Final Report
STATUS AND HABITAT USE OF OAKS

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Introduction

Gambel oak (*Quercus gambelii*) is common throughout the western United States, occurring on about 3.76 million hectares (Harper et al. 1985). It typically occurs as scattered individuals or clumps in these forests. Although Gambel oak is a slow-growing tree, reaching an average diameter of 30 – 35 cm at 200 years, it is an important species for wildlife in ponderosa pine (*Pinus ponderosa*) and pinyon-juniper (*Pinus edulis-Juniperus* spp.) associations in Arizona (Kruse 1992, Brown 1994).

Although Gambel oak often represents less than 25% of the canopy cover in ponderosa pine-Gambel oak stands, it provides unique habitat for many vertebrate species. In ponderosa pine-dominated forests, the presence of Gambel oak increased bird species abundance and diversity (Marshall 1957, Szaro et al. 1990, Rosenstock 1996). Cavity-nesting species (e.g., woodpeckers, white-breasted nuthatches [*Sitta carolinensis*], western bluebirds [*Sialia mexicana*]) used Gambel oak as nest sites during the breeding season (Cunningham et al. 1980, Paine and Martin 1994).

Other wildlife species including elk (*Cervus elaphus*), mule deer (*Odocoileus hemionus*), black bear (*Ursus americanus*), wild turkeys (*Meleagris gallopavo*), blue grouse (*Dendragapus obscurus*), Abert's squirrels (*Sciurus aberti*), acorn woodpeckers (*Melanerpes formicivorus*), band-tailed pigeons (*Columba fasciata*), and many songbirds derive part of their diet from Gambel oak (Hayward 1948, Kufeld 1970, Reynolds et al. 1970, Lamb 1971, Pederson 1975, Szaro et al. 1990). Some bat species occur more frequently in ponderosa pine-Gambel oak forests than ponderosa pine forests (e.g., southwestern myotis [*Myotis auriculus*] and Allen's lappet-browed bat [*Idionycteris phyllotis*]) (Mike Rabe, Arizona Game and Fish Department Research Branch, pers. comm.). Gambel oak is also an important component of Mexican spotted owl (*Strix occidentalis lucida*) habitat (USDI Fish and Wildlife Service 1995). Habitat relationships that were known from the literature or from research projects are documented in Table 1.

Oak (particularly large diameter trees and trees near roads) may be declining in northern Arizona (Rick Miller, Arizona Game and Fish Department, 1993, unpublished report). In the past, Gambel oak was considered an undesirable species in ponderosa pine stands. Mature oak trees and oak regeneration were actively eliminated or controlled (Clary and Tiedemann 1992). Although management on public lands with regard to oak has changed to better protect the species, illegal fuelwood cutting of Gambel oak and elk and livestock grazing negatively impact oak growth and regeneration (Harper et al. 1985, Clary and Tiedemann 1992, Rick Miller, 1993, unpublished report). Because of Gambel oak's slow growth rate, Gambel oak density may be declining in forests of northern Arizona. In addition, there may be little opportunity for Gambel oak trees to attain large diameters (> 85 cm). Large hardwood trees are particularly valuable since they typically provide more natural cavities (holes created by branch breaks) and pockets of decay that allow excavation and use by cavity nesters than conifers (Gumtow-Farrior 1991). Rick Miller (1993, unpublished report) found an average of 4.7 cavities in oaks with diameters > 50 cm. There were only 2 trees per hectare of this size class however. Wildlife species may lose valuable habitat by decline in oak density and removal of large oaks.

Bat Survey Techniques

A current debate among bat researchers is the comparison of mist netting and the Anabat ultrasonic detectors to identify bat community composition (Kunz and Brock 1975, O'Farrell and Gannon 1999). Mist netting is a common technique used for capturing bats along foraging flyways and over water (Kunz and Kurta 1988). Mist netting allows for the hands-on identification of species and for the collection of biological data such as reproductive status, sex ratios, and age (Kunz and Brock 1975). However, the use of mist nets limits captures to a small area and can not be used successfully in certain locations such as large open fields, large water bodies, or high in the forest canopy (Kunz and Brock 1975). Mist nets do not capture all possible species within the netting area because some bats avoid nets, so captures do not represent the total species composition of that area (O'Farrell and Gannon 1999). Furthermore, mist-netting success has been found to decline over consecutive nights at the same location (Kunz and Brock 1975). Finally, mist netting over water sources may reveal more about when a species takes water than when it is active and feeding (Bell 1980).

Ultrasonic detectors have been used in multiple studies to detect species composition, habitat use and species call types (a few are Fenton and Bell 1979, Parsons et al. 1997, O'Farrell et al. 1999). Detectors allow for the sampling of a larger area and a larger variety of species, but do exclude certain species from identification, such as bats that use low-intensity calls (O'Farrell and Gannon 1999). Ultrasonic detectors can sample areas where mist netting is not effective. However, a major limitation in the use of ultrasonic detectors is the difficulty in identifying species-specific bats calls (O'Farrell et al. 1999). Frequently, the data recorded is of poor quality, the library of calls is not representative of the species, or the researcher is unable to identify many of the calls (O'Farrell et al. 1999).

Project Goals

An information need requested by Arizona Game and Fish (AZGF) Department through the Heritage Fund was use of Gambel oak by bats and cavity-nesting birds. I conducted 1 year of field research on cavity-nesting bird use of Gambel oak (1997) prior to receiving Heritage funding to continue cavity-nesting bird surveys and documenting use of Gambel oak by bats (1998 – 2000). I conducted 2 years of field research on bat use of Gambel oak and 1 additional year of field research on cavity-nesting bird use of Gambel oak. This report summarizes results from 1997 to 2000 (Heritage funding was used for 1998 – 2000).

Project Objectives

I identified physical characteristics of oaks and oak clumps that influenced bird nesting and foraging habitat use and southwestern myotis roost use. I compared bat communities between ponderosa pine and ponderosa pine/Gambel oak forests. I evaluated human impacts on Gambel oak (harvesting trees). Specific project objectives were:

1. To describe status (characteristics and spatial patterns) of Gambel oak in forests of the Coconino and Kaibab National Forests in north-central Arizona using stand exam data obtained from these forests.
2. To examine past and present management (harvest rates and rate of regeneration) of Gambel oak on the Coconino and Kaibab National Forests by selecting locations on these forests for surveys of Gambel oak, oak regeneration, and harvested oak.
3. To determine effects of Gambel oak tree size and Gambel oak clump size on use by diurnal breeding birds.
4. To compare bat communities between 2 habitat types: ponderosa pine/Gambel oak and ponderosa pine.
5. To describe maternal roost sites for southwestern myotis (*Myotis auriculus*).
6. To compare 2 methods for bat detection: ultrasonic detection and mist netting.

(Objectives 1 and 2 were descriptive summaries. Null hypotheses were not tested for these objectives.)

<u>Null hypothesis 1</u>: There are no differences between used and unused oak trees and oak clumps for bird nesting or foraging.
<u>Null hypothesis 2</u>: There are no differences between bat communities found in two types of habitats (ponderosa pine and ponderosa pine/Gambel oak) used by bats for foraging.
<u>Null hypothesis 3:</u> There are no differences between used and unused oak trees and oak clumps used by southwestern myotis for roosting habitat.
<u>Null hypothesis 4</u>: There is no relationship between bat detectability using ultrasonic detecting devices (AnaBat detectors) and mist netting techniques.

Study Area

I conducted all bird and bat work during summers (May – August) from 1997 to 2000 on the Coconino National Forest. Mean temperatures and precipitation (°C-cm) for the Flagstaff area for June, July and August of 1999 and 2000 were 14-2.4, 18-8.3, 17-6.2 and 17-2.8, 19-.73, 18-7.2, respectively (Western Regional Climate Center 2001). Oak transect data were collected as weather permitted throughout the year in 1998 and 1999.

Birds

I used 12 stands on the Coconino National Forest, Camp Navajo Army Depot, and on state lands in an elevation range of 2000 to 2300 m. Stands had a minimum Gambel oak canopy cover of 5%. Stand size was 18 ha (300 x 600 m) or 24 ha (300 x 800 m) (Table 2).

Bats

In the summers of 1999 and 2000, I captured bats in 2 locations in the Coconino National Forest in northern Arizona. The "pine site", located 12 km northwest of Flagstaff (35°15'N, 111°45'W), was a ponderosa pine-grassland community dominated by ponderosa pine, Arizona fescue *(Festuca arizona*), and mountain muhly (*Muhlenbergia* *montana*). Elevations ranged from 2,198 to 2,353 m. The second site, a pine-oak site, was located 25 km south of Flagstaff (35°N, 111°37'30"W) with elevations ranging from 2,042 to 2,327 m. The pine-oak site was dominated by a ponderosa pine-Gambel oak (*Quercus gambelii*) community with an understory of New Mexican locust (*Robinia neomexicana*), alligator juniper (*Juniperus deppeana*) and Utah juniper (*Juniperus osteosperma)* (Bernardos 2001).

Methods

National Forest Inventory Data

Kaibab National Forest Inventory Data

Kaibab National Forest personnel estimated that ponderosa pine dominates about 30% of the Kaibab National Forest and that Gambel oak is present in 40% of areas dominated by ponderosa pine. I obtained data for 39 stands representing 1080 ha (2699 ac) on the Kaibab National Forest. Data were completed stand exams for sites in which ponderosa pine and Gambel oak occurred and Gambel oak represented 5 to 30% of basal area. Stand exam data included ponderosa pine basal area (ft^2/ac) and number of Gambel oak trees per ac by 3-inch diameter size classes.

Coconino National Forest Inventory Data

I obtained data for 2062 stands containing 5 to 30% basal area of Gambel oak on the Coconino National Forest. Ponderosa pine was the dominant tree species. Stand exam data included basal area and trees per ac by 1-inch diameter size classes.

Gambel Oak Transects

Coconino National Forest Transects

I placed 41 transects to sample Gambel oak on the Coconino National Forest for comparison to National Forest data. Transects were located within 75 km of Flagstaff at 11 locations (1 to 12 transects at each location) (Table 3) and sampled between July 1998 and May 1999. Each 500-m long transect was started randomly at a location 50 m and perpendicular from the road. I measured characteristics of each Gambel oak tree or clump encountered on transects to estimate Gambel oak regeneration and previous human impacts on Gambel oak distribution (Table 4). I defined a clump as $\geq$2 Gambel oak trees with interlocking or adjacent crowns, with Gambel oak crowns $\geq$3 m from next nearest oak crowns.

Both the Coconino and Kaibab National Forests measured diameter of Gambel oak at breast height (1.4 m above ground). I measured Gambel oak at root collar (ground level) to eliminate effects of bole swelling. Although the measures are from different locations, I believe diameters do not vary enough with these methods to preclude comparison between National Forest inventories and my transects.

Birds

Nest Searches and Foraging

Seven 800-m or 5 500-m parallel transects were established in each stand. Transects were 50 m apart. Observers randomly selected a transect number, walked the selected transect and then walked every other transect, completing as many transects as possible from dawn to 4 hours after dawn. Signs of foraging on or nesting in Gambel oak were recorded. Observers were rotated among sites to avoid bias due to different levels of experience (Ford et al. 1990). I identified individual oak clumps used by birds for foraging and nesting, and described characteristics of those clumps. For nest trees, I measured diameter at root collar (drc), height, crown area, crown complexity, and decay class. For clumps in which I observed birds foraging, I measured diameter at root collar, average height, stem density, crown area, crown complexity (Table 5), and decay class (Tables 6 and 7). I compared each used clump to 2 randomly selected oak clumps within 20 m of the used clump to determine differences between used and randomly selected clumps.

When a bird was observed foraging on living Gambel oaks, oak snags, on the ground at the base of oaks, or in oak saplings, the observer assessed the bird's activity after waiting 5 seconds before beginning data collection (Hejl and Verner 1990) to allow resumption of normal activity if the bird was disturbed by the observer (W. Block, USDA Forest Service, Rocky Mountain Research Station, pers. comm.). Observations among individuals of different bird species were considered independent if there is at least 30 m between observations and/or 10 minutes. Observations within species were considered independent if there is at least 100 m and/or 10 minutes between observations (Hejl et al. 1990). Only initial observations for bird species with $\geq$35 independent observations will be statistically analyzed for comparing use of oak and ponderosa pine (Hejl et al. 1990, W. Block, USDA Forest Service, Rocky Mountain Research Station, pers. comm.). Sequential foraging observations were not be statistically analyzed because of autocorrelation (Bell et al. 1990, Hejl et al. 1990).

Bats

Community comparison

Bats were captured in June and July 1999 over earthen water tanks using mist nets. I captured bats for 20 nights at 25 man-made earthen water tanks (pine site, n = 12, pine-oak site n = 13) to compare bat community differences between the 2 types of habitat. Mist nets were set across open water in a Z-, W-, or V- configuration (Kunz et al. 1996). Length of net used varied with the size of each water body. Nets were opened at dusk (between 19:40-20:00) and remained open for at least 2 hours or until midnight depending on bat activity. Bat activity was monitored with a bat echolocation detector. If <5 bat echolocation calls were detected within a 30-minute period, I ended the netting session. All captured bats were identified to species, gender, and age. I determined age (juvenile or adult) by looking for the presence of cartilaginous epiphyseal plates in the phalanges (Anthony 1982). I measured mass with a Pesola™ spring scale (to nearest 0.2 g) and forearm length (to nearest 0.1 mm) to aid in identification of some species. I also assessed reproductive condition. Abdomens of females were palpated for evidence of pregnancy, and mammary glands were checked for evidence of lactation. I examined males to determine if they were in a scrotal or non-scrotal condition. Bats were released usually ≤15 minutes of capture.

Anabats

In June and July 1999, I recorded bat echolocation calls in ponderosa pine and ponderosa pine-Gambel oak, to evaluate bat activity and patterns of habitat use. I used Anabat II bat detectors (Titely Electronics, Ballina, NSW, Australia) in combination with delay switches and tape recorders to record and time stamp bat echolocation calls onto audiotapes. Sensitivity of Anabat detectors was calibrated using a flea repeller device for pets at the beginning of each sampling week (Krusic et al. 1996). Time clocks on delay switches were checked and synchronized each night. Anabat detectors were placed in 50 caliber ammunition boxes with a hole cut in one end so the microphone could protrude. Microphones were protected by a 6 cm overhang on the box (Rabe 1999).

I established 2 echolocation stations per night (n = 15 nights) from June 2 to July 15. One station was located in a pine site (n = 15 detector stations) and one in a pine-oak site (n = 14 detector stations), approximately 30 km from each other. I placed 2 bat detectors in each study area adjacent to an earthen stock tank (<10 m from the tank) and 2 bat detectors 200 m in a random direction from the earthen stock tank (pine site: n = 10 tanks and pine-oak site: n = 10 tanks). I simultaneously recorded bat echolocation calls using Anabat II detectors at 2 heights: 1m (ground) and 6 m (lower canopy; also called tower) above ground. Ideally, ground detectors surveyed the area below the canopy and lower canopy detectors surveyed a portion of the forest canopy. Detectors at the earthen stock tank and 200 m from the tank were placed facing the same direction. I turned detectors on prior to dusk (between 18:00-19:00) and shut them off at midnight.

Data collected from Anabats placed near water sources were compared with the concurrent bat community mist netting study conducted in the same locations. Data collected from Anabats placed 200 m from the earthen stock tank were compared with data from Anabats near the tank. I visited 9 of 20 water sources a second time. However, bat detectors were placed in a new different location.

Anabat and Mist Netting Comparison

I downloaded all recorded calls using a ZCAIM interface and analyzed calls using Anabat 6 and Analook software (Titley Electronics, Ballina, NSW, Australia). I recorded time and location for each bat call sequence. I examined all calls recorded and identified the species when possible by examining shape, minimum and maximum frequency and duration (Hayes and Gruver, 2000) and comparing them to a call library. I also classified certain sequences into a general group called, Myotis species, when calls were unidentifiable to species, but met the characteristics of a myotis echolocation call (high frequency, short duration calls). Lastly, I classified calls as undetermined fragmentary calls that lacked sufficient information to be classified (Hayes and Gruver, 2000). Calls collected on Anabats were compared to a species list from mist netting.

Southwestern myotis (Myotis auriculus) Roost Sites

In the summers of 1999 and 2000, I conducted a radio-telemetry roost study within the pine-oak study area. I attached radio-transmitters between the scapulae of 18 southwestern myotis females (6 in 1999, 12 in 2000) (Table 8) with non-toxic, latex-based glue. All radio-tagged females were lactating and weighed greater than 7 g. On average, transmitter mass was ≤7% of the mass of the bat, which is only slightly over the 5% rule (Aldridge and Brigham 1988). I also placed transmitters on 4 male southwestern myotis (≥7 g) (1 in 1999, 3 in 2000) to describe day roosts of males and compare with roosts used by females. All bats were released ≤25 minutes after the glue had dried. I located day roosts using radio telemetry by ground tracking. I located each bat daily until the transmitter fell off or ceased to produce a signal. I performed exit counts (n = 11) on Gambel oak roosts when time, personnel, and weather permitted to check for the occupancy of the radio-tagged bat and to determine if other bats were present.

Statistical Analyses

I used logistic regression to investigate the influence of characteristics of oak trees (e.g., diameter at root collar, live crown area) and oak clumps (e.g., vertical structure, density, diameter distribution) on occurrence of bird nesting or foraging.

I compared differences in bat communities between ponderosa pine and ponderosa pine-Gambel oak sites. I pooled gender for each bat species. Because area of net used and time spent at each water source differed among sites, I calculated an index of abundance by weighting the number of captures based on netting effort (Rabe 1999). I calculated percent capture for each bat species and made comparisons between both forest types.

For analysis of tree and surrounding forest characteristics associated with Gambel oak maternity roost trees used by southwestern myotis, I compared used roosts to randomly selected trees (random trees). I selected a random tree approximately 200 m from the roost tree in a randomly selected compass direction (Brigham et al. 1997). Random trees were either Gambel oak trees ≥26 cm diameter at root collar and ≥3 m in height, decay class 2 to 6 or ponderosa pine snags ≥30.5 cm diameter at breast height and >3 m in height (Rabe et al. 1998, Bernardos 2001). I used 4 *a priori* models. I based models on roost characteristics found to be significant in past bat roost studies. Roost trees tended to be taller in height and have larger diameters at breast height, and were closer to other available trees than were random trees (Campbell et al. 1996, Sasse and Pekins 1996, Vonhof and Barclay 1996, Brigham et al. 1997, Betts 1998, Rabe et al. 1998). I used multiple logistic regression (Hosmer and Lemeshow 1989) to determine which characteristics of trees and surrounding forest best discriminated between Gambel oak roosts and random trees. I pooled Gambel oak roosts for all females since roost sample sizes for individual bats ranged from 1 to 6 roosts (x = 3.0 ± 0.4 SE) and made examination of roost selection by individual bats inappropriate (White and Garrott

1990:191). I used Akaike's Information Criterion (AIC) for model selection and ranked models using Δ AIC (Burnham and Anderson 1998:43-48). I accepted models with Δ AIC <4 (Burnham and Anderson 1998:48). Models were validated using jackknife procedures.

I tested counts of bats echolocation passes recorded for a 4-hour period at both heights (ground and lower canopy) in each forest type to test for differences in number of bat passes recorded in ponderosa pine and ponderosa pine-Gambel oak forests (Ott 1992). I then used paired *t*-tests to test for differences between ground and lower canopy detectors within each forest type. Because counts of species group calls were not normally distributed, sample size was small (n = 14 detectors in each forest type), and numbers of undecided calls were high (n = 104 calls), I reported medians and quartiles (25 and 75%) for each species group.

To determine effectiveness of the 2 bat survey techniques (mist netting and ultrasonic detecting devices) in determining species richness, I compared percent similarity of bat species using Jaccard's coefficient (Brower et al. 1990). This coefficient describes the percent of species that are similar between 2 communities. The closer to 1.0, the higher the number of species shared between the 2 communities (the more similar they are).

Results

Gambel Oak

Kaibab National Forest Inventory Data

For the 39 stands representing 1080 ha (2699 ac) on the Kaibab National Forest on which Gambel oak co-occurred (5 to 30% of basal area) with ponderosa pine, most Gambel oak trees were in the smallest size classes (approximately 884 trees per ha in the 2.5 cm dbh size class) and <1 Gambel oak per ha occurred in the >52.5 cm dbh (>21 in). Gambel oak followed an inverse-J distribution with fewer trees in larger size classes (Figure 1).

Coconino National Forest Inventory Data

For the 2062 stands containing 5 to 30% basal area of Gambel oak and dominated by ponderosa pine, ponderosa pine averaged 79 ft^2/ac and 318 trees per ac. Gambel oak averaged 11 ft^2/ac basal area and 471 trees per ac. In the <5 in diameter class, ponderosa pine averaged 196 trees per ac (3.3 ft^2/ac basal area; average 1.8 in dbh) and Gambel oak averaged 455 trees per ac (1.3 ft^2/ac basal area; average 0.7 in dbh). In the 5 to 8.9 in diameter class, ponderosa pine averaged 64 trees per ac (16.7 ft^2/ac basal area; average 6.9 in dbh) and Gambel oak averaged 9 trees per ac (2.3 ft^2/ac basal area; average 6.8 in dbh). In the ≥9 in diameter class, ponderosa pine averaged 58 trees per ac (58.9 ft^2/ac basal area; average 13.6 in dbh) and Gambel oak averaged 7 trees per ac (7.6 ft^2/ac basal area; average 14.4 in dbh).

Gambel oak was most abundant in the smallest size class (1090 trees per ha for trees <2.5 cm diameter), and followed an inverse-J distribution with fewer trees in larger size classes. There were no Gambel oak trees >82.5 cm dbh (>33 in dbh) measured on these plots (Figure 2).

Coconino National Forest Transects

I measured 31,838 Gambel oak stems in 715 Gambel oak clumps on 41 transects on the Coconino National Forest and Arizona state forest lands. Relative abundance of Gambel oak stems by 5-cm size class was distributed in an uneven-aged (inverse-J) distribution with most stems (89%) in the 0-5 cm size class (Table 8, Figure 3). I found 298 Gambel oak ≥30 cm drc (0.9%) on 41 transects (this size class represents that most likely to be used by birds and bats). Average number of Gambel oak stems ≥30 cm drc per transect ranged from 5.3 to 17.

Basal area of Gambel oak was variable on transects (range 0 to 180 ft^2/ac) and did not appear to increase with distance from road (Table 9, Figure 4). I counted 330 cut Gambel oak stumps in 117 clumps on 41 transects (average 8 per transect). Stumps ranged from 7 to 60 cm drc but averaged 21 cm drc. I found stumps distributed along transects from 0 to 499 m with the average distance from start of transect for stumps 236 m (standard deviation [SD] = 143). Stumps were found in Gambel oak clumps that had an average crown area of 92 m^2 (range 0.1 to 720 m^2, SD = 110) and an average height of 8 m (range 1 to 22 m, SD = 4 m). More stumps were found in clumps with simple vertical structure than complex structure (85 simple, 32 complex).

I found 140 natural cavities in 96 Gambel oak trees. Average drc of Gambel oak trees with natural cavities was 39 cm (SD = 13) (range 10 to 86 cm drc). Most trees with natural cavities (85%) were live trees with some decay (decay classes 2a and 2b).

I found 32 excavated cavities in 26 Gambel oak trees. Average drc of Gambel oak trees with excavated cavities was 40 cm drc (SD = 12) (range 17 to 62 cm drc). Most trees with excavated cavities (75%) were live trees with some decay (decay classes 2a and 2b). I found excavated cavities in 17% of live Gambel oak trees with no evidence of decay (decay class 1).

Birds

Foraging

In 1997, I recorded 195 foraging observations representing 18 bird species (Table 10). I analyzed foraging data for 3 species (n >35): white-breasted nuthatch, mountain chickadee, and dark-eyed junco. Mountain chickadees and white-breasted nuthatches foraged in oak clumps that were taller, larger diameter, and structurally more complex than randomly selected oak clumps. Dark-eyed juncos foraged in oak clumps with trees of larger diameter, large crown areas, and that were structurally more complex than randomly selected oak clumps.

In 2000, I recorded 93 foraging observations representing 17 bird species (Table 10). The 3 species (dark-eyed junco, mountain chickadee, white-breasted nuthatch) that were most commonly observed in 1997 also dominated observations in 2000. However, sample sizes were too small (n <35) for analysis of 2000 data. Mountain chickadees (n = 24) were observed foraging on Gambel oak that averaged 32.8 cm drc and 9.4 m in height (taller, larger diameter trees). However, there did not appear to be a selection for foraging in structurally complex oak clumps (only 20% of foraging observations were noted in oak clumps with high vertical structure, 80% were in clumps of simple structure).

Nesting

I found 17 nests of 4 species in 1997 and 29 nests of 5 species in 2000 (Table 10). Nest searches were time consuming. In 1997, I averaged 1 nest per 7 human-hours (including non-cavity nesters) (unpublished data). Despite increasing search time in 2000, I found only a total of 29 cavity-nesting bird nests (n = 46 for both years). Sample size (both years) was 17 nests for western bluebird, 14 nests for mountain chickadee, and 11 nests for white-breasted nuthatch.

Mountain chickadees selected live Gambel oak nest trees with average drc >29 cm and height >7 m. Mountain chickadees used both natural and excavated cavities but appeared to select complex vertical structure (multilayered canopy in nest clump) over simple structure. Clump area varied but most nest trees were live with some evidence of decay (Table 11).

Nest trees selected by white-breasted nuthatches averaged >34 cm diameter at root collar (drc) and >8 m in height. I found nests only in natural cavities. White-breasted nuthatches selected live trees with some evidence of decay, and nest height was >3.5 m (Table 11).

Western bluebirds selected natural or excavated cavities in live trees with some decay and clumps with simple vertical structure and low clump density (e.g., open areas around nest tree). Nest trees averaged >29 cm drc and >6 m tall. Average nest height was >3 m (Table 11). For species with larger home ranges and/or less frequently encountered ($n \leq 2$), I described nests found (hairy woodpecker, northern flicker, pygmy nuthatch) (Table 11).

Bats

Community Comparison

I captured 429 bats representing 12 species in ponderosa pine forest (Table 12). I captured 412 bats representing 14 species in the ponderosa pine-Gambel oak forest. All species captured at pine sites were also captured at pine-oak sites. Netting effort was 1186 hr-m^2 in the pine-oak forest and 1176 hr-m^2 in the pine forest. The long-legged myotis (*Myotis volans*), fringed myotis (*Myotis thysanodes*), Mexican free-tailed bat (*Tadarida brasiliensis*), and hoary bat (*Lasiurus cinereus*) had a higher capture rate in pine sites than in pine-oak sites (Table 12). Southwestern myotis (*Myotis auriculus*), pallid bat (*Antrozous pallidus*), and silver-haired bat (*Lasionycteris noctivagans*) were captured more often in pine-oak than in pine sites. The long-eared myotis (*Myotis evotis*), big brown bat (*Eptesicus fuscus*), and Arizona myotis (*Myotis occultus*) were captured equally in both types of forest. The big brown bat and Arizona myotis had the highest number of captures over both forest cover types.

Anabats

Over 15 nights, I recorded 726 bat call sequences. I classified 714 sequences as passes and 12 as feeding buzzes. I categorized 258 sequences as Myotis species, 364 as non-Myotis species and 104 as undecided fragmented calls. I did not detect a difference in bat activity between ponderosa pine and ponderosa pine-Gambel oak forests. However, activity differed within the ponderosa pine-Gambel oak forest. Non-Myotis calls were detected more often with lower canopy detectors in the ponderosa pine-Gambel oak forest than ground detectors. I did not detect a difference in Myotis calls between ground and canopy detectors in either forest type. Bat activity was greatest during the first hour after sunset (20:00-21:00) and declined thereafter. In the 2 types of forest, bat activity appeared to differ at different heights above the ground as bats commuted from roosting habitat to foraging habitat. Detectors placed at more than 1 height should be used to adequately sample non-Myotis species. Although I did not detect a difference in Myotis calls at the 2 heights, examining echolocation calls at the species level instead of the group level might show differences between the 2 heights which can not been seen from this study (Bernardos 2001) (Table 15).

Anabat and Mist Netting Comparison

I compared mist netting and Anabat survey results for 3 water tanks: Jones, Mudspring, and Kelly235. At these 3 water sources, I captured a total of 109 bats representing 11 species (Table 16) (Jones, 28 bats, 9 species; Kelly235, 21 bats, 8 species; and Mudspring, 60 bats, 9 species). Ten bats escaped before being identified. Hours spent mist netting ranged from 120 min to 165 min.

Anabats recorded between 32 to 51 minutes of data. I identified 11 species from the recorded bat calls (Table 16). I captured 1 species (*Myotis californicus*) that was not identified using the Anabat technique. Conversely, *Myotis ciliolabrum* and *Lasionycteris noctivagans* echolocation calls were recorded, but were not captured in mist nets in 1 instance. A total of 202 and 134 call sequences were classified as undetermined fragments and Myotis species group respectively. Two species, *Lasiurus cinereus* and *Eptesicus fuscus* were recorded being active around the water source an hour or more before they were captured.

I used a Jaccard coefficient (Brower et al. 1990) to compare bat species captured between mist-netting and tower Anabats and mist netting and ground Anabats. Jaccard coefficients ranged from 0.5 to 0.89 (□ = 0.69), indicating approximately two-thirds of bat species were identified using both techniques (mist netting and Anabat) (Table 16).

Southwestern myotis (Myotis auriculus) Roost Sites

I tracked 15 of 18 southwestern myotis females (1 transmitter failed and 2 radio-tagged females could not be located due to signal bounce from surrounding canyon walls). I tracked all 4 males. I located 39 maternity roosts. Thirty-four of the maternity roosts were located in Gambel oak trees (10 roosts used by 5 females in 1999, 24 roosts used by 9 females in 2000); 5 maternity roosts (1 female in 1999) were located in ponderosa pine snags (Tables 13 and 14).

Most (85%) Gambel oak roosts used by female southwestern myotis were live trees with decay present. Five oak roosts were snags (decay class 3 or 4). Gambel oak roosts were large (average 46 cm drc, range 26 to 70 cm drc), tall (average 11 m tall, range 6 to 18 m) trees with a high percentage of bark remaining (Table 18). Oak maternity roosts were found mainly on southwestern- to western-facing slopes. Southwestern myotis females used natural cavities (n = 10) caused by branch scars and 1 excavated cavity. Only once were females found exiting from underneath loose bark. Mean cavity entrance height was 6.2 m ± 1.0 SE (range = 1.7 – 12.5). Number of bats observed exiting from Gambel oak roosts ranged from 0 to 43 bats (Bernardos 2001).

One female southwestern myotis used 5 ponderosa pine snags with decay classes ranging from 2 to 4. Pine snag roosts had a mean dbh and height of 82.5 cm ± 5 SE (range: 71.7 to 95.5) cm and 25.4 m ± 1 SE (range: 23.4 to 27.4) m, respectively. Percent bark varied from 1 to 95%. Roosts were found on the same western facing slope (Bernardos 2001).

Male roosts were located in 8 Gambel oak trees, 1 ponderosa pine snag, 1 ponderosa pine stump, and 1 fallen pine snag. Males used from 1 to 6 roosts and stayed at each roost for 1 to 4 days. Two males each returned to 1 previously used roost during the time they were tracked. Mean distance between roosts was 379 m ± 66 SE (range: 50 to 562). Gambel oak trees used by males were live trees, decay class 2 (only 1 snag, decay class 5, was used) with mean drc of 30.1 cm ± 6.7 SE (range: 11.5 to 65.3) and mean height of 8.5 m ± 2.3 SE (range: 3 to 18.8). The pine snag roost had dbh of 75 cm and height of 8.8 m. One male was located in the upright branch of a fallen ponderosa pine snag. Diameter of the branch was 16.4 cm and the branch was 3.3 m high. Another male was located behind bark of a 1 m tall, 26 cm diameter ponderosa pine stump (Bernardos 2001).

The habitat relationships model that best described female southwestern myotis habitat use included tree height and density of potential roost trees (potential roost trees were similar size and decay condition to active roosts I located, thus presumed available for southwestern myotis to use as roost sites). This model had the lowest ΔAIC and accurately classified 75% of roosts and 69% of random trees. Gambel oak roosts were taller than random trees and had a higher density of potential roost trees surrounding them than did random trees (Bernardos 2001).

Discussion

Gambel Oak

Kaibab and Coconino National Forest Inventory Data

Gambel oak was distributed in an uneven-aged distribution, dominated by smaller size classes (< 5 cm dbh). There were no measured Gambel oak trees in large size classes (>52.5 cm dbh for Kaibab National Forest; >82.5 cm dbh for Coconino National Forest). Based on the data I received, it appeared that the Coconino National Forest had more Gambel oak in large size classes, possibly due to the location along the Mogollon Rim where Gambel oak is widely distributed.

The uneven-aged distribution of Gambel oak and scarcity of large diameter trees was similar to the distribution that I found on the transects I placed on the Coconino National Forest. However, I was able to develop a more detailed description (e.g., effects of grazing, presence of excavated and natural cavities) of Gambel oak on the small-scale sites where I placed transects.

Coconino National Forest Transects

I found Gambel oak stems to be distributed in an uneven-aged distribution, dominated by stems in small size classes (<5 cm drc). These small trees may actually be quite old; small trees often are grazed by elk, mule deer, and livestock (cattle and sheep) and may represent suppressed growing stock. Growth potential for small Gambel oak is unknown.

I found few Gambel oak that were adequate size (>30 cm drc) for roosting by southwestern myotis females or nesting by cavity-nesting birds. Most Gambel oak with natural or excavated cavities were live trees with some evidence of decay, not snags. I encountered few snags on my transects. I found 33 Gambel oak trees ≥50 cm drc but I found cavities in only 23. Secondary cavity-nesting species that use Gambel oak may not have adequate nest/roost sites. Rick Miller (1993, unpublished report) found an average of 4.7 cavities in oaks with diameters >50 cm. He found only 2 trees per hectare of this size class. Although I could not quantify Gambel oak density from line transect data, my index of abundance for Gambel oak >50 cm drc was 1 tree per transect. Number of cavities averaged 1.8 per Gambel oak ≥50 cm (this included both excavated and natural cavities). The cavity density in large oaks was lower in my study than in Miller's (1993). The 33 Gambel oak trees ≥50 cm drc in my study represented only 0.1% of all Gambel oaks that I measured. Large Gambel oak with cavities represent a scarce resource.

Many of the cavities I found in Gambel oak were in clumps with simple vertical structure (1 canopy layer). This may indicate grazing occurred in the past (ungulates simplify structure of clumps by removing layers that are close to the ground) or that the trees in the clump originated at the same time (same age).

Stump location did not appear to be related to road location. Stumps were found on all parts of transects (0 to 499 m from road, average distance 236 m). Because much of the area is relatively flat ground and easily accessible by vehicles even 500 m from road, it was easy to harvest Gambel oak within 500 m of a road. In some locations, it may have been desirable to conceal cutting (if this occurred during the time period that it has been against Coconino National Forest policy to harvest standing Gambel oak) and fuelwood cutters may have chosen to move farther from the road edge. Some stumps appeared weathered and may have been cut prior to policy prohibiting cutting; however, we did see evidence of recent harvest at on or near many transects. Cut stump size averaged 21 cm drc (range 7 to 60 cm drc). Most of the cavity-nesting birds and bats in this study used >30 cm drc trees. I found an average of 8 cut stumps per transect. The average number Gambel oak trees >30 cm drc per transect averaged 7, so if these larger trees were targeted for fuelwood, many of the trees with wildlife value would be quickly removed.

Birds

Foraging

Mountain chickadees and white-breasted nuthatches foraged in oak clumps that were taller, larger diameter, and structurally more complex than randomly selected oak clumps. Dark-eyed juncos foraged in oak clumps with trees of larger diameter, large crown areas, and that were structurally more complex than randomly selected oak clumps. Protecting clumps with complex crown structure will provide foraging habitat for these bird species.

Nesting

Mountain chickadees used more natural than excavated cavities (10 natural, 4 excavated). However, I found more natural cavities available than excavated cavities, so mountain chickadees may be selecting cavity type in proportion to availability. Mountain chickadees were more often found in clumps with complex structure than simple structure and clumps were mixed size classes with high density of stems.

The western bluebirds I found used 6 natural and 11 excavated cavities. Nests were more often found in clumps of oak that were of simple structure than complex structure. Western bluebirds used about equal proportions of mixed size class, large, and medium sized clumps. They used clumps of high, medium, and low density. Western bluebirds are associated with open foraging opportunities, and clumps where I found nests were open.

Of the 11 white-breasted nuthatch nests I found in 1997 and 2000, all used natural cavities; I found no nests in excavated cavities. White-breasted nuthatch nests were found in Gambel oak clumps with simple structure more often than complex structure. Nests were found in clumps of mixed size classes. Nests occurred in clumps with high, medium, or low stem density clumps.

For all species, average drc of nest trees ranged from 29.7 to 72 cm drc. Protecting oak clumps with large diameter stems (>30 cm drc) should provide nesting habitat for cavity-nesting birds. However, each bird species appeared to use different types of Gambel oak clumps. Mountain chickadees selected clumps with more complex structure, possibly for foraging opportunities in combination with nest concealment. Western bluebirds, however, selected Gambel oak clumps that were more variable, but mostly in clumps with simple structure. White-breasted nuthatches also were more commonly found nesting in Gambel oak clumps with simple structure.

Because of small sample sizes, these data for nest trees should be considered as guidelines for nest tree sizes and types of oak clumps to protect for cavity nesters. Resources vary among years, and a nest that was good habitat 1 year may not be in other years. I found 1 nest for mountain chickadees in 1997, and 13 nests in 2000, despite similar nest searching effort. This could represent higher mountain chickadee population density in 2000 compared with 1997 and higher density could have affected nest tree selection. For example 1 mountain chickadee nest found in 2000 was in a 17.5 cm drc oak stump that was 1 m tall. The nest was 0.6 m above ground. Based on all other nests found, this did not appear to represent high quality habitat.

Based on the amount of variability I found in nest trees, a variety of Gambel oak clumps are needed to support cavity-nesting bird population. However, nest trees in this study averaged 30 cm drc, so larger trees provide more opportunities for nesting. Other species (e.g., red-faced warbler, Virginia's warbler) use dense clumps of small Gambel oak stems and nest on or near the ground.

Bats

Community Comparison

Bat communities were similar in species richness between ponderosa pine and ponderosa pine-Gambel oak forests, although relative abundance of some species differed. Morrell et al. (1999) found similar results across a broader range of elevations (2,262 to 2,621 m ponderosa pine, 2,018 to 2,276 m ponderosa pine-Gambel oak). Relative abundances of bats in pine and pine-oak did not appear to change during the 4-year period between this study and Morrell et al.'s (1999).

Differences in relative abundance of species between ponderosa pine and ponderosa pine-Gambel oak forests may be linked to geographic range and habitat requirements of bats. Pallid bat, southwestern myotis and silver-haired bat were all captured more often at pine-oak mist netting sites than at pine sites. Pallid bats, which were captured solely in pine-oak during this study, are considered a bat of desert scrub and scrub-grassland communities (Hoffmeister 1986:113). However, pallid bats previously have been captured in pine-oak forests (Jones 1965, Lutch 1996, Morrell et al. 1999) and these forests may represent fringe habitat for this species.

Ponderosa pine-Gambel oak forests may provide different foraging opportunities (e.g., insect species present, insect biomass, forest structure) for certain bat species (e.g., foliage-gleaning species such as southwestern myotis) than ponderosa pine forests. Ponderosa pine-Gambel oak forests also may provide more opportunities for cavity-roosting bats. Southwestern myotis in this study were found roosting in cavities of Gambel oak. Pallid bats were found roosting in cavities of Arizona white oak (*Quercus* *arizonica*) in the Tonto National Forest in central Arizona (Lutch 1996). Pallid bats may use Gambel oak when it is available.

Anabats

Activity did not differ between forest types. I do suggest caution in interpreting these results, since I only sampled a small portion of the actual forest. Furthermore, I used number of bat passes to represent bat activity. A problem with echolocation recording is that the researcher cannot distinguish which calls were recorded from multiple bats or an individual bat (Kunz and Brock 1975). However, use of bat passes, whether representing many bats or an individual bat does create a relative index of activity (Kalcounis et al. 1999).

Anabat and Mist Netting Comparison

The 2 techniques performed similarly with the exception of the Kelly235 Tower Anabat, which failed to produce the same number of species. However, since many calls were unidentifiable some species could have been underrepresented. I suggest caution with the interpretation of these results. A major limitation in the use of ultrasonic detectors is the difficulty in identifying species-specific bats calls (O'Farrell et al. 1999). Frequently, the data recorded is of poor quality, the library of calls is not representative of the species, or the researcher is unable to identify many of the calls (O'Farrell et al. 1999). Although I feel I identified all calls to the best of our ability some calls could have been misidentified especially with species that produce similar looking calls such as *Myotis auriculus* and *Myotis evotis* or certain calls of *Eptesicus fuscus* and *Lasionycteris noctivagans.*

One advantage in using echolocation detectors is the ability to identify certain species that are physically similar and difficult to identify in the hand. In this study, I captured what I identified as a *Myotis californicus*. Around the same time period the Anabat detector recorded a *Myotis ciliolabrum.* These 2 bats are very difficult to identify in the hand, but have very different looking echolocation calls. Since the time frame is so close, I hypothesize that I really captured a *Myotis ciliolabrum* and misidentified it as a *Myotis californicus*. This is a decision that could not have been made without the Anabat data.

Another advantage of echolocation detectors is the monitoring of bat activity. With mist netting the researcher receives a narrow view of when certain bat species are active based on capture data. Realistically, I am only capturing bats that are flying low for water. However, with echolocation detectors the researcher is able to monitor bats in a wider area around the water source. In this study, I captured *Eptesicus fuscus* and *Lasiurus cinereus* near 21:00 or after. I recorded echolocation calls of both species before we actually started capturing any bats in the nets just after 20:00. This suggests that both species are active near the water source for almost an hour before they come in for water. However, echolocation detectors can not be used to determine how many individual bats are active in an area since the researcher can not distinguish which calls were recorded from multiple bats or an individual bat (Kunz and Brock, 1975).

In this study, I used passive echolocation monitoring system. Calls were recorded onto tapes and then transferred to a computer. Data could have been distorted during this process. Likewise, although I mist netted for more than 2 hours, Anabat detector tapes quickly filled up and only recorded up to an hour's worth of activity. I suggest that active monitoring should be done when possible is place of the passive system. Active monitoring requires an Anabat detector linked to a ZCAIM and computer and one person to run the equipment. The operator can monitor bat calls in real time and discard fragmented calls. The operator can also position the Anabat toward flying bats to maximize the number and quality of the calls recorded.

Echolocation detectors can sample areas where mist netting of bats is not effective (e.g., open areas, within forests [away from water], and over large water bodies). However, mist netting provides important biological information and, in most cases, definite identification of species present (e.g., it is sometimes difficult to distinguish between *Myotis ciliolabrum* and *Myotis californicus* in the hand). Depending on research objectives, I feel both methods should be used to create a complete picture of bat activity and species presence when possible.

Southwestern Myotis (Myotis auriculus) Roost Sites

Southwestern myotis females used Gambel oak trees as maternity roosts with the exception of 1 southwestern myotis that used ponderosa pine snags. Males also roosted more often in Gambel oak trees, but appeared more opportunistic in selection of roosts (e.g. ponderosa pine stump and fallen ponderosa pine tree). Females and males both used live but decaying Gambel oak trees with cavities. However, males selected smaller diameter trees than females, 75% of male Gambel oak roost trees were <26 cm drc whereas 94% of female roosts were >33 cm drc. Males roosted alone in small cracks or in cavities that were large enough for only 1 bat. Females roosted with other bats in cavities that appeared to be larger than those used by males.

Female southwestern myotis used tall, large diameter, live Gambel oak trees with a high percentage of bark remaining, but with some decay. Bats used natural cavities whose entrances were created by decaying branch scars. Habitat modeling showed that tree height and density of potential roost trees more accurately distinguished between roost and random trees. Further, Gambel oak roosts were taller than random trees and had a higher density of potential roost trees surrounding them than random trees. These findings support previous studies that showed that bat roost trees tended to be taller, have larger diameters and were closer to other available trees than random trees (Campbell et al. 1996, Sasse and Pekins 1996, Vonhof and Barclay 1996, Brigham et al. 1997, Betts 1998, Rabe et al. 1998).

Gambel oak naturally produces many cavities of various sizes within the limbs and bole of the tree. Cavities are caused most often by heart rot fungus (*Polyporus dryophilus*), which is common in Arizona (Kruse 1992). Size of a tree may limit cavity size and in turn limit the size of a bat maternity colony (Vonhof and Barclay 1996). Large, live trees with some decay (decay class 2), but with a large percentage of bark remaining would have more solid wood present and thus have greater insulating value (Betts 1998). Cavities in taller trees might receive more solar radiation during part of the day. These factors (size of cavity, amount of solar radiation received, and the insulating value of the tree) could greatly affect thermoregulatory energy costs of females and their offspring.

Conclusions

Past management of Gambel oak has focused on control and removal of this species, since it was considered a pest by the timber industry and people who graze livestock (Harper et al. 1985, Harrington 1985, Clary and Tiedemann 1992). The importance of Gambel oak as a resource for wildlife has been discussed since the late 1940s. Early management recommendations for Gambel oak suggested only leaving oaks <38 cm dbh with more than 80% live tops as a reasonable compromise to preserve wildlife habitat (McCulloch et al. 1965). Later management recommendations added the need to preserve "old, decadent oaks" that showed sign of den use (Reynolds et al. 1970, Neff et al. 1979).

Protecting oak clumps with large diameter individuals (>30 cm drc) and complex crown structure will provide foraging and nesting habitat for many cavity-nesting bird species and for southwestern myotis. However, some birds nest in large Gambel oak but in more open clumps with simple crown structure, so a variety of Gambel oak are needed to supply habitat for all species.

Large Gambel oak trees should be retained for southwestern myotis, but also for other vertebrate species that may benefit from cavities. Large Gambel oak trees can be lost by fire, windthrow, branch and bole breakage that exposes the cavities, or fuelwood cutting. Fuelwood cutting is of particular concern since Gambel oak is a popular fuelwood that possesses superior heat-producing qualities and is quite accessible to populated areas (Wagstaff 1984). Although the National Forests in northern Arizona have regulations against cutting standing Gambel oak trees, cutting of trees occurs. Fuelwood cutters tend to target mature trees; often abandoning cut trees if they are hollow (Kruse 1992, and personal observation). I found signs of Gambel oak harvest near all roosting and nesting areas. Gambel oak has a very slow volume growth rate of about 2% each year (Barger and Ffolliott 1972). Therefore, replacement of large trees will occur slowly. This replacement rate of large Gambel oak may be too slow for maintaining roosting and nesting habitat.

I recommend that forest managers consider Gambel oak/wildlife relationships when proposing prescribed burns, harvesting, or restoration treatments. Destruction of known bat roosts or habitat should be avoided. I suggest that large oak trees, >30 cm drc need to be protected whether or not they show signs of wildlife use. However, all Gambel oak growth forms, brushy, sapling pole, mature stages, should be considered when managing for wildlife. These growth forms are a source of food, cover, den sites, nest sites, and foraging substrates for many wildlife species. Likewise, management and protection of the smaller size classes will promote replacement of large Gambel oaks in the future.

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Project Deliverables

Initial (and primary) funding support was provided by the AZGF Heritage Fund ($40,250), Northern Arizona University (NAU) ($48,343), and USDA Forest Service ($1125). I used this to obtain additional funding from NAU Organized Research ($11,000), Bat Conservation International ($3661), and USDA Forest Service ($2000 plus $306 equipment loan). Total project cost was $106,685; Heritage Funds accounted for 38% of the project cost.

Completed:
- Presentations:
    - Debra Bernardos, Carol L. Chambers, and Michael J. Rabe, *Use of ponderosa pine/Gambel oak forests by bats in Northern Arizona,* Arizona/New Mexico Chapters of The Wildlife Society 33rd Joint Annual Meeting (February 2000), Presentation
    - Debra Bernardos and Carol L. Chambers, *Use of ponderosa pine-Gambel oak forests by bats in northern Arizona,* The Wildlife Society 8th Annual Conference (September 2000), Presentation
- Graduate Research Project: Debra Bernardos completed her Masters thesis in May 2001. A copy of the thesis is attached with this report.
- Undergraduate Student Project: John Pieper, Effect of roads on Gambel oak habitat availability (completed 2000)

In progress:
- Debra Bernardos is completing the final edits on a manuscript to be submitted to Journal of Wildlife Management. This manuscript will compare bats communities in ponderosa pine with ponderosa pine/Gambel oak and describe southwestern myotis roost sites.
- Debra is preparing a second manuscript comparing anabat and mist netting techniques that will be submitted to Southwestern Naturalist.
- I am collaborating with Steve Rosenstock (Arizona Game and Fish Department, Research Branch) on a third manuscript on wildlife use of Gambel oak. We will (1) describe oak availability in northern Arizona, (2) describe wildlife use of Gambel oak, and (3) include diurnal breeding bird use of Gambel oak for foraging and nesting. We expect to submit this manuscript to Forest Ecology and Management.

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Table 1. Wildlife associated with Gambel oak in the southwestern United States. Wildlife – Gambel oak relationships have been classified by oak growth form (Shrub-like, drc <10cm; Small Tree, drc 10 - 20 cm; Mature Tree, drc >20 cm) and exact use (F = foraging, C = cover, N = nesting, and R = Roosting). A general association classification has been provided for species that are observed more often in Gambel oak habitats, but exact habitat use is unknown.

Species	**Shrub-Like**				**Small Tree**				**Mature Tree**				**General**	
MAMMALS	**F**	**C**	**N**	**R**	**F**	**C**	**N**	**R**	**F**	**C**	**N**	**R**	**Assoc.**	**Source Information**
Southwestern Myotis[1]												X		Bernardos 2001
Big Brown Bat												X		Lutch 1996
Long-eared Myotis												X		Rabe et al. 1998
Pallid Bat[1]													X	Bernardos 2001
Silver-haired Bat[1]													X	Bernardos 2001
Mule Deer	X	X				X								Patton 1968, Neff 1974
Coues White-tailed Deer[2]									X					Smith and Anthony 1992
Rocky Mountain Elk	X													Kufeld 1973
Abert Squirrel [2]									X		X			Patton 1975, Keith 1965
Red Squirrel											X			Patton 1975
Javelina[2]									X					Knipe 1957
Cottontail	X	X												Costa et al. 1976
Porcupine					X				X			X		Strickland et al. 1995
Piñon Mouse[1]												X		Chambers pers. obs.
BIRDS														
Virginia's Warbler[1]			X						X					Rosenstock 1998
Red-Faced Warbler			X		X				X					Rosenstock 1998
Grace's Warbler					X				X					Rosenstock 1998
Yellow-Rumped Warbler					X				X					Rosenstock 1998
Western Tanager[1]					X				X					Rosenstock 1998
Mountain Chickadee[1]	X				X		X		X		X			Rosenstock 1998
White-Breasted Nuthatch[1]					X				X		X			Cunningham et al. 1980

Western Bluebird[1]	X					X		X			X		X				This report
Black-headed Grosbeak											X						Rosenstock 1998
Dark-eyed Junco						X					X						This Report
Plumbeous Vireo[1]						X					X						Rosenstock 1998
Northern Flicker[1]													X				This report
Pygmy Nuthatch													X				Cunningham et al. 1980
Merriam's Wild Turkey[2]		X					X				X	X					Wakeling and Rogers 1995
Band-tailed pigeon[2]											X						Nefe 1947
Mexican Spotted Owl													X				Ganey et al. 1992
Cordilleran Flycatcher																X	Rosenstock 1998
Acorn woodpecker																X	Rosenstock 1998
Warbling Vireo																X	Rosenstock 1998

[1]Data can be found in this report.
[2] Forage on acorns produced by mature trees.

Table 2. Location of study sites for bird foraging observations and nest searches, Coconino National Forest, northern Arizona, 1997 and 2000. Sites used in 1997 were 24 ha; sites used in 2000 were 18 ha.

Code	Location[1]	Township	Range	Section
1997 Sites				
CM3	CNF, 235J Rd (Mountainaire)	19N	7E	3
CM5	CNF, 225C Rd	18N	8E	30
CM7	CNF, 225 Rd (Rocky Top)	17N	8E	16
CM9	CNF, 80 Rd (Rocky Park Rd)	17N	8E	19
CM10	CNF, 132 Rd (Lake # 1)	19N	7E	1, 12
CM11	CNF, 132 Rd (Antelope Park)	19N	8E	33
SF1	NAU Forest (Budweiser Tank)	21N	6E	21
CN2	Camp Navajo	21N	5E	18
2000 Sites				
C235	CNF, 235 Rd	19N	7E	3, 4, 9, 10
C235/236	CNF, junction 235 and 236 Rds	19N	7E	15
C236A	CNF, 236A Rd	19N	7E	22
C700	CNF, 700 Rd	20N	7E	32

[1]CNF = Coconino National Forest, Mormon Lake Ranger District; CN = Camp Navajo, SF = NAU School Forest.

Table 3. Location of 41 500-m long transects used to estimate Gambel oak availability, Coconino National Forest (CNF) and Arizona state lands (SF), July 1998 – May 1999. Transects were randomly started 50 m from road and placed perpendicular to the road.

Code	Location[1]	#Transects	Township	Range	Section
80	CNF, 80 Road	1	17N	8E	30 NW
132A-L	CNF, 132 Road	12	19N	8E	33 SW
211	CNF, 211 Road	2	15N	10E	31 SW
211B	CNF, 211B Road	2	15N	9E	36 NW
226	CNF, 226 Road	1	18N	8E	31 S
226C	CNF, 226C Road	1	18N	8E	30 SE
235	CNF, 235 Road	10	19N	7E	4, 9
235J	CNF, 235J Road	1	19N	7E	3
239	CNF, 239 Road	1	17N	8E	30 NW
700	CNF, 700 Road	6	20N	7E	5, 8, 32
SF	SF, Budweiser Tank	4	21N	6E	21

Table 4. Characteristics of Gambel oak trees and clumps measured on each transect.

Variable	Acronym	Description
Tag Number	TAG#	Unique number for each oak clump.
Date	DATE	Date clump data were collected (MM/DD/YY).
Stand Number	ST	Stand location as identified by Forest Service road location. Coded variable (132A, 80, SF, etc.).
Observer	OBS	Initials of observer.
Transect Number	T	Transect number (A through L).
Station	STN	Number of nearest station if transects overlap bird search locations (1-17). Stations were placed every 50-m on each transect to help locate bird use of Gambel oak.
Direction	DIR	Direction from nearest station.
Distance	DIST	Distance from nearest station.
Live Stems	LIVESTEM	Number of live oak stems and their diameter at root collar (cm).
Dead Stems	DEADSTEM	Number of oak snags and their diameter at root collar (cm).
Crown Cover	CROWN	Radius (m) and height (m) of each tree crown.
Stumps	STUMP	Number of stumps and their diameter at root collar (cm).
Cavities	CAVITIES	Number of cavities per live or dead oak stem. Coded variable: #Nat=number of natural cavities; #Ex=number of excavated cavities.

Table 5. Nest Protocol: Information collected for bird nest sites.

Variable	Acronym	Description
Tag Number	TAG#	Unique number for each observation will be written on aluminum tag and attached to tree. The number will be Julian date (1-365) followed by the observation number for that day. (e.g., for the 2nd nest found on June 1, the tag number would read: 152-02). Date (MM/DD/YY) will also be written on tag.
Date	DATE	Date nest was found (MM/DD/YY).
Stand Number	ST	Stand location. Coded variable (CM1, CM3, CM4, CM5, etc.).
Observer	OBS	Initials of observer, first name then last.
Species	BIRD	4 letter acronym for bird species.
Transect Number	T	Transect number (A through G).
Station	STN	Number of nearest station (1-17). Stations were placed every 50-m on each transect to help locate bird use of Gambel oak.
Direction	DIR	Direction from nearest station.
Distance	DIST	Distance from nearest station.
Aspect	ASP	Azimuth (degrees) of nest location (from tree facing out).
Cavity Type	CAV	Cavity type: Excavated or naturally-formed. Coded variable (E=Excavated, N=Natural).
Tree Species	TRSP	Tree species where nest was found. Coded variable (PIPO = ponderosa pine; QUGA = Gambel oak).
Tree Diameter	DRC	Diameter at root crown (cm) for Gambel oak; diameter at breast height (1.4 m) (cm) for ponderosa pine.
Tree Height	HT	Height of tree (m) measured with a clinometer.
Vertical Structure	VSTR	Structure of canopy layers. Coded variable: S=Simple, predominantly single-layer canopy, difference between average height of tallest and shortest trees is $\leq$ 3m. C= Complex, multi-layer canopy; difference between average height of tallest and shortest trees is > 3m.
Clump Tree Size	TDRC	Average diameter of trees in clump. Coded variable: S=Small, average diameter at root collar of oak trees in clump is < 20 cm (< 8 in). M=Medium, average diameter at root collar of oak trees in clump is 20 to 38 cm (8 to 15 in). L=Large, average diameter at root collar of oak trees in clump is > 38 cm (> 15 in). X=Mixed, combination of categories (small, medium, and/or large) listed above.

Table 5. Continued.

Variable	Acronym	Description
Clump Density	CDEN	Density of clump. Coded variable: L=low density, ≤ 3 stems; M=medium density, 4-10 stems; H=high density, >10 stems.
Clump Size	CAREA1	Ground coverage of clump measured along longest axis (m).
Clump Size	CAREA2	Ground coverage of clump measured along axis perpendicular to longest axis (m).
Decay	DECAY	Decay classification (1-7) (see Table 5 for definitions)
Height	NHT	Height of bird nest in tree (m).
Eggs/Nestlings	#EGG	Number of eggs or nestlings in nest.

Table 6. Decay classification system used to categorize living Gambel oak trees and Gambel oak snags.

Decay class	Description
1	Live, healthy.
2a	Live, declining, dead side limbs, top alive and intact.
2b	Live, declining, dead top.
3	Dead with top and most of all limbs intact, tight bark, base solid.
4	Dead with broken top and/or missing limbs, most bark tight, base solid.
5	Dead with broken top, most of limbs missing, loose bark, > 50% bark remaining, some decay at base.
6	Dead with broken top, most limbs missing, few stubs present, loose bark, < 50% bark remaining, sapwood decay.
7	Little or no bark remaining, advanced sapwood decay, few/no stubs present.

Table 7. Decay classification system used to categorize ponderosa pines. Modified from Brigham et al. 1997.

Decay class	Description
1	Live, healthy; no decay; no obvious defects
2	Live, usually unhealthy; obvious defects such as broken top, cracks, or hollows present
3	Recently dead; dead needles still present, little decay; heartwood hard
4	Dead; no needles and few twigs present; top often broken; <50% of branches lost; bark loose; heartwood hard; sapwood spongy
5	Dead; most branches and bark lost; top broken; heartwood spongy; sapwood soft
6	Dead; no branches or bark; broken off along mid-trunk; sapwood sloughing from upper bole; heartwood soft
7	Dead; stubs >3 m in height; heartwood soft; extensive internal decay; outer shell may be hard
8	Dead; stubs <3 m in height; heartwood soft; extensive internal decay; outer shell may be soft
9	Debris; downed stubs or stumps; extensive decay

Table 8. Capture locations for Myotis auriculus (MYAU) that were radiotracked to determine roost locations. Captures are listed by date of capture from earliest to last capture.

Tank Name	Location/Quad	Date	Species	Gender	Weight (g)	Transmitter Frequency
T-Six 2	Mormon Mountain	09-Jul-99	MYAU	Female	7.50	149.658
Coulter	Mountainaire	13-Jul-99	MYAU	Female	8.00	149.700
Coulter	Mountainaire	13-Jul-99	MYAU	Female	7.80	149.641
Jones	Mormon Mountain	16-Jul-99	MYAU	Female	8.00	149.540
Coulter	Mountainaire	22-Jul-99	MYAU	Female	7.80	149.581
Coulter	Mountainaire	22-Jul-99	MYAU	Female	7.80	149.559
Scooter	Mormon Mountain	22-Jun-00	MYAU	Female	7.50	149.760
VA	Dutton Hill	27-Jun-00	MYAU	Female		149.778
VA	Dutton Hill	27-Jun-00	MYAU	Female	8.00	149.601
Coulter	Mountainaire	29-Jun-00	MYAU	Female	7.50	149.739
Coulter	Mountainaire	29-Jun-00	MYAU	Female	7.50	149.622
Jones	Mormon Mountain	03-Jul-00	MYAU	Female	7.50	149.980
Cowboy Junior	Mormon Mountain	05-Jul-00	MYAU	Female	8.00	149.803
Lost Lake	Mormon Mountain	06-Jul-00	MYAU	Female	7.70	149.824
Oak Grove	Stoneman Lake	12-Jul-00	MYAU	Female	7.30	149.839
T-6 II	Mormon Mountain	13-Jul-00	MYAU	Female	7.60	149.860
Kelly	Stoneman Lake	16-Jul-00	MYAU	Female	7.30	149.879
Pen	Mormon Mountain	18-Jul-00	MYAU	Male	7.00	149.902
Gash	Hutch Mountain	20-Jul-00	MYAU	Male		150.083
Gash	Hutch Mountain	20-Jul-00	MYAU	Female	7.00	149.960
Norris	Dutton Hill	31-Jul-00	MYAU	Male	7.30	150.234

Table 9. Average number of Gambel oak stems on 500-m transects, Coconino National Forest and Arizona state lands, July 1998 – May 1999. Locations included 1 to 12 transects spaced 50-m apart.

		Stem size class (cm)										
Location	#Transects	0-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40	40-45	45-50	>50
80	1	1564	124	61	35	18	10	7	3	4	2	1
132A-L	12	235.9	48.9	36.5	25.1	9.3	3.3	3.2	1.3	1.5	1.0	0.5
211	2	1083	15	35.5	19	5	1.5	1.5	0.5	1.5	2	3
211B	2	36.5	1	5	14.5	17	9	5.5	3	0	1	1.5
226	1	2321	40	10	4	5	4	5	6	1	0	1
226C	1	2975	62	48	20	9	6	3	6	1	0	2
235	10	1128.2	7.4	12.4	14.1	10.6	4.7	2.9	0.9	1.2	0.3	0.9
235J	1	216	5	21	13	4	3	2	3	0	0	0
239	1	4164	56	47	39	20	8	7	3	2	0	0
700	6	78.3	6.5	8.8	11.0	5.7	4.3	2.5	1.0	0.5	0.3	0.5
SF	4	34.3	11.5	15.0	19.3	8.5	4.8	1.8	1.5	0.5	1.0	0.5
Average		1257.8	34.3	27.3	19.5	10.2	5.3	3.8	2.7	1.2	0.7	1.0

Table 10. Average basal area (ft^2/ac) and standard error for ponderosa pine (PIPO) and Gambel oak (QUGA) for 50m-intervals on 500-m transects, Coconino National Forest and Arizona state lands, July 1998 – May 1999. Locations included 1 to 12 transects; for locations with only 1 transect, standard errors could not be calculated and are indicated by (.).

			Distance from road (m)									
Location	#Transects	Species	50	100	150	200	250	300	350	400	450	500
80	1	PIPO	270 (.)	20 (.)	20 (.)	20 (.)	20 (.)	60 (.)	170 (.)	0 (.)	0 (.)	0 (.)
		QUGA	0 (.)	80 (.)	20 (.)	0 (.)	70 (.)	0 (.)	30 (.)	60 (.)	20 (.)	10 (.)
132A-L	12	PIPO	63 (13)	83 (20)	96 (22)	98 (11)	92 (16)	92 (22)	78 (18)	62 (12)	109 (21)	62 (15)
		QUGA	7 (4)	7 (5)	5 (3)	42 (27)	27 (14)	20 (10)	30 (15)	10 (5)	32 (12)	7 (5)
211	2	PIPO	80 (60)	30 (10)	100 (10)	90 (10)	70 (40)	100 (50)	90 (90)	65 (55)	30 (10)	40 (40)
		QUGA	20 (20)	20 (20)	35 (25)	35 (35)	30 (30)	0 (0)	10 (10)	30 (10)	0 (0)	10 (10)
211B	2	PIPO	180 (120)	70 (10)	80 (20)	80 (60)	20 (20)	100 (0)	160 (140)	70 (50)	20 (20)	0 (0)
		QUGA	20 (20)	0 (0)	50 (50)	10 (10)	0 (0)	0 (0)	20 (0)	10 (10)	60 (60)	0 (0)
226	1	PIPO	30 (.)	90 (.)	110 (.)	180 (.)	60 (.)	120 (.)	170 (.)	80 (.)	230 (.)	30 (.)
		QUGA	0 (.)	0 (.)	10 (.)	20 (.)	50 (.)	0 (.)	30 (.)	90 (.)	0 (.)	0 (.)
226C	1	PIPO	50 (.)	100 (.)	0 (.)	200 (.)	70 (.)	110 (.)	260 (.)	50 (.)	170 (.)	90 (.)
		QUGA	0 (.)	50 (.)	0 (.)	0 (.)	0 (.)	0 (.)	0 (.)	0 (.)	20 (.)	20 (.)
235	10	PIPO	107 (18)	113 (28)	105 (26)	32 (7)	49 (12)	67 (12)	64 (11)	89 (15)	106 (26)	58 (19)
		QUGA	14 (10)	53 (29)	20 (12)	19 (9)	50 (17)	13 (6)	7 (3)	17 (17)	14 (7)	4 (4)
235J	1	PIPO	70 (.)	20 (.)	150 (.)	120 (.)	80 (.)	200 (.)	120 (.)	150 (.)	50 (.)	70 (.)
		QUGA	0 (.)	20 (.)	0 (.)	0 (.)	10 (.)	0 (.)	0 (.)	0 (.)	0 (.)	0 (.)
239	1	PIPO	20 (.)	0 (.)	0 (.)	20 (.)	40 (.)	70 (.)	80 (.)	60 (.)	20 (.)	100 (.)
		QUGA	0 (.)	20 (.)	180 (.)	140 (.)	30 (.)	0 (.)	0 (.)	0 (.)	30 (.)	0 (.)
700	6	PIPO	70 (20)	73 (17)	87 (8)	33 (11)	67 (23)	77 (27)	63 (20)	93 (21)	97 (26)	77 (23)
		QUGA	17 (17)	20 (14)	7 (7)	27 (12)	3 (3)	3 (3)	13 (10)	0 (0)	17 (13)	0 (0)
SF	4	PIPO	200 (45)	120 (14)	175 (24)	130 (13)	135 (35)	75 (34)	155 (21)	95 (24)	65 (26)	85 (39)
		QUGA	0 (0)	0 (0)	0 (0)	5 (5)	0 (0)	75 (68)	20 (14)	35 (22)	25 (25)	10 (6)

Table 11. List of birds observed nesting in or foraging on Gambel oak, May – July, 1997 and 2000, Coconino National Forest, Camp Navajo, Arizona state forest land. Birds are in descending order based on number of foraging observations. Cavity-nesting birds are shown in bold type.

Bird Species (common/scientific name)	Number of Nests Found 1997	Number of Nests Found 2000	Number of Foraging Observations 1997	Number of Foraging Observations 2000
Dark-eyed junco (*Junco hyemalis*)	3		45	10
Mountain chickadee (*Parus gambeli*)	**1**	**13**	43	24
White-breasted nuthatch (*Sitta carolinensis*)	**4**	**7**	36	15
Western bluebird (*Sialia mexicana*)	**11**	**6**	13	7
Plumbeous vireo (*Vireo plumbeus*)	1		12	5
Western wood-pewee (*Contopus sordidulus*)	1		9	4
Western tanager (*Piranga ludoviciana*)	0		7	8
Virginia's warbler (*Vermivora virginiae*)	0		4	1
Chipping sparrow (*Spizella passerina*)	0		4	0
Brown creeper (*Certhia americana*)	0		3	0
Grace's warbler (*Dendroica graciae*)	0		3	0
Red-faced warbler (*Cardellina rubrifrons*)	0		3	1
Hairy woodpecker (*Picoides villosus*)	**1**	**0**	3	3
Steller's jay (*Cyanocitta stelleri*)	0		3	0
Yellow-rumped warbler (*Dendroica coronata*)	0		2	4
Black-headed grosbeak (*Pheucticus melanocephalus*)	0		2	3
Northern flicker (*Colaptes auratus*)	**0**	**2**	2	0
Brown-headed cowbird (*Molothrus ater*)	0		1	0
Townsend's solitaire (*Myadestes townsendi*)	1		0	0
Wild turkey (*Meleagris gallopavo*)	0		0	1
American robin (*Turdus migratorius*)	0		0	1
Hermit thrush (*Catharus guttatus*)	0		0	2
Bushtit (*Psaltriparus minimus*)	0		0	1
Pygmy nuthatch (*Sitta pygmaea*)	**0**	**1**	--	3
Total observations (**total cavity nesters**)	23 (**17**)	29	195	93

Table 12. Description of nest trees used by cavity-nesting birds in Gambel oak, Coconino National Forest, May – July 1997 and 2000. Drc is diameter at root collar (cm), height is height of nest tree (m), CavType is type of cavity: N = naturally formed, E = excavated, Vert Struc is vertical structure of clump: C = complex (multilayered), S = simple (single foliage layer), Clump size is the average diameter of trees in nest tree clump: S = small, average diameter at root collar of oak trees in clump is < 20 cm, M = medium, average diameter at root collar of oak trees in clump is 20 to 38 cm, L = large, average diameter at root collar of oak trees in clump is > 38 cm, X = mixed, combination of categories (small, medium, and/or large). Clump density is coded as L = low density, $\leq$ 3 stems; M = medium density, 4-10 stems; H = high density, >10 stems; clump area is average ground coverage (m^2) of the clump. Decay is decay classification for Gambel oak (see Table 4), and nest height is average height of nest entrance (m).

Species		n	Drc	Height	CavType	Vert Struc	Clump Size	Clump Density	Clump Area	Decay	Nest Height
mountain	1997	1	33.3	10	0 N, 1 E	1 C, 0 S	0 X, 0 L, 0 M, 1 S	1 H, 0 M, 0 L	42.3	2	5.5
chickadee	2000	13	29.7	7.6	10 N, 3 E	9 C, 4 S	10 X, 0 L, 2 M, 1 S	10 H, 1 M, 2 L	122	2.3	3.1
white-breasted	1997	4	43.7	10.4	4 N, 0 E	2 C, 2 S	1 X, 1 L, 1 M, 1 S	1 H, 1 M, 2 L	54.3	2	4.5
nuthatch	2000	7	34.4	8.7	7 N, 0 E	2 C, 5 S	5 X, 1 L, 1 M, 0 S	2 H, 4 M, 1 L	71.8	1.9	3.5
western bluebird	1997	11	42	11.2	3 N, 8 E	3 C, 8 S	3 X, 5 L, 3 M, 0 S	1 H, 3 M, 7 L	64.3	1.8	4.3
	2000	6	29.9	6.8	3 N, 3 E	2 C, 4 S	4 X, 0 L, 2 M, 0 S	4 H, 2 M, 0 L	136.4	2.3	3.4
northern flicker	1997	0									
	2000	2	41.3	6.3	0 N, 2 E	0 C, 2 S	1 X, 1 L, 0 M, 0 S	0 H, 0 M, 2 L	48.4	2	3.5
hairy woodpecker	1997	1			0 N, 1 E	0 C, 1 S	0 X, 0 L, 1 M, 0 S	0 H, 0 M, 1 L		5	4
	2000	0									
pygmy nuthatch	1997	0									
	2000	1	72	14	0 N, 1 E	0 C, 1 S	0 X, 1 L, 0 M, 0 S	0 H, 0 M, 1 L	94.6	2	8

Table 13. Species (listed by forest site), number of bats captured, number of bats captured per netting effort (m^2-hr), and percent bat capture for bats captured by mist netting in ponderosa pine (pine) and ponderosa pine-Gambel oak (pine-oak) forests of northern Arizona, 1999. Net effort equals hours spent netting in 1 forest type x total area of net (m^2) used in that forest)/100. Percent capture was calculated by dividing the number of bats per net effort for each species captured in one forest type by the total number of captures per net effort of that species (Bernardos 2001).

Species	Pine		Pine-oak				
	Number captured	Number captured/net effort	Number captured	Number captured/net effort	Total number captured/net effort	Percent captured in pine	Percent captured in pine-oak
No difference							
Eptesicus fuscus	109	9.3	71	6.0	15.3	61	39
Myotis evotis	84	7.1	81	6.8	14.0	51	49
Myotis occultus	71	6.0	90	7.6	13.6	44	56
Pine-oak species							
Antrozous pallidus	0	0.0	19	1.6	1.6	0	100
Myotis auriculus	9	0.8	46	3.9	4.6	16	84
Lasionycteris noctivagans	6	0.5	32	2.7	3.2	16	84
Pine species							
Lasiurus cinereus	11	0.9	4	0.3	1.3	73	27
Myotis thysanodes	37	3.1	37	1.6	4.7	66	34
Myotis volans	73	6.2	16	1.3	7.6	82	18
Tadarida brasiliensis	20	1.7	4	0.3	2.0	83	17
Unknown							
Idionycteris phyllotis [a]	0	0.0	4	0.3	0.3	0	100
Myotis californicus [a]	3	0.3	1	0.1	0.3	75	25
Myotis ciliolabrum [a]	5	0.4	5	0.4	0.8	50	50
Myotis yumanensis [a]	1	0.1	2	0.2	0.3	34	66
Total	429		412				

[a] Insufficient sample size to be considered in comparison.

Table 14. Mean and 95% confidence intervals for bat passes recorded at 2 heights (ground = 1 m above ground, tower = 6 m above ground) with in ponderosa pine and ponderosa pine-Gambel oak forests in Coconino National Forest, Arizona, June and July 1999. Means and confidence intervals were calculated for log-transformed numbers and back-transformed for ease of interpretation.

	Ponderosa Pine			Ponderosa Pine-Gambel oak		
Detector type	X	Lower 95% CI	Upper 95% CI	X	Lower 95% CI	Upper 95% CI
Ground	8.5	4.0	18.2	6.4	3.6	11.3
Tower	10.9	5.2	22.7	12.3	10.2	14.9

Table 15. Bat species identified by capture through mist netting and echolocation detection at 3 earthen eater tanks in the Coconino National Forest in northern Arizona. M = mist netting, T = Tower Anabat, and G = Ground Anabat. Jaccard coefficients (a measure of community similarity) are comparisons between number of bat species captured by mist netting with tower anabat (T column) or ground anabat (G column).

	Jones				**Kelly235**				**Mudspring**		
Species	**M**	**T**	**G**		**M**	**T**	**G**		**M**	**T**	**G**
Antrozous pallidus	X	X	X		X						
Eptesicus fuscus	X	X	X		X	X	X		X	X	X
Lasiurus cinereus	X	X	X		X		X		X	X	X
Lasionycteris noctivagans							X		X	X	X
Myotis auriculus	X	X	X		X				X		
Myotis californicus	X										
Myotis ciliolabrum		X	X								
Myotis evotis	X	X	X		X	X	X		X	X	X
Myotis occultus	X	X	X		X	X	X		X	X	X
Myotis thysanodes	X	X	X		X		X		X		X
Myotis volans	X								X		X
Tadarida brasiliensis					X	X	X		X	X	X
Jaccard Coefficient		0.7	0.7			0.5	0.7			0.7	0.9

Table 16. Locations and legal descriptions ("legals" and UTM coordinates) for southwestern myotis (*Myotis auriculus*) roosts found July 1999 in Gambel oak (*Quercus gambelii*) or ponderosa pine (*Pinus ponderosa*), Coconino National Forest, Arizona. Tag # is the tag attached to each roost tree.

Tag #	Roost Type	Roost Description	Date of visit	Legals	UTM East	UTM North
192-01	maternity	Gambel oak	7/11/1999	Sensitive site-specific information contained in these columns. Contact Arizona Game and Fish Department, Heritage Data Management System, 602-789-3918.		
196-02	maternity	Gambel oak	7/15/1999			
196-01	bachelor	Gambel oak	7/15/1999			
197-01	bachelor	Ponderosa Pine	7/16/1999			
198-01	bachelor	Ponderosa Pine	7/17/1999			
199-01	bachelor	Gambel oak	7/18/1999			
198-02	maternity	Gambel oak	7/17/1999			
200-01	maternity	Gambel oak	7/19/1999			
200-02	maternity	Gambel oak	7/19/1999			
201-01	maternity	Gambel oak	7/20/1999			
201-02	maternity	Ponderosa Pine	7/20/1999			
202-01	maternity	Ponderosa Pine	7/21/1999			
202-02	bachelor	Gambel oak	7/21/1999			
203-01	bachelor	Gambel oak	7/22/1999			
203-02	maternity	Ponderosa Pine	7/22/1999			
204-01	maternity	Gambel oak	7/23/1999			
204-02	maternity	Ponderosa Pine	7/23/1999			
205-01	maternity	Ponderosa Pine	7/24/1999			
205-02	maternity	Gambel oak	7/24/1999			
209-01	maternity	Gambel oak	7/28/1999			
210-01	maternity	Gambel oak	7/29/1999			

Table 17. Locations and legal descriptions (“legals” and UTM coordinates) for southwestern myotis (*Myotis auriculus*) roosts found July 2000 in Gambel oak (*Quercus gambelii*) or ponderosa pine (*Pinus ponderosa*), Coconino National Forest, Arizona. Tag # is the tag attached to each roost tree. Exit count is the number of bats observed exiting the roost during 1 exit count conducted within 5 days of date of visit.

Tag #	Roost Type	Roost Description	Date of visit	Legals	UTM E	UTMN	Exit Count
623-01	Maternity	Gambel Oak	6/23/2000	Sensitive site-specific information contained in these columns. Contact Arizona Game and Fish Department, Heritage Data Management System, 602-789-3918.			39
626-01	Maternity	Gambel Oak	6/26/2000				
627-01	Maternity	Gambel Oak	6/27/2000				33
628-01	Maternity	Gambel Oak	6/28/2000				
630-01	Maternity	Gambel Oak	6/30/2000				
630-02	Maternity	Gambel Oak	6/30/2000				5
703-01	Maternity	Gambel Oak	7/3/2000				43
706-01	Maternity	Gambel Oak	7/6/2000				
706-02	Maternity	Gambel Oak	7/6/2000				26
713-01	Maternity	Gambel Oak	7/13/2000				
714-01	Maternity	Gambel Oak	7/14/2000				
715-01	Maternity	Gambel Oak	7/15/2000				
715-02	Maternity	Gambel Oak	7/15/2000				
716-01	Maternity	Gambel Oak	7/16/2000				
718-01	Maternity	Gambel Oak	7/18/2000				
718-02	Maternity	Gambel Oak	7/18/2000				36
719-01	Maternity	Gambel Oak	7/19/2000				
719-02	Maternity	Gambel Oak	7/19/2000				
719-03	Maternity	Gambel Oak	7/19/2000				
719-04	Bachelor	Gambel Oak	7/19/2000				43
721-01	Maternity	Gambel Oak	7/21/2000				
721-02	Bachelor	Gambel Oak	7/21/2000				
722-01	Bachelor	Gambel Oak	7/22/2000				

722-02	Maternity	Gambel Oak	7/22/2000				
722-03	Maternity	Gambel Oak	7/22/2000				
723-01	Maternity	Gambel Oak	7/23/2000				
724-01	Maternity	Gambel Oak	7/24/2000				
801-01	Bachelor	Ponderosa Pine Stump	8/1/2000				
802-01	Bachelor	Gambel Oak	8/2/2000				

Table 18. Means, standard errors, and ranges of Gambel oak trees and surrounding forest (0.1 ha circular plot) used by southwestern myotis as maternity roosts compared to randomly selected Gambel oak trees and surrounding forest (0.1 ha circular plot) in northern Arizona, 1999 and 2000. Gambel oak = QUGA, ponderosa pine = PIPO, potential roost Gambel oak tree (≥26 cm drc) = PTQ.

	Roost			Random		
Characteristics	$\bar{x}$	SE	Range	$\bar{x}$	SE	Range
Individual Tree						
Diameter at root collar (cm)	46.4	2.0	26.2 - 70.0	43.6	2.6	26.9 - 85.5
Height (m)	10.7	0.6	5.9 - 18.0	8.2	0.6	3.1 - 19.0
Bark remaining (%)	96.2	0.9	80.0 - 100.0	93.0	1.0	70.0 - 100.0
Decay Class (ranking)	2	0	2 - 4	2	0	2 - 5
Surrounding Forest						
Slope (%)	10.0	2.0	2.0 - 25.0	5.0	1.0	0.0 - 17.0
Aspect (degrees)	217.0	13.0	6.0 - 352.0	192.0	15.0	15.0 - 354.0
PIPO density (stems/ha)	450.6	38.9	180.0 - 1110.0	457.2	69.7	40.0 - 1760
QUGA density (stems/ha)	303.8	36.9	60.0 - 900.0	289.7	42.5	50.0 - 1160.0
PTQ density (stems/ha)	81.1	8.9	4 - 230	47.5	4.5	10.0 - 100.0
Basal Area PIPO (m^2/ha)	24.6	1.7	5.0 - 42.0	21.1	2.2	2.0 - 63.0
Basal Area QUGA (m^2/ha)	13.8	1.4	2.0 - 42.0	9.6	1.0	2.0 - 33.0

Figure 1. Average number of Gambel oak stems per ha by 7.5-cm diameter classes for 39 locations representing 1080 ha on the Kaibab National Forest. Locations were sites with ponderosa pine and Gambel oak present and with completed stand exams as of November 1997.

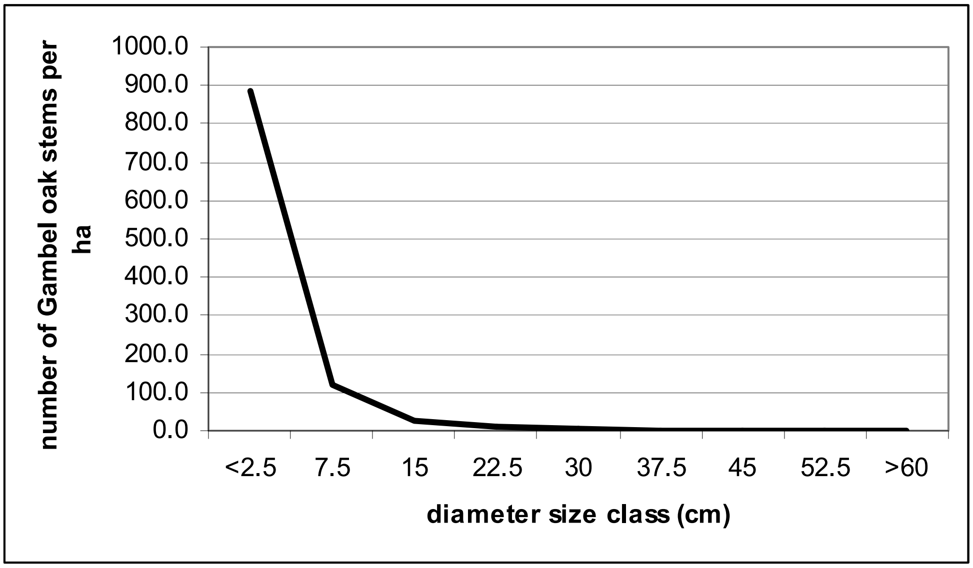
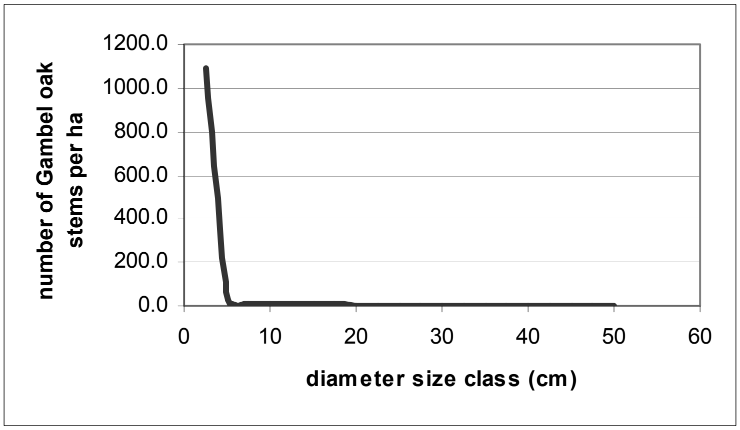
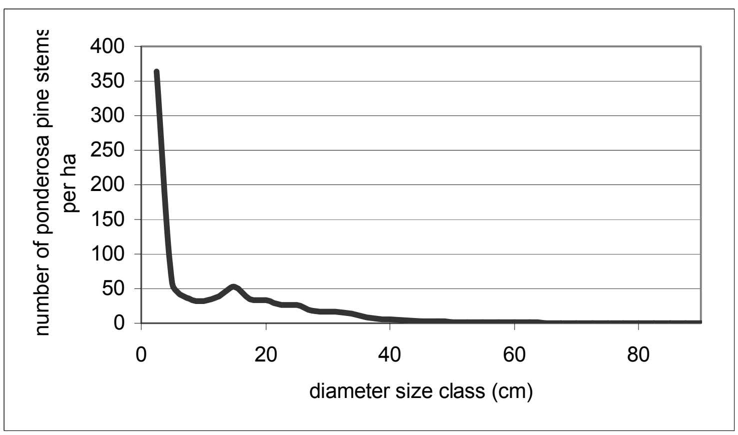


Figure 2. Average number of A. Gambel oak stems and B. ponderosa pine stems per ha by 2.5-cm diameter classes for 2062 stands on the Coconino National Forest. Locations were sites dominated by ponderosa pine and with Gambel oak present (5 to 30% of basal area was Gambel oak). C. Log-transformed data for Gambel oak.

A.



B.



C.

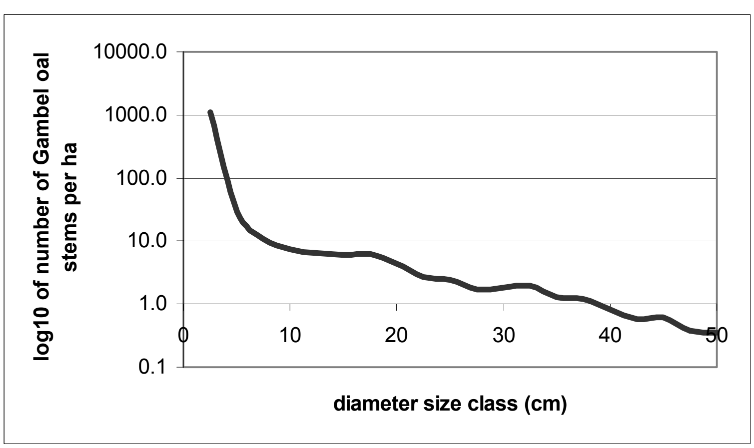
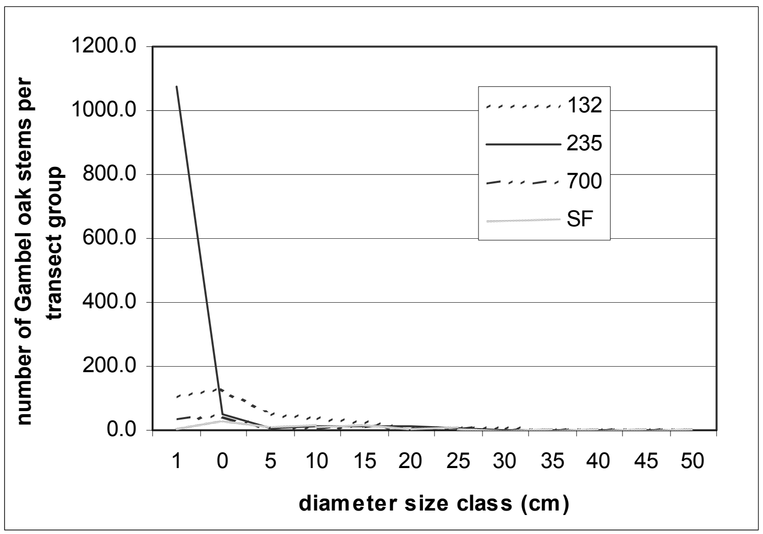


Figure 3. Average number of Gambel oak stems (A) and log-transformed number of Gambel oak stems (B) for locations with >4 transects for 5-cm diameter classes on 500-m transects, Coconino National Forest and Arizona state lands, July 1998 – May 1999. Diameter size class 1 includes stems less than 1 m tall; size class 0 includes stems >1m and <5 cm dbh, size class 5 includes stems 5 to 9.9 cm diameter, size class 10 includes stems 10 to 14.9 cm diameter, size class 15 includes stems 15 to 19.9 cm diameter, size class 20 includes stems 20 to 24.9 cm diameter, size class 25 includes stems 25 to 29.9 cm diameter, size class 30 includes stems 30 to 34.9 cm diameter, size class 35 includes stems 35 to 39.9 cm diameter, size class 40 includes stems 40 to 44.9 cm diameter, size class 45 includes stems 45 to 49.9 cm diameter, size class 50 includes stems >50 cm diameter.

A.



B.

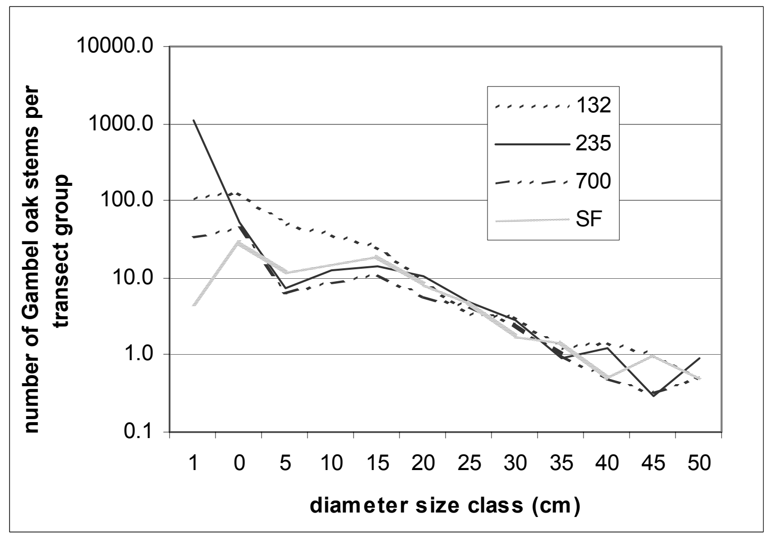
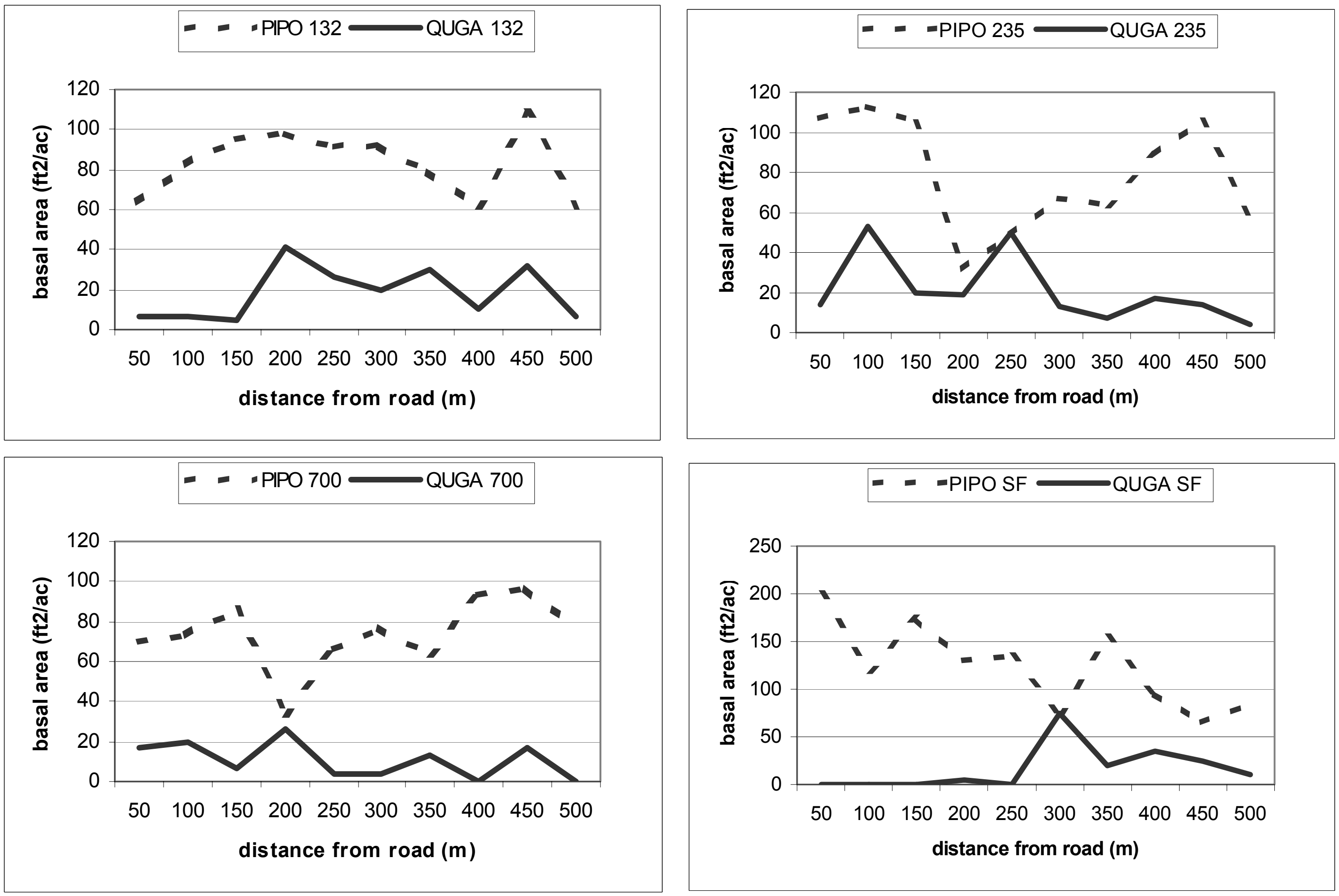


Figure 4. Average basal area (ft^2/ac) for locations with >4 transects for ponderosa pine (PIPO) (dashed line) and Gambel oak (QUGA) (solid line) for 50 m-intervals on 500-m transects, Coconino National Forest and Arizona state lands, July 1998 – May 1999. Locations were: Forest Service (FS) Road 132 (12 transects), FS Road 235 (10 transects), FS Road 700 (6 transects), and State Forest (4 transects).



Appendix A. Scientific names for species cited in this report.

COMMON NAME	SCIENTIFIC NAME
MAMMALS	
Abert's Squirrel	*Sciurus aberti*
Allen's Lappet-browed Bat	*Idionycteris phyllotis*
Arizona Myotis	*Myotis occultis*
Big Brown Bat	*Eptesicus fuscus*
Black Bear	*Ursus americanus*
California Myotis	*Myotis californicus*
Cottontail	*Sylvilagus nuttalli*
Coues White-tailed Deer	*Odocoileus virginianus*
Fringed Myotis	*Myotis thysanodes*
Hoary Bat	*Lasiurus cinereus*
Javelina	*Pecari angulatus*
Long-eared Myotis	*Myotis evotis*
Long-legged Myotis	*Myotis volans*
Mexican Free-tailed Bat	*Tadarida brasiliensis*
Mule Deer	*Odocoileus hemionus*
Pallid Bat	*Antrozous pallidus*
Piñon Mouse	*Peromyscus truei*
Porcupine	*Erethizon dorsatum*
Red Squirrel	*Tamias hudsonicus*
Rocky Mountain Elk	*Cervus canadensis*
Silver-haried Bat	*Lasionycteris noctivagans*
Southwestern Myotis	*Myotis auriculus*
Western Small-footed bat	*Myotis ciliolabrum*
Yuma bat	*Myotis yumanensis*
BIRDS	
Acorn Woodpecker	*Melanerpes formicivorus*
Band-tailed Pigeon	*Columba fasciata*
Black-headed Grosbeak	*Pheucticus melanocephalus*
Blue Grouse	*Dendragapus obscurus*
Cordilleran Flycatcher	*Empidonax occidentalis*
Dark-eyed Junco	*Junco hyemalis*
Grace's Warbler	*Dendroica graciae*
Hairy Woodpecker	*Picoides villosus*

COMMON NAME	SCIENTIFIC NAME
Merriam's Wild Turkey	*Meleagris gallopavo merriami*
Mexican Spotted Owl	*Strix occidentalis lucida*
Mountain Chickadee	*Poecile gambeli*
Northern Flicker	*Colaptes auratus*
Plumbeous Vireo	*Vireo plumbeus*
Pygmy Nuthatch	*Sitta pygmaea*
Red-faced Warbler	*Cardellina rubrifrons*
Virginia's Warbler	*Vermivora virginiae*
Warbling Vireo	*Vireo gilvus*
Western Bluebird	*Sialia mexicana*
Western Tanager	*Piranga ludoviciana*
White-breasted Nuthatch	*Sitta carolinensis*
Yellow-rumped Warbler	*Dendroica dominica*