Wildlife Society Bulletin; DOI: 10.1002/wsb.136

Original Article

Distribution and Derivation of White-Winged Dove Harvests in Texas

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ABSTRACT Band recoveries provide requisite data for evaluating the spatial distribution of harvest relative to the distribution of breeding stocks for a wide variety of migratory species. We used direct and indirect band-recovery data to evaluate the distribution and derivation of harvest of white-winged doves (*Zenaida asiatica*) banded before hunting season in 3 distinct strata in Texas, USA, during 2007–2010. We banded 60,742 white-winged doves during 2007–2010, and based on 2,458 harvest recoveries, the majority (>95%) of white-winged dove harvest occurred during the first 2 months of the hunting season (Sep–Oct). Juvenile white-winged doves represented a greater percentage of the direct recoveries than adults across all strata (north = 80%, central = 69%, south = 82%) and the majority of direct band recoveries (north = 75%, central = 90%, south = 78%) occurred within the original banding strata. Age-specific weighting factors and harvest derivation indicated that both juvenile and adult harvest were highest within the strata of original banding. Harvest distribution data corrected for band-reporting rates indicated high fidelity of white-winged doves to specific geographic strata, with little interplay between strata. Our results suggest that population vital-rate estimates for survival and harvest for use in future Adaptive Harvest Management should focus on stock-specific levels.

KEY WORDS band-recovery, fidelity, harvest derivation, migration, spatial distribution, Texas, white-winged dove, *Zenaida asiatica*.

The white-winged dove (*Zenaida asiatica*) is a widely distributed dove species within the southwestern United States and Mexico (George et al. 1994) with populations introduced in Florida, USA, in the late 1950s (Schwertner et al. 2002). Historically confined to semi-arid and arid habitats in the southwestern United States and Mexico, white-winged doves have slowly expanded into a variety of environments across the southwestern United States (George et al. 1994). Outside of their historical thorn-scrub habitats in the Lower Rio Grande Valley (Cottam and Trefethen 1968, George et al. 1994) white-winged dove breeding colonies in Texas, USA, are found primarily in urban environments (Schwertner and Johnson 2005). As white-winged dove populations continue expansion to the north throughout the southwestern range (Veech et al. 2011), it is important to identify changes in white-winged dove distribution because regulatory and management decisions must account for geographic shifts in breeding populations and the potential impacts on harvest distributions and species demography (Munro and Kimball 1982, Sheaffer and Malecki 1996, Royle and Dubovsky 2001).

Although limited in distribution, white-winged doves are second only to mourning doves in terms of total harvest of webless migratory game birds (approx. 1.6 million total annual harvest nationwide with approximately 1.3 million harvested in TX; Raftovich et al. 2010). Within their known range, population trajectories are variable, with historical strongholds such as Arizona (USA; George et al. 1994) showing long-term declines in breeding dove surveys (Pacific Flyway Council 2003, Rabe and Sanders 2010) while expansion in both white-winged dove distribution (Veech et al. 2011) and harvest (Raftovich et al. 2010) has occurred in Texas. Concomitant with expansion, white-winged doves have experienced changes in habitat selection, migration phenology, regional fidelity, and harvest distribution (Schwertner et al. 2002, Schwertner and Johnson 2005, Rabe and Sanders 2010). Previous analysis of banding data (George et al. 2000) contributed to our knowledge of species demography; however, those data were collected 40 years ago in the pre-expansion historical species range (Cottam and Trefethen 1968, Schwertner et al. 2002) and thus likely do not provide a representative evaluation of current population status. Additionally, updated spatial distribution of harvested

Received: 8 July 2011; Accepted: 20 February 2012

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white-winged doves provides insights into geographical stratification of breeding (stock) populations available for harvest and thus has implications for ongoing regulatory planning and management (Otis et al. 2008).

To date, there has been no focus on evaluating harvest distribution, derivation, or other population parameters requisite for supporting rangewide management planning for white-winged doves even though population distribution data are necessary for development of Adaptive Harvest Management (AHM) strategies (Munro and Kimball 1982, Johnson and Moore 1995, Williams and Johnson 1995, Conroy et al. 2002). Because accurate spatial stratification can reduce uncertainty in demographic parameters and increase accuracy of model predictions (Otis 2004, Zimpfer and Conroy 2006) and because >80% of the annual harvest of white-winged doves occurs in Texas (Raftovich et al. 2010), our focus was to 1) evaluate and update information on the distribution of harvest of white-winged doves banded in Texas and the derivation of doves harvested in Texas, 2) compare distribution of recoveries based on banding conducted within the historical South Texas range pre-expansion to current distribution and recovery locations of white-winged doves banded within the South Texas range postexpansion to evaluate whether harvest distribution is changing over time, and 3) determine whether distinct trends in extent, recovery direction, and population distribution exist for better informing management actions and regulatory timing.

METHODS

We compiled records of white-winged doves banded before the hunting season across Texas during March–August from 2007 to 2010 ($n = 60{,}742$) as part of a larger white-winged dove population-ecology study. Banding efforts within geographic strata were distributed proportional to white-winged dove density based on Texas Parks and Wildlife survey data and historical banding records. When captured, all birds were aged into hatch year (HY) and after hatch year (AHY) based on gross morphological characteristics (Cottam and Trefethen 1968) and banded with U.S. Fish and Wildlife Service (USFWS)–U.S. Geological Survey (USGS) size-4 metal bands (2007 used toll-free bands; 2008–2010 used both toll-free and web-address bands in an approximate 50:50 split concurrent with the USFWS shifting to a web-address return option; Sanders and Otis 2012). A majority (>95%) of our banding effort was focused on white-winged doves in urban environments because dense breeding colonies have moved to urban environments over the last 20 years as availability of native habitats have declined (George et al. 1994, 2000; Veech et al. 2011). We obtained band-recovery records ($n = 2{,}458$) from the USGS Bird Banding Laboratory (USGS-BBL) and we used data on recoveries of all banded individuals killed, retrieved, and reported by hunters in a known location with a known age. Dove season in Texas overlaps 2 calendar years, so we designated each hunting season by the year in which it began (e.g., 2007 hunting season begins 1 Sep 2007 and ends in Jan–Feb 2008), and we note that during our study November was closed for dove hunting across Texas. Each recovery was characterized by date of recovery and spatial coordinates (to the SE corner of the 10-min block in which harvest occurred), which provides both temporal and spatial information on the distribution of white-winged doves harvested in Texas each year. For each recovery, we converted locations from the southeast corner to the centroid of the 10-minute blocks. For a descriptive comparison to historical band-recovery data, we compiled records of white-winged doves banded prior to the hunting season across Texas during 1950–1978 ($n = 66{,}629$; George et al. 2000) from the USGS-BBL, as well as data on recoveries of all banded individuals killed, retrieved, and reported by hunters in a known location during 1951–1980 ($n = 5{,}639$), and applied the same methods described above.

During the course of our study, Texas had 3 dove-hunting zones and, based on these data, we created 3 strata approximating these hunting zones (Fig. 1). Texas dove-hunting zones are typically separated by recognizable boundaries (e.g., interstate highways) that simplify hunter interpretation of hunting zones, but because these are political boundaries that can be easily adjusted, we used the 10-minute latitude closest to each boundary on its western edge to designate strata (north, central, south) for our study. We categorized capture locations for white-winged doves in Texas into specific strata (Fig. 1) for distribution and harvest derivation analysis and used the same geographic strata for all capture and recovery data for this study. We calculated age-specific, stratum-specific harvest distribution (%) using direct recoveries from white-winged doves adjusted for reporting rate (Munro and Kimball 1982, Otis et al. 2008). We used estimates of reporting rates for mourning doves (Sanders and Otis 2012) because no reporting-rate information is

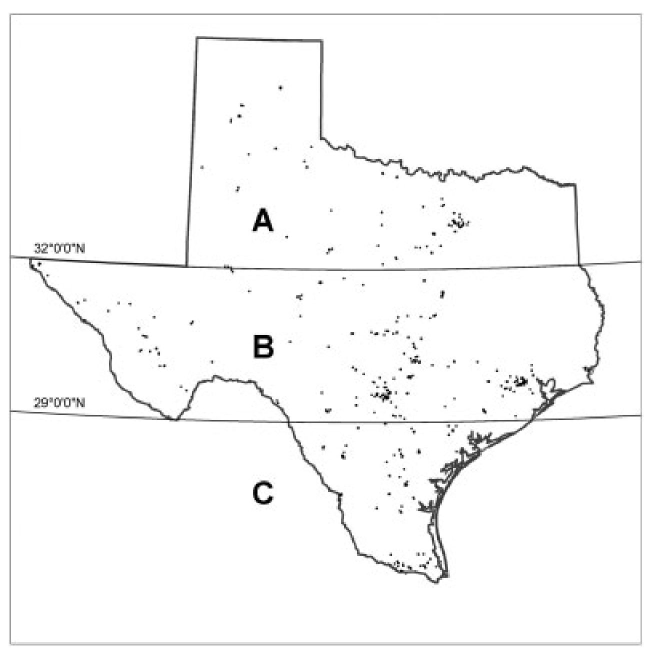

Figure 1. Banding and recovery strata (A, B, C) delineations used for evaluating distribution and derivation of harvest for white-winged doves banded (banding locations indicated by "·") in Texas, USA, and recovered in the United States and Mexico during 2007–2010.

available for white-winged doves and we assumed that reporting rates were constant across strata. We evaluated harvest derivation between and among strata adjusted for population weighting following Kiel (1959), Dunks (1977), Dunks et al. (1982), Munro and Kimball (1982), and Otis et al. (2008). For each strata, we estimated area (north = 26.2 million ha, central = 33.9 million ha, south = 8.5 million ha) and used Texas Parks and Wildlife white-winged dove survey data (unpublished) to estimate average white-winged dove breeding density for each strata during our study period (2007–2010) for harvest derivation (Kiel 1959, Dunks 1977, Dunks et al. 1982, Munro and Kimball 1982). We calculated the number and proportion of white-winged doves harvested in each strata relative to all individuals banded in Texas. In addition, we compared direct recovery distribution of white-winged doves banded in our south strata (historical habitats; George et al. 1994) with band-recovery data conducted before white-winged dove expansion had begun in earnest (George et al. 2000). We used 1-way analysis of variance to evaluate whether average distance from banding to harvest location differed between strata and we created rose-diagram plots to evaluate the circular distribution of band recoveries relative to banding locations between strata across years. We based harvest distribution analysis (%) on direct recoveries adjusted for band-reporting rates. We used band-reporting rates for toll-free (0.407) and web-address (0.440) bands and assumed no differences in reporting rate between HY and AHY individuals. Additionally, we compared harvest distribution of white-winged doves banded between 1950 and 1978 (George et al. 2000) and doves banded between 2007 and 2010.

RESULTS

We captured and banded 60,742 white-winged doves between 2007 and 2010 in Texas. We banded 7,098 in the northern stratum; 20,300 in the central stratum; and 33,344 in the southern stratum. We did not have accurate age information on 96, 441, and 140 individuals in the northern, central, and southern strata, respectively; therefore, we removed those individuals from any age-specific analyses. Recovery data (both direct and indirect) for white-winged doves harvested in 2008–2010 consisted of 873 web-address recoveries and 1,107 toll-free recoveries. The proportion of web-address direct recoveries ($n = 680$; no. web-address direct recoveries/total direct recoveries) were consistent each year (2008 = 41%, 2009 = 49%, 2010 = 47%). Juvenile white-winged doves represented a greater percentage of the direct recoveries than adults across all strata (north = 80%, central = 69%, south = 82%). Overall, harvest of white-winged doves primarily occurred during the first 2 months of season (Sep–Oct), with $\leq$3% (57 of 1,801) of direct recoveries occurring after 1 November (Fig. 2). Direct recoveries of Texas-banded white-winged doves in United States locations outside of Texas were low, with the north and central strata having only 6 and 9 individual harvested outside of Texas, respectively. The south stratum had no recoveries outside of Texas within the United States, but had 97 direct recoveries in Mexico (which for analysis was included in the south stratum) during our study period, relative to only 1 and 7 direct recoveries in Mexico from the north and central strata, respectively. Overall, we saw no clear evidence of unique migratory directionality based on our harvest distribution data either between strata or across years (Fig. 3). Analysis of variance indicated that mean distance between capture and recovery differed between capture strata ($F_{2,2434} = 4.578$, $P = 0.010$) with approximate mean distance being greater for doves banded in stratum A (110 km) than stratum B (73 km) or C (93 km). We did not detect any differences between years ($F_{3,2434} = 1.735$, $P = 0.158$) with mean distance between banding and recovery locations ranging from 81 km to 107 km and doves in the central stratum showing less annual variation than the north and southern stratum (Table 1). However, considerable variability of movements within and between strata precludes any specific inferences about temporal changes.

Biologists banded 60,356 white-winged doves in the south stratum of Texas during the historical banding efforts, whereas we banded 33,344 white-winged doves during 2007–2010. In general, the distribution of direct recoveries were similar between historical ($n = 5,678$ direct recoveries over 28 yr) and current ($n = 1,018$ direct recoveries over 4 yr) banding with the exception being a noticeable cluster of 432 recoveries in Costa Rica, Guatemala, El Salvador, Nicaragua, and Honduras during the historical banding period compared to only 10 from current banding efforts (Fig. 4).

A majority of recoveries within each recovery strata originated from birds banded within those strata (Tables 2 and 3; Fig. 5). Across all strata, the majority (north = 75%, central = 90%, south = 78%) of direct band recoveries occurred within the original banding strata (Table 2), as did the majority of indirect recoveries (north = 73%, central = 96%, south = 75%). Age-specific weighting factors (Table 4) and harvest-derivation estimates indicated that both juvenile and adult harvest was highest within the strata of original banding (Table 5). For example, of the total number of white-winged doves harvested in recovery region 1 (banding stratum A), the derivation of harvest estimates weighted for population size indicated that 54% of the juveniles and 57% of the adults originated from that banding stratum (Table 5). Banding stratum B was the primary source for harvested white-winged doves outside the original banding strata, and banding stratum A and C provided little to no birds to each other (Tables 2 and 5).

DISCUSSION

Our results indicate that white-winged doves in Texas exist in distinct breeding aggregations with only limited harvest interplay over the north–south gradient. Our harvest distribution and derivation estimates show that white-winged dove harvest within each stratum was supported by those white-winged doves captured or recruited within those strata. Our estimates of regional fidelity were similar, but slightly lower than estimates for mourning doves at the state scale

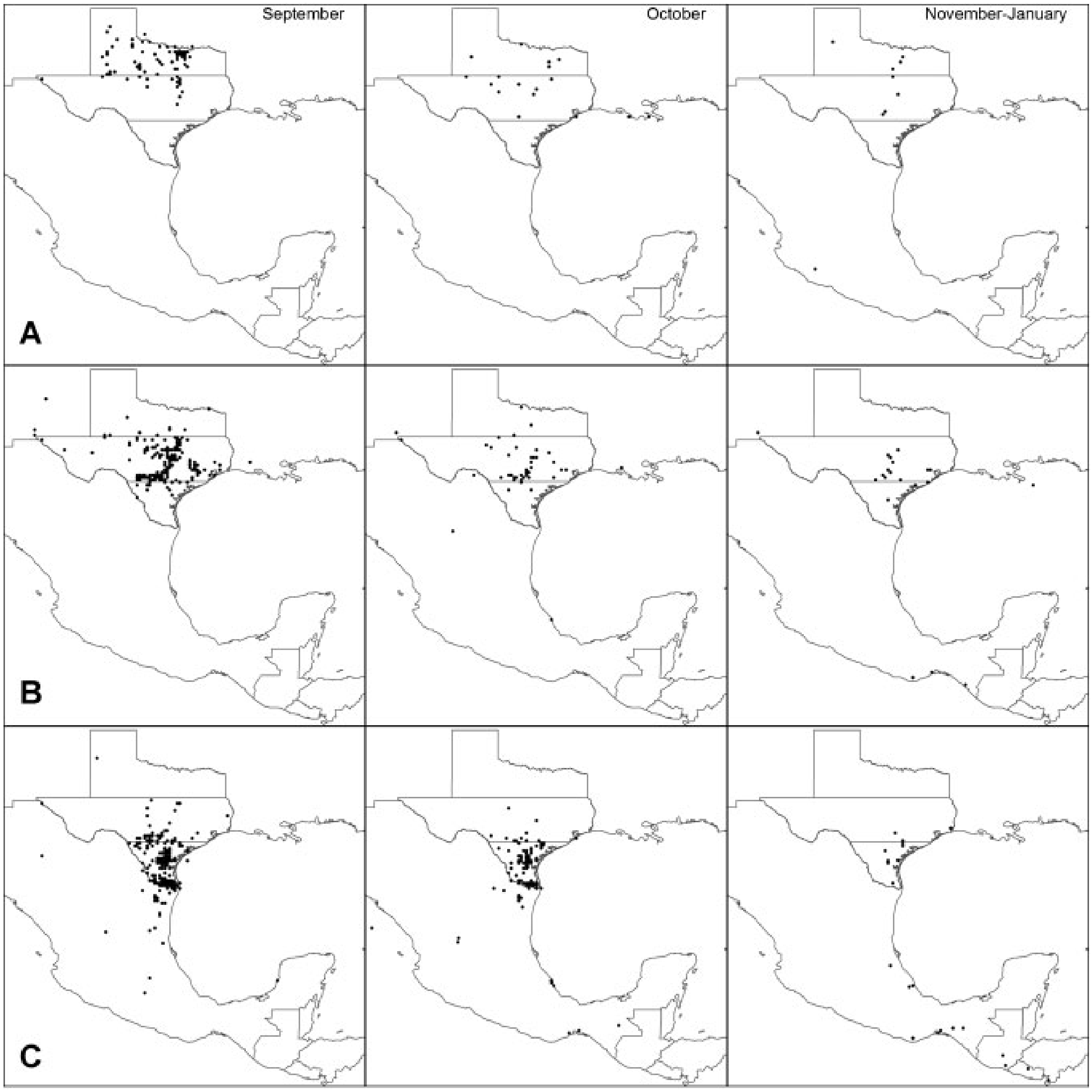

Figure 2. Distribution of direct recoveries (n = 1,801) from white-winged doves banded prior to the hunting season in Texas, USA, during 2007–2010. We categorized recoveries by month and grouped the period 1 from November to January because few (<3%) recoveries occurred during this period (A = North, B = Central, C = South banding and recovery strata).

(Dunks et al. 1982, Otis et al. 2008). Our results suggest that population vital rate estimates for survival and harvest (Otis 2002) for use in future AHM models should be evaluated at similar stock-specific levels, approximately concordant with the strata used in our research, or perhaps by combining nontraditional (north and central) strata into one zone and treating the historical range (southern stratum) as a separate zone. The most comprehensive analysis of white-winged dove demography to date (George et al. 2000) used only individuals banded in the historical Texas range and Mexico because expansion had not begun in earnest at that time. If other white-winged populations, which are both expanding and contracting in certain areas of New Mexico, Arizona, and California (Rabe and Sanders 2010), are shown to exhibit similar geographic stratification, then future regulatory activities could benefit by evaluating management options and population demography at a stock-specific scale (Johnson and Moore 1995, Sæther et al. 2008) because management of individual stocks with limited interactions can reduce system complexity and simplify long-term management actions (Conroy et al. 2002).

Based on our data, we were unable to detect any significant changes in harvest or migratory patterns between our 2 study periods (George et al. 2000). However, because the majority of individuals banded during our work were captured in urban environments, it is plausible that urban white-winged doves undergo different migration patterns than historical dove populations banded in rural environments (George et al. 2000). We suggest that simultaneous to the expansion of white-winged doves is an increasing likelihood of year-round residency and decrease in migration of birds moving south during the annual cycle. Increased residency and reduced migratory activities may have been indicated by our evaluation of mean distances and direction between banding and harvest location because distances showed minimal movements between strata both within and between seasons, and migration directionality based on recovery data (Dunks et al. 1982, Munro and Kimball 1982) was approximately

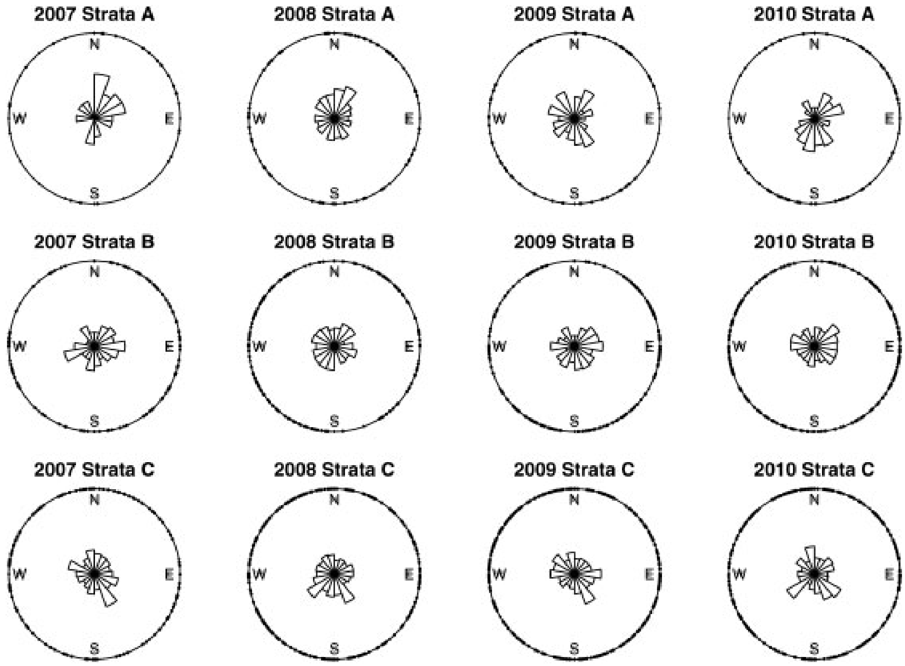

Figure 3. Direction of direct recoveries relative to original banding location across strata for white-winged doves banded prior to the hunting season in Texas, USA, during 2007–2010 (A = North, B = Central, C = South banding and recovery strata).

Table 1. Mean (SD) distance (km) from capture location to direct-recovery 10-minute block centroid for white-winged doves banded in Texas, USA, during 2007 through 2010. We categorized mean distance from capture to recovery by banding strata (A = North, B = Central, C = South) and provide strata-specific test statistics.

	Distance					
Strata	**2007**	**2008**	**2009**	**2010**	***t*-Statistic**	***P***
A	77 (141)	123 (169)	82 (108)	158 (272)	8.55	<0.001
B	65 (72)	90 (155)	84 (219)	57 (80)	−2.77	0.005
C	92 (169)	110 (239)	86 (216)	87 (243)	−1.56	0.11

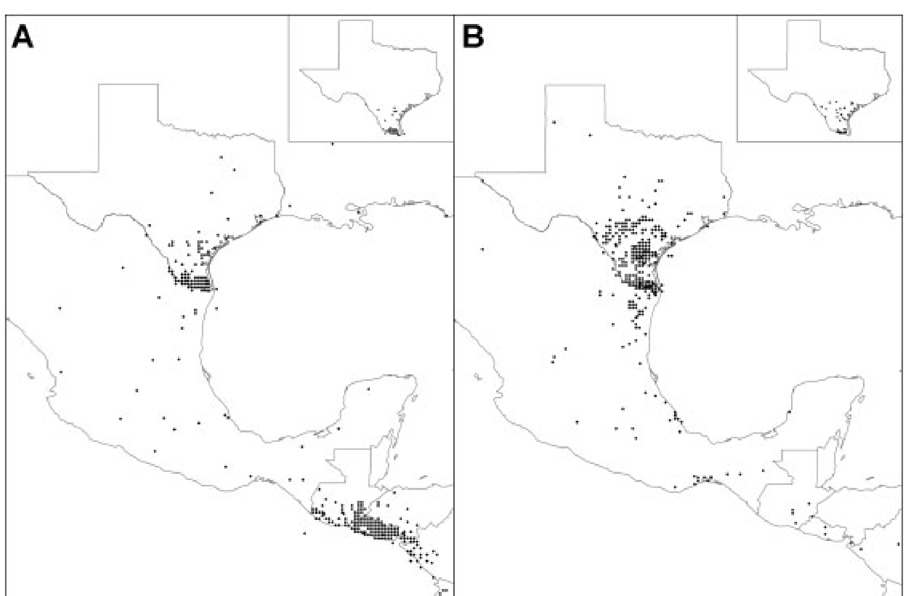

Figure 4. Harvest distribution of white-winged doves (A) banded in the historical range during 1950–1978 relative to (B) white-winged doves banded prior to hunting season during 2007–2010 in Texas, USA.

Table 2. Distribution of direct and indirect band recoveries of white-winged doves banded ($n = 60{,}742$) in Texas, USA, during 2007 through 2010. We categorized each recovery by both the banding and recovery strata (A = North, B = Central, C = South).

	Recovery strata				Recovery strata			
Banding strata	A	B	C	Total direct recoveries	A	B	C	Total indirect recoveries
A	128	40	1	169	38	13	1	52
B	19	504	30	553	2	149	4	155
C	2	85	992	1,079	0	30	420	450

uniform across our study strata. Strong inferences regarding migration patterns require more detailed information than can be provided by band recoveries; thus, our hypotheses represent an area of additional research need for white-winged doves. However, our analysis of indirect recoveries also supports our hypothesis of increased residency and regional fidelity because a majority of indirect recoveries ($n = 657$) of white-winged doves were faithful to original banding strata, with 73%, 96%, and 93% of white-winged doves banded in banding strata A, B, or C, respectively, being harvested in recovery strata A, B, or C, respectively. We note that our results were based on band-recovery data and could potentially be influenced by non-uniformity of dove-hunting activities across the annual cycle. Dove hunting is primarily an early season recreational pursuit, with other species such as white-tailed deer (*Odocoileus virginianus*) and waterfowl typically taking precedence in Texas by early November and continuing through January. Thus, lower numbers of recoveries later in the season, on which estimates of migratory patterns and timing would be based (Munro and Kimball 1982), could be influenced by reduced hunting pressure on doves as seasons progress.

The typical definition of harvest distribution is the distribution of harvest (band recoveries) corrected for band-reporting rate (Munro and Kimball 1982). Band-reporting rates for mourning doves have only recently been estimated across the range (Otis et al. 2008), with Texas band-reporting rate estimated between 0.407 (SE = 0.087) and 0.440 (SE = 0.095; Sanders and Otis 2012). Currently, estimates do not exist for white-winged doves because band-reporting studies have not been conducted at a rangewide scale. However, because our work was focused strictly in Texas, we would expect less variation in reporting rates than those found at the flyway or breeding reference areas (Munro and Kimball 1982, Otis 2004, Sanders and Otis 2012). Thus, we assume that reporting rates should be constant within our study area, and therefore we provided harvest distribution estimates corrected for variation in reporting rates for mourning doves in Texas and suggest that future efforts to address reporting rates be incorporated into management planning.

The information on direct and indirect recoveries herein also provides insights into the distribution of hunting effort across Texas. The majority of urban environments in Texas are located along the Interstate-Highway 35 (I35) corridor running north–south through approximately the center of the state. The area within this 100-km buffer of I-35 represents 23% of the total Texas land base and, based on the distribution of harvest, 38% of the total harvest based on both direct and indirect recoveries is occurring within 100 km of the I-35 corridor beginning at the Oklahoma–Texas state line and ending at the Texas–Mexico international border. Texas Parks and Wildlife operates a hunt-lease program wherein the agency leases private lands for public hunting access, so our results indicate that if maximizing public hunting opportunities for white-winged doves is of interest, efforts to lease lands along the I-35 corridor and the surrounding urban–rural interface would likely benefit a wide range of hunters (Schulz et al. 2003).

Based on our results, collection of empirical data to evaluate population distribution, demography, and harvest derivation across the species' southwestern United States range is paramount if AHM, or alternative options (e.g., surplus production) are to be used to drive harvest management

Table 3. Percent distribution of hatch year (HY) and after hatch year (AHY) white-winged dove harvest from banding strata to recovery strata within Texas, USA, based on direct recoveries from bandings conducted before the hunting season during 2007–2010. Values represent adjusted counts based on band-reporting rates for web address (0.440) and toll-free (0.407) band types and percentages are relative to the total harvest for each band type (A = North, B = Central, C = South banding and recovery strata).

		Age-specific recoveries corrected for band-type reporting rates (*n* [%])			
		Toll-free		Web-address	
Banding strata	Recovery strata	HY	AHY[a]	HY	AHY[a]
A	A	109 (7.0)	22 (1.4)	130 (4.6)	42 (1.5)
	B	36 (2.3)	5 (0.3)	44 (1.5)	10 (0.4)
	C	2 (0.1)	0 (0)	0 (0)	0 (0)
B	A	14 (0.9)	7 (0.5)	20 (0.7)	5 (0.2)
	B	282 (18.2)	134 (8.6)	548 (19.8)	241 (8.6)
	C	30 (2.0)	11 (0.7)	25 (0.9)	5 (0.2)
C	A	2 (0.1)	0 (0)	2 (0.7)	0 (0)
	B	66 (4.3)	16 (1.0)	96 (3.5)	25 (0.9)
	C	634 (41.0)	179 (11.6)	1,211 (44.0)	346 (12.5)

[a] Any birds with unknown age were considered AHY in the appropriate band-type column.

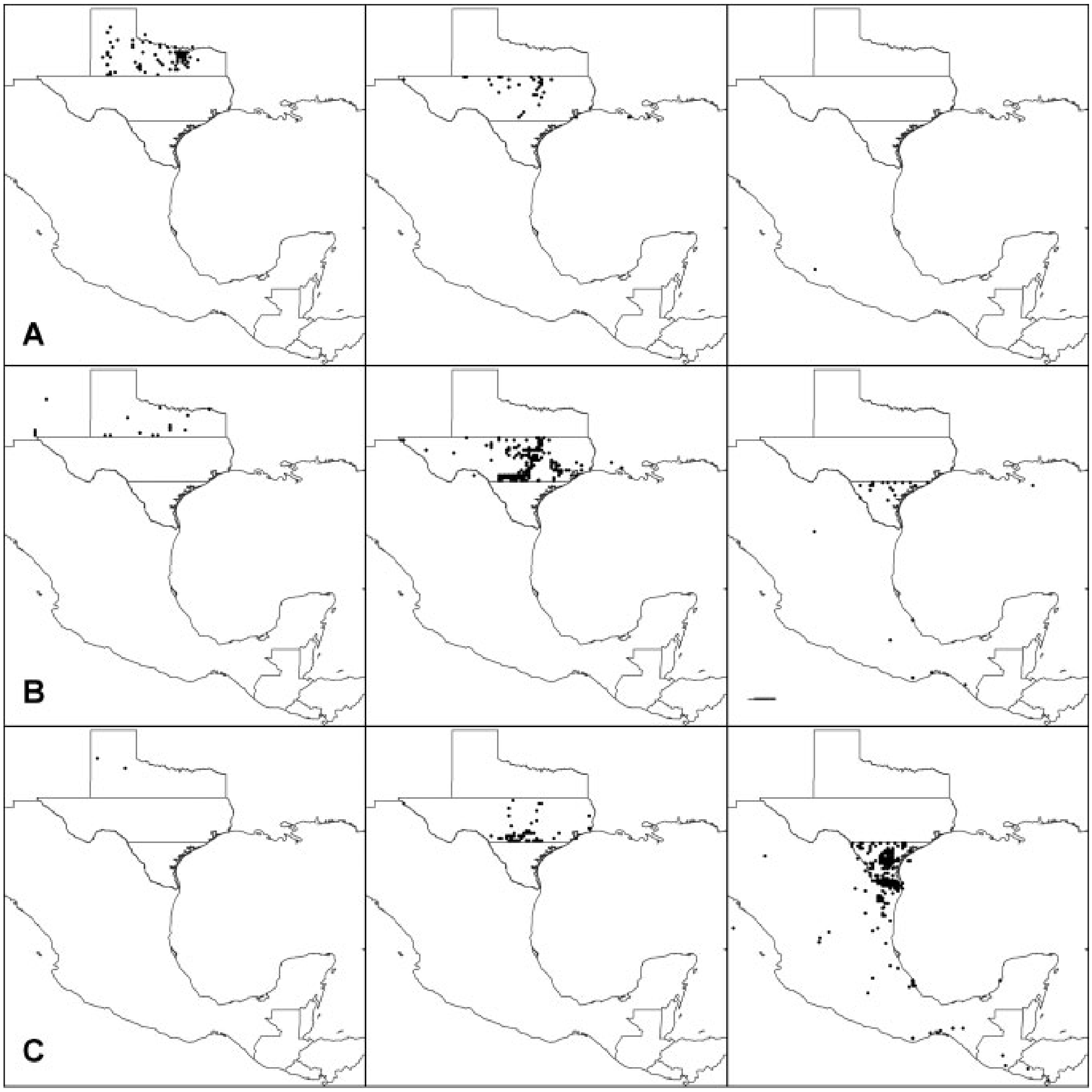

Figure 5. Banding-strata–recovery-strata combinations where each row shows the banding-origination strata (A = North, B = Central, C = South) and the distribution of white-winged dove direct recoveries within each potential recovery strata (A, B, C left to right) for those individuals banded prior to hunting season during 2007–2010 in Texas, USA.

of white-winged doves across their range. Our results provide an initial step for identifying spatial variation in white-winged dove populations, which may affect vital rates and thus should provide the foundation for further exploration of managing stocks uniquely. Further, if rangewide white-winged dove populations exhibit similar spatial structuring at the state or regional scale, this information should underlie development of modeling frameworks on which to base population management decisions (Johnson and Moore 1995).

MANAGEMENT IMPLICATIONS

Our study identifies distinct stocks of white-winged doves in Texas, and as such we recommend initiation of a regional banding program in Texas, New Mexico, Arizona, and

Table 4. Age-specific weighting factors (w_i; J = juveniles, A = adults, T = total) for recoveries of hatch year (HY) and after hatch year (AHY) white-winged doves banded before the hunting season in Texas, USA, during 2007–2010. Mean breeding density was based on point-count surveys conducted during 2008–2010 by Texas Parks and Wildlife and represent the average number of white-winged doves visually observer per point count survey location (A = North, B = Central, C = South).

Banding strata	Land area[a] wt	Mean breeding density	HY banded	AHY banded	Total banded[b]	w_J	w_A	w_T
A	26.15	0.87	4,640	2,362	7,002	0.49	0.96	0.32
B	33.91	2.11	10,802	9,057	19,859	0.66	0.79	0.36
C	8.56	3.07	20,715	12,489	33,204	0.12	0.21	0.08

[a] Land wt area is calculated as the total area (km^2/100,000) of each strata.
[b] Note that the totals listed here are lower than totals in text due to removal of individuals with unknown age.

Table 5. Estimated age-specific and total derivation of harvest for white-winged doves banded in Texas, USA, based on direct recoveries from bandings conducted before the hunting season during 2007–2010 (A = North, B = Central, C = South banding and recovery strata).

			Age-specific recoveries		Age-specific contribution (%)		
Banding strata	Recovery strata	No. recoveries	HY	AHY	HY	AHY	Total
A	A	128	101	26	11.75	12.59	12.07
	B	40	34	4	3.96	1.93	3.77
	C	1	1	0	0	0	0.09
B	A	19	14	3	2.19	1.19	2.01
	B	504	347	144	54.4	57.40	53.44
	C	30	23	6	3.61	2.39	3.18
C	A	2	2	0	0.05	0	0.05
	B	85	68	16	1.93	1.69	2.00
	C	992	775	215	22.09	22.78	23.38

California because these are the 4 states with substantial white-winged dove populations within the continental United States. Furthering our understanding of white-winged dove stocks will assist in development of a modeling framework on which to base regulatory management decisions distinct from those currently proposed for mourning doves (Otis 2004, 2006; Otis et al. 2008). Additionally, as significant breeding populations and harvest opportunities of white-winged doves occur across Mexico, we recommend that future efforts attempt to integrate white-winged dove population management in Mexico into a combined bi-national regulatory framework.

ACKNOWLEDGMENTS

Funding for our work was provided by the Texas Parks and Wildlife Migratory Game Bird Stamp and the Institute of Renewable Natural Resources at Texas A&M University. We gratefully acknowledge L. Reitz and M. Frisbie with Texas Parks and Wildlife for managing daily banding and survey operations over the course of our research. In addition, we appreciate the considerable support from Texas Parks and Wildlife staff for their tireless efforts banding white-winged doves across Texas. B. A. Collier acknowledges partial support for his work from Award no. KUS-C1-016-04 made by the King Abdullah University of Science and Technology (KAUST). We appreciate comments on a draft of this manuscript from D. L. Otis.

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Associate Editor: Donaghy.