

## FLAMMULATED OWL (*OTUS FLAMMEOLUS*) BREEDING HABITAT ABUNDANCE IN PONDEROSA PINE FORESTS OF THE UNITED STATES

MARK D. NELSON,<sup>1,4</sup> DAVID H. JOHNSON,<sup>2</sup> BRIAN D. LINKHART,<sup>3</sup> AND PATRICK D. MILES<sup>1</sup>

<sup>1</sup>U.S. Department of Agriculture Forest Service, Northern Research Station, 1992 Folwell Avenue, St. Paul, Minnesota 55108, USA;

<sup>2</sup>Global Owl Project, Center for Biological Diversity, 6504 Carriage Drive, Alexandria, Virginia 22310, USA; and

<sup>3</sup>Colorado College, 14 East Cache La Poudre, Colorado Springs, Colorado 80903, USA

*Abstract.* Flammulated Owl (*Otus flammeolus*) inhabits mid-elevation montane forests of ponderosa pine (*Pinus ponderosa*) and Jeffrey pine (*Pinus jeffreyi*) across western North America during the breeding season. We employed data from the USDA Forest Service's Forest Inventory and Analysis (FIA) program to assess historic and current extent of ponderosa and Jeffrey pines comprising the majority of Flammulated Owl habitat within 11 western states of the USA. We cross-referenced breeding habitat characteristics to FIA data attributes; then produced estimates and maps of forest land area and potential habitat abundance from FIA data and made comparisons with other published data. We estimated area of current ponderosa and Jeffrey pine forest types on forest land as 98 633 km<sup>2</sup> and 83 000 km<sup>2</sup>, from FIA and LANDFIRE data, respectively. Area of ponderosa and Jeffrey pine forest types on timberland (a subset of forest land) decreased from 136 200 km<sup>2</sup> to 86 827 km<sup>2</sup> (36%.) between 1953 and 2007. Within the past two decades these forest types decreased by 14% overall; increased 16% within stand-ages of 100-149 years and decreased 49% within stand-ages of 150 years or older; increased 22% within diameters of 30-49 cm and decreased 28% within diameters of 50 cm and larger; and increased 115% within stocking classes of 10-59%. We estimated area of potential breeding habitat abundance for Flammulated Owl at about 48 000 km<sup>2</sup> from FIA data, 50 000 km<sup>2</sup> from LANDFIRE data, and 522 000 km<sup>2</sup> from GAP data sources. FIA provides data and information for producing estimates of Flammulated Owl breeding habitat abundance.

*Key Words:* Flammulated Owl, *Otus flammeolus*, ponderosa pine, *Pinus ponderosa*, habitat, forest inventory, FIA.

## TECOLOTE OJO OSCURO (*OTUS FLAMMEOLUS*) ABUNDANCIA DEL HÁBITAT REPRODUCTIVO EN BOSQUES DE PINO PONDEROSA EN LOS ESTADOS UNIDOS

*Resumen.* El tecolote ojo oscuro (*Otus flammeolus*) habita en elevaciones medias de bosques de montaña de pinos ponderosa (*Pinus ponderosa*) y de Jeffrey (*Pinus jeffreyi*) en el oeste de Norte America durante la temporada reproductiva. Empleamos datos del Inventario Forestal y Análisis (FIA) del Servicio de Bosques de USDA para evaluar la extensión histórica y actual de los bosques de pino ponderosa y de Jeffrey que componen la mayoría del hábitat del tecolote ojo oscuro en 11 estados del oeste de los Estados Unidos. Referenciamos las características del hábitat reproductivo con atributos de FIA e hicimos estimaciones y mapas del área forestal y abundancia potencial del hábitat de datos de FIA y los comparamos con otros datos publicados. Estimamos el área actual de los tipos de bosque de ponderosa y de Jeffrey como 98 633 km<sup>2</sup> y 83 000 km<sup>2</sup>, de FIA y datos de LANDFIRE, respectivamente. El área de los bosques de pino ponderosa y de Jeffrey en áreas maderables (una división de área boscosa) decreció de 136 200 km<sup>2</sup> a 86 827 km<sup>2</sup> (36%.) entre 1953 y 2007. En las pasadas dos décadas estos bosques decrecieron un 14% en toda el área; incrementaron un 16% dentro de los parches de 100-149 años y decrecieron un 49% dentro de los parches de 150 o mas años; incrementó un 22% dentro de diámetros de 30-49 cm y decreció un 28% dentro de diámetros de 50 cm y mayores; e incrementó 115% dentro de las clases en reserva de 10-59%. Estimamos la abundancia el área potencial del hábitat reproductivo para el tecolote ojo oscuro de alrededor de 48 000 km<sup>2</sup> de los datos de FIA, 50 000 km<sup>2</sup> de los datos de LANDFIRE, y 522 000 km<sup>2</sup> de los datos de GAP. La FIA provee datos e información para producir estimaciones de la abundancia del hábitat reproductivo del tecolote ojo oscuro.

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<sup>4</sup>E-mail: mdnelson@fs.fed.us

## INTRODUCTION

Ponderosa pine (*Pinus ponderosa*) is the most wide-ranging conifer species in the United States and Canada (Graham and Jain 2005). Prior to Euro-American settlement, dry ponderosa pine and mixed conifer forests of the Inland Northwest burned frequently from low- or mixed-severity surface fires (Hessburg et al. 2005), which favored fire-tolerant trees, such as ponderosa pine and maintained low and variable tree densities, light and patchy ground fuels, simplified forest structure, and a low and patchy cover of associated fire-tolerant shrubs and herbs (Hessburg et al. 2005).

Ponderosa pine forest has decreased in abundance and has changed in forest structure during the past century, attributed to European settlement and resulting land management practices of timber harvest and wildfire suppression, introduction of domestic livestock, and climate cycles (Cooper 1960, Graham and Jain 2005). These "dry forests" now are dominated not only by ponderosa pine, but also by dry mixed conifer forests of grand fir (*Abies grandis*), white fir (*Abies concolor*), and Douglas-fir (*Pseudotsuga menziesii*) zones. Furthermore, these forests now comprise large landscapes that are more homogeneous in their composition and structure, and are more susceptible to severe, large fire and insect disturbance events (Hessburg et al. 2005).

Concerns over these changes in ponderosa pine forest, especially as they relate to habitat for cavity-nesting birds, led to a special session on this topic at the 4th International Partners In Flight (PIF) conference, held 13–16 February 2008, McAllen, Texas, USA. This paper addresses Inventory and Monitoring needs for producing a PIF Bird Conservation Needs Assessment pertaining to ponderosa pine restoration and bird habitat.

## HABITAT TERMINOLOGY

Hall et al. (1997) define 'habitat' as "...the resources and conditions present in an area that produce occupancy—including survival and reproduction by a given organism." Animals select habitat through a process of hierarchical spatial scaling at four levels: (1) geographic range of a species during a particular season, which may be genetically determined; (2) home ranges of individual animals; (3) specific sites or components within a home range; and (4) resources procured within microsites (Johnson 1980, Hutto 1985). Habitat 'abundance' is a term preferred over habitat 'availability', because the latter implies a measure of "...accessibility and

procurability of physical and biological components of a habitat by animals"—attributes which are difficult to quantify (Hall et al. 1997).

Our study focused on assessing the abundance of potential breeding habitat for the Flammulated Owl (*Otus flammeolus*) over the United States portion of the owl's range. Our rationale was that (1) PIF sets population goals for each bird species based in part on abundance of breeding habitat, (2) sufficient studies of breeding habitat have been conducted to characterize the vegetation component of species-habitat relationships for the Flammulated Owl, and (3) sufficient forest inventory data on vegetation composition and structure are available across nearly the entire breeding range of this species, allowing for estimates of potential breeding habitat abundance.

## FLAMMULATED OWL

The Flammulated Owl is a cavity-nesting, insectivorous, Neotropical migratory bird. During the breeding season, it typically occupies mid-elevation montane forest with seasonably temperate climates, primarily within forests of western yellow pine-ponderosa pine, Jeffrey pine (*Pinus jeffreyi*), and Washoe pine (*P. washoensis*)—and submontane Douglas fir (*Pseudotsuga menziesii*). The range of this owl extends from northern Mexico into southern British Columbia, Canada, including the states of Washington, Oregon, California, Idaho, Utah, Nevada, Arizona, Montana, Colorado, New Mexico, and a small portion of western Texas (McCallum 1994, Dunham et al. 1996, van Woudenberg 1998) (Fig. 1). Barnes (2007) provides an estimate of 300 000 adult Flammulated Owls in the United States, based on the following assumptions: 24 million ha of habitat (Morgan 1994), a ratio of adult females to adult males of 0.65 (Reynolds and Linkhart 1987), and a mean density of 0.3 singing males per 40 ha.

## Habitat

Barnes (2007) described spatial scales of Flammulated Owl habitat selection for an Idaho study area—terms corresponding to spatial scaling levels in Johnson (1980) and Hutto (1985) are shown in parentheses: landscape (geographic range); home range (home range); and nest vegetation, nest tree, and day roost (specific sites or components of a home range). Landscape-scale habitat selection was strongly influenced by slope position and aspect variables—mid to upper slopes, often with east- or south-facing aspects. In colder regions like Idaho, south and east-facing upper slopes may warm faster,

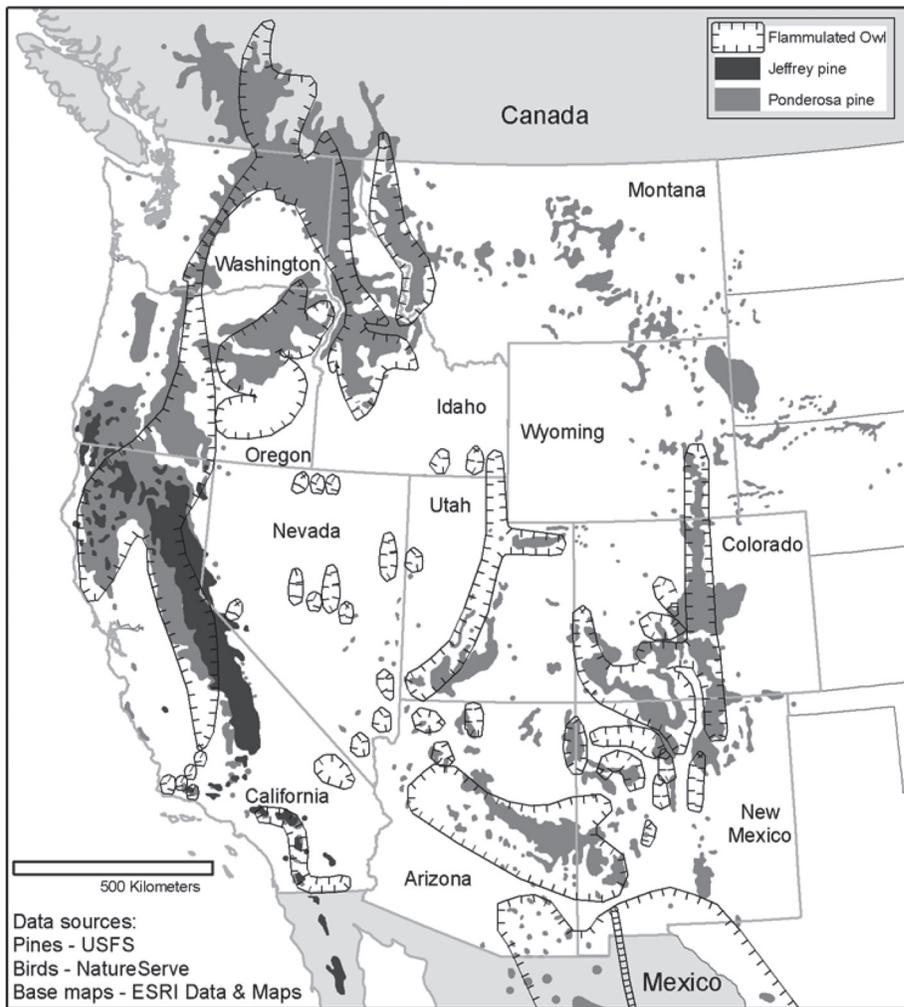


FIGURE 1. Geographic distribution of Flammulated Owl (*Otus flammeolus*), ponderosa pine (*Pinus ponderosa*), and Jeffrey pine (*Pinus jeffreyi*) within Canada, Mexico, and 11 western states, USA.

thereby creating more favorable microclimates for insects, the primary prey of Flammulated Owls. Forest cover exhibited moderate influence on selection at the landscape scale—forest cover of 25–75% being selected most. At the home-range scale, areas with high density of snags were more likely to be occupied compared with adjacent areas with lower densities of snags. But the proportion of forest and clearings was highly variable within home ranges. Habitat selection at the nest-vegetation and nest-tree scale showed no differences between used and available sites for any measured variable or between used and available cavity trees in the Idaho study, suggesting that availability of nest cavities at the home-range scale constrained owl use to certain areas, whereas foraging habi-

tat may have been adequate throughout the entire study area. Ponderosa pines used as day-roosts were 55–70 cm diameter at breast height (dbh; 1.37 m) (peak of the frequency distribution); ponderosa pine was selected disproportionately more than available, and Douglas fir disproportionately less than available (Barnes 2007). In a Colorado study, Flammulated Owls occupied home ranges that contained more old ponderosa pine/Douglas fir than other types of overstory vegetation, likely a result of a corresponding abundance of lepidopteran prey (Linkhart et al. 1998).

Western yellow pines do not typify Flammulated Owl breeding habitat within the Great Basin. In Nevada, yellow pines are limited to the eastern slope of the Sierra Nevadas

and adjacent large mountain ranges, and to mountain ranges in the extreme eastern and southern portions of the state. Where western yellow pines are absent, montane conifer forests comprised of white fir (*Abies concolor*), subalpine fir (*A. lasiocarpa*), and limber pine (*Pinus flexilis*) provide breeding habitat for Flammulated Owls in Nevada (Dunham et al. 1996).

Although Flammulated Owl nest sites are not limited to cavities in snags (standing dead trees), snags provide an important source of both nest and roost sites for the species (Scott et al. 1977). Limited abundance of nesting substrates constrains nest-site selection for most owl species (Marks 2001). In Arizona's ponderosa pine forests, for example, secondary cavity-nesters, including the Flammulated Owl, comprise one-third of breeding bird species, most of which nest in snags (Balda 1975).

## METHODS

We employed data from the USDA Forest Service's Forest Inventory and Analysis (FIA) program and the Forest and Rangeland Renewable Resources Planning Act of 1974 (RPA) forest resource assessments database to assess historic and current amount and structure of two western yellow pine tree species in the United States: ponderosa pine and Jeffrey pine. These pine types encompass the majority of the breeding habitat of the Flammulated Owl within 11 western states of the USA (Arizona, California, Colorado, Idaho, Montana, Nevada, New Mexico, Oregon, Utah, Washington, and Wyoming). We compiled literature descriptions of Flammulated Owl breeding habitat characteristics, cross-referenced these to FIA data attributes of forest composition and structure, and estimated and mapped habitat abundance. We compared the FIA-based results with estimates and maps of owl habitat distribution obtained from other sources.

### VEGETATION CHARACTERISTICS OF HABITAT

We characterized vegetation within Flammulated Owl breeding habitat at or near nest sites in the context of data attributes available in inventory tables and geospatial datasets. Specifically, we compiled data from 16 papers and reports that described Flammulated Owl breeding habitat at 185 territories, including 153 nest sites in seven states, from which we tabulated specific habitat characteristics and summarized the following characteristics of forest type, size, and density: (1) type—presence of ponderosa pine or Jeffrey pine forest type—referred to collectively as ponderosa pine

forest type group—or trees of these species within associated forest types (Fig. 2); (2) size—presence of one or more trees at least 30 cm diameter at breast height (dbh) or canopy height of at least 10 m; and (3) density—tree density of 300–700 trees per ha (tph) or canopy cover of 30–80%.

## DATA AND ANALYSES

### *Geographic range maps*

We used data from NatureServe (Ridgely et al. 2005) to produce a map of the Flammulated Owl geographic range. We used polygon delineations digitized from Little (1971) to map Ponderosa pine and Jeffrey pine geographic ranges, which we overlaid with the owl range map and a state boundary dataset to visualize the correspondence among these ranges.

### FIA

The FIA program conducts detailed surveys of the nation's forests across all ownerships. FIA collects data from field plots, with a sampling intensity of approximately one plot per 2 400 ha (Reams et al. 2005). FIA defines *forest land* as land with 10% minimum tree stocking level or, for several western woodland types where stocking cannot be determined, 5% minimum tree canopy cover; minimum area of 0.4047 ha; and a minimum continuous canopy width of 36.58 m (Bechtold and Patterson 2005). *Timberland* is a designation referring to a subset of forest land that "...is producing or capable of producing in excess of 20 cubic feet per acre per year [ $1.4 \text{ m}^3 \text{ ha}^{-1} \text{ yr}^{-1}$ ] of wood at culmination of mean annual increment", excluding *reserved forest land*, which "...is permanently reserved from wood products utilization through statute or administrative designation" (Bechtold and Patterson 2005). Estimates of forest land and timberland area within each state were obtained by multiplying total area inventoried by the mean proportion estimated from forest inventory plot observations (Scott et al. 2005).

We used draft tables of the 2007 RPA report (Smith et al. 2009) and historic RPA data to produce area estimates of current and past forest land and ponderosa and Jeffrey pine forest type for each state. For some attributes, RPA estimates represent groups of forest types: ponderosa and Jeffrey pines types are combined into the ponderosa pine forest type group. For some attributes, historic RPA estimates apply only to timberland, which captures more than 87% of forest land area in the ponderosa pine forest type group and thus is assumed to be



FIGURE 2. Ponderosa pine (*Pinus ponderosa*) forest with vegetation composition and structure typical of breeding habitat for Flammulated Owl (*Otus flammeolus*), Colorado, USA. Photograph by Brian Linkhart.

representative of historic trends in forest land for this forest type group.

We produced estimates of the area of Flammulated Owl habitat abundance for 11 western states by querying the FIA database (U.S. Department of Agriculture Forest Service 2008) and constraining estimates to ponderosa pine forest type group on forest land with tree diameters of at least 30 cm and trees per ha in the range 300–700. Using a hexagon sampling array developed by the U.S. Environmental Protection Agency, Environmental Monitoring and Assessment Program (EMAP) (White et al. 2005), we produced estimates for each hexagon within the 11 western states. EMAP provides a sampling grid with each hexagon measuring approximately 648 square kilometers in area (U.S. Environmental Protection Agency 2002). We used a geographic information system (GIS) to produce hexagon-based maps for all forest land in ponderosa pine forest type group, and for Flammulated Owl potential breeding habitat abundance under the same conditions used for producing state-wide estimates.

#### LANDFIRE

The Landscape Fire and Resource Planning Tools Project, or LANDFIRE, is a project for producing maps and data describing vegetation,

wildland fuel, and fire regimes across the United States (Rollins and Frame 2006). LANDFIRE geospatial data are produced as 30-m spatial resolution raster datasets and distributed by mapping zones in Albers Conical Equal Area Projection (USGS parameters), North American Datum of 1983. LANDFIRE data products analyzed in this study include attributes corresponding to forest type, size and density: (1) Existing Vegetation Type (EVT) (Comer 2003), and linked to a classification system from the Society of American Foresters and Society for Range Management (Eyre 1980); (2) Canopy Height (CH), which is the average height (m) to the top of the vegetation canopy; and (3) Canopy Cover (CC), which is the percent cover of tree canopy. We obtained these geospatial datasets for all mapping zones that encompass any portion of the 11-state study area and used a GIS to constrain the LANDFIRE data to the 11-state geographic extent, and attribute each pixel with the state code in which the pixel is located. We used the following filters to label LANDFIRE forest pixels as potential habitat: EVT = SAF237 (Interior Ponderosa Pine) or SAF247 (Jeffrey Pine), CH  $\geq$  10 m, and CC  $\geq$  30% and CC < 80%. We estimated abundance of Flammulated Owl breeding habitat by tabulating the number of selected pixels and weighting by the per-pixel area (900 m<sup>2</sup>).

Gap Analysis Program (GAP)

Gap Analysis Program (GAP) geospatial datasets representing known or likely habitat for animal species are based on a combination of land cover classes associated with habitats and counties or hexagons for which animal species occurrence information is recorded (Gap Analysis Program 2008). GAP data are appropriate for use in regional analyses or planning applications, but not for site-specific analyses. Stockenberg et al. (2008) describe the role of GAP data for setting biological objectives for habitats and associated bird species within a Bird Conservation Region. GAP data were obtained for each of the 11 western states in the study area. We used a GIS to process and analyze GAP data including: converting data to 90-m spatial resolution raster format, merging datasets from 11 states to produce a single geospatial dataset, masking out non-‘habitat’ pixels, reprojecting the dataset to Albers ‘USGS’ projection (as described for LANDFIRE, above), and attributing each pixel with its corresponding state code. We produced estimates of habitat abundance by tabulating the number of ‘habitat’ pixels and weighting by the per-pixel area (8100 m<sup>2</sup>).

RESULTS

GEOGRAPHIC RANGE MAPS

Flammulated Owl breeding range corresponds closely with ponderosa pine and Jeffrey pine range, illustrating the strong positive association of this owl with the two western yellow pines (see Fig. 1). Exceptions include the extension beyond the owl range of ponderosa pine in western Oregon, central and eastern Montana, northeastern Wyoming and in the Black Hills of western South Dakota, which is partially outside the 11-state study area; and of Jeffrey pine in southcentral California and southwestern Oregon. Also, portions of the owl range encompass areas beyond the geographic range of the two yellow pines (i.e., southern British Columbia and Mexico).

FOREST LAND AND TIMBERLAND AREA

Current estimates of ponderosa and Jeffrey pine forest types on forest land were 98 633 km<sup>2</sup> and 83 000 km<sup>2</sup> from FIA and LANDFIRE data, respectively (Fig. 3). RPA estimates of ponderosa pine forest type group on timberland declined by 36% from about 136 200 km<sup>2</sup> in 1953 to 86 827 km<sup>2</sup> in 2007, with modest fluctuations

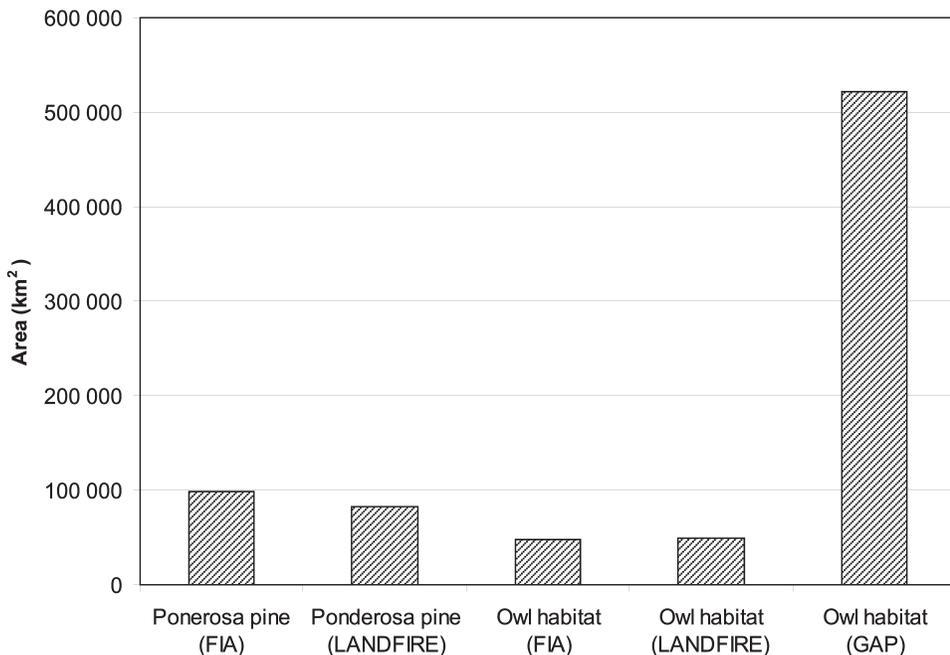


FIGURE 3. Area estimates of ponderosa pine (*Pinus ponderosa*) forest type group on forest land, derived from FIA and LANDFIRE data; and estimates of Flammulated Owl (*Otus flammeolus*) potential breeding habitat, derived from FIA, LANDFIRE, and GAP data, within 11 western states, USA.



FIGURE 4. Historical area estimates of ponderosa pine (*Pinus ponderosa*) forest type group on timberland within 11 western states, USA, 2007.

during intermediate years (Fig. 4). Between 1987 and 2007, a decrease in these forest types on timberland was estimated at 14%, characterized by a 16% increase within stand-ages of 100–149, but a 49% decrease within stand-ages of 150 or older (Fig. 5); a 22% increase within diameter classes of 30–49 cm, but a 28% decrease for diameters of 50 cm and larger (Fig. 6); and a 115% increase within the poorly stocked and medium stocked classes (10–59%) (Fig. 7). Figure 8A reveals an FIA-based map of ponderosa and Jeffrey pine spatial distribution that is very similar to Little's range maps for these tree species (Fig. 1).

#### EXTENT OF BREEDING HABITAT

The extent of Flammulated Owl breeding habitat was estimated to be 47 890 km<sup>2</sup> from FIA data, 49 740 km<sup>2</sup> from LANDFIRE data, and 521 548 km<sup>2</sup> from GAP data (Fig. 3). Figure 8B portrays the spatial distribution of Flammulated Owl potential breeding habitat, which encompasses most of the geographic range of ponderosa and Jeffrey pine (Fig. 8A), but at lower densities per hexagon across the range and with fewer hexagons containing habitat, especially within the eastern extent of the range.

#### DISCUSSION

Literature reports tend to have high agreement in how they characterize vegetation

compositional and structural components of Flammulated Owl breeding habitat. Minimum area requirements and other landscape metrics were not emphasized in the Flammulated Owl literature, although these features are known to affect habitat quality of many other species of wildlife. Thus, we felt justified in using FIA data to assess forest vegetation relating to the extent of Flammulated Owl potential breeding habitat across the United States portion of this owl's geographic range.

The geographic range of Flammulated Owl corresponds closely, but not perfectly, with ponderosa and Jeffrey pine distribution, illustrating the strong positive association between this owl and these two western yellow pines (Fig. 1). This is expected, given the generalized nature of species range maps, which are not intended for estimating area of vegetation, abundance of habitat, or population size. Large areas of western yellow pine range appear to be unoccupied by the owl, primarily in the northeast extent of ponderosa pine range. Recent field surveys in Montana (Cilimburg 2005) resulted in additional observations of Flammulated Owls, east of the previously delineated owl range. We recommend that the owl geographic range map be revised to capture these new records. To date, Flammulated Owls have not been observed during field surveys of the Black Hills, an area visible in Figure 1 as a large island of ponderosa forest in eastern Wyoming and western South

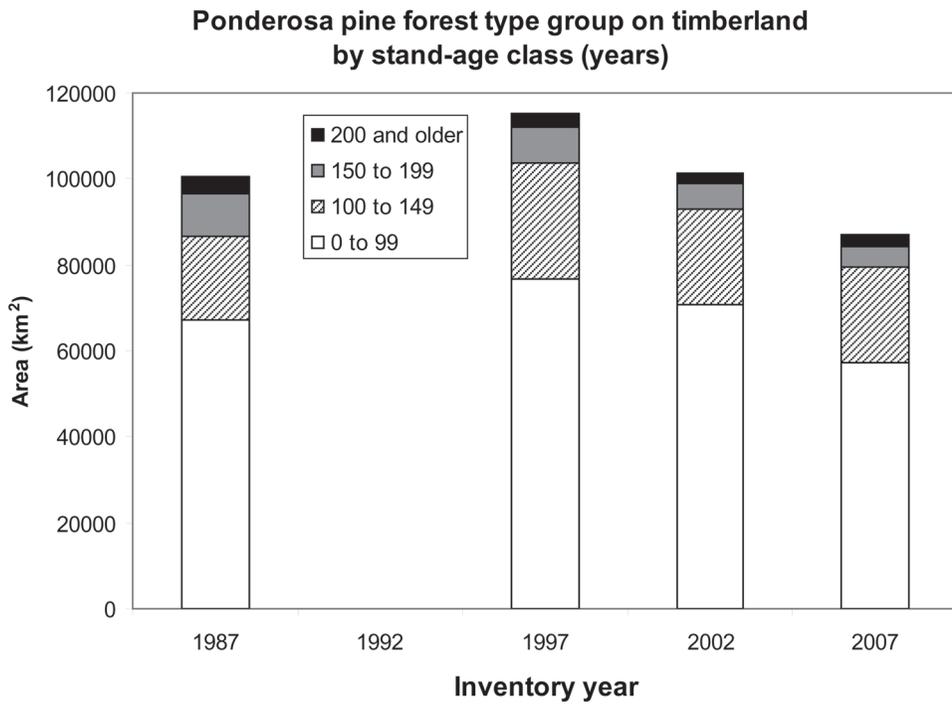


FIGURE 5. Area estimates of ponderosa pine forest type group on timberland by stand-age class within 11 western states, USA, 2007.

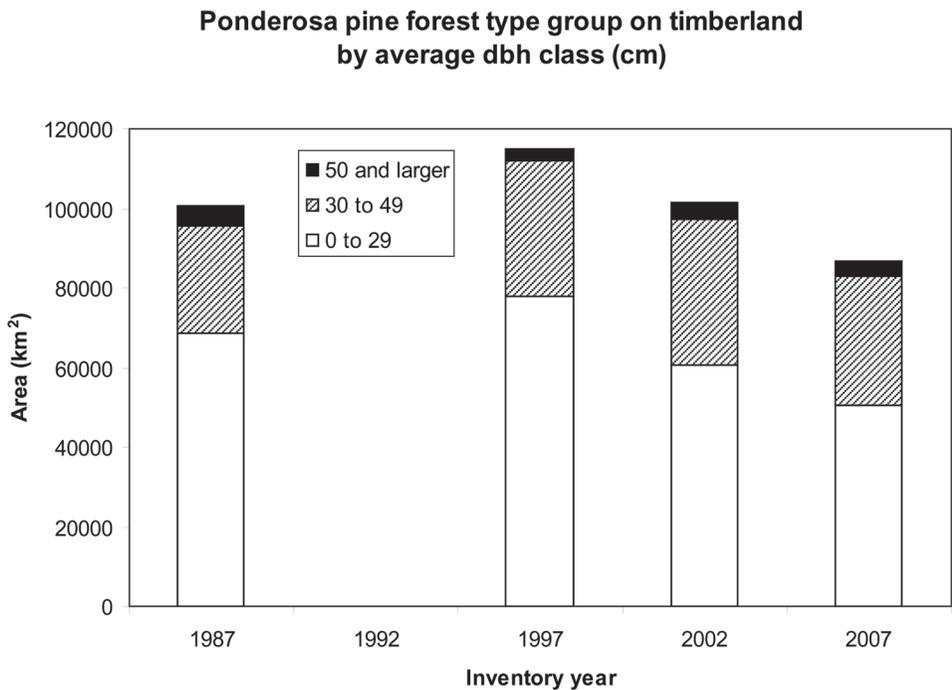


FIGURE 6. Area estimates of ponderosa pine forest type group on timberland by average dbh class within 11 western states, USA, 2007.

**Ponderosa pine forest type group on timberland by percent stocking class**

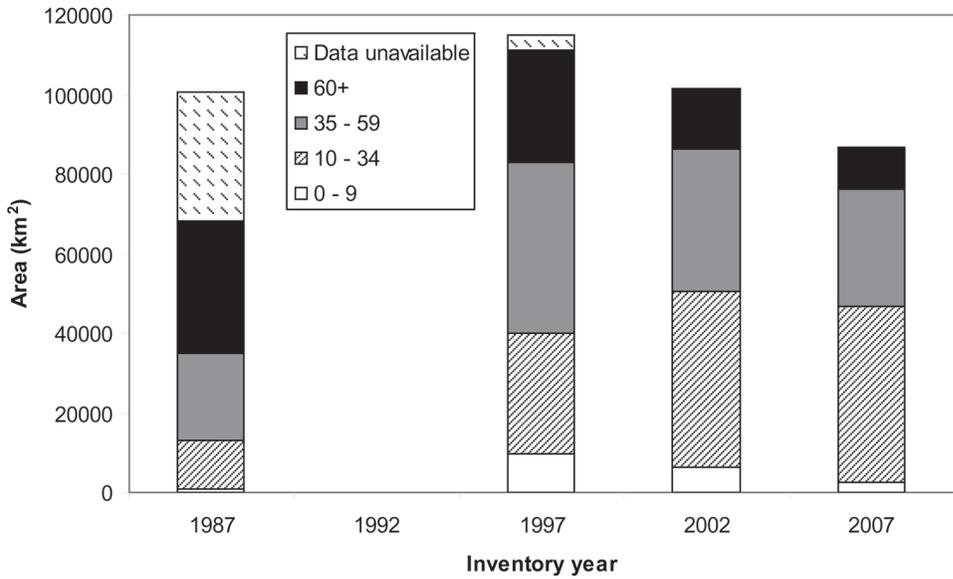


FIGURE 7. Area estimates of ponderosa pine forest type group on timberland by stocking class within 11 western states, USA, 2007.

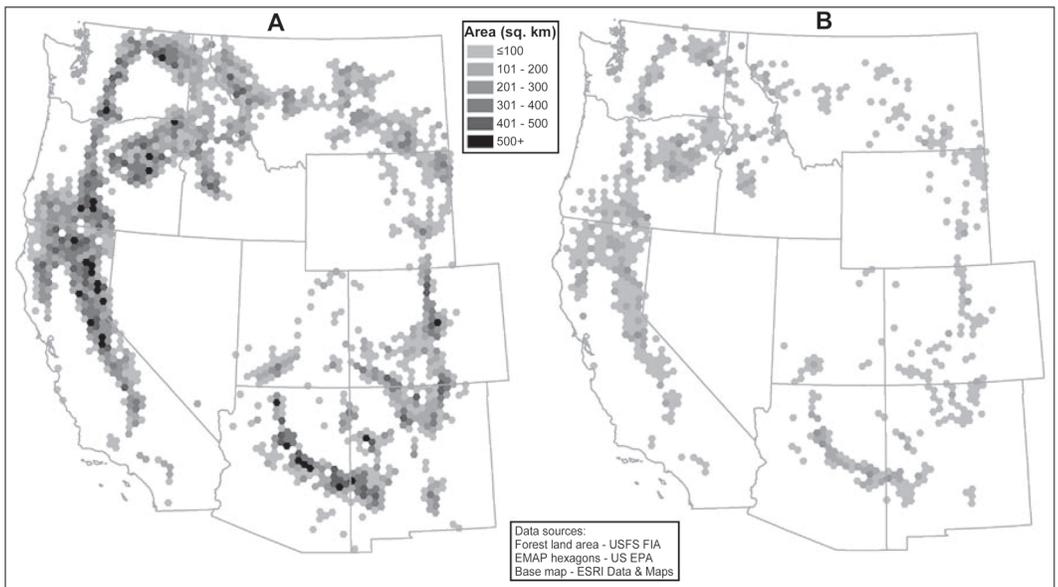


FIGURE 8. Geographic distribution within 11 western states, USA of (a) ponderosa pine (*Pinus ponderosa*) or Jeffrey pine (*Pinus jeffreyi*) forest land; and (b) potential abundance of Flammulated Owl (*Otus flammeolus*) breeding habitat, where one or more ponderosa pine or Jeffrey pine trees are  $\geq 30$  cm dbh, and tph of all trees are between 300 and 700 stems/ha.

Dakota (Rocky Mountain Bird Observatory, Online database).

RPA statistical reports, derived from FIA data, provided historical estimates of forest land and timberland area, by common attributes of forest type, age, size, and density. Forest types of ponderosa and Jeffrey pines comprise about 10% of all forest land in the West, and the area of forest in these types has decreased by 36% over the past 5 decades. Little of this forest is in stand-age classes older than 100 years, dbh classes larger than 30 cm, and intermediate stocking classes, attributes that are typical of Flammulated Owl breeding habitat. Ganey and Vojta (2007) predict that densities of snags in ponderosa pine forests in Northern Arizona will increase over the next 30 years, but densities of large snags will remain below target densities for management and conservation of wildlife.

Compared with FIA estimates, LANDFIRE-based estimates of forestland area in ponderosa pine forest type group and potential breeding habitat abundance appear slightly lower, but GAP-based habitat estimates appear to greatly overestimate habitat abundance, likely due to GAP's more general land cover classes.

Although the FIA- and LANDFIRE-based estimates of habitat area are constrained to ponderosa pine forest type group and omit habitat within other forest types, we suggest that these estimates capture the core resources needed by breeding Flammulated Owls. However, the thresholds of forest size and density selected for defining habitat may have led to overestimates of habitat abundance. Our minimum threshold of 30 cm dbh characterizes the minimum size of trees recorded as nesting sites, but the mean dbh of these nesting trees was about 50 cm. Constraining our estimates to trees at least 50 cm would have reduced both the geographic extent and the total area of our estimates of habitat abundance. Therefore, our estimates are reported as potential habitat abundance, which includes habitat of low quality.

#### CONCLUSIONS

Abundance of Flammulated Owl potential breeding habitat in ponderosa and Jeffrey pines declined substantially over the past five decades. Current estimates of Flammulated Owl potential breeding habitat area were about 48 000 km<sup>2</sup> from FIA data and about 50 000 km<sup>2</sup> from LANDFIRE data—a consistency that suggests reliability of these data sources. Additional analyses are recommended to assess spatial consistency between these two datasets. A GAP-based estimate of known/likely Flammulated Owl habitat (522 000 km<sup>2</sup>) was considerably

greater than from FIA- and LANDFIRE-based estimates, likely due to the less specific land cover classes available in the GAP data. Recent enhancements to GAP, i.e., the Southwest Regional Gap Analysis Project (SWReGAP), may provide for improved estimates and we recommend that these data be assessed.

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