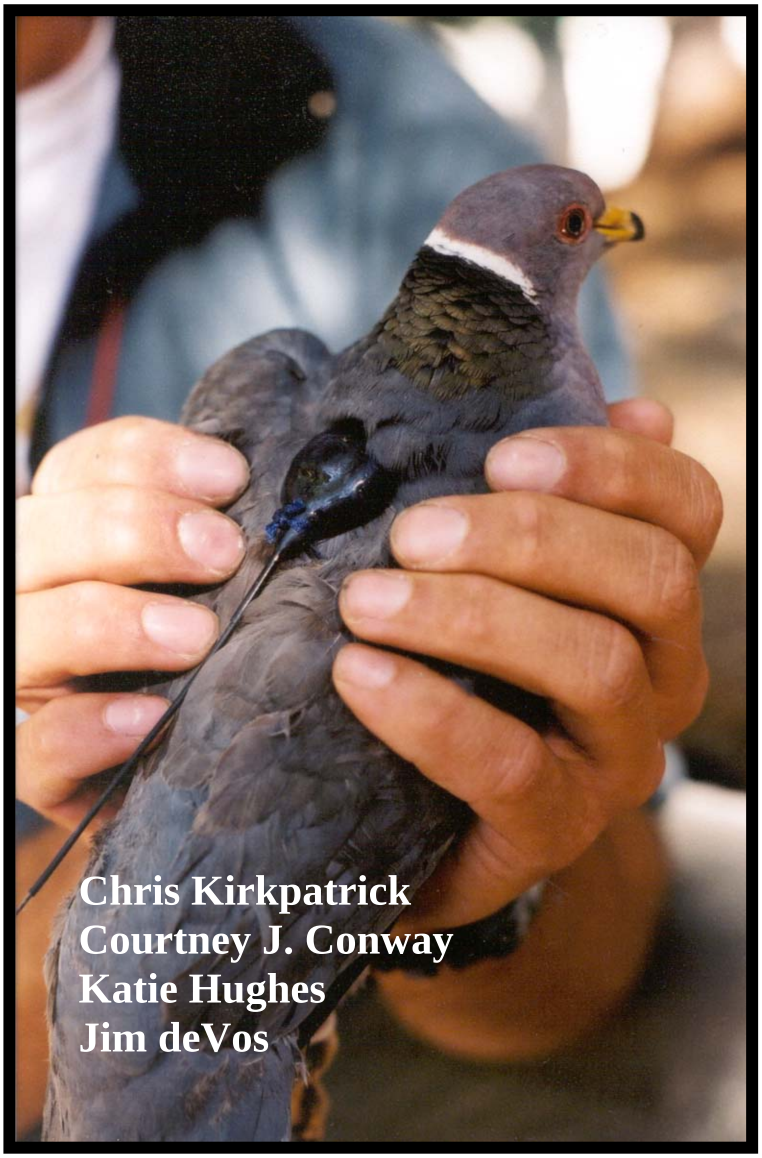
ARIZONA COOPERATIVE FISH AND WILDLIFE RESEARCH UNIT - FEBRUARY 2005

An Evaluation of Survey Methods for Monitoring Interior Populations of Band-tailed Pigeons



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Wildlife Research Report #2005-03

Funding Provided by:

An Evaluation of Survey Methods for Monitoring Interior Populations of Band-tailed Pigeons

Final Report

Submitted to:

U.S. Fish and Wildlife Service
Webless Migratory Game Bird Research Program

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15 February 2005

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Suggested citation: Kirkpatrick, C., C. J. Conway, K. Hughes, and J. deVos. 2005. An evaluation of survey methods for monitoring interior populations of band-tailed pigeons. Final Report. Wildlife Research Report #2005-03, U.S. Geological Survey, Arizona Cooperative Fish and Wildlife Research Unit, Tucson, AZ.

ABSTRACT

Harvest data from the southwestern U.S. indicate that populations of the interior sub-species of band-tailed pigeon (*Patagioenas fasciata fasciata*) have declined since the late 1960's. Management of these populations requires better knowledge of the distribution, abundance, and population trajectory of the species. However, no standardized protocol currently exists for monitoring band-tailed pigeons in the interior region. From 2002 to 2004, we evaluated 5 potential survey methods (short-duration auditory surveys, longer-duration auditory surveys, call-broadcast surveys, capture-recapture, and bait-site counts) in an attempt to identify a precise, accurate, and cost-effective survey method for monitoring interior populations of band-tailed pigeons. Because information on band-tailed pigeon natural history is lacking, we also collected data on breeding biology, reproductive success, nest site characteristics, rate of *Trichomoniasis* infection, movement patterns, and potential causes of mortality for band-tailed pigeons by trapping pigeons and tracking radio-marked pigeons. In addition, we collected data on the effects of recent wildfires on band-tailed pigeons and estimated the population trajectory of band-tailed pigeons in the Santa Catalina Mountains by repeating a survey originally conducted in the late 1960s. Our primary study site was located in the Santa Catalina Mountains, Arizona, but we also conducted fieldwork in 4 additional mountain ranges in southeastern Arizona and in mixed-conifer forests throughout the state. Use of call-broadcast increased the average number of pigeons detected during surveys by 22% and increased the number of replicate surveys with ≥1 pigeon detection by 16% compared to strictly auditory survey methods. Moreover, based on estimates of detection probability, use of call-broadcast increased both the accuracy and precision of band-tailed pigeon counts during surveys. Relative to other survey techniques, we found that capture-recapture and bait-site counts were the least effective survey methods and will likely be of limited use for monitoring band-tailed pigeons in southeastern Arizona (and perhaps elsewhere in the interior region). The rate of *Trichomoniasis* infection was low (4%) for birds trapped in the Santa Catalina Mountains. By tracking radio-marked pigeons, we observed movements of band-tailed pigeons up to 105 km between 4 mountain ranges in southeastern Arizona and located 12 band-tailed pigeon nests that were initiated between May and August. Overall nest survival was low (0.335) and 50% of the nests that failed were known (or suspected) to have been depredated. Most nests were placed in coniferous trees located on north-facing slopes in mixed-conifer forest. Compared to other forest types, we detected *cooing* band-tailed pigeons more frequently at survey points located in mixed-conifer forest in southeastern Arizona. Density of *cooing* band-tailed pigeons in mixed-conifer forest throughout the state was low (0 = 0.0044 [SE = 0.0012] pigeons/ha). We were unable to detect an association between band-tailed pigeons and evidence of recent fire at survey points, nor were we able to detect a difference in relative abundance of band-tailed pigeons at survey points before and after recent wildfires. Numbers of band-tailed pigeons appear to have declined substantially (82%) in the Santa Catalina Mountains since the late 1960s. We recommend that managers begin regular call-broadcast surveys in at least some portions of band-tailed pigeon habitat in Arizona (and perhaps elsewhere in the interior region) to monitor trends for interior populations of band-tailed pigeons. Further research is needed to examine the impact of potential limiting factors on interior populations of band-tailed pigeons including mortality risks for adults and factors contributing to the low nest success rate observed during this study.

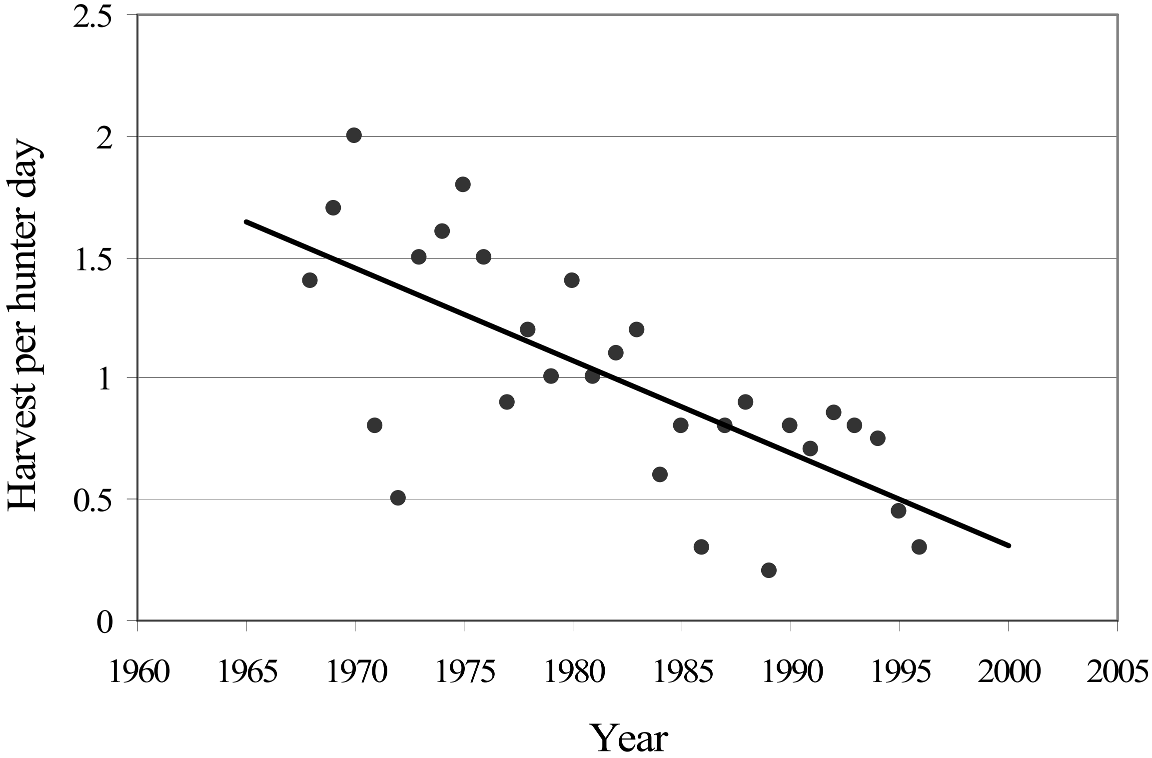
INTRODUCTION

The band-tailed pigeon (*Patagioenas fasciata*) is a migratory game bird that inhabits forest and woodland of western North America. A coastal sub-species (*P. f. monilis*) breeds in California, Oregon, Washington and British Columbia and an interior sub-species (*P. f. fasciata*) breeds in Mexico, Colorado, Utah, New Mexico, and Arizona (Braun 1994). Survey data from several independent sources indicate population declines of the coastal sub-species over the past 30 years (Braun 1994, Keppie and Braun 2000). Population trends of the interior sub-species are not available because few surveys have been conducted in the region. Nevertheless, available evidence suggests that we should be concerned about the interior sub-species. For example, overall population size for the interior sub-species is substantially lower than that of the coastal sub-species (Braun 1994) and declines in annual harvest of band-tailed pigeons in Arizona (Fig. 1), Colorado, New Mexico, and Utah suggest that the interior sub-species has experienced substantial population declines (Pacific Flyway Study Committee 2001). Consequently, the band-tailed pigeon has been identified as a priority species of conservation concern at the national level in the Audubon/Partners-in-Flight Watchlist (Audubon Society 2002) and as a priority species of conservation concern at the state level in the Arizona Partners in Flight Bird Conservation Plan (Latta et al. 1999).

Management of the interior sub-species requires better knowledge of its distribution, abundance, and population trajectory. Yet, estimates of these population parameters are not available because no standardized survey method exists for monitoring band-tailed pigeons in the interior region. This is due in part to the inherent difficulties associated with surveying band-tailed pigeons. Marshall (1957, p. 73) observed that, "It is difficult to count band-tailed pigeons because they fly far, the nesting birds flock, and the breeding season is either irregular or very long". Given these difficulties, the development of reliable population monitoring methods is considered one of the top research priorities for the interior sub-species (Braun 1994, Casazza et al. 2000, Keppie and Braun 2000, Pacific Flyway Study Committee 2001). Current monitoring programs designed to estimate population trends of all birds in North America (e.g., the Breeding Bird Survey) do not effectively sample the interior subspecies. Survey methods used to monitor the coastal sub-species have either not been tested in the interior region or have met with limited success (Pacific Flyway Study Committee 2001). Other potential survey methods have yet to be evaluated thoroughly in either region.

From 2002 to 2004, we collected data in mountain ranges of southeastern Arizona and in mixed-conifer forests throughout the state to test 5 potential survey methods for monitoring interior populations of band-tailed pigeons. Our primary goal was to compare the accuracy, precision, and cost-effectiveness of these 5 potential techniques; therefore, we estimated parameters associated with these 3 variables by evaluating the 5 survey methods concurrently in mountain ranges with known populations of band-tailed pigeons in southeastern Arizona. Although largely beyond the scope of the current study, we were also interested in seeing how well at least one of these survey methods would work in a random sampling framework. Therefore, after the first year of our study, we analyzed our initial data and selected our two most promising survey methods (short-duration auditory surveys and call-broadcast surveys) for use at random points located throughout mixed-conifer forest in Arizona.

Figure 1. Decline in average number of band-tailed pigeons taken per hunter per day in Arizona from 1968 to 1997. Figure adapted from Pacific and central flyways management plan for the four-corners population of band-tailed pigeons (Pacific Flyway Study Committee 2001). Data are based on questionnaires from a non-random sample of Arizona hunters and the effort to obtain these data was terminated in 1997 (M. Rabe, Arizona Game and Fish Department, pers. comm.).



The 5 potential survey methods that we evaluated were:

1) Short-duration auditory surveys (i.e., 6-minute auditory surveys): Short-duration auditory surveys have been conducted along roads for decades to monitor populations of the coastal sub-species (Keppie and Braun 2000). Only a few attempts have been made to adapt this technique for use in the interior region (but see Fitzhugh 1974) and these efforts have been largely unsuccessful because road access into pigeon breeding habitat is limited, breeding populations are patchily distributed, and density of pigeons is low (Braun et al. 1975, Pacific Flyway Study Committee 2001). The interior sub-species breeds in mountainous terrain where the highest density of nests is found between 1,600-2,700 m elevation in the Southwest (Braun 1994) and access to these breeding areas, especially in the isolated mountain ranges of southeastern Arizona, is primarily by foot rather than by vehicle. Therefore, instead of conducting surveys from a vehicle, we established survey routes by walking along trails, drainages, ridges, and roads (where available) within band-tailed pigeon breeding habitat and conducted 6-minute auditory surveys at survey points along these survey routes.

2) Longer-duration auditory surveys (i.e., 20-minute auditory surveys): Sanders (2000) used a variation of the standard short-duration auditory survey to monitor band-tailed pigeons in the coastal region. Instead of conducting 3-minute surveys at multiple points along road routes (Keppie et al. 1970), he randomly located survey points in band-tailed pigeon habitat near roads and counted pigeons at each point for a longer duration (20 or 60 minutes). These longer-duration surveys at random survey points have been recommended for testing in the interior region (Pacific Flyway Study Committee 2001), but low densities and irregular distributions of pigeons may limit the usefulness of this method. We evaluated the usefulness of longer-duration counts by conducting 20-minute auditory surveys at randomly-selected points along our established survey routes.

3) Call-broadcast surveys (i.e., 6-minute call-broadcast surveys): Call-broadcast surveys have been used successfully with many species of birds to increase the number of detections during surveys and thus increase the efficiency of sampling (Marion et al. 1981). However, the effectiveness of call-broadcast surveys for monitoring band-tailed pigeons has not been tested in either the coastal or the interior region. Broadcasting recorded calls can increase detection for species that are elusive, secretive, or territorial (Marion et al. 1981). Band-tailed pigeons are thought to be territorial though evidence for this behavior is equivocal (Braun 1994). Males occasionally exhibit aggression toward intruding males (Jeffrey et al. 1977, C. Kirkpatrick, pers. obs.) and males increase their rate of calling as the number of calling pigeons in the vicinity increases (Keppie et al. 1970, but see Sanders 2000). These behaviors would increase the probability of an observer detecting band-tailed pigeons during a survey and thus increase the efficiency of sampling efforts. We evaluated this technique by conducting 6-minute call-broadcast surveys at survey points along our established survey routes.

4) Bait-site counts: This technique takes advantage of the habit of band-tailed pigeons to supplement their diet of natural foods with sodium and calcium obtained from mineral sites (Sanders and Jarvis 2000) and waste grains from agricultural fields (Braun 1994). Coastal populations use mineral sites frequently during the breeding season and visual counts of pigeons at these sites are considered the most efficient method for monitoring coastal populations

(Casazza et al. 2000). However, in the interior region pigeons utilize mineral sites to a lesser extent (Neff 1952, Braun 1994) and counts at mineral sites may not be an effective method for monitoring interior populations (Casazza et al. 2000, Pacific Flyway Study Committee 2001). Curtis and Braun (1983a) recommended counting pigeons at baited feed stations; a technique that may work better in areas of the Southwest that lack suitable mineral sites. We evaluated this technique by conducting morning counts of band-tailed pigeons visiting baited feed sites at our primary study area in the Santa Catalina Mountains, Arizona.

5) Capture-recapture: The use of baited feed sites also provides an opportunity to capture, mark, and recapture large numbers of band-tailed pigeons. This capture-recapture (or re-sight) technique may allow estimation of band-tailed pigeon population size and trends. We tested this technique by trapping and color-marking band-tailed pigeons at baited feed sites in the Santa Catalina Mountains and collecting subsequent recapture and re-sight data. The effectiveness of this technique (and the bait-site count technique) depends on attracting large numbers of band-tailed pigeons to baited feed sites. However, interior populations of band-tailed pigeons will switch from one food resource to another as new food resources become available during the year (Braun 1976). The availability of natural food resources (e.g., oak [*Quercus* spp.] acorns or flowers; Neff 1947) may reduce the effectiveness of both capture-recapture and bait-site counts by reducing the number of band-tailed pigeons that visit baited feed sites. To examine how changes in availability of natural food resources may affect these 2 potential survey techniques, we calculated a fruit phenology index (sensu Malizia 2001) for a common band-tailed pigeon forage species (silver-leaf oak [*Quercus hypoleucoides*]) found throughout the Santa Catalina Mountains.

One of the most important factors affecting the accuracy and precision of any survey method is detection probability (P_{detect}; the probability that an observer will record a bird that is present during a survey; Pendleton 1995). An effective survey method should be accurate (i.e., high detection probability), but more importantly, it should be precise (i.e., low temporal variation in detection probability; Johnson 1995). Monitoring efforts commonly ignore variation in detection probability, and thus, make the unrealistic assumption (Barker et al. 1993) that detection probability is constant across time. However, survey data used to estimate trends in population size can be biased if the proportion of birds detected varies temporally (Burnham 1981, Skalski and Robson 1992, Link and Nichols 1994). The estimation of detection probability is considered by some authors to be the "central methodological problem associated with the study of natural animal populations" (Nichols 1992).

By measuring detection probability associated with each of the 5 potential survey methods, we sought to accomplish 2 important objectives. First, we wanted to evaluate the accuracy and precision of these different survey methods by comparing values of detection probability estimated for each method. Second, we wanted to estimate absolute abundance (true population size) by using estimates of detection probability to adjust counts of relative abundance generated during surveys. The probability of detecting birds aurally during surveys (P_{detect}) is the product of 2 components: 1) the probability that a bird sings (P_{sings}); and 2) the probability that a bird is heard given that it sings (P_{heard}). We estimated these 2 components of detection probability associated with auditory surveys and call-broadcast surveys by: 1) recording when each pigeon was detected during each of several different time intervals during our surveys (sensu

Farnsworth et al. 2002); 2) conducting observer-bias detection trials during surveys (sensu Nichols et al. 2000, Conway and Simon 2003); 3) conducting detection trials on active nests (sensu Conway and Kirkpatrick 2001); and 4) conducting detection trials on radio-marked focal pigeons (sensu Conway and Kirkpatrick 2001). We estimated detection probability ($P_{capture/re-sight}$) associated with capture-recapture efforts and bait-site counts by trapping and color-marking birds and collecting capture-recapture/re-sight data during subsequent trapping and counting sessions.

Although the development of a standardized survey protocol remains one of the top management objectives for band-tailed pigeons (Pacific Flyway Study Committee 2001), we also need more information on the breeding biology, reproductive success, habitat needs, and potential causes of mortality for band-tailed pigeons to more effectively manage the species (Braun 1994, Pacific Flyway Study Committee 2001). To address these issues, we collected throat swab samples from pigeons during trapping efforts at feed sites to test for the presence of trichomoniasis (a disease common in *Columbidae*). We also attached radio transmitters to adult pigeons and tracked their movements to locate nests. We visited nests regularly during the breeding season to estimate reproductive success, identify causes of nest failure, and quantify habitat characteristics at nest sites.

In addition, we need more information on the current trajectory and the effects of various habitat disturbances on populations of band-tailed pigeons to better manage the species. We employed several different methods in an attempt to address this lack of information. We estimated population trajectory for band-tailed pigeons in the Santa Catalina Mountains by repeating pigeon surveys conducted from 1968-1970 (Fitzhugh 1974). In an effort to document the effect of fire on band-tailed pigeons, we collected data on burn severity at each survey point and correlated these data with numbers of pigeons detected during surveys. We also repeated surveys in 2004 along routes that had been burned in the Santa Catalina Mountains during wildfires in 2002/2003 and compared these post-burn survey data to pre-burn survey data collected before the wildfires.

To summarize, the objectives of this study were to:

1. Evaluate the accuracy, precision, and cost-effectiveness of 5 potential methods for monitoring populations of interior band-tailed pigeons.

2. Estimate components of detection probability (and variation in detection probability) associated with each of the 5 survey methods.

3. Develop a monitoring technique that can be used to estimate population trends of band-tailed pigeons throughout the interior region.

4. Establish survey routes and collect baseline data so that future monitoring efforts can estimate population trends of band-tailed pigeons in southeastern Arizona.

5. Quantify movement patterns, breeding biology, nest success, and habitat needs of band-tailed pigeons by tracking the movements of radio-marked birds and monitoring nests.

6. Investigate potential causes of mortality for band-tailed pigeons by documenting prevalence of trichomoniasis, determining reasons for nest failures, and recording cause of death for radio-marked birds.

7. Identify the population trajectory of band-tailed pigeons in the Santa Catalina Mountains by repeating band-tailed pigeon surveys conducted from 1968-1970.

8. Examine the effects of recent wildfires on band-tailed pigeons in southeastern Arizona.

The wildfires of 2002 and 2003: In late May and early June of 2002, the Bullock wildfire consumed over 12,000 hectares of forests and grasslands in the Santa Catalina Mountains (our primary study site). Our field crew was evacuated during the fire for obvious safety concerns and only essential fire-fighting personnel were allowed into the Santa Catalina Mountains. The Bullock wildfire was the largest fire in the nation at the time and was given highest national priority by Interagency Fire Management teams. The wildfire was eventually contained, but we were restricted from accessing a major portion of our primary study area for a 3-week period. Hence, we were unable to conduct surveys, trap and count pigeons at baited feed sites, track radio-marked birds, monitor active nests, and conduct detection trials for a substantial period during the 2002 breeding season. In addition, we were prevented from continuing with surveys on 6 of 18 survey routes located within burned areas for the remainder of the field season.

In June of 2003, the 34,300-ha Aspen wildfire burned most of the remaining high-elevation forests and woodlands within the Santa Catalina Mountains. This wildfire burned for over a month and was the largest and costliest wildfire in the nation at the time. Ultimately, more than 300 homes in the mountain town of Summerhaven were destroyed by the blaze. As with the Bullock wildfire, our field crew was evacuated from the Santa Catalina Mountains and not permitted to return to our study site for almost 2 months. In addition, most of our band-tailed pigeon survey routes and baited feed sites were burned. Hence, we were unable to conduct surveys, trap and count pigeons at baited feed sites, track radio-marked birds, monitor active nests, and conduct detection trials for the majority of the 2003 breeding season in the Santa Catalina Mountains.

Because of the Bullock and Aspen wildfires, our sample sizes were smaller and our data were more fragmented than we had anticipated which made it difficult to reach some of our stated project objectives.

METHODS

Study area: We conducted this study primarily in montane forests (mixed-conifer and ponderosa pine) and woodlands (oak, pine-oak, and oak-juniper-pinyon) between 1,500 to 3,000 m elevation in 5 "Sky Island" mountain ranges in southeastern Arizona (Fig. 2). These "Sky Island" mountains are characteristic of a basin and range topography with high-elevation (2,280-3,267 m) mountain ranges separated by low-elevation (762-1,372 m) desert basins. Our study area was located on public lands administered by the Coronado National Forest. We selected our study sites in areas that had known populations of band-tailed pigeons based on knowledge from local resource managers (e.g., AGFD, USFS) and results from an extensive bird survey effort conducted in montane forests in the region in 2000 (Conway and Kirkpatrick 2001). Our principal study site was located in the Santa Catalina Mountains (Pima County) where we conducted surveys and trapped, banded, and radio-marked pigeons. We also conducted surveys in the Chiricahua (Cochise County), Huachuca (Cochise County), Pinaleno (Graham County), and Santa Rita (Santa Cruz County) Mountains. During the second year of the study (2003), we expanded our fieldwork to include surveys in mixed-conifer forests throughout Arizona. These surveys were conducted on the Apache/Sitgreaves (Apache County), Coronado (Pima and Cochise Counties), Kaibab (Coconino County), and Prescott (Yavapai County) National Forests.

Personnel: Fieldwork was conducted by Katie Hughes, Dominic LaRoche, Eduardo Martinez-Leyva, Eric Nolte, and Chuck Seal in 2002; by Kristen Hemmelgarn, Katie Hughes, Greg Gryniewicz, Eduardo Martinez-Leyva, Chris Murray, and Julie Warr in 2003; and by Moez Ali, Kelly Bergstrand, Bryon Cariss, Greg Gryniewicz, Johanna Havelaar, Dominic LaRoche, and Dylan Holstein-Radin in 2004. Chris Kirkpatrick supervised field crews and Dr. Courtney J. Conway supervised all aspects of the project.

Evaluation of Survey Methods Conducted along Survey Routes

Survey routes: We established survey routes within our various study areas to test the effectiveness of 3 of the 5 potential survey methods (short-duration auditory surveys, longer-duration auditory surveys, and call-broadcast surveys). During the first year of the study (2002), we established 10 survey routes in the Chiricahua Mountains, 12 survey routes in the Huachuca Mountains, 18 survey routes in the Santa Catalina Mountains, and 3 survey routes in the Santa Rita Mountains (Figures 3-5; Appendix A). We established survey routes along trails, drainages, ridges, and roads (where available) within areas where band-tailed pigeons had been detected previously (Conway and Kirkpatrick 2001). After our first round of surveys along each route, we dropped any survey routes that were situated in unsuitable pigeon habitat or presented logistical difficulties (2 routes in the Chiricahuas, 4 routes in the Huachucas, and all 3 routes in the Santa Ritas).

During the second year of the study (2003), we established 10 survey routes in the Pinaleno Mountains and expanded the survey area to include 48 survey routes located at 24 randomly selected points in mixed-conifer forest throughout Arizona (Appendix B). The objectives of this statewide survey of band-tailed pigeons were: 1) to collect preliminary data on the distribution of band-tailed pigeons in mixed-conifer forests throughout Arizona; 2) to further test the

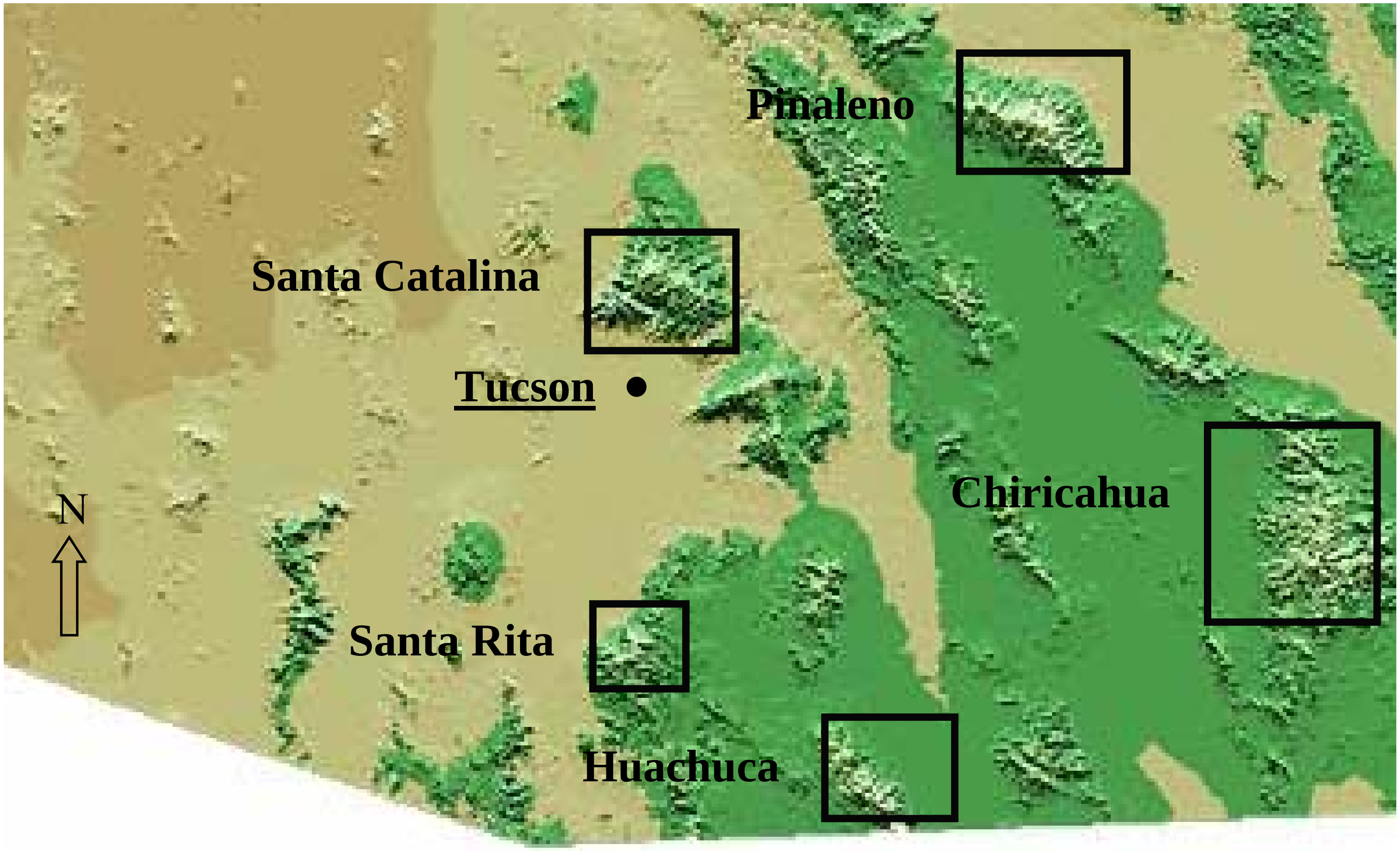


Figure 2. Map of southeastern Arizona showing study sites in the Pinaleno, Santa Catalina, Chiricahua, Santa Rita, and Huachuca Mountains.

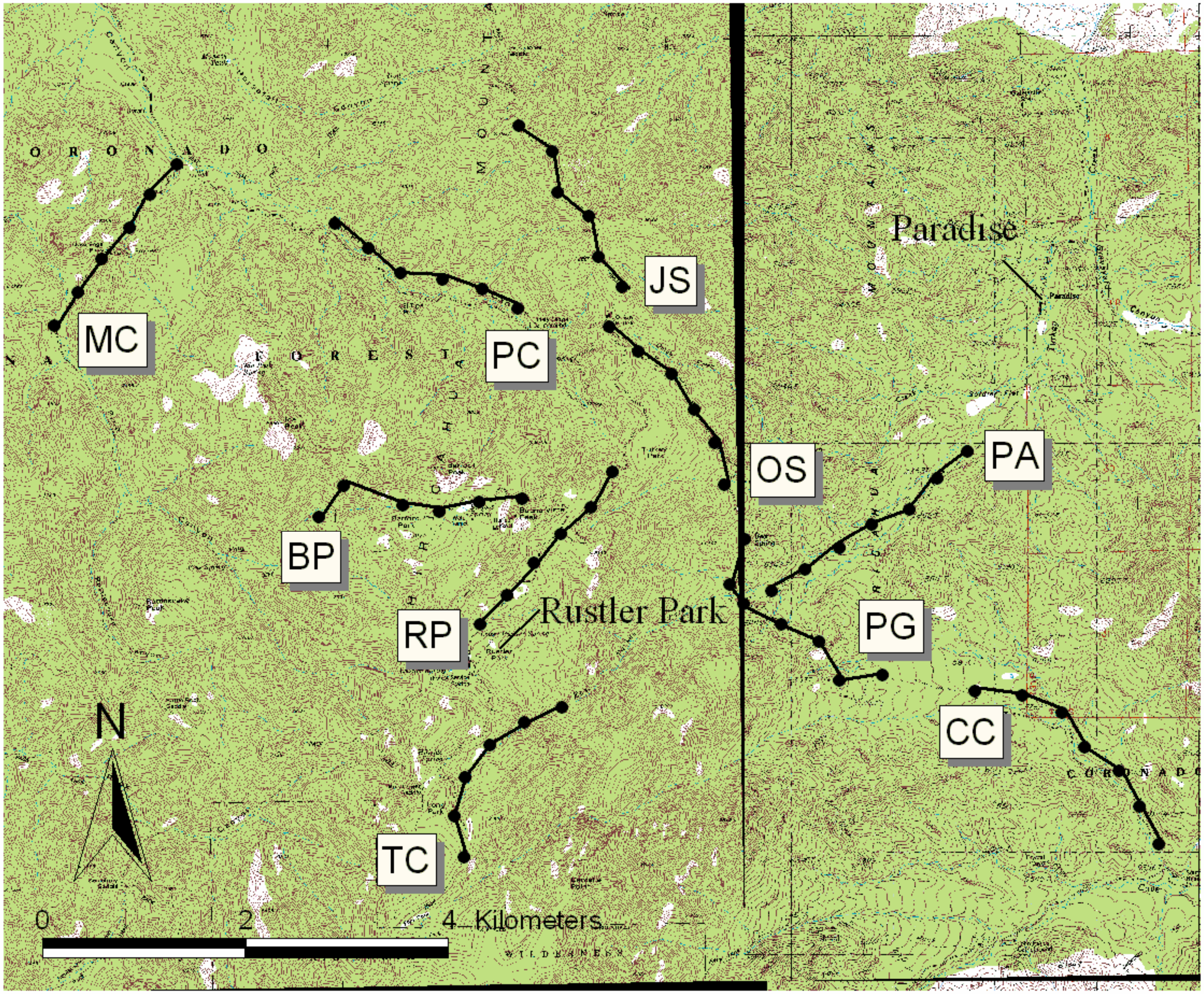


Figure 3. Location of band-tailed pigeon survey routes in the Chiricahua Mountains, Arizona from 2002 to 2003. See Appendix A for expalnation of route codes and UTM coordinates for each point.

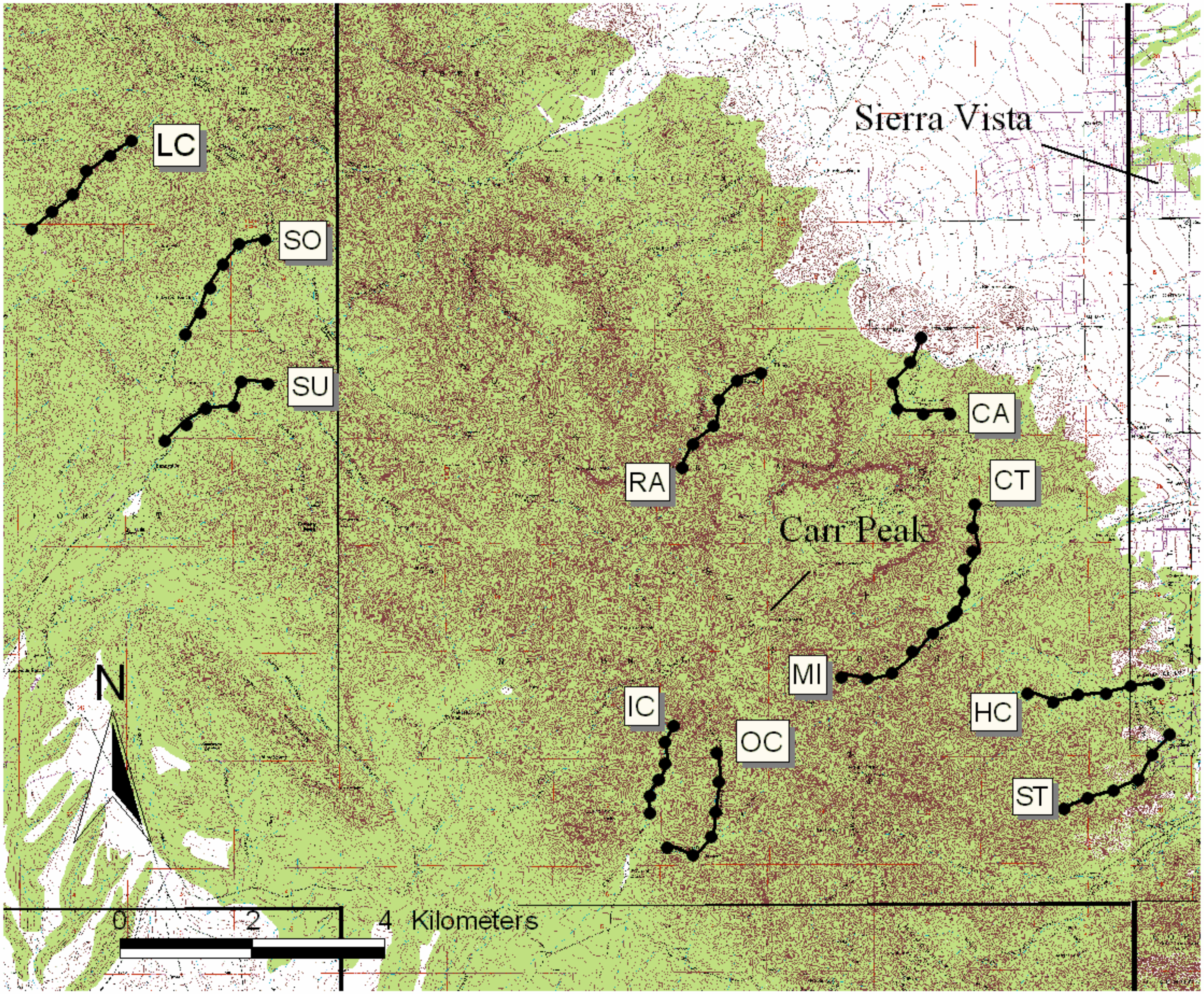


Figure 4. Location of band-tailed pigeon survey routes in the Huachuca Mountains, Arizona from 2002 to 2003 (Lutz Canyon route not shown). See Appendix A for explanation of route codes and UTM coordinates for each survey point.

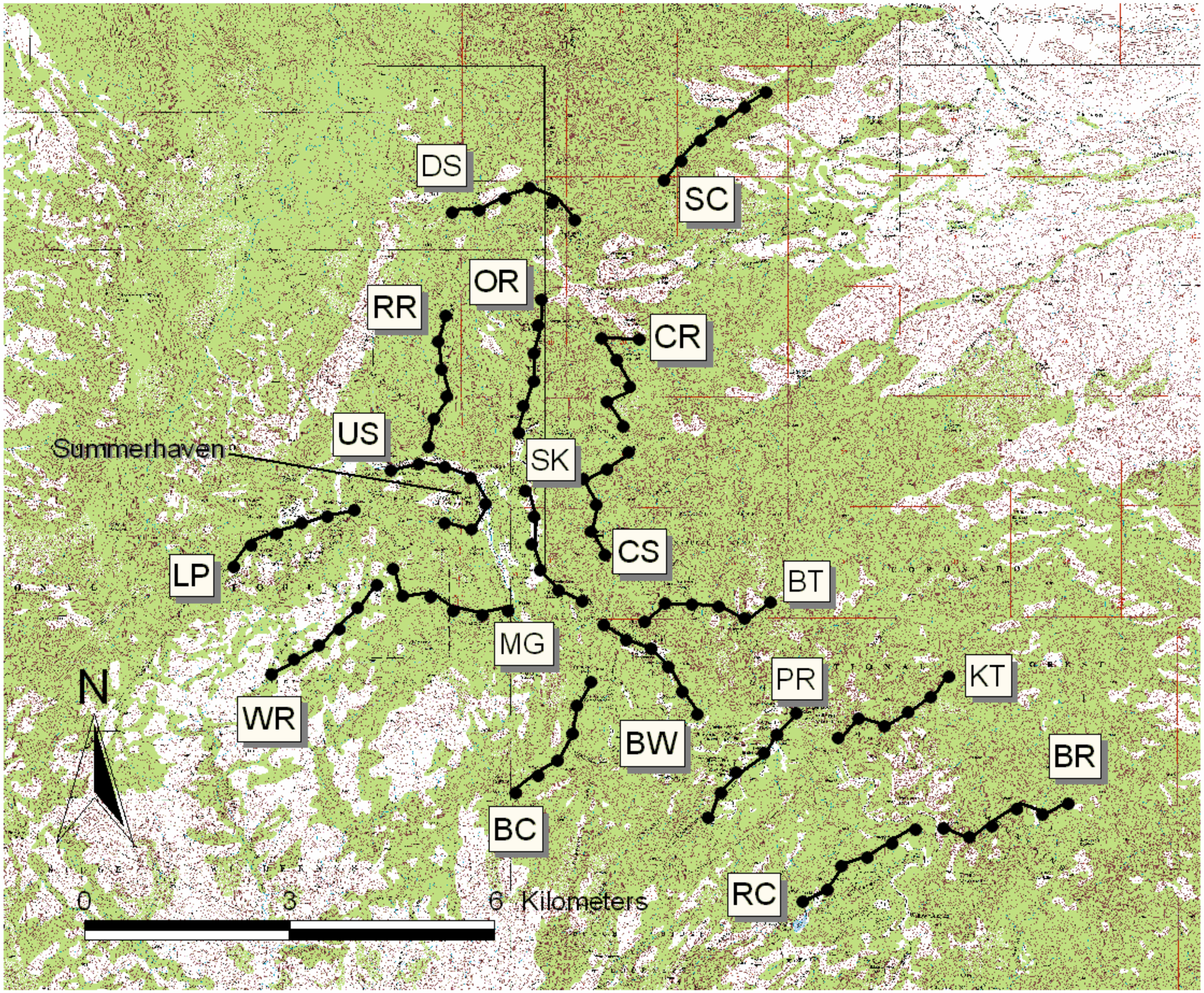


Figure 5. Location of band-tailed pigeon survey routes in the Santa Catalina Mountains, Arizona from 2002 to 2004. See Appendix A for explantion of route codes and UTM coordinates for each survey point.

effectiveness of short-duration auditory surveys versus call-broadcast surveys; and 3) to test the effectiveness of using these 2 survey methods at random locations in band-tailed pigeon habitat to estimate pigeon density and population size. Using a Geographic Information System (GIS), we selected 24 random points in Arizona and established 2 survey routes (starting 500 m apart and running in opposite directions from one another) at each random point. We used the following constraints when selecting the 24 random points with the GIS: 1) points were in 1 of 3 AZ GAPVEG "mixed-conifer" forest types (Douglas fir-mixed conifer, Douglas fir-mixed conifer [Madrean], and Engleman spruce [*Picea englemanni*]; 2) points were within 500 meters of a passable road (TIGER road class 1-4 only); 3) points were in areas with slopes <35 degrees; 4) points were >5 km from one another; and 5) points were not located on private land, the Navajo Reservation, the White Mountain Apache Reservation, or the Grand Canyon National Park. We were unable to survey in these areas because we could not acquire the necessary permits in time (the decision to conduct these statewide surveys was made after the Aspen wildfire limited access to our principal study area). This statewide sampling effort encompassed an area of mixed-conifer forest estimated to be 109,548 ha in size.

The majority of our survey routes were 2 km in length with 6 survey points situated at 400 m intervals along the route. In order to collect additional data, we lengthened a few survey routes to 2.4 km and included a 7th survey point (e.g., Upper Sabino, Santa Catalina Mountains). Several survey routes were <2 km in length due to difficulties completing the entire route (e.g., terrain was too steep after 2-3 survey points on proposed route). We used a hand-held Global Positioning System (GPS) receiver to determine the distance between survey points and document the exact location (UTM coordinates) of each survey point to facilitate future survey efforts (Appendices A and B). Within our 3 principal study areas (Chiricahua, Huachuca, and Santa Catalina Mountains), we stratified survey routes by vegetation type so that approximately 1/3 of survey routes were within mixed-conifer forest, 1/3 were within ponderosa pine forest or pine-oak woodland, and 1/3 were within oak or oak-juniper-pinyon woodlands. Some routes contained a mixture of different forest types because of the large elevation change encompassed by the routes; therefore, we recorded the forest type found at each survey point while conducting surveys along each route (Appendices A and B).

Timing of surveys: We conducted surveys for band-tailed pigeons along our survey routes beginning in late-April and continuing through mid-August (the breeding season for most band-tailed pigeons in southeastern Arizona; Fitzhugh 1974). Each survey began 15 minutes before local sunrise and ended <2 hours after sunrise; the time period in which band-tailed pigeons vocalize most frequently (Keppie et al. 1970, Fitzhugh 1974). During the 2002 field season, the Bullock wildfire interrupted surveys on all routes in the Santa Catalina Mountains for 3 weeks starting 26 May and prevented access to 6 routes for the duration of the field season. During the 2003 field season, the Aspen wildfire prevented access to all survey routes in the Santa Catalina Mountains from 17 June to 15 August.

Standardization of surveys: We conducted surveys on days without rain and when average wind speed did not exceed 11 km/hr (we recorded wind speed at each survey point using a hand-held anemometer; Keppie et al. 1970, Pacific Flyway Study Committee 2001). In addition, we always conducted replicate surveys in the same direction along each survey route. Prior to the start of fieldwork, we trained all personnel in the identification (both visual and aural) of band-tailed pigeons and the estimation of distances (m) to broadcasts of recorded band-tailed pigeons during practice surveys. Finally, all personnel took a hearing test in 2003 and 2004 to ensure that their hearing was within the normal range before the start of the field season.

Short-duration auditory surveys and call-broadcast surveys: To test the efficacy of call-broadcast surveys relative to auditory surveys, we conducted a 6-minute auditory survey followed immediately by a 6-minute call-broadcast survey at each survey point along each survey route. This paired survey design increased the power of our statistical tests and thus increased our ability to detect differences between these 2 survey methods. We conducted replicate surveys (roughly 1 every 3 weeks) along each of our survey routes in our 3 principal study areas (Chiricahua, Huachuca, and Santa Catalina Mountains) in 2002 and 2003 and single surveys along each of our survey routes in the Pinaleno Mountains and at the random points located throughout Arizona in 2003 (these single surveys were conducted primarily in July and early August). We also conducted 1-2 replicate surveys along each of our survey routes in the Santa Catalina Mountains in 2004.

During the 12-minute combined survey period at each survey point, we recorded each band-tailed pigeon that we detected on a separate line of our data sheet (see sample data sheet in Appendix H). For each pigeon detected, we recorded the type and frequency of the detection(s) (visual flying, visual perched, *coo-call*, *chirp*, *grunt*, and *wing-clap*; Keppie and Braun 2000) during specific time intervals within the 12-minute combined survey period. We divided the 6-minute auditory survey into 6 1-minute intervals and the 6-minute call-broadcast survey into 4 1.5 minute intervals (a 15- to 30-second broadcast interval followed by a 60- to 75-second silent interval with this pattern repeated 4 times). We also estimated the distance (m) to each pigeon and determined whether each pigeon was a repeat detection (i.e., a pigeon that was also detected earlier during the survey at a previous survey point).

For the call-broadcast sequences, we created 4 broadcast tracks using vocalizations from 4 different band-tailed pigeons recorded in Oregon (T. Sanders pers. comm). We did not use recordings of band-tailed pigeons from the interior region because the quality of available recordings was poor. In the first year of the study (2002), we used 4 30-second broadcast tracks consisting of 2 *coo-calls* followed by several *chirps* and a *grunt*. We used a portable CD player (Phillips AX5111/17) and a musical power horn (Radio-Shack 32-2037) to broadcast the calls at 80-90 decibels (measured at 1-m from the speaker). We held the power horn at arms length during broadcasts and rotated 45° between each of the 4 broadcast intervals to provide maximum coverage at the survey point. To minimize pseudoreplication of call-broadcasts (Kroodsma 1989), we alternated the use of the 4 broadcast tracks during surveys so that a different track was played on each replicate survey.

We modified our call-broadcast protocol slightly during the second and third years of the study by dropping 1 of the *coo-calls* from all of the broadcast tracks to better simulate the normal rate of *coo-calls* given by band-tailed pigeons (approximately 0.5 per minute; see results below), eliminating *grunts* from all tracks, and removing *chirps* from 2 of the 4 tracks. Consequently, the length of broadcast tracks was slightly shorter (roughly 15 seconds) for each broadcast track in 2003 and 2004. We also used paired amplified computer speakers (Radio Shack models 40-1404 and 40-1432) instead of musical power horns to improve the sound quality of our broadcast. We placed the paired speakers roughly 1 m off the ground (e.g., on a stump, rock, or pack) facing opposite directions and stood roughly 5 m from the speakers during the broadcast.

Longer-duration auditory surveys (i.e., 20-minute auditory surveys): To test the efficacy of longer-duration auditory surveys relative to short-duration auditory surveys, we randomly selected 2 of the 6 survey points along each of the 18 established survey routes in the Santa Catalina Mountains (randomly selected survey points were ≥800 m apart; Appendix A). At these 36 survey points, we conducted a 20-minute auditory survey on either the day before or the day after (order randomly determined for each replicate survey) we conducted the combined auditory/call-broadcast survey on those survey routes. As with the combined auditory/call-broadcast surveys, this paired survey design increased the power of our statistical tests and thus increased our ability to detect differences between short- and longer-duration auditory surveys. We compared these two survey methods in 2002 and 2003.

We recorded the number of pigeons detected and the number and type of detection(s) given by each pigeon during 20 1-minute time intervals during each 20-minute auditory survey. We also estimated the distance to each pigeon (m) and determined whether each pigeon was a repeat detection. In order to collect additional data during the morning survey window, we conducted an additional 20-minute auditory survey at a 3rd survey point along the survey route after the first 2 20-minute auditory surveys had been completed. Whereas the 2 randomly-selected survey points did not change from one replicate survey to another, the location of this additional survey point changed from one survey to the next at the discretion of the observer conducting the survey. Generally, the observer selected the 3rd survey point in an area where pigeons would likely be detected (e.g., a survey point where pigeons were detected during the combined auditory/call-broadcast survey the day before). Combined with data from the 2 randomly selected survey points, we used data from additional band-tailed pigeons detected at the 3rd survey point to measure attenuation in band-tailed pigeon detections through time.

Estimating Detection Probability for Survey Methods Conducted along Survey Routes

We measured 2 components of detection probability (P_{sings} and P_{heard}) associated with short-duration auditory surveys, longer-duration auditory surveys, and call-broadcast surveys using the following methods.

Probability of pigeons vocalizing (P_{sings}) during surveys: We estimated the probability that a pigeon present in the survey area would vocalize during a typical survey (P_{sings}) by recording whether or not band-tailed pigeons were detected aurally during specific time intervals during each survey (sensu Farnsworth et al. 2002). We then generated "detection histories" for each pigeon and used these like one would use "capture histories" in a removal model analysis. We used 6 1-minute sub-segments for the 6-minute auditory survey, 20 1-minute sub-segments for the 20-minute auditory survey, and 4 90-second sub-segments (approximately 15-30 seconds of calls followed by approximately 60-75 seconds of silence) for the 6-minute call-broadcast survey.

Observer detection probability (P_{heard}) during surveys: In 2003 and 2004, we conducted 17 double-observer trials (sensu Nichols et al. 2000) in which pairs of observers independently recorded pigeons during auditory/call-broadcast surveys along survey routes. We used data from these double-observer surveys (using only those surveys where ≥1 pigeon was detected by at least 1 observer) to estimate observer detection probability (P_{heard}) of band-tailed pigeons for the auditory and call-broadcast segments of the survey. For each observer (n = 7), we estimated the proportion of band-tailed pigeons vocalizing that the primary observer detected as:

$$\frac{(\text{\# pigeons detected by primary observer})}{([\text{\# pigeons detected by primary observer}] + [\text{\# pigeons detected only by other observer}])}$$

We then averaged estimates of P_{heard} for the 7 primary observers to generate an overall estimate of P_{heard} for the 6-minute auditory portion of the survey, the 6-minute call-broadcast portion of the survey, and the combined 6-minute auditory/6-minute call-broadcast survey. We did not include observers that were paired with only 1 other observer (n = 5) because of the small sample size of pigeons (often only 1 pigeon) detected by these observers during the single double-observer trial and the potential problem of pairing the primary observer with a single "exceptional" observer (which might artificially depress P_{heard} for the primary observer) or with a single "poor" observer (which might artificially increase P_{heard} for the primary observer).

Detection probability (P_{detect}) during surveys: To generate an estimate of detection probability (P_{detect}) for each survey method conducted along survey routes, we multiplied our estimate of P_{heard} from double-observer trials with our estimates of P_{sings} from modeling detection histories for each survey method.

Detection probability (P_{sings} and P_{heard}) at nests: From 2002 to 2004, we conducted detection trials at nests to estimate the probability that nesting band-tailed pigeons vocalize and the probability that observers detect a nesting pigeon given that it vocalizes (sensu Conway and Kirkpatrick 2001). We controlled for stage of the nesting cycle and distance from the nest site to the observer. In addition, we estimated detection probability separately for male and female pigeons at nests. Nest detection trials were conducted roughly every 3 days on band-tailed pigeon nests that we had located during the breeding season. To make inferences to our survey methods conducted along survey routes, we conducted most of our nest detection trials during the peak survey window (between 15 minutes before sunrise until 2 hours after sunrise) when we would normally conduct morning surveys. In addition, we conducted several nest detection trials later in the morning and in the afternoon.

We recorded whether or not we detected pigeons during a 6-minute auditory survey period (similar to survey protocol used during a 6-minute auditory survey; see above) with the observer initially standing 400 m from the nest (on successive visits to the same nest, we approached the nest from the opposite direction). We moved towards the nest in 100-m increments and repeated a 6-minute auditory nest detection trial every 100 m until we were 100 m from the nest. Following the completion of the auditory detection trial, we conducted a 6-minute call-broadcast nest detection trial in a similar manner except that we randomly-selected the distance from the nest (e.g., 100, 200, 300, or 400 m) at which we started the trial and moved toward the nest (if applicable) in 100-m increments until we were 100 m from the nest. We recorded whether or not we detected pigeons during a 6-minute call-broadcast survey conducted at each distance interval (similar to survey protocol used during a 6-minute call-broadcast survey; see above). To determine if an adult pigeon was at the nest during nest detection trials, a second observer watched the nest from a concealed location 50-100 m away during 82% of the trials and recorded any activity (e.g., vocalizations) that occurred during the trial (we used data collected from both observers to estimate P_{heard}). During 18% of nest detection trials, a single observer conducted the trials and then checked the nest for activity after completing the final trial.

Detection probability (P_{sings} and P_{heard}) of focal pigeons: We conducted detection trials on focal male pigeons to estimate the probability that band-tailed pigeons vocalize and the probability that an observer detects a pigeon given that it vocalizes (sensu Conway and Kirkpatrick 2001). We controlled for the time that the trial was performed and the distance from the focal bird to the observer. We also controlled for the reproductive status of each focal bird by utilizing data collected during trapping (see below). Focal bird detection trials were conducted by 2 observers on radio-marked pigeons (see below) throughout the 2002 breeding season. To conduct a detection trial on a focal pigeon, one observer first located (using a hand-held radio receiver and antenna) and then observed a radio-marked pigeon while another observer initiated a detection trial approximately 50-200 m away from the focal pigeon. The observers used hand-held radios to communicate with one another and coordinate the timing of each trial.

The observer conducting the detection trial recorded whether or not a pigeon was detected during a 6-minute auditory survey followed immediately by a 6-minute call-broadcast survey (similar to the survey protocol used during combined 6-minute auditory/6-minute call-broadcast surveys; see above). The second observer watched the focal bird from a concealed location and recorded any movements or activity (e.g., vocalizations) by the focal bird during the trial (we used data collected from both observers to estimate P_{heard}). We did not conduct a detection trial on the same day that a survey occurred within the area to minimize the potential effects of habituation to the call-broadcast by band-tailed pigeons. In addition, we never conducted >1 detection trial per day on any focal bird.

Evaluation of Capture-recapture and Bait-site Counts

Baited feed sites: Before the start of the study, we contacted local biologists from state and federal agencies to inquire about the location of any mineral springs or established band-tailed pigeon feeding areas in proximity to our study areas. We also posted a similar inquiry to an email listserv that reaches >650 bird watchers in the region. Based on the information that we received, we concluded that there were no mineral springs close to our study areas known to be used by band-tailed pigeons. However, we received several reports of pigeons flocking to feeders at private cabins at higher elevations in the Santa Catalina Mountains and we knew that Fitzhugh (1974; pers. comm.) had trapped band-tailed pigeons at an old cattle salt lick/baited feed site at lower elevations on the north side of this range in the late 1960s.

Therefore, we relocated the baited feed site previously used by Fitzhugh (1974) and, after assessing which backyard bird feeders were attracting the most band-tailed pigeons, sought permission from 6 private land owners in the town of Summerhaven (2,500 m elevation) to trap pigeons on their property. We also selected 5 high-elevation forest clearings located 1-4 km from Summerhaven with the assistance of a biologist who has trapped thousands of band-tailed pigeons (C. Braun, pers. comm.). Starting 1 April 2002, we baited these sites with a mixture of whole and cracked corn (prior to 26 July 2002) and millet and sunflower seed (after 26 July 2002). We had to change our choice of bait because a black bear (*Ursus americanus*) was reported eating corn at one of our bait sites in late July 2002. We spread 0.5-1.0 liters of bait in a 0.5-m radius circle on the ground at each baited feed site on a regular basis (every 2-3 days in 2002 and daily in 2003) so that pigeons would not abandon sites (Braun 1976). In 2003, we visited sites at various times each day and recorded the number of band-tailed pigeons (and any pigeon sign such as tracks or feathers) that we observed at each site. Before leaving each site, we removed pigeon feathers and raked/swept the ground around the bait (C. Braun, pers comm.). We abandoned the Fitzhugh (1974) bait feed site after several weeks of observing no pigeons (or pigeon sign) at the site and after access to the site was limited due to the 2002 Bullock fire.

Bait-site counts: During 2002, we conducted a morning bait-site count approximately once per week from mid-June to mid-August at 4 of the most-frequently visited baited feed sites in Summerhaven. At the baited feed sites where we also trapped pigeons, the majority of the counts were conducted on days when we did not trap. However, we did conduct several bait-site counts concurrent with trapping sessions (e.g., when we monitored sites continuously to guard against potential predators). We avoided counts on weekends to minimize disturbance to foraging flocks at baited feed sites near roads. The Bullock wildfire interrupted bait-site counts at all sites from 26 May to 13 June 2002.

During 2003, we conducted a morning bait site count approximately 2 times per week from early May to mid-June primarily at 1 site located 2-km from Summerhaven that was visited frequently by band-tailed pigeons and where we had trapped only 2 birds during 1 trap day early in the season. We changed the location of our bait-site count to a location where few pigeons had been trapped because band-tailed pigeons learn to avoid trap sites (Kautz 1977; Curtis and Braun 1983a). The Aspen wildfire prevented access to the bait site for the duration of the field season following the start of the fire on 17 June 2003.

To conduct bait-site counts, we used a modified version of a protocol used to count band-tailed pigeons visiting mineral springs in California (Casazza et al. 2000). We sat concealed in a vehicle or hidden in the forest approximately 25 to 75 m from the bait site and used binoculars or a spotting scope to observe pigeons. We counted all pigeons that were observed arriving on the ground to feed during each half-hour interval of the count period and the maximum number of pigeons observed on the ground at any one time during the entire count period. Bait-site counts began <1 hour after sunrise and generally continued for 3-4 hours. We also conducted 2 afternoon bait-site counts in 2003.

Detection probability for bait-site counts: To estimate the probability that individual pigeons visit baited feed sites ($P_{re\text{-}sight}$), we collected re-sight data from banded pigeons that were observed during bait-site counts and from banded pigeons that were detected when baiting sites on a regular basis.

Capture-recapture: In 2002, we trapped band-tailed pigeons approximately 4 times per week from mid-June to mid-August at 3-5 of the baited feed sites in Summerhaven and 1 baited feed site located 4-km away in a forest clearing near Mt. Bigelow. We trapped at baited feed sites where we observed the most band-tailed pigeon activity and avoided trapping on the weekends to minimize disturbance to foraging flocks at baited feed sites near roads and other areas frequented by the public. If we were not catching pigeons at a particular site, we moved the trap site to a more productive location early in the breeding season. The Bullock wildfire interrupted trapping at all trap sites from 26 May to 13 June 2002. In 2003, we trapped band-tailed pigeons approximately 3 times per week from early May to mid-June at 4-5 baited feed sites in Summerhaven. The Aspen wildfire prevented access to all trap sites for the remainder of the field season following the start of the fire on 17 June 2003. In 2004, we trapped pigeons approximately 3 times per week from early May to early August at 4-5 baited feed sites in Summerhaven.

We trapped band-tailed pigeons at each bait site using 1-2 funnel traps (91.4 x 91.4 x 25.4 cm each) constructed of 2.5 x 5.1 cm welded wire (Braun 1976, C. Braun, pers. comm.). We cut 2 entrances (10.1 x 15.2 cm) on either side of the trap and equipped each entrance with a narrowing funnel (25.4 cm long) leading into the interior of the trap where most of the bait was located. Generally, we opened traps just before sunrise and checked traps once every 2-3 hours until the early afternoon. To assure the safety of trapped pigeons, we decreased the interval between trap checks to once every 1-2 hours during warmer weather and monitored sites continuously while trapping if there was a chance that a predator (e.g., grey fox [*Urocyon cinereoargenteus*]) might attack trapped pigeons at that site.

Effects of pigeon decoys on trap success: During each trap day in 2004, we placed 2 groups of band-tailed pigeon decoys on the ground at 2 randomly-selected baited feed sites to test whether the presence of decoy pigeons would attract band-tailed pigeons in greater and more consistent numbers to these sites. We positioned the decoy pigeons so that they appeared to be feeding (heads down) and placed the flock of decoys in a U-shaped pattern in front of the funnel traps to provide a landing zone (approximately 1.5 m in diameter) for approaching band-tailed pigeons within the decoy flock. The band-tailed pigeon decoys were created using “flexi” wood pigeon (*Patagioenas palumbus*) decoys (Dowlings Ironwork and Fieldsports, Beaconfield, United Kingdom) that we painted to resemble adult band-tailed pigeons. We placed one group of 5 decoys at a single randomly-selected trap site for an entire week and moved the second group of 5 decoys from one trap site to the next on successive trap days.

For each captured pigeon, we recorded body mass (g), determined sex and age (by plumage and/or tail length), and identified breeding status by examining crop glands (Fitzhugh 1974, C. Braun, pers. comm.). We banded each pigeon with a USFWS #5 aluminum band and a unique combination of 3 celluloid leg bands (size 3FB; www.avinet.com) of the following colors: black, red, orange, dark blue, light blue, white, light pink. Because band-tailed pigeon tarsi are relatively short, it was necessary to grind the colored bands with a hand-file from 7 to 5 mm in width to assure that they would fit one above the other on the bird’s tarsus. We placed the USFWS band on the left tarsus and used superglue to secure a color band snuggly over the aluminum band. We placed the 2 other color bands on the right tarsus. We trimmed leg feathers if they obscured the color bands.

Phenology index: To estimate a phenology index (sensu Malizia 2001) for silver-leaf oaks in the Santa Catalina Mountains, we established 3 vegetative plots following a point-centered-quarter method at survey points 1, 4, and 6 along each of the 18 established survey routes. Once each month during the first year of the study (2002), we estimated the phenology of silver-leaf oak trees by locating the tree >1.5 meters in height in each of 4 quadrants within a 20-meter radius of the 3 vegetative plots along each survey route. For each tree, we estimated the percentage of the crown that was flowering, the percentage of the crown that had fruit, and the percentage of the fruits that were ripe. We used binoculars to see into the crowns of taller trees and placed our percentage estimates into 1 of 5 categories: 1) 0%, 2) 1-25%, 3) 26-50%, 4) 51-75%, and 5) 76-100%. For example, a tree's crown might be 20% in flower and 45% in fruit (of which 70% are ripe). This tree would receive phenology index values of 2 for flowers, 3 for fruit, and 4 for fruit ripeness.

Detection probability for capture-recapture: We measured the capture probability ($P_{capture/re\text{-}sight}$) of pigeons at baited feed sites by collecting recapture data from banded pigeons that were caught during successive trapping sessions and re-sight data from banded pigeons that were observed incidentally in the area.

Natural History of Band-Tailed Pigeons

To collect data on the breeding biology, habitat needs, movement patterns, and causes of mortality for band-tailed pigeons, we placed radio-transmitters on pigeons captured during trapping sessions in the Santa Catalina Mountains. We placed 7-g radio transmitters on pigeons weighing 300-350 g and 10-g radio transmitters on pigeons weighing >350 g. Transmitters were attached with ribbon to form a backpack harness (Leonard 1998, M. Casazza, pers. comm.), or glued to a patch of trimmed feathers on the back of the bird using superglue gel (2002) or eyelash cement (2003). In addition, a few transmitters were attached using collar mounts in 2003. Because trichomoniasis has been reported in band-tailed pigeons in southeastern Arizona (Sileo and Fitzhugh 1969), we swabbed throats of a subset of captured pigeons in 2003 and cultured these samples to identify the prevalence of trichomoniasis in the local pigeon population.

To maximize our chances of finding nests, we placed radio transmitters primarily on band-tailed pigeons of breeding age (i.e., after-second-year birds) and pigeons that were thought to be active breeders based on examination of crop glands (see above). We placed radio transmitters on male and female band-tailed pigeons because both sexes build nests, incubate eggs, and feed nestlings (Keppie and Braun 2000). In 2002, we placed the majority of our radio transmitters on male pigeons because radio-marked males have been found on nests during a larger proportion of daylight hours than females (Curtis and Braun 1983b, Leonard 1998). This gave us more time to locate nests during ground searches conducted in the middle of the day. In 2003 and 2004, we tracked radio-marked pigeons both from the ground and from the air (average of 1 plane flight per month). Thus, we placed approximately half of our radio transmitters on females so that we could take advantage of morning plane flights to locate females on nests.

We monitored nests every 3-5 days to document laying dates, clutch size, hatching success, and fledging success. We identified the frequency and cause of nest failure whenever possible because predation on eggs and squabs is thought to be an potential factor limiting pigeon populations (Peeters 1962). Following the completion of the nesting cycle, we measured a suite of vegetative features associated with each nest (sensu Leonard 1998) including: the species, diameter at breast height (DBH), and height of the nest tree; height of the nest; distance and azimuth of the nest from bole; and canopy closure measured under the nest. We also measured vegetative and landscape features in a 25-m radius plot centered at each nest tree (forest type, burn severity index [see below]; average height of canopy; dominant or co-dominant tree species in canopy; and slope and aspect across plot; see Leonard 1998).

Effects of Fire on Band-Tailed Pigeons

We correlated data on the visible evidence of fire at each survey point along our auditory/call-broadcast survey routes with data on the number of pigeons detected during surveys along these routes. At each point along our survey routes, we classified visible evidence of burn severity on both sides of the survey transect using the following index: 0) no evidence of fire; 1) low-severity surface fire (evidence of fire-charring on bases [0-0.3 m] of a few trees); 2) medium-severity surface fire (evidence of fire-charring on bases [roughly 0.3-1.5 m above ground] of most trees with a few small oaks and pines killed in understory; 3) high-severity surface fire (almost all understory oaks and pines killed, some oaks re-sprouting, and fire-charring often >1.5 m above ground); and 4) high-severity crown fire (all vegetation killed with some re-growth from stumps and seeds) (Conway and Kirkpatrick 2001). Following the Bullock and Aspen wildfires, we also conducted 1-2 replicate surveys in 2004 along both burned and unburned auditory/call-broadcast survey routes in the Santa Catalina Mountains. We compared these post-burn survey data to pre-burn survey data collected in 2002 and 2003 to identify the direction and magnitude of short-term trends (1 to 2 years) in band-tailed pigeon relative abundance following wildfire.

Band-Tailed Pigeon Population Trajectory in the Santa Catalina Mountains

To identify the population trajectory of band-tailed pigeons in the Santa Catalina Mountains, we repeated band-tailed pigeon surveys that had been conducted along a road route in the Santa Catalina Mountains (Fig. 6) during the breeding seasons of 1968-1970 (Fitzhugh 1974). The exact location and number of survey points along this road route changed from 1968 to 1970; however, the survey covered the same general area from year to year. We used a hand-drawn map and verbal description (E. Fitzhugh, pers. comm.) to relocate the established survey points of the 1970 survey route. This survey route was roughly 8-km in length, had a total of 13 survey points, and began near the summit of Mt Bigelow and finished several kilometers down U.S. Forest Service Road 38. Once we had located the survey points, we recorded the exact location (using a GPS receiver), forest type, and any evidence of recent fire at each survey point (Appendix A). From early May to early September, we surveyed the route once per week (generally midweek to avoid weekend traffic along the route) using a vehicle to traverse the length of the route.

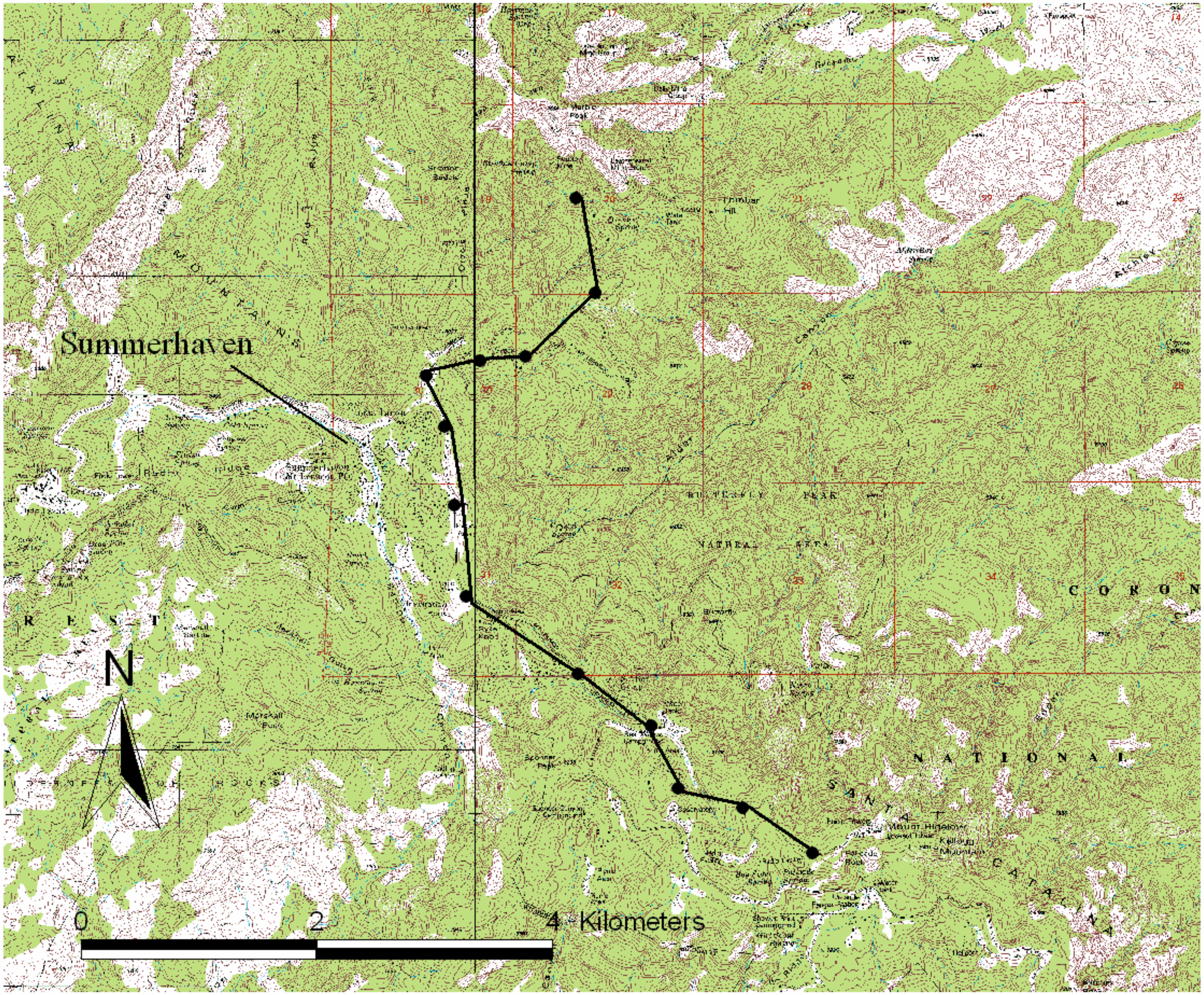


Figure 6. Location of 1970 band-tailed pigeon survey route in the Santa Catalina Mountains, Arizona (Fitzhugh 1974). See Appendix A for UTM coordinates for each survey point.

Following the survey protocol used by Fitzhugh (1974), we started surveys 10 minutes before local sunrise and finished surveys <1 hour after sunrise. We counted all pigeons heard and/or seen during a 3-minute count period at each of the 13 survey points. No surveys were conducted when average wind speeds exceeded 8 km/hr during the survey (measured using a hand-held anemometer). Our weekly surveys were interrupted by the Bullock wildfire for a 3-week period beginning in late May 2002. Because of the subsequent closure of Forest Service Road 38, we were forced to abbreviate the route by excluding the last 4 survey points for the remainder of the field season. The Bullock fire also burned part or all of 8 survey points along the route with the most severe burning occurring at the last 4 survey points on Forest Service Road 38. The Aspen wildfire halted weekly surveys for the duration of the breeding season after 17 June 2003. Because of the closure, our survey data from 2003 did not include the peak period of band-tailed pigeon activity in late June and July (Fitzhugh 1974). We were able to survey the Fitzhugh survey route without interruption during the 2004 breeding season.

Data Analysis

Surveys methods conducted along survey routes: For our comparison of different survey methods conducted along survey routes, we restricted our analyses to data on band-tailed pigeons that we detected aurally. We did this for several reasons. First, we detected 73% of band-tailed pigeons aurally (64% by *coo-calls* alone) during surveys (see below). Second, band-tailed pigeons that were observed solely as flyovers were not associated directly with survey routes. Third, band-tailed pigeons that were observed solely as perching, non-vocalizing birds were observed at only a handful of survey points ($n = 17$) and, unlike other modes of detection, the number of perching, non-vocalizing pigeons detected at these survey points varied dramatically (1 to 19 birds). And finally, for the sake of comparison, other monitoring efforts (e.g., Fitzhugh 1974, Keppie 1970) have recorded only *coo-call* detections during surveys.

We used paired *t*-tests to compare the number of band-tailed pigeons detected at: 1) survey points where we paired a 6-minute auditory survey and a 6-minute call-broadcast survey; 2) survey routes where we paired 6 6-minute auditory surveys (36 minutes total survey time) and 2 20-minute auditory surveys (40 minutes total survey time); and 3) survey routes where we paired 6 12-minute combined auditory/call-broadcast surveys (72 minutes total survey time) with 3 20-minute auditory surveys (60 minutes total survey time). For all analyses, we did not include repeat detections of pigeons recorded at multiple survey points. For the last 2 analyses, we did not include band-tailed pigeons detected during surveys at any additional point (e.g., 7th survey point) along auditory/call-broadcast survey routes. We used a one-tailed paired *t*-test to compare 6-minute auditory and 6-minute call-broadcast surveys because of the presumption that call-broadcasts increase numbers of birds detected during surveys. For each survey method, we also calculated the Coefficient of Variation (% CV) so that we could compare temporal variation in the number of band-tailed pigeons detected among replicate surveys for each survey method.

Probability of pigeons vocalizing (P_{sings}) *during surveys*: Using detection histories for each band-tailed pigeon detected during surveys, we employed closed-population, removal models in Program Capture (Patuxent Software Archive) to estimate the probability of a band-tailed pigeon vocalizing (P_{sings}) during 6-minute auditory surveys, 6-minute call-broadcast surveys, and 20-minute auditory surveys. We standardized statistics (means and standard errors) generated for

P_{sings} during call-broadcast surveys (calculated for 1.5 minute) so that we could compare them to estimates of P_{sings} for 6-minute auditory and 20-minute auditory surveys (calculated for a 1-minute time interval). To do this, we used the following equation:

$$P_{1\text{ min}} = 1 - \sqrt[1.5\text{ min}]{1 - P_{1.5\text{ min}}}$$

We transformed our 1-minute estimates of P_{sings} into estimates of P_{sings} for our 6 or 20-minute survey periods using the following equation (where x equals the duration of the survey period in minutes):

$$P_x = 1 - (1 - P_{1\text{ min}})^x$$

We also estimated P_{sings} for each month during the breeding season (May, June, July, and August) so that we could compare variation (%CV) in P_{sings} through time for 6-minute auditory versus 6-minute call-broadcast surveys.

Detection probability for capture-recapture and bait-site counts: Using encounter histories for each pigeon captured or re-sighted during trapping sessions or bait-site counts, we employed Cormack-Jolly-Sever, open-population models in Program Mark (White 1998) to estimate capture probabilities for each technique.

Effect of pigeon decoys on trap success: We used a paired t-test to compare the mean number of band-tailed pigeons trapped per day at 2 trap sites with pigeon decoys and at 2 trap sites without pigeon decoys during trapping sessions in 2004.

Phenology index: We calculated an overall phenology index value for silver-leaf oak trees in 2002 by first multiplying our indices for flowers, fruit, and ripe fruit for each tree sampled at vegetative plots along survey routes in the Santa Catalina Mountains (e.g., [index of 1 for flowers] x [index of 2 for fruit] x [index of 3 for ripe fruit] = [overall index value of 6]). We then averaged these values across all silver-leaf oak trees for each month during the band-tailed pigeon breeding season (May-August). We also calculated an index for ripe fruit alone by averaging the ripe fruit index values for all trees sampled during each month of the band-tailed pigeon breeding season.

Comparison of 5 survey methods: To evaluate the precision and cost-effectiveness of all 5 potential survey methods, we used data collected in the Santa Catalina Mountains to compare the average number (and % CV) of pigeons detected or caught per daily (and hourly) effort for each survey method. We restricted our comparison of the 5 survey methods to include data only from time periods in which we conducted all 5 survey methods concurrently (i.e., June-August 2002 and May-June 2003) and we excluded data collected from baited feed sites where we initially conducted only 1-2 replicate trap sessions or bait-site counts before moving the baited feed site to a more productive area. Because we trapped and counted pigeons at bait sites more frequently than we conducted surveys along routes, we randomly selected a number of replicate trap sessions and bait-site counts equal to the average number of surveys that we conducted each month (e.g., if 2 replicate surveys were conducted along routes in July 2002, then 2 trap sessions and 2 bait-site counts from July 2002 were randomly selected).

For the purpose of comparison, we treated each survey route, trap site, and baited-feed site as an independent sample. We estimated temporal variance in the average number of pigeons detected, captured, or counted for each survey method by first calculating variance (and % CV) across replicate surveys, trapping sessions, and bait-site counts for each sample and then calculating a weighted average (weighted by number of temporal replicates) for these parameters across all samples. For survey methods conducted along survey routes, we also calculated the average number of pigeons detected per hour per observer by using the estimated time necessary to complete each morning survey: 1.4 hours for short-duration auditory and call-broadcast surveys (0.60 hours for the survey and an average of 0.83 hours to walk between 6 survey points) and 1 hour for longer-duration auditory surveys (0.66 hours for the survey and an average of 0.33 hours to walk between 2 survey points). Because trapping sessions and bait site counts varied in duration, we limited the number of hours for each survey method to the first 4 and 3 hours respectively during the morning so that daily effort was standardized for each temporal replicate.

Nest success: We calculated Mayfield (1961) estimates of daily and overall nest survival using a 50 day nest cycle for band-tailed pigeons (4.5 days building, 1 day laying, 19 days incubation, and 25.5 days nestling; Keppie and Braun 2001). We also calculated daily and overall nest survival values using a 44.5 day nest cycle (19 days incubation and 25.5 days nestling) to compare our results with those from a previous study that measured nest survival using exposure days from the incubation and nestling nest stages only (Leonard 1998).

Effect of fire on band-tailed pigeons: We took 2 approaches to examining the effects of fire on band-tailed pigeons. First, we used logistic regression to examine whether presence/absence of pigeons was correlated with evidence of recent fire recorded at survey points. We used data collected during auditory/call-broadcast surveys in 2002 and 2003 that included only survey routes on which we had collected data on burn severity at the beginning of the study (95 routes and 562 survey points; some routes were burned by wildfires in 2002 before we could collect this preliminary burn severity data; Appendix A). At survey points where the burn severity differed from one side of the transect to another, we calculated a single measure of burn severity by averaging the burn severity class recorded on both sides of the survey transect. To increase the power of our statistical tests, we collapsed burn severity into 3 general classes: 1) no fire (burn severity class 0); 2) less-severe fire (burn severity classes 0.5 to 2); and 2) severe fire damage (burn severity classes 2.5 to 4). We included elevation as a covariate in the regression model to account for the skewed distributions of burned points and band-tailed pigeon detections across elevations. We also included route as a categorical independent variable in the regression model to account for the lack of independence between survey points located along the same route. However, route was not a significant ($P > 0.10$) variable, so we removed it and re-ran the analysis to improve our parameter estimates.

Our second approach to examining the effects of fire on band-tailed pigeons involved comparing relative abundance of band-tailed pigeons at survey points before and after the 2002/2003 wildfires. We averaged the number of pigeons detected by *coo-calls* during replicate surveys at each survey point to come up with a single value for pre-burn relative abundance and a single value for post-burn relative abundance at each survey point. We used the burn severity recorded after the wildfires at each survey point as our between-subjects factor and collapsed our burn severity values into 3 general classes (as described above). We tested the null statistical hypothesis that relative abundance of band-tailed pigeons did not change as a result of the 2002/2003 wildfires (time was the within-subjects factor). Using a repeated measures ANOVA, we calculated a Wilks' Lambda *F*-statistic for within-subjects time-by-group interaction effects.

Distribution of band-tailed pigeons in southeastern Arizona: To determine if band-tailed pigeons were associated with certain forest types, we used a chi-square test of independence to compare the frequency of survey points where we detected or did not detect band-tailed pigeons by *coo-calls* in each forest type (mixed-conifer, ponderosa pine, oak, pine-oak, and oak-juniper-pinyon). For this analysis, we used data collected during replicate auditory/call-broadcast surveys conducted along routes that were surveyed throughout the breeding season in the Chiricahua (n = 8), Huachuca (n = 8), and Santa Catalina (n = 11) Mountains in 2002 and 2003 (Appendix A).

Band-tailed pigeon population trajectory in the Santa Catalina Mountains: We used a two-sample *t*-test to compare the average number of pigeons that we detected during our weekly surveys along Fitzhugh's survey route in 2002, 2003, and 2004 to the average number of pigeons Fitzhugh (1974) detected along this same route in 1968, 1969, and 1970. Because Fitzhugh (1974) conducted from 2-3 replicate surveys per week along the 1 survey route, we calculated an average number of pigeons that he detected per week for our analysis.

RESULTS

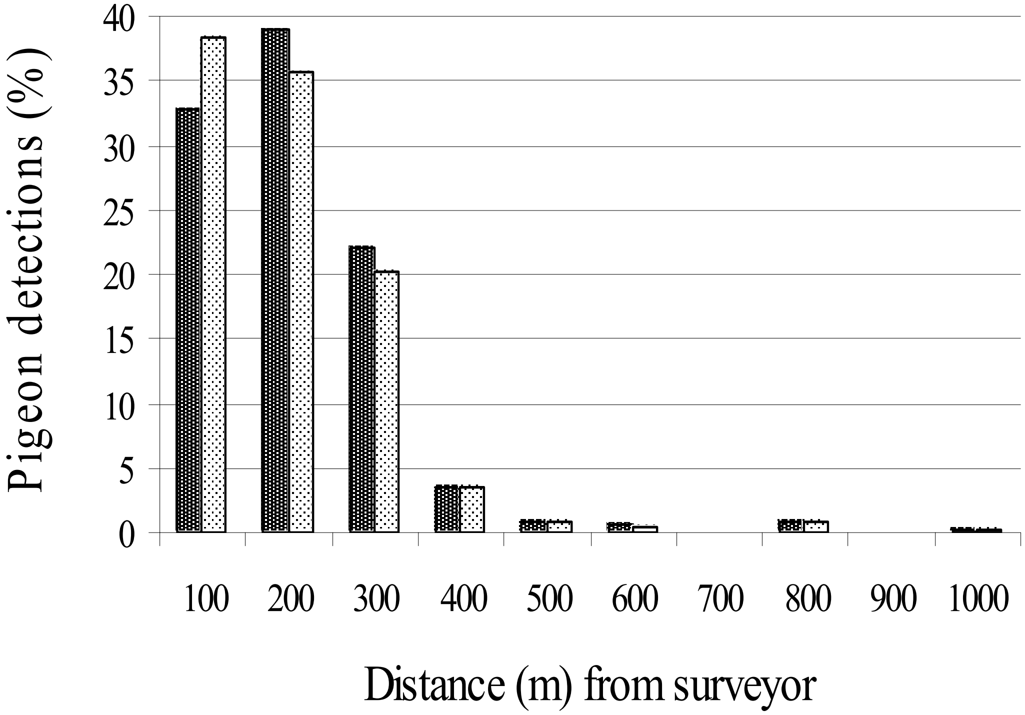
Evaluation of Survey Methods Conducted along Survey Routes

Detection type: From 2002 to 2004, we detected a total of 577 band-tailed pigeons during replicate 6-minute auditory/6-minute call-broadcast surveys, 20-minute auditory surveys (including all 3 survey points), and surveys along Fitzhugh's 1970 pigeon route (note that the number of individual pigeons detected was likely <577 because some unknown percentage of pigeons was probably detected more than once from one replicate survey to the next). Seventy-seven percent of the 577 pigeon detections were made by only 1 detection type (e.g., *coo-call*), 18% were made by 2 detection types (e.g., *coo-call* and *chirp*), and 5% were made by 3 to 5 detection types. Sixty-four percent of the total number of these combined detection types (n = 718) were aural (52.2% *coo-calls*, 9.6% *wing claps,* 1.5% *chirps*, and 0.7% *grunts*) and 36% were visual (27.6% flyovers and 8.4% perched). Of the 577 pigeon detections, surveyors detected 71% by an aural detection type initially (63% *coo-calls*, 7% *wing claps,* and 1% *chirps*) and 29% by a visual detection type initially (24% flyovers and 5% perched). Six percent of the pigeons that were first detected visually were subsequently detected aurally (4% by *coo-calls* alone). Thus, surveyors detected 73% of the 577 pigeon detections aurally (64% by *coo-calls* alone).

Distance to band-tailed pigeons: We estimated distance to a total of 399 band-tailed pigeons detected aurally (362 by *coo-calls* alone) during replicate 6-minute auditory/6-minute call-broadcast surveys, 20-minute auditory surveys (including all 3 morning survey points), and surveys along Fitzhugh's 1970 survey route. The average distance from surveyors to band-tailed pigeons detected aurally and by *coo-calls* alone was 171 m (SE = 6) and 181 m (SE = 6) respectively. Seventy-six percent of band-tailed pigeons detected aurally (and 72% of those detected by *coo-calls* alone) were within 200 m of the surveyor and 94% of band-tailed pigeons detected aurally and by *coo-calls* alone were within 300 m of the surveyor (Fig. 7).

Short-duration auditory surveys and call-broadcast surveys: We conducted a total of 344 replicate auditory/call-broadcast surveys along 101 survey routes (with 597 survey points) from 2002 to 2004. During the 2002 field season, we conducted 130 auditory/call-broadcast surveys from 2 May to 21 August in 4 mountain ranges. Twenty-four surveys were conducted along 10 routes in the Chiricahua Mountains, 28 surveys were conducted along 12 routes in the Huachuca Mountains, 3 surveys were conducted along 3 routes in the Santa Rita Mountains, and 75 surveys were conducted along 18 routes in the Santa Catalina Mountains (Appendix C). During the 2003 field season, we conducted 188 auditory/call-broadcast surveys from 29 April to 17 August in 4 mountain ranges (Appendix D). Forty-two surveys were conducted along 8 of the 10 routes in the Chiricahua Mountains, 38 surveys were conducted along 8 of the 12 routes in the Huachuca Mountains, and 50 surveys were conducted along the 18 routes in the Santa Catalina Mountains. We also completed a single survey pass along 10 survey routes in the Pinaleno Mountains and along 48 statewide survey routes (Appendix E). During the 2004 field season, we conducted 26 auditory/call-broadcast surveys from 13 May to 8 July along 15 of the 18 survey routes in the Santa Catalina Mountains (Appendix F).

Figure 7. The percentage of band-tailed pigeons detected aurally (*n* = 399; light bars) and by *coo-calls* alone (*n* = 362; dark bars) as a function of the distance of band-tailed pigeons from the surveyor.



During the 344 replicate surveys, we detected a total of 211 pigeons aurally (185 by *coo-calls* alone) during the 6-minute auditory survey segment and a total of 241 pigeons aurally (224 by *coo-calls* alone) during the 6-minute call-broadcast survey segment. Average rate of *coo-calls* given by pigeons was 0.45 (SE = 0.03) per minute during 6-minute auditory surveys and 0.46 (SE = 0.02) per minute during 6-minute call-broadcast surveys. Compared to auditory surveys, the use of call-broadcast surveys increased the average number of band-tailed pigeons detected aurally by 15% (0.70 versus 0.61 pigeons detected per survey; paired one-tailed $t = 2.1$; df = 343; $P = 0.019$) and by *coo-calls* alone by 22% (0.65 versus 0.54 pigeons detected per survey; paired one-tailed $t = 2.8$; df = 343; $P = 0.003$). Temporal variation in the number of band-tailed pigeons detected during surveys was approximately similar for the 2 methods (e.g., for pigeons detected by *coo-calls* alone, $CV_{auditory} = 187\%$ and $CV_{call\text{-}broadcast} = 179\%$). Furthermore, the number of pigeons detected by *coo-calls* at survey points was consistently greater during 6-minute call-broadcast surveys compared to 6-minute auditory surveys when looking at results from each of the 6 mountain ranges separately (Table 1). The use of call-broadcasts also increased the percentage of replicate surveys on which we detected ≥1 pigeon by *coo-calls* by 16% (0.36 versus 0.31; paired one-tailed $t = 2.4$; df = 344; $P = 0.007$).

Statewide surveys at random points: Despite using a GIS to select our statewide survey routes in mixed-conifer forests in Arizona, we found that some of these survey routes were actually located in other forest types (e.g., ponderosa pine; Appendix B). Nevertheless, we detected band-tailed pigeons on 17% of 48 statewide auditory/call-broadcast survey routes (5% of 281 total survey points) and detected at least a few pigeons in all of the National Forests that we surveyed (Apache-Sitgreaves, Coronado, Kaibab, and Prescott; see Appendix B). Using these data, we were able to estimate the density and total population size of band-tailed pigeons inhabiting mixed-conifer forests in Arizona (see selection criteria used to define mixed-conifer forest in methods section). To do this, we first adjusted the average number of band-tailed pigeons detected by *coo-calls* during the 6-minute call-broadcast portion of the survey at the 281 statewide survey points ($0 = 0.0463$ [SE = 0.0126] pigeons/survey point) by the estimated detection probability for call-broadcast surveys ($P_{detect} = 0.80$; see below). This gave us an adjusted average of 0.0556 (SE = 0.0151) pigeons/survey point. If we assume an effective survey radius of 200 m at each survey point (the distance at which pigeon detections begin to decline with distance from the surveyor; Fig. 7), our total survey area for our 2003 statewide survey effort was 3,544 ha out of a potential 109,548 ha of mixed-conifer forest in Arizona. This amounts to an average density of 0.0044 (SE = 0.0012) pigeons/ha and a total estimated population size of 483 (SE = 131) pigeons (note that this estimate is for total number of *cooing* males not total number of band-tailed pigeons).

Longer-duration auditory surveys (i.e., 20-minute auditory surveys): We conducted a total of 89 replicate 20-minute auditory surveys along 18 survey routes in 2002 and 2003. During the 2002 field season, we conducted 75 replicate 20-minute auditory surveys from 3 May to 23 August at 2 randomly selected survey points along each of the 18 established auditory/call-broadcast survey routes in the Santa Catalina Mountains (Appendix G). During the 2003 field season, we conducted 14 replicate 20-minute auditory surveys from 30 April to 17 June at the same 2 randomly selected survey points along each of 5 survey routes in the Santa Catalina Mountains that had the most pigeon detections from 2002. We dropped 20-minute auditory surveys from

Table 1. Number of band-tailed pigeons detected by *coo-calls* during 6-minute auditory surveys versus 6-minute call-broadcast during 2,072 replicate surveys[1] at 597 survey points along 101 survey routes in mountain ranges of southeastern Arizona and at randomly located survey routes in mixed-conifer forest throughout Arizona from 2002 to 2004.

Location	Number of Survey Points	Number of replicate surveys at survey points	Percentage of replicate surveys w/ ≥1 pigeon detection	Number of pigeons detected during 6-minute auditory surveys	Number of pigeons detected during 6-minute call-broadcast surveys	Increase in number of pigeons detected by call-broadcast[2]
SE Arizona Mountains						
Chiricahua[3]	63	405	18%	62	68	+9%
Huachuca[3]	72	392	13%	39	44	+11%
Pinaleno[4]	56	56	32%	12	17	+29%
Santa Catalina[5]	109	922	10%	61	80	+23%
Santa Rita[6]	16	16	12%	1	2	+50%
Statewide Arizona						
Mixed-conifer[4]	281	281	5%	10	13	+23%
Total	597	2,072		185	224	+21%

[1] Replicate surveys were conducted along established routes in the Chiricahua, Huachuca, and Santa Catalina Mountains but only a single survey was conducted along routes in the Pinaleno and Santa Rita Mountains and in mixed-conifer forest throughout Arizona.

[2] Percentage increase = 100 x ((# pigeons detected during 6-minute call-broadcast survey)-(# pigeons detected during 6-minute auditory survey))/(# pigeons detected during 6-minute auditory survey).

[3] Surveys conducted from 2002-2003

[4] Surveys conducted in 2003 only

[5] Surveys conducted from 2002-2004

[6] Surveys conducted in 2002 only

the remaining 13 survey routes that had few or no pigeon detections in 2002 to save time and increase our sample size for our comparison of short-duration and longer-duration auditory surveys.

During the 89 replicate surveys, we detected 28 pigeons aurally and 25 pigeons by *coo-calls* alone during counts during our 2 20-minute surveys along each route and 41 pigeons aurally and 40 pigeons by *coo-calls* alone when we included data from our surveys of the 3rd "extra" survey point along each route. We were unable to detect a difference in the number of band-tailed pigeons detected on surveys where we conducted 2 20-minute auditory surveys (40 minutes total morning survey time) versus surveys where we conducted 6 6-minute auditory surveys (36 minutes total morning survey time) in 2002 and 2003. Considering aural detections of band-tailed pigeons, we detected an average of 0.32 (SE = 0.08; CV = 227%) pigeons per route during 2 20-minute auditory surveys compared to an average of 0.34 (SE = 0.08; CV = 219%) pigeons per route during 6 6-minute passive surveys (paired two-tailed $t = 0.24$; df = 88; $P = 0.810$). Similarly, considering only band-tailed pigeon *coo-call* detections, we detected an average of 0.28 (SE = 0.07; CV = 246%) pigeons per route during 2 20-minute auditory surveys compared to an average of 0.29 (SE = 0.07; CV = 234%) pigeons per route during 6 6-minute auditory surveys (paired two-tailed $t = 0.13$; df = 88; $P = 0.901$).

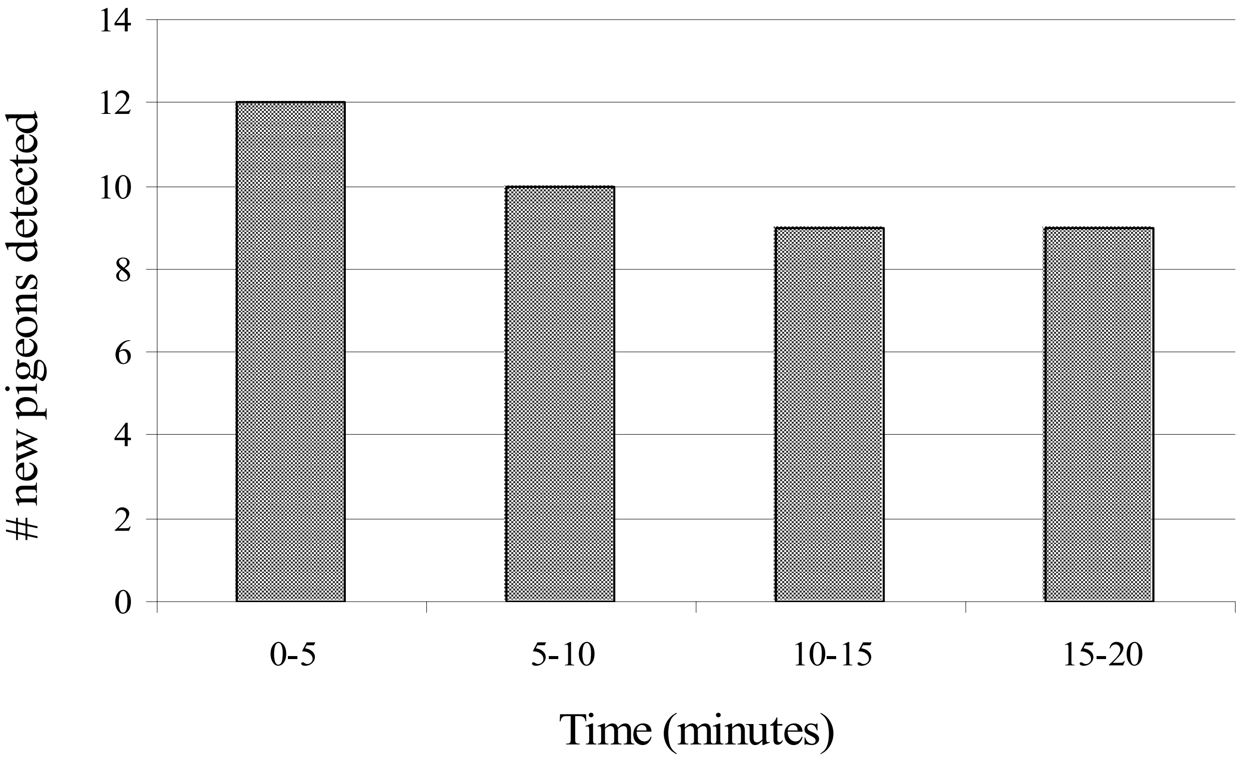
In addition, we were unable to detect a difference in the number of band-tailed pigeons detected on surveys when considering numbers of pigeons detected during 6 12-minute combined auditory/call-broadcast surveys (72 minutes total morning survey time) versus 3 20-minute auditory surveys (60 minutes total morning survey time). Considering only band-tailed pigeon *coo-call* detections, we found an average of 0.54 (SE = 0.12; CV = 210%) pigeons per route during 6 12-minute combined auditory/call-broadcast surveys compared to an average of 0.46 (SE = 0.10; CV = 214%) pigeons per route during 3 20-minute auditory surveys (paired two-tailed $t = 0.61$; df = 88; $P = 0.544$).

Attenuation in pigeon detections: For the 40 pigeons that we detected during our 89 replicate 20-minute auditory surveys (including pigeons detected at 3rd survey points), the percentage of new pigeon detections declined gradually during each 5-minute interval during the 20-minute survey period (Fig. 8). We never reached a point during the survey when pigeon detections declined substantially, suggesting that even longer surveys would have resulted in detections of additional band-tailed pigeons.

Detection Probability for Survey Methods Conducted along Survey Routes

Probability of pigeons vocalizing (P_{sings}) during surveys: We estimated the probability that pigeons would vocalize during surveys (P_{sings}) by modeling detection histories of the 185 pigeons detected by *coo-calls* during the 6-minute auditory survey segment and the 224 band-tailed pigeons detected by *coo-calls* during the 6-minute call-broadcast survey segment (total of only 302 pigeons because some pigeons were detected during both survey segments). Using the most parsimonious closed-capture removal model (M_b), Program Capture (Patuxent Software Archive) produced 2 estimates of population size (N) for our survey area: 1) $N = 250$ (SE = 10) birds using the detection history data from the 6-minute call-broadcast surveys, and 2) $N = 229$ (SE = 17)

Figure 8. Number of new band-tailed pigeons detected by *coo-calls* in each 5-minute interval during 20-minute auditory surveys. Data from 40 pigeons detected during 89 20-minute auditory surveys (including pigeons detected at 3rd survey points) in 2002 and 2003 in the Santa Catalina Mountains, Arizona.



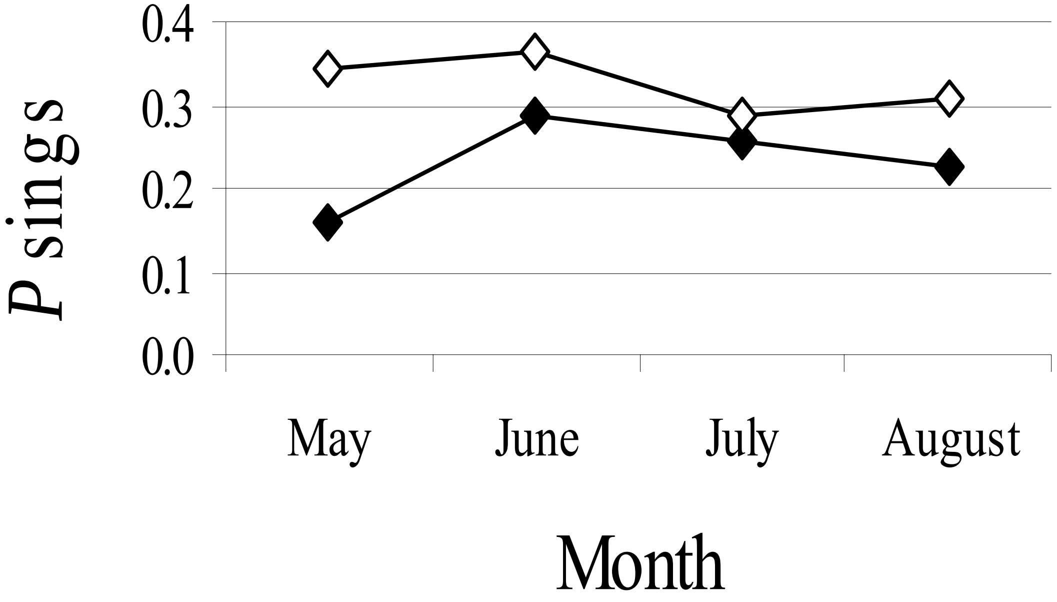
birds using the detection histories from the 6-minute auditory surveys. We were not surprised that estimated population size was greater using data from our call-broadcast surveys because the use of call broadcast can elicit responses from birds that are present in a survey area but would typically remain silent. Therefore, we used this larger estimate of N (i.e., 250 birds) to calculate P_{sings} for both 6-minute call-broadcast and 6-minute auditory surveys.

We found that the P_{sings} was 0.20 (95% CI = 0.14 to 0.28) per minute during 6-minute auditory surveys and 0.31 (95% CI = 0.26 to 0.38) per minute during 6-minute call-broadcast surveys. P_{sings} for a complete 6-minute survey period was 0.74 (95% CI = 0.62 to 0.83) and 0.90 (95% CI = 0.83 to 0.94) for auditory and call-broadcast surveys respectively. The difference between the 2 estimates of P_{sings} suggests that call-broadcast increased the probability that pigeons vocalized during surveys. In addition, we found that P_{sings} was consistently greater for 6-minute call-broadcast surveys compared to 6-minute auditory surveys when looking at estimates of P_{sings} calculated separately for May, June, July, and August (Fig. 9). Moreover, temporal variation in P_{sings} was half as much for call-broadcast surveys (CV = 11%) compared to auditory surveys (CV = 23%) across these 4 months. Much of the difference in temporal variation appeared to be due to the low number of pigeons detected during 6-minute auditory surveys relative to 6-minute call-broadcast surveys in the month of May (Fig. 9).

We estimated P_{sings} during 20-minute auditory surveys by modeling capture histories of the 25 pigeons detected by *coo-calls* at 2 of the 6 survey points along established survey routes. Using the most parsimonious closed-capture removal model (M_b), we found that average P_{sings} during each minute of the 20-minute auditory survey was 0.02 (95% CI = 0.00 to 0.43) and for the entire 20-minute survey period was 0.32 (95% CI = 0.01 to 1.00). For the sake of comparison, we estimated P_{sings} for pigeons (n = 24) detected during the 6 6-minute auditory surveys that we paired with the 2 20-minute auditory surveys in 2002 and 2003 (see methods). Using the most parsimonious closed-capture removal model (M_b), we found that P_{sings} averaged 0.16 (95% CI = 0.04 to 0.46) per minute and 0.65 (95% CI = 0.22 to 0.98) for the entire 6-minute survey period. Although the estimate of P_{sings} for 6-minute auditory surveys appeared to be greater than the estimate of P_{sings} for 20-minute auditory surveys, we lacked the power to show this difference statistically. In fact, we had expected the 2 estimates of P_{sings} to be approximately similar for both techniques. This perceived difference in P_{sings} estimates may simply reflect a chance outcome resulting from our small samples of detection histories for 6-minute auditory surveys (n = 24) and 20-minute auditory surveys (n = 25).

Observer detection probability (P_{heard}) during surveys: We conducted a total of 17 paired auditory/call-broadcast double-observer surveys. At least 1 pigeon was detected by *coo-calls* by ≥1 of the observers during 12 of the 17 double observer surveys (total of 47 pigeons detected by *coo-calls* during 12 surveys). Average detection probability calculated for the 7 observers was 0.85 (range 0.50-1) for the 6-minute auditory survey period, 0.89 (range 0.57-1) for the 6-minute call-broadcast survey period, and 0.89 (range 0.71-1) for the combined 6-minute auditory/6-minute call-broadcast survey. Observers differed in their distance estimates to band-tailed pigeons detected by *coo-calls* during double-observer surveys (0 difference = 69 m [SE = 8.4]).

Figure 9. Temporal trend in estimates of P_{sings} (probability that a band-tailed pigeon would vocalize by *coo-call* during each 1-minute interval of the survey) for 6-minute auditory surveys (solid diamonds) compared to 6-minute call-broadcast surveys (open diamonds) during 4 months of the breeding season in mountain ranges of southeastern Arizona from 2002-2004. For the sake of comparison, we transformed estimates of P_{sings} for 6-minute call-broadcast surveys (initially calculated for a 1.5-minute interval) to a 1-minute interval (see methods).



Detection probability (P_{detect}) during surveys: We multiplied our estimates of P_{heard} from double-observer trials with our estimates of P_{sings} from modeling detection histories (with 1-minute detection probabilities adjusted to the 6- or 20-minute survey periods) to get an estimate of detection probability for each survey method. Overall detection probability was greater for 6-minute call-broadcast surveys (0.80) compared to 6-minute auditory surveys (0.69) and 20-minute auditory surveys (0.32). In other words, an average observer had an 80% chance of detecting a band-tailed pigeon during a 6-minute call-broadcast survey, a 69% chance of detecting a pigeon during a 6-minute auditory survey, and a 32% chance of detecting a pigeon during a 20-minute auditory survey.

Detection probability (P_{sings} and P_{heard}) at nests: We conducted 38 auditory nest detection trials at 9 band-tailed pigeon nests (0 = 4.2 nest detection trials; range 1-9 per nest) from 2002 to 2004. Five percent of the auditory nest detection trials were performed during the building stage, 58% during the incubation stage, and 37% during the nestling stage. Thirty auditory nest detection trials were conducted in the early morning (0511 to 0906) and 8 were conducted in the late morning or afternoon (1000 to 1536). During early morning trials, the female was known to be on the nest 73% of the time and the male was known to be in the vicinity of the nest (approximately 25-500 m away) 20% of the time. During late morning/afternoon trials, the male was on the nest 88% of the time and the female was known to be in the vicinity of the nest 0% of the time. For the 38 auditory nest detection trials conducted at the 9 nests, surveyors did not detect any band-tailed pigeons because no pigeons vocalized (as recorded by the observer at the nest); therefore, the probability of detecting band-tailed pigeons (P_{detect}) during auditory nest detection trials was 0.

We conducted a total of 30 call-broadcast detection trials at the same 9 band-tailed pigeon nests (0 = 3.3; range 1-8 per nest) in 2002, 2003, and 2004. Seven percent of the call-broadcast nest detection trials were performed during the building stage, 60% during the incubation stage, and 33% during the nestling stage. Twenty-four call-broadcast nest detection trials were conducted in the early morning (0542 to 0911) and 6 were conducted in the late morning/afternoon (1103 to 1529). During early morning trials, the female was known to be on the nest 79% of the time and the male was known to be in the vicinity (roughly 25-500 m from the nest) 25% of the time. During late morning/afternoon trials, the male was on the nest 83% of the time and the female was known to be in the vicinity of the nest 0% of the time. For the 30 call-broadcast nest detection trials conducted at the 9 nests, the surveyor detected a band-tailed pigeon during 3 trials. On one occasion, the surveyor detected *coo-calls* from a male at 300 m during the incubation stage and on 2 occasions the surveyor detected *coo-calls* from the same male at 100 and 200 m during the building stage.

The surveyor conducting the trial did not detect 2 nesting males that gave *coo-calls* during call-broadcast nest detection trials (as determined by the observer watching the nest). Thus, the probability of the surveyor detecting a pigeon given that it vocalized (P_{heard}) was 3/5 = 0.60. We were not able to estimate P_{sings} using data from all of our early morning call-broadcast nest detection trials because we could not be sure if the male was near the nest during the trial unless it was a radio-marked bird (we found some nests by luck or by tracking radio-marked females) or if the observer watching the nest spotted a male pigeon near the nest (not a guarantee that the male was associated with the nest, but we assumed this for our trials). Using only data from the

6 call-broadcast nest detection trials for which the presence of the male was confirmed, we calculated that P_{sings} was 0.50 (3/6) and P_{detect} was 0.30 (0.50 x 0.60).

Detection probability (P_{sings} and P_{heard}) of focal birds: We conducted 27 detection trials on 13 radio-marked focal pigeons from 17 June to 15 August 2002 (0 = 2.1 focal bird detection trials per pigeon; range 1-7). All focal pigeons were adult males and the breeding status was known for 10 of these birds at the time of their initial capture (5 had stimulated crops and 5 had unstimulated crops). During the 27 focal bird detection trials, a total of 4 pigeons gave *coo-calls* during the 6-minute auditory survey period (as determined by the observer watching the focal pigeon) of which only 1 was detected by the surveyor conducting the trial. The pigeon that was detected was 98 m from the surveyor conducting the trial and the 3 pigeons that were not detected were at 89, 113, and 320 m from the surveyor. During the 27 focal bird detection trials, a total of 4 pigeons gave *coo-calls* during the 6-minute call-broadcast survey period of which 3 were detected by the surveyor conducting the trial. The 3 pigeons that were detected were 30, 98, and 113 m from the surveyor conducting the trial and the 1 pigeon that was not detected was 320 m from the surveyor. Detection probability for auditory focal bird detection trials was 0.04 (0.15 probability of band-tailed pigeon vocalizing x 0.25 probability of surveyor detecting pigeon given that it vocalized). Detection probability for call-broadcast focal bird detection trials was 0.11 (0.15 probability of band-tailed pigeon vocalizing x 0.75 probability of surveyor detecting pigeon given that it vocalized).

Focal pigeons were detected too infrequently during detection trials to allow us to examine the effect that breeding status or timing of focal detection trials had on detection probability. The low rate of detection may have been due in part to the use of radio-transmitters to locate focal pigeons. Many radio-marked band-tailed pigeons appeared to behave abnormally (e.g., pigeons pecking at transmitters/harnesses or pigeons reluctant to fly relative to other birds). In addition, despite efforts by observers to conceal themselves, some focal birds appeared to be aware of the observer's presence and may have altered their calling behavior consequently. For these reasons, estimates of P_{detect} for band-tailed pigeons based on focal bird detection trials may have been inaccurate (due to potentially biased estimates of P_{sings}). Hence, we abandoned focal bird detection trials in 2003 and 2004 and results from 2002 focal bird detection trials should be interpreted with caution.

Evaluation of Capture-recapture and Bait-site Counts

Bait-site counts: We conducted 22 morning and 2 afternoon counts at 5 baited feed sites (0 = 3.4 counts; range 1-8 per site) in 2002 and 2003. We counted for a total of 87 hours (176 half-hour intervals) and average duration of counts was 208 minutes (range 34-320) in the morning and 229 minutes (range 191-233) in the afternoon. The maximum number of pigeons observed on the ground averaged 5.2 pigeons per count (SE = 1.6; range 0-32). During each of the half-hour intervals, we observed an average of 1.01 pigeons (SE =0.27) on the ground and an average of 0.96 pigeons (SE =0.26) arriving to feed. Pigeons were observed on the ground during 13% of the 176 half-hour intervals.

Capture-recapture: We captured a total of 205 band-tailed pigeons during 86 trap days (total of 2,189 trap hours) from 2002 to 2004. In 2002, we trapped for 32 days (936 trap hours) from 13

June to 7 August and caught at total of 78 pigeons (including 4 recaptures) for an average of 0.082 (SE = 0.16) pigeons caught per trap hour. In 2003, we trapped for a total of 16 days (426 trap hours) from 7 May to 10 June and caught a total of 47 pigeons (including 1 recapture) for an average of 0.097 (SE = 0.032) pigeons caught per trap hour. In 2004, we trapped for a total of 38 days (827 trap hours) from 7 May to 10 August and caught a total of 80 pigeons (including 3 recaptures) for an average of 0.129 (SE = 0.058) pigeons caught per trap hour. Combining data from 2002 to 2004, the average number of band-tailed pigeons caught per trap hour was 0.106 (SE = 0.027). The number of pigeons caught per trap hour was highest in June and July (Fig. 10). We caught more adult males than adult females and fewer hatch-year birds than adults (Fig. 10, Table 2). However, we stopped trapping in mid-August at a time when we would have expected to catch more hatch-year birds (i.e., most nests were initiated in June and July; see below). Average body mass was 332 g (SD = 23.6) for adult males, 312 g (SD = 26.6) for adult females, and 266 g (SD = 46.5) for hatch year birds (Table 2).

Effect of pigeon decoys on trap success: Contrary to our expectations, the use of decoy pigeons at trap sites had a negative effect on the number of band-tailed pigeons caught at these sites. We trapped a total of 62 pigeons during 38 trap days (375 trap hours; 0 = 0.16 pigeons per trap hour) at trap sites without decoys and 9 pigeons during 38 trap days (376 trap hours; 0 = 0.02 pigeons per trap hour) at trap sites with decoys (paired one-tailed $t = 2.4$; df = 37; $P = 0.02$).

Phenology index: The productivity of silver-leaf oak flowers, fruits, and ripe fruits (i.e., acorns) as measured by our phenology index increased as the 2002 season progressed in the Santa Catalina Mountains (Fig. 11). Ripe acorns were present on silver-leaf oak trees in August and to a lesser extent in July (Fig. 11). We saw a decrease in band-tailed pigeon trap success from July 2002 (0.10 pigeons caught per trap hour) to August 2002 (0.04 pigeons caught per trap hour) that was inversely correlated with the increase in availability of ripe silver-leaf acorns observed within our study during the same time period.

Detection Probability for Capture-recapture and Bait-site Counts

An evaluation of trapping data showed that the probability of recapturing pigeons was extremely low (only 8 recaptures of 8 different banded pigeons during a total of 2,189 trap hours). Four pigeons were recaptured during the same year that they were trapped initially, 3 pigeons were recaptured approximately 1 year after they were trapped initially, and 1 pigeon was recaptured approximately 2 years after it was trapped initially. Fifty percent of the 8 recaptured pigeons were recaptured at the trap site where they had been trapped initially. We estimated that the probability of capturing a band-tailed pigeon (P_{capture}) at trap sites during a trapping session was 0.002 (SE = 0.001) using the most parsimonious Cormack-Jolly-Sever model in Program Mark (White 1998). This estimate may be biased because there were relatively few banded birds available to be recaptured during initial trapping sessions in the first year (2002) of our study.

Figure 10. Rate of capture (number caught per trap hour) for adult male, adult female, and hatch-year band-tailed pigeons during trapping sessions at 4-5 baited feed sites in the Santa Catalina Mountains during each month of the breeding season (data combined for June-August 2002, May-June 2003, and May-August 2004).

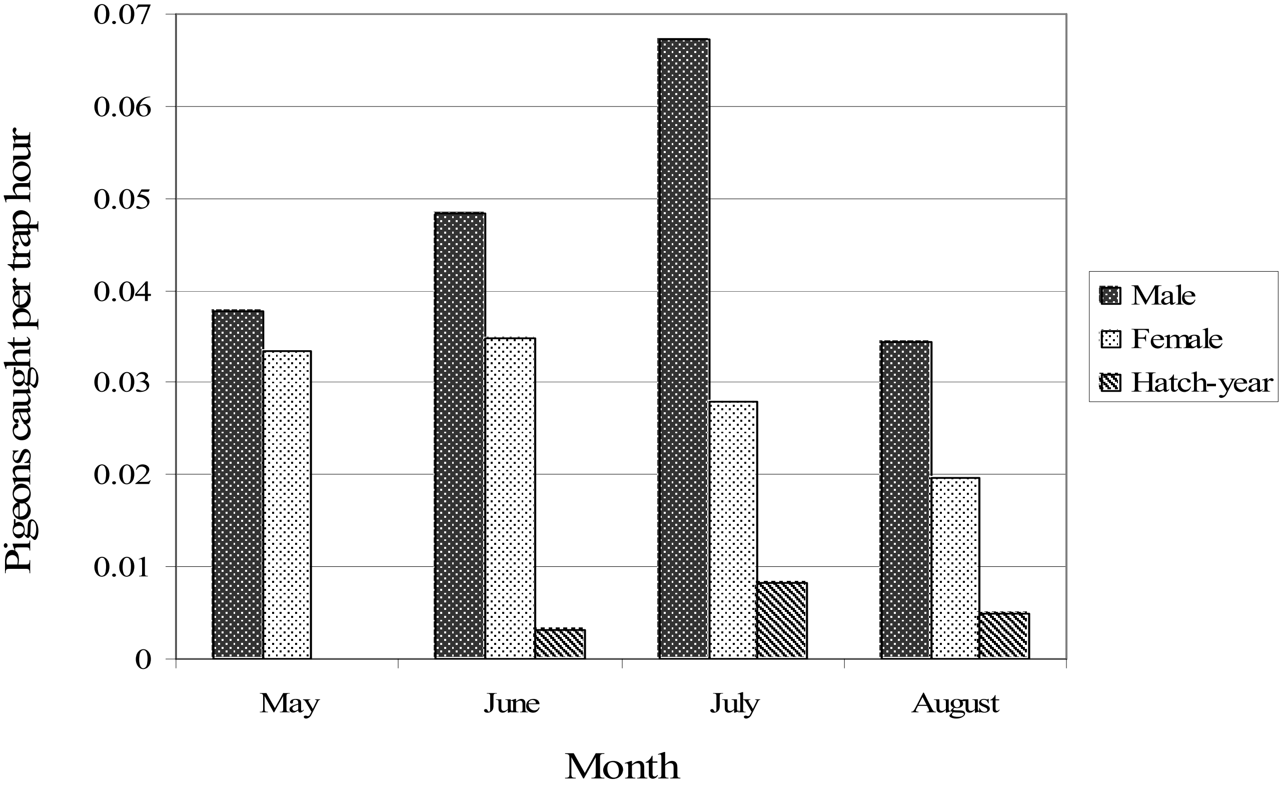


Table 2. Age, sex, and average body mass (SD and range) of band-tailed pigeons caught at trap sites in the Santa Catalina Mountains in June-August 2002, May-June 2003, and May-August 2004. Only pigeons of known sex and/or age included in summary.

			Number of	Body Mass (g)		
Year	Age Class[1]	Sex	Pigeons	Mean	SD	Range
2002	AHY	M	50	335[2]	26.1[2]	282-385[2]
	AHY	F	14	298	17.6	272-329
	HY	U	5	248	34.2	219-300
2003	AHY	M	26	326	20.0	296-372
	AHY	F	17	316[3]	30.7[3]	244-361[3]
2004	AHY	M	36	332[4]	22.1[4]	292-365[4]
	AHY	F	33	316[5]	26.4[5]	268-384[5]
	HY	U	8	281	52.4	213-340

[1] AHY = After Hatch-Year; HY = Hatch-Year.

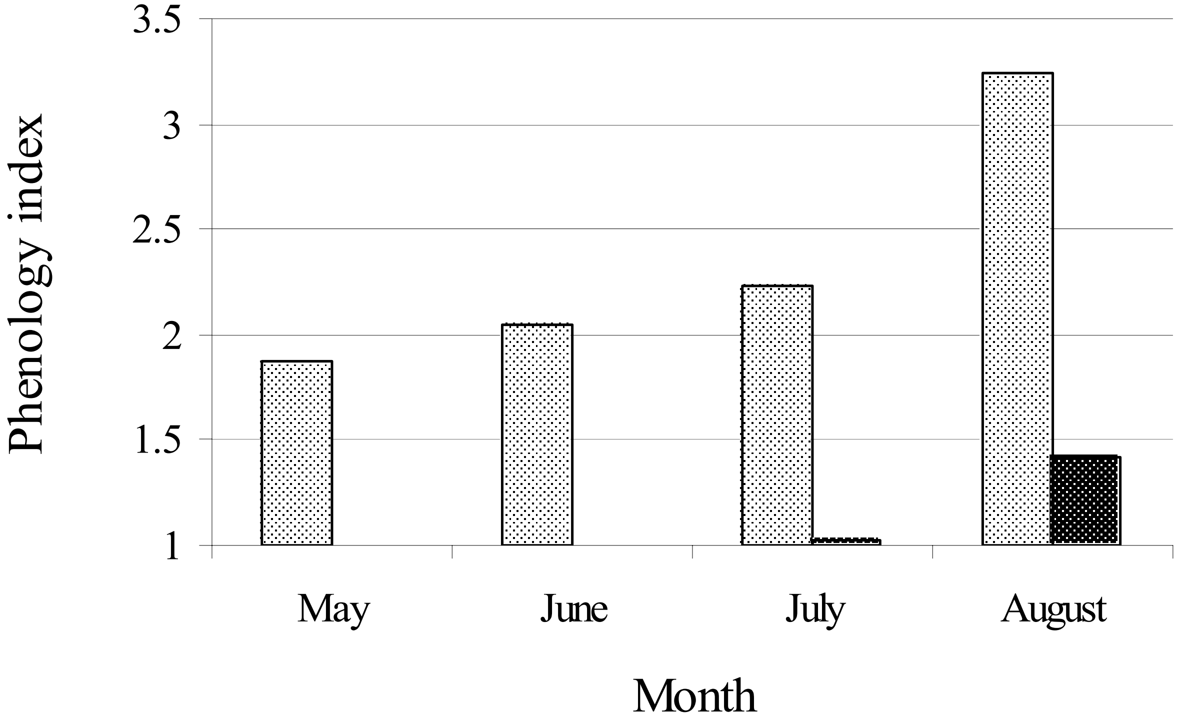
[2] Body mass recorded for subset of pigeons (*n* = 49).

[3] Body mass recorded for subset of pigeons (*n* = 16).

[4] Body mass recorded for subset of pigeons (*n* = 31).

[5] Body mass recorded for subset of pigeons (*n* = 28).

Figure 11. Phenology index for silver-leaf oak (*Quercus hypoleucoides*) trees sampled along 18 survey routes in the Santa Catalina Mountains from May to August 2002 showing: 1) overall phenology index for flowers, fruit, and ripe fruit combined (light bars); and 2) phenology index of ripe fruit only (dark bars). Phenology index of 1 indicates no flowers or fruits were present on silver-leaf oak trees; whereas, phenology index >1 indicates that these food items were present on trees (see methods for complete description of phenology index).



Similarly, an analysis of count data showed that the probability of re-sighting banded pigeons during bait-site counts was also very low (1 re-sight of 4 different banded pigeons during a total of 87 count hours). Aside from the bait-site counts, we did not detect any banded pigeons during our regular visits to place bait at our baited feed sites. Based on observations from 3 observers, we estimated that the average probability of seeing legs on band-tailed pigeons during bait-site counts (to determine if a bird was banded or not) was between 0.55-0.90. In other words, for a portion of the pigeons that we detected during bait-site counts, we never had an opportunity to observe the pigeon's legs when the pigeon was on the ground or in a nearby tree to confirm if the pigeon had at least one band. Thus, we likely missed some detections of banded pigeons. Nevertheless, if we adjust our count of re-sighted pigeons by our most conservative estimate of the proportion of pigeons for which we could not see legs (0.55), we still end up with a low number of total band-tailed pigeon re-sights ($n = 6$). We had insufficient re-sight data to construct capture histories and estimate the probability of pigeons visiting baited feed sites during bait-site counts using Program Mark.

Comparison of 5 Survey Methods

Results from the 5 survey methods evaluated concurrently in the Santa Catalina Mountains in 2002 and 2003 (Table 3) show that average number of pigeons detected, caught, or counted per daily survey effort (and per hour per observer) was consistently low (<1 pigeon) for all survey methods except bait-site counts. However, the average number of pigeons detected during bait-site counts is likely biased high because we probably counted at least some pigeons more than once as they flew to and from the baited feed site during the bait-site count. Of the remaining survey methods, call-broadcast surveys produced the greatest number of pigeon detections per daily survey effort (and per hour per observer). The percent of temporal replicates (surveys, trapping sessions, or counts) with ≥1 pigeon detected or caught was also consistently low (<50%) for all survey methods. Relative to the other survey methods, bait-site counts and call-broadcast surveys had the highest percentage of temporal replicates with ≥1 pigeon detected. Temporal variation in average number of pigeons detected, caught, or counted was relatively high (CV ≥150%) for all survey methods but was lowest for short-duration auditory surveys and call-broadcast surveys.

Natural History of Band-Tailed Pigeons

Movements of radio-marked pigeons: We placed radio-transmitters on a total of 50 pigeons (25 males and 2 females in 2002, 1 male and 9 females in 2003, and 6 males and 7 females in 2004). By tracking radio-marked pigeons, we observed movements of birds primarily within the Santa Catalina Mountains but also between the Santa Catalina Mountains and other mountain ranges in southeastern Arizona. Three males were detected during aerial surveys in the Rincon, Galiuro, and Huachuca Mountains, which are 40, 45, and 105 km respectively from the trapping sites in the Santa Catalina Mountains.

Trichomoniasis: We collected trichomoniasis samples from 23 captured pigeons in the Santa Catalina Mountains in 2003. Only 1 pigeon tested positive for the protozoan parasite; this bird appeared to be a carrier as it did not display any visible symptoms of the disease (i.e., no plaques

Table 3. Summary evaluation of the cost-effectiveness and precision of 5 potential band-tailed pigeon survey methods evaluated concurrently in the Santa Catalina Mountains, Arizona in June-August 2002 and May-June 2003. We compared the average number of pigeons (with temporal variance and % CV) detected, counted, or caught per daily effort (and hourly effort per observer) for each survey method.

Survey method (hours per daily effort)	# spatial replicates[1]	Mean # temporal replicates[2]	% temporal replicates w/ ≥1 pigeon[3]	Average number of pigeons detected, counted, or caught per daily effort			# pigeons per hour per observer
				Mean	Temporal variance	% CV	
Short-duration auditory surveys (1.5 hrs per morning)	11	6.8	20	0.37	0.98	150	0.24
Call-broadcast surveys (1.5 hrs per morning)	11	6.8	29	0.51	1.02	154	0.34
Longer-duration auditory surveys (1 hr per morning)	11	5.3	18	0.26	0.79	190	0.26
Capture-recapture (4 hrs per morning)	4	7.0	25	0.68	1.87	201	0.08[4]
Bait-site counts (3 hrs per morning)	3	5.3	42	3.94	35.41	159	1.31

[1] Number of separate survey routes, count sites, or trap sites included in calculations.

[2] Mean number of surveys, counts, or trap sessions conducted per spatial replicate

[3] Percentage of temporal replicates with ≥1 pigeon detected, counted, or caught

[4] Trapping at baited feed sites required 2 observers. We calculated the number of pigeons caught per hour per observer as 0.17/2 = 0.08.

or inflammation of oral cavity).

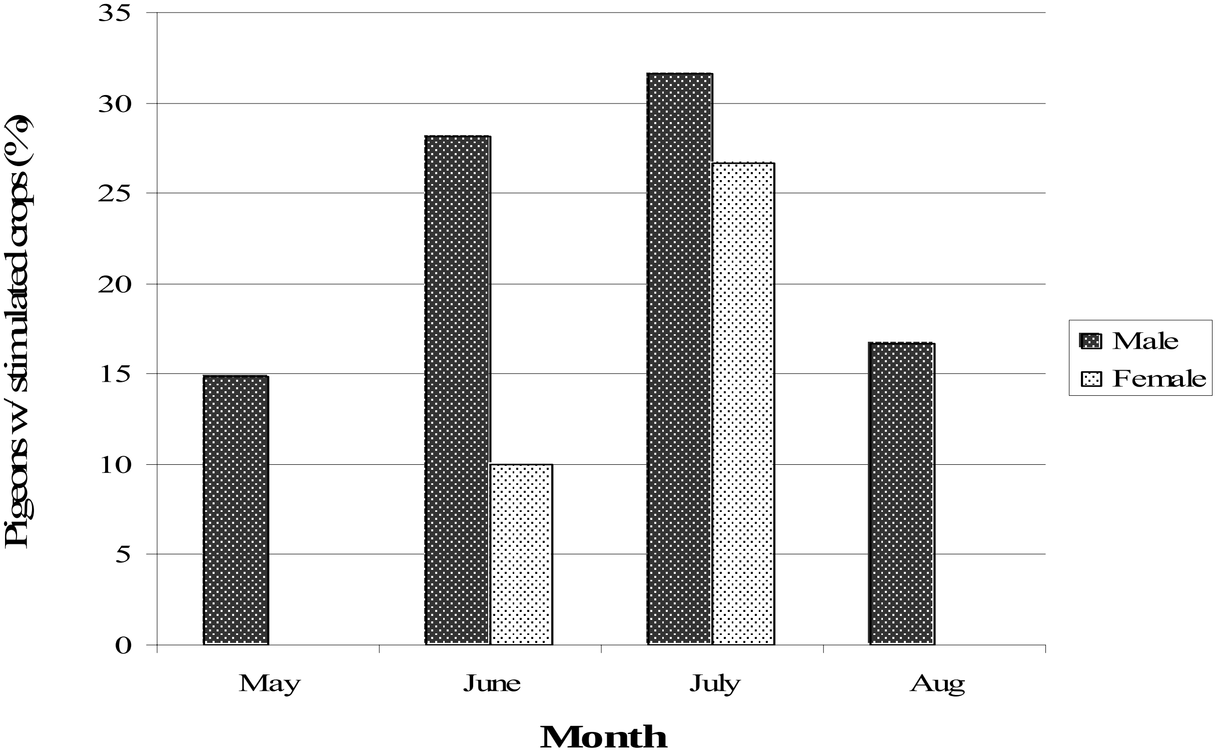
Reproductive status: We examined crops of 164 of the 205 pigeons that we trapped to determine the breeding status of adult male and female band-tailed pigeons. Twenty percent of these pigeons had stimulated crops indicating potential breeding activity. Based on combined data from 2002-2004, the peak months for breeding in the Santa Catalina Mountains were in June and July for both males and females (Fig. 12). The reason we caught proportionally more males than females with stimulated crops may reflect the fact that we trapped pigeons primarily during morning hours when more breeding males and fewer breeding females were foraging (Curtis and Braun 1983b, Leonard 1998).

Mortalities: We confirmed 5 mortalities for our radio-marked pigeons during the study. One pigeon was depredated by a northern goshawk (*Accipiter gentiles*; transmitter was found in active northern goshawk nest), 1 was depredated by an unknown raptor, 1 was depredated by a domestic cat (*Felis catus*), and 2 were likely depredated by grey foxes. Another pigeon was killed by an unknown predator (probably mammalian) in one of our funnel traps during a trap session.

Breeding biology: We found a total of 12 band-tailed pigeon nests (6 in 2002, 1 in 2003, and 5 in 2004) in the Santa Catalina and Chiricahua Mountains (Figures 13 and 14). We estimated that the 12 nests were initiated on the following dates: 15 May (rough estimate), 17 June, 29 June, 6 July, 10 July (rough estimate), and 8 August in 2002; 21 August in 2003; and 18 June, 19 June (rough estimate), 28 June, 21 July, and 23 July in 2004. Clutch size was 1 (*n* = 3) for nests at which we could confirm nest contents during incubation. We found 5 nests during the nestling stage that had 1 squab each and we presume a clutch size of 1 for these nests as well. We could not determine clutch or brood size for the remaining 4 nests. On 3 occasions in July, we observed males taking over incubation duties from females during the morning. Times for these incubation exchanges were 0817, 0905, and 0919.

Nest success: We were able to determine the fates for 11 of the 12 band-tailed pigeon nests. All 6 of the nests that we found in 2002 failed. Two nests failed near the end of the nestling period; a squab was likely depredated by a raptor (we found a pile of squab feathers under the nest) 24 days after hatching and a squab disappeared from a nest following heavy overnight rains 19 days after hatching. One nest failed at the start of the nestling period (possibly depredated) and another nest failed at either the end of the building period or the start of the incubation period (unknown cause). Two nests failed for unknown reasons during what was suspected to be the incubation period. At one of these nests a Chiricahua fox squirrel (*Sciurus nayaritensis chiricahuae*) was observed trying to get to the nest 3 times before being chased off by the adult pigeon on the nest (B. Pasch, pers. comm.). The nest subsequently failed. The 1 nest that we found in 2003 successfully fledged a young pigeon. Two of the 5 nests that we found in 2004 failed. One nest failed during the middle of the nestling period (possibly depredated) and another nest failed at the end of the building period or the start of the incubation period (unknown cause).

Figure 12. Percentage of male and female band-tailed pigeons that were caught at baited feed sites in the Santa Catalina Mountains that had stimulated crops (indicating potential breeding activity) during each month of the breeding season (data combined from June-August 2002, May-June 2003, and May-August 2004).



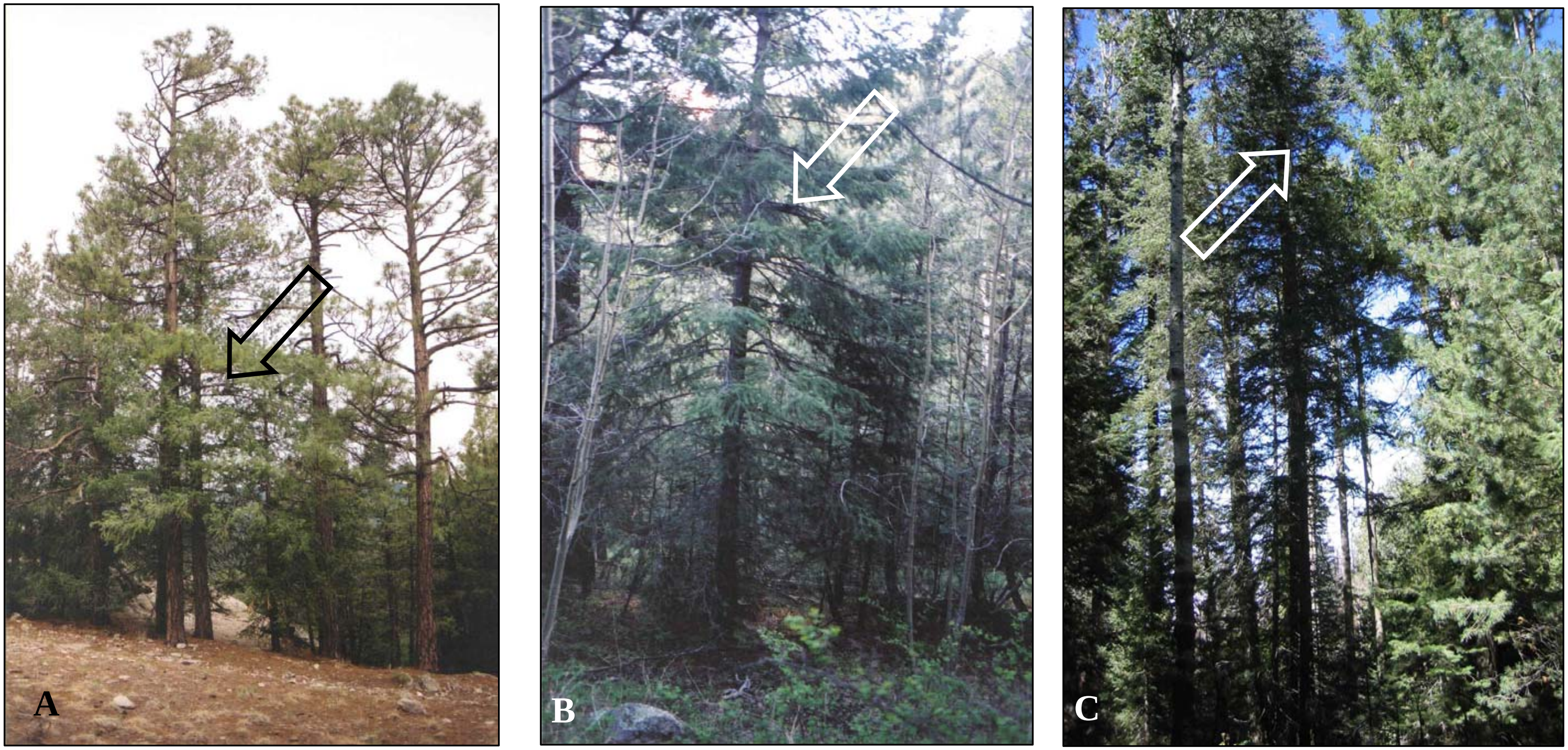


Figure 13. Band-tailed pigeon nests found in the Santa Catalina Mountains, Arizona from 2002 to 2004: A) nest # 2-02 located 6 m off the ground in a 14-m tall Douglas fir (*Pseudotsuga mensziesii*) tree along Box Camp Trail (2,478 m elevation); B) nest #5-02 located 6 m off the ground in a 13-m tall Douglas fir tree near Ski Valley (2,691 m elevation); and C) nest #11-04 located 21 m off the ground in an 36-m tall white fir (*Abies concolor*) tree in Lemmon Park (2,784 m elevation).

Figure 14. Band-tailed pigeon nest #7-04 located 3 m off the ground in an 8-m tall silver-leaf oak (*Quercus hypoleucoides*) tree at 1,841 m elevation in the Santa Catalina Mountains, Arizona (2004). The stick nest was built using small-diameter Douglas fir (*Pseudotsuga mensziesii*) and white fir (*Abies concolor*) branches.

In summary, 50% of nest failures occurred during the nestling stage, 25% of nest failures occurred during the incubation period, and 25% of nest failures occurred at either the end of the building period or the start of the incubation period. We attributed 50% of the 8 nest failures to predation (12% of nests [n = 1] apparently failed due to weather and 38% of nests [n = 3] failed due to unknown causes). Apparent nest success for the 11 nests with known fates was 27%. Mayfield (1961) estimates of daily nest survival and overall nest survival were 0.971 and 0.219 respectively using exposure days for the building, laying, incubation, and nestling stages (n = 268). Mayfield (1961) estimates of daily nest survival and overall nest survival were 0.970 and 0.335 respectively using exposure days for the incubation and nestling stages only (n = 260).

Habitat characteristics at nests and nest sites: We measured vegetative and landscape characteristics around 11 of the 12 nests located from 2002 to 2004 (Table 4; the nest site where we did not measure characteristics was partially destroyed by a fire crew cutting fire lines during the Bullock Fire). We found 2 active band-tailed pigeon nests within 100 meters of one another at Ski Valley, Santa Catalina Mountains in 2002 and observed a radio-marked male band-tailed pigeon that located its nest in 2003 within 200 m of its nest site in 2002. Following the wildfires in 2002 and 2003, we found band-tailed pigeon nests located primarily in areas that had experienced medium-severity surface fire (Table 4).

We were able to collect and identify nest material for 3 nests that were located relatively close to the ground. These nests were comprised of small-diameter (approximately 2-5 mm) Douglas fir and white fir branches. At 2 nests that were located well above the ground, we observed band-tailed pigeons collecting small branches from Douglas fir and white fir trees (located approximately 5-15 m from their nests) during the building period. We observed the male collecting nest material at one nest and the female collecting nest material at the other nest.

Distribution of band-tailed pigeons: We detected band-tailed pigeons across a range of elevations and in every major forest type. However, we detected band-tailed pigeons more frequently at survey points located in mixed-conifer forest compared to other forest types in southeastern Arizona. Using data collected during 2002 and 2003 in the Chiricahua, Huachuca, and Santa Catalina Mountains, we detected ≥1 band-tailed pigeon by *coo-calls* on ≥1 replicate survey at 75% (n = 46) of survey points located in mixed-conifer forest, at 51% (n = 68) of survey points located in oak-juniper-pinyon woodland, at 44% (n = 39) of survey points located in pine-oak woodland, and at 36% (n = 11) of survey points located in ponderosa pine forest (X^2 = 12.27, df = 3, $P < 0.01$).

We observed large foraging flocks of band-tailed pigeons (20-40 birds) on surveys in Turkey Creek, Chiricahua Mountains (17 July 2002) and in Ramsey Canyon, Huachuca Mountains (24 July 2003). We had incidental detections of flocks of 10-15 pigeons foraging on pollen cones of ponderosa pine at Lemmon Park, Santa Catalina Mountains (12 and 19 June 2002) and flocks of 20-30 birds feeding on silver-leaf oak acorns near Summerhaven (early August 2002). We

Table 4. Habitat characteristics of band-tailed pigeon nests recorded at the nest and within a 25-m radius plot centered at the nest. All nests were found in the Santa Catalina Mountains, Arizona (except nest #1-02 which was found in the Chiricahua Mountains, Arizona) from 2002-2004.

	Habitat characteristics measured at nest								Habitat characteristics measured in 25-m radius plot						
Nest ID (# -yr)	Nest tree species[1]	Elev. (m)	DBH nest tree (cm)	Height of nest tree (m)	Height of nest (m)	Azimuth of nest relative to bole (º)	Distance nest to bole (m)	Canopy closure (%)	Fores t type[2]	Top canopy height (m)	Slope (º)	Aspec t (º)	Dominant[3] canopy species	Co-dominant[4] canopy species	Burn severity index[5]
1-02	Queari	1,717	45	12	7	344	2.6	84	PO	15	35	340	Pinlyo	-	0
2-02	Psemen	2,478	35	14	6	354	0.8	87	MC	14	13	343	Psemen	Pinpon	0
3-02	Abicon	2,660	86	31	21	55	-	94	MC	38	28	27	Abicon	-	0
4-02	Psemen	2,674	138	24	21	128	1.9	54	MC	29	25	338	Psemen	-	0
5-02	Psemen	2,691	24	13	6	190	0.5	92	MC	22	30	100	Psemen	Abicon	0
6-03	Psemen	2,739	59	24	20	162	1.6	89	MC	24	27	8	Psemen	-	2
7-04	Quehyp	1,841	21	8	3	294	0.0	84	PO	14	35	17	-	-	2
8-04	Quehyp	2,103	27	15	9	45	4.3	83	PO	18	17	39	Pinpon	-	2
9-04	Psemen	2,479	93	40	19	120	2.2	87	MC	40	18	290	-	-	1
10-04	Abicon	2,694	83	34	22	241	2.0	73	MC	34	39	340	Abicon	-	3
11-04	Abicon	2,784	98	36	21	170	0.5	90	MC	36	18	322	Psemen	Abicon	2
0		2,442	64	23	14		2	83		26	26				
SE		114.3	11.4	3.4	2.3		0.4	3.4		3.0	2.6				
Min.		1,717	21	8	3		0	54		14	13				
Max.		2,784	138	40	22		4	94		40	39				

[1] Tree species codes: Psemen = Douglas fir (*Pseudotsuga mensziesii*); Abicon = white fir (*Abies concolor*); Pinlyo = Chihuahua pine (*Pinus leiophylla*); Queari = Arizona white oak (*Quercus arizonica*); Quehyp = silver-leaf oak (*Quercus hypoleucoides*).

[2] MC = mixed-conifer forest; PO = pine-oak woodland.

[3] Tree species accounting for >40% of canopy (if applicable).

[4] Second tree species (if applicable) accounting for >40% of canopy.

[5] Burn severity index: 0) no evidence of recent fire; 1) low-intensity surface fire; 2) medium-intensity surface fire; 3) high-intensity surface fire; 4) high-intensity crown fire. See methods for complete description of burn severity index.

received reports of a foraging flock of 20 birds feeding on white mulberry (*Morus alba*) at Cienaga Spring in the Chiricahua Mountains (early June 2002; R. Gerhart, pers comm.) and a flock of 25-30 pigeons at a feeder in the town of Paradise, Chiricahua Mountains (early June 2002; J. Lewis, pers. comm.). We also observed 8-15 band-tailed pigeons perched above Sprung Spring in the Santa Rita Mountains (3 October 2004); apparently the pigeons were waiting to drink water from the spring (C. Conway, pers. obs.).

Effects of Fire on Band-Tailed Pigeons

For our first analysis of fire data, we were unable to detect a positive or negative association between the presence of band-trailed pigeons and evidence of fire at survey points (Wald X^2 =3.4; $P = 0.18$). It should be noted, however, that we encountered relatively few survey points with evidence of low-severity fire ($n = 89$) and almost no survey points with evidence of high-severity fire ($n = 5$) in the Chiricahua, Huachuca, and Santa Catalina Mountains and in mixed-conifer forest throughout Arizona. Because of the small sample size of burned points, we may have lacked the power to detect associations between burned areas and presence/absence of band-tailed pigeons. For our second analysis of fire data, we were also unable to detect a difference in relative abundance of band-tailed pigeons when comparing survey data collected before the wildfires to survey data collected after the wildfires in the Santa Catalina Mountains ($F = 0.20$; $P = 0.82$). Although relative abundance of band-tailed pigeons increased at survey points that were burned severely from 0.08 (SE = 0.36) pigeons per survey point in 2002/2003 (pre-fire) to 0.17 (SE = 0.43) pigeons per survey point in 2004 (post-fire), relative abundance also increased at unburned survey points during the same time period (0.23 [SE = 0.12] to 0.32 [SE =0.17] pigeons per survey point).

Band-Tailed Pigeon Population Trajectory in the Santa Catalina Mountains

During the 2002 breeding season, we conducted a total of 15 weekly surveys along Fitzhugh's survey route from 2 May to 5 September. We detected a total of 11 band-tailed pigeons during 15 surveys in 2002. Nine of these birds were detected aurally (all *coo-calls*) and 2 were detected visually (all flyovers). Considering only birds detected by *coo-calls*, we detected an average of 0.60 (SE = 0.21) band-tailed pigeons per weekly survey. Fitzhugh (1974) noted that the first 10 survey points along the route were surveyed during the time period in which the great majority of calling took place during the morning. Hence, we likely detected the majority of the pigeons along the route despite the fact that we were not able to survey the last 4 survey points after 28 May 2002 due to the Bullock Wildfire. Even if we make the conservative assumption that a constant number of pigeons would have been detected at all survey points had we surveyed the entire route, a corrected estimate for the average number of pigeons detected per survey in 2002 (including the missing 4 survey points) would be 0.80.

During the 2003 breeding season, we conducted a total of 7 weekly surveys along the entire survey route from 30 April until the start of the Aspen fire on 12 June. We detected a total of 13 band-tailed pigeons. Nine of these birds were detected aurally (all *coo-calls*) and 4 were detected visually (all flyovers). Considering only birds detected by *coo-calls*, we detected an average of 1.29 (SE = 0.47) band-tailed pigeons per weekly survey in 2003. During the 2004 breeding season, we conducted a total of 17 weekly surveys along the entire survey route from 5 May until 26 August. We detected a total of 26 band-tailed pigeons of which 15 were detected by *coo-calls*, 2 were detected by *wing-claps*, and 9 were detected visually as flyovers. Considering only birds detected by *coo-calls*, we detected an average of 0.88 (SE = 0.27) band-tailed pigeons per weekly survey in 2004.

Fitzhugh (1974) detected an average of 2.7 (SE = 0.66), 3.7 (SE = 0.54), and 9.5 (SE = 1.97) pigeons by *coo-calls* per weekly survey in 1968, 1969, and 1970 respectively. Compared to our results from 2002 (conservative estimate), 2003, and 2004, the number of band-tailed pigeons appears to have declined substantially over the last 3 decades along the survey route in the Santa Catalina Mountains (two-sample $t = 5.4$; df = 66; $P < 0.001$). This change amounts to an 84% decrease in the average number of band-tailed pigeons detected by *coo-calls* during surveys between 1968-1970 and 2002-2004.

DISCUSSION

Evaluation of Survey Methods

Our evaluation of potential survey methods for monitoring band-tailed pigeons in the interior region revealed both differences and similarities in the effectiveness of the 5 survey methods. For instance, detection probability varied among survey methods with call-broadcast surveys producing the highest estimate of detection probability for the 3 survey methods that we evaluated along survey routes and both capture-recapture and bait-site counts producing low estimates of detection probability. All 5 survey methods shared the following characteristics: 1) the average number of pigeons detected or caught per daily effort (or per hour) was consistently low (<1 pigeon; except for bait-site counts); 2) temporal variation in average number of pigeons detected, caught, or counted was relatively high (CV ≥150%); and 3) the percent of temporal replicates (surveys, trapping sessions, or counts) with ≥1 pigeon detected, caught, or counted was consistently low (<50%). These findings reflect the difficulties of surveying a species that is both uncommon and difficult to detect.

Although capture-recapture and bait-site counts have been recommended for use in the interior region (Curtis and Braun 1983a), we believe that both of these survey methods will be of limited use for monitoring band-tailed pigeons in southeastern Arizona and perhaps elsewhere in the interior portion of their breeding range. The interior sub-species of band-tailed pigeon readily exploits waste grains in Colorado where thousands of band-tailed pigeons have been trapped and counted in agricultural fields (Curtis and Braun 1983a, Pacific Flyway Study Committee 2001). In contrast, band-tailed pigeons in Arizona do not forage in grain fields to any great extent (Fitzhugh 1974), nor are they attracted in large numbers to the limited number of available mineral sites in the state (mostly scattered salt licks for cattle). We found that band-tailed pigeons flock to established backyard bird feeders in mountain ranges of southeastern Arizona, especially in mountain towns such as Summerhaven (Santa Catalina Mountains) and Paradise (Chiricahua Mountains) where residents have been feeding birds for many years (>30 years of continuous baiting at a site in Summerhaven; L. Currin, pers. comm.).

However, even at these established sites, we caught relatively few pigeons during trap sessions (only 205 birds caught during 86 trap days [2,189 trap hours]), far fewer than the numbers typically caught in agricultural fields in Colorado (Curtis and Braun 1983a). Previous efforts to trap band-tailed pigeons in southeastern Arizona have also met with limited success relative to trapping efforts in Colorado (L. Fitzhugh, pers. comm.). Compared to other survey methods, capture-recapture was the least efficient and most-costly survey method because it required at least 2 observers to manage traps and band birds, and considerable extra time to bait the trap sites on a daily basis. Similarly, we counted relatively few band-tailed pigeons during bait-site counts (average of 1 pigeon per half-hour interval) compared to bait-site counts in Colorado (Curtis and Braun 1983a) and counts at mineral springs in California (Casazza et al. 2000). Because a single observer could perform a bait-site count, bait-site counts were more cost-effective than capture-recapture but still required daily effort to replenish bait at count sites.

Furthermore, band-tailed pigeons prefer natural foods to grain and switch easily from one food source to another (Braun 1994, Jeffrey et al. 1977). Even in the presence of several well-baited sites, we observed flocks of pigeons (20-30 individuals) foraging preferentially on natural foods during the breeding season. This was most evident in August 2002 when trap success dropped at the same time that productivity of silver-leaf oak acorns increased in the Santa Catalina Mountains (as measured by our phenology index) and flocks of band-tailed pigeons were observed feeding on this acorn crop. Thus, the relatively high temporal variation that we observed in trap success may have resulted, in part, from the preference of band-tailed pigeons for natural foods and the fluctuating availability of these food resources within our study area (although our switch from corn to millet and sunflower seed at trap sites in July 2002 may have contributed to the subsequent reduction in trap success as well [Braun 1976]). The production of acorns in the Southwest is unpredictable (Gutierrez 1975) and few species of birds are affected as strongly by available food resources as band-tailed pigeons (Neff 1947). Our results suggest that any future capture-recapture efforts in the Southwest will need to measure the phenology of local forage species to account and control for fluctuations in trap success of band-tailed pigeons at baited feed sites.

Perhaps the biggest drawback with capture-recapture and bait-site counts is that both techniques do not appear to provide a precise or accurate index of band-tailed pigeon abundance. During the current study, the number of pigeons that we recaptured or re-sighted was very low for both survey methods indicating that we sampled different portions of the population during replicate trap sessions and counts. Low rates of recapture have also been observed in Oregon where no band-tailed pigeons were recaptured at baited feed sites during a 3-year period (J. Leonard, pers. comm.). However, recapture rates for band-tailed pigeons trapped in grain fields in Colorado are reported to be relatively high (Curtis and Braun 1983a). Because there are few oak trees in the region, pigeons in Colorado are thought to be more dependent on waste grain from agricultural fields than pigeons in other areas (Kautz 1977). For the purposes of monitoring, southeastern Arizona has neither the agricultural fields nor the mineral sites required to attract large, consistent numbers of band-tailed pigeons for trapping and counting. This may also be the case for other areas within the interior range of band-tailed pigeons (e.g. New Mexico, Utah, and elsewhere in Arizona).

We believe there are several potential problems with our evaluation of capture-recapture and bait-site counts that may have limited the number of pigeons that we captured and the number of pigeons that we subsequently recaptured/re-sighted. First, we trapped and counted pigeons at several baited feed sites concurrently within a relatively small geographic area in the Santa Catalina Mountains and flocks of pigeons appeared to move daily from one site to another potentially affecting our rate of capture from one trap day to the next. Additional movements of band-tailed pigeons between mountain ranges in southeastern Arizona may have exacerbated this problem (see below). Second, we trapped band-tailed pigeons using funnel traps (Braun 1976) and pigeons may have developed an aversion to this trap type after initial capture. In an attempt to remedy these problems, we tested pigeon decoys as a means to attract larger and more consistent numbers of band-tailed pigeons to our trap sites and thus increase our rates of capture and recapture. However, we found that the use of pigeon decoys actually decreased the number of band-tailed pigeons that we captured at trap sites. Finally, during the first year of our study (2002), we conducted bait-site counts at baited feed sites where we also trapped pigeons which probably reduced the number of pigeons visiting these sites during subsequent bait-site counts (Braun 1976). For this reason, our conclusions regarding the effectiveness of bait-site counts for monitoring interior populations of band-tailed pigeons should be viewed as tentative.

Unless baited feed sites are moved away from residential areas (a difficult proposition given that band-tailed pigeons are attracted to backyard bird feeders), future capture-recapture efforts and bait-site counts will have to contend with frequent short-distance movements of pigeon flocks between multiple feed sites within a mountain range (occasional long-distance movements of individual birds between mountain ranges is another problem altogether; see below). Furthermore, attempts to create new baited feed sites away from residential areas will likely take time to become established and may never be successful (only 1 of 4 new baited feed sites that we established in the Santa Catalina Mountains attracted consistent [albeit low] numbers of pigeons). Although funnel traps have been recommended for trapping band-tailed pigeons (Braun 1976), canon nets are considered to be the most efficient method for capturing large numbers of birds (Braun 1976). Yet, cannon nets are not suitable for use in residential areas (Braun 1976; C. Kirkpatrick pers. obs.). Other trapping methods such as the Q-net (Fuhrman Diversified, Inc., Seabrook, Texas) utilize smaller nets and employ elastic bands instead of explosive charges to release the net. These trapping techniques may be more suitable for trapping pigeons in residential areas but further research is needed to assess the costs and benefits of these methods.

Longer-duration auditory surveys have been recommended for testing in the interior region (Pacific Flyway Study Committee 2001) and we found that longer-duration auditory surveys produced similar results compared to short-duration auditory surveys in terms of number of pigeons detected per survey effort. However, we believe that there are 2 potential problems with longer-duration surveys that may limit their usefulness. First, the length of longer-duration auditory surveys (20-60 minutes) can tax the patience of observers, making it more difficult for observers to focus on detecting band-tailed pigeons (T. Sanders, pers. comm., C. Kirkpatrick pers. obs.). Second, movements of pigeons during longer-duration survey (presumed to be greater as the length of the survey period increases) hinders the ability of observers to differentiate between vocalizations given by different pigeons and vocalizations given by a single pigeon that has moved from one location to another during the survey. We can only speculate on the extent of this problem because pigeon movements go largely unobserved during surveys in forested environments. To the best of our knowledge, this confounding effect did not appear to be a major problem during our longer-duration (i.e., 20-minute) auditory surveys. However, we suspect that pigeon movements will likely present a greater problem as the length of the survey period increases (e.g., 60 minutes) or the density of pigeons increases around the survey point.

Of the remaining survey methods that we evaluated, call-broadcast surveys appear to be the most effective method for monitoring band-tailed pigeons in Arizona and perhaps elsewhere in the interior portion of their breeding range. Call-broadcasts increased the number of pigeons that were detected by *coo-calls* by an average of 22% compared to auditory surveys, a pattern that was consistent across 5 mountain ranges in southeastern Arizona and in mixed-conifer forests throughout the state. Although sample sizes were small, results from our focal bird and nest detection trials also support this finding. Moreover, use of call-broadcast increased the number of replicate surveys on which ≥ 1 pigeon was detected by an average of 16%. Thus, call-broadcast increased the efficiency of survey efforts by reducing the number of surveys on which no pigeons were detected. To the best of our knowledge, this is the first time that call-broadcast has been shown to increase the probability of detecting band-tailed pigeons (or any other species of *Columbidae*) during surveys.

The probability of a band-tailed pigeon vocalizing during a survey (P_{sings}) was greater for call-broadcast surveys (0.31 per minute) compared to short-duration auditory surveys (0.20 per minute). More importantly, temporal variation in P_{sings} was half as much for call-broadcast surveys (CV = 11%) compared to short-duration auditory surveys (CV = 23%). Our double-observer trials suggested that the probability of an observer detecting a pigeon given that it vocalized (P_{heard}) was slightly higher for call-broadcast surveys relative to short-duration auditory surveys. Thus, detection probability (P_{detect}) was higher for call-broadcast surveys (0.80 for 6-minute survey period) relative to short-duration auditory surveys (0.69 per 6-minute survey period). Based on these results, use of call-broadcast appears to increase both the accuracy and precision of band-tailed pigeon counts during surveys compared to strictly auditory survey methods.

Although call-broadcasts surveys appeared to be the most effective of the 5 potential survey methods that we tested, we also wanted to know whether call-broadcast surveys (and other auditory survey methods) were a valid method for monitoring band-tailed pigeons. In other words, we were interested in knowing what proportion of the population was being sampled during surveys. We attempted to answer this question using focal bird and nest detection trials to determine the calling behavior and detection probability of male pigeons of different breeding status. We ran into methodological problems using focal bird detection trials (as described above) but results from nest detection trials suggest that breeding males are either absent from nests or present near nests but quiet during early morning hours throughout the incubation and nestling periods (breeding males were generally on nests during our late morning/afternoon nest detection trials but were never detected by surveyors). These early morning hours (sunrise to <2 hours after sunrise) corresponded to the time that we would normally conduct our band-tailed pigeon surveys. Thus, we probably failed to detect many breeding male pigeons near nests while conducting surveys during a sizeable portion of the breeding season because the combined length of the incubation and nestling stages averages almost 50 days (Braun 1994).

In addition, a previous study of captive band-tailed pigeons found that unmated males were 8 times more likely than mated males to give *coo-calls* and that unmated males gave an average of 0.42 *coo-calls* per minute when calling (Sisson 1968). We found that pigeons detected along auditory/call-broadcast survey routes gave an average of 0.46 *coo-calls* per minute during surveys. Based on these calling rates and results from our nest detection trials, we probably detected primarily unmated males advertising for females and/or males calling while foraging away from their nests. Ideally, a survey method effectively samples known breeders so that inferences can be made to the breeding population as a whole; this may not be the case with band-tailed pigeons counted during morning surveys. However, if some of these calling males ultimately find mates and reproduce, we may actually be sampling some unknown proportion of the eventual breeding population during surveys. We need to conduct additional research to clarify exactly what fraction of the breeding population is being sampled during surveys and how this fraction varies through time.

Previous attempts to use counts along survey routes for monitoring the interior sub-species of band-tailed pigeon have been criticized because survey routes did not effectively penetrate band-tailed pigeon habitat and consequently few band-tailed pigeons were detected (Pacific Flyway Study Committee 2001). We found that counts along survey routes can be used successfully in rugged terrain in southeastern Arizona when observers are willing to travel beyond roadways and enter band-tailed pigeon habitat on foot. Even though some of the terrain that we attempted to survey was probably too dangerous for many surveyors to traverse, we believe that a large portion of band-tailed pigeon habitat in Arizona and perhaps elsewhere in the interior region is accessible for these off-road surveys.

In addition, previous attempts to use counts along survey routes have been criticized because band-tailed pigeon population density is low and populations are patchily distributed in the interior region resulting in low counts of band-tailed pigeons (Pacific Flyway Study Committee 2001). We have shown that call-broadcast helps to alleviate this problem by increasing the probability of detecting band-tailed pigeons during surveys. One option for monitoring species that are both rare and difficult to detect (e.g., interior subspecies of band-tailed pigeon) is to estimate trends in site occupancy as opposed to trends in numbers of animals detected as a means to track population trends (MacKenzie et al. 2002). Count data collected during ≥3 replicate surveys are needed to estimate site occupancy if this technique were to be employed for monitoring band-tailed pigeon populations in the interior region.

Another potential problem with the use of counts along survey routes is that mobile foraging flocks of pigeons may inflate temporal variance in numbers of band-tailed pigeons detected during surveys. For example, we observed several large flocks (14, 26, and 34 pigeons per flock) during auditory/call-broadcast surveys in late July 2002 and 2003 in the Chiricahua and Huachuca Mountains. Despite the size of these flocks, we detected only a handful of the pigeons within each flock (8, 4, and 2 pigeons respectively) by *coo-calls*. Previous studies have also found greater variability in visual as compared to aural detections for band-tailed pigeons during surveys (Sisson 1968). We recommend that surveyors record the detection type(s) for each band-tailed pigeon detected during future surveys (as we did during the current study) so that data from *cooing* pigeons and data from non-vocalizing pigeons can be analyzed separately. Analyses of both data sets through time should provide insight into how detection type can influence temporal variance in population trend estimates for band-tailed pigeons.

Natural History, Distribution and Abundance, and Population Trajectory of Band-tailed Pigeons

During surveys, we detected band-tailed pigeons in a variety of forest types and across a large geographic region in Arizona. In southeastern Arizona, we detected *cooing* males more frequently in mixed-conifer forest (75% of survey points) and oak-juniper-pinyon woodland (51% of survey points) compared to other forest types, a pattern that corresponds to anecdotal reports of band-tailed pigeon distribution in southern Arizona (Braun et al. 1976; Phillips et al.

1964). By tracking the movements of radio-marked birds, we found that pigeons moved up to 105 km between montane forests in 4 different mountain ranges. This is the first time that long-distance movements between mountain ranges have been documented for breeding band-tailed pigeons in southeastern Arizona. We suspect that band-tailed pigeons are moving between mountain ranges in part to take advantage of dependable food supplies in residential areas (e.g., backyard bird feeders in Summerhaven, Santa Catalina Mountains). In mixed-conifer forest throughout Arizona, we detected band-tailed pigeons in every National Forest that we surveyed, but overall density of band-tailed pigeons was low (0.0044 *cooing* male pigeons/ha). This density estimate corresponds to previous estimates given for the interior sub-species (0.004-0.039 pigeons/ha; Jeffrey 1977).

We found that breeding activity appeared to peak in June and July in the Santa Catalina Mountains based on the following results: 1) crop glad activity of trapped birds peaked during June and July in the Santa Catalina Mountains; 2) the majority of the nests that we found were initiated in June and July; and 3) we started to capture hatch year birds beginning in June. A previous study in the Santa Catalina Mountains also found that crop gland activity and *cooing* peaked during June and July, although there was some variation within and between years (Fitzhugh 1974). We did find band-tailed pigeon nests that were initiated as early as 15 May and as late as 21 August. Although we did not conduct fieldwork between September and April, previous research has shown that interior populations of band-tailed pigeons initiate nests during these months as well (albeit in lower numbers; Keppie and Braun 2000).

Relatively few nests of band-tailed pigeons have been located and monitored (Leonard 1998), especially for the interior sub-species. We found a total of 12 nests in southeastern Arizona of which 75% were located in high-elevation, mixed-conifer forest. However, we spent more time tracking radio-marked birds and searching for nests in mixed-conifer forest than in other forest types, so band-tailed pigeons may not be as closely associated with mixed-conifer forest as these data suggest. Nevertheless, Fitzhugh (1974) also found that most pigeons nested in “tall forests at higher elevations” in the Santa Catalina Mountains. At the 11 nests at which we took measurements of nest and nest-site characteristics, we found that the majority of nests (91%) were located on north-facing slopes (between 271-360º or between 1-179º) and most nests (73%) were placed in coniferous trees. In addition, most nests (82%) were located in forests where the dominant (and co-dominant) canopy species was coniferous and average canopy closure was high (0 = 83%). Measurements of nest and nest-site characteristics such as DBH of nest tree, height of nest, height of nest tree, and azimuth of nest relative to bole were all highly variable among nests. Although our sample size of nests was too small for statistical comparison, characteristics at nests and nest sites were generally similar to results obtained from a study of nesting band-tailed pigeons in Oregon (Leonard 1998), especially with respect to the variability of many nest characteristics that we measured. As with nests found in Oregon, the majority of our band-tailed pigeon nests were placed in coniferous trees. Average DBH of nest trees was higher in Arizona than in Oregon (0 = 64 [range 21-138] cm versus 0 = 29 [range 4-83] cm). However, Leonard (1998) found some band-tailed pigeon nests in shrubs (we did not) and the inclusion of these shrub DBH measurements likely lowered the average DBH for nest trees in Oregon.

We found 2 band-tailed pigeon nests in close proximity (<100 m) to one another and observed a radio-marked male band-tailed pigeon that located its nest in 2003 within 200 m of its nest from 2002. Although thought to be primarily a solitary nester (Keppie and Braun 2000), band-tailed pigeons have been found nesting in loose colonies (Phillips et al. 1964, Jeffrey et al. 1977) and are known to exhibit strong philopatry (Leonard 1998). Following the 2002/2003 wildfires, we found that band-tailed pigeons nests were located primarily in areas that had experienced medium-severity surface fires. Approximately 90% of the forest and woodland in the Santa Catalina Mountains burned to some extent during the wildfires. Thus, instead of selecting nest sites in burned areas, band-tailed pigeons may simply have been utilizing the available habitat, which at present, is burned to some extent. The fact that we found no nests in areas that experienced high-severity crown fires suggests that band-tailed pigeons may not be selecting these areas in which to nest. Band-tailed pigeon nests were located at an average height of 14 m above the ground, high enough to avoid the potential negative effects (e.g., loss of nest branches and surrounding nest cover) of medium-severity surface fires.

Our Mayfield (1961) estimate of overall nest survival for band-tailed pigeons in southeastern Arizona was low (0.355; using exposure days from the incubation and nestling stages only). In contrast, a previous study of nesting band-tailed pigeons in Oregon found that overall nest survival was substantially higher (0.689; Leonard 1998). Fifty percent of nests that failed in Arizona were known (or suspected) to have been depredated. For adult band-tailed pigeons, we observed several mortalities of radio-marked birds due to various predators including raptors (e.g., northern goshawk), grey foxes, and a domestic cat. Other studies have found no significant effects of radio-transmitters on band-tailed pigeon survival in the Pacific Northwest (Leonard 1998). However, we observed several radio-marked pigeons exhibiting unusual behaviors that may have predisposed them to predation (e.g., pecking at transmitters and/or harnesses; reluctance to fly from ground after being equipped with snug-fitting ribbon harnesses; C. Kirkpatrick pers. obs.). In general, we found that relatively loose-fitting ribbon harnesses and glue-on mounts appeared to work best when attaching radio-transmitters to pigeons. However, a more formal study is needed to evaluate the effects of radio-transmitters (and various attachment methods) on the behavior and survival of band-tailed pigeons in the interior region. Our results suggest that trichomoniasis, another potential mortality risk, is present in band-tailed pigeons in the Santa Catalina Mountains but not currently a threat. Further monitoring may be necessary to detect any potential episodic occurrences of trichomoniasis in the region.

We were unable to detect an association between band-trailed pigeon presence/absence and evidence of recent fire at survey points. One potential problem with our correlative analysis was that relatively few survey points along our survey routes showed any evidence of fire; thus, we may have lacked the necessary sample size of burned survey points (especially those with evidence of severe fire) to detect a significant association. However, a similar analysis of data collected in 2000 during general bird surveys in southeastern Arizona (Conway and Kirkpatrick 2001) also failed to detect an association between presence/absence of pigeons and evidence of fire at survey points (C. Kirkpatrick, unpubl. data). The sample size of survey points with evidence of fire was considerably greater in this study. Moreover, we were unable to detect a difference in relative abundance of band-tailed pigeons when we compared survey data collected before and after the 2002/2003 wildfires in the Santa Catalina Mountains. At the least, results from our fire analyses suggest that band-tailed pigeons are found within recent burns and do not appear to be avoiding these areas in favor of unburned areas (we even observed pigeons nesting in areas that had experienced wildfires). Future research should examine more closely the reproductive success (and not just the abundance) of band-tailed pigeons within burned and unburned areas (Van Horne 1983; our sample size of nests was too small to make this comparison).

Band-tailed pigeons appear to have declined substantially (84%) in the Santa Catalina Mountains between 1968-1970 and 2002-2004. Although Fitzhugh (1974) surveyed band-tailed pigeons from slightly different versions of the established 1970 road route in 1968 and 1969, these modified survey routes covered the same general section of road and were thought to be similar enough to the 1970 survey route that we surveyed for valid comparison with our survey data (L. Fitzhugh, pers. comm). The Bullock fire of 2002 burned or partially-burned 62% of survey points along the survey route. The effect that this disturbance had on the number of band-tailed pigeons detected during our surveys remains unknown. Results from our fire analyses and findings from a previous fire study (C. Kirkpatrick, unpubl. data) suggest that the effect of fire may have been minimal on the presence/absence and relative abundance of band-tailed pigeons along the survey route. Despite this uncertainty, we believe that the apparent decline in band-tailed pigeon numbers in the Santa Catalina Mountains is cause for concern. Our survey data support previous findings for declines in numbers of band-tailed pigeons in the interior portion of their range (e.g., declining harvest returns for band-tailed pigeons in Arizona and elsewhere in the four-corners region; Pacific Flyway Study Committee 2001).

MANAGEMENT IMPLICATIONS

Our evaluation of potential survey methods for monitoring interior populations of band-tailed pigeons revealed that one survey method was not clearly superior to the others (i.e., there were drawbacks associated with each survey method). Nevertheless, compared to the other survey methods, call-broadcast surveys appear to be the best alternative for monitoring band-tailed pigeons in the rugged mountains of southeastern Arizona. We believe that additional research may be required to determine the most appropriate monitoring method for use in other parts of the interior region. For instance, capture-recapture or counting pigeons may provide a more reliable and cost-effective monitoring method in areas where large flocks of pigeons congregate regularly in agricultural fields or at mineral springs. We suspect that call-broadcast surveys will likely provide the best method with which to monitor band-tailed pigeons in areas that lack these attributes (a potentially sizeable portion of the rugged mountainous region within Arizona, New Mexico, and Utah). Ultimately, several different techniques may be required to effectively monitor band-tailed pigeons in different parts of the interior portion of their range.

Given that populations of the interior sub-species of band-tailed pigeon appear to be in decline in southeastern Arizona and that population density of the sub-species is relatively low in mixed-conifer forest throughout the rest of the state, we recommend that managers begin regular call-broadcast surveys (or combined auditory/call broadcast surveys) of band-tailed pigeons in at least some portions of Arizona (see Appendix H for standardized survey protocol). In southeastern Arizona, surveys should be conducted primarily in mixed-conifer forests (and perhaps oak-juniper-pinyon woodland as well) where calling males were detected most frequently and band-tailed pigeons are known to nest. Elsewhere in Arizona, surveys should be conducted in other forest types as the interior sub-species of band-tailed pigeon is associated more with ponderosa pine-oak woodland (Braun 1994) and/or oak-juniper-pinyon woodland (Phillips et al. 1964).

We recommend that managers take 1 of 2 approaches to designing a monitoring program for band-tailed pigeons in Arizona. First, population trends should be monitored by establishing survey routes non-randomly in areas with known pigeon populations in the interior region (as we did in southeastern Arizona during the current study). The area around Prescott, Arizona, for example, may be an ideal location for such a survey effort as pigeons appear to be locally common and access to band-tailed pigeon habitat may be relatively easy given the network of roads and trails in the area. By necessity, inferences will be limited to the area encompassed by the survey routes; however, trends in relative abundance can be tracked across years for these local populations and a statewide average can be calculated across survey routes. Second, population trends should be monitored in band-tailed pigeon habitat throughout Arizona using a randomized sampling design (as we did in mixed-conifer forests throughout Arizona during the current study). Although power to detect population trends will be lower because fewer routes will have band-tailed pigeons, population size can be estimated and inferences can be made to larger areas of band-tailed pigeon habitat within the state. Estimates of detection probability generated during this study can be used to adjust estimates of relative abundance to estimates of absolute abundance during future surveys.

Managers should also continue surveys along existing survey routes (including those established during the current study and the road route in the Santa Catalina Mountains [Fitzhugh 1974]) and compare their findings with baseline data collected in 1968-1970 and 2002-2004. Additional research is needed to examine the impact of potential limiting factors on the interior sub-species of band-tailed pigeons including mortality risks for adults (e.g., trichomoniasis, predation, and hunting) and factors contributing to the low nest success rates observed during the current study. Management action may be necessary to address any potential limiting factors for band-tailed pigeons if perceived population declines continue in Arizona and elsewhere in the interior region.

ACKNOWLEDGMENTS

This project was funded by the Webless Migratory Game Bird Research Program, the Arizona Game and Fish Department Heritage Fund, the U.S. Fish and Wildlife Service, the U.S. Geological Survey - Arizona Cooperative Fish and Wildlife Research Unit, and the University of Arizona. C. Braun, N. Kline, and T. Sanders reviewed a draft of the proposed project and provided comments on the study design. M. Reed helped extensively with GIS. T. Deecken, G. Gonzales, G. Helbing, L. Jones, B., J. Magehee, B. Stolp, and J. Taiz assisted with access to study areas and provided information on band-tailed pigeon locations in southeastern Arizona. C. Braun, M. Casazza, L. Fitzhugh, J. Leonard, and T. Sanders provided insight into working with band-tailed pigeons. B. Peterson and the University of Arizona Steward Observatory provided field housing. J. Heffelfinger, T. Smith, and especially S. Lanham assisted with flights to locate radio-marked pigeons. S. Bennett, S. Bensen, M. Cooper, L. Currin, D. Fagan, A. and M. Faul, and M. Stanley generously provided access to their property so that we could trap pigeons. Special thanks to C. Braun for on-the-ground project assistance.

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Appendix A. Location, forest type, and fire damage of survey points along band-tailed pigeon survey routes in mountain ranges of southeastern Arizona. Fire data recorded before the 2002/2003 wildfires.

Range[1]	Route Name	Route Code	Point	UTM East[2]	UTM North[2]	Forest Type[3]	Fire Side A	Fire Side B
CH	Barfoot Park	BP	1	661385	3532280	MC	0	0
			2	661623	3532578	MC	0	0
			3	662200	3532389	MC	1	1
			4	662564	3532323	MC	1	1
			5	662951	3532427	MC	1	1
			6	663379	3532454	MC	0	0
CH	Cave Creek Canyon	CC	1	667822	3530566	-	-	-
			2	668285	3530519	-	-	-
			3	668670	3530354	-	-	-
			4	668896	3530010	-	-	-
			5	669234	3529784	-	-	-
			6	669440	3529434	-	-	-
			7	669627	3529058	-	-	-
CH	Jhus Saddle	JS	1	664356	3534531	OJP	0	0
			2	664121	3534823	OJP	0	0
			3	664024	3535223	OJP	0	0
			4	663715	3535459	OJP	0	0
			5	663664	3535861	OJP	0	0
			6	663344	3536112	OJP	0	0
CH	Methodist Camp	MC	1	658784	3534145	OJP	0	0
			2	659014	3534470	OJP	0	0
			3	659250	3534804	OJP	0	0
			4	659518	3535106	OJP	0	0
			5	659716	3535433	OJP	0	0
			6	659981	3535734	OJP	0	0
CH	Onion Saddle	OS	1	664222	3534138	OJP	0	0
			2	664514	3533892	OJP	0	0
			3	664836	3533672	OJP	0	0
			4	665054	3533324	OJP	0	0
			5	665264	3532992	OJP	0	0
			6	665357	3532592	OJP	0	0
CH	Paradise Road	PA	1	665818	3531544	OJP	0	0
			2	666146	3531758	OJP	0	0
			3	666483	3531970	OJP	0	0
			4	666804	3532198	OJP	0	0

Appendix A. Continued.

			5	667175	3532351	OJP	0	0
			6	667445	3532649	OJP	0	0
			7	667746	3532906	OJP	-	-
CH	Pinery Canyon	PC	1	663335	3534314	OJP	0	0
			2	662984	3534509	OJP	0	0
			3	662594	3534599	OJP	0	0
			4	662185	3534660	OJP	0	0
			5	661863	3534910	OJP	0	0
			6	661541	3535148	OJP	0	0
CH	Portal Grade	PG	1	665551	3532058	OJP	0	0
			2	665413	3531611	OJP	1	0
			3	665545	3531418	OJP	0	0
			4	665913	3531213	OJP	0	0
			5	666283	3531048	OJP	0	0
			6	666481	3530673	OJP	0	0
			7	666909	3530724	OJP	0	0
CH	Rustler Park	RP	1	662961	3531216	MC	0	1
			2	663235	3531502	MC	0	1
			3	663488	3531816	MC	0	3
			4	663746	3532102	PP	0	2
			5	664049	3532367	OJP	0	0
			6	664256	3532711	OJP	0	2
CH	Turkey Creek	TC	1	662810	3528939	MC	0	0
			2	662711	3529332	MC	0	0
			3	662815	3529716	MC	0	0
			4	663057	3530031	MC	0	2
			5	663397	3530255	MC	2	2
			6	663759	3530399	MC	3	3
HU	Carr Canyon	CA	1	568192	3479644	OJP	1	1
			2	568027	3479282	OJP	1	1
			3	567772	3478976	OJP	1	1
			4	567833	3478583	OJP	1	1
			5	568223	3478495	OJP	1	1
			6	568622	3478494	OJP	1	1
HU	Cross Trail	CT	1	568719	3475553	OJP	0	0
			2	568831	3475858	OJP	0	0
			3	568840	3476172	OJP	0	0
			4	568959	3476449	OJP	0	0

Appendix A. Continued.

			5	568958	3476805	OJP	0	0
			6	568997	3477153	OJP	0	0
HU	Hunter Canyon	HC	1	571753	3474468	OJP	0	0
			2	571343	3474424	OJP	0	0
			3	570959	3474323	OJP	0	0
			4	570551	3474298	OJP	0	0
			5	570169	3474183	OJP	0	0
			6	569785	3474312	OJP	0	0
HU	Ida Canyon	IC	1	564123	3472517	PO	0	0
			2	564109	3472789	PO	0	0
			3	564248	3473030	PO	0	0
			4	564344	3473264	PO	0	0
			5	564347	3473583	PO	1	1
			6	564473	3473830	PO	1	0
HU	Lyle Canyon	LC	1	554839	3481288	OJP	0	0
			2	555150	3481538	OJP	0	0
			3	555449	3481799	OJP	0	0
			4	555668	3482149	OJP	0	0
			5	556015	3482378	OJP	0	0
			6	556341	3482599	OJP	0	0
HU	Lutz Canyon	LU	1	-	-	-	-	-
			2	-	-	-	-	-
			3	-	-	-	-	-
			4	-	-	-	-	-
			5	-	-	-	-	-
			6	-	-	-	-	-
HU	Miller Canyon	MI	1	568675	3475486	PO	0	0
			2	568360	3475222	PO	0	0
			3	568056	3474950	PO	0	0
			4	567744	3474627	PO	1	0
			5	567373	3474550	PO	1	0
			6	566985	3474561	PO	0	0
HU	Oversight Canyon	OC	1	564381	3472010	OJP	0	0
			2	564760	3471895	OJP	0	0
			3	565044	3472172	OJP	0	0
			4	565101	3472543	OJP	0	0
			5	565156	3473000	OJP	0	0
			6	565117	3473421	OJP	1	1

Appendix A. Continued.

HU	Ramsey Canyon	RA	1	565784	3479121	OJP	0	0
			2	565417	3479006	OJP	0	0
			3	565147	3478706	PO	0	0
			4	565063	3478324	PO	1	0
			5	564764	3478055	PO	0	0
			6	564600	3477692	PO	0	0
HU	Scotia Canyon	SO	1	557147	3479700	OJP	0	0
			2	557376	3480028	OJP	0	0
			3	557524	3480396	OJP	0	0
			4	557713	3480747	OJP	0	0
			5	557960	3481061	OJP	0	0
			6	558356	3481122	OJP	0	0
HU	Stump Canyon	ST	1	571919	3473706	O	-	-
			2	571660	3473399	O	-	-
			3	571447	3473028	O	-	-
			4	571082	3472865	O	-	-
			5	570699	3472745	O	-	-
			6	570331	3472595	O	-	-
HU	Sunnyside Canyon	SU	1	556852	3478094	OJP	0	0
			2	557166	3478333	OJP	0	0
			3	557466	3478588	OJP	0	0
			4	557886	3478615	OJP	0	0
			5	557996	3478990	OJP	0	0
			6	558400	3478961	OJP	0	0
PI	Ash Creek A	ACA	1	601981	3618788	MC	0	0
			2	602347	3619001	MC	0	0
			3	602545	3619338	MC	0	0
			4	602906	3619522	MC	0	0
			5	603219	3619765	MC	0	0
			6	603235	3620144	MC	0	0
PI	Ash Creek B	ACB	1	603678	3620143	MC	0	0
			2	603896	3620482	MC	0	0
PI	Clark Peak	CP	1	595877	3620223	MC	0	0
			2	595555	3620481	MC	0	0
			3	595187	3620582	MC	0	0
			4	594992	3620832	MC	0	0
			5	594800	3621175	MC	0	0
			6	594825	3621487	MC	1	1

Appendix A. Continued.

PI	Columbine Trail	CO	1	596921	3620409	MC	0	0
			2	597048	3620783	MC	0	0
			3	597250	3621136	PO	1	1
			4	597337	3621511	PO	1	1
			5	597589	3621810	PO	0	0
			6	597675	3622180	PO	0	0
PI	Grant Creek A	GCA	1	604609	3616007	MC	0	0
			2	604208	3616050	MC	0	0
			3	603811	3616129	MC	0	0
			4	603558	3616459	MC	0	0
			5	603739	3616822	MC	1	0
			6	603332	3616889	MC	1	1
PI	Grant Creek B	GCB	1	604458	3615551	MC	0	0
			2	604766	3615315	MC	0	0
			3	604963	3614966	MC	0	0
			4	605395	3614815	MC	0	0
			5	605744	3614639	MC	0	0
			6	606132	3614380	MC	0	0
PI	Shannon Campground	SCG	1	606898	3613565	MC	0	0
			2	606923	3613087	MC	0	0
			3	607090	3612731	MC	0	0
			4	607318	3612321	MC	0	0
			5	607672	3612167	MC	0	0
			6	608027	3611992	MC	0	0
PI	Squirrel Refugium	SR	1	606511	3614034	MC	0	0
			2	606924	3613991	MC	0	0
			3	606932	3614376	MC	2	0
			4	606619	3614618	MC	0	0
			5	606567	3615022	MC	0	0
			6	606760	3615291	MC	0	0
PI	Turkey Flat A	TFA	1	610118	3610052	MC	0	0
			2	610255	3609642	MC	0	0
			3	609872	3609776	MC	0	0
			4	609497	3610063	MC	0	0
			5	609260	3610419	MC	0	0
			6	608944	3610669	MC	0	0
PI	Turkey Flat B	TFB	1	609902	3610492	MC	0	0
			2	610184	3610182	MC	0	0

Appendix A. Continued.

			3	610120	3610578	MC	0	0
			4	610512	3610441	MC	0	0
			5	610906	3610624	MC	0	0
			6	611108	3610946	MC	0	0
SC	Bear Wallow	BW	1[5]	525747	3586226	MC	0	0
			2	525527	3586564	MC	1	1
			3	525318	3586916	MC	1	1
			4[5]	525070	3587183	MC	0	0
			5	524707	3587316	MC	0	0
			6	524373	3587529	MC	0	0
SC	Box Camp	BC	1	524185	3586697	PP	1	1
			2[4]	523986	3586361	PP	1	1
			3	523920	3585957	MC	1	1
			4	523707	3585551	PP	1	1
			5	523412	3585337	PP	1	1
			6[4]	523105	3585091	PP	1	1
SC	Brush Corral	BR	1	529332	3584570	OJP	0	0
			2	529705	3584439	OJP	0	0
			3[4]	530030	3584601	OJP	0	0
			4	530398	3584849	PO	0	0
			5[4]	530776	3484767	MC	0	0
			6	531141	3584938	OJP	0	0
SC	Butterfly Trail	BT	1[4]	524973	3587581	MC	-	-
			2	525264	3587844	MC	-	-
			3	525659	3587831	PP	-	-
			4	526051	3587800	MC	-	-
			5[4]	526433	3587626	MC	-	-
			6	526801	3587857	POJ	-	-
SC	Control Road	CR	1[4]	524652	3590412	OJP	0	0
			2	524425	3590772	OJP	0	0
			3	524756	3590998	OJP	0	0
			4	524556	3591397	OJP	0	0
			5[4]	524337	3591708	OJP	0	0
			6	524894	3591696	OJP	0	0
SC	Crystal Spring	CS	1	524743	3590037	OJP	0	0
			2	524423	3589797	OJP	1	1
			3[4]	524074	3589645	PO	3	1
			4	524265	3589285	PO	0	0

Appendix A. Continued.

			5[4]	524182	3588899	PO	0	0
			6	524392	3588559	PO	0	0
SC	Dan Saddle	DS	1	523945	3593425	OJP	0	0
			2[4]	523621	3593676	OJP	0	0
			3	523302	3593896	OJP	0	0
			4	522943	3593736	OJP	0	0
			5	522571	3593573	OJP	0	0
			6[4]	522173	3593534	OJP	0	0
SC	Knagge Trail	KT	1[4]	527796	3585889	PP	1	1
			2	528086	3586162	MC	0	0
			3	528472	3586060	MC	0	0
			4[4]	528815	3586267	OJP	0	0
			5	529149	3586488	OJP	0	0
			6	529414	3586786	OJP	0	0
SC	Lemmon Park	LP	1	520759	3589211	MC	0	0
			2	520356	3589117	PP	0	0
			3[5]	519983	3589027	PP	1	0
			4	519619	3588865	MC	1	0
			5[5]	519246	3588698	MC	0	0
			6	518993	3588387	MC	0	0
SC	Marshall Gulch	MG	1	523001	3587734	PO	0	0
			2	522613	3587674	PO	0	0
			3[4]	522196	3587738	PO	0	0
			4	521860	3587946	PO	0	0
			5[4]	521457	3587963	PO	0	0
			6	521316	3588347	PO	0	0
SC	Oracle Ridge	OR	1[4]	523159	3590330	PO	1	1
			2	523213	3590717	MC	0	0
			3[4]	523362	3591084	PP	0	0
			4	523352	3591480	OJP	0	0
			5	523422	3591890	OJP	0	0
			6	523467	3592273	OJP	0	0
SC	Palisade Ranger	PR	1[4]	527185	3586241	MC	0	0
			2	526907	3585933	MC	0	0
			3	526712	3585660	MC	0	0
			4	526306	3585384	MC	0	0
			5[4]	526088	3585083	MC	0	0
			6	525894	3584730	PO	0	0

Appendix A. Continued.

SC	Red Ridge	RR	1	521833	3590120	MC	0	0
			2	521921	3590521	PP	2	1
			3[5]	522098	3590865	PP	1	1
			4	522024	3591257	PO	1	1
			5[5]	521971	3591655	PO	1	1
			6	522087	3592037	PO	1	0
SC	Rose Canyon	RC	1	528921	3584558	PO	1	0
			2	528576	3584357	PO	0	0
			3[4]	528210	3584144	PO	0	0
			4	527845	3584026	PO	0	0
			5[4]	527641	3583678	PO	0	0
			6	527272	3583499	PO	0	0
SC	Stratton Canyon	SC	1	525248	3594007	OJP	0	0
			2[4]	525511	3594293	OJP	0	0
			3	525787	3594595	OJP	0	0
			4[4]	526087	3594871	OJP	0	0
			5	526422	3595071	OJP	2	2
			6	526750	3595300	OJP	0	0
SC	Sykes Knob	SK	1[5]	524057	3587881	MC	-	-
			2	523721	3588039	MC	-	-
			3	523448	3588327	MC	-	-
			4[5]	523328	3588716	MC	-	-
			5	523350	3589116	MC	-	-
			6	523251	3589492	MC	-	-
SC	Upper Sabino	US	1	521282	3589781	MC	0	0
			2[5]	521688	3589869	MC	0	0
			3	522078	3589830	MC	0	0
			4[5]	522448	3589667	MC	0	0
			5	522665	3589309	MC	0	0
			6	522467	3588935	MC	0	0
			7	522064	3589026	MC	0	0
SC	Wilderness of Rocks	WR	1[4]	521075	3588108	PO	1	1
			2	520806	3587789	PO	2	2
			3	520538	3587476	PO	1	1
			4	520229	3587239	PO	1	1
			5[4]	519881	3587028	PO	2	1
			6	519551	3586819	PO	1	1
SC	Fitzhugh’s 1970 Survey	LF	1	526378	3586120	MC	0	0

Appendix A. Continued.

			2	525791	3586508	MC	0	0
			3	525235	3586672	MC	0	0
			4	525007	3587197	MC	0	0
			5	524394	3587632	MC	0	0
			6	523454	3588296	PP	0	0
			7	523348	3589069	PP	0	0
			8	523270	3589726	PP	0	0
			9	523111	3590159	MC	0	0
			10	523573	3590282	PO	-	-
			11	523954	3590318	PO	-	-
			12	524532	3590860	OJP	-	-
			13	524370	3591658	OJP	-	-
SR	Bog Springs	BS	1	511778	3510031	-	-	-
			2	512052	3509739	-	-	-
			3	512077	3509342	-	-	-
			4	512425	3509534	-	-	-
			5	512838	3509548	-	-	-
			6	513104	3509250	-	-	-
SR	Nature Trail	NT	1	511615	3508872	O	1	1
			2	511407	3509212	OJP	1	1
			3	511077	3509440	OJP	1	1
			4	510973	3509823	OJP	1	1
			5	511251	3510110	OJP	0	0
			6	511261	3510508	OJP	1	1
SR	Vault Mine Trail	VM	1	511945	3508542	-	-	-
			2	511772	3508181	-	-	-
			3	511654	3507807	-	-	-
			4	-	-	-	-	-

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[1] CH = Chiricahuas; HU = Huachucas; PI = Pinalenos; SC = Santa Catalinas; SR = Santa Ritas.

[2] UTM Zone 12; NAD27 datum.

[3] MC = Mixed-Conifer; PO = Pine Oak; PP = Ponderosa Pine; OJP = Oak Juniper Pinyon; O = Oak.

[4] 2002 20-minute survey point.

[5] 2002/2003 20-minute survey point.

Appendix B. Location, forest type, and observed fire damage at survey points along randomly selected band-tailed pigeon survey routes within mixed-conifer forests in Arizona.

National Forest	Route Code	Point	UTM East[1]	UTM North[1]	Forest Type[2]	Fire Side A	Fire Side B
Kaibab	2A	1	395721	4028955	MC	0	0
		2	395324	4028989	MC	0	0
		3	395017	4029249	MC	0	0
		4	394617	4029262	MC	0	0
		5	394257	4029100	MC	0	0
		6	393827	4029156	MC	0	0
Kaibab	2B	1	395895	4029040	MC	0	0
		2	396121	4029368	MC	0	0
		3	396037	4029755	MC	0	0
		4	396010	4030155	MC	0	0
		5	396057	4030552	MC	0	0
		6	395822	4030875	MC	0	0
Apache - Sitgreaves	3A	1	624410	3778057	MC	0	0
		2	624078	3778289	MC	0	0
		3	623788	3778565	MC	0	0
		4	623734	3778967	MC	0	0
		5	623681	3779370	MC	0	0
		6	623569	3779775	MC	0	0
Apache - Sitgreaves	3B	1	624903	3778183	MC	0	0
		2	625229	3778429	MC	0	0
		3	625219	3778835	MC	0	0
		4	625428	3779181	MC	0	0
Apache - Sitgreaves	4A	1	653161	3747537	PP	0	0
		2	653467	3747814	PP	0	0
		3	653334	3748189	MC	0	0
		4	652978	3748377	MC	0	0
		5	652767	3748698	MC	0	0
		6	652521	3749023	MC	0	0
Apache - Sitgreaves	4B	1	652961	3747231	MC	0	0
		2	652588	3747083	MC	0	0
		3	652474	3746693	MC	0	0
		4	652452	3746289	MC	0	0
		5	652367	3745898	PP	0	0
		6	652550	3745545	MC	0	0
Apache - Sitgreaves	6A	1	660336	3753203	MC	0	0

Appendix B. Continued.

		2	660190	3752832	MC	0	0
		3	660318	3752453	MC	0	0
		4	660630	3752202	MC	0	0
		5	660902	3751899	MC	0	0
		6	661228	3751658	MC	0	0
Apache - Sitgreaves	6B	1	656781	3754119	MC	0	0
		2	657096	3754375	MC	0	0
		3	657321	3754724	MC	0	0
		4	657627	3754975	MC	0	0
		5	658016	3755084	MC	0	0
		6	658413	3755181	MC	0	0
Apache - Sitgreaves	7A	1	659085	3731919	PP	0	0
		2	658867	3732260	PP	0	0
		3	658724	3732634	PP	0	0
		4	658414	3732888	PP	0	0
		5	658107	3732140	PP	0	0
		6	657847	3733438	PP	0	0
Apache - Sitgreaves	7B	1	659252	3731045	PP	0	0
		2	659600	3730844	PP	0	0
		3	659637	3730448	PP	0	0
		4	659671	3730045	PP	0	0
		5	659722	3729651	PP	0	0
		6	660079	3729521	PP	0	0
Apache - Sitgreaves	12A	1	655243	3721455	MC	0	0
		2	655020	3721224	MC	0	0
		3	655118	3720835	MC	0	0
		4	654819	3720655	MC	0	0
		5	654482	3720876	MC	0	0
		6	654080	3720799	MC	0	0
Apache - Sitgreaves	12B	1	655420	3721602	MC	0	0
		2	655790	3721754	MC	0	0
		3	656110	3721527	MC	0	0
		4	656318	3721184	MC	0	0
		5	656400	3720796	MC	0	0
		6	656516	3720452	MC	0	0
Apache - Sitgreaves	13A	1	671087	3741675	PP	0	0
		2	671499	3741580	MC	0	0
		3	671887	3741718	MC	0	0

Appendix B. Continued.

		4	672224	3741477	MC	0	0
		5	672670	3741402	MC	0	0
		6	672780	3741020	MC	0	0
Apache - Sitgreaves	13B	1	670251	3742251	MC	0	0
		2	669852	3742295	MC	0	0
		3	669439	3742255	MC	0	0
		4	669061	3742387	MC	0	1
		5	668657	3742400	MC	1	1
		6	668251	3742559	MC	0	0
Kaibab	14A	1	403240	4032929	MC	0	0
		2	403517	4033210	MC	0	0
		3	403812	4033500	MC	0	0
		4	404124	4033756	MC	0	0
		5	404258	4034131	MC	0	0
		6	404467	4034475	MC	0	0
Kaibab	14B	1	402999	4032445	MC	0	0
		2	402785	4032101	MC	0	0
		3	402752	4031696	MC	0	0
		4	402718	4031299	MC	0	0
		5	402571	4030919	MC	0	0
		6	402239	4030638	MC	0	0
Apache - Sitgreaves	15A	1	665226	3730111	PP	0	0
		2	664852	3729970	PP	0	0
		3	664452	3729992	PP	0	0
		4	664118	3730200	PP	0	0
		5	663717	3730220	PP	0	0
		6	663319	3730273	PP	0	0
Apache - Sitgreaves	15B	1	665677	3729764	MC	0	0
		2	665937	3729459	PP	1	1
		3	666310	3729646	MC	0	1
		4	666693	3729732	MC	0	1
		5	667091	3729816	MC	0	0
		6	667485	3729927	MC	0	1
Kaibab	18A	1	382297	4030944	PP	0	0
		2	382296	4030546	PP	0	0
		3	381996	4030287	MC	0	0
		4	382244	4029968	PP	0	0
		5	382440	4029652	PP	0	0

Appendix B. Continued.

		6	382758	4029836	PP	0	0
Kaibab	18B	1	382262	4031457	MC	0	0
		2	382662	4031532	MC	0	0
		3	383021	4031354	MC	0	0
		4	383407	4031445	MC	0	0
		5	383777	4031594	MC	0	0
		6	384106	4031817	MC	0	0
Kaibab	19A	1	404595	4021725	MC	0	0
		2	404193	4021734	MC	0	0
		3	403792	4021740	MC	0	0
		4	403391	4021753	MC	0	0
		5	402993	4021749	MC	0	0
		6	402597	4021814	MC	0	0
Kaibab	19B	1	405638	4021723	MC	0	0
		2	406045	4021719	MC	0	0
		3	406325	4021431	MC	0	0
		4	406664	4021200	MC	0	0
		5	406677	4020798	MC	0	0
		6	406878	4020448	MC	0	0
Kaibab	20A	1	397047	4047169	MC	0	0
		2	397439	4047246	MC	0	0
		3	397827	4047164	MC	0	0
		4	398221	4047247	MC	0	0
		5	398584	4047443	MC	0	0
		6	398894	4047704	MC	0	0
Kaibab	20B	1	396730	4046794	MC	0	0
		2	396745	4046401	PP	0	0
		3	396758	4046004	PP	0	0
		4	397148	4046087	MC	0	0
		5	397549	4046105	MC	0	0
		6	397949	4046081	MC	0	0
Prescott	24A	1	368261	3810829	PP	0	0
		2	368255	3810429	PO	0	0
		3	368653	3810367	PP	0	0
		4	369001	3810148	MC	0	0
		5	369026	3809759	MC	0	0
Prescott	24B	1	368383	3811453	PO	0	0
		2	368290	3811839	PO	0	0

Appendix B. Continued.

		3	368306	3812231	PO	0	0
		4	368252	3812646	PO	0	0
		5	368048	3813016	PO	0	0
		6	367703	3813203	PO	0	0
Kaibab	25A	1	401590	4026383	MC	0	0
		2	401873	4026666	MC	0	0
		3	401939	4027058	MC	0	0
		4	401801	4027436	MC	0	0
		5	401829	4027831	MC	0	0
		6	402154	4028083	MC	0	0
Kaibab	25B	1	401325	4025981	SP	0	0
		2	401173	4025602	SP	0	0
		3	400809	4025765	MC	0	0
		4	400482	4025987	MC	0	0
		5	400156	4026221	MC	0	0
		6	400119	4026620	MC	0	0
Kaibab	27A	1	388077	4033215	MC	0	0
		2	387784	4033485	MC	0	0
		3	387411	4033645	MC	0	0
		4	387015	4033705	MC	0	0
		5	386611	4033722	MC	0	0
		6	386211	4033695	MC	0	0
Kaibab	27B	1	388731	4032440	MC	0	0
		2	388674	4032043	MC	0	0
		3	388777	4031654	MC	0	0
		4	388717	4031258	MC	0	0
		5	388897	4030907	MC	0	0
		6	388989	4030518	MC	0	0
Apache - Sitgreaves	28A	1	652710	3735772	PP	0	0
		2	653065	3735583	PP	0	0
		3	653167	3735201	PP	0	0
		4	653355	3734844	PP	0	0
		5	653633	3734561	PP	0	0
		6	654004	3734416	PP	0	0
Apache - Sitgreaves	28B	1	652496	3735691	PP	0	0
		2	652027	3735553	PP	0	0
		3	651881	3735153	PP	0	0
		4	651841	3734759	PP	0	0

Appendix B. Continued.

		5	651911	3734377	PP	0	0
		6	651885	3733957	PP	0	0
Coronado	29A	1	599311	3620140	MC	0	0
		2	599087	3619804	MC	0	0
		3	598703	3619681	MC	0	0
		4	598324	3619511	MC	0	0
		5	597911	3619487	MC	0	0
		6	597525	3619611	MC	0	0
Coronando	29B	1	599700	3619591	MC	0	0
		2	599790	3619167	MC	0	0
		3	600107	3618918	MC	0	0
		4	600401	3618635	MC	0	4
		5	600733	3618378	MC	4	4
		6	601134	3618361	MC	0	0
Apache - Sitgreaves	30A	1	641673	3753404	MC	0	0
		2	641994	3753149	MC	0	0
		3	642278	3752864	MC	0	0
		4	642190	3752474	MC	0	0
		5	642167	3752077	MC	0	0
		6	642347	3751724	MC	0	0
Apache - Sitgreaves	30B	1	640910	3753520	MC	0	0
		2	640519	3753597	MC	0	0
		3	640250	3753967	MC	0	0
		4	640667	3753964	MC	0	0
		5	640413	3754311	MC	0	0
		6	640167	3754673	MC	0	0
Kaibab	33A	1	393522	4036264	MC	0	0
		2	393156	4036420	MC	0	0
		3	392761	4036493	MC	0	0
		4	392407	4036680	MC	0	0
		5	392140	4036973	MC	0	0
		6	391812	4037201	MC	0	0
Kaibab	33B	1	393969	4035679	MC	0	0
		2	394316	4035476	MC	0	0
		3	394707	4035532	MC	0	0
		4	395099	4035456	MC	0	0
		5	395470	4035313	MC	0	0
		6	395878	4035336	MC	0	0

Appendix B. Continued.

Apache - Sitgreaves	34A	1	678140	3745409	PP	0	0
		2	678528	3745367	PP	0	0
		3	678899	3745206	PP	0	0
		4	679298	3745243	PP	0	0
		5	679639	3745019	PP	0	0
		6	680004	3744845	PP	0	0
Apache - Sitgreaves	34B	1	677365	3745672	PP	1	1
		2	677008	3745486	-	1	1
Apache - Sitgreaves	36A	1	666253	3736665	PP	1	1
		2	666461	3737007	-	0	0
		3	666663	3737357	-	2	2
		4	666952	3737627	-	0	0
		5	667312	3737808	-	1	1
		6	667704	3737884	MC	1	1
Apache - Sitgreaves	36B	1	666590	3736924	PP	1	1
		2	666917	3736685	PP	1	1
		3	667315	3736651	PP	1	1
		4	667715	3736650	PP	1	1
		5	668085	3736493	PP	1	1
		6	668234	3736125	PP	1	1
Apache - Sitgreaves	37A	1	657722	3742846	MC	0	0
		2	657410	3743064	MC	0	0
		3	657212	3742715	MC	0	0
		4	656977	3742392	MC	0	0
		5	656570	3742381	MC	0	0
		6	656153	3742229	MC	0	0
Apache - Sitgreaves	37B	1	658212	3742856	MC	1	0
		2	658515	3743116	PP	0	0
		3	658737	3743447	PP	0	0
		4	659136	3743418	PP	0	0
		5	659481	3743619	PP	0	0
		6	659793	3743877	PO	0	0
Apache - Sitgreaves	38A	1	660205	3724806	MC	0	0
		2	659799	3724745	MC	0	0
		3	659389	3724668	MC	0	0
		4	659087	3724405	MC	0	0
		5	658762	3724167	MC	0	0
		6	658371	3724065	MC	0	0

Appendix B. Continued.

Apache - Sitgreaves	38B	1	660874	3725357	MC	0	0
		2	661124	3725721	MC	0	0
		3	661335	3726234	MC	0	0
		4	661609	3726531	MC	0	0
		5	661757	3726930	MC	0	0
		6	661928	3727313	MC	0	0
Kaibab	56A	1	420821	3917249	PP	1	0
		2	420939	3916870	PP	3	1
		3	421028	3916499	PP	3	0
		4	421235	3916191	PP	3	0
		5	421186	3915796	PP	3	3
		6	421324	3915416	PP	2	2
Kaibab	56B	1	420356	3917713	PP	0	0
		2	420163	3918059	PP	1	1
		3	419812	3918243	MC	2	4
		4	419558	3917943	PP	3	3
		5	419280	3917658	PP	3	1
		6	419044	3917345	PP	0	1

[1] UTM Zone 12; NAD27 datum.

[2] MC = Mixed Conifer; PO = Pine Oak; PP = Ponderosa Pine; SP = Spruce.

Appendix C. Dates of replicate auditory/call-broadcast surveys on band-tailed pigeon survey routes in 4 mountain ranges of southeastern Arizona in 2002. "Fire" indicates that a route was not surveyed due to wildfire in study area.

Range[1]	Route Code[1]	Survey 1	Survey 2	Survey 3	Survey 4	Survey 5	Survey 6
CH	BP	5/30	6/21	7/18	-	-	-
CH	CC	5/31	-	-	-	-	-
CH	JS	6/19	7/16	-	-	-	-
CH	MC	5/31	6/20	7/18	-	-	-
CH	OS	5/30	6/20	7/16	-	-	-
CH	PA	5/31	6/19	7/19	-	-	-
CH	PC	5/31	-	-	-	-	-
CH	PG	5/30	6/21	7/19	-	-	-
CH	RP	6/15	7/17	-	-	-	-
CH	TC	5/30	6/18	7/17	-	-	-
HU	CA	6/6	-	-	-	-	-
HU	CT	6/6	6/26	7/26	-	-	-
HU	HC	6/6	6/26	7/26	-	-	-
HU	IC	6/4	6/27	7/24	-	-	-
HU	LC	6/6	6/28	7/23	-	-	-
HU	LU	6/5	-	-	-	-	-
HU	MI	6/4	6/25	7/25	-	-	-
HU	OC	6/4	6/27	7/24	-	-	-
HU	RC	6/4	6/25	7/25	-	-	-
HU	SO	6/5	-	-	-	-	-
HU	ST	6/6	-	-	-	-	-
HU	SU	6/5	6/28	7/23	-	-	-
SC	BC	5/2	5/20	6/13	7/3	7/26	8/12
SC	BR	5/16	fire	fire	fire	fire	fire
SC	BT	5/16	fire	fire	fire	fire	fire
SC	BW	5/9	5/24	6/14	7/4	8/1	8/17
SC	CR	5/6	fire	fire	fire	fire	fire
SC	CS	5/13	fire	fire	fire	fire	fire
SC	DS	5/9	5/24	fire	fire	fire	fire
SC	KT	5/16	fire	fire	fire	fire	fire
SC	LP	5/2	5/20	6/14	7/5	7/22	8/15
SC	MG	5/2	5/22	6/13	7/4	7/22	8/12
SC	OR	5/13	6/11	7/2	7/11	7/30	8/15
SC	PR	5/6	6/12	6/24	7/9	8/1	8/19
SC	RC	5/13	6/12	6/27	7/10	7/30	8/20
SC	RR	5/6	6/12	6/25	7/10	8/2	8/21
SC	SC	5/9	5/23	fire	fire	fire	fire
SC	SK	5/13	6/11	6/27	7/11	7/22	8/16
SC	US	5/6	6/12	6/24	7/9	7/29	8/20
SC	WR	5/9	5/25	6/14	7/8	7/29	8/19
SR	BS	6/7	-	-	-	-	-
SR	NT	6/7	-	-	-	-	-
SR	VM	6/7	-	-	-	-	-

[1] See Appendix A for description of codes

Appendix D. Dates of replicate auditory/call-broadcast surveys on band-tailed pigeon survey routes in 4 mountain ranges in southeastern Arizona in 2003. "Fire" indicates that a route was not surveyed due to wildfire in study area.

Range[1]	Route Code[1]	Survey 1	Survey 2	Survey 3	Survey 4	Survey 5	Extra Double-Observer Surveys
CH	BP	5/15	6/4	6/24	7/18	8/13	-
CH	JS	5/13	6/5	6/25	7/18	8/14	-
CH	MC	5/15	6/2	6/25	7/19	8/13	-
CH	OS	5/13	6/3	6/25	7/18	8/14	7/20
CH	PA	5/14	6/4	6/25	7/19	8/11	-
CH	PG	5/14	6/6	6/24	7/19	8/11	-
CH	RP	5/13	6/3	6/24	7/19	8/12	7/20
CH	TC	5/15	6/5	6/24	7/18	8/12	-
HU	CT	5/24	6/12	6/27	7/22	8/15	-
HU	HC	5/23	6/12	6/27	7/22	8/15	-
HU	IC	5/20	6/10	6/27	7/23	8/17	-
HU	LC	5/21	6/11	6/27	-	-	-
HU	MI	5/22	6/13	6/26	7/23	8/15	-
HU	OC	5/20	6/10	6/27	7/23	8/17	-
HU	RA	5/22	6/13	6/26	7/24	8/16	-
HU	SU	5/21	6/11	6/26	7/24	8/18	-
PI	ACA	7/22	-	-	-	-	-
PI	ACB	7/22	-	-	-	-	-
PI	CO	7/21	-	-	-	-	-
PI	CP	7/21	-	-	-	-	-
PI	GCA	8/1	-	-	-	-	-
PI	GCB	8/1	-	-	-	-	-
PI	SCG	8/2	-	-	-	-	-
PI	SR	8/2	-	-	-	-	-
PI	TFA	8/3	-	-	-	-	-
PI	TFB	8/3	-	-	-	-	-
SC	BC	4/29	5/19	6/6	fire	fire	-
SC	BR	5/5	5/27	fire	fire	fire	-
SC	BT	5/12	5/26	6/17	fire	fire	-
SC	BW	5/1	5/22	6/9	fire	fire	-
SC	CR	5/5	5/29	6/13	fire	fire	-
SC	CS	5/6	5/26	6/17	fire	fire	-
SC	DS	5/8	5/29	fire	fire	fire	-
SC	KT	5/8	5/26	6/16	fire	fire	-
SC	LP	4/29	5/20	6/16	fire	fire	-
SC	MG	4/29	5/19	6/9	fire	fire	-
SC	OR	5/2	5/30	6/10	fire	fire	-
SC	PR	5/1	5/23	6/6	fire	fire	-
SC	RC	4/30	5/19	fire	fire	fire	-
SC	RR	5/6	5/26	6/16	fire	fire	-
SC	SC	5/8	5/29	fire	fire	fire	-
SC	SK	5/2	5/22	6/10	fire	fire	-
SC	US	5/5	5/28	6/11	fire	fire	6/3
SC	WR	5/6	5/28	fire	fire	fire	-

[1] See Appendix A for description of codes

Appendix E. Dates of auditory/call-broadcast surveys on band-tailed pigeon survey routes at random points located in mixed-conifer forests throughout Arizona in 2003.

Location	Route Name	Survey Date
Kaibab	2A	7/7
Kaibab	2B	7/7
Apache - Sitgreaves	3A	7/4
Apache - Sitgreaves	3B	7/4
Apache - Sitgreaves	4A	7/3
Apache - Sitgreaves	4B	7/3
Apache - Sitgreaves	6A	7/6
Apache - Sitgreaves	6B	7/6
Apache - Sitgreaves	7A	7/4
Apache - Sitgreaves	7B	7/4
Apache - Sitgreaves	12A	7/2
Apache - Sitgreaves	12B	7/2
Apache - Sitgreaves	13A	7/3
Apache - Sitgreaves	13B	7/3
Kaibab	14A	7/8
Kaibab	14B	7/8
Apache - Sitgreaves	15A	7/2
Apache - Sitgreaves	15B	7/2
Kaibab	18A	7/9
Kaibab	18B	7/9
Kaibab	19A	7/9
Kaibab	19B	7/9
Kaibab	20A	7/6
Kaibab	20B	7/6
Prescott	24A	7/11
Prescott	24B	7/11
Kaibab	25A	7/8
Kaibab	25B	7/8
Kaibab	27A	7/10
Kaibab	27B	7/10
Apache - Sitgreaves	28A	7/5
Apache - Sitgreaves	28B	7/5
Coronado	29A	7/21
Coronado	29B	7/21
Apache - Sitgreaves	30A	7/5
Apache - Sitgreaves	30B	7/5
Kaibab	33A	7/10
Kaibab	33B	7/10
Apache - Sitgreaves	34A	8/4
Apache - Sitgreaves	34B	8/4
Apache - Sitgreaves	36A	8/5
Apache - Sitgreaves	36B	8/5
Apache - Sitgreaves	37A	8/6
Apache - Sitgreaves	37B	8/6
Apache - Sitgreaves	38A	8/7
Apache - Sitgreaves	38B	8/7
Kaibab	56A	7/11

Appendix F. Dates of replicate auditory/call-broadcast surveys on band-tailed pigeon survey routes in the Santa Catalina Mountains, Arizona in 2004.

Route Code[1]	Survey 1	Survey 2
BC	6/1	6/15
BR	5/5	-
BT	5/19	-
BW	6/8	7/6
CS	5/18	-
DS	5/6	6/7
KT	5/18	-
LP	5/21	5/27
MG	5/3	6/17
PR	5/4	5/13
RC	5/18	-
RR	6/15	7/7
SK	6/11	6/29
US	6/18	7/8
WR	5/4	5/6

Appendix G. Dates of replicate 20-minute point-count surveys on band-tailed pigeon survey routes in southeastern Arizona in 2002 and 2003. “Fire” indicates that a route was not surveyed due to wildfire in study area.

	2002 replicate survey #						2003 replicate survey #		
Route Code[1]	1	2	3	4	5	6	1	2	3
BC	5/3	5/22	6/14	7/4	7/25	8/13	-	-	-
BR	5/17	fire	fire	fire	fire	fire	-	-	-
BT	5/17	fire	fire	fire	fire	fire	-	-	-
BW	5/10	5/25	6/13	7/5	8/2	8/18	4/30	-	6/13
CR	5/7	fire	fire	fire	fire	fire	-	-	-
CS	5/15	fire	fire	fire	fire	fire	-	-	-
DS	5/10	5/23	fire	fire	fire	fire	-	-	-
KT	5/17	fire	fire	fire	fire	fire	-	-	-
LP	5/3	5/23	6/15	7/3	7/21	8/14	4/30	5/19	6/17
MG	5/3	5/23	6/14	7/3	7/23	8/13	-	-	-
OR	5/14	6/12	6/27	7/12	7/31	8/16	-	-	-
PR	5/7	6/11	6/25	7/8	8/2	8/18	-	-	-
RC	5/14	6/13	6/26	7/11	7/29	8/21	-	-	-
RR	5/7	6/11	6/26	7/11	8/1	8/23	5/5	5/27	5/17
SC	5/10	5/24	fire	fire	fire	fire	-	-	-
SK	5/14	6/12	6/26	7/10	7/23	8/17	5/1	5/21	6/11
US	5/7	6/11	6/25	7/5	7/30	8/21	5/6	5/27	6/12
WR	5/10	5/24	6/15	7/5	7/30	8/20	-	-	-

[1] See Appendix A for description of codes

Appendix H. Protocol for monitoring band-tailed pigeons along survey routes in Arizona.

General survey information:

- Band-tailed pigeon populations in Arizona can be monitored along survey routes in 1 of 2 ways: 1) by establishing survey routes non-randomly in areas with known pigeon populations (i.e., along trails, roads, drainages, ridges, etc. that penetrate pigeon habitat), and/or 2) by establishing random start points for survey routes within forest types known to support band-tailed pigeons. The choice of which sampling approach to take depends on the objectives of the monitoring effort and the scope of inference desired.
- Survey points should be spaced 400 m apart along survey routes (use a hand-held GPS unit to measure the distance between survey points).
- Band-tailed pigeon surveys conducted at each survey point along survey routes can entail either a combined 12 minute auditory/call-broadcast survey period or simply a 6-minute call-broadcast survey period. Advantages to including the 6-minute auditory survey period are; 1) survey data can be compared to other strictly auditory survey efforts (e.g., BBS), and 2) a general bird survey for all species can be conducted concurrently with the auditory portion of the survey. The advantage to using only the 6 minute call-broadcast survey period is that up to 8 survey points can be completed in a morning (compared to 6 survey points using both auditory and call-broadcast survey periods). This allows a surveyor to cover more ground and potentially detect more pigeons.
- Surveys should be conducted from early May to early August or preferentially during the peak of band-tailed pigeon breeding activity (June and July in southeastern Arizona).
- Replicate surveys along the same survey route conducted from one year to the next should be standardized to reduce extraneous variability between survey efforts. For example, surveys should be conducted beginning at the same time in the morning and on roughly the same date each year. In addition, surveys should be conducted in the same direction along each survey route, and if possible, by the same observer each year.
- Surveyors should not start a survey if it's raining or if average wind speed exceeds 11 km/hour (windy conditions make it very difficult to hear pigeon vocalizations). The survey may need to be repeated if wind conditions deteriorate during the survey. The surveyor should record weather conditions (temp [C] and cloud cover [%]) at the start and end of each survey and record the wind speed using a hand-held anemometer at each point along survey routes). Mornings when winds are >11 kph tend to occur more often early in the breeding season (May and early June) in southeastern Arizona.
- Surveyors should begin surveys 15 minutes before local sunrise and continue for up to 2 hours after sunrise. Starting the survey before sunrise is critical because band-tailed pigeons vocalize most frequently starting just before sunrise. Surveyors should start the survey at the first point (generally the one closest to the road) and navigate to the other points using a hand-held GPS unit.

Appendix H. Continued.

Auditory and/or call-broadcast surveys at each survey point:

Equipment required: binoculars, call-broadcast setup (CD player, CD with BTPI broadcast tracks [contact authors for copy of CD], audio cable, speakers, extra batteries), datasheet, clipboard, pencil, watch, thermometer, GPS unit, and wind gauge.

Auditory Period (optional):

- Stand next to the survey point, record the time that you start the survey and the wind speed at the point, and begin bird survey with the 6-minute passive period.
- Rotate slowly during the survey and look around to ensure that you don't miss detections of any pigeons.
- Record each pigeon that you detect on a separate line of the datasheet and record your detections for each pigeon during each one-minute interval of the auditory period (see sample survey data sheet below). If you detect a pigeon giving a *coo-call* starting 58 seconds into the passive period and the bird keeps cooing until 1:12, record the bird as detected by CC-1 during the 1st minute of the auditory period but not second (in other words, mark the detection in the 1-minute survey interval in which the bird **started** to vocalize).
- Record the appropriate code for each detection type encountered for each pigeon (can be more than one): CC = series of coo calls ("coo-coo, coo-coo, coo-coo" = 1 series; mark as "CC-1"); G = grunt call; CH = chirp call; VF = visual flying, VP = visual perched; WF = wing flap. At a minimum, record pigeons that are detected by *coo-calls*. However, because so few pigeons are normally detected during surveys, we encourage surveyors to record detections of all band-tailed pigeons regardless of detection type (these data may be important if site occupancy is the metric used for monitoring efforts).
- In addition to pigeon detections, you can also record information on all bird species detected during the 6-minute passive period by conducting a general bird survey concurrent with the pigeon survey. Write down the alpha code for each species detected and the number of individuals seen or heard during the passive period. Record the number of individuals detected (use hash marks or totals – not both) for each species in the first time period column in the passive period (no need to record exactly when each bird was detected during each time period). Collecting data on band-tailed pigeons takes priority, so if you detect pigeons at a point, concentrate on recording data for each pigeon and disregard recording data for other species (unless there is time to do both). Make a note that you disregarded other species so analysts realize the difference between no birds detected and no general bird survey conducted.

Call-broadcast period:

- Start the 6-minute call-broadcast period immediately following the end of the passive period.

Appendix H. Continued.

- Randomly select one of the 4 broadcast tracks on the band-tailed pigeon broadcast CD (contact authors for copy of audio CD). Set the volume of the CD player and the speakers to the appropriate level (80-90 decibels measured with a sound meter positioned 1 m in front of speakers.)
- Place the speakers on top of a stump, a rock, or your backpack (which should be placed on the ground) with the speakers pointing in opposite directions. Once you start playing the track the CD player will broadcast band-tailed pigeon vocalizations for roughly 15 seconds followed by a 75-second silent period with this pattern repeated 4 times.
- Stand away from the broadcaster (~5 m) so that you can hear pigeon vocalizations over the call-broadcasts.
- Rotate slowly and look around to ensure that you don't miss detections of any pigeons (pigeons will sometimes circle overhead without vocalizing).
- Record data on pigeons in similar manner as in the auditory period (the length of the broadcast periods are not uniform but vary from ~15 seconds for calls and ~75 seconds for silence). Use the same line on the datasheet for individual pigeons that you detected previously in the auditory period and a separate line for any new pigeons detected.

In the "repeat" column, mark pigeons that were also detected at a previous point with a "Y" followed by the point it was detected at (e.g., Y2 for a pigeon that was initially detected at survey point 2 and was detected again at survey point 3). Mark pigeons that are definitely new detections with an "N". Mark pigeons that may or may not be repeat detections (status not determined) with a "U" for unknown. In addition, estimate the distance (m) to each band-tailed pigeon detected. These distance data can be used along with estimates of detection probability generated in the current study to estimate population density.

Depending on the terrain, it may take a while to walk the 400 m between survey points; therefore, hike rapidly from one point to the next so that you can complete all of the survey points within the 2.25 hour morning survey period. If you cannot finish the survey in the allotted time, you should continue with the survey until all the points are completed. If you detect a pigeon incidentally between survey points, record data (time detected, detection type, etc.) on the bird on the datasheet but indicate in the comments field that it was an incidental detection.

Appendix H. Continued. Survey form with sample data entries for band-tailed pigeons and other bird species. Note that the data sheet includes both a 6-minute auditory and a 6-minute call-broadcast survey period (as used during current study).

pt #	time start	wind	species	6-min auditory						6-min call-broadcast (Calls ~15 secs, Silence ~75 secs)								Repeat?	Dist (m)
				1	2	3	4	5	6	C	S	C	S	C	S	C	S		
1	0517	2	BTPI		CC-1 VF		CC-2 C-1				CC-3							N	100
			BTPI	CC-1	CC-1	G-1			CC-1									N	75
			RFWA	1															
			YEJU	2															
			BTPI									VF						N	F
			CORA	2															
2	0555	4	BTPI						CC-2			CC-2						Y1	350
			BRCR	2															
			HEWA	1															
			BTPI														VP CC-1	N	25