied to specific sites or individual stands. The curves represent only a summary of field studies and, in general, what might be expected on average across broad areas such as watersheds or larger areas. Most important, wildlife species richness might not increase as orderly as the curves suggest, on any given site, with increasing size or densities of snags or down wood as the curves suggest, but again this is a scale issue. Species occurrence can vary substantially among areas with different spatial patterns of snags and down wood, surrounding landscape conditions and site histories, and site conditions including presence of tree species and specific wood rot patterns. On a site level, tree species-specific rot patterns greatly influence wildlife species occurrence.

Incomplete Species Lists

No study provided data on all snag-associated species in any given habitat. Thus, the data tables and cumulative species curves in the wildlife component of DecAID provide only a partial insight into the full assemblage of wildlife (and fungi, cryptogams, and vascular plants, as well as invertebrates) that are associated with snags and down wood. In light of this incomplete knowledge, one might use a species rarefaction approach (e.g., James and Rathbun 1981, Palmer 1990, Tackaberry and others 1997) to estimate the full richness of species associated with snags and down wood, although there are potential problems associated with such an extrapolation. For now, we preferred to present just the empirical data.

Smoothing the Curves

The cumulative species curves jitter and bounce from vagaries in everything from sampling design to differences in specific habitat conditions at study sites. One could smooth the curves by using a lowess smoothing algorithm with an appropriate tension (weighting) value (e.g., 0.40) or some other smoothing function. We tested this but chose not to use this, so that the empirical data could be preserved in the curves, showing the conditions for each individual species or species group; smoothed curves would not provide species-specific information. Also, many curves for habitat types and structures not shown here are relatively data poor, and smoothing algorithms would not be appropriate in such cases.

Consider All Uses and Conditions

It is vital that all uses of snags or down wood, such as for breeding, feeding, and roosting, for given species be considered simultaneously when assessing impacts on species or when devising management guidelines. Considering only one type of wildlife use, especially a use that correlates with the smallest or fewest snags or down wood pieces, can prove insufficient to meet population needs.

DecAID and this wildlife component address terrestrial, upland conditions. Additional consideration needs to be made for snags and down wood in riparian, aquatic, and wetland environments.

The data and our synthesis do not explicitly represent some features of snags found to correlate well with some wildlife use. These data were entered into the master spreadsheet but have not been synthesized at this point. Such features include snag height and top condition (Raphael and White 1984). For some cavity-using birds and bats, snag height relative to live canopy height may be more critical than absolute height (Ormsbee, pers. comm.), and live foliage cover near snag cavities may provide important cover for birds (Nelson, pers. comm.).

Also, cautions need to be aimed at interpreting and using data from studies that spanned a variety of vegetation structures, treatments, or seral conditions. In a sense, each point for each species from such a study is a probability cloud itself representing variation among such conditions. Regressions or curves spanning different points may represent spurious relations. This is a major concern in meta-analysis methods of combining data from different studies. The best thing to do is be aware of the conditions in each reported study and interpret results accordingly.

Consider Other Decadence Elements

Some species select for decadence conditions not represented here, specifically hollow trees and logs, and dead parts of live trees. Such elements should be considered in addition to those presented here and will be included in DecAID. In many cases they may be rare enough to warrant complete protection where found, in coordination with health and safety standards.

Consider Use vs. Selection

Data based on patterns of selection (use compared with availability) should be interpreted differently than data based on occurrence or just use with no comparison to availability. Selection, as for particular sizes or densities of snags or down wood, when demonstrated, provides far greater evidence of what is needed to provide for wildlife. Still, use data can be applied to develop helpful guidelines for what to provide while selection studies get underway to test the guidelines.

Understanding the range over which snag or down wood sizes or densities were studied is also important. In some cases, there may appear to be no correlation or selection because more than adequate sizes or densities of snags or down wood were already provided, and the wildlife response had already leveled off.

Even if selection is demonstrated, some species may still be able to persist and even thrive if their preferred sizes or densities of snags or down wood were not available (e.g., Carey and others 1991). However, it is largely impossible to predict this for most species, and it may be prudent nonetheless to provide for sizes or densities according to the empirical selection studies.

Data on stand averages of snag or down wood density may or may not represent unmanaged conditions. Often, we could not determine this from the literature, so great care needs to be exercised when interpreting such data.

Population Response

The ultimate, and really the only authentic, measure of the effectiveness of snag and down wood management guidelines is how well they provide for fit, viable populations. Fitness is the reproductive vitality of offspring, and viability is the persistence of well-distributed populations over the long term. Few if any studies we reviewed truly measure fitness and viability. Thus, a major operating assumption is that wildlife (i.e., plant and animal) populations associated with snags and down wood would be fit and viable if 100 percent of all reported species' needs were met at the high statistical level. This can be empirically tested in large landscapes through an experimental approach, if desired, although such a study would be expensive and take many years. We encourage the reader to devise more tractable ways to model and test this critical assumption.

Under some conditions, populations of snag- and down wood-associated species may be limited by factors other than snag density, size, and condition. For example, based on a simulation model, Raphael (1983) suggested that, in Sierra Nevada mixed conifer forests, secondary cavity-nesting birds may be limited by territoriality rather than cavity abundance when snags are sufficiently numerous to provide nesting habitat for primary cavity-excavating species, at least for a time. His model then suggests that, in a burned forest with no further recruitment of snags, numbers of both primary cavity excavator species and secondary cavity-nesting species are limited by snag abundance as snag numbers decline beyond about year 20.

Remember Hardwoods

The data we gathered inadequately represent how hardwood trees provide for natural or excavated cavities for many species, such as for downy woodpecker *(Picoides pubescens)* and acorn woodpecker *(Melanerpes formicivorous)* in Westside Lowland Conifer/Hardwood Forests. Hardwoods would have to be added to the equation, particularly in forest types in which oaks, maples, and other broadleaf or hardwood species naturally occur.

Conclusions

We provide a new way to synthesize available scientific data on wildlife use of snags and down wood. This approach results in a series of "cumulative species curves" depicting low, moderate, and high statistical levels (means +/- SE or equivalent variant) of species' use of snag density, snag size, down wood cover, and down wood size. This constitutes the wildlife component of the DecAID snag and down wood management advisory model. It provides an empirical and probabilistic "risk analysis" basis for determining snag and down wood management to meet wildlife management goals. It also provides a means of determining the degree to which wildlife species can be provided for a given density and size of snags and down wood by comparing to known use patterns from the literature. This approach provides a replicable framework by which to summarize existing studies, to integrate future studies, and to determine major information needs. The examples we present in this paper are but a small portion of all the literature we reviewed and analyzed *(appendix B)*. Other publications (Marcot and others 2002) will provide the full set of analyses, cumulative species curves, management implications, and research guidelines.

Findings presented here also suggest that secondary cavity-using species associated with snags may use or select for greater snag numbers (or more locally dense snag clumps) and larger diameter snags than many of the primary cavity-excavating wildlife species. This suggests that the assumption used in previous models, that providing for primary species takes care of all species, may be invalid at least in some habitat types. This is also one example of how the wildlife component of DecAID can be used to generate testable working hypotheses for guiding future empirical research.

Acknowledgments

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Appendix A—*Species names and codes used in tables and figures.*

Species codes	Species names
ABBE	American black bear *(Ursus americanus)*
MAKE	American kestrel *(Falco sparverius)*
AMMA	American marten *(Martes americana)*
BBWO	Black-backed woodpecker *(Picoides arcticus)*[1]
BRCR	Brown creeper *(Certhia americana)*
BTWO	Bushy-tailed woodrat *(Neotoma cinerea)*
CBCH	Chestnut-backed chickadee *(Parus rufescens)*[1]
CLSA	Clouded salamander *(Aneides ferreus)*
CNB	Cavity nesting birds (unspecified species group)[1]
DEMO mammals	Several small mammal species included in the DEMO study
DOSQ	Douglas squirrel *(Tamiasciurus douglasii)*
DUSA	Dunn's salamander *(Plethodon dunni)*
ENSA	Ensatina *(Ensatina eschscholtzii)*
EUST	European starling *(Sturnus vulgaris)*
FUNG	Fungus spp. (unspecified species group)
GMGS	Golden-mantled ground squirrel *(Spermophilus lateralis)*
HAWO	Hairy woodpecker *(Picoides villosus)*[1]
HOWR	House wren *(Troglodytes aedon)*
LEWO	Lewis' woodpecker *(Melanerpes lewis)*[1]
MAPG	Mazama (western) pocket gopher *(Thomomys mazama)*
MASH	Marsh (Pacific Water) shrew *(Sorex bendirii)*
MOBL	Mountain bluebird *(Sialia currucoides)*
NFSQ	Northern flying squirrel *(Glaucomys sabrinus)*
NOFL	Northern flicker *(Colaptes auratus)*[1]
NOSA	Northwestern salamander *(Ambystoma gracile)*
NSOW	Northern spotted owl *(Strix occidentalis caurina)*
NTWO	Northern Three-toed Woodpecker *(Picoides tridactylus)*[1]
PCE	Primary cavity excavators (unspecified species group) [1]
PCFR	Pacific chorus frog, = Pacific treefrog *(Pseudacris regilla, = Hyla regilla)*
PGSA	Pacific giant salamander *(Dicamptodon tenebrosus)*
PIWO	Pileated woodpecker *(Dryocopus pileatus)*[1]
PJMO	Pacific jumping mouse *(Zapus trinotatus)*
PYOW	Northern pygmy-owl *(Glaucidium gnoma)*
RBNU	Red-breasted nuthatch *(Sitta canadensis)*[1]
RBSA	Red-breasted sapsucker *(Sphyrapicus ruber)*[1]
RONE	Rough-skinned newt *(Taricha granulosa)*
SCNB	Secondary cavity-nesting birds (unspecified species group)
SHMO	Shrew-mole *(Neurotrichus gibbsii)*
SMMA	Small mammals (unspecified species group)
SPFR	Spotted frog *(Rana pretiosa)*
SPSK	Spotted skunk *(Spilogale putorius)*
SRBV	Southern red-backed vole *(Clethrionomys gapperi)*
STWE	Shorttail weasel *(Mustela erminea)*
TOCH	Townsend's chipmunk *(Eutamias townsendi)*
TOVO	Townsend's vole *(Microtus townsendii)*

(*appendix A* continued)

Species code	Species name
TRSW	Tree swallow *(Iridoprocne bicolor)*
VASH	Vagrant shrew *(Sorex vagrans)*
WEBL	Western bluebird *(Sialia mexicana)*
WHHO	White-headed woodpecker *(Picoides albolarvatus)*[1]
WIWR	Winter wren *(Troglodytes troglodytes)*
WRSA	Western red-backed salamander *(Plethodon vehiculum)*

[1] Primary cavity-excavating species. All others are secondary cavity-using species or down wood-using species.

Appendix B—*The full set of habitat types and structures for which snag and down wood data have been synthesized for use in the wildlife component of the DecAID advisory model. The full data sets, table summaries, and confidence curves for snag and down wood amounts and sizes will be presented elsewhere.*

Parameter	Habitat type	Habitat structure	Type of wildlife use	Examples given in this paper
Snag density (no. snags per ha)	Eastside mixed conifer/ponderosa pine forest	post-fire	nesting/breeding	*table 1, figure 1*
	Eastside mixed conifer forest	forested	nesting/breeding and roosting/resting	
	Ponderosa pine forest	various	nesting/breeding and roosting/resting	
	Upland aspen forest	forested	nesting/breeding	
	Westside lowland conifer/hardwood forest	various	nesting/breeding	*table 1, figure 2*
	Westside lowland conifer/hardwood forest	clearcut plantations	nesting/breeding	
	Montane mixed conifer/lodgepole pine forest	various	roosting/denning	
Snag size (diameter)	Eastside mixed conifer/Ponderosa pine forest	post-fire	nesting/breeding	*table 2, figure 3*
	Eastside mixed conifer/ponderosa pine forest	various	foraging	
	Eastside mixed conifer forest	various	roosting/resting	
	Eastside mixed conifer forest	various (forested mosaic)	nesting/breeding	
	Ponderosa pine forest	various (forested mosaic)	nesting/breeding	
	Ponderosa pine forest	various	roosting/resting	
	Upland aspen forest	forested	nesting/breeding	

(*appendix B* continued)

Parameter	Habitat type	Habitat structure	Type of wildlife use	Examples given in this paper
Snag size (diameter)	Westside lowland conifer/hardwood forest	clearcut plantations	nesting/breeding	
	Westside lowland conifer/hardwood forest	various	nesting/breeding	*table 2, figure 4*
	Westside lowland conifer/hardwood forest	various forested	roosting/resting	
	Westside lowland conifer/hardwood forest	various	foraging	
	Lodgepole pine forests and woodlands	various	nesting/breeding	
	Lodgepole pine forests and woodlands	various	roosting/resting	
	Lodgepole pine forests and woodlands	various	foraging	
	Montane mixed conifer forest	various	nesting/breeding	
Down wood cover (percent)	Eastside mixed conifer forest	various	density and foraging	*table 3, figure 5*
	Southwest Oregon mixed conifer-deciduous forest	various	presence and nesting	
	Westside lowland conifer/hardwood forest	various	presence, abundance, and nesting	*table 3, figure 6*
	Lodgepole pine/subalpine fir forest	mature forest	nesting and density	
Down wood size (diameter)	Eastside mixed conifer/ponderosa pine	various	presence and foraging	*table 4, figure 7 (combined)*
	Westside lowland conifer/hardwood forest	various	presence and selection	*table 4, figure 7 (combined)*
	Lodgepole pine/montane forest	various	breeding and resting	