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Estimating Canopy Cover in Forest Stands Used by Mexican Spotted Owls: Do Stand-Exam Routines Provide Estimates Comparable to Field-based Techniques?

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Abstract

Canopy cover has been identified as an important correlate of Mexican spotted owl (*Strix occidentalis lucida*) habitat, yet management guidelines in a 1995 U.S. Fish and Wildlife Service recovery plan for the Mexican spotted owl did not address canopy cover. These guidelines emphasized parameters included in U.S. Forest Service stand exams, and canopy cover typically is not sampled in these inventories. Algorithms exist to estimate canopy cover from stand-exam data, but the accuracy of resulting estimates is unknown. We compared existing field data on observed canopy cover within forest stands used by radio-marked Mexican spotted owls with estimates derived from those analysis routines. Based on arbitrary criteria for minimum canopy cover, we also estimated proportions of these stands that would be misclassified by derived estimates. Canopy-cover estimates derived from stand-exam data differed widely from observed canopy cover in many stands, and derived estimates frequently misclassified stands based on canopy-cover criteria. These algorithms performed worst in mesic mixed-conifer forest, the forest type in which spotted owls occur most commonly. We conclude that existing algorithms for estimating canopy cover from stand-exam data are not useful in forest habitat for Mexican spotted owls.

Keywords: Arizona, habitat assessment, methodology, Mexican spotted owl, New Mexico

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Introduction

Both canopy cover and closure (see Jennings and others 1999 for differences between parameters) have been identified as important correlates of habitat use or selection for many species of native wildlife, including all three recognized subspecies of spotted owls (*Strix occidentalis*; Gutiérrez and others 1995). Numerous studies have documented strong associations between either canopy cover or canopy closure and habitat use by the threatened Mexican spotted owl (*S. o. lucida*; Ganey and Dick 1995; Grubb and others 1997; May and others 2004; Rinkevich and Gutiérrez 1996; Seamans and Gutiérrez 1995; Tarango and others 1997; Young and others 1998). However, despite its apparent importance, no measure of canopy cover was included in specific recommendations for spotted owl habitat in a recovery plan prepared for this owl (USDI 1995: table III.B.1). This omission occurred primarily because these recommendations emphasized parameters included in U.S. Forest Service (USFS) stand exams in hopes that available stand-exam data could provide a means to assess habitat suitability for spotted owls. Neither canopy cover nor canopy closure typically is measured in such exams. Algorithms exist to estimate canopy cover from stand-exam data, but accuracy of the resulting estimates is unknown. Existing field data on canopy cover within forest stands used by radio-marked spotted owls provided an opportunity to compare observed canopy cover with estimates derived using stand-exam data and existing algorithms. Here, we (1) compare stand-scale, field-based estimates of canopy cover (hereafter observed cover) with estimates derived from stand-analysis routines for those stands (hereafter derived cover); and 2) estimate proportions of stands that would be misclassified by estimates of derived cover based on arbitrary criteria for minimum canopy cover. Our overall objective was to evaluate whether derived estimates of canopy cover could be used effectively to facilitate assessment of habitat suitability for Mexican spotted owls using existing data.

Study Areas

We monitored movements and habitat use of radio-marked Mexican spotted owls in three study areas, one in north-central Arizona and two in the Sacramento Mountains, south-central New Mexico. The Bar-M Canyon study area was located within the Bar-M and Woods Canyon watersheds, Coconino National Forest, approximately 26 km south of Flagstaff, Arizona. Elevation in this area ranged from 1,800 to 2,500 m. Topography was relatively gentle with rolling terrain broken by scattered volcanic buttes and small canyons. Most of the study area consisted of ponderosa pine (*Pinus ponderosa*) or ponderosa pine-Gambel oak (*Quercus gambelii*) forest with scattered meadows or parks. Alligatorbark juniper (*Juniperus deppeana*) was present in many stands, particularly on warmer, drier sites. Small pockets of quaking aspen (*Populus tremuloides*) also occurred throughout the study area, and narrowleaf cottonwood (*P. angustifolia*) and box-elder (*Acer negundo*) occurred in some canyons.

The other two study areas were located within the Sacramento Mountains of south-central New Mexico. One study area (the "mesic" study area in Ganey and others 2000, 2005) was located along the Rio Peñasco approximately 12 km southeast of Cloudcroft, New Mexico. Montane canyons dominated topography in this area, where elevation ranged from 2,400 to 2,800 m. Montane meadows were common in canyon bottoms, whereas most canyon slopes and ridgetops were forested. The predominant forest type was a mesic mixed-conifer forest dominated by Douglas-fir (*Pseudotsuga menziesii*), white fir (*Abies concolor*), or both. Southwestern white pine (*P. strobiformis*) was prominent in many stands, and ponderosa pine and quaking aspen were common. In contrast, drier cover types dominated the second New Mexico study area (the "xeric" study area in Ganey and others 2000, 2005) located in and around the Sixteen Springs drainage approximately 18 km northeast of Cloudcroft and approximately 30 km from the mesic study area. Elevation in this area ranged from 2,000 to 2,500 m, and montane canyons again dominated topography. Vegetation in this area consisted of a mosaic of mesic and xeric forest types. Mixed-conifer forest was restricted to cooler microsites such as drainage bottoms and north-facing slopes. Woodlands of piñon pine (*P. edulis*) and alligatorbark juniper dominated most ridgetops and south-facing slopes. Other slopes were dominated by ponderosa pine forest, sometimes with a prominent component of Gambel oak. Gray oak (*Q. griseus*) and wavyleaf oak (*Q. undulatus*) also were present in some areas.

Methods

Methods for capturing and radio tracking owls, (as discussed in Ganey and others 1999), were similar in all study areas and will be summarized here only briefly. We captured owls, attached radio transmitters, and located the owls 4 to 5 days and nights per week throughout the year at all hours. We used the accumulated owl locations to estimate 95 percent adaptive kernel home ranges (Worton 1989) and used these home ranges to define a sampling universe for sampling stand characteristics.

We sampled canopy cover using vertical-projection methods within forest "stands" mapped by the USFS. Methods for locating plots and sampling canopy cover in these stands differed slightly between study areas. In the Bar-M Canyon study area, we sampled canopy cover in plots at 200-m intervals on a grid laid out along a randomly selected bearing from a known starting point. Within each plot, we sampled canopy cover at point intercepts located at 1-m intervals along a randomly oriented, 36-m transect centered at plot center. At each intercept, we recorded the presence/absence of overhead foliage using a sighting tube equipped with a central crosshair (Ganey and Block 1994). Percent canopy cover was computed as [(number of intercepts with overhead cover/36) x 100]. All plots were sampled during the summer when deciduous trees had leaves.

We modified sampling methods in the Sacramento Mountains study areas based on lessons learned while sampling in the Bar-M Canyon

area. Here, we allocated plots to stands based on stand area and a desired sampling intensity of one plot/2 ha. Plot locations were mapped systematically within stands to obtain uniform coverage throughout the stand. To establish plots in the field, crews used topographic maps to locate the approximate mapped point and then paced a randomly selected distance between one and 36 paces in a randomly-selected direction to locate the plot center.

We again sampled canopy cover at 36 point intercepts along line transects, but located intercepts along a pair of perpendicular 18-m line transects centered at plot center (the center point was sampled once) rather than along a single longer transect. Percent canopy cover was computed as described above, and all plots were sampled during the summer.

We queried the USFS stand-exam data base to determine which stands with estimates of observed canopy cover also had recent stand-exam data. Most of the stand-exam data used was collected from approximately 1985 to 1995, which corresponded reasonably well with the field sampling (1993 to 1995). No timber harvests occurred in these stands during this period, nor were these areas subject to any large wildfires. Thus, no major stand-disturbing events occurred between sampling for stand exams and field sampling of canopy cover.

For all stands with recent data, we estimated canopy cover using routines available in RMSTAND, a computer program developed by USFS to aid in summarizing stand-exam data. These routines are based on Moeur (1981, 1985), and estimate canopy separately by species due to the variation in growth form among different species. Estimates were derived from conifers native to the northern Rocky Mountain Region and extrapolated to similar southwestern conifer species.

Two estimates of derived canopy cover were computed using RMSTAND: 1) total percent canopy cover for all vegetation and 2) total percent canopy cover for all vegetation >1.8 m in height. Estimate 2 thus included only “overhead” cover and appeared most compatible conceptually with field-based estimates which sampled only overhead cover.

We computed within-stand differences between estimates by subtracting estimates of derived cover from estimates of observed cover. Thus, positive differences meant that derived cover underestimated relative to observed cover, and negative values meant that derived cover overestimated relative to observed cover. Because small samples of field plots in some stands might bias estimates of canopy cover if they happened to fall in either canopy openings or areas of excessively dense canopy, we also used Pearson’s product-moment correlation coefficient to evaluate relationships between number of field plots per stand and differences between derived and observed canopy cover.

Based on guidelines for minimum canopy cover, we also estimated proportions of stands that would be misclassified by derived estimates. These guidelines were study-area specific and based on the lower bound of the 95% confidence interval around mean observed

stand-scale canopy cover for each study area. Although these guidelines could be viewed as arbitrary, this should not matter in assessing agreement between techniques in habitat classification.

Results

Estimates of observed canopy cover were available for 375 stands in the Bar-M study area, 94 stands in the Sacramento Mountains—mesic study area, and 135 stands in the Sacramento Mountains-xeric study area. Stand-exam data were available for 143 of these stands in the Bar-M study area (38.1 percent of total stands sampled), 85 stands in the Sacramento Mountains—mesic study area (90.4 percent), and 98 stands in the Sacramento Mountains-xeric study area (72.6 percent). Number of plots per stand averaged 6.87 ± 0.54 (SE), 6.44 ± 0.50, and 6.58 ± 0.49 in the Bar-M, Sacramento Mountains—mesic, and Sacramento Mountains—xeric study areas, respectively. Plot number was not significantly correlated with differences between observed cover and either of the derived estimates in any study area (all P-values >0.259).

Derived estimates both under- and over-estimated canopy cover relative to observed cover (fig. 1). Because under- and over-estimates tended to cancel each other, median differences between estimates were close to zero. However, differences within individual stands often were quite large, exceeding 50 percent for at least some estimates in all study areas and exceeding 100 percent in the Sacramento Mountains—mesic study area (fig. 1).

Misclassification rates for stands were high for all derived estimates of canopy cover in all study areas (table 1). Stands that met the minimum criterion for canopy cover based on observed canopy cover (45 percent in the Bar-M Canyon area, 65 percent in the Sacramento Mountains—mesic area, and 53 percent in the Sacramento Mountains—xeric area; see table 1) frequently did not meet the criterion based on derived canopy cover, and stands that did not meet the minimum criterion based on observed canopy cover frequently did meet that criterion based on derived canopy cover. Misclassification rates varied among study areas, canopy estimates, and type of error, but generally were highest in the Sacramento Mountains—mesic study area.

Discussion and Management Implications

Our results suggest several potential problems in using estimates of canopy cover derived using RMSTAND routines to assess habitat suitability for Mexican spotted owls. First, the stand exam data to conduct this assessment simply do not exist for many stands (for example, over 60 percent of stands in the Bar-M area lacked recent stand-exam data). Second, differences between observed canopy cover and derived estimates were large for many stands (fig. 1), and misclassification rates for individual stands were high (table 1). Third,

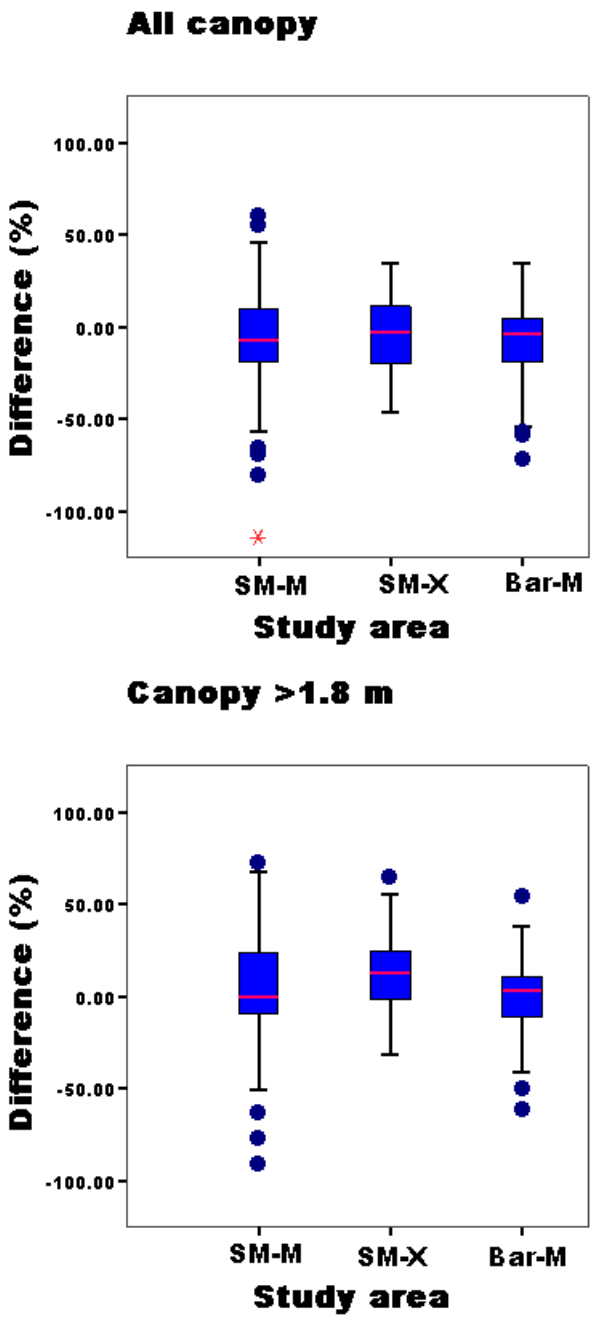

Figure 1. Boxplots of differences between observed canopy cover and two estimates of derived canopy cover (all canopy, top, and canopy >1.8 m, bottom) for three study areas (SM-M and SM-X refer to Sacramento Mountains-mesic and Sacramento Mountains-xeric areas, respectively). Differences were computed by subtracting derived estimates from observed canopy cover. Thus, positive differences meant that derived estimates underestimated relative to observed canopy cover, and negative values meant that derived estimates overestimated relative to observed canopy cover. Blue boxes indicate the interquartile range (from 25th to 75th percentile), the red line indicates the median, and exterior black lines indicate the range in the data excluding outliers (blue circles) and extremes (red asterisks). Outliers and extremes were defined as observations more than 1.5 and 3 times the box length outside the box, respectively.

RMSTAND estimates generally performed worst in the study area dominated by mesic mixed-conifer forest (fig. 1, table 1), the forest type most strongly associated with Mexican spotted owls in most parts of their range (Ganey and Dick 1995). Collectively, these issues suggest that analytical routines in RMSTAND should not be used in habitat assessment based on canopy cover. Fiala and others (2006) reached similar conclusions regarding the Forest Vegetation Simulator (Donnelly and Johnson 1997), a growth-and yield model commonly used by USFS to evaluate treatment effects (but apparently not commonly used in static habitat assessment).

Available evidence strongly implicates canopy cover as an important correlate of Mexican spotted owl habitat. Consequently, it would

Table 1. Proportions of individual forest stands misclassified by derived estimates with respect to criteria for minimum canopy cover in Mexican spotted owl habitat, by study area and canopy-cover estimate.

Study area	Number of stands	Canopy-cover estimate	Percent misclassified as non-habitat[a]	Percent misclassified as habitat[b]	Overall percent misclassified
Bar-M Canyon	142	All canopy	46.7	30.9	35.9
		Canopy >1.8 m high	24.4	46.4	39.4
Sacramento Mtns - mesic	85	All canopy	33.3	72.0	44.7
		Canopy >1.8 m high	45.0	44.0	44.7
Sacramento Mtns -xeric	98	All canopy	27.5	45.0	34.7
		Canopy >1.8 m high	58.6	12.5	39.8

[a] Misclassification here means that a stand met the minimum criterion for canopy cover based on observed canopy cover, but did not meet that minimum criterion based on derived canopy cover. Minimum criteria used for this study were 45 percent in Bar-M Canyon area, 65 percent in the Sacramento Mountains-mesic area, and 53 precent in the Sacramento Mountains-xeric area.

[b] Misclassification here means that a stand did not meet the minimum criterion for canopy cover based on observed canopy cover, but did meet or exceed that criterion based on derived canopy cover.

be desirable to include canopy cover in guidelines for management of owl habitat. However, it would be pointless to do so without a reliable means to assess canopy cover, and we currently lack a viable option. Our results strongly argue against basing such an assessment on existing routines. These routines could perhaps be improved, but our results also suggest that recent stand-exam data are lacking for many USFS lands and generally are not available for lands in other ownerships. Thus, improving stand-exam routines would provide only a partial solution to this problem. Field sampling is possible on a limited basis, but is both time-consuming and costly, precluding its use on a widespread basis.

If canopy cover is to be incorporated into broad-scale habitat assessment, the most viable approach to accomplish that appears to be use of remote-sensing data. Several types of remotely-sensed data appear to hold promise for assessing canopy structure. For example, Sisk and others (2006) modeled canopy cover across large areas using 1-m resolution digital orthophotos and a fractal classification technique to separate areas of crown, shadow, and non-forest vegetation (see also Xu et al. 2006). Fiala and others (2006) suggested that light detection and ranging (LIDAR) remote sensing technology might provide another viable alternative (see also Lefsky and others 2001, 2002; Parker and others 2004). Koy and others (2005) successfully estimated canopy cover using Landsat imagery. Landsat imagery appears to have several desirable attributes, including being readily available for many areas, being updatable, and covering all land ownerships. Use of satellite imagery to assess canopy cover would require initial efforts to classify imagery and ground truth resulting classifications. Classified images then could be helpful in assessing habitat not only for Mexican spotted owls, but for many other species of interest as well. Further, once techniques are worked out, imagery could be periodically updated to assess changes in forest canopies. Given the difficulties inherent in funding and accomplishing

wide-scale sampling of forest canopy cover on the ground, we encourage agencies to explore the use of remote-sensing technologies so that accurate estimates of canopy cover could be used to improve management of forest habitat for selected species of native wildlife, including spotted owls.

Epilogue

Since this work was initiated, the Southwestern Region (and other Regions) of USFS has begun using FSVEG (http://fsweb.nris.fs.fed.us/products/FSVeg/index.shtml/) in place of RMSTAND. However, RMSTAND routines are still maintained, with the option of running such routines and importing results to FSVEG (Georgi Porter, USFS, Southwestern Region, personal communication 19 Dec 2006). Thus, conclusions drawn here are still relevant to potential analyses using canopy-cover routines, despite the general de-emphasizing of RMSTAND.

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