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Survival rates of band-tailed pigeons estimated using passive integrated transponder tags

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Abstract

Obtaining survival estimates on the Interior population of band-tailed pigeons (*Patagioenas fasciata*) is challenging because they are trap shy, but the joint use of passive integrated transponder (PIT) tags and bands is a potential solution. We investigated the use of PIT tags to passively recapture band-tailed pigeon at 3 locations in New Mexico, USA, to estimate survival. From 2013–2015, we captured, banded, and marked >600 individual band-tailed pigeons with PIT tags. To estimate annual survival rates, we used a Barker multi-state joint live and dead encounters and resighting model. Survival models excluding transience had survival estimates across site, sex, and year of 0.86 (95% CI = 0.84–0.88) for after hatch year birds and 0.63 (95% CI = 0.48–0.76) for hatch year birds. These results are consistent with other survival estimates reported for the Interior population of band-tailed pigeons using band return data and potentially provide an effective alternative method of monitoring survival of this population.

KEYWORDS

band-tailed pigeon, mark-recapture, New Mexico, passive integrated transponder, *Patagioenas fasciata*, survival

Band-tailed pigeons (*Patagioenas fasciata*) are a migratory game bird found in 2 distinct regions of temperate North America managed as separate populations: Pacific and Interior. Band-tailed pigeons breed from northern Colorado and east-central Utah south through Arizona, New Mexico, and the Trans Pecos area of west Texas, USA, into the Sierra Madre Occidental of Mexico. The Interior population winters primarily from northern Mexico south to at least Michoacán (Braun et al. 1975, American Ornithologists' Union 1983), but some winter in New Mexico, and likely in parts of Arizona and Texas (Collins et al. 2019). Interior and Pacific populations migrate in winter to southern portions of their respective ranges and mingle with resident band-tailed pigeons (Neff 1947, Jarvis and Passmore 1992, Collins et al. 2019, Keppie and Braun 2020).

Information about demographics and status of the Interior population is limited. Habits, visibility, and geographic inaccessibility make comprehensive counts of individual band-tailed pigeons in the Interior population impractical (Braun et al. 1975, Casazza et al. 2015, Seamans Braun 2016). The difficulty in locating and observing concentrations of individuals has also resulted in unreliable estimates of absolute and relative abundance (Casazza et al. 2000). From the 1970s through the late 1980s, researchers described movements, demographics, and natural history of the Interior population of band-tailed pigeons in Colorado and Arizona (Gutierrez et al. 1975, Kautz and Braun 1981, Curtis and Braun 1983, White and Braun 1990). Other portions (i.e., NM, UT) of the interior range have not been investigated until recently, with many life-history traits left to be studied (i.e., survival; Coxen et al. 2017, Collins et al. 2019, Ross et al. 2022). These difficulties make the conservation and management of band-tailed pigeons in the Interior population especially challenging across their entire range (Seamans and Braun 2016). Long-term banding data from Colorado suggest there is a need for baseline demographic data for the Interior population in other parts of its range and researchers suggested more information could be gleaned using additional capture-recapture analytical techniques (Burnham et al. 1987, Lebreton et al. 1992, Williams et al. 2002, Seamans and Braun 2016). A potential approach to improving our demographic estimates for this species could be in the use of passive integrated transponder (PIT) tags.

A PIT tag is a small electromagnetic microchip encapsulated in a sealed glass tube that can be attached externally or implanted. These tags do not require a power source. A transceiver that generates an electromagnetic field is all that is needed to activate the PIT tag. The unique alphanumeric code, emitted by each PIT-tagged animal when passing close to a reader antenna, is detected and stored in a data logger (Ratnayake et al. 2014). Passive integrated transponder tag technology has been widely used in industry, commerce, animal and veterinary science, and fisheries research since the early 1990s (Schooley et al. 1993, Gibbons and Andrews 2004, Rehmeier et al. 2006, Bonter and Bridge 2011). For example, Rose et al. (2018) used PIT tags in giant gartersnakes (*Thamnophis gigas*), an elusive species making traditional capture-recapture methods of survival estimation impracticable. Within the avian ecology realm, the technology has been used to study feeding rates (Wilkin et al. 2009), dispersal (Becker et al. 2008), and identification of individual nests in a colony (Booms and McCaffery 2007). Sanders and Koch (2017) used PIT tags to estimate visitation and use of supplemental mineral sites by the Pacific population of band-tailed pigeons. Widespread application of this technology specifically investigating survival and recapture rates is, however, limited (Bonter and Bridge 2011).

Passive integrated transponder tag technology can be used alone or in conjunction with traditional methods of marking individual birds (i.e., banding), allowing for the continuous generation of valuable recapture data that would allow for estimation of survival across multiple time scales (Bonter and Bridge 2011). Other techniques present their own unique drawbacks in estimating survival. For example, very high frequency transmitters do not allow individuals to be relocated when they display nomadic or migratory behaviors and contemporary estimates using band recoveries would require intensive re-trapping efforts to compensate for reduced hunter recovery (Casazza et al. 2015). On the contrary, PIT tag technology enables collecting large quantities of accurate and reliable data, through a fully automated data collection system, minimizing handling effects and trapping effort (Ratnayake et al. 2014). Specifically, band-tailed pigeons become trap shy after even just 1 capture event and the application of PIT tags to passively track and record visitation rates seasonally and across years has the potential to improve vital rate estimates for this species (Coxen et al. 2018).

Our objective was to estimate annual survival for band-tailed pigeons banded and marked with PIT tags at 3 different sites in New Mexico and assess whether this technique could meet survival estimation objectives specified by the Pacific and Central Flyway Council Management Plan for the Interior population. We predicted survival estimates would differ between age, sex, and site, and that transience (Pradel et al. 1997) may influence apparent survival estimates of newly banded birds.

STUDY AREA

We captured band-tailed pigeons from 2013–2015 at 3 private land sites in Silver City, Weed, and Los Alamos, New Mexico (314,333 km^2, Coxen et al. 2017; Figure 1). We chose sites at locations where band-tailed pigeons had been observed visiting for ≥5 years. Elevations in New Mexico range from 866 m to 4,013 m with a mean elevation of 1,737 m above sea level and has 3 topographic zones. The Rocky Mountain zone extends through the north central section of New Mexico. The Plains extend from the eastern border west to the first range of the mountains that extends from the Sangre de Cristos south to the Guadalupe Mountains. The Intermountain Plateau includes the remainder of the state. The landscape that surrounds the capture locations is composed of United States National Forest Service lands that are multi-use (e.g., grazing, timber allotments, wilderness). In general, New Mexico is primarily defined as having a cold steppe Köppen climate; however, our Silver City (32.7701°N, 108.2803°W) and Weed (32.8022°N, 105.5170°W) study areas are also characterized by Mediterranean warm temperature climates with hot dry summers, whereas Los Alamos (35.8800°N, 106.3031°W) has a continental warm temperature, fully humid climate (Kottek et al. 2006). Biotic communities at mid-elevations near our study areas are primarily Great Basin conifer woodland and petran montane conifer forest but also include grasslands at elevations <2,000 m, and petran subalpine conifer forest at elevations >3,000 m (Brown et al. 1979). The study areas support a diverse faunal community, such as American black bear (*Ursus americanus*), elk (*Cervus canadensis*), mule deer (*Odocoileus hemionus*), turkey (*Meleagris gallopavo*), coyote (*Canis latrans*), a variety of song birds (e.g., dark-eyed junco [*Junco hyemalis*], and white-breasted nuthatch [*Sitta carolinensis*]), and a variety of reptiles and amphibians (e.g., western diamondback [*Crotalus atrox*], and Woodhouse's toad [*Anaxyrus woodhousii*]).

METHODS

We began trapping in early May and continued through September 2013–2015 (Coxen et al. 2018). We captured band-tailed pigeons using whoosh nets at baited sites where homeowners had been feeding birds for many years (Coxen et al. 2018). Each band-tailed pigeon received a standard size 5 United States Geological Survey band and a PIT tag injected under the skin at the base of the neck between the shoulders. We weighed, aged, and sexed all birds (Braun 1976, Passmore and Jarvis 1979, Sanders and Braun 2014, Coxen et al. 2017). We captured and monitored birds at Silver City during 2013, 2014, and 2015, and capture and monitoring occurred in Los Alamos and Weed during 2014 and 2015.

We installed PIT tag reader antenna arrays at each field site to passively record the daily visitation patterns of tagged birds. Antenna arrays provide the data to construct the mark-recapture histories needed to estimate annual survival rates at each study site. The PIT tag reader arrays consisted of 3–4 antennae configurations connected to waterproof data loggers (Oregon RFID, Portland, OR, USA). Each antenna was constructed using repeated wraps of 16-gauge wire until the height of the electrical field was achieved to pick up band-tailed pigeons with PIT tags as they passed through and left the array. Each antenna was connected to a tuning box, which ensured PIT tags were read with efficiency (i.e., as band-tailed pigeon enter and leave the array they are recorded and allow new birds to be recorded). The data logger records the exact time and date of a PIT tag once it enters the antenna field and continuously records until the tag leaves the field. Daily visitation can be established from the time and date stamped records for each tagged bird. We tested the antenna array performance by running a PIT tag through the array multiple times before deployment and checked for proper data logging. We deployed antenna arrays prior to or directly after the first band-tailed pigeon spring visitation for the year, and removed them after pigeons had been absent for ≥2 weeks in fall (2013–2015). We downloaded data logs from the reader during each trapping session (every ~10 days).

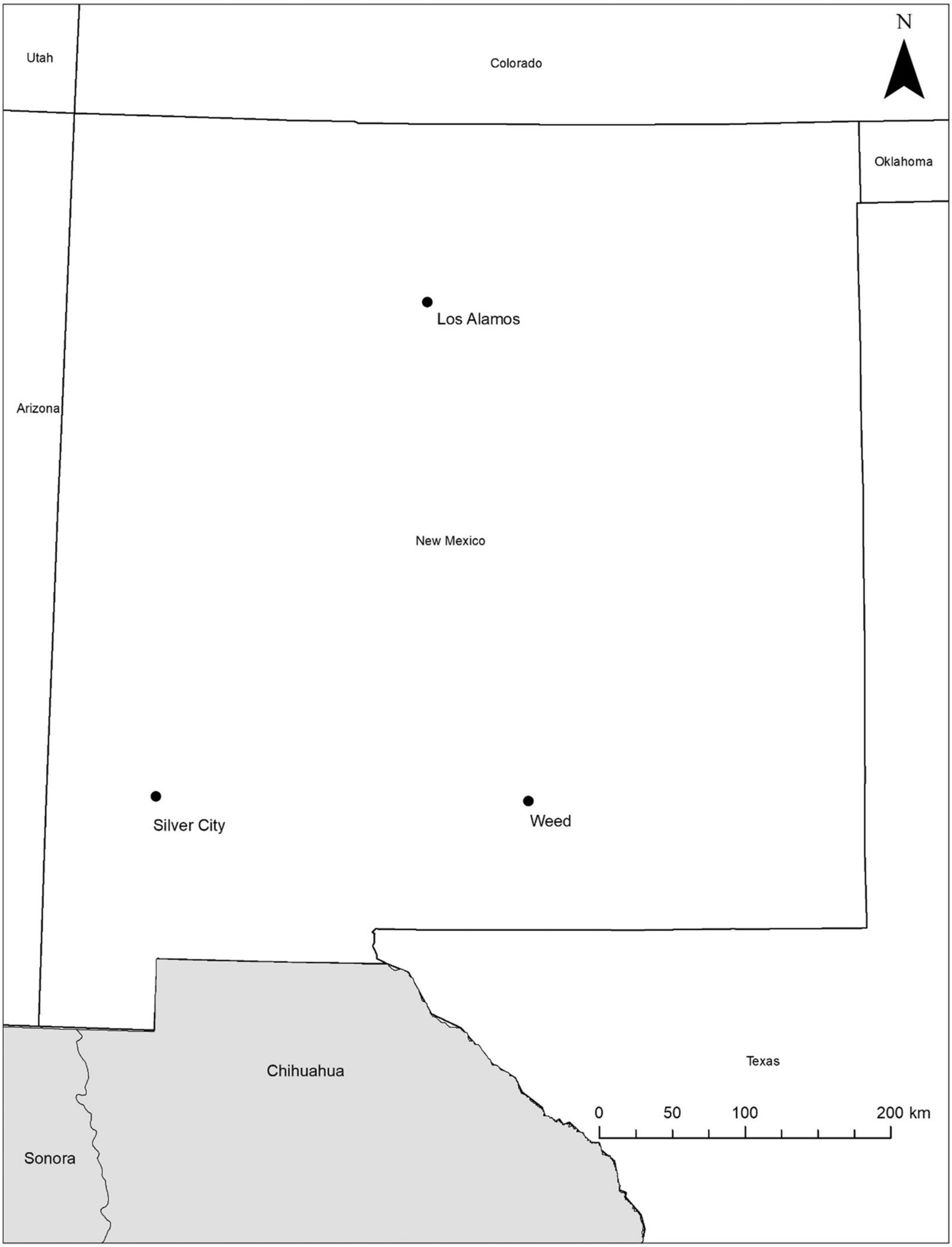

FIGURE 1 Capture and banding sites of band-tailed pigeons in Weed, Silver City, and Los Alamos, New Mexico, USA, 2013–2015.

Data analysis

We used the Barker multi-state joint live and dead encounters and resighting model in program MARK (White and Burnham 1999, Barker and White 2004), an extension of Kendall et al. (2013), to analyze the PIT tag data. This model includes parameters for survival and transitions among states between defined sampling periods. It uses recaptures or resightings within capture periods, which could identify the state the individual occupies, and it uses auxiliary dead recoveries and live resightings between sampling periods, which also could indicate which state the individual occupied in the previous sampling period. Individuals had to return to feeding stations to be detected after banding, and we know that some individuals left the area after being banded and were unavailable for resighting. Thus, we considered 2 states: available to be resighted (observable) and unavailable to be resighted (unobservable). We fixed the live recapture probability to zero for the unobservable state. We organized the sampling period into weekly intervals within the trapping season and assumed an open population, which allowed birds to move out of and into the capture area between sampling periods.

We estimated the following parameters in the models: survival rate (S), transition between observable and unobservable states (ψ), live recapture probability (p), live resighting probability (at arrays after birds obtained a PIT tag) for those that survive the interval (R), and probability of live resight before dying for those that do not survive the interval (R'). We fixed p, R, and R' to zero for the unobservable state because there was no detection effort outside the PIT tag array or capture area. We also assumed that survival was identical for observable and unobservable states (Kendall et al. 1997). Because there is only 1 observable state, there is no ambiguity about which state a detected pigeon is in. Therefore, we fixed all parameters related to state assignment to 1.0. Because we did not have dead recoveries, we fixed dead recovery probabilities to zero.

From the beginning of the study in 2013 to the end in 2015, we had 18 time intervals of various lengths (12, 17, 14, 23, 14, 14, 255, 15, 11, 16, 12, 34, 14, 272, 11, 22, 28, and 142 days). For all analyses, we rescaled survival estimates for each of these intervals to an annual rate, using the time intervals setting option in MARK. We considered 2 age classes (hatch year [HY] and after hatch year [AHY]), sex, and location (Silver City, Weed, Los Alamos). We could not identify the sex with certainty for some individuals, so we compared a model including an indicator variable for known females (i.e., unknown sex band-tailed pigeons were grouped with males) with 1 including known males and identified the better-supported variable for handling unknown sex of birds. In addition to temporary emigration, we also allowed for the possibility that some captured pigeons were transients, with zero probability of returning to an antenna array. To determine how transience would influence survival estimates, we specified models focusing on the relationship between transience, age, and year on survival. Data were not collected consistently among sites and time, so we did not consider interactions between them. We assumed an interaction between age and state for ψ, age-specific p, and age-specific R and R' for all models. We compared the performance of the models in our model set using corrected Akaike's Information Criterion (AIC$_c$; Hurvich and Tsai 1989).

We conducted a second set of analyses focusing on estimates of survival after assessing the importance of transience, and estimating the best structure on ψ, p, R, and R'. For this set of analyses, we explored whether survival rates were constant among age, sex, and site, and whether these effects appeared to be additive, or with interactions among these factors. We could not include interactions between age and sex of HY birds because the sex of HY could not be determined.

RESULTS

We captured 641 band-tailed pigeons and banded birds at all 3 sites in New Mexico (2013–2015): 596 individuals were physically captured 1 time, 17 were captured 2 times, 25 were captured 3 times, 1 was captured 4 times, 1 was captured 5 times, and 1 was captured 6 times. Most (n = 577) were AHY, and most of the AHY birds were males (Table 1). The sex

TABLE 1 Summary of the number of band-tailed pigeons captured and banded with passive integrated transponder (PIT) tags for each site in New Mexico, USA, 2013–2015, age (after hatch year [AHY] and hatch year [HY]), and sex (female [F], male [M], and unknown [U]).

	Silver City				Los Alamos				Weed			
	AHY			HY	AHY			HY	AHY			HY
Year	F	M	U	U	F	M	U	U	F	M	U	U
2013	43	77	0	1	0	0	0	0	0	0	0	0
2014	34	97	1	19	20	49	1	8	15	34	0	21
2015	26	10	0	4	29	41	0	2	76	24	0	9

of 2 AHY and all 64 HY band-tailed pigeons could not be determined. Only a single HY band-tailed pigeon was captured in 2013, which precluded us from getting a reliable survival estimate for that age-class during that year. Of the 641 banded and marked band-tailed pigeons, 479 were detected (i.e., live capture, antenna array capture, or combination of both) in a single year, 129 were detected (i.e., live capture, antenna array capture, or combination of both) in 2 years, and 33 were detected (i.e., live capture, antenna array capture, or combination of both) in all 3 years. A single band-tailed pigeon was detected at 2 different sites (Los Alamos in 2014, Silver City in 2015, Los Alamos in 2015). Of the 641 band-tailed pigeons included in the analysis, 296 were detected at an antenna array at least once, while 345 were never detected at an antenna array after initial capture. All HY band-tailed pigeons transitioned to AHY detections the next year.

Models that ignored transience estimated annual survival across site, sex, and year as 0.86 (95% CI = 0.84–0.88) for AHY and 0.63 (95% CI = 0.48–076) for HY birds. Transition probabilities from observable to unobservable states was higher for HY birds (0.74, 95% CI = 0.53–0.89) compared to AHY birds (0.10, 95% CI = 0.05–0.17). In contrast, we did not detect a strong difference in transition from unobservable to observable states between the 2 age classes (HY = 0.34, 95% CI = 0.10–0.71; AHY = 0.28, 95% CI = 0.18–0.41). Live recapture probabilities of AHY pigeons were very low (0.02, 0.01–0.03), and those of HY were higher and less precise (0.28, 95% = 0.11–0.57). Estimates of resight probabilities at arrays were also lower and more precise for AHY (0.41, 95% CI = 0.37–0.46) than HY (0.79, 95% CI = 0.51–0.93) birds. The top fitting models from our first analysis included transience (Table 2); however, not all parameters were estimable in models with transience, and estimates of survival for non-transients were unrealistically high in some cases (Figure 2). Most models had parameter estimates that did not converge, which were usually R′ and survival for HY birds during 2013 (Table 2). Therefore, we reformulated the model set without accounting for transience.

The second step of our analysis with the reformulated model set suggested differential survival among age, sex, and location (Table 3). Age and location effects were in each of the top 5 models, which represented all model weight. Sex effects were included in the top 3 models, constituting 85% of the model weight. The top model indicated an additive effect among the 3 factors, but the second-ranked model suggested a potential interaction between location and sex (ΔAIC_c = 0.81) and a third-ranked model indicated a potential interaction between age and location (ΔAIC_c = 1.26; Table 3). These 3 models indicated similar patterns in survival rates with survival rates being highest for AHY males, followed by AHY females, and then HY birds; we observed the highest survival rates in Silver City and lowest for birds captured in Weed (Figure 3). The one deviation from this general pattern was from the third-ranked model that indicated HY survival in Los Alamos was slightly higher than survival for AHY females in Los Alamos and HY survival in Silver City (Figure 3). The parameter estimates in the top-ranked model of the revised model set excluding transience supported strong differences in these variables (Table 4).

TABLE 2 Models selection using corrected Akaike's Information Criterion (AIC_c) for models including transience considered for estimating survival of band-tailed pigeons banded and marked with passive integrated transponder (PIT) tags at Silver City, Los Alamos, and Weed, New Mexico, USA, 2013–2015. Models with parameters that did not converge are indicated with an asterisk.

Model number	Model[a]	AIC_c	ΔAIC_c	AIC_c weights	Number of parameters	Number of estimated parameters	Deviance
1	*{S(a × y × trans), ψ(state × a), p(a), R(a), R'(0)}	4,224.71	0.00	0.88	20	19	4,184.08
2	*{S(a × y × trans), ψ(state × a), p(a), R(a), R'(a)}	4,228.63	3.93	0.12	22	21	4,183.88
3	*{S(a × t × trans), ψ(state × a), p(a), R(a), R'(a)}	4,254.56	29.85	0.00	78	62	4,088.92
4	*{S(a × trans + location + sex), ψ(state × a), p(a), R(a), R'(a)}	4,272.00	47.30	0.00	17	16	4,237.55
5	*{S(a × trans + location), ψ(state × a), p(a), R(a), R'(a)}	4,273.72	49.01	0.00	16	15	4,241.31
6	*{S(a × trans × location), ψ(state × a), p(a), R(a), R'(a)}	4,280.21	55.51	0.00	22	20	4,235.45
7	*{S(a × trans + female), ψ(state × a), p(a), R(a), R'(a)}	4,304.09	79.39	0.00	15	14	4,273.73
8	*{S(a × trans + male), ψ(state × a), p(a), R(a), R'(a)}	4,305.15	80.44	0.00	15	14	4,274.79
9	{S(a × trans), ψ(state × a), p(a), R(a), R'(0)}	4,307.73	83.02	0.00	12	12	4,283.49
10	*{S(a × trans × female), ψ(state × a), p(a), R(a), R'(a)}	4,310.18	85.47	0.00	18	15	4,273.67
11	{S(a × trans), ψ(state × a), p(a), R(a), R'(a)}	4,311.74	87.04	0.00	14	14	4,283.43
12	*{S(a × y × trans), ψ(state × a), p(a), R(a), R'(0)}	4,304.07	79.36	0.00	20	19	4,271.66
13	{S(a × trans), ψ(0), p(a), R(a), R'(0)}	4,417.56	192.85	0.00	8	8	4,401.45
14	*{S(a + location), ψ(state × a), p(a), R(a), R'(a)}	4,423.66	198.96	0.00	14	12	4,395.35
15	{S(a × t × trans), ψ(0), p(a), R(a), R'(0)}	4,469.39	244.69	0.00	10	10	4,449.23
16	{S(a), ψ(state × a), p(a), R(a), R'(0)}	4,497.82	273.12	0.00	10	10	4,477.66
17	{S(a), ψ(0), p(a), R(a), R'(0)}	4,533.48	308.77	0.00	6	6	4,521.42

[a] Parameters include survival (S), transition probability between observable and unobservable states (ψ), live capture probability (p), live recapture probability at PIT arrays (R), and probability of being seen alive before dying (R'). Covariates include age (a; hatch year and after hatch year), year (y; 2013, 2014, and 2015), location (Los Alamos, Silver City, or Weed), transience (trans; transient or resident), and state (observable or unobservable).

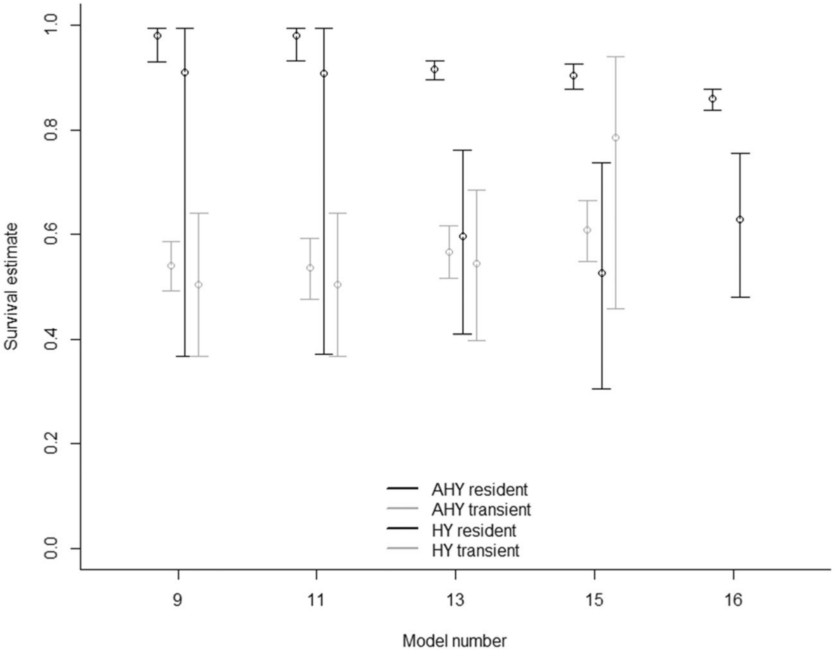

FIGURE 2 Survival estimates and 95% confidence intervals from models with full convergence exploring the potential influence of transience (resident vs. transient) for after hatch year (AHY) and hatch year (HY) band-tailed pigeons banded and marked with passive integrated transponder (PIT) tags at Silver City, Los Alamos, and Weed, New Mexico, USA, 2013–2015.

TABLE 3 Model selection results based on small sample corrected Akaike's Information Criterion (AIC_c) for models assessing differences in survival among age, sex, and site covariates for band-tailed pigeons banded and marked with passive integrated transponder (PIT) tags in Silver City, Los Alamos, and Weed, New Mexico, USA, 2013–2015.

Model[a]	AIC_c	ΔAIC_c	AIC_c weights	Number of parameters	Deviance
{*S*(a + site + sex), ψ(state × a), *p*(a), *R*(a), *R*′(0)}	4,416.79	0.00	0.39	13	4,390.52
{*S*(a + site × sex), ψ(state × a), *p*(a), *R*(a), *R*′(0)}	4,417.60	0.81	0.26	15	4,387.25
{*S*(a × site + sex), ψ(state × a), *p*(a), *R*(a), *R*′(0)}	4,418.05	1.26	0.21	15	4,387.70
{*S*(a + site), ψ(state × a), *p*(a), *R*(a), *R*′(0)}	4,419.58	2.79	0.10	12	4,395.35
{*S*(a × site), ψ(state × a), *p*(a), *R*(a), *R*′(0)}	4,421.03	4.24	0.05	14	4,392.71
{*S*(a + AHY female), ψ(state × a), *p*(a), *R*(a), *R*′(0)}	4,489.57	72.78	0.00	11	4,467.37
{*S*(a), ψ(state × a), *p*(a), *R*(a), *R*′(0)}	4,497.82	81.03	0.00	10	4,477.66
{*S*(a), ψ(state × a), *p*(a), *R*(a), *R*′(a)}	4,501.89	85.10	0.00	12	4,477.66

[a] Parameters include survival (*S*), transition probability between observable and unobservable states (ψ), live capture probability (*p*), live recapture probability at PIT arrays (*R*), and probability of being seen alive before dying (*R*'). Covariates include age (a; hatch year [HY] and after hatch year [AHY]), year (y; 2013, 2014, and 2015), site (Los Alamos, Silver City, or Weed), and state (observable or unobservable).

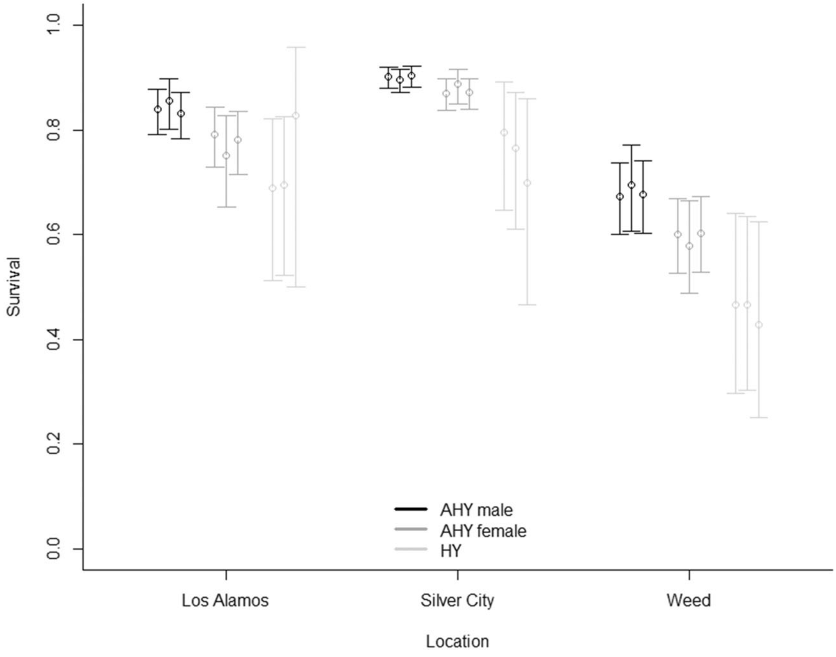

FIGURE 3 Estimated annual survival rates and 95% confidence intervals of band-tailed pigeons among models within 2 small-sample corrected Akaike's Information Criterion (AIC_c; from left to right = best model, second-ranked model, and third-ranked model) for each age (after hatch year [AHY] and hatch year [HY]), sex (male and female), and site (Los Alamos, Silver City, and Weed), New Mexico, USA, 2013–2015.

TABLE 4 Parameter estimates on the logit scale from the top-ranked model for estimating survival (*S*) of band-tailed pigeons in Los Alamos and Weed, New Mexico, USA, 2013–2015.

Parameter	Covariate[a]	Estimate	SE	95% CI
β_o	Intercept	1.36	0.38	0.61–2.11
β_1	AHY	0.86	0.38	0.12–1.61
β_2	Los Alamos	−0.57	0.17	−0.91–−0.23
β_3	Weed	−1.50	0.17	−1.83–−1.17
β_4	Female	−0.31	0.14	−0.59–−0.04

[a] $\text{logit}(S) = \beta_o + \beta_1 \times \text{AHY} + \beta_2 \times \text{Los Alamos} + \beta_3 \times \text{Weed} + \beta_4 \times \text{female}$; after hatch year (AHY) = 1 for AHY and 0 for hatch year (HY), Los Alamos = 1 for Los Alamos and 0 for other locations, Weed = 1 for Weed and 0 for other locations; and female = 1 for AHY females and 0 for AHY males.

DISCUSSION

We estimated survival for band-tailed pigeons in the Interior population using mark-recapture techniques through PIT tag technology. This novel mark-recapture technique is potentially practical for operational monitoring of band-tailed pigeon survival rates and could meet the Pacific and Central Flyway Council Management Plan for the Interior population objective to estimate survival rates through a long-term (5 yr) banding program and potentially estimate population abundance if conducted at the appropriate scale (Pacific and Central Flyway Councils 2018).

Annual survival of Pacific population AHY band-tailed pigeons was 0.661 (95% CI = 0.466–0.813; Casazza et al. 2015). These birds were equipped with platform terminal transmitters, which have limitations in estimating survival. For example, difficulty in differentiating mortality from platform transmitter terminal failure (e.g., battery does not recharge or internal components stop working such as the global positioning system) may inflate survival rates because known fate models assume a detection probability of 1.0 and signal detection is uncorrelated with individual fate (Tsai et al. 1999). Kautz and Braun (1981) reported mean annual survival rates of 73% (95% CI = 65–80%) for adult and 66% (95% CI = 45–88%) for juvenile band-tailed pigeons in Colorado. Analysis of band return data in Colorado resulted in annual survival estimates of 71.9 ± 1.6% for adults and 63.3 ± 3.1% for juveniles (Seamans and Braun 2016). Our results are similar to estimates obtained from band-recovery data reported by Seamans and Braun (2016); our estimates were slightly higher for adults but within the stated confidence intervals for juveniles. This may be an indication that this mark-recapture technique is more precise in estimating survival because observability of adult band-tailed pigeons is better. Seamans and Braun (2016) reported that of 25,730 band-tailed pigeons trapped and aged in the southern Rocky Mountain region of Colorado, 88.8% (*n* = 22,852) were classified as adults and 11.2% (*n* = 2,878) were classified as young-of-the-year (juveniles; Braun et al. 1975). While our sample size was markedly smaller, age structure was similar; 90% (*n* = 577) were classified as adults and 9.9% (*n* = 64) were classified as HY birds. These findings provide a novel methodological approach to gathering baseline information on annual survival and age structure for the Interior population outside of Colorado that were previously lacking.

MANAGEMENT IMPLICATIONS

Our results suggest a small concentrated banding program across the interior range could be useful to aid in the monitoring of band-tailed pigeon survival with added resights at PIT tag readers and address objectives laid out by the Pacific and Central Flyways to maximize the potential for sustained consumptive and nonconsumptive uses. The ability to identify all individuals in a study population with limited disturbance is an advantage of PIT tags, especially with a species like band-tailed pigeons that show high site fidelity, become trap shy, and are negatively affected by the presence of humans. Minimizing human disturbance can be particularly important when repeated captures may interfere with the behavior or physiology of birds, as seen in band-tailed pigeons.

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CONFLICTS OF INTEREST STATEMENT

The authors have no conflict of interest to report.

ETHICS STATEMENT

This study was conducted with approval and authorization under the Institutional Animal Care and Use Committee at New Mexico State University (2014-016), New Mexico Department of Game and Fish (3535), and United States Geological Survey Federal Bird Banding Permit (22440).

DATA AVAILABILITY STATEMENT

Data available on request from the authors.

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