Research Article

Survival, Fidelity, and Recovery Rates of White-Winged Doves in Texas

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ABSTRACT Management of migratory birds at the national level has historically relied on regulatory boundaries for definition of harvest restrictions and estimation of demographic parameters. Most species of migratory game birds are not expanding their ranges, so migratory corridors are approximately fixed. White-winged doves (*Zenaida asiatica*), however, have undergone significant variation in population structure with marked range expansion occurring in Texas, and range contraction in Arizona, during the last 30 years. Because >85% of white-winged dove harvest in the United States (approx. 1.3 million annually) now occurs in Texas, information on vital rates of expanding white-winged dove populations is necessary for informed management. We used band recovery and mark–recapture data to investigate variation in survival and harvest across 3 geographic strata for white-winged doves banded in the pre-hunting season in Texas during 2007–2010. We banded 60,742 white-winged doves, recovered 2,458 bands via harvest reporting, and recaptured 455 known-age birds between 2007 and 2010. The best supporting model found some evidence for geographic differences in survival rates among strata (A–C) in both hatch-year (juvenile; A = 0.205 [SE = 0.0476], B = 0.213 [SE = 0.0278], C = 0.364 [SE = 0.0254]) and after-hatch year (adult; A = 0.483 [SE = 0.0775], B = 0.465 [SE = 0.0366], C = 0.538 [SE = 0.251]) birds. White-winged doves had a low probability of moving among strata (0.009) or being recaptured (0.002) across all strata. Harvest recovery rates were concordant with estimates for other dove species, but were variable across geographic strata. Based on our results, harvest management strategies for white-winged doves in Texas and elsewhere should consider differences in population vital rates among geographic strata.

KEY WORDS banding, harvest, multi-state capture recapture, site fidelity, survival, recovery rates, Texas, white-winged dove, *Zenaida asiatica*.

Informed harvest management of migratory birds calls for detailed knowledge of demographic parameters for use in mechanistic models to predict population response to environmental variation or alternative harvest scenarios (Williams and Johnson 1995, Runge et al. 2004, Otis 2006). Ideally, population models would synthesize existing data and provide insight into additional system parameters where further data acquisition should focus (Johnson and Kendall 1997). However, requisite data for model development is scarce for all but a few migratory game species (Nichols et al. 2007), thus hindering our ability to effectively manage species at the local, regional, and national scale. Doves (*Zenaida* spp.) represent one of the most widespread species in United States. Population estimates for doves exceed 300 million individuals (Otis et al. 2008), with an annual harvest of approximately 20 million, and >1 million hunters spending >3 million days afield annually pursuing doves (Raftovich et al. 2010). Because of tremendous interest in dove hunting and reported declines in mourning dove (*Z. macroura*) abundance (Sanders and Parker 2010), development of adaptive management strategies for mourning doves has garnered considerable management attention nationally in recent years (Otis 2002, Anonymous 2005, Otis 2006, Otis et al. 2008). As doves provide benefits to state and local economies, and often are the gateway for introducing individuals to hunting (Hayslette et al. 2001), both state and federal regulatory agencies have emphasized gathering information on mourning dove populations (Williams and Johnson 1995, Anonymous 2005, Otis 2009).

The white-winged dove (*Z. asiatica*) is less ubiquitous than the mourning dove, with a native range restricted to the southwestern United States and Mexico, and with introduced populations in Florida (Cottam and Trefethen 1968, George et al. 1994). Historically, white-winged doves were confined to semi-arid and arid habitats in the southwestern United States and Mexico (Schwertner et al. 2002); however,

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white-winged doves have slowly expanded their distribution by transitioning to urban environments across the southwestern United States (Rabe and Sanders 2010, Veech et al. 2011). In Texas, white-winged doves currently breed in >200 counties, excluding most of east Texas, whereas in 1980 only 10 counties in the Lower Rio Grande Valley had consistent white-winged dove breeding populations. Outside of the species' historic range in Texas, white-winged doves are confined almost exclusively to urban environments and preliminary evidence suggests most birds have developed breeding colonies in the residential centers of cities (Schwertner and Johnson 2005), with unknown impacts on population demography.

White-winged doves represent a significant recreational resource, with approximately 1.3 million white-winged doves harvested annually in Texas, relative to a total annual harvest of approximately 1.6 million throughout the United States (Raftovich et al. 2010). Similar harvest levels likely occur in Mexico (Pacific Flyway Council 2003). Even though white-winged doves represent the second most harvested webless migratory game bird in the United States, and more white-winged doves are harvested annually in Texas than nationwide harvest for many waterfowl species (Raftovich et al. 2010), little focus has been placed on collecting data requisite for supporting management planning for white-winged doves. The only current evaluation of population status for this species focused on Arizona (Rabe and Sanders 2010), with little discussion of white-winged dove status in California, New Mexico, and Texas (native ranges) or Florida (introduced range). Previous banding studies (George et al. 2000) advanced our knowledge on white-winged dove vital rates, but those data were collected between 1950 and 1980 in the Lower Rio Grande Valley and Mexico, thus these data do not provide a representative evaluation of current population vital rates given the white-winged dove's range expansion in this region (Veech et al. 2011). For these reasons, lack of basic information on white-winged dove demography inhibits management, particularly because regulatory restrictions should be based on informed knowledge of a species' population dynamics (Williams and Johnson 1995, Otis 2002).

White-winged doves exhibit characteristics of a species that is both expanding its range within Texas and the Central Flyway, and potentially shifting from an annual migrant to resident, with unknown implications for population-level distribution, demography, and availability to harvest. Several studies have focused on demographic parameter estimation and provide insight into local population dynamics (Hayslette et al. 2000, Small et al. 2005). However, large-scale banding studies are necessary to evaluate rangewide demography, potential implications of differential breeding stocks relative to harvest distribution and derivation (Collier et al. 2012), and future impacts of regulatory actions and hunting activities (Otis and White 2002). As white-winged doves show high site fidelity and limited dispersal from natal environments to harvest location (Collier et al. 2012), we expected that birds would remain faithful during the hunting season immediately post-banding to their original banding locations whether captured as hatch-year or after-hatch-year. During the course of our study, Texas had 3 dove hunting zones separated by recognizable boundaries (e.g., interstate highways), so we created 3 strata similar to these zones (Fig. 1). Strata A and B had the same regulatory structure (same season length, bag length, and opening day), whereas strata C opened approximately 20–25 days later and included 2 2-day special season hunting periods in the interim weekends between 1 September and opening of strata C during which mourning doves were limited to 4 per day in the bag.

Our objective was to evaluate variation in survival and harvest rates across geographic strata associated with the ongoing expansion of white-winged doves north through Texas relative to their historic breeding range in the Lower Rio Grande Valley (George et al. 1994, George et al. 2000) because regulatory programs that identify stock-specific management can be beneficial via reduced uncertainty regarding vital rates (Johnson and Moore 1995, Zimpfer and Conroy 2006). Additionally, we were interested in geographic fidelity and recovery of banded white-winged doves relative to capture stratum because a priori evidence (Collier et al. 2012) has clearly shown regional fidelity of harvested birds, and thus may contribute to differential recovery rates. During our study, white-winged doves were banded using both toll-free and web-address bands, so we also used this opportunity to determine whether recovery rates differed by band designation type.

METHODS

Personnel from Texas Parks and Wildlife Department and Texas A&M University banded white-winged doves across

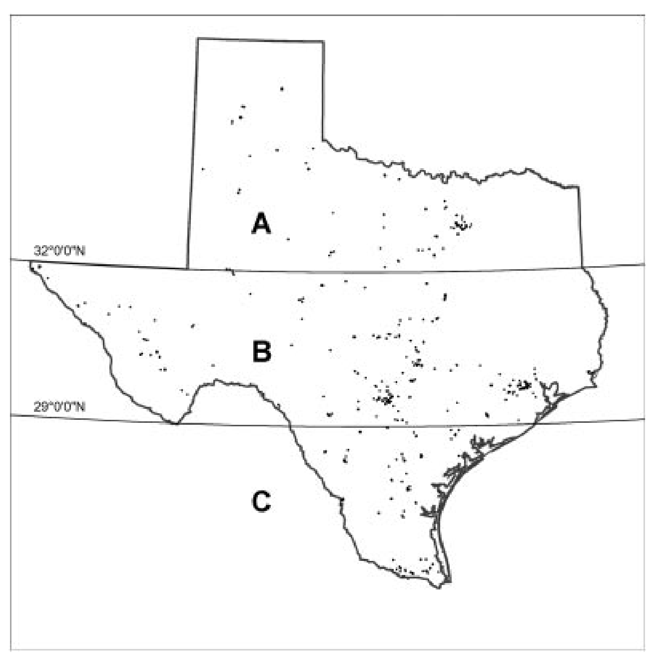

Figure 1. Banding and recovery strata delineations used for evaluating distribution and derivation of harvest for white-winged doves banded (banding locations indicated by •) in Texas and recovered in the United States and Mexico (we included Mexico in strata C) during 2007–2010.

Texas during March–August, 2007–2010. We captured and banded white-winged doves throughout this period using funnel-traps baited with standard bulk birdseed, black oil sunflower and milo. We aged all captured birds (hatch-year: HY; after-hatch-year: AHY) based on gross morphological characteristics (Cottam and Trefethen 1968) and banded each individual with United States Geological Survey Bird Banding Laboratory (BBL) size 4 aluminum bands. In 2007, we used only toll-free bands, whereas in 2008–2010 we used both toll-free and web-address bands in an approximate 50:50 split concurrent with the BBL shifting to a web-address return option; Sanders and Otis 2012). We focused most (>95%) of our banding efforts on white-winged doves in urban environments as dense white-winged dove breeding colonies have migrated to urban environments over the last 20 years (Schwertner and Johnson 2005).

We obtained banding and recovery data from the BBL in Laurel, Maryland. We included only normal, wild (BBL status code 3) white-winged doves banded in Texas by Texas A&M University, Texas Parks and Wildlife staff, and Texas Parks and Wildlife volunteers. Most (>96%) of doves were banded between 15 June and 15 August with the remainder banded between March and May during an intensive breeding population study in 2008 and 2009, which we do not expect to bias survival or recovery estimates. We did not include white-winged dove banding records from other banding projects because in many cases age codes were incomplete, we could not independently verify data accuracy, or toll-free and web-address bands were not used in an approximately 50:50 ratio during banding. We used records of inter-year recaptures of white-winged doves (e.g., doves banded in year t and recaptured during pre-hunting season banding in year $t + i$, $i = 1, \ldots, 4$) maintained by Texas Parks and Wildlife and Texas A&M University, whereas recoveries of white-winged doves constituted those that were shot or found dead and reported during hunting season to the BBL. As the dove hunting season in Texas overlaps 2 calendar years, we designated each hunting season by the year in which it began (e.g., 2007 hunting season began 1 Sep 2007 and ended approx. 12 Jan 2008). We post-stratified banding and recovery data into geographic strata using the 10-minute latitude closest to each boundary on its western edge to designate strata (A = north banding stratum and recovery region, B = central banding stratum and recovery region, C = south banding stratum and recovery region) for our study (Fig. 1).

We used a multi-strata mark–recapture and recovery model (Kendall et al. 2006) implemented in MSSRVRCV (Hines and Conn 2002) via R (R Development Core Team 2011). An R package (wwdoBR) containing all data and code is available from the primary author. We constructed multinomial models (White 1983, Hines and Conn 2002) to represent survival (S), strata-specific transition probabilities between sample (annual) periods (ψ), strata-specific transition probabilities between sample and recovery periods (τ), recapture probability (p), and recovery probability (f; Brownie et al. 1985). We modeled survival, recovery, and recapture parameters as age-, time-, and strata-specific, but constrained strata-specific transition probabilities (ψ) between sample periods to a constant for all models as our recapture data did not support detailed modeling of this parameter at an inter-strata or intra-annual basis (White 1983). We used an information–theoretic approach to model selection (Burnham and Anderson 2002) wherein we constructed a set of a priori candidate models for analysis (Table 1). We evaluated support for alternative models, given our data, using model rankings via Akaike's Information Criterion (AIC).

We considered 9 candidate models with survival and recovery probabilities varying by strata, age, band type, and time according to our initial hypotheses and descriptive evaluation of our band recovery data conducted previously (Collier et al. 2012; Table 1). We constrained movement probabilities (ψ) across all models to be constant among strata as few doves (3%) were captured and then recaptured in a subsequent year within different stratum. Because of limited recaptures (<0.01% of total banded), we used either a constant or stratum-specific parameter for estimating recapture probability because time-dependent models led to overparameterization. We fixed recovery transitions between banding stratum A and recovery region C and banding stratum C and recovery region A (Fig. 1) to 0 ($\tau = 0$), as those transitions occurred only 3 total times during the course of our study. Because banding stratum B saw birds transition to both recovery region A and C in roughly

Table 1. Model selection results for multi-strata mark–recapture and recovery models for white-winged doves banded in the pre-hunting season in Texas 2007–2010, with parameters S (survival), ψ (movement), p (recapture probability), f (recovery rate), and τ (transition between banding and recovery strata). We provide Akaike's Information Criterion (AIC) values, AIC differences between models (ΔAIC), and model weights (w_i) relative to the −2 log-likelihood for the best fitting model (i.e., 1,564.893).

Model	No. of parameters	AIC	ΔAIC	w_i
S(age × strata), ψ(.), p(strata), f(age × strata × band), τ(strata)	25	1,614.8933	0	0.9989
S(age × strata), ψ(.), p(strata), f(age × strata), τ(strata)	19	1,629.8069	14.92	<0.0001
S(age × strata), ψ(.), p(strata), f(age × band), τ(strata)	17	1,630.3026	15.41	<0.0001
S(age), ψ(.), p(.), f(age), τ(strata)	9	1,677.8631	62.97	0
S(age), ψ(.), p(.), f(age × time), τ(.)	13	1,741.8271	126.93	0
S(age × time), ψ(.), p(strata), f(age), τ(strata)	21	1,818.0632	203.17	0
S(age × strata), ψ(.), p(strata), f(strata × band), τ(strata)	19	1,819.2210	204.33	0
S(age × strata), ψ(.), p(strata), f(strata), τ(strata)	16	1,834.6127	219.72	0
S(age × time), ψ(.), p(strata), f(strata), τ(strata)	18	1,846.8892	231.99	0

equal proportions, we constrained τ to be equal for those strata transitions. Additionally, as we had no web-address bands during 2007, we fixed the band recovery parameter for that year to 0.

RESULTS

We captured and banded 60,742 white-winged doves prior to the hunting season from 2007 through 2010 in Texas using 39,526 toll-free and 21,216 web-address bands. We banded 7,098 in the northern stratum (A), 20,300 in the central stratum (B), and 33,344 in the southern stratum (C; Fig. 1). This included 23,908 AHY, 36,157 HY, and 677 unknown age-class birds. We recaptured 455 white-winged doves $\geq$1 year post-initial banding. Ninety-seven percent ($n = 441$) of recaptured white-winged doves were recaptured within their original banding stratum. We recovered 2,458 white-winged doves via harvest between 2007 and 2010, comprised of 654 AHY, 1,776 HY, and 28 unknown age-class birds, with 1,583 toll-free and 875 web-address recoveries.

The best approximating model, S(age $\times$ strata), ψ(.), p(strata), f(age $\times$ strata $\times$ band), τ(strata), indicated that survival (S) rates were both age- and stratum-specific, transitions from banding to recovery strata were stratum specific, and recovery (f) rates varied by age, stratum, and type of band used (Table 1). Models that did not address geographic structure in survival, recapture, or harvest had uniformly lower performance than models that included some geographic structure in these parameters. We based subsequent inferences on the best approximating model as all models incorporated the constraints detailed above to ensure numerical convergence, and as we found only limited model-based uncertainty (Table 1).

Predictably, stratum-specific HY survival of white-winged doves (A = 0.205, SE = 0.0476; B = 0.213, SE = 0.0278; C = 0.364, SE = 0.0254) was lower than AHY (A = 0.483, SE = 0.0775; B = 0.465, SE = 0.0366; C = 0.538, SE = 0.251), with the highest survival for both age classes occurring in stratum C (Fig. 1). The probability of movement and recapture among strata was low (0.009, SE = 0.025), with recapture rates $\leq$2% across all strata (A = 0.017, SE = 0.004; B = 0.021, SE = 0.003; C = 0.016, SE = 0.001). White-winged doves banded in stratum A were recovered in B ($\tau_{ij} = 0.19$, SE = 0.029) more regularly than birds banded in stratum B were recovered in either A or C ($\tau_{ij} = 0.042$, SE = 0.007), or birds banded in stratum C and recovered in B ($\tau_{ij} = 0.078$, SE = 0.009). The probability of white-winged doves being harvested within their original banding stratum was high (A = 0.81, B = 0.91, C = 0.92). Recovery probabilities ranged between 0.009 and 0.046 across age classes and recovery strata (Table 2), with HY recovery rates being approximately double AHY rates across all strata and showing an increasing trend from north to south. Finally, we found evidence for slight differences in recovery rates between toll-free and web-address band types, with recovery probabilities being greater for web-address based in 5 of 6 stratum–class combinations and with recovery rates generally increasing from north to south (Table 2).

Table 2. Estimated recovery probabilities for white-winged doves banded in the pre-hunting season in Texas, 2007–2010, categorized by harvest recovery stratum (A: north, B: central, C: south) based on the best-approximating model.

Recovery stratum	Age class[a]	Recovery probability (SE) Band type: Toll-free	Recovery probability (SE) Band type: Web-address
A	HY	0.0239 (0.0032)	0.0283 (0.00414)
	AHY	0.0107 (0.0022)	0.0093 (0.00252)
B	HY	0.0343 (0.0022)	0.0364 (0.00292)
	AHY	0.0163 (0.0014)	0.0197 (0.00198)
C	HY	0.0328 (0.0015)	0.0463 (0.00273)
	AHY	0.0183 (0.0011)	0.0206 (0.00167)

[a] HY = hatch-year; AHY = after-hatch-year.

DISCUSSION

Annual survival probabilities for white-winged doves banded during our study exhibited both age- and stratum-specific variability, ranging from a low of 21% for HY white-winged doves in the northernmost stratum to a high of 54% for AHY birds in the southernmost stratum. Survival probabilities in stratum C for HY (36%) and AHY (54%) birds were lower than those of George et al. (2000) for HY (59%) and AHY (65%) white-winged doves banded during the 1960s in an area of south Texas equivalent to our stratum C. Not surprisingly, our results indicated that HY white-winged doves exhibited lower survival and greater harvest rates than AHY birds, which is consistent with George et al. (2000) and recent work on mourning doves (Otis et al. 2008). Similar to George et al. (2000), we found little evidence for annual variation in survival or recovery estimates. Recovery estimates from George et al. (2000) varied between 0.03 and 0.059 during their banding study, which were similar to our estimates for the same geographic stratum. Based on our results, variation in survival and harvest was attributable to geographic location rather than annual cycles, similar with recent estimates by Otis et al. (2008), who found stratum (state-level) estimates rather than year-specific estimates.

Although our model selection results indicated evidence of differences in band recovery rates by band type (i.e., toll-free and web-address), variation in recovery rates was low, typically with greater recovery rates for web-address bands than toll-free bands, similar to results from Sanders and Otis (2012), and recovery rates increasing from north to south (Table 2). Although variation in band reporting rates has implications for accurately estimating dove harvest and recruitment rates (Conroy and Blandin 1984, Otis et al. 2008), no rangewide operational banding of white-winged doves is currently ongoing; thus, any future banding operations for white-winged doves should use web-address bands, eliminating the need for comparisons between reporting rates of different band types. Regardless, because of low band recovery rates across band types, we suggest that future efforts should focus on evaluating band reporting rates associated with reward banding (Tomlinson 1968, Nichols et al. 1991, Royle and Garrettson 2005, Otis et al. 2008).

Management of migratory birds at the national level has historically relied on designations of migratory corridors (e.g., flyways) that define regulatory boundaries for harvest and population monitoring (Munro and Kimball 1982, Sheaffer and Malecki 1996, Royle and Dubovsky 2001). However, knowledge of how vital rates vary spatially is important for regulatory planning (Munro and Kimball 1982, Johnson and Moore 1995) because the contribution of multiple breeding stocks to harvested populations can add complexity to models supporting harvest management decisions (Johnson and Moore 1995, Conroy et al. 2002). We found little evidence of white-winged dove movement between strata, with 97% of recaptured doves and 81–92% of recovered doves in the same stratum as when banded, contrary to the findings of Dunks et al. (1982) and Tomlinson et al. (1988) for mourning doves. We suggest that management for white-winged doves should consider spatially explicit substocks in Texas, and possibly elsewhere within the nationally recognized dove harvest management areas (Kiel 1959).

We investigated 1 a posteriori model wherein we combined the survival and recovery parameters for the north (A) and central (B) strata and re-evaluated our model predictions under the hypothesis that differences in vital rates in these 2 strata were not sufficiently different to warrant the increased regulatory complexity required by 3 Texas strata (Fig. 1). Although this model was not originally posited as a potential candidate model, when integrated into our model selection results, the additional model was somewhat supported ($\Delta AIC = 3.7528$) by our data. However, based on our a posteriori model, age-specific survival in the combined north-central banding strata (A + B; HY = 0.206, SE = 0.024; AHY = 0.467, SE = 0.034) and age-specific recovery rates for the same strata (HY = 0.031, SE = 0.002; AHY = 0.015, SE = 0.002), are similar enough ($\leq$0.01 difference) to the stratum-specific estimates from our best approximating model that strata A and B may be worth considering as a single management area in Texas. However, as survival is only one portion of those data necessary for harvest management planning, further information on variation in reproductive ecology, and the relationship between harvest and survival across geographic strata will be necessary for informed decision making before significant regulatory changes should be made.

White-winged dove populations in Texas have undergone continued expansion since the 1960s (Veech et al. 2011). Population vital rates mirror the white-winged dove expansion, with vital rates in the historic core of the species range (strata C; George et al. 1994) exhibiting higher levels of HY and AHY survival, and with survival decreasing for both age classes north of the historic range. As populations typically are more stable within their core ranges, and as demography is more stochastic at species range boundaries (Caughley et al. 1988, Lande 1991), white-winged dove vital rates appear to be following expectations of an expanding population.

MANAGEMENT IMPLICATIONS

Our results provide demographic estimates for use in development of mechanistic population models that may in turn be used to inform harvest management decisions in Texas and possibly elsewhere. Assuming that white-winged dove populations exhibit vital rates that also are geographically specific, one implication of our research is that once identified, these geographic areas can be used to facilitate and inform banding programs for white-winged doves across the southwestern United States as outlined by Rabe and Sanders (2010). Additionally, until a national banding program for white-winged doves is implemented across the United States, our recovery rate estimates could be combined with age-specific harvest information collected via a parts collection survey for recruitment monitoring to inform population management actions (Nichols and Tomlinson 1993). Finally, ongoing development of harvest management strategies for white-winged doves should focus on evaluating which geographic delineations are appropriate for harvest management planning as white-winged doves exist in a host of available habitats across the southwestern United States.

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