Selection and Distribution of Band-tailed Pigeon (*Columba fasciata*) Nesting Habitat in Managed Forests in Northern Arizona

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Introduction

The band-tailed pigeon (*Columba fasciata*, herafter BTPI) is a game bird that inhabits mixed conifer-oak forests in western North America and Central and South America. Eight subspecies of BTPI are recognized; however, only two occur north of Mexico (Pacific Flyway 2001). The Pacific coast subspecies (*C. f. monilis*) breeds in northern California, Oregon, Washington, and British Columbia; and winters from central California into Baja California. The Interior subspecies (*C. f. fasciata*) (also known as the Four Corners population) breeds in Arizona, New Mexico, Utah, Colorado, and Mexico; and winters from northern Mexico to Michoacán (Corman and Wise-Gervais 2005). These two BTPI populations are separated geographically; however, some interchange can occur (Schroeder and Braun 1993).

Early 1970's harvest reports and band recovery rates estimated that the Interior BTPI population was considerably smaller (< 250,000) and more scattered than the Pacific coast population (2.9-7.1 million). The inconspicuous nature of Interior BTPI, coupled with inaccessible mountain terrain and dense forest habitat make it challenging to obtain reliable sample sizes for estimates of population size (Pacific Flyaway 2001). Monitoring trends obtained through point counts, capture-recapture, and bait stations have failed to produce reliable trend information (Casazza et al. 2000). There have also been several unsuccessful attempts to develop population indices through broadcast stations (Sanders 1999, McCaughran and Jeffrey 1980).

The current status of the Interior BTPI is suspected to be in decline. Sanders (2001) used a log-linear hierarchical model and Bayesian analytical framework to estimate trends in abundance of *C. f. fasciata* from 1968 to 2010. The trend in the median annual count was a 4.3% decrease per year, although small sample sizes could make these findings inconclusive. The lack of reliable population estimates of BTPI in Arizona impedes effective adjustment of hunting bag limits to ensure its conservation. Typical BTPI clutch size consists of one egg per nest (Neff 1947, Braun 1994, Leonard 1998) and the total number of BTPI clutches is variable. In years containing abundant forage, BTPI can potentially rear three broods per year; however, average number of annual broods has been estimated at 1.14-1.26 (Leonard 1998). Because any event resulting in mortality (e.g., disease or overharvest) could negatively impact the population, *C. f. fasciata* is currently classified as a species of concern by Partners in Flight (Latta et al. 1999).

Most of the existing habitat information for BTPI has been collected from the Pacific Coast region (e.g. MacGregor and Smith 1955, Leonard 1998); whereas, little information exists on what constitutes nesting habitat for this species in the Interior states (Kirkpatrick et al. 2005). Evaluation of BTPI nesting habitat selection within the southwestern United States is needed to provide information for maintaining a healthy Interior population. Furthermore, with forest restoration and fuel reduction activities increasing in the Southwest, managers are in need of empirical data regarding the impact of forest management practices on nesting BTPI.

Study Objectives

The primary objectives of this study were to estimate the current potential BTPI nesting habitat within the White Mountain region of Arizona.

This project addressed the following specific objectives:

1) Describe habitat conditions selected by nesting BTPI in northern Arizona;

2) Use measured nest stand characteristics to model BTPI nesting habitat within northern Arizona using the Forest Ecosystem Restoration Analysis (ForestERA) cumulative modeling package, and;

3) Develop forest management guidelines for BTPI nesting habitat for the coniferous forests of northern Arizona.

Study Area

All BTPI were captured and tracked north of the Mogollon Rim in the White Mountains of north-central Arizona at elevations between 1900 and 2900 meters. There were five local sampling sites throughout the White Mountains: Forest Lakes, Timberland Acres, Pinetop-Lakeside, Greer, and Nutrioso (Figure 1). Temperatures within the study area can range from below 30° F to 58° F in Greer, and 35° F to 66° F in Show Low. Average annual total precipitation is over 22 inches in Greer and over 16 inches in Show Low consisting of summer monsoons and winter rain and snow. The sampling locations are described below.

Forest Lakes

Forest Lakes is a small residential community on the edge of the Mogollon Rim adjacent to Coconino National Forest about 54 miles west of Show Low. The area has an elevation of 2300 m (7546 ft) and is dominated by ponderosa pine (*Pinus ponderosa*) (Brown 1994).

Timberland Acres

Timberland Acres is a residential community 10 miles west of Show Low with an elevation of 1980 m (6496ft) and is adjacent to the Apache Sitgreaves National Forest and the White Mountain Apache Reservation. Much of Timberland Acres and the surrounding forest were burnt by the Rodeo-Chediski fire of 2002. As a result, much of the ponderosa pine dominant stands were replaced by young oak trees and shrubs (Brown 1994).

Pinetop-Lakeside

Pinetop-Lakeside is a town in Navajo County southeast of Show Low surrounded by the Apache Sitgreaves National Forest and adjacent to the White Mountain Apache Reservation. At 2073 m (6801 ft), the vegetation is primarily ponderosa pine and gambel's oak (*Quercus gambelii*) (Brown 1994).

Greer and Nutrioso

Greer, also in Apache County, is a small town in a valley at an elevation of 2740 m (8989 ft). The Little Colorado River runs through Greer and the vegetation consists of ponderosa pine, fir, spruce, and aspen trees. The east side of Greer burnt in the Wallow fire of 2011, leaving large stands of dead trees. Nutrioso is a small residential community in Apache County 32 miles east of Greer with an elevation of 2338 meters. The vegetation consists of mixed-conifer and gambel's oak, including ponderosa pine, fir, spruce, and alligator juniper (Brown 1994).

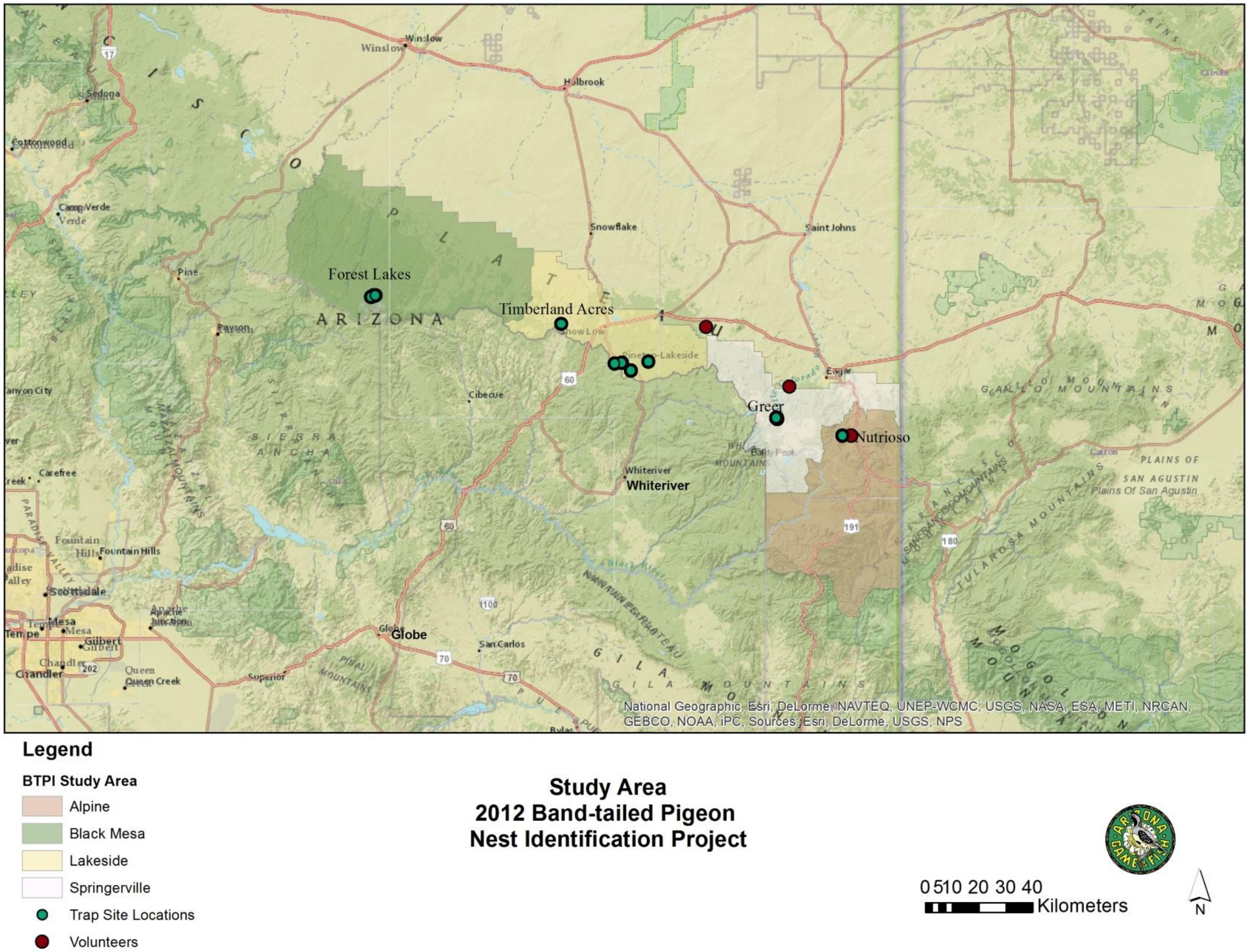

Figure 1. Band-tailed pigeon project area within Arizona and trap site locations.

Methods

Volunteers and Trap Sites

Local knowledge from residents and AZGFD biologists facilitated trap-site selection in areas containing summer populations of BTPI with suitable nesting habitat (conifer/oak forest). We contacted AZGFD biologists in the Region 1 (Pinetop) office to inquire about volunteers that were willing to bait BTPI using birdfeeders in their yards. Some volunteers already had flocks of pigeons visiting their bird feeders, while others had not yet detected BTPI. We recruited volunteers and provided each with 50 lbs of pigeon feed and a wire box trap. The volunteers were instructed to bait the trap (while the trap was in an inactive state) every day in order to habituate or attract BTPI. We acquired additional volunteers and trap sites through information received from current volunteers and the general public, and by personally recruiting homeowners when we detected flocks of pigeons at their feeders. We ensured that our trap sites were representative of the study area by geographically distributing the recruitment of our volunteers throughout the White Mountains. Therefore, the 5 locations we chose for trap sites across the study area from west to east were Forest Lakes, Timberland Acres, Pinetop-Lakeside, Greer, and Nutrioso (Figure 1).

Trapping

If BTPI flocks were not already feeding at the trap site, we waited until the volunteers informed us of their arrival. Once we established the presence of BTPI, we planned trapping sessions at the volunteers' homes. BTPI were trapped from late May to early September with baited traps. Initially, we used wire box traps with swinging trap doors, and small mesh net spring traps; however, because the pigeons were feeding in flocks of 15 or more, our capture rate was relatively low with these smaller traps (1 to 3 birds per session). Thus, we employed a swoosh net, (10x10 feet), a large box trap, and a bow net, often supplemented with the smaller wire box traps and small mesh spring traps. This increased our capture rate to 5-10 birds per trap session. We baited the traps with pigeon feed consisting of cracked corn, sunflower seed, millet, and peas. If necessary, we covered or removed other bird feeders to encourage BTPI into traps. Active traps were monitored constantly to avoid injury to captives.

Our trap sessions were initially in the early morning in order to target male pigeons. However, we observed both genders were active at the feeders throughout the day at most trap sites. Therefore, for the remainder of the study, we trapped both sexes in the morning, midday, afternoon, and evening. We recorded weight (g), gender, age (adult or juvenile based on plumage), and crop development to determine breeding status for each captured pigeon. Additionally, we collected blood samples and cloacal and crop swabs to be tested for disease in the AZGFD veterinary laboratory. Each captured pigeon was fitted with a USFWS aluminum band (band size 5), and a radio transmitter was attached to breeding pigeons (adult birds with a developed crop) to find nests.

Radio Marking Techniques

Previous studies have demonstrated that BTPI females incubate at night and males incubate during midday (Curtis and Braun 1983b). We initially placed transmitters on males only, as tracking during daylight hours would facilitate finding nests. However, we trapped both sexes throughout the day after determining that any breeding bird could potentially be tracked to the nest. We mounted radio transmitters (3.8g; PD-2, Holohil systems) on the back of each breeding pigeon using medical skin glue (TORBOT bonding cement™) or super glue gel. Transmitter battery life was reported as 2 months and glue bonding was predicted to last approximately 15-20 days, after which the transmitter was expected to fall off. Receivers (Communication Specialists, Inc., Model R-1000) were programmed and fine-tuned for best reception prior to release from the trap site.

Radio-Tracking

We conducted radio-tracking using handheld yagi antennas on the ground and aerial telemetry flights to locate missing birds when necessary. Since we did not observe a gender specific incubation pattern that had been observed in previous studies (females at night and males during the day) (Curtis and Braun 1983b), we were unable to schedule the time that BTPI males and females would be incubating. We assumed that some individuals could be in the brooding and feeding stage of the nest cycle, making it more difficult to determine what times marked individuals would be at the nest. Therefore, we tracked both males and females at all times throughout the day. Each marked bird was tracked at least once a day for several weeks in each of the following time intervals: early morning (0500-0900), mid-morning (0900-1100), midday (1100-1400), afternoon (1400-1700), and evening (1700-2000).

Our objective was to obtain at least one location in each time interval for every marked BTPI individual in order to locate the bird on the nest. We recorded our locations using hand-held GPS units (Garmin models III and V plus) and documented signal direction using compass bearings aligned with the antenna spine pointing toward the peak signal (i.e., transmitter location). Tracking was conducted until the transmitter failed or was shed, the individual could no longer be detected due to long distance movements out of the study area, or the nest location was identified. Lost individuals were tracked using aerial telemetry flights and were often located out of the study area (i.e., on the White Mountain Apache Reservation) or the transmitter had been dropped in an area where a poor radio signal would make ground tracking difficult.

Habitat Measurements and Model Development

The following variables were extracted from the collected nest stand data (Table 1): forest type, site index, number of trees by Vegetation Structural Stage (VSS) class, basal area (BA) by VSS class, overall stand VSS class, percent canopy cover by tree species, and number of dead standing trees > 14 inches dbh.

Landsat imagery from 2004 was coupled with spatial data layers from northern Arizona Forest Ecosystem Restoration Analysis (Lab of Landscape Ecology and Conservation Biology, Northern Arizona University) (basal area, tree density, canopy cover, slope, and aspect) to determine thresholds within the range of habitat conditions that could be used to separate areas with and without BTPI nests. We employed the Mahalanobis distance (M-distance) statistic to develop a measure of the likelihood that a given portion of the landscape would be used for nesting. M-distance is a measure of dissimilarity between two multivariate datasets (Farber & Kadmon 2003). In the case of wildlife habitat modeling, one dataset is the mean vector of habitat characteristics for a set of locations used by a species (in this case nest sites), while the other dataset is the range of conditions across the entire landscape (Clark et al. 1993; Farber & Kadmon 2003). The first vector is assumed to represent "preferred" habitat conditions for a species (Farber & Kadmon 2003). Thus, the "distance" value can be used as an index of habitat preference and to model potential nesting habitat for band-tailed pigeons within the study area.

Table 1. Standard measurements used to measure tree vegetation structure within a 25.3 m radius (1/2 acre) fixed plot.

Variable	Description/Method
Stem diameter	Dbh or drc of stems >30.5 cm, measured to the nearest cm with a dbh tape, and recorded by species.
Basal Area	Basal area, measured with a 10 factor sighting gauge from BTPI nest tree.
Live crown ratio	Green crown percent, 100(l/h), where l is the length of the living crown and h is the total tree height. Based on hypsometer measurements to the nearest meter.
Canopy density	At each percent ground cover point the presence or absence of canopy intersected by a vertical cross hair should be recorded.
Dead and Down	All dead and down trees 4 m long and 30.5 cm diameter should be tallied and measured.
Stem count (stems 2.5 cm dbh)	Tally number of stems 2.5 cm, by species, within an 11.3m radius plot ($1/10^{th}$ acre) centered within the 25.3m-radius plot.
Stem measurements (all stems >2.5 and <30.5 dbh)	Measure the height and diameter of all stems (and snags) within an 11.3 m radius plot centered within the 25.3 m-radius plot [heights measured with a hypsometer and dbh or drc (for non-mercantile timber, e.g., willows)] to the nearest cm with a dbh tape, and record to species.
Stems measurements (all stems 30.5 cm dbh)	Measure the height and diameter of all stems within the 25.3 m radius plot heights measured with a hypsometer and dbh or drc (for non-mercantile timber, e.g.,, willows) to the nearest cm with a dbh tape, and record to species. Trees recorded in the basal area measurement should be noted.
Snags	All snags (by species and 30.5 cm dbh/drc) within the plot should be measured (height and dbh)

Dbh = diameter at breast height (1.4m or 4.5ft above ground)
DRC = diameter at root crown

Results

During this four month project, 257 trapping hours at 10 trap sites resulted in the capture of 47 BTPI. Of the 47 captured BTPI, 12 were female, 35 were male, 44 were adults, and three were juveniles. Thirty-nine BTPI were banded, 33 were radio-marked, and tissue samples were collected from 27 individuals. Of the 33 radio-marked birds, we were unable to relocate seven due to their departure from the study area or transmitter failure. Twenty six birds produced a total of 71 locations resulting in ten nest locations (Figure 2). One of the nests was not derived from any of the marked birds, but was incidentally detected while searching for marked individuals. Ten BTPI nest locations are described below along with a brief description of the trap site.

Bird 2 (Transmitter 148.0491): Hart Lake Drive Nest
This adult male was our second capture, caught on the morning of May 14 in Lakeside, AZ at our Mountain View Drive trap site. The nest was located in a ponderosa pine early morning on May 15 in the same neighborhood half a mile away from the trap site. The nest tree was on private property consisting of a ponderosa pine monoculture. Because access to the property was difficult to obtain, the outcome of the nest is uncertain.

Bird 4 (Transmitter 148.0886): Upper (N. Wildcat Drive) and Lower Timberland Acres Nest
Our eighth capture was an adult female caught on May 21 in the afternoon in Lakeside, AZ at our Mountain View Drive trap site. This individual led us to two nests in Timberland Acres near Show Low, AZ, which were later abandoned. The female was observed copulating with her mate on Forest Service land near the nests. First, the individual was found sitting in a nest early afternoon in a ponderosa pine tree on private property in the upper part of Timberland Acres. The property consisted of ponderosa pine, Gambel's oak and alligator juniper trees, including many burnt dead trees. The first nest was later found to be used by another one of our marked pigeons. A few weeks later, the Bird 4 abandoned the first nest and began building a second nest in the lower portion of Timberland Acres in an Alligator Juniper tree on private property. This property consisted of Utah juniper, alligator juniper, Gambel's oak, and Ponderosa pine trees. The transmitter was found underneath the nest tree.

Bird 19 (Transmitter 148.6889): Apache Sitgreaves National Forest Nest (by Sky Hi Retreat)
The thirty-fifth pigeon to be captured was caught on the morning of July 11 at the Sky-Hi Retreat trap site in Pinetop, AZ. The adult male was found perched on the nest in the evening in a ponderosa pine tree about 500 meters away from the trap site on Forest Service land. Fresh eggshells were found underneath the tree, indicating a hatchling in the nest. Habitat consisted mostly of ponderosa pine with some Gambel's oak and alligator juniper trees. Although not confirmed, the hatchling likely fledged.

Bird 21 (Transmitter 148.7484): Sky Hi Retreat Nest
Our thirty-eighth capture was an adult male caught on the afternoon of July 11 at the Sky-Hi Retreat trap site in Pinetop, AZ. The individual's nest was found in the morning down the street in a ponderosa pine on private property. The transmitter was found on the ground underneath the nest tree, and the nest was most likely abandoned after the offspring fledged. The property was a ponderosa pine monoculture.

Bird 22 (Transmitter 148.5100): Colter Canyon Creek
Capture twenty-nine was an adult male caught on the morning of July 18 at our Juniper Lane trap site in Nutrioso, AZ. This individual was incubating in the late afternoon on a nest in a Douglas fir tree by Colter Creek. The nest tree was in a canyon that had been severely burnt during the Wallow Fire. There were no live trees in the stand.

Bird 23 (Transmitter 148.5687): Colter Canyon Creek

Our 30th capture was an adult male caught on the morning of July 18 at our Juniper Lane trap site in Nutrioso, AZ. The nest was found in the evening in a Douglas fir tree in a partially burnt stand consisting of Douglas fir, quaking aspen, Ponderosa pine, white fir, Arizona white pine. When the nest was found, the pigeon was incubating an offspring, which eventually fledged.

Bird 27 (Transmitter 148.8276): Upper Timberland Acres Nest (N. Wildcat Drive)
Our forty-second capture was an adult male caught on the morning of August 2 at our Sky-Hi Retreat trap site in Pinetop, AZ. This individual was found late afternoon sitting in the first nest that bird # 4 (capture # 8) had been using.

Bird 28 (Transmitter 149.7247): Forest Service: Vernon/McNary Road (UTM NAD83: 616253E 3779502
Our forty-third capture was an adult male caught on the morning of August 2 at our Sky-Hi Retreat trap site in Pinetop, AZ. The nest was found in the early morning in a ponderosa pine tree on forest service land by McNary. The nest contained a downy hatchling estimated to be 12-15 days old.

Bird 33 (No Transmitter): Random Nest around Nutrioso by reservoir (UTM NAD83 659546E 3758074N)
This final nest was not derived from any of the marked birds but was incidentally detected while searching for marked individuals. A pigeon of unknown gender was detected incubating on the nest on the morning of August 13. The nest tree was a ponderosa pine located in a stand of ponderosa pine and Gambel's oak trees.

BTPI Nest Tree Characteristics (Data summarized in Table 2)
BTPI nest trees were located mostly in Ponderosa pine (N=7), however, alligator juniper (N=1) and Douglas fir (N=2, including one snag) were also documented as nest trees. Nest site elevations ranged from 6471-9006 ft. Nest tree DBH ranged from 14.6-93.2 cm and averaged 38.85 cm (SE 7.06). The lowest live branch (bottom live crown) ranged from 0-12 m with an average of 6.24 m (SE 0.87). Tree height ranged from 11.3-19.5 m with an average of 15.25 m (SE 3.43). Canopy cover ranged from 5-90 % with an average of 64 %. Nest trees were on a terrain slope ranging from 0-28 % and averaged 12.2%). Actual nest height within the nest tree ranged from 7.4-12.5 m with an average of 10.14 (SE 1.86). Nest diameter ranged from 20-40 cm with an average of 26.22 cm (SE 7.19). Distance from the nest to the tree trunk ranged from 0-20 cm with an average of 3.56 cm (SE 6.98). The largest branch diameter containing the nest ranged from 5.3-29.5 cm with an average of 10.79 (SE 7.38). Canopy cover directly above the nest ranged from 5-100% with an average of 57%. Distance to cover above the nest ranged from 0-250 cm with an average of 73.06 cm (SE 101.3). Terrain aspect ranged from 0-340.

Nest Site Characteristics
The average DBH for all trees within respective BTPI nest sites ranged from 16.3-66.5 cm (Table 3). Average percent canopy cover for all trees ranged from 16-67 % and the distance to the lowest live branch (bottom live crown) ranged from 2.8-10.7 m (Table 3). Average tree height for all trees ranged from 8.4-18.9 m (Table 3). Average snag DBH for all trees within respective nest sites ranged from 25.6-56.9 cm (Table 3). Average snag height within each nest site ranged from 6.9-19.5 m (Table 3).

Average DBH for all trees across all plots within BTPI nest sites was 33.98 cm (SE 4.82). Average canopy cover for all trees across all BTPI nest sites was 39.97 % (SE 6.21). Average distance to the lowest live branch (bottom live crown) was 5.92 m (SE 1.02). Average tree height was 13 m (SE 1.9). Average DBH for snags across all BTPI nest sites was 39.78 cm (SE 2.13). Average downed tree DBH was 20.45 cm (SE 0.7) and the average downed tree length was 8.9 m (SE 0.9).

The average basal area for stands containing BTPI nests was 134 m^2 and ranged from 20 to 290 m^2 (Table 4). The quadratic mean diameter ranged from 16.9 to 70.7 cm with an average of 37.5 cm (Table 4). Vegetative structural stages for BTPI nest stands ranged from 3 to 5 with the majority of the stands characterized by VSS class 4 based on the quadratic mean diameter for each stand (Table 4).

Mahalanobis Distance Models

Mean values of each variable and the respective covariance matrix generated a grid of Mahalanobis Distance values over the landscape. M-distance values are dimensionless units analogous to multivariate versions of standard deviations. Mahalanobis distances were calculated to generate models for BTPI habitat (Figure 3) and BTPI nesting habitat (Figure 4). The resulting maps illustrate BTPI habitat (Figure 3) and BTPI nesting habitat (Figure 4) with the darker shades representing high suitability and the lighter shades representing low suitability for BTPI.

Table 2. BTPI nest tree characteristics.

Frequency	Location Date	UTM Easting	UTM Northing	Tree Species	Tree Status	Burnt	DBH (cm)	Live Crown (m)	Tree Height (m)	Canopy Cover (cm)	Slope	Elev. (ft)
148.0491	5/15/2012	594774	3775950	Ponderosa	Live	N	38.9	7.2	12	83	0	6844
148.0886	5/24/2012	575655	3791233	Ponderosa	Live	N	14.6	5.4	11.3	75	15	6600
148.0886	6/25/2012	576710	3792339	Juniper	Live	N	93.2	3.2	12.2	62	8	6471
148.6889	7/24/2012	602701	3780650	Ponderosa	Live	N	23.2	6.3	13.6	90	3	7281
148.7484	7/18/2012	602316	3480206	Ponderosa	Live	N	34.1	12	19.5	40	1	7253
148.5100	7/25/2012	659382	3758472	Doug Fir	Dead	Y	46.2	-	18.1	5	28	8432
148.5687	7/25/2012	658572	3756044	Doug Fir	Live	Y	39.3	6.4	18.3	63	15	9006
148.8276	8/8/2012	575655	3791233	Ponderosa	Live	N	14.6	5.4	11.3	62	15	6600
149.7247	8/7/2012	616253	3779502	Ponderosa	Live	N	43.9	2.5	17.8	85	22	8245
Random	8/13/2012	659546	3758074	Ponderosa	Live	N	40.5	7.8	18.4	70	15	8906

Table 2 cont. BTPI nest tree characteristics.

Frequency	Nest Height (m)	Nest Diam. (cm)	Nest Twig Species	Nest aspect Tree	Nest Bole Dist.	Diam. Stem Nest	% Canopy over nest	Dist Nest overhead Cover (cm)	Aspect terrain
148.0491	10	20	Ponderosa	228	10	10	60	250	0
148.0886	10.3	22	Ponderosa	148	0	5.3	93	31	340
148.0886	9.1	40	Ponderosa	140	20	9	40	19	54
148.6889	9	30	Ponderosa	225	0	8	100	0	276
148.7484	13	25	Ponderosa	260	0	12	45	40	102
148.5100	7.4	20	White Fir	255	0	29.5	5	35	100
148.5687	12.5	22	Doug Fir	178	0	10	70	250	56
148.8276	10.3	22	Ponderosa	148	0	5.3	93	31	340
149.7247	11.8	35	Ponderosa	334	2	8	10	1.5	225
Random	8	-	-	220	-	-	-	-	100

Table 3. BTPI nest site habitat characteristics. Values are presented as plot averages with associated standard errors (SE).

Nest	Frequency	Live DBH cm (SE)	% Canopy Cover (SE)	Bottom Live Crown m (SE)	Tree Height m (SE)	Snag DBH cm (SE)	Snag Height m (SE)	Down Tree DBH cm (SE)	Down Tree Length m (SE)
1	148.0491	24.2 (1.6)	49 (6.2)	6.2 (0.8)	10.9 (0.9)	-	-	-	-
2	148.0886	15.8 (2.0)	52.2 (7.7)	5.1 (0.6)	9.2 (0.9)	47.0 (8.4)	6.9 (0.8)		
3	148.0886	62.1 (13.8)	74.3 (8.1)	1.9 (0.5)	8.5 (0.7)	34.4 (9.8)	19.5 (1.1)	5.7 (1.0)	5.5 (0.5)
4	148.6889	49.2 (7.7)	35 (10.0)	5.5 (4.0)	12.1 (6.4)	56.9 (11.4)	15.3 (8.1)	-	-
5	148.7484	39.3 (3.0)	38.4 (3.8)	8.6 (0.9)	18.1 (0.9)	-	-	-	-
6	148.5100	31.8 (4.7)	9.0 (3.8)	Burn	19.3 (1.4)	25.6 (2.1)	16.5 (2.3)	-	-
7	148.5687	40.7 (3.7)	26.2 (6.4)	9.6 (1.1)	18.7 (1.5)	36.6 (2.3)	17.4 (0.9)	-	-
8	148.8276	16.1 (2.1)	48.4 (6.9)	5.6 (0.4)	9.6 (0.8)	47.0 (8.4)	6.9 (0.8)	-	-
9	149.7247	25.8 (4.8)	34.9 (6.0)	3.7 (0.8)	10 (1.5)	39.0 (4.5)	13.1 (0.8)	35.2 (0.4)	12.3 (1.3)
10	Random	34.8 (4.8)	32.3 (7.0)	7.1 (0.8)	13.6 (1.7)	31.7 (4.8)	14.2 (2.2)	-	-

Table 4. BTPI nest stand forestry variables extracted from each nest site.

Nest	Frequency	Forest Type	Basal Area	VSS Class	Quadratic Mean Diameter
1	148.0491	Pipo/Quga	140	3	24.8
2	148.0886	Pipo/Quga/Jude	110	3	16.9
3	148.0886	Quga/Juut/Jude	70	5	70.7
4	148.6889	Pipo/Quga/Jude	20	5	49.7
5	148.7484	Pipo/Quga	290	4	42.4
6	148.5100	Potr/Psme/Pipo/Abco	100	4	34.9
7	148.5687	Psme/Potr/Pipo/Abco/Pist	240	4	44.4
8	148.8276	Pipo/Quga/Jude	100	3	17.2
9	149.7247	Pipo/Quga/Pist	130	4	30.7
10	Random	Pipo/Quga/Psme	140	4	38.8

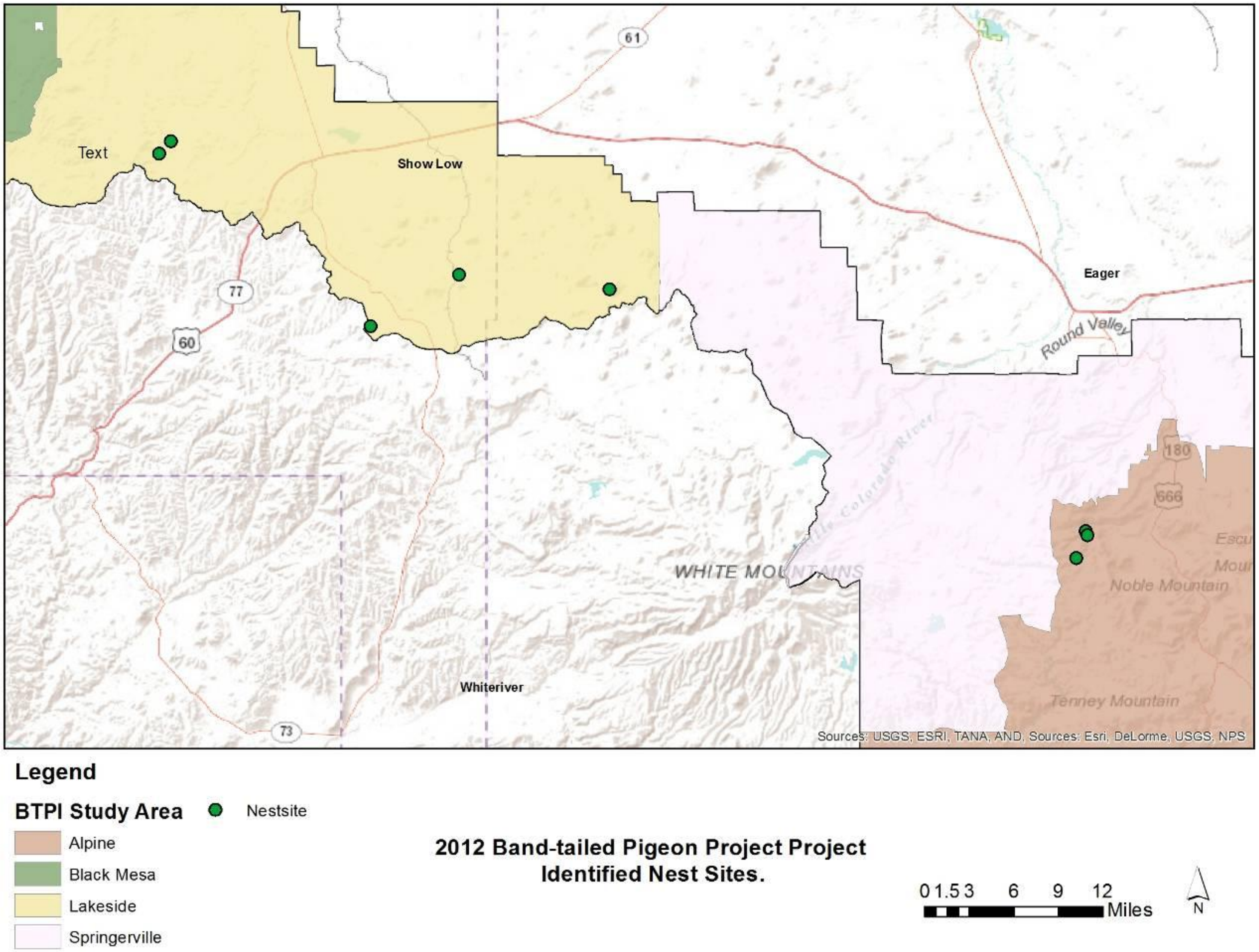

Figure 2. Band-tailed pigeon nest locations within project area.

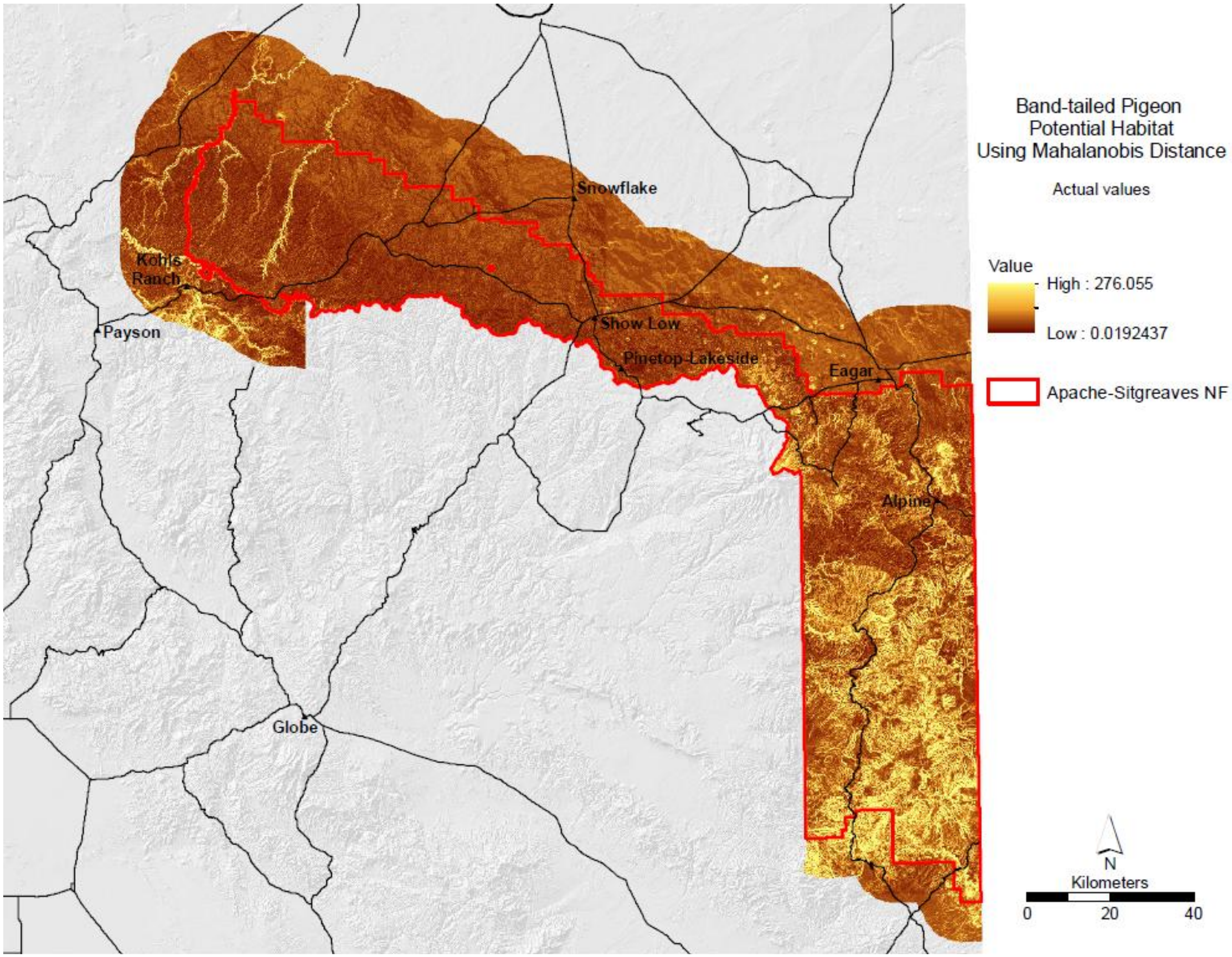

Figure 3. Band-tailed pigeon potential habitat Mahalanobis distances. Darker shades represent BTPI habitat.

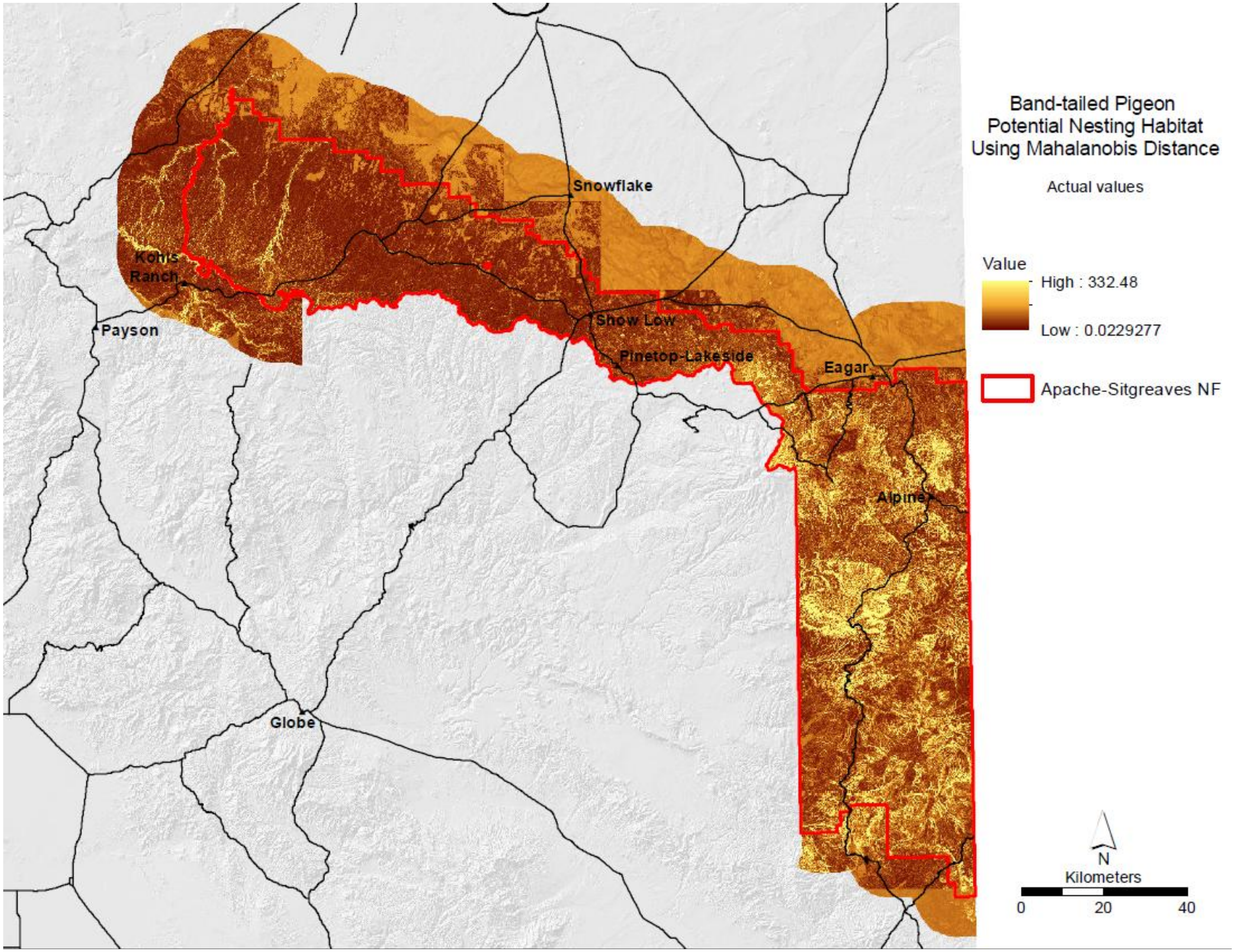

Figure 4. Band-tailed pigeon potential nesting habitat Mahalanobis distances. Darker shades represent BTPI nesting habitat.

Discussion

BTPI nest placement was highly variable, located in Ponderosa pine, alligator juniper and Douglas fir at elevations ranging from 6471-9006 ft (Table 2). Nest tree DBH, lowest live branch (bottom live crown), canopy cover and terrain slope and aspect were correspondingly diverse for BTPI nest trees (Table 2). Nest tree height was less variable than other parameters, ranging from 11.3-19.5 m (Table 2). At the nest stand level, average DBH, average percent canopy cover and the distance to the lowest live branch (bottom live crown) for all trees within respective BTPI nest sites were less variable than for nest tree characteristics, but still contained a large range of values (Table 3). Thus, we confirmed that BTPI nest site selection was highly variable in Arizona as has been previously documented for other parts of this species range (Keppie and Braun 2000). Correspondingly, the observed flexibility of this species for nest site selection indicates that current forest management practices are adequate for BTPI nesting, depending on the availability of foraging areas.

While nesting, BTPI will forage in cultivated fields and livestock feeding areas, as well as consume buds, flowers, and fruits of wild trees and shrubs including oaks (*Quercus*) and pines (*Pinus*) (Kautz 1977). Available forage greatly impacts the habits, range, distribution, and initiation and duration of nesting of BTPI (Gutiérrez et al. 1975, Jarvis and Passmore 1992). Long distance movements to foraging areas, flock foraging behavior and high foraging area fidelity are all characteristics that make this species vulnerable. Commuting greater distances on a daily basis exposes individuals or flocks to many threats when compared to groups that forage in a smaller area. Urban foraging areas (e.g., bird feeders at private residences) can provide a safe refuge for this species from hunting; however, these foraging areas provide reliable sources for ambush predators such as raptors and house cats. Foraging areas outside of urban areas where BTPI regularly congregate may provide a hunting sink, where hunters can capitalize on BTPI vulnerability while feeding.

The BTPI M-distance habitat model predicted areas where BTPI are known to occur as the most suitable habitat; however, the model also predicted some areas where BTPI occur as least suited for BTPI (Figure 3). Reasons for this model output are difficult to surmise, but probably can be explained by the scarcity of this species, our low sample size and the apparent flexibility of nest-site selection of BTPI. Additionally, nest site and stand data collected from BTPI nest location data is too fine-scaled to incorporate in landscape scale modeling exercises such as M-distance calculations because companion data from reference sites is necessary to make appropriate comparisons. Thus, fine scale data such as that collected at BTPI nest sites (e.g., DBH, tree height and canopy cover) would need to be available for any comparison areas.

M-distances are used to quantify how similar areas are to "ideal" areas or parameters, in this case habitat. Thus, using M-distance limits our predictive power to a set of ideals that many BTPI may not adhere to, especially if the species is plastic regarding habitat use and nest site selection. The BTPI M-distance nest model (Figure 4) was undoubtedly hindered by our low sample size for nest locations, but probably corresponds loosely to actual BTPI nest habitat.

We documented BTPI nests in a variety of habitat types (e.g., ponderosa-oak, spruce-fir and ponderosa-juniper associations) and landscapes (e.g., urban, remote, burned and unburned areas) and correspondingly located nests in different tree species. Thus, BTPI nest site preferences appear to vary and may be more plastic than previously believed and may be difficult to predict, even with larger sample sizes.

Much like the nesting habits of other bird species, the BTPI nesting cycle consists of four phases: courtship and breeding; nest construction, incubation; and hatching to fledgling development. Nest construction usually requires 3-6 days (Peeters 1962). The incubation phase has been documented to last 16-22 days (MacGregor and Smith 1955) and hatchlings fledge at 24-31 days (White and Braun 1978). We used these approximate time frames to extrapolate nest chronologies for specific BTPI nests observed during the course of this study. We used the minimum and maximum nest building days to extrapolate back dates to BTPI nest initiation. We then estimated BTPI hatchling dates for each located nest by using the minimum hatch dates available for BTPI and assuming that the nest was early in the incubation phase when discovered. Minimum fledgling dates were also used to extrapolate timing of BTPI fledglings to prevent overestimation. Table 5 summarizes the extrapolated nesting chronology windows for individual BTPI nests located in the White Mountains during this study in 2012.

Table 5. BTPI nest chronology extrapolated from available data.

BTPI	Nest Stage	Date Found	Nest initiated (within Range)	Estimated Hatch Date	Estimated Fledge Date	Nest Success
2	Initiation	5/15/2012	5/9-5/12	6/1/2012	6/24/2012	Unknown
4a	Initiation	5/24/2012	5/18-5/21	NA	NA	Fail
4b	Initiation	6/25/2012	6/19-6/22	7/9/2012	8/3/2012	Unknown
19	Hatchling 0-3 days	7/24/2012	7/18-7/21	8/9/2012	9/2/2012	Fledged
21	Fledged	7/18/2012	6/6/2012	6/25/2012	7/18/2012	Fledged
22	Incubation	7/25/2012	7/19-7/22	8/10/2012	9/3/2012	Unknown
23	Incubation	7/25/2012	7/19-7/22	8/10/2012	9/3/2012	Unknown
27	Incubation	8/8/2012	8/2-8/5	8/24/2012	9/17/2012	Unknown
28	Hatchling 12-15 days	8/7/2012	6/23/2012	7/11/2012	7/23/2012	Unknown
33 (Random)	Incubation	8/13/2012	8/7-8/10	8/29/2012	9/22/20012	Unknown

BTPI nests have been documented into late October (Corman and Wise-Gervais 2005). The hunting season for BTPI in Arizona is brief (Sept. 7-30), and limited to 5 birds per day per person with a maximum of 10 BTPI per person. However, no imposed tag limit exists as there is a comparatively limited interest in BTPI amongst hunters and falconers. BTPI breed from May-October, and we confirmed that the hunting season overlaps with the end of BTPI breeding. BTPI also exhibit flock foraging behavior and high foraging area habituation and fidelity, making them especially vulnerable when baited. Thus, despite the limited hunting season and interest within the hunting community towards BTPI, the timing of the hunting window and bag limit may hinder population growth or be detrimental to the species in Arizona.

Many of the BTPI tracked during the course of this study used the White Mountain Tribal lands for at least a portion of their routine. It is difficult to ascertain what value the Tribal lands have for BTPI owing to the restricted access during this study. However, it is reasonable to assume that these lands provide important breeding and foraging habitat for this species. Thus, tribal lands may provide an important safe refuge for BTPI due to access limitations for hunters and the general public. Conversely, tribal lands may act as a population sink if areas where BTPI congregate contain unforeseen threats to foraging flocks. Future BTPI studies should include the tribal lands to accurately assess the population viability of this species in Arizona.

Management Recommendations

- The hunting season for BTPI in Arizona is brief (Sept. 7-30), and limited to 5 birds per day per person with a maximum of 10 BTPI per person. However, no imposed tag limit exists as there is a comparatively limited interest in BTPI amongst hunters and falconers. BTPI breed from May-October. The hunting season for BTPI appears to overlap with the breeding window for this species. It would benefit this species if the hunting window was adjusted later to ensure that BTPI breeding has been completed

- This species is vulnerable because of long distance movements to foraging areas, flock foraging behavior and high foraging area fidelity. Foraging areas outside of urban areas where BTPI regularly congregate may provide a hunting sink, where hunters can capitalize on BTPI vulnerability. Additionally, the Wallow fire may have significantly reduced the number of foraging areas outside of urban areas (e.g. riparian vegetation such as elderberries).

- BTPI individuals tracked during this study used the White Mountain Tribal lands. It is difficult to ascertain what value the Tribal lands have for BTPI owing to the restricted access during this study. However, it is reasonable to assume that these lands provide important breeding and foraging habitat for this species. Future BTPI studies should include the tribal lands (contingent upon tribal cooperation) to accurately assess the population viability of this species in Arizona.

- BTPI nested in a variety of habitat types (e.g., ponderosa-oak, spruce-fir and ponderosa-juniper associations) and landscapes (e.g., urban, remote, burned and unburned areas) and correspondingly located nests in different tree species. Nest site preferences appear to vary and may be difficult to predict, even with larger sample sizes. Forest management practices should include a diverse array of potential BTPI nest tree species.

- The average basal area for stands containing BTPI nests was 134 m^2 and ranged from 20 to 290 m^2. The quadratic mean diameter ranged from 16.9 to 70.7 cm with an average of 37.5 cm. Vegetative structural stages for BTPI nest stands ranged from 3 to 5 with the majority of the stands characterized by VSS class 4 based on the quadratic mean diameter for each stand. Thus, although variable, forestry management practices should favor VSS class 4 with an average basal area of 134 m^2 and an average quadratic mean diameter of 37.5 to support BTPI nesting. However, these results should be interpreted with caution do to our small sample size.

- The average DBH (cm) for all trees across all plots within BTPI nest sites was 33.98 cm (SE 4.82). Average canopy cover for all trees across all BTPI nest sites was 39.97 % (SE

6.21). Average distance to the lowest live branch (bottom live crown) was 5.92 m (SE 1.02). Average tree height was 13 m (SE 1.9). The average DBH for snags across all BTPI nest sites was 39.78 cm (SE 2.13). The average downed tree DBH was 20.45 cm (SE 0.7) and the average downed tree length was 8.9 m (SE 0.9). BTPI nest site selection appears to be extremely variable. Correspondingly, it is difficult to make forestry management recommendations for this species based on our small sample size and apparent plasticity of this species regarding nest site selection.

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