NSO Habitat "Treat and Maintain" Canopy Cover Requirements vs. Canopy Condition References in Supporting Literature

Introduction:

The BLM and USFS are currently trying to minimize the impacts of their commercial thinning projects so that they can be categorized as "may effect but not likely to adversely effect" northern spotted owls (NSO). This treatment is categorized as "treat and maintain." The USFWS has established canopy condition requirements that must be met in order for them to concur with the "not likely to adversely effect" determination. The requirements are that NRF habitat must maintain at least 60% canopy cover and dispersal habitat must maintain at least 40% canopy cover in order to maintain its habitat standing. A review of the supporting literature (Appendix C) reveals that the vast majority of on-the-ground research associated with NSO use of habitat actually measured canopy closure rather than canopy cover and many research papers used the term interchangeably. In reality, canopy cover and canopy closure are very different and canopy cover is typically 15% to 40% lower than canopy closure in canopy closure ranges of 30% to 70% (see Appendix B and discussion below).

Canopy cover is a measure of whether or not a specific point on the forest floor has canopy directly above it or not (see Appendix A). Tools used to determine such a canopy condition (vertical densitometer or "moose horn") look straight up from a single point on the forest floor and record a "yes" or "no" as to whether the cross hairs hit canopy when the tool is held perfectly vertical. However, much of the scientific literature cited by the USFWS in developing the rules specifically measured (or aggregated studies that measured) "canopy closure," which is a measurement of the percentage of sky (or inversely, canopy) that can be seen in a hemisphere surrounding a given point on the forest floor (measured by a concave or convex spherical densitometer). As measurements of canopy cover are typically lower than those of canopy closure, the current rules are preventing critical management and restoration activities in spotted owl habitat by maintaining a canopy condition threshold that is both artificially high and not scientifically necessary for the maintenance of various habitat conditions.

a) The terms canopy "cover" and "closure" are different measurements, are not interchangeable, and there is inconsistent use of the terms in the cited literature

The terms canopy closure and canopy cover are used inconsistently and in many cases interchangeably in the research papers that conclude that the condition of the canopy is important to spotted owls. While the two measurements are somewhat related, they are not interchangeable, and the most common tools used to measure each type of canopy condition are not especially accurate at assessing each type of canopy condition. This problem can lead to inconsistent management of forest resources. Hyunh 2005.

For example, in Bond et al. 2009 (a paper cited in the 2011 Recovery Plan used to develop the 60% and 40% canopy cover requirements), the researchers refer to the data they are collecting as including "canopy cover." However, the researchers measured this condition using a spherical densitometer, which measures canopy closure, not cover, and this study is important as it provided part of the basis for current cover requirements. Again, in Lehmkuhl et al. 2006, the researchers estimated "canopy cover by [using] a convex spherical densitometer," a tool used for measuring canopy closure. Courtney et al. 2004 incorrectly defined canopy closure as "total cover of all plant growth forms above a point on the forest floor."

Thomas et al. 1990, a study widely cited in both the Recovery Plan and the 2012 Critical Habitat Rule, cite canopy closure at least 26 times and canopy cover only in a couple and those when they are recommending the 40% and 60% standard. Thomas et al. 1990 itself doesn't even define canopy cover and canopy closure is defined as "the degree to which the crowns of trees are nearing general contact with one another." It is clear that Thomas et al. used the two terms as being synonymous and should have used canopy closure instead of cover in its recommendations.

The 2012 Critical Habitat Rule also interchanges the two terms. In the background section, a study is cited describing canopy condition as "cover" when in fact the study (while getting the terminology wrong in its own right) actually measured closure. *See* Lehmkuhl et al. 2006, Irwin et al. 2000.

It is important that consistent methods are used to determine canopy condition, as either cover or closure measure different characteristics of the forest canopy and are not interchangeable. Studies have shown that when a spherical densitometer is used to measure canopy cover (a tool normally used for measuring closure) that the results are 15 - 25% lower than methods calibrated to properly measure canopy cover. *See* Cook et al. 1995, Fiala et al. 2006, and Korhonen et al. 2006. This might mean that studies that actually measured canopy closure (though they were labeled canopy cover) were used to develop the standards in the 2012 Rules, and Rules have since established the standards in terms of canopy cover in the consultation process. In essence the Rules may now require using a standard that requires 15 - 25% more canopy then is scientifically necessary and these potentially unnecessarily high standards are limiting needed forest management in spotted owl habitat.

b) There is little research to suggest that "cover" is a favorable measurement over "closure" in determining NSO habitat.

While it is indisputable that studies show that canopy condition is important to spotted owl habitat, none of the studies suggest how or why a measure of canopy cover is a superior measurement for the spotted owl, especially for the purposes of science-based regulation, than a measure of canopy closure. The studies have documented correlations between high canopy cover

and the presence of habitat for spotted owls. However, as outlined above, many of the studies (either intentionally or mistakenly) also found a correlation between the presence of spotted owl habitat and instances of high canopy closure. And as these two measures of canopy condition are related (i.e. canopy closure, in looking at the entire observable hemisphere, necessarily includes the point directly above the observer), it would suggest that stands (or even individual plots) with high canopy cover would often also be stands that have high canopy closure.[1] However, as cover and closure measure canopy condition in different ways, the specific numbers derived from those measurements are not interchangeable.

The studies mention a number of reasons why canopy condition is important to owls. Some of these reasons include: thermal cover (Weathers et al. 2001), prey habitat (Lehmkuhl et al. 2006a, Lehmkuhl et al. 2006b, Lehmkuhl et al. 2008), and protection from predators (Thomas et al. 1990), among others. Some of these studies and others cited by the USFWS measured cover, others closure. Others still suggested that canopy layering was at least as important, if not more so, to spotted owls than the discreet measure of cover or closure. Mills et al. 1993.[2] However, none of them discussed why the measurement of cover was superior to measuring closure in terms of assessing these important characteristics of spotted owl habitat. In fact, there seems to be little reason to think that these important habitat conditions would not be better accounted for by measuring canopy closure as opposed to only measuring vertical canopy cover. In other words, a spotted owl would probably assess the canopy condition of its habitat in a hemisphere of all surrounding canopy, not only canopy cover directly above.

Conclusion:

The measurements of canopy closure and canopy cover are fundamentally two different assessments of canopy condition. The data gathered from the two methods are not interchangeable, yet the critical habitat rules, and many of the studies used inform those rules, appear to treat these two measurements as interchangeable. This has led to rules that might not reflect what the science of spotted owls is telling us.[3] At the very least, consistency and care should be exercised to ensure

[1] It should be noted that a measurement of canopy cover, since it only looks directly above a point on the forest floor, could miss large spots of open sky along stand edges and other canopy openings, and not necessarily represent the true nature of the canopy condition at that plot point, at least in terms of what a spotted owl might prefer as it travels through the forest. Assuming that spotted owls prefer high percentages of canopy, a vertical measurement of cover may or may not account for the discrepancy of the stand edge, whereas a hemispherical measure of canopy closure surely would account for a stand edge.

[2] "In our study, vertical canopy layering was a much better predictor of spotted owl presence than total canopy cover, and factors such as tree size, vegetation and log [ground] cover, and tree species composition were relatively unimportant predictors."

[3] For example, if a study calls for 60% canopy closure, and that study is used to set a rule calling for 60% canopy cover, the rule has essentially reached far beyond what the science has called for and effectively used a study calling for 60% canopy closure to justify a requirement for 75 – 85% canopy closure.

that the proper terms are used to describe the proper assessments of canopy condition, and the rules should be written to reflect the proper assessment.

Additionally, there is little reason to think that the use of a measurement of canopy cover is superior to canopy closure. Nearly all of the habitat conditions associated with canopy cover can be properly assessed using canopy closure, and many field-based studies cited by the USFWS show that it can be an effective measurement of spotted owl canopy conditions. Finally, the fact that a spherical densitometer actually attempts to measure canopy condition as it is experienced by spotted owls (not simply in one arbitrary direction but all around) should also support the use of canopy closure measurements in spotted owl critical habitat rules and consultations.

Literature Cited:

Bond, M.L., D.E. Lee, R.B. Siegel and J.P. Ward, Jr. 2009. Habitat use and selection by California spotted owls in a postfire landscape. J. Wildlife Man. 73:1116-1124.

Cook, J.G., T.W. Stutzman, C.W. Bowers, K.A. Brenner, and L.L Irwin. 1995. Spherical densiometers produce biased estimates of forest canopy cover. Wildlife Soc. Bulletin 23(4): 711-717.

Courtney, S.P., J.A. Blakesley, R.E. Bigley, M.L. Cody, J.P. Dumbacher, R.C. Fleischer, A.B. Franklin, J.F. Franklin, R.J. Gutiérrez, J.M. Marzluff and L. Sztukowski. 2004. Scientific evaluation of the status of the northern spotted owl. Sustainable Ecosystems Institute, Portland, OR.

Fiala, A.C.S., S.L. Garman, A.N. Gray. 2006. Comparison of five canopy cover estimation techniques in the western Oregon Cascades. Forest Ecol. and Man. 232: 188-197.

Hyunh, M.L. 2005. Assessment of various methods of canopy cover estimation that yield accurate results with field repeatability. M.Sc. thesis. Northern Arizona Univ., Flagstaff, AZ.

Irwin, L.L., D.F. Rock and G.P. Miller. 2000. Stand structures used by northern spotted owls in managed forests. J. Raptor Research 34:175–186

Korhonen, L., K.T. Korhonen, M. Routiainen, and P. Stenberg. 2006. Estimation of forest canopy cover: a comparison of field measurement techniques. Silva Fennica 40(4): 577-588.

Lehmkuhl, J.F., K.D. Kistler and J.S. Begley. 2006a. Bushy-tailed woodrat abundance in dry forests of eastern Washington. J. Mammalogy 87:371-379.

Lehmkuhl, J.F., K.D. Kistler, J.S. Begley and J. Boulanger. 2006b. Demography of northern flying squirrels informs ecosystem management of western interior forests. Ecol. Appl. 16:584-600.

Lehmkuhl, J.F., Peffer, R.D., O'Connell, M.A. 2008. Riparian and upland small mammals on the east slope of the Cascade Range, Washington. Northwest Sci. 82(2): 94–106.

Mills, L.S., R.J. Frederickson, and B.B. Moorhead. 1993. Characteristics of old-growth forests associated with northern spotted owls in Olympic National Park. J. Wildlife Man. 57:315-321.

Thomas, J.W., E.D. Forsman, J.B. Lint, E.C. Meslow, B.R. Noon, and J. Verner. 1990. A conservation strategy for the northern spotted owl. A report by the Interagency Scientific

Committee to address the conservation of the northern spotted owl. USDA Forest Service, and U. S. Dept. of the Interior, Fish and Wildlife Service, Bureau of Land Management, and National Park Service. Portland, OR.

U.S. Fish and Wildlife Service. 2011. Revised Recovery Plan for the Northern Spotted Owl (Strix occidentalis caurina). U.S. Fish and Wildlife Service, Portland, Oregon. xvi + 258 pp.

[U.S. Fish and Wildlife Service.] Endangered and Threatened Wildlife and Plants; Designation of Revised Critical Habitat for the Northern Spotted Owl, 77 Fed. Reg. 71,876 (Dec. 4, 2012) (to be codified at 50 CFR pt. 17).

Weathers, W.W., P.J. Hodum and J.A. Blakesley. 2001. Thermal ecology and ecological energetics of California spotted owls. Condor 103:678-690.

Appendix A

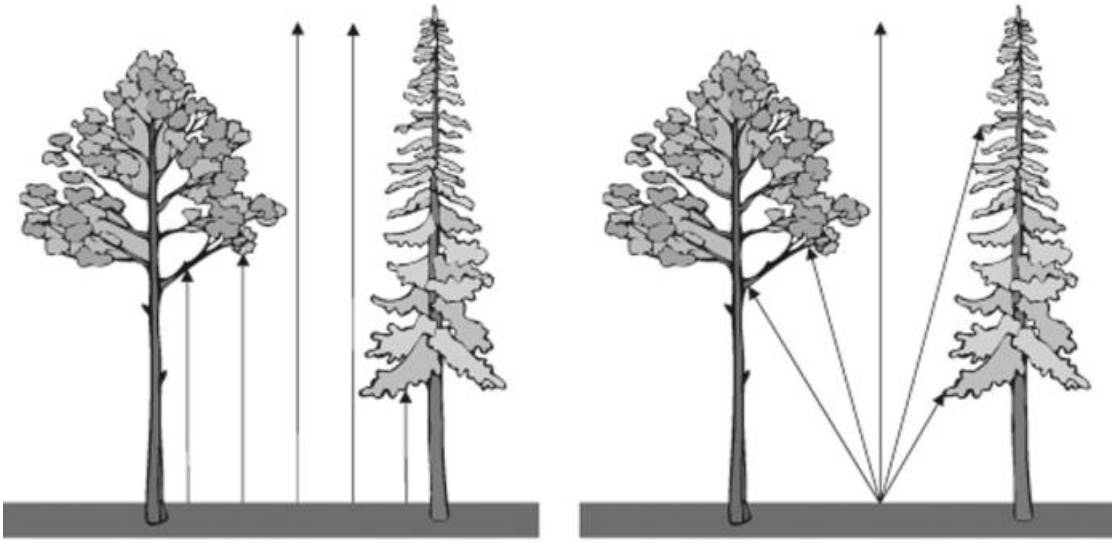
Canopy Cover vs. Canopy Closure

Canopy cover:

> The proportion of the forest floor covered by the vertical projection of the tree crowns

Canopy closure:

> The proportion of sky hemisphere obscured by vegetation when viewed from a single point



Canopy cover (left) is always measured in vertical direction, whereas canopy closure (right) involves an angle of view.

Appendix B

Habitat Relationships of Northern Spotted Owls (Strix occidentalis caurina) on Timber Products Forestlands in Northern California, Stuart Farber Ryan Crans June 1, 2000

Table 15 Inventory of Structure and Canopy Closure – Commercial Thinning

Metric	Structure (/Acre)	Canopy Closure (Concave) Densiometer	Canopy Closure (Convex) Densiometer	Canopy Closure (Siting Tube)
Mean for All Stands	2.01 /acre	62 %	66 %	46 %
Dense Comm.Thin	0.84	70 %	72%	52 %
Open & Moderate Comm Thin	2.37	60 %	66 %	43 %

Monitoring Results of Alternative Watercourse and Lake Protection Zones in the Etna Creek Watershed in interior, Northern California. Stuart Farber,Timber Products Company 2010

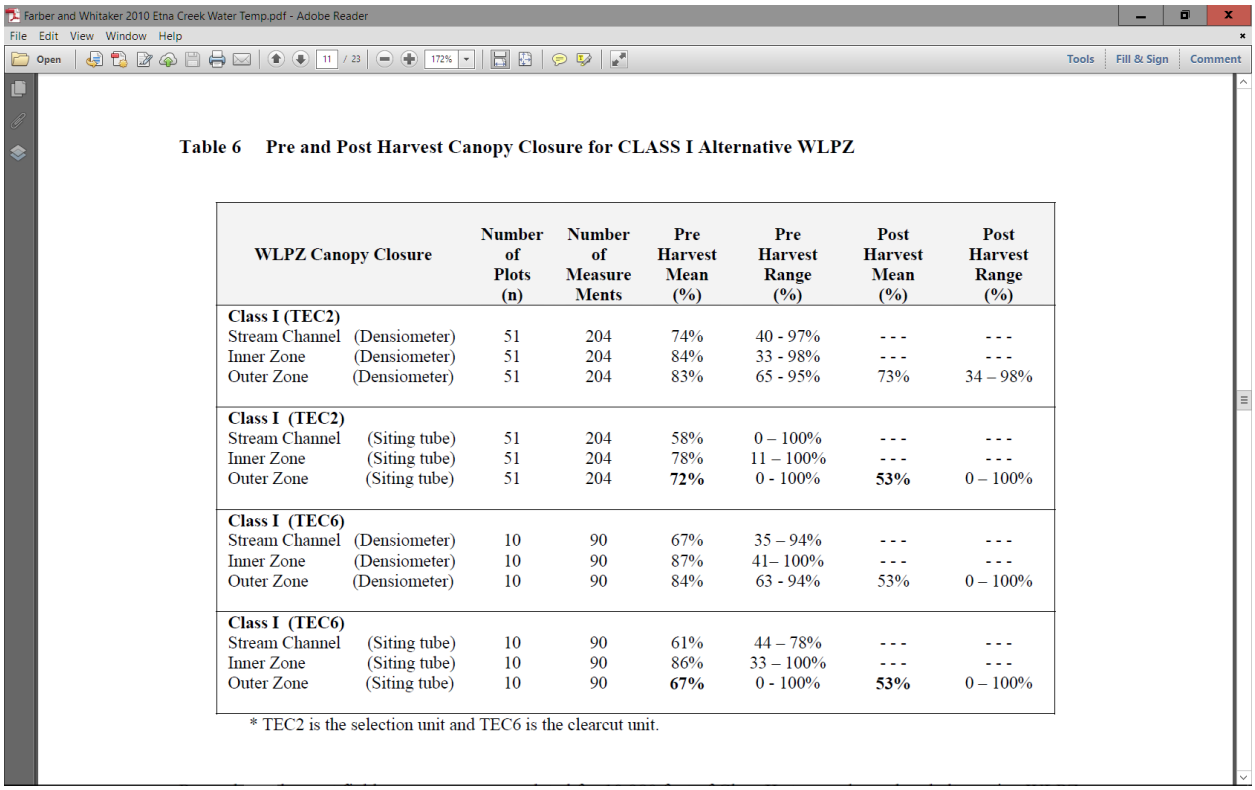


Table 6 Pre and Post Harvest Canopy Closure for CLASS I Alternative WLPZ

WLPZ Canopy Closure		Number of Plots (n)	Number of Measure Ments	Pre Harvest Mean (%)	Pre Harvest Range (%)	Post Harvest Mean (%)	Post Harvest Range (%)
Class I (TEC2)							
Stream Channel	(Densiometer)	51	204	74%	40 - 97%	- - -	- - -
Inner Zone	(Densiometer)	51	204	84%	33 - 98%	- - -	- - -
Outer Zone	(Densiometer)	51	204	83%	65 - 95%	73%	34 – 98%
Class I (TEC2)							
Stream Channel	(Siting tube)	51	204	58%	0 – 100%	- - -	- - -
Inner Zone	(Siting tube)	51	204	78%	11 – 100%	- - -	- - -
Outer Zone	(Siting tube)	51	204	**72%**	0 - 100%	**53%**	0 – 100%
Class I (TEC6)							
Stream Channel	(Densiometer)	10	90	67%	35 – 94%	- - -	- - -
Inner Zone	(Densiometer)	10	90	87%	41– 100%	- - -	- - -
Outer Zone	(Densiometer)	10	90	84%	63 - 94%	53%	0 – 100%
Class I (TEC6)							
Stream Channel	(Siting tube)	10	90	61%	44 – 78%	- - -	- - -
Inner Zone	(Siting tube)	10	90	86%	33 – 100%	- - -	- - -
Outer Zone	(Siting tube)	10	90	**67%**	0 - 100%	**53%**	0 – 100%

* TEC2 is the selection unit and TEC6 is the clearcut unit.

Appendix C

Canopy Closure and Canopy Cover Literature References

T**he bolded citations are those that were directly cited in the primary source materials** (i.e. recovery plan, critical habitat rule, BiOps, etc.). Additionally, cited studies that could not be easily found or accessible (e.g. study is behind a pay-wall) will have the citation written in red font.

The color coding in the text to delineate the general area of the study cited:

Field Study with Canopy Measurement
Field Study without Canopy Measurement
Remote Sensing used for Canopy Measurement
Computer Model
Literature Review

Revised Recovery Plan for the NSO – 2011

I. REFERENCES TO CANOPY CLOSURE IN PRIMARY MATERIALS (proportion of sky hemisphere obscured by veg. Measured with a spherical densitometer.)

A. Revised Recovery Plan for the NSO – 2011

1. Pg III-30: "In addition, roost sites from which stand measurements were taken had high levels of canopy closure (i.e., greater than 60 percent) and a large tree component, regardless of burn severity (Clark 2007, Bond et al. 2009)."

a. Clark, D.A. 2007. Demographic and habitat selection of northern spotted owls in post-fire landscapes of southwestern Oregon. Thesis, Oregon State University, Corvallis, Oregon.

i. Pg 11: "Within each 15m fixed radius ground plot, I estimated fire severity using a modified composite burn index (CBI) (Key and Benson 1999a), obtained an estimate of canopy closure and measured diameter at breast height (DBH) of dominant trees."

ii. Pg 20: "Furthermore, forest stands used by spotted owls usually have large proportions of down woody debris and snags, high canopy closure, and high structural diversity (Forsman et al. 1984, Thomas et al. 1990, Hershey et al. 1998, North et al. 1999, Irwin et al. 2000)."

iii. Pg 96: "Overstory canopy cover was estimated using a densitometer and averaging canopy cover values at 13 points within the plot (1 point at the plot center, and 3 points evenly placed in each cardinal direction)."

NOTE: Clark 2007 appears to use the term "closure" and "cover" interchangeably. However, author primarily uses "cover" throughout the paper describing his own methods. Author does not specify which kind of "densiometer" is used in the study, though the method described seems to suggest a vertical densiometer.

iv. Pg 113: “This was a surprising result, which I did not predict because high severity burns were previously thought of as unsuitable owl habitat, as it no longer provided sufficient overstory canopy cover, structural complexity, and downed wood (Mills et al. 1993, Buchanan et al. 1995, North et al. 1999, Herter et al. 2002).”

v. Pg 126: “Spotted owl habitat with high severity burn was previously thought of as unsuitable habitat because it no longer provided sufficient canopy cover, structural complexity, and downed wood (Mills et al. 1993, Buchanan et al. 1995, North et al. 1999, Herter et al. 2002).”

vi. Additional References from Clark 2007:

- Buchanan, J.B., L.L. Irwin, and E.L. McCutchen. 1995. Within-stand nest site selection by spotted owls in the eastern Washington Cascades. Journal of Wildlife Management 59(2):301-310.

- Herter, D.R., L.L. Hicks, H.C. Stabins, J.J. Millspaugh, A.J. Stabins, and L.D. Melampy. 2002. Roost site characteristics of northern spotted owls in the nonbreeding season in central Washington. Forest Science 48:437-446.
  - Pg 439: “Overstory canopy cover (%) of the roost site was estimated using a moosehorn densiometer (Robinson 1947, Garrison 1949) at the four cardinal points 8 m from the roost tree.”

- Mills, L.S., R.J. Frederickson, and B.B. Moorhead. 1993. Characteristics of old-growth forests associated with northern spotted owls in Olympic National Park. Journal of Wildlife Management 57:315-321.
  - Pg 317: “We visually estimated overhead canopy cover at different heights from the center of the reconnaissance plot (see Vales and Bunnell 1988 for favorable comparison between this and more objective methods).”
  - Pg 317: “We recorded, in 10% cover classes, the percent of the sky covered by canopy in each of the following vertical layers: 2-10 m, 11-20 m, 21-30 m, 31-40 m, and >40 m. All 5 overhead layers were summed to calculate an index to vertical canopy layering (VERT) that incorporated the height of the stand as well as the amount and the distribution of foliage in the canopy.”
  - Pg 319: “In our study, vertical canopy layering was a much better predictor of spotted owl presence than total canopy cover, and factors such as tree size, vegetation and log cover, and tree species composition were relatively unimportant predictors.”

- North, M.P., J.F. Franklin, A.B. Carey, E.D. Forsman, and T. Hamer. 1999. Forest stand structure of the northern spotted owl’s foraging habitat. Forest Science 45:520-527.
  - Pg 523: “Canopy cover was measured using the average of 10 moosehorn readings (a modified funnel topped with a clear sighting grid with 100 points) systematically collected at each plot.”

b. Bond, M.L., D.E. Lee, R.B. Siegel and J.P. Ward, Jr. 2009. Habitat use and selection by California spotted owls in a postfire landscape. Journal of Wildlife Management 73:1116-1124.

i. Pg 1116: "Because California spotted owl nests and roosts are associated with older forests and high tree-canopy cover (Bias and Gutie´rrez 1992, Call et al. 1992, Gutie´rrez et al. 1992, Moen and Gutie´rrez 1997, Bond et al. 2004), many forest managers postulate that high-severity fires could have a negative impact on persistence of the species and, therefore, believe that fire poses the greatest risk to owl habitat [citation omitted].

ii. Pg 1118: "At each of the 80 sites, we measured tree-canopy cover, tree size by condition (dead or alive), herb and shrub cover, and size and number of fallen logs, and we assessed vegetation burn severity… We measured canopy cover by taking a spherical densitometer reading every meter for 50 readings."

iii. Pg 1120: "Sampled roost sites averaged tree-canopy cover of 63% (SE 5 3.5), similar to unburned forests, a mean tree diameter at breast height of 63 cm (SE 5 3.6), and a high basal area of large trees, averaging 30 m2/ha (SE 5 3.2)."

NOTE: Actually a measure of canopy closure, based on methods, plus or minus the margin of error.

iv. Pg 1122: "Our field-sampled roost sites had an average tree-canopy cover >60% and were dominated by large trees. California spotted owl roost sites in previous studies also were characterized by higher canopy cover and larger diameter trees (Call et al. 1992, Gutie´rrez et al. 1992, Moen and Gutie´rrez 1997)."

v. Additional references from Bond et al.

- Bias, M. A., and R. J. Gutierrez. 1992. Habitat associations of California spotted owls in the central Sierra Nevada. Journal of Wildlife Management 56:584–593.
  - References and measures "canopy closure" percentages throughout, especially in results section. Methods section does reference "canopy cover" classes.

private land. Habitat types of mixed-conifer, large-tree successional stage, with ≥70% total canopy closure were most abundant (38.1%) on public land; whereas mixed-conifer, pole-medium successional stage, with ≥70% total canopy closure habitat types dominated private land (44.1%). Roost sites occurred in habitats with relatively greater total canopy closure, and basal areas of snags, medium, and old-growth trees than the abundance of habitat (Johnson 1980). Nests of owls occurred in habitats with relatively greater basal areas of live trees, snags, medium, mature, and old-growth trees; and total canopy closure than found in the abundance of habitat. Twenty-six of 29 observed roosts (89.7%) and all 11 owl nests were on public land.

- Call, D. R., R. J. Gutierrez, and J. Verner. 1992. Foraging habitat and home-range characteristics of California spotted owls in the Sierra Nevada. The Condor 94:880–888.
  - References and measurements to "crown closure" and "canopy closure," as well as "cover classes."

- Pg. 882: "[Call, D. R. 1990. Home-range and habitat use by California Spotted Owls in the central Sierra Nevada. M.Sc.thesis. Humboldt State Univ.. Arcata. CA] presented a complete description of our variables and measurement techniques."
- Pg 884 (Table 2): "Plot Variable: Percent canopy closure[f]" → footnote f: "Estimated with concave densitometer."

- Moen, C. A., and R. J. Gutierrez. 1997. California spotted owl habitat selection in the central Sierra Nevada. Journal of Wildlife Management 61:1281–1287.

- Bond, M. L., R. J. Gutierrez, and M. E. Seamans. 2004. Modeling nesting habitat selection of California spotted owls (Strix occidentalis occidentalis) in the central Sierra Nevada. Forest Science 50:773–780.
  - Pg 775: "To estimate canopy cover, we recorded overstory using a vertical densitometer (Stumpf 1993) at 1-m intervals beginning at meter 1 and proceeding along the center line of the plot for 100 readings. Canopy cover for each plot was expressed as the percentage of readings with closed canopy above sample points."

2. **Pg III-55: "Due to its potential impact on forest dynamics and alteration of key prey and spotted owl habitat components (e.g., hardwood trees, canopy closure, and nest tree mortality), sudden oak death poses a potential threat to spotted owls, especially in the southern portion of the spotted owl's range (Courtney et al. 2004)."**

   a. **Courtney, S.P., J.A. Blakesley, R.E. Bigley, M.L. Cody, J.P. Dumbacher, R.C. Fleischer, A.B. Franklin, J.F. Franklin, R.J. Gutiérrez, J.M. Marzluff and L. Sztukowski. 2004. Scientific evaluation of the status of the northern spotted owl. Sustainable Ecosystems Institute, Portland, Oregon.**
      i. Pg 4-6: "Solis and Gutiérrez found that canopy closure (as defined by the total cover of all plant growth forms above a point on the forest floor) was highest in roosting habitat, and lowest in areas infrequently used for foraging (typically on the edge of a home range)."

      - Solis, D.M., and R.J. Gutierrez. 1990. Summer habitat ecology of northern spotted owls in northwestern California. Condor 92(3): 739-748.

      NOTE: inconsistent definition of canopy closure?

      ii. Pg 4-18, 19: "Note however Solis and Sisco commented on owls foraging along the edges of such clearcuts and old growth. Young forests have 'low vertical diversity of vegetation and high canopy closure with few low structures beneath the canopy that would be suitable as hunting perches', therefore are 'structurally poor for sit-and-wait predators' (Carey et al. 1992:246)."
      - Carey, A.B., S.P. Horton, and B.L. Biswell. 1992. Northern spotted owls: influence of prey base and landscape character. Ecological Monographs 62(2):223-250.

NOTE: the terms "overhead cover" and "lateral cover" is also used in Carey et al 1992 to describe roost sites. There is no real mention of how "cover" or "closure" was determined for the study, although specific values are used to describe it.

- Cite from quote above: Carey, A. B., M. M. Hardt, S. P. Horton, and B. L. Biswell. 1991 b. Spring bird communities in the Oregon Coast Ranges. Pages 123-144 in L. F. Ruggiero, K . B. Aubry, A . B. Carey, and M. H. Huff, technical coordinators. Wildlife and vegetation of unmanaged Douglas-fir forests. United States Forest Service General Technical Report PNW-285. (no information was found on how they measured canopy closure or cover.).

iii. Pg 5-3: "Thomas et al. (1990:164) characterized Northern Spotted Owl habitat as follows: 'Structural components that distinguish superior Spotted Owl habitat from less suitable habitat in Washington, Oregon, and northwestern California include: a multilayered, multispecies canopy dominated by large (>30 inches in d.b.h.) conifer overstory trees, and an understory of shade-tolerant conifers or hardwoods; a moderate to high (60 to 80%) canopy closure; substantial decadence in the form of large, live coniferous trees with deformities—such as cavities, broken tops, and dwarf mistletoe infections; numerous large snags; ground-cover characterized by large accumulations of logs and other woody debris; and a canopy that is open enough to allow owls to fly within and beneath it.'"

- Thomas, J.W., E.D. Forsman, J.B. Lint, E.C. Meslow, B.R. Noon, and J. Verner. 1990. A conservation strategy for the northern spotted owl. A report by the Interagency Scientific Committee to address the conservation of the northern spotted owl. USDA, Forest Service, and U. S. Department of the Interior, Fish and Wildlife Service, Bureau of Land Management, and National Park Service. Portland, OR.

NOTE: "Cover" (at [28, 147, 162] [all in tables], 166, 274 (referencing Appx P where term "closure" is used) and "closure" are used interchangeably in Thomas et al. 1990. Most values are labelled as "canopy closure." In the glossary, pg 416, canopy closure is defined as: "the degree to which the crowns of trees are nearing general contact with one another."

- Additional cited studies using labeled as using "cover" in Thomas et al. 1990:
  LaHaye, W. S. 1988. Nest site selection and nesting habitat of the northern spotted owl (Strix occidentalis caurina) in northwestern California. M.S. Thesis, Humboldt State Univ., Arcata, Calif. 111pp.

  Hays, D. W., H. L. Allen, L. H. Egtvedt, and K. R. Dixon. 1989b unpubl. Home range size and habitat use of spotted owls in Washington: Preliminary report. Wash. Dep. Wildl. Manage. Nongame, Olympia. 30pp.

  Thrailkill, J. A., and E. C. Meslow. 1989 unpubl. Home range size and habitat utilization of northern spotted owls in the Wolf Creek Study area, Eugene BLM District, Oregon. Progress Rep. for 1 June

1987-1 September 1989. Oregon Wildl. Res. Unit, Oreg. State Univ., Corvallis. 26pp.

Thrailkill, J. A., and E. C. Meslow. 1990 unpubl. Home range size and habitat utilization of northern spotted owls in the Wolf Creek Study area, Eugene BLM District, Oregon: Draft final rep. Oreg. Coop. Wildl. Res. Unit, Oreg. State Univ. Corvallis. 68pp.

Allen, H.L., K.R. Dixon, and K. L. Knutson. 1989 unpubl. Cooperative administrative study to monitor spotted owl management areas in National Forests in Washington: Final report. Wash. Dep. Wildl., Olympia. 165pp.

iv. Pg 5-4: "Stand condition is a general classification based on species composition, tree age or size, canopy closure, fire regime, soil, climate and/or topographic characteristics … At a finer spatial scale, forest structure (canopy cover, tree diameter distribution, snag density, coarse woody debris, etc.) was quantified from detailed measurements at nest, roost, and random locations."

- Buchanan, J.B., L.L. Irwin, and E.L. McCutchen. 1995. Within-stand nest site selection by spotted owls in the Eastern Washington Cascades. J. Wildlife Management 59(2):301-310. (See above at I.A.1.a.vi.)

- Oliver, C.D. 1981 [1980]. Forest development in North America following major disturbances. Forest Ecology and Management 3:153-168.

3. **Pg III-60, 61 (Table III-1): fn 2"Nest-Roost habitat in California is generally defined as 60-90% canopy closure, multi-layered/species canopy with trees >30 inches diameter, trees with deformities, woody debris on ground and open space below canopy to allow spotted owls to fly."**

4. **Pg A-8: "Habitat supporting the transience phase of dispersal contains stands with adequate tree size and canopy closure to provide protection from avian predators and minimal foraging opportunities … While the stand-level and landscape-level attributes of forests needed to facilitate successful dispersal have not been thoroughly evaluated (Buchanan 2004), an early attempt to describe dispersal conditions in the Interagency Scientific Committee (ISC) Report (Thomas et al. 1990) recommended managing the forested landscape such that 50 percent of each quarter-township has a mean diameter at breast height (dbh) of at least 11 inches and a canopy closure of at least 40 percent (the 50-11-40 rule)."**
   a. **Buchanan, J.B. 2004. Managing habitat for dispersing northern spotted owls - are the current management strategies adequate? Wildlife Society Bulletin 32:1333-1345.**

   NOTE: Buchanan 2004 examines several different studies and HCPs to come up with the range of management techniques employed so far (see Pg 1338, Table 1). In those various studies, a mix of canopy "cover" and "closure" values are given as potential standards.

i. Miller,G. S., R. J. Small, and E. C. Meslow. 1997. Habitat selection by spotted owls during natal dispersal in western Oregon. Journal of Wildlife Management 61:140–150.

b. Thomas et al. 1990. A conservation strategy for the northern spotted owl. (see above at I.A.2.a.iii.)

5. **Pg A-10: "Features that support nesting and roosting typically include a moderate to high canopy closure (60 to 90 percent); a multilayered, multi-species canopy with large overstory trees (with dbh of greater than 30 inches); a high incidence of large trees with various deformities (large cavities, broken tops, mistletoe infections, and other evidence of decadence); large snags; large accumulations of fallen trees and other woody debris on the ground; and sufficient open space below the canopy for spotted owls to fly (Thomas et al. 1990)."**

   a. **Thomas et al. 1990. A conservation strategy for the northern spotted owl.** (see above I.A.2.a.iii).

6. **Pg A-10: "Forested stands with high canopy closure also provide thermal cover (Weathers et al. 2001) and protection from predators."**

   a. Weathers, W.W., P.J. Hodum and J.A. Blakesley. 2001. Thermal ecology and ecological energetics of California spotted owls. Condor 103:678-690.
   i. Pg 686: "On a landscape scale, Spotted Owls prefer relatively cool old-growth or late seral stage forests characterized by high structural diversity, large numbers of residual trees, and a high degree of canopy closure (LaHaye et al. 1997, Moen and Gutie´rrez 1997).

   - LaHaye, W. S., R. J. Gutierrez, and D. R. Call. 1997. Nest-site selection and reproductive success of California Spotted Owls. Wilson Bulletin 109:42–51.
     - Pg 43: "We estimated percent canopy closure using a concave, spherical densiometer (Lemmon 1957)."

   - Moen, C. A., and R. J. Gutierrez. 1997. California Spotted Owl habitat selection in the central Sierra Nevada. Journal of Wildlife Management 61: 1281–1287.

7. **Pg A-10: "Dispersal habitat, at a minimum, consists of stands with adequate tree size and canopy closure to provide protection from avian predators and at least minimal foraging opportunities (USFWS 1992b)."**

   a. USFWS (U.S. Fish and Wildlife Service). 1992b. Draft final recovery plan for the northern spotted owl. U.S. Fish and Wildlife Service, Portland, Oregon.

   NOTE: Earliest draft I could find was dated 2007 (draft for the initial final recovery plan in 2008).

8. **Pg A-12: "In the western Washington Cascades, spotted owls roosted in mature forests dominated by trees greater than 50 centimeters (19.7 inches) dbh with greater than 60 percent canopy closure more often than expected for roosting during the non-breeding season. Spotted owls also used young forest (trees of 20 to 50 centimeters (7.9 inches to 19.7 inches) dbh with greater than 60 percent canopy closure) less often than expected based on this habitat's availability (Herter et al. 2002)."**

    a. **Herter, D.R., L.L. Hicks, H.C. Stabins, J.J. Millspaugh, A.J. Stabins and L.D. Melampy. 2002. Roost site characteristics of northern spotted owls in the nonbreeding season in central Washington. Forest Science 48:437-446.** (see above I.A.1.a.vi, moosehorn densiometer)

9. **Pg G-1: "Dispersal Habitat: … The Interagency Scientific Committee (ISC) defined dispersal habitat as forest stands with average tree diameters >11 inches and conifer overstory trees with closed canopies (>40 percent canopy closure in moist forests and >30 in dry forests) and with open space beneath the canopy to allow spotted owls to fly can provide the minimum conditions needed for successful dispersal (Thomas et al. 1990:310)."**

    a. **Thomas, J.W., et al. 1990. A conservation strategy for the northern spotted owl. (see above I.A.2.a.iii).**
        i. Pg 310: "Standards and guidelines in this conservation strategy also specify that at least 50% of the forest matrix outside HCAs be maintained in stands of timber with a mean d.b.h. of 11 inches or greater with at least 40% canopy closure."

II. REFERENCES TO CANOPY COVER IN PRIMARY MATERIALS (proportion of forest floor covered by vertical crown. Measured with a vertical densitometer.)

A. Revised Recovery Plan for the NSO – 2011

1. **Pg III-49: "For example, Lemkuhl et al. (2006) confirmed the importance of maintaining snags, downed wood, canopy cover, and mistletoe to support populations of spotted owl prey species."** (unsure of which Lehmkuhl et al. 2006 study was referenced, so I included both).

    a. **Lehmkuhl, J.F., K.D. Kistler and J.S. Begley. 2006a. Bushy-tailed woodrat abundance in dry forests of eastern Washington. Journal of Mammalogy 87:371-379.**
        i. Pg 372: "Young stands also have relatively less food production as a result of more xeric understories under moderate canopy cover."

        ii. Pg 372: "Stand overstory and understory live and dead structure and composition were measured from sixteen 0.02-ha plots using methods described by Everett et al. (1997) for the same study area.

        "Dry open pine stands had canopy closure of 30–45% and were dominated by scattered large (≥40 cm diameter at breast height [dbh]) ponderosa pines (Table 1) … The more mesic young mixed-conifer stands had moderate canopy closure of 50–70%, with a relatively high tree density (96% <40 cm dbh) … The most mesic mature mixed-conifer stands had closed canopies (70–83%) dominated by a mixture of large grand fir and

Douglas-fir >40 cm dbh, with some scattered large ponderosa pines, and a well-developed midstory and understory of grand fir and Douglas-fir."

NOTE: While both "cover" and "closure" are used, all measured values for canopy refer to "closure." Otherwise, there is no specific mention of how canopy was measured.

- Everett, R., D. Shellhaas, D. Spurbeck, P. Ohlson, D. Keenum, and T. Anderson. 1997. Structure of northern spotted owl nest stands and their historical conditions on the eastern slope of the Pacific Northwest Cascades, USA. Forest Ecology and Management 94:1–14.
  - Pg 3: "Forest structure variables recorded at each included: basal area, crown density, species, diameter at breast height (DBH), and height for all trees and snags."

NOTE: There is no mention in Everett et al. 1997 about how they went about measuring or classifying canopy beyond the sentence quoted. In Everett et al. 1997, they do refer to both canopy cover (pg 8) and canopy closure (pg 2) in reference to data collection for the study, but fail to mention how it may have been measured (if measured at all). I also searched alternative words like "density" and "crown," among others, but found nothing about how they assessed canopy.

b. Lehmkuhl, J.F., K.D. Kistler, J.S. Begley and J. Boulanger. 2006b. Demography of northern flying squirrels informs ecosystem management of western interior forests. Ecological Applications 16:584-600.

i. Pg 586: "We estimated canopy cover by averaging four readings of a convex spherical densiometer."

NOTE: This would mean that all recorded values for canopy are actually measures of canopy closure.

ii. Pg 586: "Open pine stands had canopy closure of 30–45% and were dominated by large (≥40 cm dbh) widely spaced ponderosa pine (Table 1)."

iii. Pg 586: "Young, mixed-conifer stands had moderate canopy closure of 50–70%, with a relatively high density (2595 trees/ha) of trees, most (96%) of which were <40 cm dbh (Table 1).

iv. Pg 591: "Among sample stands, tree canopy cover was the single best habitat correlate (r=0.77) of squirrel density (Huggins [estimator]) (Fig. 2)."

2. **Pg III-67: "Recovery Action 32: … These high-quality spotted owl habitat stands are characterized as having large diameter trees, high amounts of canopy cover, and decadence components such as broken-topped live trees, mistletoe, cavities, large snags, and fallen trees."**

a. Dugger, K.M., R.G. Anthony and L.S. Andrews. [2011]. Transient dynamics of invasive competition: barred owls, spotted owls, habitat composition and the demons of competition present. [Ecological Applications 21(7): 2459-2468.]

i. Pg 2561: “Data on vegetative characteristics were collected from the specific sites occupied by territorial Northern Spotted Owls within the study area, following the general approach used by Franklin et al. (2000), Olson et al. (2004), and Dugger et al. (2005) to link habitat characteristics to Spotted Owl demography.”

NOTE: No other mention of site characteristics measurements was discussed in Dugger et al. 2011.

ii. Additional references from Dugger et al. 2011:

- Franklin, A. B., D. R. Anderson, R. J. Gutie´rrez, and K. P. Burnham. 2000. Climate, habitat quality, and fitness in Northern Spotted Owl populations in northwestern California. Ecological Monographs 70:539–590.
    - Pg 548: “We used a digital vegetation map, developed by the California Timberland Task Force (TTF), that covered both private and public lands over the extent of our entire study area (Geographic Resource Solutions 1996). This map was developed from 1990 Landsat Thematic Mapper imagery that resampled to a pixel size of 25 x 25 m … Polygon attributes pertinent to this study were (1) average quadratic mean diameter (Husch et al. 1982) at breast height of all conifer trees in the polygon, (2) average quadratic mean diameter at breast height of all hardwood trees in the polygon, (3) canopy closure of all trees in the polygon, and (4) percentage of conifers in the total canopy closure.”

- Olson, G. S., R. G. Anthony, E. Glenn, E. D. Forsman, J. A. Reid, and W. J. Ripple. 2004. Modeling Demographic performance of northern spotted owls relative to forest habitat in Oregon. Journal of Wildlife Management 68:1039–1053.

NOTE: Olsen et al. 2004 was only about the development of a cover-type model, and did not assess canopy measurements.

- Dugger, K. M., F. Wagner, R. G. Anthony, and G. S. Olson. 2005. The relationship between habitat characteristics and demographic performance of northern spotted owls in southern Oregon. Condor 107:865–880.

NOTE: There was no indication that they conducted an independent canopy measurement. It appears that their canopy cover data was taken from remote sensing photos assessments of canopy cover.

b. Forsman, E.D., R.G. Anthony, K.M. Dugger, E.M. Glenn, A.B. Franklin, G.C. White, C.J. Schwarz, K.P. Burnham, D.R. Anderson, J.D. Nichols, J.E. Hines, J.B. Lint, R.J. Davis, S.H. Ackers, L.S. Andrews, B.L. Biswell, P.C. Carlson, L.V. Diller, S.A. Gremel, D.R. Herter, J.M. Higley, R.B. Horn, J.A. Reid, J. Rockweit, J. Schaberl, T.J. Snetsinger and S.G. Sovern. 2011. Population demography of northern spotted owls: 1985-2008. Studies in Avian Biology 40. Cooper Ornithological Society.

i. Pg 6: “The percent cover of suitable owl habitat was in the top fecundity model for all study areas in Oregon, and in competitive models for two of the three study areas in Washington. In Oregon, all 95% confidence intervals on beta coefficients for the habitat covariate excluded zero, and on four of the five areas the relationship between the percent cover of suitable owl habitat and fecundity was positive, as predicted.”

ii. Pg 8: “Ownership category, percent cover of suitable owl habitat, or latitude had little to no effect on apparent survival.”

iii. Pg 24: “Our definition of suitable habitat was based on Davis and Lint (2005) who created a base map of suitable Spotted Owl habitat for Washington and Oregon based on multiple covariates, including tree diameter, stand structure, canopy cover, and elevation … Although there were exceptions, the majority of forests that fit the Davis and Lint (2005) definition of suitable habitat were characterized by large overstory conifers (dbh > 50 cm) and high (>70 %) canopy cover (e.g., see Table 3-3 in Davis and Lint 2005:41). The Davis and Lint definition of “suitable owl habitat” does not perfectly define suitable habitat for Northern Spotted Owls throughout their geographic range, but was the best and most current habitat map that was available for our study areas in Oregon and Washington.”

- Davis, R., and J. B. Lint. 2005. Habitat status and trend. Pp. 21–82 in J. B. Lint (technical coordinator). Northwest Forest Plan—the first ten years (1994–2003): status and trend of Northern Spotted Owl populations and habitat. USDA Forest Service General Technical Report PNW-GRT-648.

NOTE: Davis and Lint 2005 discusses developing a computer model to estimate NSO habitat based on satellite imagery to assess canopy cover. The authors refer to this measurement throughout as both “cover” (to discuss the numbers assessed in this study) and “closure” (mostly in the definitions as they were pulled from other studies, but also referring to this own study’s assessed numbers) although it is most accurately “cover.”

iv. Pg 25: “To produce annual estimates of suitable habitat, we plotted the estimated percent cover of suitable owl habitat in each time step and then estimated the percent cover of habitat in the years between time steps by assuming a linear trend between the 4-year intervals (Appendix C)… “The second covariate (HAB3) was based on the percent cover of suitable habitat within a 23-km-radius of all historical owl activity centers minus the area in HAB2 (Fig. 2, Appendix C).”

v. Pg 81: “As a result, Anthony et al. (2006) recommended the development and use of biological covariates to help explain the variability in demographic rates and better understand the possible reasons for population changes. Consequently, we devoted considerable time to the development and refinement of covariates for evaluating the potential effects of reproduction, Barred Owls, climate, and percent cover of suitable owl habitat on fecundity, apparent survival, and recruitment at the population (study area) scale.”

- Anthony, R. G., E. D. Forsman, A. B. Franklin, D. R. Anderson, K. P. Burnham, G. C. White, C. J. Schwarz, J. D. Nichols, J. E. Hines, G. S. Olson, S. H. Ackers, L. W. Andrews, B. L. Biswell, P. C. Carlson, L. V. Diller, K. M. Dugger, K. E. Fehring, T. L. Fleming, R. P Gearhardt, S. A. Gremel, R. J. Gutierrez, P. J. Happe, D. R. Herter, J. M. Higley, R. B. Horn, L. L. Irwin, P. J. Loschl, J. A. Reid, and S. G. Sovern. 2006. Status and trends in demography of Northern Spotted Owls, 1985–2003. Wildlife Monographs No. 163.

vi. Other mentions of "percent cover" (canopy cover) in Forsman et al. 2011: Pgs 52, 53, 70, 75, 78, 88.

c. USDA (U.S. Department of Agriculture). 2010. The Okanogan-Wenatchee National Forest Restoration Strategy: adaptive ecosystem management to restore landscape resiliency. U.S. Forest Service, Pacific Northwest Region. September 2010. 99 pp.

i. Pg 14:

Table 1--Description of forest structural classes to be used in the landscape assessment for forest restoration projects and structural classes that correspond to the habitat associations for dry and mesic forest and for some focal wildlife species (based on Gaines et al. in prep)

Structural class	Description	Key functions for focal wildlife species
Understory reinitiation	Broken overstory canopy; ≥2 canopy strata; two cohorts; overstory is poles, small, or medium trees; understory is seedlings, saplings, or poles.	**Northern spotted owl** – high-quality habitat depending on the canopy closure and size of overstory trees. **Northern goshawk** – source habitat depending on the canopy closure and size of overstory trees.
Young-forest multistory	Broken overstory canopy; >2 canopy strata; >2 cohorts; large trees are absent in the overstory; stands are characterized by diverse horizontal and vertical distributions of trees and tree sizes; seedlings, saplings, poles, and medium trees are present.	**Northern spotted owl** – high-quality habitat depending on the canopy closure and size of overstory trees. **Northern goshawk** – high-quality habitat depending on the canopy closure and size of overstory trees. **White-headed woodpecker** – habitat may be provided depending on cover of large trees and cover of understory.

ii. Pg 20: "Canopy closure, canopy bulk density, canopy base height, and surface fuel loading influence torching and crowning fire behavior. Thinning generally reduces canopy closure, canopy bulk density, and increases canopy base height (Stephens and Moghaddas 2005a, Agee and Lolley 2006, Harrod et al. 2007a, Harrod et al. 2007b, Harrod et al. 2008a, Harrod et al. 2009).

- Stephens, S.L.; Moghaddas, J.J. 2005a. Experimental fuel treatment impacts on forest structure, potential fire behavior, and predicted tree

mortality in a California mixed conifer forest. Forest Ecology and Management 215: 21–36.

- Pg 24: “Canopy cover was measured at 25 points on each 0.04 ha plot using a 5 m x 5 m grid using a GRS densitometer (Gill et al., 2000).”

- Agee, J.K.; Lolley, M.R. 2006. Thinning and prescribed fire effects on fuels and potential fire behavior in an eastern Cascades forest, Washington, USA. Fire Ecology 2(2): 142-158.
  - Pg 8: “We sampled canopy closure, herb and shrub biomass, and tree data sufficient to develop estimates of tree height, canopy base height, canopy bulk density, basal area, and tree list data needed for fire effects simulations (variables listed above plus tree density, diameter by size class, and live crown ratio or live crown base) using equations available in FMA Plus (Carlton 2004).
    “Canopy closure was measured the same way before and after sampling using a convex spherical densiometer with four readings at 90 [degree] increments relative to aspect at each sample point.”

- Harrod, R.J.; Fonda, R.W.; McGrath, M.K. 2007a. Role of fire in restoration of a ponderosa pine forest, Washington. In: Butler, B.W.; Cook, W., compilers. The fire environment—innovations, management, and policy; conference proceedings. March 26- 30, 2007; Destin, FL. Proceedings RMRS-P-46. USDA Forest Service, Rocky Mountain Research Station. Fort Collins, CO.

NOTE: This study aggregation did not appear to assess canopy closure or cover. Its primary area was in fire behavior.

- Harrod, R.J.; Povak, N.A.; Peterson, D.W. 2007b. Comparing the effectiveness of thinning and prescribed fire for modifying structure in dry coniferous forests. In: Butler, B.W.; Cook, W., compilers. The fire environment—innovations, management, and policy; conference proceedings. March 26-30, 2007, Destin, FL. USDA Forest Service, Rocky Mountain Research Station, Proceedings RMRS-P-46. Fort Collins, CO.
  - Pg 332: “Canopy closure was measured in the center of the plot using a Lemmon Spherical Densiometer, Model-C. Slope, aspect, and elevation were also recorded for each plot.
  - Pg 339: “Canopy cover increased slightly when burning was used alone; while the reduction in canopy fuels on thin-only and thin + burn units led to a more open canopy. The minimal effect of burning alone on canopy cover was similar to the unmanaged control (P=0.9991, fig. 1D). However, thinning accounted for a 10 percent reduction in canopy cover on average over all thin-only and thin + burn units.”

NOTE: in Harrod et al. 2007b, “canopy cover” was not independently measured in this study. I think that the authors were using closure and cover interchangeably, but actually measured closure.

- Harrod, R.J.; Peterson, D.W.; Ottmar, R. 2008a. Effects of mechanically generated slash particle size on prescribed fire behavior and subsequent vegetation effects. Final Report to the Joint Fire Science Program, Project Number 03-3-2-06.

- Harrod, R.J.; Peterson, D.W.; Povak, N.A.; Dodson, E.K. 2009. Thinning and prescribed fire effects on overstory tree and snag structure in dry coniferous forest of the interior Pacific Northwest. Forest Ecology and Management 258(5): 712–721.

iii. Pg 23: "Additional requirements for flying squirrels are canopy cover over about 55 percent and fruit and seed producers such as Douglas maple, Oregon grape, serviceberry, rose, snowberry, and huckleberry. Lehmkuhl et al. (2008) suggests that retaining these conditions within riparian buffers could provide adequate habitat for small mammal species associated with riparian areas."

- Lehmkuhl, J.F.; Peffer, R.D.; O'Connell, M.A. 2008. Riparian and upland small mammals on the east slope of the Cascade Range, Washington. Northwest Science 82(2): 94–106.

NOTE: The term "canopy," in reference to either canopy cover or canopy closure, does not appear anywhere in Lehmkuhl et al. 2008. The "cover" referred to in the paper appears to refer to ground cover.

iv. Pg 28: "Hot Box 2: 'High-quality habitat' and 'habitat-capable' areas should be defined by local conditions and a provincial-level interdisciplinary team. They should include the following elements: multi-layer conifer forest with large trees, high amounts of canopy cover, broken top live trees and large snags, and large-diameter down wood."

v. Pg 28: "Spring burning (without mechanical treatment) may not accomplish the desired restoration of habitat structure (reducing canopy closure, removing small trees, creating canopy gaps, creating large snags) for avian species if conducted when conditions are too cool and moist (Gaines et al. 2010)"

- Gaines, W.L.; Haggard, M.; Begley, J.; Lehmkuhl, J.F.; Lyons, A.L. 2010. Short-term effects of thinning and burning restoration treatments on avian community composition, density and nest survival in the eastern Cascades dry forests, Washington. Forest Science 56(1): 88–99.
  - Pg 95: "Mountain chickadees were associated with high canopy closure in northeast Oregon (Mannan and Meslow 1984, Sallabanks et al. 2002) and in west-central Idaho (Medin 1985). Gaines et al. (2007) and Hurteau et al. (2008) reported that restoration treatments in ponderosa pine forests resulted in lower densities of mountain chickadee."
  - Pg 96: "Restorative treatments that reduce canopy closure may provide bluebirds with open perches from which to hunt and thereby improve the availability of invertebrates as a food source (Wightman and Germaine 2006. Hurteau et al. 2008)."

vi. Pg 29: "Their results suggest that thinning to restore forest structure would not negatively influence the species as long as canopy closure would be more than ten percent."

- Gaines, W.L.; Lyons, A.L.; Sprague, A. 2005. Predicting the occurrence of a rare mollusk in the dry forests of north-central Washington. Northwest Science 79(2 -3): 99–105.

vii. Pg 94: "6. For about 1 acre around retained WL, remove DF to about 20% canopy cover."

3. **Pg A-10,11: "In Oregon Klamath and Western Oregon Cascade Provinces, Dugger et al. (2005) found that apparent survival and reproduction was positively associated with the proportion of older forest near the territory center (within 730 meters) (2,395 feet). Survival decreased dramatically when the amount of non-habitat (non-forest areas, sapling stands, etc.) exceeded approximately 50 percent of the home range (Dugger et al. 2005).The authors concluded there was no support for either a positive or negative direct effect of intermediate-aged forest—that is, all forest stages between sapling and mature, with total canopy cover greater than 40 percent—on either the survival or reproduction of spotted owls."**

   a. **Dugger et al. 2005. The relationship between habitat characteristics and demographic performance of northern spotted owls in southern Oregon.** (See above at II.A.2.a.ii)

4. **Pg C-16: "For our modeling, we selected from a set of 163 variables, including basal area and tree density by size class and species, canopy cover of conifers and/or hardwoods, stand height, age, mean diameter and quadratic mean diameter by dominance class, stand density index, and measures of snags and coarse woody debris."**

   NOTE: Section C of the Recovery Plan discusses the development of a computer model to help predict NSO habitat. Previous studies (which aren't listed) provide data that is used to build the model used for examining satellite imagery. It appears that canopy cover is estimated using the remote sensing data and those values become part of the model. Pg C-16: "The assumption behind GNN ["Gradient nearest neighbor" of associated vegetation models] is that two locations with similar combined spatial "signatures" should also have similar forest structure and composition."

5. **Pg C-23: "For example, several published studies concluded that nesting spotted owls strongly select for areas with canopy cover >70% and many large trees nearby and strongly select against areas with lower amounts of canopy cover and few or no large trees nearby. We therefore created definition "NR1" (nesting-roosting definition number 1) based on canopy cover and density of large trees (e.g., trees >75 cm dbh)."**

6. **Pg C-23 (Table C-5): "Habitat characteristics from expert panel, literature: Canopy cover of conifers is ≥ than 80%."**

7. **Pg C-24: "In general, foraging habitat definitions had lower thresholds of canopy cover, tree size, and canopy layering than nesting-roosting definitions (Tables C7 and C8 provide an example of this process)."**

8. **Pg C-24 (Table C-7): "Habitat characteristics from expert panel, literature: Canopy cover of conifers is ≥ than 70%"**

9. **Pg C-27: "At the smallest scale we evaluated, features such as the amount of nesting-roosting and/or foraging habitat within a core area, the amount of edge between spotted owl habitat and non-habitat, or amount of "core habitat" (sensu Franklin et al. 2000) have all be shown to influence spotted owl distribution, abundance, or fitness. Each of those variables, however, is a structural variable. That is, they are based on habitats comprised of various structural elements (e.g., large trees, high canopy cover)."**

   a. **Franklin et al. 2000. Climate, habitat quality, and fitness in northern spotted owl populations in northwestern California**. (See above at II.A.2.a.ii).

   b. **Franklin, J.F., D. Lindenmayer, J.A. MacMahon, A. McKee, J. Magnuson, D.A. Perry, R. Waide and D. Foster. 2000. Threads of Continuity. Conservation Biology in Practice 1:8-16.**

   NOTE: Citation was not explicit as to which Franklin et al. 2000 was meant to be cited (though the other was most likely as this is in the modeling section). I included a quick search of this one just in case. My search revealed no discussion of canopy cover or closure in Threads of continuity.

   c. **Olson et al. 2004. Modeling Demographic performance of northern spotted owls relative to forest habitat in Oregon.** (see above at II.A.2.a.ii)

   d. **Dugger et al. 2005. The relationship between habitat characteristics and demographic performance of northern spotted owls in southern Oregon.** (See above at II.A.2.a.ii)

   e. **Glenn, E.M. 2009. Local weather, regional climate, and population dynamics of northern spotted owls in Washington and Oregon. Dissertation, Oregon State University, Corvallis.**
      i. Pg 25: "Field methods followed Franklin et al. (1996), and data collection was standardized across all areas for all years (Anthony et al. 2006).

         - Franklin, A. B., D. R. Anderson, K. P. Burnham, and F. F. Wagner. 1996. Methods for collecting and analyzing demographic data on the northern spotted owl. Studies in Avian Biology 17:12-20.

         - Anthony et al. 2006. Status and trends in demography of Northern Spotted Owls, 1985–2003. (see above at II.A.2.b.v.)

      ii. Pg 63: "Additionally, CLE had lower % canopy cover relative to other study areas possibly favoring different foraging strategies at CLE [Cle Elum Study Area in Wenatchee NF]."

iii. Additional References from Glenn 2009:
- Lint et al. 2009 (full cite not available)

10. **Pg C-27: "Spotted owl experts noted that mid-scale or landscape level patterns such as tree species composition and topography may also influence the local distribution and density of spotted owls. For example, within many of the modeling regions, there exists variation in tree species composition, but forests with different species compositions may still have similar structural attributes (e.g., high canopy cover, multi-storied, large trees)."**

11. **Pg C-38 (Table C-18): "Definition: Canopy Cover of all live trees; Canopy cover of all conifers" (describing definition for modeling variables).**

12. **Pg G-2: "High-Quality Habitat: Older, multi-layered structurally complex forests that are characterized as having large diameter trees, high amounts of canopy cover, and decadence components such as broken-topped live trees, mistletoe, cavities, large snags, and fallen trees."**

13. **Pg G-3: "Nesting and Roosting Habitat: Habitat that provides nesting and roosting opportunities for spotted owls. Important stand elements may include high canopy closure, a multi-layered, multi-species canopy with larger overstory trees and a presence of broken-topped trees or other nesting platforms (e.g., mistletoe clumps (USFWS 1992b)."**

    a. **USFWS 1992b. Draft final recovery plan for the northern spotted owl.** (See above I.A.7.a.)

Federal Rule on NSO Critical Habitat – 2012

I. **REFERENCES TO CANOPY CLOSURE IN PRIMARY MATERIALS** (proportion of sky hemisphere obscured by veg. Measured with a spherical densitometer.)

A. **Federal Rule on NSO Critical Habitat – 2012**

NOTE: Nowhere in the federal register is the term "canopy closure" used.

II. **REFERENCES TO CANOPY COVER IN PRIMARY MATERIALS** (proportion of forest floor covered by vertical crown. Measured with a vertical densitometer.)

B. **Federal Rule on NSO Critical Habitat – 2012**

1. **Pg 71884: "Dispersal habitat, at a minimum, consists of stands with adequate tree size and canopy cover to provide protection from avian predators and at least minimal foraging opportunities (57 FR 1805, January 15, 1992). In this rule, we consider canopy cover as a vertical measurement of the amount of canopy that would cover the ground."**

    a. **51 FR 1805, Jan. 15, 1992:**

2. **Pg 71884: "Additional features that support nesting and roosting typically include a moderate to high canopy cover; a multilayered, multispecies canopy with large overstory trees; large accumulations of fallen trees and other woody debris on the ground; and sufficient open space below the canopy for northern spotted owls to fly (Thomas et al. 1990, p. 164). Forested stands with high canopy cover also provide thermal cover (Weathers et al. 2001, p. 686) and protection from predators."**

    a. **Thomas, J.W., E.D. Forsman, J.B. Lint, E.C. Meslow, B.R. Noon and J. Verner. 1990. A conservation strategy for the northern spotted owl. Interagency Scientific Committee to Address the Conservation of the Northern Spotted Owl. U.S. Forest Service, U.S. Bureau of Land Management, U.S. Fish and Wildlife Service, and U.S. National Park Service, Portland, Oregon, at 164**

        i. Pg 1: "Habitats selected by northern spotted owls typically exhibit moderate to high canopy closure; a multilayered, multispecies canopy dominated by large overstory trees; a high incidence of large trees with large cavities, broken tops, and other indications of decadence; numerous large snags; heavy accumulations of logs and other woody debris on the forest floor; and considerable open space within and beneath the canopy."

        ii. Pg 4: "We considered dedicating corridors of forests between HCAs to facilitate dispersal by juvenile owls, but decided corridors were unnecessary, provided at least 50% of the forest landbase outside of HCAs is maintained in stands of timber with an average d.b.h. of 11 inches or greater and at least 40% canopy closure."

        iii. Pg 19: "Most studies of habitat use (appendix F) indicate that superior habitats for owls in Washington, Oregon, and northwestern California have moderate to high canopy closure (60 to 80%); a multilayered, multispecies

canopy dominated by large (>30 inches in d.b.h.) overstory trees; a high incidence of large trees with various deformities (for example, large cavities, broken tops, dwarf mistletoe infections, and other indications of decadence); numerous large snags (standing dead trees); large accumulations of fallen trees and other woody debris on the ground (appendix F); and considerable open space through which owls can fly within and beneath the canopy."

iv. Pg 27: "The standards and guidelines discussed later ensure adequate dispersal habitat by requiring that 50% of the forest matrix outside of HCAs be in stands with an average d.b.h. of 11 inches and a 40% canopy closure."

v. Pg 28 (Table 2): "Rule: Maintain 50% of forest landscape with mean tree d.b.h. of 11 inches and 40% canopy cover."

vi. Pg 29: "Usually, we found close agreement between these methods for determining HCA size: …

"Adequate portions of the forested areas between HCAs must be in appropriate structural condition to provide at least marginal foraging habitat for dispersing owls. This need is addressed by requiring that 50% of the forest matrix outside the HCAs be covered with stands of trees averaging 11 inches or more in d.b.h., and with at least 40% canopy closure."

vii. Pg 62: "A general characterization of the forested habitat in specific forest types used by spotted owls includes the following attributes (see details in appendices F, G, and H): Large, tall, live trees with cavities, broken tops, dwarf mistletoe, or platforms of branches capable of holding accumulated organic matter suitable for use as a nest; dead standing trees and fallen, decaying trees and limbs to support abundant populations of prey species, especially northern flying squirrels and woodrats; dominant trees in the stand with relatively large diameters; and multilayered tree canopies with a moderate to high canopy closure in overstory, midstory, and understory."

viii. Pg 97: "Higher harvest rates and the need to achieve regrowth will result in reduced canopy closure in selectively cut stands and further fragmentation."

ix. Pg 114: "Beyond this, criteria did not appear to be standardized, although criteria such as 65% canopy closure and lots of dead and down material were mentioned."

x. Pg 145: "Stand structure is based on quantitative measurements of vegetative plots centered at or around a roost, foraging, or nest location. Information on stand structure usually includes canopy closure, size and abundance (basal area and density) by tree species, and ground cover. Stand condition is a broad seral-stage classification based on such factors as tree age and d.b.h., and canopy closure."

xi. Pg 146: "Old growth was usually defined as a dominant overstory >200 years old, with a multilayered, multispecies canopy, relatively high canopy closure, and large numbers of snags and logs."

xii. Pg 147 (Table F1, cont.): See below

Table F1—continued

Study	Condition	Definition
	"Sapling" in the central Coast Range	Trees 25 to 35 years old, 4 to 7.9 inches in d.b.h.
	Clearcut	Trees 5 to 24 years old Overgrown with shrubs, or grass/forb
Allen et al. 1989	Old Growth	Trees >30 inches in d.b.h.; codominants >16 inches in d.b.h.; multilayered
	Large sawtimber	Trees in canopy 20 to 31 inches in d.b.h.; few canopy layers
	Small sawtimber	Trees 14 to 20 inches in d.b.h.
	Pole	Trees 6 to 14 inches in d.b.h.
	Open-canopy conifer	Canopy cover 40 to 60%; variety of tree sizes
	Other	Shrub/forb/sapling; shrub/forb/grass; rock/barren; water; snow/shadow
Hays et al. 1989b	Old growth	Trees >32 inches in d.b.h.; codominants >16 inches in d.b.h.; multilayered
	Large sawtimber	Trees 20 to 34 inches in d.b.h.; few canopy layers
	Small sawtimber	Trees 13 to 20 inches in d.b.h.
	Pole	Trees 6 to 13 inches in d.b.h.
	Open Canopy	Canopy cover 40 to 60%; variety of tree sizes
	Other	Shrub/sapling; grass/forb; rock; water; snowfield
Miller and Meslow 1989	Old growth	Doublas-firs >32 inches in d.b.h., >200 years old; multilayered
	Mature	Trees >21 inches in d.b.h., but not old growth
	<Mature	All other stands including clearcuts
Thrailkill and Meslow 1989; Thrailkill and Meslow 1990	Old growth	Trees >34 inches in d.b.h., >200 years old, more than two canopy layers
	Mature	Trees >21 inches in d.b.h., 80 to 199 years old
	Young	Trees 1 to 21 inches in d.b.h., 10 to 79 years old, canopy cover <60%
	Mixed	Primarily young growth with poorly stocked mature/old growth in the overstory; canopy closure variable
	Clearcut	Trees 0 to 9 years old; shrub canopy <40% or devoid of vegetation; trees <1 inches in d.b.h.
	Hardwood/ riparian	Dominated by hardwoods long stream or river; 50 to 100% canopy cover

- Allen, H.L., K.R. Dixon, and K. L. Knutson. 1989 unpubl. Cooperative administrative study to monitor spotted owl management areas in National Forests in Washington: Final report. Wash. Dep. Wildl., Olympia. 165pp.

- Hays, D. W., H. L. Allen, L. H. Egtvedt, and K. R. Dixon. 1989b unpubl. Home range size and habitat use of spotted owls in Washington: Preliminary report. Wash. Dep. Wildl. Manage. Nongame, Olympia. 30pp.

- Thrailkill, J. A., and E. C. Meslow. 1989 unpubl. Home range size and habitat utilization of northern spotted owls in the Wolf Creek Study area, Eugene BLM District, Oregon. Progress Rep. for 1 June 1987-1 September 1989. Oregon Wildl. Res. Unit, Oreg. State Univ., Corvallis. 26pp.

- Thrailkill, J. A., and E. C. Meslow. 1990 unpubl. Home range size and habitat utilization of northern spotted owls in the Wolf Creek Study area, Eugene BLM District, Oregon: Draft final rep. Oreg. Coop. Wildl. Res. Unit, Oreg. State Univ. Corvallis. 68pp.

xiii. Pg 159: "Mean canopy closure in stands was 87% far summer locations and 80% at winter locations (Gutiérrez et al.1984)."

- Gutiérrez, R. J., D. M. Soils, and C. Sisco. 1984. Habitat ecology of the spotted owl in northwestern California: Implications for management. Pages 368-373 in Proc., Soc. Am. For.

xiv. Pg 160: "Canopy closure, stem density, and basal area for both old-growth conifers >35 inches in d.b.h. and all hardwoods were greater in roosting habitats (Gutiérrez et al. 1984, Sisco and Gutiérrez 1984, Solis 1983). Summer roosting habitat had the highest density and basal area of large conifers (d.b.h. >35 inches; 16.4 stems per acre, 215 square feet per acre) and the highest canopy closure (92.8%) (Solis 1983)."

- Gutiérrez et al. 1984. Habitat ecology of the spotted owl in northwestern California: Implications for management. (see II.A.2.a.xiii)

- Sisco, C., and R. J. Gutiérrez. 1984 unpubl. Winter ecology of radio-tagged owls on Six Rivers National Forest, Humboldt Co., CA. Six Rivers National Eureka, Calif. l40pp.

- Solis, D. M. 1983. Summer habitat ecology of spotted owls in northwestern California. M.S. Thesis, Humboldt State Univ., Arcata, Calif. 169pp.

xv. Pg 160: "Canopy closure in nest stands ranged from 81 to 82% in the three forest types."

- LaHaye, W. S. 1988. Nest site selection and nesting habitat of the northern spotted owl (Strix occidentalis caurina) in northwestern California. M.S. Thesis, Humboldt State Univ., Arcata, Calif. 111pp.

xvi. Pg 162:

Table F13—Mean basal area (ft ^{2}/acre) and other site attributes in different forest stand types used for nesting by northern spotted owls in northwestern California (data are based on 4 variable-radius plots on the 4 cardinal compass direction 82 feet from the nest trees)[a, b]

D.b.h. class in inches	Douglas-fir/ tanoak stands (n = 32)	Mixed-conifer stands (n = 6)	Redwood/ Calif. laurel (n = 6)
Conifers			
0.4-12	27	91	23
12-24	18	41	58
24-35.4	33	42	73
35.4+	133	94	59
Subtotal	211	268	213
Hardwoods			
0.4-8	33	12	33
8-16	48	19	43
16-24	27	3	18
24+	18	6	5
Subtotal	126	40	99
Grand total	337	306	312
Mean canopy cover *(%)*	81	81	82
Mean elevation (ft)	2572	4261	574
Mean slope *(%)*	49	40	42

[a] Tabled values include both live trees and snags.
[b] Data are from LaHaye (1988).

xvii. Pg 164: "Tree-canopy closure commonly exceeds 70% in these sites, with stands composed of mixtures of interior live oak, California sycamore, California buckeye, and blue oak."

- Neal, D. L., J. Verner, G. N. Steger, and G. P. Eberlein. 1990 unpubl. A study of spotted owl home-range size and composition in the Sierra National Forest: Annual progress report for 1989. USFS, PSW For. Range Exp. Stn., Fresno, Calif. 44pp.

xviii. Pg 164: "Structural components that distinguish superior spotted owl habitat from less suitable habitat in Washington, Oregon, and northwestern California include: a multilayered, multispecies canopy dominated by large (>30 inches in d.b.h.) conifer overstory trees, and an understory of shade-tolerant conifers or hardwoods; a moderate to high (60 to 80%) canopy closure; substantial decadence in the form of large, live coniferous trees with deformities—such as cavities, broken tops, and dwarf mistletoe infections; numerous large snags; ground-cover characterized by large accumulations of logs and other woody debris; and a canopy that is open enough to allow owls to fly within and beneath it."

- Irwin, L. 1., J. B. Buchanan, E. McCutchen, and C. Phillips. 1989a unpubl. Characteristics of spotted owl nest sites in eastside National Forests, Washington: Progr. rep. for 1988-89. 51pp.

xix. Pg 166: “Such information should include tree densities and basal area by d.b.h.-class and species, canopy closure, and occurrence of trees and snags with large cavities, broken tops, dwarf mistletoe infections, and other indications of decadence.

“The full range of suitable habitats for spotted owls in California has not yet been determined, although much is known. Current FS guidelines for spotted owl habitat in northern California (Simon-Jackson, pers. comm.) specify multilayered stands of mature timber, with ≥70% canopy closure, at least 40% of that in trees ≥21 inches in d.b.h., and with obvious decadence (for example, many snags, including some large ones; broken-topped trees; logs and other woody debris on the ground).”

xx. Pg 166: “For example, in mixed-conifer and conifer/hardwood forests of northern California, and on the east slope of the Washington Cascades, breeding spotted owls have been located on lands where historical timber harvesting activity emphasized overstory removal or other partial cutting techniques that retained relatively high canopy cover.”

xxi. Pg 179: “Canopy closure ranged from 50 to 90%, with a mean of 81%.”

- Diller, L.. 1989 unpubl. Status of the northern spotted owl in managed forests on Simpson redwood lands in northern California. Interim report submitted to Simpson Redwood Co., Arcata, Calif., 20 October 1989.

xxii. Pg 274: “Those features (including retention of 50% of the forest in that landscape matrix in trees at least 11 inches in d.b.h., totaling at least 40% canopy cover—see appendices P and O) significantly reduce the contrast between HCAs and the surrounding landscape in which they are embedded.”

- Carey, A. B., J. A. Reid, and S. P. Horton. 1990. Spotted owl home range and habitat use in southern Oregon Coast Ranges. 3. J. Wildl. Manage. 54(1):11-17.

NOTE: This study did not examine canopy at all. Aerial photos were used to estimate spotted owl home ranges.

- Forsman, E. D., E. C. Meslow, and H. M. Wight. 1984. Distribution and biology of the spotted owl in Oregon. Wildl. Monogr. 87:1-64.
  - Pg 12: “Variables measured at nest sites included percent slope aspect, canopy closure, and distance to the nearest stream or spring. Canopy closure at nests was estimated at 4 points around the nest tree and averaged.”
  - Pg 16: “Although the density and closure of individual canopy layers within these forests varied considerably, composite canopy closure usually averaged moderate to high (65-80%) as a result of the layered structure.”
  - Pg 17: “Canopy closure was reduced to <50%.”
  - Pg 30: “Canopy closure was measured at 26nests and averaged 69% (range 85-91,SE 2.65). Only 2 nests were located in stands with canopy closure less than 55%.”
  - Pg 60:

Appendix 2. Cover types used for habitat selection analyses on the H. J. Andrews and BLM study areas.

Cover type	Area in which cover type occurred	Description
Old-growth conifer forest	HJA, BLM	Multilayered old-growth associations of Douglas-fir, western hemlock, and western redcedar with understories dominated by western hemlock, vine maple, Pacific dogwood, bigleaf maple, and western yew. Also included mixed associations of old-growth Pacific silver fir, Douglas-fir, and western hemlock on the HJA study area. On the HJA study area, old-growth overstory trees were typically 275–450 years old, 50–70 m tall, and 100–150 cm dbh. On the BLM study area, old-growth overstory trees were typically 220–350 years old, 50–65 m tall, and 100–170 cm dbh. Canopy closure in most stands averaged between 70 and 80%.
Selectively logged old-growth conifer forest	HJA	Same as above except that some removal of logs and dead or damaged trees had occurred, resulting in a slight reduction in canopy closure. On the BLM study area this cover type was uncommon and was lumped with unlogged old-growth conifer forest.
81–200-year-old conifer forest	HJA, BLM	Unlogged mature forests of Douglas-fir with variable amounts of western hemlock, vine maple, and Pacific dogwood in the understory. Also included small areas of mixed associations of Pacific silver fir, Douglas-fir, and western hemlock on the HJA study area. Trees typically 40–65 m tall and 40–130 cm dbh.
Mature hardwoods	HJA, BLM	This type included a 4-ha mixed stand of large Oregon ash and Oregon white oak on the BLM study area. On the HJA study area it included riparian mixtures of bigleaf maple, red alder, western redcedar, western hemlock and Douglas-fir.

xxiii. Pg 310: "Standards and guidelines in this conservation strategy also specify that at least 50% of the forest matrix outside HCAs be maintained in stands of timber with a mean d.b.h. of 11 inches or greater, with at least 40% canopy closure."

xxiv. Pg 326-27: "Lands Suited for Timber Production

"…

"For every quarter township, timber harvest shall be permitted only when 50% of the forest landscape consists of forest stands with a mean d.b.h. of 11 inches and a canopy closure of 40% (50-11-40 rule)."

xxv. Pg 327: "Where the quarter township contains multiple ownerships, the percentage is computed separately for each owner, based on the amount of ownership.

"Example: If owner A has 2880 acres in the quarter township, it would have a 1440-acre quota under the 50-11-40 rule before harvest would be permitted. If owners B and C each had 1440 acres, their quota under the rule would be 720 acres of forest stands, each with a mean d.b.h. of 11 inches and a 40% canopy closure."

xxvi. Pg 416 (glossary): "**canopy closure** -- the degree to which the crowns of trees are nearing general contact with one another."

xxvii. Pg 420 (glossary): "**old growth** -- a forest stand with moderate to high canopy closure; a multilayered, multispecies canopy dominated by large overstory trees; a high incidence of large trees with large, broken tops, and

other indications of decadence; numerous large snags; and heavy accumulations of logs and other woody debris on the ground"

b. Weathers, W.W., P.J. Hodum and J.A. Blakesley. 2001. Thermal ecology and ecological energetics of the California spotted owl. Condor 103:678–690, at 686.

i. Pg 686: "On a landscape scale, Spotted Owls prefer relatively cool old-growth or late seral stage forests characterized by high structural diversity, large numbers of residual trees, and a high degree of canopy closure (LaHaye et al. 1997, Moen and Gutie´rrez 1997)."

3. **Pg 71884: "As noted above, the same habitat generally serves for both nesting and roosting functions; technically 'roosting habitat' differs from nesting habitat only in that it need not contain those specific structural features used for nesting (cavities, broken tops, and mistletoe platforms), but does contain moderate to high canopy cover; a multilayered, multispecies canopy; large accumulations of fallen trees and other woody debris on the ground; and open space below the canopy for northern spotted owls to fly."**

4. **Pg 71885: "Such short-term dispersal habitats must, at minimum, consist of stands with adequate tree size and canopy cover to provide protection from avian predators and at least minimal foraging opportunities."**

5. **Pg 71886: "Northern flying squirrel densities tend to be higher in older forest stands with ericaceous shrubs (e.g., Pacific rhododendron (*Rhododendron macrophyllum*)) and an abundance of large snags (Carey 1995, p. 654), and higher tree canopy cover (Lehmkuhl et al. 2006, p. 591) likely because these forests produce a higher forage biomass … Flying squirrel density tends to increase with stand age (Carey 1995, pp. 653–654; Carey 2000, p. 252), although managed and second-growth stands sometimes also show high densities of squirrels, especially when canopy cover is high (e.g., Rosenberg and Anthony 1992, p. 163; Lehmkuhl et al. 2006, pp. 589–591)."**

a. Carey, A.B. 1995. Sciurids in Pacific Northwest managed and old-growth forests. Ecological Applications 5(3):648–661, at 653-54.

i. Pg 652: "Canopy closure (r = -0.84) and total density of snags (r = -0.74) decreased with age. Means were significantly different between old and young stands for all but coarse woody debris (Table 3); coarse woody debris, large snags, and canopy closure were more variable among the old stands than among the young stands."

ii. Pg 652: "Shrub, tall understory. and total understory abundances were not significantly correlated with canopy closure: only tall understory was highly correlated with age (r = 0.76)."

b. Carey, A.B. 2000. Effects of new forest management strategies on squirrel populations. Ecological Applications 10(1):248–257, at 252.

i. Pg 248: "Extensive management for high canopy closure and long rotations (>90 yr) after retention of standing live trees, standing dead trees, and fallen trees at harvest, singly and in patches, has been suggested as one pathway to maintaining or restoring natural biodiversity in second-growth forests; I refer

to this approach as legacy retention (Hopwood 1991, Franklin 1993, Franklin et al. 1997)."

c. Lehmkuhl, J.F., K.D. Kistler, J.S. Begley and J. Boulanger. 2006. Demography of northern flying squirrels informs ecosystem management of western interior forests. Ecological Applications 16:584–600, at 589-91.

i. Pg 584: "Tree canopy cover was the single best correlate of squirrel density (r=0.77), with an apparent threshold of 55% canopy cover separating stands with low- from high-density populations.

ii. Pg 586: "We estimated canopy cover by averaging four readings of a convex spherical densiometer."

NOTE: Lehmkuhl et al. 2006 uses canopy cover and closure interchangeably. This type of tool, though, measures closure, so all values in this study are actually measures of canopy closure.

iii. Pg 586: "Open pine stands had canopy closure of 30–45% and were dominated by large (40 cm dbh) widely spaced ponderosa pine (Table 1)… "Young, mixed-conifer stands had moderate canopy closure of 50–70%, with a relatively high density (2595 trees/ha) of trees, most (96%) of which were ,40 cm dbh (Table 1)."

iv. Pg 588: "We also used an individual animal covariate (mass), two stand-based covariates (canopy cover, understory cover), and two temporal covariates (maximum snowfall depth, precipitation) in various model formulations in an attempt to account for differences in capture probabilities between individual squirrels, stands, and years sampled within a cover type."

v. Pg 588: "In young and mature forests, capture heterogeneity generally was associated with squirrel mass (a proxy for age) and variation in understory cover or canopy cover (mature forest) among stands."

vi. Pg 591: "Among sample stands, tree canopy cover was the single best habitat correlate (r=0.77) of squirrel density (Huggins) (Fig. 2). Density also was correlated positively with estimates of truffle biomass (r = 0.68) and richness (r = 0.58), basal area (r = 0.60), large tree density (r = 0.57), and severe mistletoe infection (r = 0.55); but those factors each were highly correlated with tree canopy cover ($0.61 < r < 0.75$). Instead of a continuous linear relationship between density and canopy cover in sample stands, there appeared to be a threshold of approximately 55% canopy cover that separated low-density, mostly open pine stands from high-density mixed-conifer stands (Fig. 2)."

vii. Pg 594: "High flying squirrel density in both young and mature stands was strongly associated with closed canopy cover (>55%), abundant den sites, inherently high productivity of truffles and forage lichens, and diverse understory plant foods … Canopy cover would have a direct effect via canopy connectivity and its effects on squirrel movement (Carey 1991). Canopy cover also has indirect effects on food resources: canopy cover and truffle food production in all study stands are strongly correlated (r ¼ 0.75; Lehmkuhl et al. 2004)."

viii. Pg 594-95: “The 55% canopy threshold for stands with low vs. high densities of squirrels was confounded by plant association because all but one (young) stand with <55% canopy cover were in the most xeric, least-productive Douglas-fir plant associations. Stands with <55% canopy cover might be below a threshold for canopy connectivity or site productivity, but little support for such a threshold can be found in the literature as canopy cover values for study stands are rarely given for natural or thinned stands (Carey 2000a, b, Ransome and Sullivan 2002, Bull et al. 2004). Waters and Zabel (1995), however, found that old white fir/red fir forest logged by shelterwood harvesting to about 25% canopy cover 6–7 years prior to sampling supported approximately one-tenth the density of flying squirrels compared to unlogged forest in northern California.”

ix. Pg 596: “A basic prediction from our results is that simply reducing canopy cover below ~50% will result in a shift to low-density populations of flying squirrels in treated stands, but there is little firm guidance on such thresholds in the literature, other than that much-reduced squirrel densities occur when old forest canopies are reduced to 25% cover (Waters and Zabel 1995).”

x. Pg 596: “Given our results, however, variable-density thinning of mesic stands might be neutral or beneficial to flying squirrel habitat if canopy cover remained above 50%, den sites and truffle and lichen biomass were unaffected, and understory plant diversity increased.”

d. Rosenberg, D. K., and R.G. Anthony. 1992. Characteristics of northern flying squirrel populations in young second- and old-growth forests in western Oregon. Canadian Journal of Zoology 70:161–166, at 163.

NOTE: Rosenberg and Anthony 1992 conducted field studies, but did not measure canopy.

6. **Pg 71896: “In identifying those physical or biological features within an area, we focus on the principal biological or physical constituent elements (PCEs—primary constituent elements such as roost sites, nesting grounds, rainfall, canopy cover, soil type) that are essential to the conservation of the species.”**

7. **Pg 71898: “The high-quality habitat can help maintain a stable prey base, thereby reducing the cost of foraging during the early breeding season, when energetic needs are high (Carey et al. 1992, pp. 223–250; Franklin et al. 2000, p. 559). In addition, mature and old forest with high canopy cover typically remains cooler during summer months than younger stands.”**

a. Carey, A.B., S.P. Horton and B.L. Biswell. 1992. Northern spotted owls: influence of prey base and landscape character. Ecological Monographs 62(2):223–250, at 223-250.

NOTE: the terms “overhead cover” and “lateral cover” is also used in Carey et al 1992 to describe roost sites. There is no real mention of how “cover” or “closure” was determined for the study, although specific values are used to describe it.

i. Pg 228: “We defined stands as homogeneous units of vegetation based on tree diameter class, canopy closure, and vegetative composition.”

ii. Pg 232: “Overstory cover was usually sparse (the modal cover class was 6-12%), mid- to understoryc over was dense (24- 48%), and shrub cover was usually >48%.”

iii. Pg 232: “Roosts were protected by 69 ± 1% overhead cover and 36 ± 1% lateral cover … Only 2% of the variability in the sum of lateral and overhead cover could be explained by regression(F= 14.88, df= 1, 654, P < .01).”

iv. Pg 234: “The abundances of both species were positively correlated with total vegetative cover <6 m (Spearman rank correlation, r , = 1.0, P = .0, N = 5 for dusky-footed woodrats and r, = 0.88, P < .05, N = 9 for bushy-tailed woodrats).”

v. Pg 246: “Young forests had a low vertical diversity of vegetation and high canopy closure with few low structures beneath the canopy that would be suitable as hunting perches. Old forests had a high vertical diversity of vegetation and moderate canopy closure (Carey et al. 1991 b) that provide hunting perches continuously from the forest floor to the upper canopy; similarly, the irregular canopy produces heterogeneous understory cover resulting in a mixture of open and dense patches of vegetation, an environment that could make the flying squirrel more vulnerable to predation.”

b. Franklin, A.B., D.R. Anderson, R.J. Gutiérrez and K.P. Burnham. 2000. Climate, habitat quality, and fitness in northern spotted owl populations in northwestern California. Ecological Monographs 70:539–590, at 559

i. Pg 548: “We used a digital vegetation map, developed by the California Timberland Task Force (TTF), that covered both private and public lands over the extent of our entire study area (Geographic Resource Solutions 1996). This map was developed from 1990 Landsat Thematic Mapper imagery that resampled to a pixel size of 25 x 25 m … Polygon attributes pertinent to this study were (1) average quadratic mean diameter (Husch et al. 1982) at breast height of all conifer trees in the polygon, (2) average quadratic mean diameter at breast height of all hardwood trees in the polygon, (3) canopy closure of all trees in the polygon, and (4) percentage of conifers in the total canopy closure.”

ii. Pg 549: “Spotted owl habitat was mature and old-growth forest with a quadratic mean diameter of conifers ≥53 cm, quadratic mean diameter of hardwoods ≥15 cm, percentage of conifers ≥ 40%, and overstory canopy coverage ≥70%.”

8. **Pg 71902: “Although optimal dispersal habitat would be the same as suitable nesting, roosting, or foraging habitat (mature and old-growth stands), dispersing owls will use younger forest for dispersal, and the Interagency Scientific Committee (Thomas et al. 1990) suggested the 50–11–40 rule for maintaining baseline forest conditions between blocks of old forest to enhance dispersal. Forests composed of at least 50 percent of trees with 11 inches (in) (28 centimeters (cm)) diameter at breast height (dbh) or greater, and with roughly a**

minimum 40 percent canopy cover, were considered to meet this baseline condition for northern spotted owl dispersal."

a. **Thomas et al. 1990. A conservation strategy for the northern spotted owl.** (See above II.A.2.a)

9. **Pg 71903: "Our habitat modeling indicated that vegetation structure had a dominant influence on owl population performance, with habitat pattern and topography also contributing. High canopy cover, high density of large trees, high numbers of subcanopy vegetation layers, and low to moderate slope positions were all important features…**

"The subset of foraging habitat that is not nesting/ roosting habitat generally had slightly lower values than nesting habitat for canopy cover, tree size and density, and canopy layering."

10. **Pg 71904: "Additional foraging habitat in this zone generally resembles nesting and roosting habitat, with reduced canopy cover and tree size, and reduced canopy layering."**

11. **Pg 71904: "High canopy cover, high levels of canopy layering, and the presence of very large dominant trees were all important features of nesting and roosting habitat. Compared to other zones, additional foraging habitat for this zone showed greater divergence from nesting habitat, with much lower canopy cover and tree size."**

12. **Pg 71905: "Nesting stands typically include a moderate to high canopy cover (60 to over 80 percent); a multilayered, multispecies canopy with large (greater than 30 in (76 cm) dbh) overstory trees; a high incidence of large trees with various deformities (e.g., large cavities, broken tops, mistletoe infections, and other evidence of decadence); large snags; large accumulations of fallen trees and other woody debris on the ground; and sufficient open space below the canopy for northern spotted owls to fly (Thomas et al. 1990, p. 164; 57 FR 1798, January 15, 1992). These findings were recently reinforced in rangewide models developed by Davis and Dugger (2011, Table 3–1, p. 39), who found that stands used for nesting (moderate to high suitability) exhibited high canopy cover of conifers (65 to 89 percent), large trees (mean diameter from 20 to 36 in (51 to 91 cm)), with a forest density of 6 to 19 large trees (greater than 30 in dbh) per acre (15 to 47 large trees (greater than 76 cm dbh) per hectare), and high diameter diversity."**

a. **Thomas et al. 1990. A conservation strategy for the northern spotted owl, at 164** (See above II.A.2.a)

b. **57 FR 1798, Jan 15, 1992**

c. **Davis, R.J., and K.M. Dugger. 2011. Chapter 3: Habitat status and trend. Pp. 21-62 in Davis, R.J., K.M. Dugger, S. Mohoric, L. Evers, and W.C. Aney. Northwest Forest Plan—the first 15 years (1994-2008): status and trends of northern spotted owl populations and habitats. U.S.D.A. Forest Service General Technical Report PNW-GTR-850. Pacific Northwest Research Station, Portland, Oregon, at 39**

i. Pg 28: “Canopy characteristics are usually the most easily determined via space-borne remote sensing instruments, and the most accurate GNN variable was conifer canopy cover, with an average plot correlation of 0.74 (±1 standard deviation [SD] = 0.07).”

ii. Pg 33: “As previously noted, we were restricted to only a few basic factors (i.e., tree diameter, canopy cover) for the habitat modeling done in the 10-year monitoring cycle (Davis and Lint 2005); however, the GNN map products provided us a more extensive “menu” of forest vegetation variables to consider.”

iii. Pg 34: “We also did not include total canopy cover or stand density index variables because both had high correlations with conifer cover, which had the highest plot accuracy of all GNN variables.”

iv. Pg 38: “High-quality owl habitat was described by Thomas et al. (1990) and generally includes older, multilayered, structurally complex forests characterized by large-diameter trees, high amounts of canopy cover, numerous large snags, and lots of downed wood and debris … As can be seen in table 3-1 and appendix C, the transition from unsuitable to suitable conditions is more complex than a simple increase in a stand’s average tree diameter and canopy closure.”

v. Pg 40: “Thomas et al. (1990) predicted that much of the forested area between owl conservation areas would be suitable for passage by dispersing spotted owls as long as at least 50 percent of the landscape was forested with conifer stands with an average d.b.h. of ≥11 in with at least 40 percent canopy closure.”

vi. Pg 48: “Increases in tree bole diameter and forest canopy cover happen at a faster rate in younger coniferous forests than in older forests, however, and the satellite-measured signal changes faster as well. Within the 10- to 12-year period of this investigation, mapping of such changes in early successional, pre-canopy-closure conditions are relatively robust (Kennedy 2010).

vii. Pg 53: “We cautiously accounted for gains in dispersal habitats after examination of the dispersal habitat maps on aerial imagery and through GIS analysis of changes in the tree diameter and canopy cover variables that were used in its definition.”

viii. Pg 99:

Table A-1—Environmental variables that were used for habitat modeling

Variable	Description	Units
Diameter diversity index	A measure of the structural diversity of a forest stand based on tree densities in different diameter at breast height (d.b.h.) classes. Calculation procedures are described in appendix 1 of McComb et al. (2002)[a]	Index
Canopy cover of all conifers	Percentage of conifer cover in the canopy as calculated using methods in the Forest Vegetation Simulator	Percentage
Stand height	Average height of dominant and codominant trees	Meters

ix. Pg 141: "As in the 10-year report, the "query groups" in table H-1 represent a progression of stand conditions, based on conifer diameter, total canopy cover, and stand structure complexity (strata) that represent habitat similarity to conditions used by spotted owls for nesting and roosting."

13. **Pg 71905: "Nesting northern spotted owls consistently occupy stands having a high degree of canopy cover that may provide thermoregulatory benefits (Weathers et al. 2001, p. 686), allowing northern spotted owls a wider range of choices for locating thermally neutral roosts near the nest site. A high degree of canopy cover may also conceal northern spotted owls, reducing potential predation. Studies of roosting locations found that northern spotted owls tended to use stands with greater vertical canopy layering (Mills et al. 1993, pp. 318–319), canopy cover (King 1993, p. 45), snag diameter (Mills et al. 1993, pp. 318–319), diameter of large trees (Herter et al. 2002, pp. 437, 441), and amounts of large woody debris (Chow 2001, p. 24; reviewed in Courtney et al. 2004, pp. 5–14 to 5–16, 5–23).**

a. **Weathers et al. 2001. Thermal ecology and ecological energetics of the California spotted owl, at 686** (see above II.A.2.b)

b. **King, G. 1993. Habitat Characteristics of Northern Spotted Owls in Eastern Washington. Master's thesis; Univ. of California, Berkeley. 81 pp, at 45**

c. **Mills, S.L., R.J. Fredrickson, and B.B. Moorhead. 1993. Characteristics of old-growth forests associated with northern spotted owls in Olympic National Park. Journal of Wildlife Management 57(2): 315-321, at 318-19**

i. Pg 317: "We visually estimated overhead canopy cover at different heights from the center of the reconnaissance plot (see Vales and Bunnell 1988 for favorable comparison between this and more objective methods) … We recorded, in 10% cover classes, the percent of the sky covered by canopy in each of the following vertical layers: 2-10 m, 11-20 m, 21-30 m, 31-40 m, and >40 m. All 5 overhead layers were summed to calculate an index to vertical canopy layering (VERT) that incorporated the height of the stand as well as the amount and the distribution of foliage in the canopy … Total overhead canopy cover was not included as a variable because it was highly correlated with VERT, and preliminary logistic regression analyses with VERT consistently performed much better than similar analyses with total cover."

ii. Pg 319: "Our finding that vertical canopy layering and snag diameter were important contributors to models that accurately predict whether an owl will be present at a given owl calling site during the day differs from studies in a mosaic of disturbed and undisturbed forests, where owls roosted in stands with higher canopy closure, lower herb and shrub cover, and higher basal area of large conifers (Solis and Gutierrez 1990). In our study, vertical canopy layering was a much better predictor of spotted owl presence than total canopy cover, and factors such as tree size, vegetation and log cover, and tree species composition were relatively unimportant predictors."

iii. Pg 319-20: "We believe that although total canopy cover is currently easier to measure from aerial and satellite imagery, it cannot replace the index of vertical canopy layering in assessing the probability of northern spotted owl occupancy. However, total canopy cover in conjunction with canopy depth as measured from aerial or satellite imagery (Short and Williamson 1986, Martens et al. 1991) may prove to be useful predictors."

d. Herter, D.R., L.L. Hicks, H.C. Stabins, J.J. Millspaugh, A.J. Stabins, and L.D. Melampy. 2002. Roost site characteristics of northern spotted owls in the nonbreeding season in central Washington. Forest Science. 48:437-444.

i. Pg 438-39: "Mature Forest habitat included old growth and mature coniferous stands dominated by large (>50 cm dbh) overstory trees with >60% canopy closure. Young Forest habitat consisted of coniferous stands dominated by medium-sized trees (generally >20 cm dbh) with >60% canopy closure. All other areas comprised the Non-Habitat category and included forest stands dominated by trees <20 cm dbh [generally stands too small and dense for subcanopy movements (Rosenberg and Anthony 1992)], the few stands with <60% canopy cover, stands containing >70% canopy cover of deciduous trees (based on Hanson et al. 1993), stands above 1,372 m elevation, all sapling, seedling, shrub, forb, and grass dominated habitats, open water, and bare rock (Hanson et al. 1993)."

ii. Pg 439: "We used point and transect methods to measure tree canopy closure and down wood, respectively …
"Overstory canopy cover (%) of the roost site was estimated using a moosehorn densiometer (Robinson 1947, Garrison 1949) at the four cardinal points 8 m from the roost tree."

iii. Pg 439: "We transformed percent data (e.g., canopy closure) for all ANOVA analyses, using the arcsine of the square root to meet assumptions of normality."

e. Chow, N. 2001. Distribution and habitat associations of northern spotted owls in Marin County, California. Master's thesis, Humboldt State University. 56 pages, at 24 (in Courtney et al 2004, 5-14 → 5-16, 5-23)

i. Courtney, S.P., J.A. Blakesley, R.E. Bigley, M.L. Cody, J.P. Dumbacher, R.C. Fleischer, A.B. Franklin, J.F. Franklin, R.J. Gutiérrez, J.M. Marzluff and L. Sztukowski. 2004. Scientific evaluation of the status of the northern spotted owl. Sustainable Ecosystems Institute, Portland, Oregon.

- Pg 4-6: "Solis and Gutiérrez found that canopy closure (as defined by the total cover of all plant growth forms above a point on the forest floor) was highest in roosting habitat, and lowest in areas infrequently used for foraging (typically on the edge of a home range). (Note that Carey et al. 1992 described roosting cover as being high overhead and lateral cover around the roosting owl and high foliage height diversity within the roosting stand.)"

  - Solis, D.M., and R.J. Gutierrez. 1990. Summer habitat ecology of northern spotted owls in northwestern California. Condor 92(3): 739-748.

- Carey, A.B., S.P. Horton, and B.L. Biswell. 1992. Northern spotted owls: influence of prey base and landscape character. Ecological Monographs 62(2):223-250.

NOTE: the terms "overhead cover" and "lateral cover" is also used in Carey et al 1992 to describe roost sites. There is no real mention of how "cover" or "closure" was determined for the study, although specific values are used to describe it.

- Pg 4-18, 19: "Note however Solis and Sisco commented on owls foraging along the edges of such clearcuts and old growth. Young forests have "low vertical diversity of vegetation and high canopy closure with few low structures beneath the canopy that would be suitable as hunting perches", therefore are "structurally poor for sit-and-wait predators" (Carey et al. 1992:246)."

- Solis and Sisco

- Carey et al. 1992. Northern spotted owls: influence of prey base and landscape character. (see above)

NOTE: the terms "overhead cover" and "lateral cover" is also used in Carey et al 1992 to describe roost sites. There is no real mention of how "cover" or "closure" was determined for the study, although specific values are used to describe it.

- Pg 5-4: "Third-order selection by Spotted Owls has been evaluated at a variety of spatial scales, from gross categorization of forest stands to detailed measurements of forest structure. Stand condition is a general classification based on species composition, tree age or size, canopy closure, fire regime, soil, climate and/or topographic characteristics …

"…"
"At a finer spatial scale, forest structure (canopy cover, tree diameter distribution, snag density, coarse woody debris, etc.) was quantified from detailed measurements at nest, roost, and random locations.

- Pg 5-7: "Habitat dominated by brush (< 25% canopy cover, woody plants < 15.2 cm dbh) comprised 24% of owl use areas (SE = 1) and 40% of unused areas (SE = 18)."

- Gutiérrez, R.J., J.E. Hunter, G. Chávez-león, and J. Price. 1998. Characteristics of spotted owl habitat in landscapes disturbed by timber harvest in northwestern California. J. Raptor Res. 32(2):104-110.

- Pg 5-10: "Vegetation was classified as: "preferred owl habitat" (conifer stands with ≥ 61 cm quadratic mean diameter [qmd] and ≥ 70% canopy cover, and hardwood stands with ≥ 76 cm qmd and ≥ 70% canopy cover); "marginal habitat" (conifer stands with ≥ 61 cm qmd and < 70% canopy cover, conifer stands with < 61 cm qmd, hardwood stands with ≥ 76 cm qmd and < 70% canopy cover, and hardwood stands with < 76 cm qmd); "woodrat habitat" (conifer stands with < 61 cm qmd and 10-50% canopy cover and hardwood

stands with < 76 cm qmd and 10-50% canopy cover); grass and shrub; non-forest (urban, barren and water)."

- Keithley, C. And B. Motroni. 2000 (draft). Examining the influence of land management on the habitat configuration surrounding northern spotted owl sites in northern California. California Department of Forestry and Fire Protection, Sacramento, CA.

- Pg 5-12: "Spotted Owl habitat was defined as having ≥ 60% canopy closure, numerous snags, and ≥ 2 canopy layers, and was measured from field-verified aerial photo interpretation before the fire, immediately post-fire, and one year post-fire (Gaines et al. 1997)."
- Gaines, W.L., R.A. Strand, and S.D. Piper. 1997. Effects of the Hatchery Complex Fires on northern spotted owls in the eastern Washington Cascades. Pages 123-129 in Dr. J.M. Greenlee, ed. Proceedings of the First Conference on Fire Effects on Rare and Endangered Species and Habitats, November 13-16, 1995. International Association of Wildland Fire. Coeur d'Alene, ID.

NOTE: Gaines et al 1997 defines suitable habitat for NSOs as including at least 60% "canopy closure," which was "completed from aerial photo-interpretation followed by field verification." However, the paper does not go into how canopy closure was measured in the field.

- Pg 5-13: "Old-growth and mature forest were combined in analyses and defined as forest dominated by trees > 53 cm dbh, generally 100% canopy closure, at least two height classes of trees, and decayed living trees, snags and downed woody material. Other cover types defined were closed sapling-pole-sawtimber stands (2.5 to 53 cm dbh and > 60% canopy closure), open sapling-pole stands (2.5 to 53 cm dbh and < 60% closure) and clearcuts."
- Miller, G.S., R.J. Small, and E.C. Meslow. 1997. Habitat Selection by Spotted Owls During Natal Dispersal in Western Oregon. J. Wildlife Management 61(1):140- 150

- 5-14: "In the Western Cascades of Washington, Spotted Owls used mature/old forest (dominated by trees > 50 cm dbh with > 60% canopy closure) more often than expected for roosting during the non-breeding season (n = 175 roosts) and used young forest (trees 20-50 cm dbh with > 60% canopy closure) less often than expected based on availability (Herter et al. 2002)."
- Herter et al. 2002. Roost site characteristics of northern spotted owls in the nonbreeding season in central Washington. (See above II.A.13.d)

- Pg 5-15: "They measured tree and snag density by diameter class, canopy cover, cover of downed wood, and shrubs within three 0.8-ha plots at each location. Locations with a single visit were similar to random locations whereas locations with multiple visits had greater snag density > 50 cm dbh and higher canopy closure."
- Buchanan, J.B., J.C. Lewis, D.J. Pierce, E.D. Forsman, and B.L. Biswell. 1999. Characteristics of young forests used by spotted owls

on the western Olympic Peninsula, Washington. Northwest Science 73(4):255-263.

Pg 257: “We measured canopy opening (the inverse of canopy closure) at the central point and at the plot edge in each octant in the smaller plots using a concave spherical densitometer (Lemmon 1956). To address concerns about the precision of single densiometer readings within a stand (Cook et al. 1995, but see Nuttle 1997) we recorded multiple estimates within each plot and then used the mean value of all plot measurements to represent the stand value. At each of these five points we recorded canopy opening in each of the four cardinal directions.”

- Pg 5-15: “Spotted owls roosted in areas lower in elevation, with larger tree dbh, fewer trees/ha, greater canopy cover, less shrub cover, and less down wood than found at random locations (n = 60).”
  - Herter et al. 2002. Roost site characteristics of northern spotted owls in the nonbreeding season in central Washington. (See above II.A.13.d)

- Pg 5-16: “Owls used sites with higher canopy closure, higher basal areas of medium-sized fir trees (27.5-52.4 cm dbh), higher slopes, taller mature-sized trees (52.5-89.9 cm dbh), and lower shrub height, grass cover, bare ground, and herb cover. Canopy cover was by far the most important discriminator between owl and random sites. Pidgeon (1995) conducted a study similar to that of King (1993) on the unmanaged portion of the Yakama Indian Reservation, comparing 163 owl use sites (88% roosting locations combined with 12% foraging locations) with 138 random loctations. Ground cover of litter, canopy cover, basal area of large conifers, and log volume were the best discriminators between used and random locations and were higher at random locations.”
  - King, G.M. 1993. Habitat characteristics of northern spotted owls in eastern Washington. M.S. thesis, University of California, Berkeley, CA

  - Pidgeon, A.M. 1995. Habitat characteristics of northern spotted owls in the unmanaged forest of the Yakama Indian Reservation, eastern Washington. M.S. thesis, Central Washington University, Ellensburg, WA.

- Pg 5-17: “Volume of coarse woody debris and percent canopy closure were similar between nest sites and random sites within nest stands.”
  - Buchanan, J.B., L.L. Irwin, and E.L. McCutchen. 1995. Within-stand nest site selection by spotted owls in the Eastern Washington Cascades. J. Wildlife Management 59(2):301-310.

- 5-18: “Evidence of past fire was visible at 71% of nest sites. Buchanan (1996) found few structural differences between nest sites and paired random sites within the same stands (e.g., total basal area and height of live trees, total canopy closure, snag density, volume of

downed wood) except that the number of canopy layers was greater at nest plots (median = 2.0) than random plots (median = 1.8; z = 2.20, P = 0.028)."

- Buchanan, J.B. 1996. Characteristics of spotted owl nests and nest sites in Klickitat County, Washington. Final report to the National Council for Air and Stream Improvement, Inc., Olympia, WA.

- 5-18: "All stands used by owls had canopy cover > 80% (estimated using a spherical densiometer)."
- Irwin, L.L., D.F. Rock, and G.P. Miller 2000. Stand structures used by northern spotted owls in managed forests. J. Raptor Res. 34(3):175-186.

Pg 177: "We estimated canopy cover using a concave densitometer
(after this study was well underway, we learned that this tool inflates estimates in high closure classes, see Cook et al. 1995)."

NOTE: As this was measured by a spherical densitometer, the measurement actually recorded canopy closure.

- 5-18: "Although no statistical comparisons were made and random sites were not measured, total canopy closure in nest and roost stands was similar (nest mean = 83%, SE = 1.7, median = 86; roost mean = 85%, SE = 1.0, median = 86). Mean conifer tree age was 73 years (SE = 12.0, median = 63, n = 41) in nest stands and 63 years (SE = 5.1, median = 69, n = 14) in roost stands."
- Pious, M. 1994. Nesting and roosting habitat of spotted owls in managed Redwood/Douglas-fir forests, California. Louisiana-Pacific Corporation, Forestry Department, Calpella, CA.

- 5-18: "No differences were found in any variable measured (e.g., tree and snag basal area by diameter class, log volume, shrub cover, canopy cover, ground cover) except diameter of the tree at the plot centers."
- White, A.E. 1996. Nest-site microhabitat of the spotted owl in the Klamath National Forest, California. M.S. thesis, University of Arkansas, Little Rock, AR.

- White, K. 1996.Comparison of fledging success and sizes of prey consumed by spotted owls in northwestern California. J. Raptor Res. 30(4):234–236.

- 5-18: "Mean canopy closure within one ha plots was 67% (range 48–80) using a sighting tube. In other stands, mean canopy closure was 16 to 23% lower using a sighting tube than using densiometers (Farber and Crans 2000)."
- Farber, S. and R. Crans. 2000. Habitat relationship of northern spotted owls (Strix occidentalis caurina) on Timber Products forestlands in northern California. Prepared for: The U.S. Fish & Wildlife Service for their Review of Management Activities

Conducted in Compliance with the Spotted Owl Management Plan. By: Timber Products Company, Yreka, CA.

- 8-16: "Franklin et al. (2000) mapped vegetation within 158 ha around each owl site center, defining two habitat categories: suitable owl habitat or older forest (mature and old-growth conifer ≥ 53 cm dbh, percent of conifers ≥ 40%, overstory canopy cover ≥ 70%) and all other habitat."
  - Franklin et al. 2000. Climate, habitat quality, and fitness in northern spotted owl populations in northwestern California. (see above II.A.7.b)

- Pg 8-28: "Canopy cover was nearly 80% in occupied stands and reproduction and occupancy were greatest where shrub cover was <20% (Finn et al. 2002b)."
  - Finn, S.P., J.M. Marzluff, and D.E. Varland. 2002. Effects of landscape and local habitat attributes on Northern Goshawk site occupancy in western Washington. Forest Science 48(2):427-436.

NOTE: Finn 2002b cited his "standard forest inventory techniques" from Finn S.P. 2000. Multi-scale habitat influences on Northern Goshawk occupancy and reproduction on the Olympic Peninsula, Washington. M.Sc. thesis, Boise State Univ., Boise, ID. 116 p. This study was not available online.

14. **Pg 71905: "Across regions, moderate to high suitability nesting habitat was characterized as having high canopy cover (65 to over 80 percent) and high basal area (240 ft2/ac; (55 m2/ha), mean dbh of conifers at least 16.5 to 24 in (42 to 60 cm), and a significant component of larger trees (greater than 30 in (75 cm))."**

15. **Pg 71905: "Foraging activity is positively associated with tree height diversity (North et al. 1999, p. 524), canopy cover (Irwin et al. 2000, p. 180; Courtney et al. 2004, p. 5–15), snag volume, density of snags greater than 20 in (50 cm) dbh (North et al. 1999, p. 524; Irwin et al. 2000, pp. 179–180; Courtney et al. 2004, p. 5–15), density of trees greater than or equal to 31 in (80 cm) dbh (North et al. 1999, p. 524) density of trees 20 to 31 in (51 to 80 cm) dbh (Irwin et al. 2000, pp. 179–180), and volume of woody debris (Irwin et al. 2000, pp. 179–180).**

    a. **North, M.P., J.F. Franklin, A.B. Carey, E.D. Forsman, and T. Hamer. 1999. Forest stand structure of the northern spotted owl's foraging habitat. Forest Science 45(4):520-527, at 524**
        i. Pg 523: "Canopy cover was measured using the average of 10 moosehorn readings (a modified funnel topped with a clear sighting grid with 100 points) systematically collected at each plot."

    b. **Irwin, L.L., D.F. Rock and G.P. Miller. 2000. Stand structures used by northern spotted owls in managed forests. Journal of Raptor Research 34:175–186, at 179-180**

NOTE: Used a concave densitometer. See above II.A.13.e.i. (under Courtney et al. 2004, page 5-18).

c. **Courtney et al. 2004. Scientific evaluation of the status of the northern spotted owl., p. 5–15** (see above II.A.13.e.i)

16. **Pg 71906: "As in other regions, foraging northern spotted owls select stands with mature and old-forest characteristics such as increasing mean stand diameter and densities of trees greater than 26 in (66 cm) dbh (Irwin et al. 2012, p. 206) and a dominant canopy of large conifer trees greater than 21 in (52.5 cm) dbh (Solis and Gutierrez 1990, p. 747), high canopy cover (87 percent at frequently used sites; Solis and Gutierrez 1990, p. 747, Table 3), and multiple canopy layers (Solis and Gutierrez 1990, pp. 744–747; Anthony and Wagner 1999, pp. 14, 17).**

    a. **Irwin L. L., D.F. Rock and S. C. Rock. 2012. Habitat selection by northern spotted owls in mixed-coniferous forests. Journal of Wildlife Management. 76:200-213, at 206**

    b. **Solis, D.M., and R.J. Gutierrez. 1990. Summer habitat ecology of northern spotted owls in northwestern CA. Condor 92: 739-748, at 744-747**

    c. **Anthony, R.G., and F.F. Wagner. 1999. Reanalysis of northern spotted owl habitat use on the Miller Mountain Study Area. Unpublished report. Submitted to Bureau of Land Management, Medford District and Forest and Rangeland Ecosystem Science Center, Biological Resources Division, U.S. Geological Survey, at pp. 14, 17**

17. **Pg 71906: "Dispersal habitat, at a minimum, consists of stands with adequate tree size and canopy cover to provide protection from avian predators and at least minimal foraging opportunities; there may be variations over the owl's range (e.g., drier site in the east Cascades or northern California)."**

18. **Pg 71907: "These habitats must provide [primary constituent elements]: (a)… (b) Stands for nesting and roosting that are generally characterized by: (i) Moderate to high canopy cover (60 to over 80 percent)…"**

19. **Pg 71907: "(a) West Cascades/Coast Ranges of Oregon and Washington … (ii) Moderate to high canopy cover (60 to over 80 percent); … (c) Klamath and Northern California Interior Coast Ranges … (v) High canopy cover (87 percent at frequently used sites); …"**

20. **Pg 71907: "(a) Habitat supporting the transience phase of dispersal, which includes: (i) Stands with adequate tree size and canopy cover to provide protection from avian predators and minimal foraging opportunities; in general this may include, but is not limited to, trees with at least 11 in (28 cm) dbh and a minimum 40 percent canopy cover; and (ii) Younger and less diverse forest stands than foraging habitat, such as even-aged, pole-sized stands, if such stands contain some roosting structures and foraging habitat to allow for temporary resting and feeding during the transience phase."**

21. **Pg 71910: "Other treatments, however, may involve reductions in stand densities, canopy cover, or ladder fuels (understory vegetation that has the**

potential to carry up into a crown fire)—and thus affect the physical or biological features needed by the species."

22. **Pg 71910: "High canopy cover, high levels of canopy layering, and the presence of very large dominant trees were all important features of nesting and roosting habitat."**

23. **Pg 71942: "For example, portions of the landscape can be identified where there may be no conflict between objectives, and where relatively aggressive approaches to ecosystem restoration can occur without placing listed species at substantial risk (Prather et al. 2008, pp. 147–149; Gaines et al. 2010, pp. 2049–2050). Conflicts between objectives will remain in some locations, such as in places where removing younger, shade-intolerant conifers to reduce competition with larger, legacy conifers may result in a substantial decrease in canopy cover that translates into a reduction in northern spotted owl habitat quality."**

    a. **Prather, J.W., R.F. Noss, and T.D. Sisk. 2008. Real versus perceived conflicts between restoration of ponderosa pine forests and conservation of the Mexican spotted owl. Forest Policy and Economics 10:140-150, at pp. 147–149.**
        i. Pg 143: "A canopy cover layer was developed using Digital Orthophoto Quads (DOQs) and a form of advanced exploratory data analysis (Xu et al., 2006). In this methodology each 1-m pixel in the DOQ is classified as canopy foliage, shadow, or ground vegetation based on its spectral signature. Percent canopy cover is derived by determining the number of 1-m pixels identified as canopy foliage within a larger window."

    b. **Gaines, W.L., R.J. Harrod, J. Dickinson, A.L. Lyons and K. Halupka. 2010. Integration of Northern spotted owl habitat and fuels treatments in the eastern Cascades, Washington, USA. Forest Ecology and Management 260:2045–2052, at pp. 2049–2050**
        i. Pg 2046: "We used published literature from local studies to determine a set of variables that we thought would best describe spotted owl habitat and also be of use to managers designing forest treatments in and around Northern spotted owl habitat … We used canopy closure as it is commonly used to describe spotted owl habitat (Davis and Lint, 2005; Tari, 2007) and Buchanan and Irwin (1998) identified canopy closure as one of several variables that provide important functions for spotted owls."

        ii. Pg 2046: "Based on these premises, we identified a set of seven a priori models to evaluate against our spotted owl activity center and reproductive site location data (Table 1):"

Table 1
Data source for the variables used to model habitat for the Northern spotted owl and identify priority areas for fuels treatments in the eastern Cascades, Washington.

Model variables	Categories	Data source
Forest group	Dry Forest Wet Forest	Based on Plant Association Groups data-layer for the east-Cascades Province
Canopy closure	High = > 60% canopy closure Moderate = 40–60% canopy closure Low = 10–40% canopy closure	Interagency Vegetation Mapping Program
Tree size	Small = <10″ QMD Medium = 10–15″ QMD Large = >20″ QMD	Forest-wide tree structure datalayer developed from Nieman (1998)
Aspect	North = 316–45° East = 46–135° South = 136–225° West = 226–315°	30 m digital elevation model re-sampled to 25 m resolution
Slope	Flat = < 5° Gentle = 5–14° Moderate = 15–25° Steep = > 25°	30 m digital elevation model re-sampled to 25 m resolution

NOTE: It is uncertain from Gaines et al. 2010 if the data used for building the canopy closure model was derived from remote sensing data (in which case it would actually be canopy cover measurements) or if it is from field studies (which could be either closure or cover).

24. **Pg 71950: "There are two baseline conditions that will be maintained under the SHA: (1) Protection of an 11.2-ac (5-ha) no-harvest area that will buffer the most recent active northern spotted owl nest site, but will also be maintained in the absence of a nest site; and (2) maintenance of 216 ac (87 ha) on the property such that the trees will always average 12 to 24 in (30 to 60 cm) dbh with a canopy cover of 60 to 100 percent. At the time of the agreement, forest conditions were on the lower end of the diameter and canopy cover ranges. By the end of the agreement, the property will be at the upper end of the diameter and canopy cover ranges."**

    a. **Forster-Gill, Inc. Safe Harbor Agreement**

25. **Pg 71979: "In addition, the SORP stipulates a series of actions intended to increase canopy cover and move management of forest stands to uneven-aged management to promote multilayered canopies and protect old growth stands and individual trees with old-growth structural features."**

26. **Pg 72017: "PCE 4 (habitat to support the transience and colonization phases of dispersal) is described in the preamble of the proposed rule as those forests with at least an average diameter at breast height (DBH) of 11 inches (28 centimeters) and at least a 40 percent canopy cover."**

27. **Pg 72051: "(B) Stands for nesting and roosting that are generally characterized by: (1) Moderate to high canopy cover (60 to over 80 percent)."**

28. **Pg 72051: "(A) West Cascades/Coast Ranges of Oregon and Washington … (2) Moderate to high canopy cover (60 to over 80 percent)."**

29. **Pg 72051: "(C) Klamath and Northern California Interior Coast Ranges … (5) High canopy cover (87 percent at frequently used sites)."**

30. **Pg 72052: "(D) Redwood Coast … (A) Habitat supporting the transience phase of dispersal, which includes: (1) Stands with adequate tree size and canopy cover to provide protection from avian predators and minimal foraging opportunities; in general this may include, but is not limited to, trees with at least 11 in (28 cm) dbh and a minimum 40 percent canopy cover; …"**