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Using Terrestrial Ecosystem Survey Data to Identify Potential Habitat for the Mexican Spotted Owl on National Forest System Lands: A Pilot Study

Joseph L. Ganey and Mary Ann Benoit

Abstract

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We assessed the usefulness of Terrestrial Ecosystem Survey (TES) data as a means of identifying habitat for the Mexican spotted owl (*Strix occidentalis lucida*) in three National Forests in Arizona. This spatial data set incorporates information on soils, vegetation, and climatic conditions in defining a set of ecological "map units" showing potential vegetation. We used three separate data sets consisting of spotted owl locations resulting from: (1) U.S. Forest Service (USFS) surveys; (2) mark-recapture sampling of 12 randomly selected "quadrats" ranging from 40 to 76 km^2, conducted in conjunction with population monitoring efforts; and (3) monitoring of radiomarked owls in four study areas. For each data set and National Forest, we overlaid owl locations on geographical information system (GIS) coverages of TES map units and summarized data on relative use patterns. Using standardized criteria specific to each data set, we identified subsets of map units strongly associated with owl use based on that data set and assessed subset consistency among data sets. All data sets identified a subset of map units as associated with owl use. Most map units identified by quadrat or radiotelemetry data also were identified by the more extensive but less detailed USFS survey data, but the converse was not true. Map units identified as associated with owl use generally consisted of mixed-conifer or pine-oak forest, and those units most strongly associated with owl use typically occurred on steep slopes containing rock outcrops. These ecological characteristics are consistent with existing knowledge of Mexican spotted owl habitat. We concluded that: (1) TES data was useful in identifying areas associated with owl use; and (2) with certain caveats, USFS survey data can be used in the absence of more detailed data sets. We also present an objective technique that can be used to identify a subset of owl-associated map units using flexible criteria that can be tailored to meet different objectives.

Keywords: Arizona, habitat modeling, map units, Mexican spotted owl, potential habitat, *Strix occidentalis lucida*, Terrestrial Ecosystem Survey

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Photos by Joseph L. Ganey

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CONTENTS

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Using Terrestrial Ecosystem Survey Data to Identify Potential Habitat for the Mexican Spotted Owl on National Forest System Lands:

A Pilot Study

By
Joseph L. Ganey
Mary Ann Benoit

INTRODUCTION

The Mexican spotted owl (*Strix occidentalis lucida*) occurs in canyonlands and forested highlands throughout the southwestern United States and northern Mexico (Gutiérrez and others 1995; Ward and others 1995). Although this owl occurs in a variety of habitats, it is frequently associated with well-structured mixed-conifer or pine (*Pinus* spp.) - oak (*Quercus* spp.) forests throughout much of its range (Ganey and Dick 1995; Gutiérrez and others 1995). The owl was listed as a threatened subspecies in 1993, largely due to concerns over loss of forested habitat from timber harvest and wildfire (U.S. Department of Interior 1993). Following this listing, a recovery plan was published that outlined management actions necessary to recover the owl (U.S. Department of Interior 1995). This plan recommended: (1) surveying for owls prior to conducting management actions in potential habitat (U.S. Department of Interior 1995:84); (2) managing specific portions of the landscape to create replacement habitat for spotted owls; and (3) monitoring trends in amount and distribution of owl habitat (U.S. Department of Interior 1995:91–93). The first recommendation requires land managers to identify areas with potential for owl use when planning management treatments, so that such areas can be surveyed for owl occupancy. The second requires that managers identify specific areas with the potential to develop into spotted owl habitat, so that such areas can be managed as replacement habitat for spotted owls. The third requires that we develop an understanding of the amount and distribution of spotted owl habitat. Implementing these recommendations thus requires that a standardized, objective means of identifying potential owl habitat be developed.

Efforts to develop an objective means for identifying owl habitat at broad scales have been hampered by a general lack of digital coverages showing vegetation types with adequate resolution. One data set that appears to hold promise for use on National Forest System lands in the Southwestern Region (Arizona and New Mexico) is the Terrestrial Ecosystem Survey (TES; U.S. Department of Agriculture 1986). This spatial data set incorporates information on soils, vegetation, and climatic conditions in defining a set of ecological "map units" and mapping those units at 1:24,000 scale. Thus, unlike most other spatial data sets describing vegetation in the Region, the spatial scale is appropriate for use in identifying owl habitat. TES data is currently available for seven of 11 National Forests in this Region, with work in progress on the remaining four Forests. Further, because the classification scheme incorporates soil and climatic information as well as information on vegetation composition, it can be used to define areas based on potential natural vegetation. This is important when attempting to identify areas with the potential to develop into spotted owl habitat.

Because of the obvious need for an objective means of identifying owl habitat at large spatial scales, and the apparent potential of TES data for use in identifying owl habitat, we evaluated the utility of using TES data for this purpose on three National Forests in Arizona. These Forests were chosen because TES data were available for all three, and because spotted owl data sets used (see below) were available for all three Forests. If this approach proves successful at identifying map units associated with spotted owls, the approach could be extended to other Forests that have both TES data and data on owl distribution, and to additional Forests as TES data becomes available.

The primary objective of this study was to use two to three different data sets to determine whether particular TES map units were strongly associated with owl presence and/or use in different areas. If such an association was documented, we then were interested in: (1) determining whether different spotted owl location data sets consistently identified the same map units as used by the owl; (2) identifying common ecological features of map units associated with owl use; (3) determining the spatial extent of these map units of suspected importance; and (4) mapping the spatial extent of these map units to allow for visual inspection of areas with suspected potential for Mexican spotted owls.

Study Areas

Study areas included the Apache-Sitgreaves and Coconino National Forests, and part of the Kaibab National Forest, Arizona (fig. 1). The Kaibab National Forest consists of three geographically disjunct subunits (Williams, Tusayan, and North Kaibab Ranger Districts). Only the Williams Ranger District had recent verifiable spotted owl locations, however, so the other districts were not included in this study.

Elevation within these Forests varied from 800 to 3,800 m, with climate ranging from hot steppe at the lower elevations to boreal at the highest elevations. Mean annual precipitation varied from approximately 24 to >90 cm and fell mainly in two seasons: July through October and December through March (U.S. Department of Agriculture 1989, 1991, 1995).

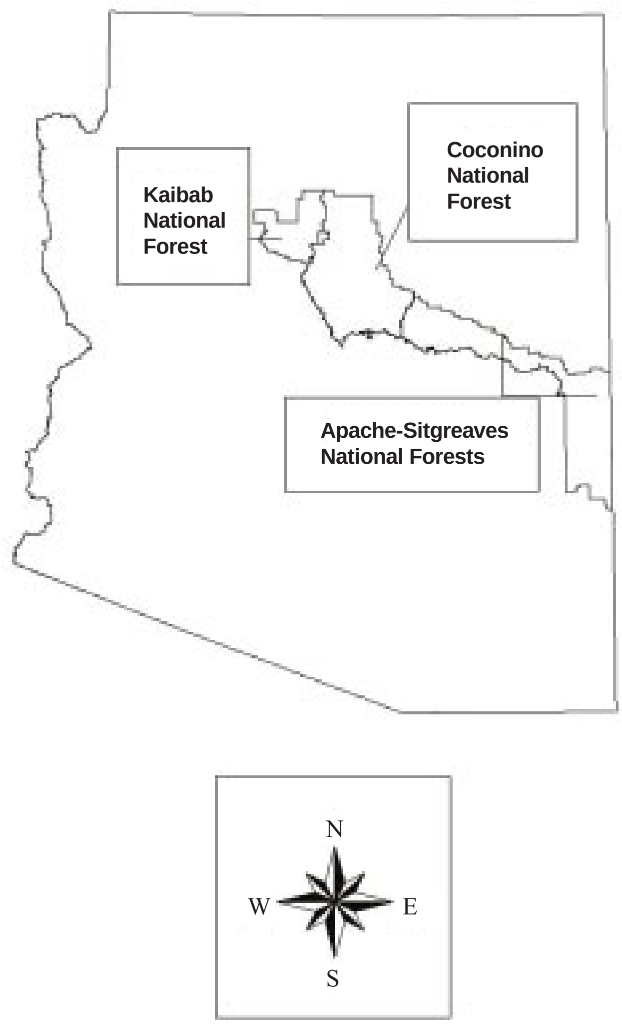


Figure 1. Location of three National Forests in Arizona where owl use of Terrestrial Ecosystem Survey map units was evaluated. Only the Williams Ranger District is shown for the Kaibab National Forest.

METHODS

TES Data

Briefly, the Terrestrial Ecosystem Survey as applied by the U. S. Forest Service (USFS) involves "mapping and interpreting ecosystems through a systematic examination, description, classification and integration (gradient analysis) of the primary ecosystem components (soil/vegetation/climate)" (U.S. Department of Agriculture 2000: foreword). This survey emphasizes the relationships that exist among ecosystem components and uses these relationships to define and classify terrestrial ecosystems into "map units" (U.S. Department of Agriculture 1986). Consequently, the survey incorporates data on geology, landforms, soils, and vegetation. It also uses these data to generate projections of erosion potential and production potential (i.e., timber and forage production). It is designed as a comprehensive land and resource management planning tool, and fits within the national hierarchical system for ecosystem classification (W. Robbie, USFS, Albuquerque, pers. comm.).

Because these surveys were completed at different times for different Forests, the exact methodology and authorities used differed slightly from Forest to Forest (U.S. Department of Agriculture 1989, 1991, 1995). In general, climatic data were obtained from available weather stations within the Forest, and the best currently available authorities for soil and plant taxonomy were used to classify soil and vegetation types.

Ecological map units initially were delineated on 1:24,000 aerial photographs using a stereoscope. Delineations were based on differences in soils, topography, landform, slope, vegetation, and/or geology. Field surveys then were conducted to verify the accuracy of the original delineations and to identify map unit characteristics. Data were collected on physical and chemical characteristics of soils; landform; steepness, length, and shape of slopes; geology; geomorphology; and vegetation.

Terrestrial ecosystems were classified as a series of map units that were uniquely numbered within a National Forest. The classification process was consistent across Forests, but numbering systems differed among Forests. For example, the Apache-Sitgreaves National Forest numbered map units based on lithology, whereas the Coconino National Forest numbered map units based on general climatic zone. Each map unit consisted of one to four components, which differed slightly from each other in terms of ecological characteristics. A series of tables summarizing the characteristics and properties of individual map units and their respective components was included in reports produced for each National Forest (for further details, see U.S. Department of Agriculture 1989, 1991, 1995). Map units were represented spatially in digital geographical information system (GIS) coverages, but components were not identified spatially within map units (U.S. Department of Agriculture 1989, 1991, 1995).

Mexican Spotted Owl Location Data Sets

Three data sets were available containing location data for Mexican spotted owls. For convenience, we will refer to these (from least to most detailed) as: (1) USFS survey data, (2) quadrat data, and (3) radiotelemetry data. Each of these data sets had strengths and weaknesses for use in this study. We hoped that each would provide unique and useful information, and that collectively they would strengthen inferences about associations between owl use and particular map units at different spatial scales.

USFS survey data

The most extensive data set available resulted from standardized nocturnal surveys (U.S. Department of Agriculture 1990) conducted by the USFS. One of the primary objectives of these surveys was to determine whether or not areas slated for management projects were occupied by owls. Surveys for this purpose have been conducted from approximately 1985 to the present, but the bulk of the survey effort occurred from 1989 to 1993. As part of the recovery planning process for the owl (U.S. Department of Interior 1995), results of these surveys through 1993 were collated by crews from the Rocky Mountain Research Station. These crews traveled to USFS Ranger Districts and Supervisor's Offices, thoroughly searched the files to access all survey records, and compiled a database containing location and associated attribute data for all verified locations of Mexican spotted owls.

The primary strength of this data set was that it was extensive, both in terms of area covered (all National Forests in the Southwestern Region) and number of owl records (4,908 records, of which 1,619 records fell within the three National Forests considered here). There were several weaknesses associated with this data set, however. First, it contained multiple records for an unknown number of individual owls and owl territories, and many locations could not be assigned to a particular territory with confidence. Consequently, some territories were represented by numerous observations and others by a single observation. This lack of independence among observations could result in biased estimates of how often owls use particular TES map units.

A second weakness associated with this data set was that it contained no information on which map units were surveyed for owls. Areas surveyed usually were not digitized to create coverages that could be used to estimate areas of different map units that were surveyed for owls. Consequently, while this data set could be used to identify map units *used* by owls at a landscape scale, it could not be used to estimate *selection* of map units relative to their "availability" within surveyed areas.

A third potential weakness results from the fact that surveys often were conducted in areas where management activities (often timber harvest) were proposed. As a result, surveys may have focused on a subset of the available TES map units, and the full range of map units may not be represented in the survey data.

A fourth potential weakness was that surveys were conducted only during the breeding season. Thus, if particular map units were used only during the nonbreeding season, survey data would not identify such units as used by owls.

A fifth potential weakness relates to the accuracy of owl locations, which was basically unknown. In theory, diurnal roosting and nesting locations should be reasonably accurate, because they were based on visual observations. In practice, this depends on the observer's skill in locating a position on a topographic map, as global positioning system (GPS) units were not readily available to most crews. Given the relatively high numbers of observers involved, skill levels (and hence positional accuracy) likely varied greatly. Thus, there was some unknown probability that roost or nest locations could be misclassified as to the particular TES map unit used. This probability also depends on the size, shape, and juxtaposition of TES map units (i.e., misclassification is more likely in a diverse landscape containing many small polygons than in landscapes containing a few large polygons, regardless of location accuracy).

Problems with accuracy of locations were much greater when nocturnal foraging locations are considered, because most of these were based either on the intersection of compass bearings from two or more (often relatively inaccurate) road locations, or on a single compass bearing and an estimated distance. For all of these reasons, we viewed the diurnal roosting and nesting locations as more reliable than the nocturnal foraging locations.

Quadrat data

A second data set contained location data for Mexican spotted owls located during complete surveys of randomly selected "quadrats" ranging from approximately 40 to 76 km^2. Twenty-five such quadrats, of which 12 fell wholly or partly within the study area of interest here (table 1, fig. 2), were surveyed in 1999 while monitoring spotted owl populations (Ganey and others 1999a, 2000). These study areas were surveyed completely and repeatedly for owls using standardized survey techniques (Ganey and others 1999a, 2000), so that all map units contained within their boundaries could be considered available to owls. Some, but not all, of the owls located were captured and uniquely colorbanded (Ganey and others 1999a). Thus,

Table 1. General location and area of randomly located study quadrats surveyed for Mexican spotted owls within the Kaibab, Coconino, and Apache-Sitgreaves National Forests, Arizona, 1999. For information on quadrats and survey results, see Ganey and others (1999a, 2000).

Quadrat number[a]	Quadrat name	Area (km^2)	National Forest	Ranger District
H01	Red Mountain	43.7	Coconino/Kaibab[b]	Peaks/Williams
H02	Peaks	61.2	Coconino	Peaks
H03	Wing Mountain	46.5	Coconino	Peaks
H04	White Horse	76.4	Kaibab	Williams
H07	General Springs	59.6	Coconino	Blue Ridge
H08	Chevelon	55.7	Apache-Sitgreaves	Chevelon
H09	Heber	54.9	Apache-Sitgreaves	Heber
H13	Springerville	66.8	Apache-Sitgreaves	Springerville
H18[c]	Pueblo Creek	66.9	Apache-Sitgreaves/Gila[b]	Alpine/Glenwood
H20	Rose Peak	71.0	Apache-Sitgreaves	Clifton
L01	Lake Montezuma	40.9	Coconino	Beaver Creek
L02	Jack's Canyon	66.1	Coconino	Blue Ridge

[a] H indicates quadrat was selected from a high-elevation stratum; L indicates quadrat was selected from a low-elevation stratum (see Ganey and others 1999a).
[b] Quadrat straddled the boundary between National Forests.
[c] Only a portion of quadrat area fell within the Apache-Sitgreaves National Forest.

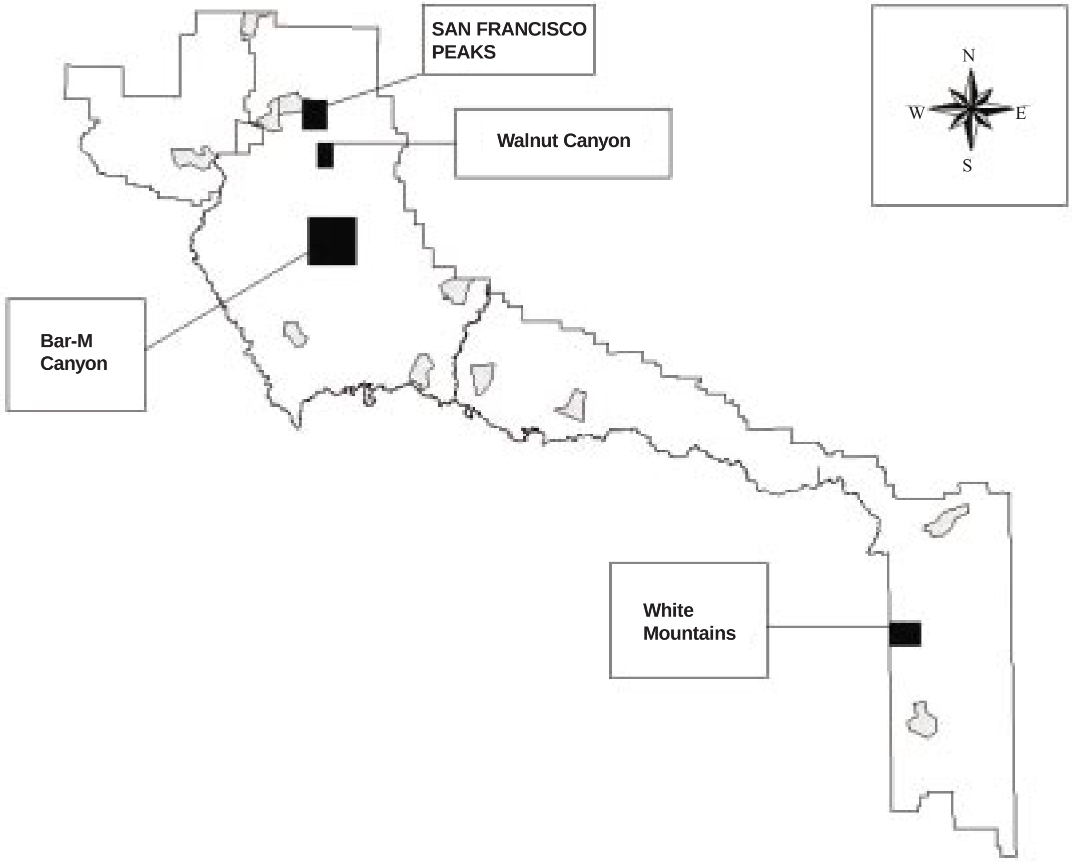


Figure 2. Locations of 12 randomly selected "quadrats" (stippled areas) and four radiotelemetry study areas (solid-color areas) within three National Forests in Arizona. Quadrats were surveyed for owls as part of a pilot study evaluating mark-recapture methods for population monitoring (Ganey and others 1999a), and movements and habitat use of radiomarked owls were monitored within radiotelemetry study areas (Ganey and Balda 1989, 1994; Ganey and others 1999b).

because not all owls were banded, use of map units could not always be linked to a particular individual. This was true particularly for nocturnal locations, as bands often could not be read at night. Consequently, we considered this data set to represent Design I of Manly and others (1993), with use and availability measured at the population level rather than for individual animals.

This data set was not as extensive as data set 1 (above), but was more detailed, and allowed estimation of resource selection. It was not as detailed as data set 3 (below), but had the advantage of covering more of the study area. Like the USFS survey data, this data set was collected during the breeding season, and so may not represent patterns of nonbreeding-season use.

In general, locations should be reasonably accurate in this data set. Crews used GPS units to record coordinates for roost and nest locations, so such locations should be accurate within ±100 m (usually much better). Foraging locations were estimated more crudely, however, and accuracy of foraging locations is unknown but lower than accuracy of roost/nest locations. Note also that misclassification can occur even with accurate locations, if such locations fall near the edge of a map unit. Consequently, we again recognize that there is an unknown probability of misclassification, which probability is greater for foraging locations than for roost/nest locations.

Radiotelemetry data

A third data set contained detailed data on locations of radiomarked Mexican spotted owls. Owls were radiomarked and tracked in four study areas (table 2, fig. 2) over periods ranging from months to years (Ganey and Balda 1989, 1994; Ganey and others 1999b). This data set had the advantage of providing extensive and detailed information on movements of uniquely identified owls throughout the year. In addition, these data could be used to define home ranges (sensu Burt 1943) for individual owls. Home-range boundaries then could be used to define a universe of available map units, allowing a comparison of use and availability (i.e., selection) of map

Table 2. Characteristics of study areas where movements of radiomarked Mexican spotted owls were monitored in Arizona.

Study area	National Forest	Ranger District	General landform	Cover types[a]	Number of owls (territories)
San Francisco Peaks[b]	Coconino	Peaks	Montane slopes	MC, PIPO-QUGA, PIPO	4 (2)
Walnut Canyon[b]	Coconino	Mormon Lake/ Peaks	Incised canyon	MC, PIPO, P-J-O, R	2 (1)
White Mountains[b]	Apache-Sitgreaves	Alpine	Montane canyons	MC, PIPO-QUGA, PIPO	2 (2)
Bar-M Canyon[c]	Coconino	Mormon Lake/ Long Valley	Rolling hills, cinder cones	PIPO-QUGA, PIPO	13 (7)

[a] Cover types: MC = mixed-conifer forest; PIPO = ponderosa pine forest; PIPO-QUGA = ponderosa pine-Gambel oak forest; P-J-O = pinyon-juniper-oak mix; R = canyon-bottom riparian forest.
[b] Source: Ganey and Balda (1989, 1994).
[c] Source: Ganey and others (1999b).

units. This corresponds to Design III (use and availability both measured for individual animals) as defined by Manly and others (1993). The primary disadvantages of this data set were that it represented a relatively small number of owls (n = 21), the radiotelemetry study areas covered a relatively small portion of the overall study area (most radiomarked owls occurred on the Coconino National Forest, and none occurred on the Kaibab National Forest), and sample sizes were quite small (2 to 4 owls) for three of the four study areas (table 2).

Roosting locations contained in this data set generally should be relatively accurate. Coordinates for roost locations were recorded by a relatively small number (2 to 8 per study area) of well-trained observers who were intimately familiar with the study areas. Foraging locations were less accurate, being based on remote triangulations. Consequently, as with the other data sets, we recognize that there is an unknown probability of misclassification, which probability is greater for foraging locations than for roost/nest locations.

Field Sampling

USFS survey data

Briefly, standardized methods for USFS surveys entailed: (1) delineating survey areas (often areas slated for management projects); (2) establishing calling points or routes to completely cover the designated survey area; (3) conducting nocturnal calling surveys to locate owls; and (4) using daytime followup surveys to locate owl roost and nest sites (U.S. Department of Agriculture 1990). Nocturnal calling surveys were conducted by visiting calling stations or routes, imitating spotted owl vocalizations, and listening for a response (Forsman 1983). Areas were surveyed four times per year, with 15 minutes spent at each calling point (U.S. Department of Agriculture 1990). Where owls were heard during nocturnal surveys, daytime follow-up surveys were conducted in the area of the vocal response. These surveys involved hiking drainages in the area and hooting for owls, then attempting to locate the roost site if owls responded. Where roosting owls were located during the nesting season, they were offered live mice to aid in locating nest sites (nesting owls will sometimes capture mice and carry them to the nest to feed the young, thus facilitating location of otherwise cryptic nest sites; Forsman 1983). Data on owl locations (Universal Transverse Mercator [UTM] coordinates; Grubb and Eakle 1988) and associated attribute data (i.e., nest site, roost site, or nocturnal calling location) were recorded on standardized survey forms.

Quadrat data

The quadrats considered here were originally delineated and sampled as part of a pilot study evaluating methods for monitoring populations of Mexican spotted owls (Ganey and others 1999a, 2000). A comprehensive sampling frame for quadrat selection was developed using spatial modeling in a GIS environment to break the entire study area for the pilot study (the Upper Gila Mountains Recovery Unit; U.S. Department of Interior 1995) into separate quadrats of similar size, using size and shape constraints, topography (1:250,000 digital elevation models), and other spatial information. Further details are contained in Arundel (1999).

Once all quadrats (n = 744; Ganey and others 2000) were mapped throughout the Recovery Unit, 25 quadrats were randomly selected. Twelve of the quadrats sampled fell wholly or partly within the three National Forests evaluated in this study (table 1, fig. 2). For descriptions of quadrats sampled, see Ganey and others (1999a).

Field sampling followed methods established for studies of spotted owl demography (Franklin and others 1996), with some differences. Nocturnal calling surveys (Forsman 1983) were conducted using calling routes and points established to ensure that the entire area within the quadrat was surveyed effectively. Ten minutes were spent at each call point, alternately calling and listening for a response from territorial owls.

Crews attempted to complete four survey passes through the quadrats, except for quadrats where no owls were located by the end of the third survey pass. In those cases, a fourth survey pass was not conducted. A survey pass was considered complete when all calling stations were surveyed and all required daytime follow-up surveys were finished. Daytime follow-up surveys were used wherever an owl was detected during night time surveys; two follow-up surveys were allowed per response per survey pass. UTM coordinates were recorded for all owl locations, along with data on location type (nest site, roost site, or nocturnal calling location).

Crews attempted to capture and individually mark all territorial adult and subadult owls observed on the quadrat, using noose poles and board traps (Forsman 1983; Johnson and Reynolds 1998). All adult and subadult owls captured were marked with a numbered locking aluminum band and a unique color band on the other leg (Forsman and others 1996). Not all owls were captured, however, so only some individuals could be uniquely identified. In addition, owls located at night rarely could be identified individually.

Radiotelemetry data

Movements of radiomarked owls were monitored on four study areas (table 2, fig. 2). Details on study areas, capture methods, tracking periods, and sampling regimes can be found in Ganey and Balda (1989, 1994) and Ganey and others (1999b). All nocturnal locations were assumed to represent foraging activity, and all diurnal locations were classified as roosting locations. Locations of incubating or brooding females were not used in analyses, because nesting females are restricted to the nest area for approx-imately two months.

Roosting locations were based on visual observations. Nocturnal locations were based on triangulation of compass bearings to the radiomarked owl from $\geq$3 known locations. Fixed tracking points were established at 0.16 to 0.32 km intervals along roads. Locations were accepted only if $\geq$3 bearings formed an intersection polygon <2 ha in size. For intersection polygons $\geq$2 ha in size, bearings were estimated from different tracking points until a suitable polygon was obtained. We assumed that the owl was located at the center of the intersection polygon. UTM coordinates were recorded for all locations.

Data Analysis

USFS survey data

Owl locations from the database compiled from USFS survey data were converted to a GIS point coverage using ArcView (ESRI, Redlands, CA). Locations were then linked with polygon coverages of TES map units for the three Forests, using the Spatial Join feature in ArcView. Data then were summarized to show the number and percentage of locations in TES map units by location type (nest site, roost site, or nocturnal location). We also computed a mean index of use as: ([% foraging locations + % roosting locations + % nesting locations]/3). This index thus incorporates information on foraging, roosting, and nesting use. These types of use were weighted equally here, but the index could be modified to afford different weights to different types of locations (i.e., more weight to nest locations). Unequal weighting would likely be a good idea where data are sufficient, as foraging locations are easier to obtain (and less accurate, see above) than roost or nest locations. We did not weight different categories here because we suspected that field crews were more successful in locating roosts and nests in some Forests or areas than in others. Consequently, we feared that deempha-sizing foraging locations might create area-specific biases.

Quadrat data

We clipped the TES polygon coverage for each Forest to the boundaries of quadrats sampled within that Forest to create coverages of TES map units within quadrat boundaries. We recalculated areas for all map units, then summarized area surveyed by Forest and map unit, to estimate relative availability of map units across survey areas within each Forest. We linked locations of spotted owls within the quadrats to the clipped coverage to estimate relative use of TES map units by owls, using the Spatial Join feature in ArcView. We eliminated records containing locations of juvenile owls, so that our estimate of use was based on locations of territorial adult and subadult owls. We summarized results by map unit and activity type (foraging vs. roosting) within each Forest. We estimated resource selection ratios ($\hat{w}_i$) and standardized resource selection ratios (B_i) following Manly and others (1993; Design I), using a Visual Basic macro for Excel written by R. M. King (Rocky Mountain Research Station, Fort Collins, CO). Because of generally small sample sizes, resultant imprecise parameter estimates, and possible lack of independence among observations, we view these resource selection estimates as exploratory and descriptive. Where we do report significant selection, this indicates that the lower limit of the Bonferroni-adjusted 95 percent confidence interval around $\hat{w}_i$ was greater than one. This incorporates information on both the relative magnitude of use and the precision of the estimate. We also computed a mean index of use by map unit as: ([diurnal B_i + nocturnal B_i]/2). This index thus incorporates information on both foraging and roosting use.

Radiotelemetry data

We used locations of radiomarked owls to define a minimum convex polygon (MCP) home range (Mohr 1947), and used the boundaries of that home range to estimate overall area of TES map units available to owls. We used the MCP home range rather than a probabilistic estimator such as the adaptive kernel because: (1) we wanted a comprehensive estimate of habitats available; and (2) we wished to avoid locations falling outside the home range boundary (which does happen with probabilistic estimators such as the adaptive kernel). Where we had good information on owls throughout the year, we used the annual MCP to estimate habitat availability. For other owls where we lacked good information in a particular season, we used seasonal MCP estimates to estimate habitat availability. We recognized two seasons, breeding (1 March through 30 August) and nonbreeding (1 September through 28 February), and computed seasonal estimates only for owls with >50 locations per season.

We clipped the TES coverages to the boundaries of MCP home ranges to create coverages of TES map units within home-range boundaries. We recalculated areas for all map units within home-range boundaries to estimate relative availability of map units to individual owls. We linked owl locations to the TES coverage to estimate relative use of particular map units by individual owls, using the Spatial Join feature in ArcView. We estimated resource selection ratios following Manly and others (1993; Design III). Separate analyses were conducted for each of four study areas, because availability of TES map units varied greatly among areas. Again, we do not emphasize significance tests in this analysis, but instead focus on estimating relative use patterns. Where we do report significant selection, this indicates that the lower limit of the Bonferroni-adjusted 95 percent confidence interval around $\hat{w}_i$ was greater than one. This incorporates information on both the relative magnitude of use and the precision of the estimate. We computed a combined index of use by map unit as: ([foraging B_i + roosting B_i]/2); this was computed separately for each season. This index thus incorporates information on both foraging and roosting use.

Comparisons among data sets

We used standardized criteria to define a subset of map units that we considered strongly associated with owl use for each of the three data sets. There are numerous ways that such units can be identified, and all are as much art as science. We used different criteria for different data sets. For USFS survey data, we ranked map units based on the mean use index, plotted cumulative percent use versus map-unit rank, identified the minimum subset of map units needed to include 95 percent of mean use, and identified the specific map units included in that subset. For quadrat and radiotelemetry data, we included any map units with a combined $B_i \geq 0.100$. These criteria are admittedly arbitrary, but represent a compromise between our desire to avoid either including unimportant units or omitting important units.

We qualitatively assessed agreement among data sets by seeing which units were strongly associated with owl use in more than one data set, versus those that were associated in only a single data set. Because most Forests lack detailed data on owl use such as the quadrat or radiotelemetry data, we were specifically interested in assessing how many map units were strongly associated with owl use based on those detailed data sets, but not based on USFS survey data. This could provide an index of how useful the survey data are in the absence of other data sets.

We summarized potentially important ecological characteristics of map units associated with owl use, using information from U.S. Department of Agriculture (1989, 1991, 1995). These included descriptions of overstory vegetation, climatic information, slope characteristics, and geology. We also summarized USFS interpretation of the suitability of these map units for timber harvest, to assess the extent to which management of spotted owl habitat might conflict with our ability to harvest timber on USFS lands. Finally, we estimated the area encompassed by map units strongly associated with owl use in each National Forest and mapped the distribution of those units to display the spatial distribution of map units associated with owl use.

RESULTS

USFS Survey Data

Apache-Sitgreaves National Forest

The 718 records of spotted owls in the Apache-Sitgreaves National Forest fell within 44 different map units (table 3). Roosting owls were documented in 33 different map units in this Forest, with 12 of these used in greater than trace amounts (i.e., > 2% of roosting locations). Nesting owls were documented in 14 different map units, with 11 used in greater than trace amounts (table 3).

Coconino National Forest

Thirty-six different map units contained all 849 records of spotted owls in the Coconino National Forest (table 4). Roosting owls were documented in 21 different map units in this Forest, with 11 of these used in greater than trace amounts. Nesting owls were documented in 13 different map units, with nine of these used in greater than trace amounts (table 4).

Kaibab National Forest

Only 52 records of spotted owls were available for the Kaibab National Forest. These were located in 12 different map units (table 5). Roosting owls were documented in only six map units on this Forest, and nesting owls in only two map units (table 5).

Quadrat Data

Apache-Sitgreaves National Forest

Sixty-six map units occurred in the five quadrats surveyed in this Forest. Owls representing an estimated 4 to 5 separate territories were located in 13 of these map units (table 6). Owls were located during the day in eight map units (n = 55 diurnal locations), and appeared to select for three of these units (206, 565, and 650). Owls were located at night in 12 map units (n = 51 nocturnal locations), and appeared to select for two of these units. Both of these map units (206 and 565) also showed evidence of selection for diurnal locations (table 6). Although not selected for by our criteria, map units 584 and 638 also showed evidence of consistent nocturnal use by owls (table 6).

Coconino National Forest

Seventy map units occurred in six quadrats surveyed in this Forest. Twelve of these were used by owls from an estimated 7 to 8 separate territories (table 6). Owls were located during the day in 10 different map units (n = 80 diurnal locations), and appeared to select for three of these units (555, 611, and 654). Owls were located in 11 map units at night (n = 102 nocturnal locations), and appeared to select for two of these. Both map units that showed evidence of selection for nocturnal locations (555 and 654) also showed evidence of selection for diurnal locations. Although not selected for by our criteria, map units 550 and 611 also showed evidence of consistent nocturnal use (table 6).

Kaibab National Forest

One quadrat was located completely in this Forest, and a second was shared with the Coconino National Forest. Twenty-four map units occurred in these quadrats. Four of these showed use by owls from a single territory (table 6). Owls primarily used two map units (539 and 540) for both foraging (n = 18 locations) and roosting (n = 11 locations). Both were selected for foraging, whereas only map unit 539 was selected for roosting.

Radiotelemetry Data

Bar-M Canyon

Home-range composition was relatively variable in this study area, and a number of TES map units were represented on home ranges at low levels, making estimation of selection ratios problematic. Map unit 565 was selected for during the breeding season for both foraging and roosting activities (table 7; note that map unit 565 here is not the same as map unit 565 selected for in quadrats in the Apache-Sitgreaves National Forests; see U.S. Department of Agriculture [1989, 1995]). Although not selected for, map units 582 and 584 also were used at relatively high levels (see mean B_i; table 7).

During the nonbreeding season, owls again showed selection for map unit 565 for roosting. They did not significantly select for any map units for foraging during the nonbreeding season, but generally used map units 565, 582, and 584 at relatively high levels (table 8).

San Francisco Peaks

Owls in this study area showed selection for map unit 613 for roosting during both the breeding and nonbreeding seasons, and for map unit 596 for foraging during the nonbreeding season (tables 7 and 8). Owls also used map units 584, 653, and 654 at relatively high levels during one or both seasons, for one or both activities (tables 7 and 8).

Walnut Canyon

Owls in this study area showed selection for map unit 555 for both foraging and roosting during both the breeding and nonbreeding seasons, and for map unit 455 for foraging during the nonbreeding season (tables 7 and 8). Map unit 455 also was used at relatively high levels for foraging during the breeding season. Other map units within the home range showed little use for either activity and in either season.

White Mountains

Habitat use during the nonbreeding season was not evaluated in this study area, due to small numbers of owl locations during this season. During the breeding season, owls in this area showed selection for map units 565 and 650 for both foraging and roosting (table 7; again note that map unit 565 here is not the same as map unit 565 in the Bar-M Canyon area; see U.S. Department of Agriculture [1989, 1995]). Other map units within the home range were generally used at low levels for foraging and not at all for roosting (table 7).

Map Units Associated With Owl Use

Based on our standardized criteria, some map units were identified as strongly associated with owl use by all three data sets, whereas others were identified by two or only one data set (table 9). Many map units were identified as associated with owl use only by the USFS survey data. This could simply represent the different criteria for inclusion using this data set. It also may be due to the fact that this data set was more extensive and covered more of the map units within the Forests than did the other, more detailed, data sets.

In the Apache-Sitgreaves National Forest, 19 map units were identified as strongly associated with owl use (table 9). All were identified using USFS survey data (table 9, fig. 3). Two also were identified as important by the radiotelemetry data, and four by the quadrat data, including both units identified by the radiotelemetry data. Many map units identified by USFS survey data but not by more detailed data sets either were not represented in those data sets, or comprised ≤2 percent of survey area or home range (table 9; 11 of 15 units [73.3 percent] for quadrat data and 14 of 17 units [82.3 percent] for radiotelemetry data).

In the Coconino National Forest, 14 map units were identified as strongly associated with owl use (table 9). Thirteen of these were identified based on USFS survey data (table 9, fig. 3). Nine of these units also were identified by either quadrat data, radiotelemetry data, or both. A single map unit was identified as important only by radiotelemetry data, based on foraging use during the nonbreeding season (table 8). Again, many map units identified by USFS survey data but not by more detailed data sets either were not present in those data sets, or comprised ≤2 percent of survey area or home range (table 9; seven of 14 units [50.0 percent] for quadrat data and five of six units [83.3 percent] for radiotelemetry data).

In the Kaibab National Forest, nine map units were identified as strongly associated with owl use (table 9). All but one of these were identified based on USFS survey data (table 9, fig. 3). Two map units were identified as important by the quadrat data. All map units identified by USFS survey data but not by quadrat data either were not present in quadrats surveyed, or comprised ≤2 percent of quadrat area (table 9).

In summary, most map units identified as associated with owl use based on more detailed data sets (quadrat and radiotelemetry data) also were identified using the more extensive USFS survey data. One of the two exceptions (Coconino unit 596) represented a map unit identified as strongly associated only with nonbreeding-season foraging use on a single radiotelemetry study area (table 8). The remaining map unit (Kaibab 539) was a ponderosa pine-Gambel oak forest type (table 10) that occurred adjacent to a mixed-conifer type identified as important to owls (540; table 10).

The following pages contain tables 3 through 10, followed by figure 3.

Ecological Characteristics of Map Units Associated With Owl Use

With a few exceptions, map units associated with owl use consisted of either mixed-conifer or pine-oak forest (table 10). One map unit (100) in the Apache-Sitgreaves National Forest was a riparian type, and another (585) consisted of spruce-fir forest. In the Coconino National Forest, two map units (455 and 471) consisted of woodland or brush on steep canyon slopes (table 10). One woodland map unit (541) also was identified in the Kaibab National Forest (table 10). These woodland types were common on steep canyon slopes adjacent to forest types showing stronger evidence of owl use (i.e., map unit 555 in the Coconino and map unit 540 in the Kaibab National Forest).

Most map units associated with owl use fell in the low sun/cold (LSC) climate class (table 10, first column in climate field). Most also fell within climate zones typical of ponderosa pine or mixed-conifer forests (zones 5 and 6, second column in climate field; table 10). These map units encompassed the full spectrum of these climatic zones (third column in climate field; table 10), but a relatively high number of map units fell towards the warm, dry end of the mixed-conifer zone (i.e., LSC, 6, –1). One map unit in the Apache-Sitgreaves (585) fell in the warm, dry end of the spruce-fir zone (LSC, 7, –1). One unit in the Coconino fell in the high sun/cold zone, one unit in the Apache-Sitgreaves fell in the high/sun mild zone, and three units fell in the low sun/mild zone (Coconino unit 471; Kaibab units 540 and 541; table 10). Three of these four units fell in the climatic range typical of the woodland life zone (zone 4), with the fourth (541) falling in the mixed-conifer climate zone (zone 6).

Many map units associated with owl use occurred on steep slopes (>40%). Rock outcrops and/or cliffs also were prominent in a number of map units on each Forest (table 10). Largely as a result of these steep slopes, many map units were classified as presenting severe limits for timber harvest, or provided no information on limits to timber harvest, suggesting that timber harvest was not a priority activity in those map units (table 10). In a few cases, map units were classified as presenting moderate to severe limits

Table 3. Use of Terrestrial Ecosystem Survey (TES) Map Units by Mexican spotted owls in the **Apache-Sitgreaves National Forest**, based on USFS survey data through 1993. Shown are numbers of locations and percent of total locations (in parentheses[a]), by location type. Map units are described in U.S. Department of Agriculture (1989).

TES map unit	Nocturnal locations	Roost locations	Nest locations	Mean use index[b]	% of total Forest area[c]
016	1 (0.3)	0	0	0.1	0.28
055	1 (0.3)	0	0	0.1	0.33
100	1 (0.3)	3 (1.0)	2 (2.3)	1.2	0.18
130	2 (0.6)	2 (0.7)	0	0.4	4.70
131	2 (0.6)	2 (0.7)	0	0.4	1.36
140	3 (0.9)	0	0	0.3	0.52
141	3 (0.9)	2 (0.7)	0	0.5	0.25
179	1 (0.3)	1 (0.3)	0	0.1	1.39
182	3 (0.9)	0	0	0.3	1.87
183	0	1 (0.3)	0	0.1	1.75
186	0	2 (0.7)	0	0.2	0.80
189	16 (4.7)	37 (12.7)	21 (24.1)	13.8	1.08
191	2 (0.6)	0	0	0.2	1.60
192	17 (5.0)	11 (3.8)	2 (2.3)	3.7	2.39
193	24 (7.0)	12 (4.1)	6 (6.9)	6.0	1.48
196	5 (1.4)	1 (0.3)	2 (2.3)	1.3	1.61
197	2 (0.6)	0	0	0.2	1.50
199	2 (0.6)	3 (1.0)	2 (2.3)	1.3	0.88
201	2 (0.6)	0	0	0.2	0.38
202	36 (10.6)	35 (12.0)	15 (17.2)	13.3	0.60
203	0	3 (1.0)	0	0.3	0.33
206	13 (3.8)	20 (6.9)	12 (13.8)	8.2	0.72
208	0	1 (0.3)	0	0.1	0.17
535	2 (0.6)	1 (0.3)	0	0.3	0.65
537	8 (2.3)	8 (2.7)	0	1.7	3.40
538	7 (2.0)	0	0	0.7	1.56
543	0	2 (0.7)	0	0.2	0.81
560	1 (0.3)	1 (0.3)	0	0.2	0.32
565	90 (26.5)	58 (19.9)	10 (11.5)	19.3	2.73
567	1 (0.3)	8 (2.7)	0	1.0	0.41
570	0	1 (0.3)	0	0.1	0.20
574	16 (4.7)	11 (3.8)	4 (4.6)	4.4	2.28
576	2 (0.6)	1 (0.3)	0	0.3	0.59
577	1 (0.3)	2 (0.7)	1 (1.1)	0.7	1.07
584	1 (0.3)	2 (0.7)	0	0.3	0.23
585	16 (4.7)	18 (6.2)	0	3.6	0.61
624	2 (0.6)	2 (0.7)	0	0.4	0.47
638	9 (2.6)	4 (1.4)	1 (1.1)	1.7	0.30
650	14 (4.1)	3 (1.0)	0	1.7	0.75
667	17 (5.0)	7 (2.4)	1 (1.1)	2.8	0.49
672	1 (0.3)	0	0	0.1	0.62
673	14 (4.1)	26 (8.9)	8 (9.2)	7.4	0.71
690	1 (0.3)	0	0	0.1	0.57
732	1 (0.3)	0	0	0.1	2.15
Total	**340**	**291**	**87**		**47.09**

[a] Percentages are rounded to one decimal place and do not sum exactly to 100.
[b] Computed as: (% foraging locations + % roosting locations + % nesting locations)/3.
[c] % of National Forest area contained in a particular map unit.

Table 4. Use of Terrestrial Ecosystem Survey (TES) Map Units by Mexican spotted owls in the **Coconino National Forest**, based on USFS survey data through 1993. Shown are numbers of locations and percent of total locations (in parentheses[a]), by location type. Map units are described in U.S. Department of Agriculture (1995).

TES map unit	Nocturnal locations	Roost locations	Nest locations	Mean use index[b]	% of total Forest area[c]
053	1 (0.2)	0	0	0.1	0.32
055	1 (0.2)	0	0	0.1	0.87
060	2 (0.4)	0	0	0.1	0.03
430	8 (1.7)	1 (0.4)	0	0.7	3.69
455	7 (1.5)	8 (2.9)	0	1.5	0.55
470	2 (0.4)	0	0	0.1	0.28
471	32 (6.7)	0	0	2.2	2.25
493	1 (0.2)	0	0	0.1	0.48
500	1 (0.2)	1 (0.4)	0	0.2	1.09
536	2 (0.4)	0	0	0.1	0.94
546	23 (4.8)	8 (2.9)	1 (1.0)	2.9	2.79
549	17 (3.6)	8 (2.9)	1 (1.0)	2.5	0.78
550	19 (4.0)	14 (5.1)	3 (3.1)	4.1	1.91
551	1 (0.2)	0	0	0.1	1.37
555	169 (35.4)	108 (39.3)	21 (21.6)	32.1	2.51
557	2 (0.4)	0	0	0.1	0.22
565	3 (0.6)	5 (1.8)	6 (6.2)	2.9	0.63
567	7 (1.5)	2 (0.7)	0	0.7	1.63
572	1 (0.4)	0	0	0.1	0.22
575	5 (1.0)	5 (1.8)	1 (1.0)	1.3	0.29
578	0	5 (1.8)	0	0.6	2.30
579	5 (1.0)	5 (1.8)	0	0.9	1.49
582	20 (4.2)	7 (2.5)	6 (6.2)	4.3	6.86
584	25 (5.2)	20 (7.2)	22 (22.7)	11.7	3.04
585	15 (3.1)	8 (2.9)	4 (4.1)	3.4	3.83
586	5 (1.0)	0	0	0.3	2.74
596	1 (0.2)	0	0	0.1	0.12
610	2 (0.4)	0	0	0.1	0.05
611	13 (2.7)	5 (1.8)	5 (5.2)	3.2	0.40
613	36 (7.6)	30 (10.9)	16 (16.5)	11.7	0.48
620	1 (0.2)	0	0	0.1	0.01
650	1 (0.2)	0	0	0.1	0.48
651	17 (3.6)	6 (2.2)	0	1.9	0.84
653	8 (1.7)	3 (1.1)	1 (1.0)	1.3	0.24
654	21 (4.4)	25 (9.1)	10 (10.3)	7.9	0.63
785	3 (0.6)	1 (0.4)	0	0.3	0.15
Total	**477**	**275**	**97**		**46.51**

[a] Percentages are rounded to one decimal place and do not sum exactly to 100.
[b] Computed as: (% foraging locations + % roosting locations + % nesting locations)/3.
[c] % of National Forest area contained in a particular map unit.

Table 5. Use of Terrestrial Ecosystem Survey (TES) Map Units by Mexican spotted owls in the **Kaibab National Forest**, based on USFS survey data through 1993. Shown are numbers of locations and percent of total locations (in parentheses[a]), by location type. Map units are described in U.S. Department of Agriculture (1991).

TES map unit	Nocturnal locations	Roost locations	Nest locations	Mean use index[b]	% of total district area[c]
302	3 (8.1)	2 (16.7)	1 (33.3)	19.4	0.67
303	1 (2.7)	0	0	0.9	0.02
310	0	3 (25.0)	0	8.3	1.01
312	0	0	2 (66.7)	22.2	0.23
322	4 (10.8)	2 (16.7)	0	9.2	0.81
324	1 (2.7)	1 (8.3)	0	3.7	2.30
402	1 (2.7)	0	0	0.9	2.30
519	1 (2.7)	0	0	0.9	5.55
540	20 (54.1)	0	0	18.0	0.45
541	3 (8.1)	1 (8.3)	0	5.5	0.97
659	2 (5.4)	3 (25.0)	0	10.1	0.17
660	1 (2.7)	0	0	0.9	0.26
Total	**37**	**12**	**3**		**14.84**

[a] Percentages are rounded to one decimal place and do not sum exactly to 100.
[b] Computed as: (% foraging locations + % roosting locations + % nesting locations)/3.
[c] % of total area contained in a particular map unit. Percent area calculated for the Williams Ranger District only. This was the only Ranger District within the Kaibab National Forest containing verified spotted owl locations.

Table 6. Resource selection ratios[a] for use of Terrestrial Ecosystem Survey (TES) Map Units by Mexican spotted owls within 11 sample quadrats surveyed in three National Forests in Arizona, 1999.

National Forest	TES map unit[b]	% of area surveyed[c]	Diurnal Locations[d]	Diurnal $\hat{w}_i$	Diurnal SE $\hat{w}_i$	Diurnal B_i	Nocturnal Locations[d]	Nocturnal $\hat{w}_i$	Nocturnal SE $\hat{w}_i$	Nocturnal B_i	Mean B_i[e]
Apache-Sitgreaves	189	4.16	4 (8.7)	2.09	1.00	0.045	6 (11.8)	2.83	1.09	0.050	0.048
	196	11.20	1 (2.2)	0.19	0.19	0.004	8 (15.7)	1.40	0.46	0.025	0.015
	199	6.25	0			0.000	4 (7.8)	1.26	0.60	0.022	0.011
	206	2.40	19 (41.3)	17.21*	3.03	0.370	10 (19.6)	8.17*	2.32	0.144	0.257
	537	0.85	1 (2.2)	2.56	2.53	0.055	0			0.000	0.028
	538	1.59	0			0.000	1 (2.0)	1.23	1.22	0.022	0.011
	565	1.87	9 (19.6)	10.46*	3.13	0.230	10 (19.6)	10.49*	2.97	0.184	0.207
	574	0.92	2 (4.4)	4.73	3.27	0.102	1 (2.0)	2.13	2.11	0.037	0.070
	584	0.22	0			0.000	1 (2.0)	8.91	8.83	0.157	0.079
	638	0.37	0			0.000	3 (5.9)	15.90	8.90	0.280	0.140
	650	2.48	9 (19.6)	7.89*	2.36	0.170	3 (5.9)	2.37	1.33	0.042	0.106
	673	1.84	1 (2.2)	1.18	1.17	0.026	1 (2.0)	1.07	1.06	0.019	0.023
	732	5.30	0			0.000	3 (5.9)	1.11	0.62	0.020	0.010
	Other	60.55	0			0.000	0			0.000	0.000
Coconino	437	7.57	4 (4.9)	0.61	0.32	0.017	1 (1.0)	0.13	0.13	0.003	0.010
	455	2.19	4 (4.9)	2.28	1.13	0.057	10 (9.8)	4.48	1.34	0.099	0.078
	527	0.25	0			0.000	1 (1.0)	3.92	3.90	0.087	0.044
	546	5.29	2 (2.4)	0.47	0.33	0.012	12 (11.8)	2.22	0.60	0.049	0.031
	549	0.87	3 (3.7)	4.31	2.44	0.108	0			0.000	0.054
	550	0.69	2 (2.4)	3.62	2.53	0.091	4 (3.9)	5.68	2.79	0.126	0.109
	555	4.41	29 (35.4)	8.22*	1.22	0.206	23 (22.6)	5.11*	0.94	0.113	0.160
	611	1.99	9 (11.0)	5.65*	1.78	0.142	12 (11.8)	5.91	1.60	0.131	0.137
	613	1.23	4 (4.9)	4.07	1.98	0.102	5 (4.9)	3.99	1.74	0.088	0.095
	652	1.79	0			0.000	2 (2.0)	1.10	0.7	0.024	0.012
	653	1.89	1 (1.2)	0.66	0.66	0.017	8 (7.8)	4.15	1.41	0.092	0.055
	654	2.77	22 (26.8)	9.93*	1.8	0.249	24 (23.5)	8.49*	1.52	0.188	0.219
	Other	69.10	0			0.000	0			0.000	0.000
Kaibab	519	28.16	0			0.000	4 (22.2)	0.79	0.35	0.011	0.001
	537	19.97	1 (9.1)	0.46	0.43	0.006	0			0.000	0.003
	539	1.61	6 (54.6)	33.88*	9.33	0.439	7 (38.9)	24.16*	7.14	0.342	0.391
	540	0.85	4 (36.4)	42.78	17.06	0.555	7 (38.9)	45.75*	13.52	0.647	0.599
	Other	49.40	0			0.000	0			0.000	0.000

[a] Selection ratios computed following Manly and others (1993). $\hat{w}_i$ = resource selection ratio; values followed by an asterisk indicate positive selection for that map unit (i.e., lower limit of 95% Bonferroni confidence interval around $\hat{w}_i$ is >1). B_i = standardized resource selection ratio. These values sum to one and can be crudely interpreted as denoting relative probabilities of use of TES map units given equal availability of those units.

[b] TES map units are described in U.S. Department of Agriculture (1989, 1991, 1995).

[c] Percent of total area surveyed in quadrats within a National Forest.

[d] Number of locations, followed by percentage of locations (in parentheses). Percentages, computed by National Forest and location category (diurnal versus nocturnal), are rounded to one decimal place and do not sum exactly to 100.

[e] Computed as (diurnal B_i + nocturnal B_i)/2.

Table 7. Resource selection ratios[a] for use of Terrestrial Ecosystem Survey (TES) Map Units during the breeding season by radiomarked Mexican spotted owls in four study areas in northern Arizona. Estimates of availability of map units based on minimum convex polygon (MCP) home ranges.

			Foraging[b]				Roosting[b]				
Study area[c]	TES map unit[d]	Mean proportion of MCP home range	Mean proportion of locations	$\hat{w}_i$	SE $\hat{w}_i$	B_i	Mean proportion of locations	$\hat{w}_i$	SE $\hat{w}_i$	B_i	Mean B_i[e]
BMC	55	0.012	0.009	0.757	0.168	0.106	0.000	0.000		0.000	0.053
	520	0.011	0.011	0.000		0.000	0.000	0.000		0.000	0.000
	565	0.056	0.156	2.714*	0.588	0.378	0.369	8.029*	2.317	0.759	0.567
	578	0.012	0.012	0.000		0.000	0.000	0.000		0.000	0.000
	579	0.102	0.045	0.443	0.276	0.062	0.027	0.245	0.146	0.023	0.043
	582	0.47	0.469	1.001	0.059	0.140	0.337	0.692	0.242	0.065	0.103
	584	0.172	0.246	1.410	0.159	0.197	0.246	1.459	0.613	0.138	0.168
	585	0.143	0.068	0.487	0.307	0.068	0.021	0.152	0.114	0.014	0.041
	586	0.019	0.008	0.359	0.314	0.050	0.000	0.000		0.000	0.025
SFP	551	0.293	0.293	0.771	0.191	0.196	0.012	0.030	0.024	0.007	0.051
	584	0.032	0.008	0.483	0.323	0.123	0.012	0.919	0.971	0.206	0.165
	596	0.101	0.005	0.102	0.107	0.026	0.024	0.577	0.136	0.129	0.078
	613	0.380	0.629	1.662	0.340	0.422	0.905	2.392*	0.137	0.537	0.480
	640	0.017	0.000	0.000		0.000	0.000	0.000		0.000	0.000
	653	0.036	0.030	0.563	0.385	0.143	0.000	0.000		0.000	0.072
	654	0.135	0.035	0.358	0.213	0.091	0.048	0.538	0.063	0.121	0.106
	785	0.010	0.000	0.000		0.000	0.000	0.000	0.000	0.000	0.000
WC	455	0.131	0.239	1.825	0.765	0.462	0.020	0.150	0.141	0.053	0.258
	550	0.386	0.065	0.169	0.042	0.043	0.039	0.102	0.096	0.036	0.040
	555	0.366	0.687	1.877*	0.346	0.475	0.941	2.572*	0.151	0.911	0.693
	567	0.114	0.009	0.076	0.090	0.019	0.000	0.000		0.000	0.010
WM	537	0.251	0.028	0.112	0.004	0.020	0.000	0.000		0.000	0.010
	565	0.451	0.699	1.545*	0.078	0.279	0.759	1.754*	0.051	0.373	0.326
	574	0.147	0.048	0.327	0.009	0.059	0.000	0.000		0.000	0.030
	576	0.042	0.031	0.031	0.738	0.133	0.000	0.000		0.000	0.067
	577	0.039	0.003	0.087	0.002	0.016	0.000	0.000		0.000	0.008
	650	0.071	0.190	2.722*	0.079	0.492	0.241	2.949*	0.238	0.627	0.560

[a] Selection ratios computed following Manly and others (1993). $\hat{w}_i$ = resource selection ratio; values followed by an asterisk indicate positive selection for that map unit (i.e., lower limit of 95% Bonferroni confidence interval around $\hat{w}_i$ is >1). B_i = standardized resource selection ratio. These values sum to one and can be crudely interpreted as denoting relative probabilities of use of TES map units given equal availability of those units.
[b] Number of locations (foraging, roosting): BMC = 533, 483; SFP = 372, 84; WC = 230, 51; WM = 289, 29.
[c] Study areas (and numbers of owls monitored): BMC = Bar-M Canyon (8); SFP = San Francisco Peaks (4); WC = Walnut Canyon (2); WM = White Mountains (2).
[d] TES map units are described in U.S. Department of Agriculture Forest Service (1989, 1991, 1995).
[e] Computed as (diurnal B_i + nocturnal B_i)/2.

Table 8. Resource selection ratios[a] for use of Terrestrial Ecosystem Survey (TES) Map Units during the nonbreeding season by radiomarked Mexican spotted owls in four study areas in northern Arizona. Estimates of availability of map units based on minimum convex polygon (MCP) home ranges.

			Foraging[b]				Roosting[b]				
Study area[c]	TES map unit[d]	Mean proportion of MCP home range	Mean proportion of locations	$\hat{w}_i$	SE $\hat{w}_i$	B_i	Mean proportion of locations	$\hat{w}_i$	SE $\hat{w}_i$	B_i	Mean B_i[e]
BMC	55	0.021	0.009	0.430	0.080	0.059	0.002	0.100	0.091	0.012	0.071
	520	0.006	0.001	0.119	0.079	0.016	0.000	0.000		0.000	0.008
	565	0.035	0.078	1.896	0.420	0.258	0.162	4.093*	0.781	0.484	0.371
	578	0.007	0.007	0.831	0.603	0.113	0.000	0.000		0.000	0.057
	579	0.087	0.037	0.419	0.120	0.057	0.049	0.539	0.170	0.064	0.061
	582	0.477	0.499	1.077	0.068	0.147	0.378	0.811	0.080	0.096	0.122
	584	0.179	0.245	1.332	0.129	0.181	0.299	1.615	0.235	0.191	0.186
	585	0.133	0.100	0.734	0.109	0.100	0.072	0.556	0.102	0.066	0.083
	586	0.052	0.024	0.503	0.110	0.068	0.038	0.744	0.208	0.088	0.078
SFP	551	0.293	0.142	0.543	0.057	0.081	0.119	0.363	0.082	0.064	0.073
	584	0.032	0.064	1.726	0.472	0.256	0.034	1.302	0.975	0.231	0.244
	596	0.101	0.176	1.506*	0.033	0.224	0.085	1.034	0.099	0.183	0.204
	613	0.380	0.471	1.238	0.303	0.184	0.644	1.697*	0.210	0.301	0.243
	640	0.017	0.000	0.000		0.000	0.000	0.000		0.000	0.000
	653	0.036	0.027	0.916	0.365	0.136	0.017	0.402	0.131	0.071	0.104
	654	0.135	0.119	0.802	0.138	0.119	0.102	0.844	0.463	0.150	0.135
	785	0.010	0.009	0.000		0.000	0.000	0.000		0.000	0.000
WC	455	0.131	0.221	1.690*	0.239	0.444	0.111	0.848	0.188	0.260	0.352
	550	0.386	0.107	0.277	0.169	0.073	0.074	0.192	0.021	0.059	0.066
	555	0.366	0.672	1.835*	0.264	0.483	0.815	2.226*	0.045	0.682	0.583
	567	0.114	0.000	0.000		0.000	0.000	0.000		0.000	0.000

[a] Selection ratios computed following Manly and others (1993). $\hat{w}_i$ = resource selection ratio; values followed by an asterisk indicate positive selection for that map unit (i.e., lower limit of 95% Bonferroni confidence interval around $\hat{w}_i$ is >1). B_i = standardized resource selection ratio. These values sum to one and can be crudely interpreted as denoting relative probabilities of use of TES map units given equal availability of those units.
[b] Number of locations (foraging, roosting): BMC = 974, 986; SFP = 295, 59; WC = 131, 27.
[c] Study areas (and numbers of owls monitored): BMC = Bar-M Canyon (13); SFP = San Francisco Peaks (4); WC = Walnut Canyon (2).
[d] TES map units are described in U.S. Department of Agriculture Forest Service (1989, 1991, 1995).
[e] Computed as (diurnal B_i + nocturnal B_i)/2.

Table 9. Terrestrial Ecosystem Survey (TES) Map Units identified as strongly associated with Mexican spotted owl use in three National Forests in northern Arizona, based on three separate data sets.

National Forest	TES map unit[b]	Data set(s)[c]	Map unit present in > trace[a] amount? Quadrat data	Radiotelemetry data
Apache-Sitgreaves	100	1	N	N
	189	1	Y	N
	192	1	Y	N
	193	1	N	N
	196	1	Y	N
	199	1	Y	N
	202	1	N	N
	206	1, 2	Y	N
	537	1	N	Y
	538	1	N	N
	565	1, 2, 3	Y	Y
	567	1	N	N
	574	1	N	Y
	577	1	N	Y
	585	1	N	N
	638	1, 2	Y	N
	650	1, 2, 3	Y	Y
	667	1	N	N
	673	1	N	N
Coconino	455	1, 3	Y	Y
	471	1	N	N
	546	1	Y	N
	549	1	N	N
	550	1, 2	N	Y
	555	1, 2, 3	Y	Y
	565	1, 3	N	N
	582	1, 3	Y	Y
	584	1, 3	N	Y
	596	3	N	Y
	611	1, 2	N	N
	613	1, 3	N	Y
	651	1	Y	N
	654	1, 2, 3	Y	Y
Kaibab	302	1	N	NA
	310	1	N	NA
	312	1	N	NA
	322	1	N	NA
	324	1	N	NA
	539	2	N	NA
	540	1, 2	N	NA
	541	1	N	NA
	659	1	N	NA

[a] Trace amount defined as ≥2% of survey area or home range. Codes: Y = yes, N = no, NA = not applicable. Not applicable indicates that the data set was not available (i.e., radiotelemetry data for the Kaibab National Forest).
[b] TES map units are described in U.S. Department of Agriculture (1989, 1991, 1995).
[c] Numbers indicate data set(s) that documented positive association: 1 = USFS survey data; 2 = quadrat survey data; 3 = radiotelemetry data. See text for criteria for inclusion.

Table 10. Ecological characteristics of Terrestrial Ecosystem Survey (TES) Map Units identified as positively associated with Mexican spotted owl use on three National Forests in northern Arizona.

National Forest	TES map unit[a]	Vegetation[b]	Climate[c]	Slope (%)	Limits to timber harvest[d]
Apache-Sitgreaves	100	POAN/PIPO	LSC, 5	0-5	NI
	189	PSME/PIPO/QUGA/ROCK	LSC, 6, -1	40-120	NI
	192	PIPO/QUGA	LSC, 5, 0	15-40	Severe
	193	PIPO/QUGA	LSC, 5, 0	0-15	Severe
	196	PIPO/QUGA	LSC, 5, 0	0-15	Slight
	199	PIPO/QUGA	LSC, 5, 0	15-40	Slight-moderate
	202	ABCO/PSME/PIPO/QUGA	LSC, 6, 0	15-40	Severe
	206	ABCO/PSME/PIPO/QUGA/ROCK	LSC, 5, 0 to LSC, 6, -1	40-120	NI
	537	PIPO/QUGA	LSC, 5, 0	0-15	Severe
	538	PIPO/QUGA	LSC, 5, 0	15-40	Moderate-severe
	565	PSME	LSC, 6	40-120	NI
	567	PSME/PIPO/QUGA	LSC, 6, -1	15-80	Severe
	574	PSME/PIPO/QUGA	LSC, 6, -1	15-40	Severe
	577	ABCO/PSME/PIPO/QUGA	LSC, 6, 0	0-15	Moderate
	585	PIEN/ABLA/ABCO/PSME/ROCK	LSC, 7, -1	40-80	NI
	638	PIPO/QUHY/ROCK	HSM, 5, 0	40-120	NI
	650	PIPO/QUGA	LSC, 5, 0	40-80	NI
	667	ABCO/PSME/PIPO/QUGA	LSC, 6, 0	15-40	Moderate
	673	PSME/PIPU/PIPO/ROCK	LSC, 5, 0 to LSC, 6, -1	40-120	NI
Coconino	455	PIED/JUMO/ROCK	HSC, 4, 0	40-120	NI
	471	QUTU/ARPU/CEMO/ROCK	LSM, 4	40-120	NI
	546	PIPO/QUGA/MUVI	LSC, 5, 0	0-15	Severe
	549	PIPO/QUGA/MUVI	LSC, 5, 0	15-40	Moderate
	550	PIPO/QUGA	LSC, 5, 0	15-40	Moderate to severe
	555	PSME/PIPO/ROCK	LSC 5 to LSC 6	40-120	Severe
	565	PIPO/QUGA	LSC, 5, 0	15-40	Severe
	582	PIPO/QUGA	LSC, 5, 0	0-15	Moderate to severe
	584	PIPO/QUGA	LSC, 5, 0	0-40	Severe
	596	PIPO/PSME/ROCK	LSC, 5 to LSC, 6	40-120	Severe
	611	POTR/PSME/PIPO	LSC, 6, -1	0-15	Moderate
	613	PSME/ROCK	LSC, 6	40-80	Severe
	651	ABCO/PSME/PIPO/QUGA	LSC, 6, 0	15-40	Severe
	654	ABCO/PSME/PIPO/QUGA	LSC, 6, 0	15-40	Moderate
Kaibab	302	ABCO/PSME/PIPO/QUGA	LSC, 6, 0	15-40	Moderate
	310	PIPO/QUGA	LSC, 5, 0	15-40	Moderate
	312	PSME/ROCK	LSC, 6	40-80	Severe
	322	PSME	LSC, 6	40-80	Severe
	324	PIPO/QUGA	LSC, 5, 0	0-15	Moderate
	539	PIPO/QUGA/ROCK	LSC, 5	40-120	Severe
	540	PSME/PIPO/JUDE/QUTU/ROCK	LSM, 6, -1	40-120	Severe
	541	PIED/JUDE/QUTU/ARPU/ROCK	LSM, 4, +1	40-120	NI
	659	ABCO/PSME/PIPO/QUGA	LSC, 6, 0	15-40	Moderate

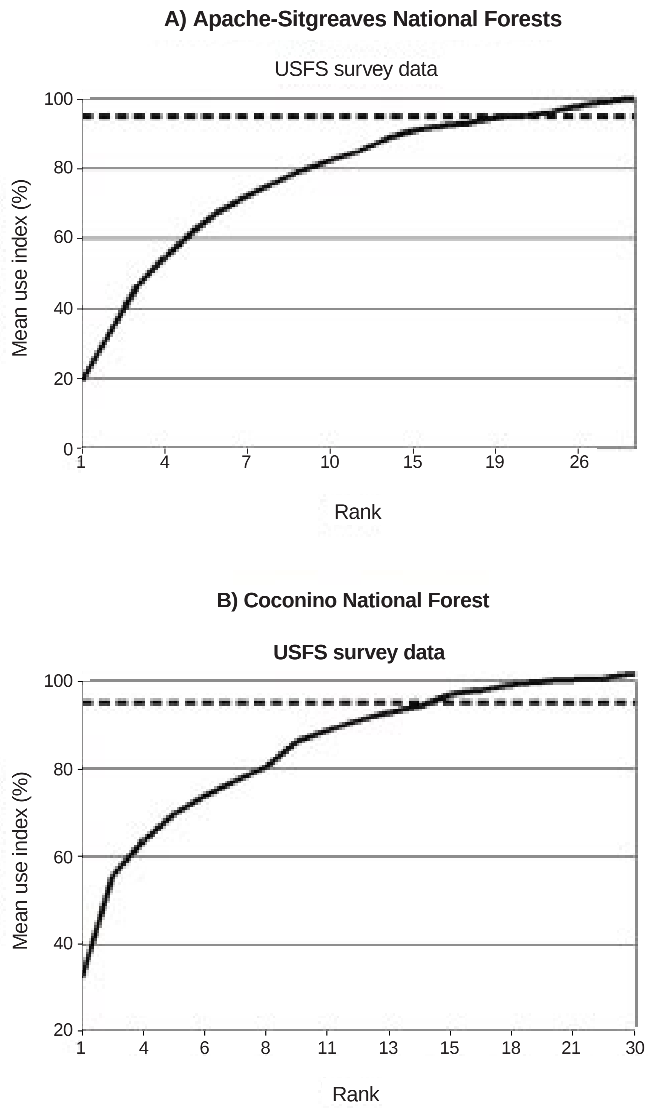
[a] TES map units and their ecological characteristics are described in U.S. Department of Agriculture (1989, 1991, 1995).

[b] Vegetation acronyms: ABCO = *Abies concolor* (white fir); ABLA = *A. lasiocarpa* (subalpine fir, corkbark fir var. *arizonica*); ARPU = *Arctostaphylos pungens* (pointleaf manzanita); CEMO = *Cercocarpus montanus* (mountain mahogany); JUDE = *Juniperus deppeana* (alligator juniper); JUMO = *J. monosperma* (one-seed juniper); MUVI = *Muhlenbergia virescens* (screwleaf muhly); PIED = *Pinus edulis* (pinyon pine); PIPO = *P. ponderosa* (ponderosa pine); PIEN = *Picea engelmannii* (Engelman spruce); PIPU = *P. pungens* (blue spruce); POAN = *Populus angustifolia* (narrowleaf cottonwood); POTR = *P. tremuloides* (quaking aspen); PSME = *Pseudotsuga menziesii* (Douglas-fir); QUGA = *Quercus gambelii* (Gambel oak); QUHY = *Q. hypoleucoides* (silverleaf oak); QUTU = *Q. turbinella* (scrub liveoak). Plant names follow Dick-Peddie (1993). ROCK = rock outcrops (indicates significant rock outcrops and/or cliffs through at least part of the map unit).

[c] Climate classes are defined by three parts, separated by commas. Part 1 denotes overall climate category: LSC = low sun cold; LSM = low sun mild; HSC = high sun cold. Low sun indicates that ≥50% of annual precipitation falls from 1 October through 31 March; high sun indicates that ≥50% of annual precipitation falls from 1 April through 30 September; mild indicates a mesic soil temperature regime; cold indicates a frigid soil temperature regime. Part 2 indicates general life zone: 4 = woodland; 5 = ponderosa pine forest; 6 = mixed-conifer forest; 7 = spruce-fir forest. Part 3 indicates where a map unit falls within a life zone: 0 = at or near the central concept for that life zone; +1 indicates the cool, moist end of the life zone; -1 indicates the warm, dry end of the life zone; no information indicates a map unit encompasses the full range of the life zone.

[d] NI = no information. This typically occurred either where non-timber species dominated the map unit or where steep slopes precluded timber harvest.

Sources: U.S. Department of Agriculture (1989, 1991: Map unit descriptions; U.S. Department of Agriculture 1995: table 3).



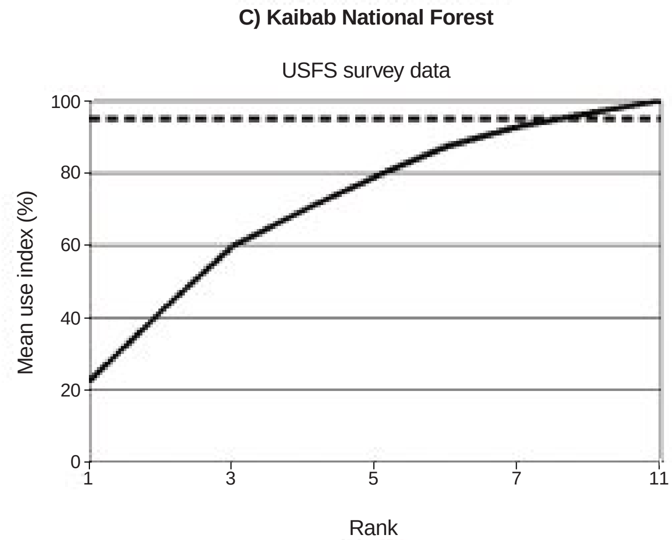


Figure 3. Plots of cumulative percent use, based on the mean use index, for Terrestrial Ecosystem Survey (TES) map units on three National Forests in Arizona. Map units were ranked from highest use to lowest use based on a mean use index computed using USFS survey data. Cumulative use then was plotted against map unit rank. The dotted reference line intersects the use curve at a point indicating 95% of the cumulative use function. A) Apache-Sitgreaves National Forest; B) Coconino National Forest; C) Kaibab National Forest.

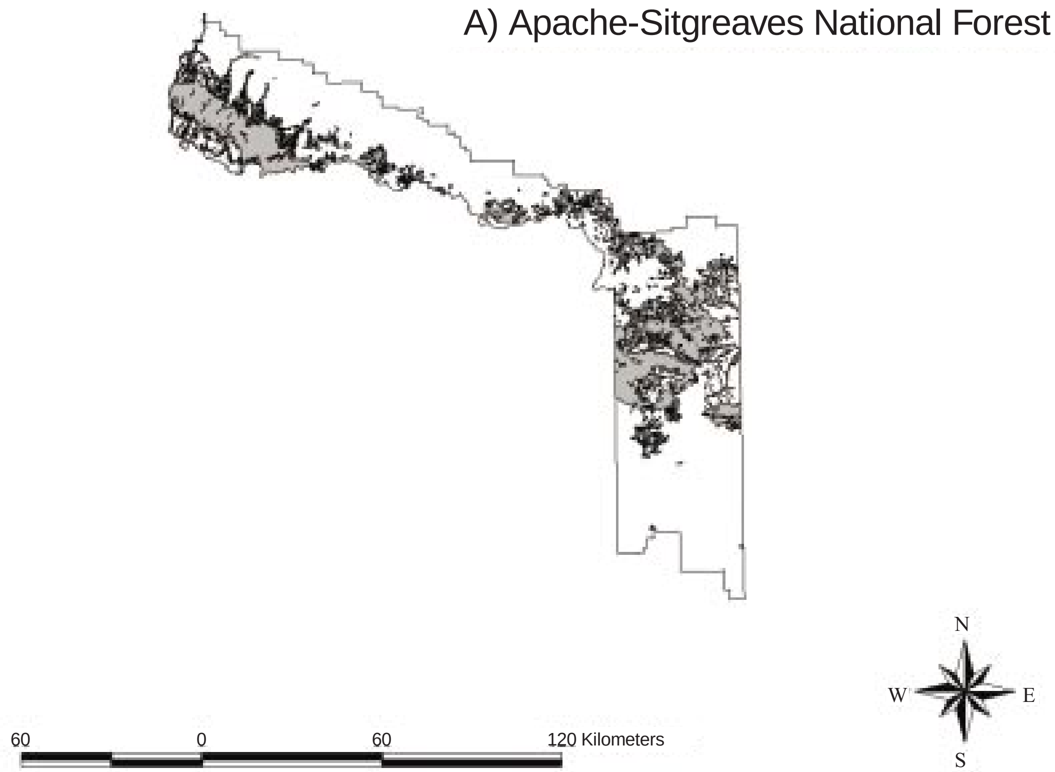
for timber harvest based on soil considerations rather than steep slopes (i.e., map units 192, 193, 202, Apache-Sitgreaves [U.S. Department of Agriculture 1989]; map units 565, 582, and 584, Coconino [U.S. Department of Agriculture 1995]).

Spatial Extent of Map Units Associated With Owl Use

Collectively, the 19 map units identified as strongly associated with spotted owl use comprised 23.3 percent of total area in the Apache-Sitgreaves National Forest. In the Coconino National Forest, the 14 map units identified as strongly associated with owl use comprised 23.8 percent of total area. The nine map units identified as strongly associated with owl use comprised 7.6 percent of total area in the Williams Ranger District of the Kaibab National Forest.

In the Apache-Sitgreaves National Forest, map units associated with owl use were sparse below the Mogollon Rim, but fairly well-distributed along the top of the Mogollon Rim, with the exception of an area in the center of the Forest (fig. 4). This area generally lacked the map units designated as associated with owl use, and may be larger than portrayed here, as some of the surrounding units identified as associated were among the least-used units in that category. Removal of these map units would increase the size of the gap here, essentially fragmenting the eastern and western concentrations of owls (and owl habitat) in this Forest.

In the Coconino National Forest, map units identified as associated with owl use form a fairly continuous block extending from the border with the Apache-Sitgreaves National Forest across the central Coconino, connecting to the red rock canyons around Sedona and the volcanic peaks north of Flagstaff (fig. 4).



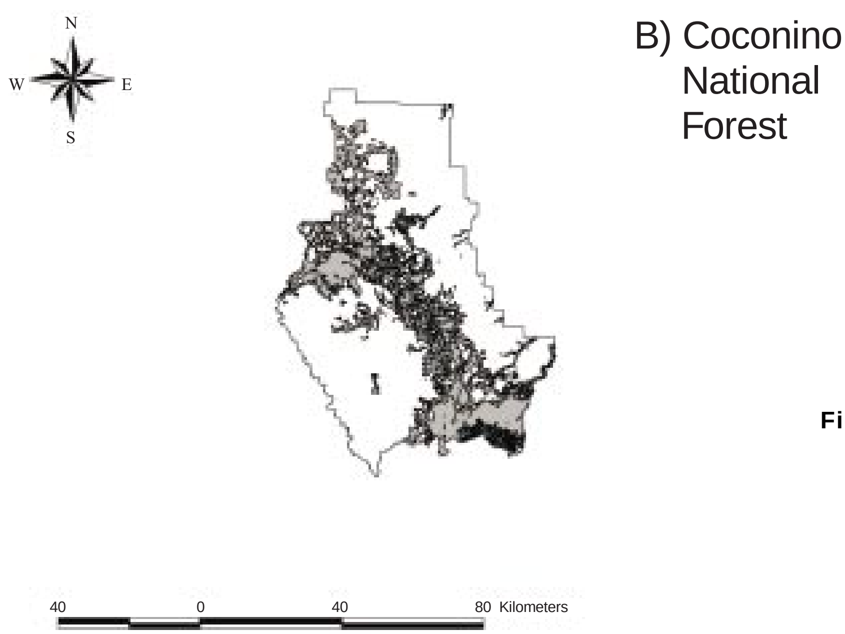
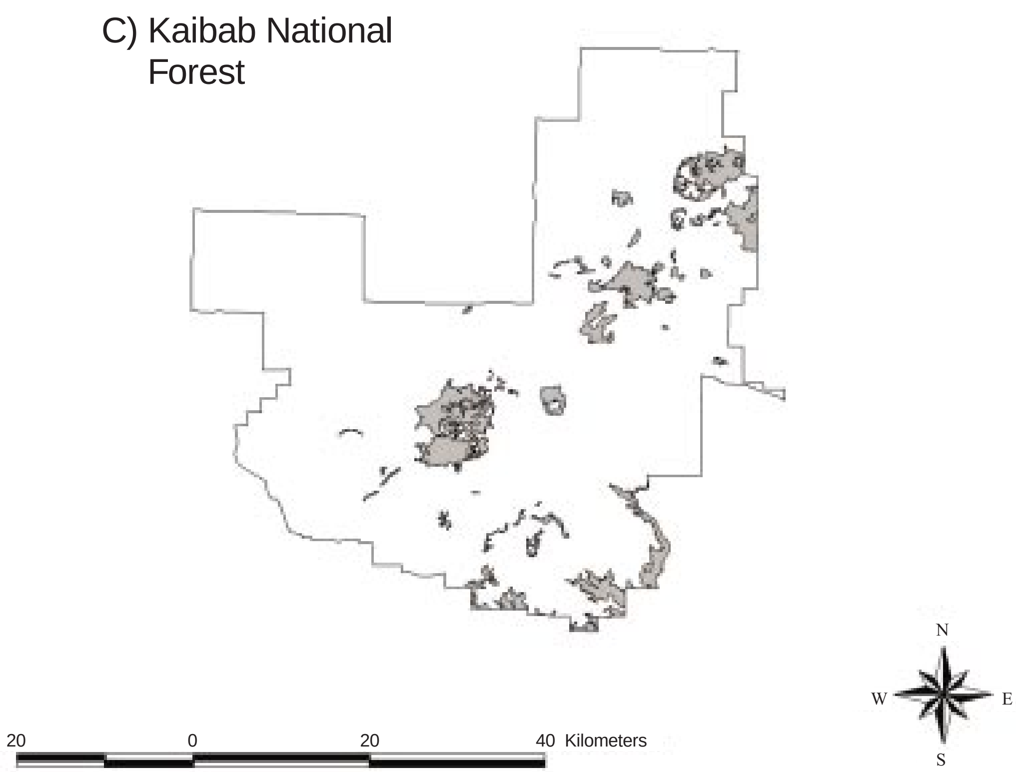
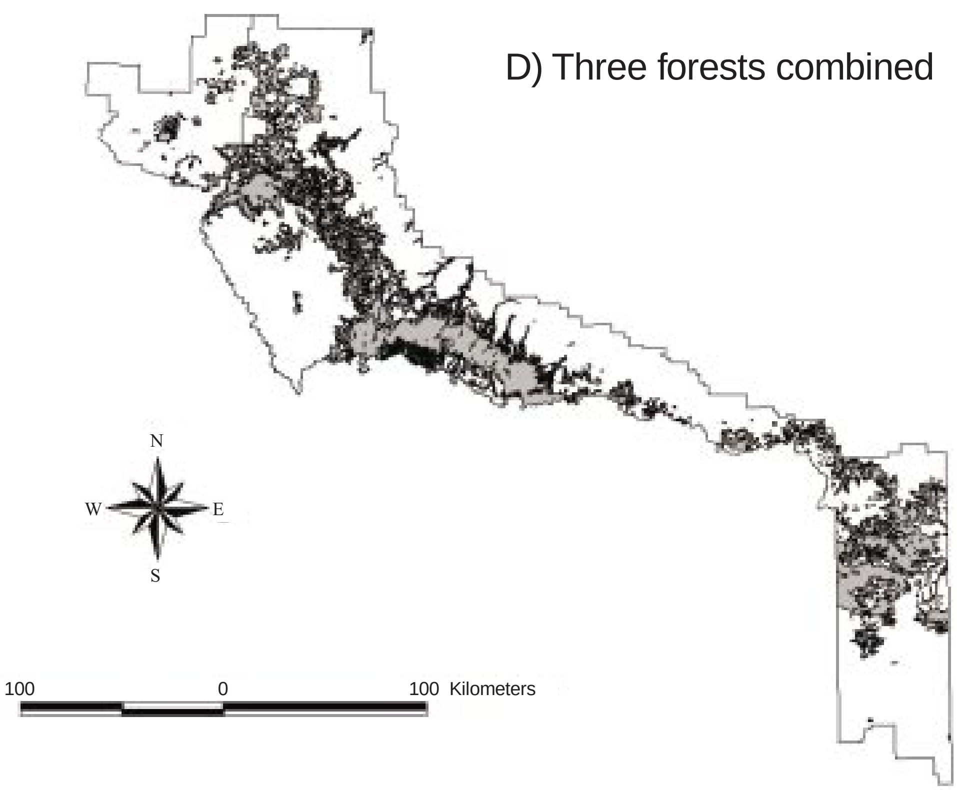


Figure 4. Spatial distribution of Terrestrial Ecosystem map units identified as strongly associated with Mexican spotted owls. A) Apache-Sitgreaves National Forest; B) Coconino National Forest; C) Kaibab National Forest; D) three Forests combined. Maps show Forest boundary and distribution of map units associated with owl use (shaded areas).


C) Kaibab National Forest
N
W
E
S
20
0
20
40 Kilometers


D) Three forests combined
N
W
E
S
100
0
100 Kilometers

In the Kaibab National Forest, map units identified as associated with spotted owl use are both sparser and more patchily distributed than in the other two Forests (fig. 4). In general, these map units are concentrated either in canyon systems dissecting the Mogollon Rim, or on the higher volcanic peaks such as Bill Williams, Sitgreaves, and Kendrick Mountains.

DISCUSSION

Our data suggest that owls show a strong positive association with a subset of available map units in these three Forests (table 9). The particular subset of map units identified is related to the selection criteria and will change somewhat if those criteria are changed (see below). We recognize that the data sets used in our assessment involved pseudo replication (Hurlbert 1984), and that this could have introduced bias into our results. In particular, this could affect whether or not some of the lesser-used map units are defined as strongly associated with owl use. Some map units were used so consistently that bias is unlikely to be a factor, however. That is, the magnitude of the bias would need to be astronomical to explain our results with respect to the more heavily used map units (tables 3 to 8).

Most map units identified as associated with owl use by the more detailed quadrat and radiotelemetry data also were identified as such by USFS survey data, but the converse was not true. However, in many cases map units identified as important only by USFS survey data either were not represented in the more detailed data sets, or were present in such small amounts that it was difficult to estimate their importance.

We were encouraged that most map units identified as associated with owl use by more detailed data sets also were identified by USFS survey data (table 9), that only one map unit (Coconino 596) was identified as associated with owl use based solely on nonbreeding-season use, and that this map unit comprised only 0.1 percent of total area within the Coconino National Forest (table 4). This suggests that USFS survey data collected during the breeding season can be used to identify map units associated with owl use. This is important because most National Forests will lack the types of detailed data on owl movements and nonbreeding-season use provided by radiotelemetry data.

Where inferences about wildlife use of TES map units are based solely on survey data, however, survey areas should be mapped so that amounts of different map units surveyed can be quantified, and surveys should be extensive enough to adequately cover the full spectrum of map units. Unless composition of areas surveyed is quantified, TES data can be used only to document where species have been found, not where they were looked for but not found. Further, relative levels of use of different map units can not be quantified in this case. Extensive surveys are necessary both to ensure an adequate sample, and to avoid bias in understanding of habitat relationships caused by looking for species only where you expect to find them.

If the above considerations are heeded, the technique used here with USFS survey data to identify a subset of map units strongly associated with owl use provides an objective means of identifying such units. This method could be extended to other Forests where both TES data and adequate USFS survey data are available. The specific criterion used in identifying that subset of map units is flexible and can be tailored to individual situations. We chose to include 95 percent of the cumulative mean use function because we wished to be inclusive. However, if the goal was to identify a smaller subset of map units more strongly associated with owl use, a smaller percentage of the cumulative use function can be used. For example, if that percentage were dropped to 75 percent, the number of map units included would drop to eight in the Apache-Sitgreaves National Forests, six in the Coconino National Forest, and four in the Kaibab National Forest (fig. 3). It would also be possible to weight location types differently, for example giving more weight to roost and especially nest locations on the assumption that such locations are a better indicator of importance to owls than foraging locations (U.S. Department of Interior 1995: 83). This should be done only where sample sizes are reasonably high (>100 locations where indices are based on percentages) and roost and/or nest locations are distributed over a large number of owl territories, to avoid problems due to imprecise estimates and possible survey bias.

Map units identified as associated with owl use generally had common ecological characteristics (table 10). Further, those characteristics were consistent with results of previous studies (reviewed in Ganey and Dick 1995) showing that Mexican spotted owls in this geographic region typically occur in relatively cool and moist mixed-conifer and pine-oak forests, often in association with steep rocky slopes. This analysis thus confirms these general habitat trends, using three different data sets that together include more owls and cover larger areas than did previous studies.

An intriguing question raised by this study is why some map units do not show an association with owl use, although they appear to have ecological characteristics similar to units that do show a positive association. One possible explanation is that data on owl use were lacking for these units, because they were not surveyed and did not occur in quadrats or radiotelemetry study areas. This does not always appear to be the case, however.

A second possible explanation is that existing vegetation may have differed between these map units and those showing an association with owl use. This could also explain why some polygons of a particular map unit were used, but not others. TES data do not allow us to quantify current vegetation structure or successional stage. This points out perhaps the biggest limitation of TES data for this type of application, as well as the pressing need for a region-wide coverage showing current vegetation at 1:24,000 (or similar) scale. Until such a coverage is available, our ability to conduct large-scale assessments of habitat quantity and distribution for the Mexican spotted owl and other species of management concern will be limited.

Obviously, the strength of inferences about owl association with particular TES map units will depend on the quantity and quality of data available. In the current study we are most confident about inferences in the Coconino National Forest, because (1) USFS survey data were extensive there (table 4); (2) data were available from six quadrats in this Forest (table 1); (3) radiotelemetry data were available for 19 owls in three study areas (table 2); and (4) quadrats and radiotelemetry study areas combined occurred in five Ranger Districts and in mixed-conifer forests, pine-oak forests, and rocky canyons. Thus, data were extensive, geographic representation was good, and the major habitats associated with spotted owls were included.

We also are reasonably confident about inferences in the Apache-Sitgreaves National Forest. USFS survey data also were extensive for this Forest (table 3). In addition, data were available for five quadrats in five Ranger Districts (table 1), and for two radiomarked owls in one Ranger District (table 2). Thus, data were reasonably extensive, geographic representation was good, and the major habitat associations (mixed-conifer and pine-oak forests and rocky canyons) were covered.

In contrast, data were fairly sparse for the Kaibab National Forest. USFS survey data for this Forest included relatively few locations (table 5). Only one quadrat occurred completely in this Forest, with part of a second shared between the Coconino and Kaibab National Forests (table 2). Finally, no radiotelemetry data were available for this Forest. Consequently, there was little information to work with, and inferences remain much more tentative for this Forest.

Even where data used in this assessment were extensive, it is possible that some areas important to owls were overlooked. This is most likely to have occurred in areas where timber harvest is not an issue, as many surveys targeted areas where timber harvest was planned. A possible example of such an area is the Clifton Ranger District, Apache-Sitgreaves National Forest. We suspect that surveys here were limited, at least as of 1993 when distributional data were compiled. Owls may occur in this Ranger District in map units not well represented by surveys conducted above the Mogollon Rim. With this exception, we suspect that surveys were comprehensive enough and covered a large enough spectrum of the available map units in the three Forests covered in this assessment that results are reasonably comprehensive. Further, because criteria for including map units were fairly liberal, we suspect that amounts of owl-associated habitat may be over- rather than under-estimated here.

This study indicates that TES data can be used to identify map units associated with owl use and to map their spatial extent. This suggests that TES data could be used to develop a baseline map of potential owl habitat. Because TES data do not distinguish between current and potential habitat, however, TES data probably are not useful alone in portraying distribution of current owl habitat. This would require a coverage showing current vegetation type and structure. Further, by design, TES map units do not change over time. In contrast, existing vegetation structure and composition within those map units does change over time, and those changes can alter the suitability of those areas as owl habitat. Thus, TES data can perhaps be helpful in establishing a baseline understanding of the amount and distribution of potential spotted owl habitat, but can not be used to monitor changes in habitat amount or distribution. This again points out the need for a digital coverage showing current vegetation type and structure.

MANAGEMENT IMPLICATIONS

We recommend focusing initial habitat management efforts in these three National Forests on the map units identified as strongly associated with owl use (table 9). In many cases these areas may already be protected under the recovery plan for the Mexican spotted owl (U.S. Department of Interior 1995), which called for placing all mixed-conifer and pine-oak forest with slopes >40 percent and no recent history of timber harvest in a protected category. Many of the map units identified would thus fall in those categories and be afforded *de facto* protection. The remaining units would appear to be logical places to target efforts to develop replacement habitat in "restricted" habitat as defined by the recovery plan. If this does not successfully meet area requirements for replacement habitat in restricted habitat, map units with similar ecological characteristics could be targeted for management as replacement habitat. Areas could be targeted based on adjacency to existing habitat managed as protected or replacement habitat, or managers could look for areas that would fill gaps in owl habitat as currently distributed. This latter idea is possible because the TES data, where available, are in digital format amenable to spatial analysis and display.

In terms of owl surveys, all of the map units identified as strongly associated with owl use should be targeted when and where surveys for owl presence are required (generally when management actions are planned in an area). As a second tier, it might also be desirable to target surveys in map units with ecological characteristics similar to those units identified as strongly associated with owl use.

Our results suggest that, with a few exceptions, the map units most strongly associated with owl use are not well suited for timber harvest, due to either steep slopes or soil-based considerations (table 10). This suggests that it may be possible to protect the best owl habitat while simultaneously minimizing impacts to timber harvest programs.

With respect to TES map units characterized by steep slopes, we do not know whether spotted owls are associated with these TES map units because they occur naturally in the types of terrain represented, or whether the association is driven by the fact that less forest management has occurred in these areas. This question has limited our understanding of habitat relationships of Mexican spotted owls for years, because owls generally are associated with both steep canyon slopes and old-growth forests, and these variables are confounded. A GIS coverage showing current vegetation type and structure would allow us to address this question, by assessing vegetation structure while controlling for slope conditions. Such a coverage could also be useful in monitoring trends in owl habitat and could facilitate numerous other large-scale assessments. Consequently, we strongly recommend that such a coverage be developed as soon as reasonably possible. We further recommend that efforts focus on coverages based on satellite imagery, because such imagery is readily available and can be used in the type of change-detection analysis (Iverson and others 1989; Spies and others 1994) required to monitor trends in owl habitat.

EPILOGUE

This paper essentially (1) documents that TES data show promise for use in identifying habitats associated with owl use; (2) makes some preliminary recommendations on which TES map units should be targeted for management; and (3) documents an objective and flexible technique that can be used with survey data to identify a subset of map units important to spotted owls. This study is not intended to provide a final estimate of which map units should be managed for spotted owls. We recognize that land managers have access to larger and more current (i.e. including owl locations obtained since 1993) data sets, and recommend that they use such data sets to refine the preliminary estimates presented here.

At this time, one of us (MAB) is currently using updated data to refine our understanding of owl use of TES map units in the Coconino National Forest, and to develop an objective process to prioritize TES map units for survey and management efforts. This effort involves (1) creating digital coverages of areas surveyed for owls, to allow quantification of area surveyed by TES map unit; (2) assessments of use patterns based on results of owl surveys through 2000; (3) assessments of dominant map units in Protected Activity Centers (U.S. Department of Interior 1995) created by land managers to protect owl nesting areas; and (4) using results from 1 to 3 to develop a standardized process for rating map units with respect to priority for further survey and placement in management categories (protected, restricted, or unrestricted, following U.S. Department of Interior 1995). This effort should result in a better understanding of the relative value of TES map units to Mexican spotted owls in this Forest. We hope that it also will provide guidance for similar efforts in other National Forests.

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