Abstract.—Surveys of Flammulated Owl (*Otus flammeolus*) were conducted in five mountain ranges in western New Mexico to estimate the density and distribution of territorial males. Flammulated Owls were moderately abundant throughout the survey areas, particularly in pine-oak forest as well as cottonwood and aspen groves within coniferous forest. The results show that owl density varied significantly between study areas and that territory density varied between areas with similar cavity density. The results also suggest that the presence or absence of cavities is a primary influence on the distribution of this species, but it is not the sole indicator of habitat quality.

Flammulated Owls (*Otus flammeolus*) are Neotropical migrants whose summer breeding range extends from southern British Columbia to the mountains of central Mexico, and whose wintering grounds extend from central Mexico south to northern Central America (McCallum 1994). As a migrant with a high degree of intermixing between populations (Arsenault et al. 2005), this species can colonize remote areas with suitable habitat. They occur in isolated mountain ranges surrounded by vast areas of desert in Arizona, Nevada, and New Mexico. For example, Flammulated Owls breed in at least eleven mountain ranges in Nevada, including forest patches as small as 40 hectares (Dunham et al. 1996, Arsenault et al. 2003).

Flammulated Owls occur throughout New Mexico’s montane coniferous and mixed coniferous-deciduous forest (Dick-Peddie 1993). They have been reported during the breeding season in the Animas, Black, Guadalupe, Jemez, Magdalena, Mogollon, Sacramento, San Mateo, Sandia, Sangre de Cristo, Santa Fe, Tularosa, and Zuni Mountains in New Mexico (Ligon 1961, Balda et al. 1975, Johnson and

The Flammulated Owl’s primary nesting habitat is montane coniferous forest generally comprised of a yellow pine, such as ponderosa pine (Pinus ponderosa), mixed with other conifers, such as Douglas fir (Pseudotsuga menziesii) at higher elevations (McCallum 1994). This owl will also breed in lower elevation yellow pine forest mixed with pinyon pine (Pinus edulis) and juniper (Juniperus spp.), as well as conifer forests (yellow pine and/or fir) mixed with deciduous trees including quaking aspen (Populus tremuloides), cottonwood (Populus spp.), and Gambel Oak (Quercus gambelii) (Bent 1938, Marshall 1939, Johnson and Russell 1962, Winter 1974, Marcot and Hill 1980, Bull et al. 1990, Dunham et al. 1996, Groves et al. 1997). Reynolds and Linkhart (1992) and Linkhart (2001) found that Flammulated Owls preferred old-growth forests for nesting in Colorado.

The Flammulated Owl’s use of old-growth forest may relate to cavity and prey availability. However, second-growth forests can also provide the habitat components necessary for this species. Studies have found that owls use small forest patches (Dunham et al. 1996) and habitat without yellow pine (Powers et al. 1996, Marti 1997, Oleyar 2000). In New Mexico, Flammulated Owls nested in areas ranging widely in tree species composition, canopy closure, and tree density. This included dense habitat types such as aspen stands in Douglas fir forest with no ponderosa or other pines present and dense Gambel oak-ponderosa pine forest with high oak densities due to extensive historic logging of ponderosa pine (Arsenault 1999 and 2004). In Utah, Marti (1997) and Oleyar (2000) found owls in forests dominated by quaking aspen and big-toothed maple (Acer grandidentatum) with no yellow pine. Similarly, Powers et al. (1996) located owls in mixed-deciduous forest in Idaho without yellow pine. These studies indicate that this species may not be as limited by old-growth ponderosa pine as earlier studies suggested (Reynolds and Linkhart 1992).
I conducted standardized nighttime surveys in five mountain ranges in western New Mexico to characterize the distribution and density of Flammulated Owl territories, as well as determine indicators of habitat quality and its relationship with owl density and reproduction.

METHODS

Study Area.—Survey transects and study areas were located between 2000 m and 2700 m in montane coniferous and mixed deciduous forests in the Black Range, San Mateo, Magdalena, Zuni, and Jemez Mountains of western New Mexico. Forests within the survey areas consisted primarily of ponderosa pine and Gambel oak with herbaceous understories and scattered shrubs. Remnant groves of narrowleaf cottonwood (*Populus angustifolia*) occurred in some riparian areas. Ponderosa pine was mixed with quaking aspen and Douglas fir at higher elevations, and with pinyon pine at lower elevations.

Transect Surveys.—Survey areas were defined by transects located in suitable Flammulated Owl habitat defined as all montane coniferous and mixed deciduous forest similar to that used by Flammulated Owls as reported in the literature (see introduction). Transects were located in any accessible area that provided the best aural aspect for surveys including roads, trails, canyon bottoms, ridgelines, and slopes (Fig. 1) and survey points were spaced 350 to 500 m from each other (Groves et al. 1997). Transect surveys were conducted from May through June, 1996 to 1998 by stopping at survey points and listening for 5 minutes for Flammulated Owls calling, after which a male territorial call was vocally imitated or a recording was played for 1 to 2 minutes, and then the observer listened for calling owls for an additional 10 minutes. Each transect was surveyed at least 2 times in a breeding season (mid May to beginning of July) and in two consecutive years.

Study Area Surveys.—Study areas were chosen based on the location of owl territories detected during transect surveys. Thirteen study areas were chosen and they were surveyed systematically by walking parallel transects no more than 150 m apart and vocally imitating Flammulated Owl calls at least every 250 m. The study areas were surveyed in one or two years. Surveys were not conducted when
FIGURE 1. The distribution of Flammulated Owls detected in the northern San Mateo Mountains, New Mexico. Small circles represent owl territories, dotted lines encircle study areas (Lower and Upper Bear Trap, Big Pigeon, and West Red), and the large shaded area is the approximate survey area.
wind speed was greater than approximately five km/hr because of reduced probability of detecting owls.

**Spot Mapping.**—In study areas, locations of owls heard during nighttime surveys as well as during daytime nest and roost searches, were spot-mapped (Robbins 1970). Two pinhole cameras mounted on telescopic poles (Proudfoot 1996) were used to search the survey areas systematically two to three times each year for nesting cavities and to monitor nests during the breeding season (mid-May through June). Standardized methods were also used for nest finding, such as observing cavities at dusk, and for determining territory boundaries, such as observing territorial interactions and calling behavior (Reynolds and Linkhart 1984). Each nest was visited from one to six times (mean = 2.9 ± 1.2 visits) from egg laying to fledging to determine reproductive success in three core study areas (Surprise, Upper Bear Trap, Lower Bear Trap). Reproductive success summed across years (1996 to 1998), including failed nests, was compared with cavity density and the proportion of breeding males. A male was considered a non-breeder if a female or nest-site was never located within his territory, and he continued to call through the breeding season (Reynolds and Linkhart 1987).

In three study areas (Surprise, Upper Bear Trap, Lower Bear Trap), I mapped all of the cavities that were large enough (≥3.5 cm diameter entrance) for owls and in good condition for breeding (i.e., intact cavity floor and not filled with debris) to estimate the density of available nesting cavities. The size of each study area was estimated by drawing a convex polygon around the perimeter of all territories estimated with spot mapping.

**Territory Density.**—The densities of owls along transects were calculated as the number of males detected every one km of transect, equivalent to 100 ha with a 500 m detection distance included on either side of the transect (approximate survey area). Nearest-Neighbor Distance (NND) was calculated as the distance between the estimated centers of adjacent territories (based on spot mapping). The nearest-neighbor distance data set was examined for skewness, normality, outliers and influential observations, homogeneity of variances, and autocorrelation (Wilkinson et al. 1996). Nearest-Neighbor Distances were compared among study areas with ANOVA and Tukey’s pairwise
mean comparison method using SYSTAT 7.0 (Wilkinson et al. 1996). All means are reported ± standard error (SE).

RESULTS

Owls were detected in montane forest at elevations ranging from 2070 to 2680 m (Table 1). Owls were observed on 86 territories along 149 km of transect (mean = 0.7 ± 0.3 territories/km). Owl nests were located in coniferous and mixed deciduous forest composed of pinyon pine, ponderosa pine, narrowleaf cottonwood, Gambel oak, quaking aspen, and Douglas fir.

TABLE 1. Density of Flammulated Owl territories along survey transects.

<table>
<thead>
<tr>
<th>Mountain range</th>
<th>Total length of transects (km)</th>
<th>Elevation (m) where owls were detected</th>
<th>Number of territories</th>
<th>Territories/1 km</th>
</tr>
</thead>
<tbody>
<tr>
<td>Black</td>
<td>76</td>
<td>2260-2440</td>
<td>26</td>
<td>0.3</td>
</tr>
<tr>
<td>San Mateo</td>
<td>31</td>
<td>2260-2530</td>
<td>28</td>
<td>0.9</td>
</tr>
<tr>
<td>Magdalena</td>
<td>17</td>
<td>2070-2620</td>
<td>9</td>
<td>0.5</td>
</tr>
<tr>
<td>Zuni</td>
<td>15</td>
<td>2290-2680</td>
<td>17</td>
<td>1.1</td>
</tr>
<tr>
<td>Jemez</td>
<td>10</td>
<td>2500-2620</td>
<td>6</td>
<td>0.6</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>149</strong></td>
<td><strong>2070-2680</strong></td>
<td><strong>86</strong></td>
<td>-</td>
</tr>
<tr>
<td><strong>Mean</strong></td>
<td><strong>30</strong></td>
<td>-</td>
<td><strong>17</strong></td>
<td><strong>0.7</strong></td>
</tr>
</tbody>
</table>

Study areas ranged from 175 to 800 ha in size and contained 3 to 11 territories, with densities of 1.3 to 5.7 territories every 100 ha (Table 2). The average nearest-neighbor distance (NND) within aggregations ranged from 330 to 900 m (Table 2). Nearest Neighbor Distance in four study areas in the San Mateo Mountains (U. Bear Trap, Big Pigeon, L. Bear Trap and West Red) were not significantly different from one another (P > 0.5). In contrast, owls were spaced significantly closer to one another in Surprise, and significantly farther from one another in 74 Draw, compared to other locations (P < 0.5). The density of cavities...
available to nesting owls in three study areas was nearly identical (Table 3). Reproductive success (average number of young fledged per female) was also similar between the three areas (Table 3). However, the proportion of males that nested in each area varied (from 57% to 83%), as did territory density and nearest-neighbor distance (Table 3).

### Table 2. Density of Flammulated Owl territories in thirteen study areas.

<table>
<thead>
<tr>
<th>Mountain range</th>
<th>Study area</th>
<th>Size (ha)¹</th>
<th>Number of territories</th>
<th>Territories/100 ha</th>
<th>Nearest neighbor (m) mean ± SE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Black</td>
<td>Indian Cr.</td>
<td>250</td>
<td>4</td>
<td>1.6</td>
<td>700 ± 245</td>
</tr>
<tr>
<td></td>
<td>Scales</td>
<td>300</td>
<td>4</td>
<td>1.3</td>
<td>900 ± 115</td>
</tr>
<tr>
<td></td>
<td>74 Draw</td>
<td>800</td>
<td>11</td>
<td>1.4</td>
<td>855 ± 165 a²</td>
</tr>
<tr>
<td>San Mateo</td>
<td>Big Pigeon</td>
<td>250</td>
<td>5</td>
<td>2.0</td>
<td>580 ± 76 ab</td>
</tr>
<tr>
<td></td>
<td>West Red</td>
<td>350</td>
<td>6</td>
<td>1.7</td>
<td>758 ± 306 a</td>
</tr>
<tr>
<td></td>
<td>L. Bear Trap</td>
<td>350</td>
<td>7</td>
<td>2.0</td>
<td>600 ± 100 a</td>
</tr>
<tr>
<td></td>
<td>U. Bear Trap</td>
<td>350</td>
<td>7</td>
<td>2.0</td>
<td>500 ± 200 b</td>
</tr>
<tr>
<td>Magdalena</td>
<td>Mill</td>
<td>200</td>
<td>3</td>
<td>1.5</td>
<td>717 ± 29</td>
</tr>
<tr>
<td></td>
<td>Water</td>
<td>175</td>
<td>3</td>
<td>1.7</td>
<td>567 ± 115</td>
</tr>
<tr>
<td>Zuni</td>
<td>CWG</td>
<td>200</td>
<td>4</td>
<td>2.0</td>
<td>438 ± 144</td>
</tr>
<tr>
<td></td>
<td>Sedgewick</td>
<td>175</td>
<td>3</td>
<td>1.7</td>
<td>650 ± 0</td>
</tr>
<tr>
<td></td>
<td>Oso Ridge</td>
<td>175</td>
<td>10</td>
<td>5.7</td>
<td>330 ± 177 b</td>
</tr>
<tr>
<td>Jemez</td>
<td>Barley</td>
<td>175</td>
<td>3</td>
<td>1.7</td>
<td>567 ± 115</td>
</tr>
<tr>
<td></td>
<td>Mean</td>
<td>288</td>
<td>5.4</td>
<td>2.0</td>
<td>621 ± 237</td>
</tr>
</tbody>
</table>

¹ Estimated by drawing a convex polygon around the perimeter of all territories.
² Means followed by the same letter are not significantly different (P > 0.05, Tukey's HSD).
TABLE 3. Owl and cavity densities and productivity for three Flammulated Owl study areas.

<table>
<thead>
<tr>
<th>Study area</th>
<th>Size (ha)</th>
<th>Territories/100 ha</th>
<th>NND ± SE</th>
<th>Cavities/100 ha</th>
<th>Number of males</th>
<th>Number of breeding males</th>
<th>Fledged young per female ± SE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surprise</td>
<td>175</td>
<td>6.8</td>
<td>259 ± 90</td>
<td>30</td>
<td>12</td>
<td>10 (83)</td>
<td>2.1 ± 0.9</td>
</tr>
<tr>
<td>U. Bear Trap</td>
<td>75</td>
<td>5.3</td>
<td>369 ± 181</td>
<td>28</td>
<td>4</td>
<td>3 (75)</td>
<td>2.3 ± 0.5</td>
</tr>
<tr>
<td>L. Bear Trap</td>
<td>200</td>
<td>3.5</td>
<td>526 ± 219</td>
<td>30</td>
<td>7</td>
<td>4 (57)</td>
<td>2.0 ± 0.8</td>
</tr>
</tbody>
</table>

**DISCUSSION**

Suitable nesting cavities may be a potentially limiting resource in apparently suitable owl habitat. Flammulated Owls are obligate secondary cavity-nesting birds and in New Mexico use cavities excavated by Acorn Woodpeckers (*Melanerpes formicivorus*) and Northern Flickers (*Colaptes auratus*) (Arsenault 2004). The distribution of Acorn Woodpeckers is closely associated with oaks (a major food item) and with snags (standing dead trees) or dead tree limbs for use as storage granaries (Stacey and Koenig 1984, Koenig et al. 1995), which were provided by Gambel oak and narrowleaf cottonwood in many of the study areas. The distribution of Northern Flickers is limited mostly by suitably soft wood or the presence of knotholes or other existing cavities for excavation of nest-sites (Moore 1995), as was provided by ponderosa pine snags and large quaking aspen in study areas.

The distribution of Flammulated Owls in study areas may have been influenced by the presence of suitable nesting cavities. Peterson and Gauthier (1985) noted that the distribution of cavities was naturally clumped in parkland habitat and boreal forest in British Columbia. This might be due to the distribution of suitable substrates for cavity
excavation by woodpeckers. In New Mexico, however, the density and spacing of owls where cavities were present was not related to the density of these cavities.

The density of owl territories varied significantly between study areas, but there was low variation in Nearest-Neighbor Distance within each study area. This indicates that habitat with suitable nesting cavities was saturated with owl territories. Nearest-Neighbor Distance (i.e. owl density) in an area may have been related to the proportion of males that were nesting, a possible indicator of habitat quality. However, the sample size was too small to adequately test this hypothesis. The number of young fledged per female was very similar between three core study areas, regardless of owl density. Therefore, higher density study areas produced more young per area than those with lower density. The close association between the presence of owls and suitable nesting cavities emphasizes the importance of woodpeckers and their habitat needs for the conservation of secondary cavity-nesting birds (Arsenault 2004).

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