Survival and Recovery Rates of Mottled Ducks Banded in Texas and Louisiana

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Abstract: The Western Gulf Coast population of the mottled duck (*Anas fulvigula*) is dependent on the Gulf coastal marsh to complete its entire life cycle. Band recovery data can be used to monitor mottled duck populations by estimating annual survival, indexing harvest rate, and assessing movements. Band returns from hunting seasons 1997–2013 were used to evaluate factors influencing annual survival, recovery rates, and movements of mottled ducks in Texas and Louisiana. For banding years of 1997–2013, 58,349 normal, wild mottled ducks were banded and released in Texas and Louisiana. Since 2002, 86% of mottled duck bandings have occurred on the Chenier Plain of Texas and Louisiana. Hunters shot, recovered, and reported 7,061birds with bands during this period. Direct recovery rates were greater for juveniles than adults but changed little since the 1970s. Estimates of annual survival did not differ between Texas and Louisiana, but did among years and between sex and age classes. Adult male and juvenile female mottled ducks had the greatest and lowest annual survival rates, respectively. Recovery of birds banded on the Chenier Plain was four times greater for birds banded in Texas and harvested in Louisiana than banded in Louisiana and harvested in Texas. Much of the current inference of results from banding mottled ducks is limited to the Chenier Plain. To monitor the entire Western Gulf Coast population of mottled ducks, managers can consider expanding operational banding operations with annual quotas, which would improve survival and recovery estimates and allow for inference beyond the Chenier Plain region.

Key words: Anas fulvigula, band recovery, mottled duck, movement, survival

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The mottled duck (*Anas fulvigula*) is a relatively sedentary migratory bird that typically exhibits only short-distance movements, and dependent on coastal marsh and other habitats along the Gulf Coast from Florida to northern Mexico for its entire life cycle (Bielefeld et al. 2010). The Western Gulf Coast population is primarily located in coastal marshes of Texas and Louisiana, with greatest densities on the Chenier Plain of the upper Texas and western Louisiana coasts, and is genetically distinct from the Florida population (McCracken et al. 2001). Closely related to the mallard (*A. platyrhynchos*) and American black duck (*A. rubripes*), mottled ducks are the only year-round and representative breeding waterfowl species of coastal marsh and associated habitats of the western Gulf Coast. Industrial, agricultural, and residential development causing habitat loss along the Gulf Coast has a disproportionate impact on mottled ducks compared to other waterfowl, most of which use the region just for wintering or migration habitat.

Because of the species' dependence on coastal marsh and associated coastal prairie habitats for its entire life cycle, mottled ducks serve as an indicator species for many species that use these habitats in addition to being indicative of trends related to the quality of localized habitats (Stutzenbaker 1988, Gulf Coast Prairie Landscape Conservation Cooperative 2013, USFWS 2013). Mottled duck populations serve as an indicator species for many species that use these habitats in addition to being indicative of trends related to the quality of localized habitats for other waterfowl and wetland-dependent migratory bird species. Therefore, conservation and management beneficial to mottled ducks should be advantageous to many other species.

Johnson (2009) and Rigby and Haukos (2014) used matrix population modeling approaches and reported that the Western Gulf Coast population of mottled ducks was in decline. Their estimated finite population growth rates ($\lambda = 0.82$ and 0.54, respectively) were much less than $\lambda = 1$ necessary for a stable population. These predicted population trends are consistent with recent results from abundance surveys of breeding mottled ducks on Texas National Wildlife Refuges and wintering mottled ducks in Texas; the trend for wintering mottled ducks in Louisiana is less clear (USFWS 2013). However, all indices indicate declines since the mid-1990s. Coastal marshes are experiencing a number of threats to their quality and quantity including subsidence (White and Tremblay 1995), development (Morton and Paine 1990), and sea level rise and changes in hydrology (Moon 2014). The relative importance of various stressors to the Western Gulf Coast population have not been quantified, but factors known to influence mottled duck survival and reproductive output include increasing predator populations (Elsey et al. 2004), loss of coastal prairie and marsh habitats (Visser et al. 2000), conversion of native habitat to agriculture (Durham and Afton 2003), saltwater intrusion (Moorman et al. 1991), hybridization with mallards (P. Walther, USFWS, personal communication), invasive plant species (e.g., Chinese

tallow [*Sapium sebiferum*]; Oswalt 2010), and continued exposure to lead (Merchant et al. 1991, Merendino et al. 2005, McDowell et al. 2015). Because mottled ducks do not migrate, considered a biomonitor of coastal marsh health, operational population monitoring and assessment programs would provide contemporary information necessary to make informed conservation and management decisions relative to their Western Gulf Coast population.

Banding of waterfowl is a critical component for conservation of North American waterfowl (Smith et al. 1989, Blohm 2006). An operational banding program provides managers with abundant information to aid in the management of waterfowl (Smith et al. 1989). Banding data are primarily used to (1) describe movements, (2) assess harvest pressure, (3) measure vulnerability of age/sex classes to harvest pressure, (4) estimate waterfowl production rates, and (5) estimate annual survival rates. Only sporadic banding of mottled ducks using various capture methods occurred prior to the 1990s (Stutzenbaker 1988). However, starting in 1994 in Louisiana and in 1997 in Texas, preseason banding efforts were standardized in these two states and approximately 3,400 mottled ducks, on average, have been banded each year in these states. Although occasional unpublished analyses of mottled duck band recovery data have occurred (e.g., USFWS 2013), this is the first assessment of survival and recovery rates using all the preseason banding data collected since the increased banding efforts in Louisiana and Texas (but see Johnson et al. [1995] for the Florida population). My goal was to assess effectiveness of the current banding effort for monitoring the Western Gulf Coast population of mottled ducks. My objectives included estimation of annual survival, description of temporal patterns of direct recovery rates, and comparison of patterns of band recoveries between Texas and Louisiana.

Methods

The study area included the entire range inhabited by the Western Gulf Coast population of mottled ducks in Texas and Louisiana. Mottled ducks were captured and banded on numerous state Wildlife Management Areas and federal National Wildlife Refuges, as well as private lands. Birds were primarily captured in coastal marsh, but also were captured in managed freshwater moist-soil wetlands, rice fields, aquaculture ponds, and irrigation ditches (Haukos et al. 2010).

Mottled ducks were primarily captured from June–August by nightlighting from airboats and baited (i.e., rice or grit) rocket nets. Because of the prolonged breeding effort by mottled ducks (March–August) and need for new-moon conditions for nightlighting, it was necessary to expand the preseason banding effort compared to other waterfowl species. All captured birds were sexed and aged (AHY [after-hatch-year; adult], HY [flighted hatch-year; juvenile], or local [unflighted HY; juvenile]) using morphometric or cloacal characteristics (Stutzenbaker 1988, Carney 1992). Metal, numbered, U.S. Geological Survey Bird Banding Lab (BBL) bands were placed around one leg of all captured birds large enough to hold a band. Local and HY birds were combined as juveniles following Johnson et al. (1995). In 1996, band inscriptions changed with the implementation of a toll-free number 1-800-327-BAND (and subsequently internet reporting option) to facilitate reporting a recovered band. For this analysis, only banding and recovery data from birds banded during 1997–2013 were used to avoid confounding of results due to potential changes in band-reporting rates from changes in band inscriptions. All banding and recovery data from 1997–January 2014 were provided by the BBL.

Any bird that was not coded as a normal wild-caught mottled duck captured and banded during June and August was excluded from the analyses. Occasionally, birds were captured during the last few days of May and first few days of September due to timing of new moon; these individuals were considered part of the June–August period. Individuals receiving radio-transmitters or reward bands as part of research studies were also excluded because bands from such birds are likely reported at a higher rate than those banded only with a standard leg band. Only banded birds shot and recovered during the general hunting season (September–January) were included in the analyses. Direct recovery rates (% birds recovered during the first hunting season following banding) were calculated by year and age/sex class separately for Texas and Louisiana. These values are presented by band year, which represents the year of banding and the subsequent hunting season of recovery. For example, the direct recovery rate for 1997 is presented as band year 1997, but refers to the 1997–1998 hunting season (September–January).

Estimates of annual survival and recovery rates based on hunter-harvested banded mottled ducks were generated by comparing potential models using the band-recovery option (Brownie approach) in Program MARK (White and Burnham 1999). Brownie models estimate two variables, annual survival rate (S) and recovery rate (f, the probability that a banded bird is shot and retrieved, and its band reported to the BBL). The estimated annual survival rate is the probability of the banded bird surviving from the midpoint of the banding period of one year to the same point in the following year (for mottled ducks, starting approximately mid-July). The survival estimates are reported according to the start of the survival period (e.g., survival estimates for July 1997–July1998 are reported under band year 1997).

Variables considered in the survival modeling process were time (year), state (Texas, Louisiana), sex (male, female), and age (adult,

juvenile). I first developed a generalized model in which annual survival and recovery rates differed among years, states, sexes, and ages. Model assessment then proceeded in a hierarchical manner. First, the survival estimate was modeled by the full general model and held constant while a series of combinations of variables were assessed for fit to the recovery portion of the model. Once the best-fit recovery parameterization was determined, the recovery portion of the model was held constant while the model fit of the survival portion was assessed based on seven competing models of various combinations of variables. Competing models were ranked using Akaike's Information Criterion (AIC_c; Burnham and Anderson 2002). The following model criteria for the best-fitting model(s) are presented: number of parameters, ΔAIC_c (differences in AIC_c values compared to top-ranked model), and AIC_c weight (w_i) (Anderson and Burnham 2002).

I hypothesized that differences in harvest regulations and, potentially, habitats of the Chenier Plain between Texas and Louisiana would influence recovery of banded birds. Direct recovery rates of hunter reported birds were calculated for adults and juveniles within each state. The percentage of direct recoveries of banded birds that were recovered in the state other than that in which it was banded was calculated for 1997–2013.

Results

For banding years of 1997–2013, 58,349 normal, wild mottled ducks were banded and released in Texas and Louisiana. Hunters shot, recovered, and reported 7,061 birds with bands during this period. Initially, banding efforts were distributed throughout the Texas and Louisiana coastal regions; however, since 2002, 86.2% of annual bandings have occurred in the Chenier Plain geographic area (Galveston Bay east of Houston, Texas, to Vermilion Bay, Louisiana; Figure 1). Across all years, 77.2% of all bandings have occurred on the Chenier Plain, which limits inferences about recoveries and survival beyond this region and restricts comparisons with other geographic regions.

Average annual direct recovery rates during 1997–2013 did not differ between Texas and Louisiana for any age and sex class (Figure 2). However, average annual direct recovery rates varied among age and sex classes, with the greatest values for juvenile males followed by juvenile females, adult males, and adult females. Within years, this among-cohort pattern was the most common for direct recovery rates (Figure 3). The average direct recovery rate 1997–2013 for mottled ducks banded in Texas and Louisiana was greater for juveniles than adults and males than females (Table 1).

While maintaining the survival portion of the model as a general model (survival differed by year [1997–2011], state [Texas or Louisiana], age [adult or juvenile], and sex [male or female]), a series of models was evaluated to determine the structure of the recovery rate (f) that best fit the data. The structure that best fit f was global with recovery rate estimated by additive effects of year, state, age, and sex ($AIC_w = 1.0$), which was maintained for all subsequent models used to estimate annual survival rate.

A series of seven models was evaluated and ranked to estimate annual survival of mottled ducks in Texas and Louisiana. The top ranked model ($AIC_w = 0.996$, number of parameters = 200, model likelihood = 1.0) indicated that annual survival was not influenced by state, with annual survival varying across the study period and among sex and age classes. The second model that included an-

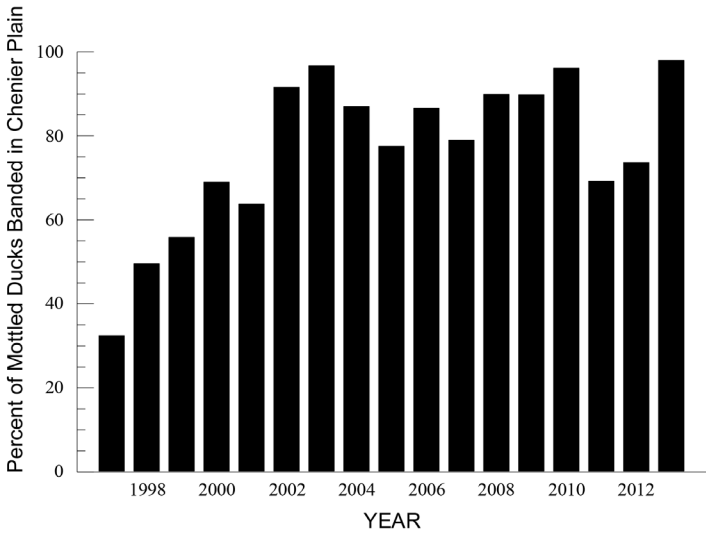

Figure 1. The percent of all annually banded Western Gulf Coast mottled ducks captured on the Chenier Plain (i.e., Galveston Bay, Texas, to Vermilion Bay, Louisiana) of Texas and Louisiana for band years 1997–2013.

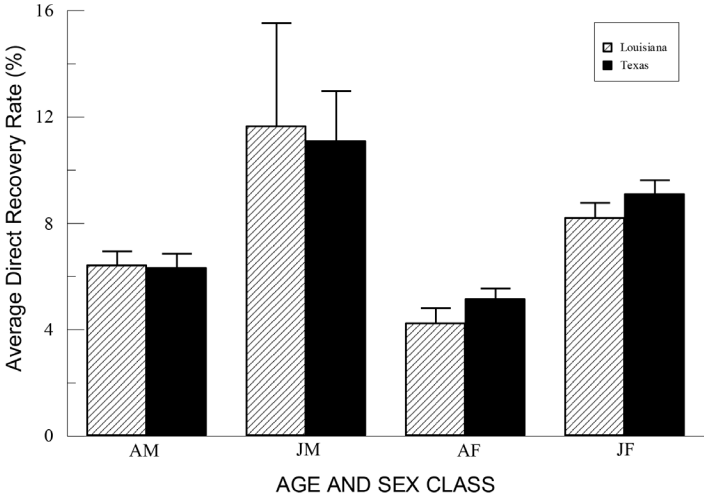

Figure 2. Average direct recovery rate (± SE) for mottled ducks banded in Texas and Louisiana from 1997–2013 by age (A = Adult, J = Juvenile) and sex (M = Male, F= Female) class.

Table 1. Comparison of annual average (SE) direct recovery rates (DRR; percent of bands reported within first hunting season following banding) and estimated harvest rate[a] (HR: direct recovery rate divided by band reporting rate) by sex and age between 1969–1971 and 1979 and for 1997–2012 for mottled ducks of the Western Gulf Coast population of Texas and Louisiana.

	Male				Female			
	Adult		Juvenile		Adult		Juvenile	
Band Years	DRR	HR	DRR	HR	DRR	HR	DRR	HR
1969–1971, 1979[b]	5.3 (2.1)	16.6	7.9 (1.3)	24.7	6.4 (1.6)	20.0	6.9 (0.7)	21.6
1997–2013	6.1 (0.3)	9.4	11.1 (0.5)	17.0	5.0 (0.5)	7.7	8.4 (0.6)	12.9

a. The band reporting rate was estimated as 32% prior to 1995 and 65% for mottled ducks during 1997–2013.
b. Only band years 1969–1971 and 1979 had sufficient bandings to calculate an annual direct recovery rate

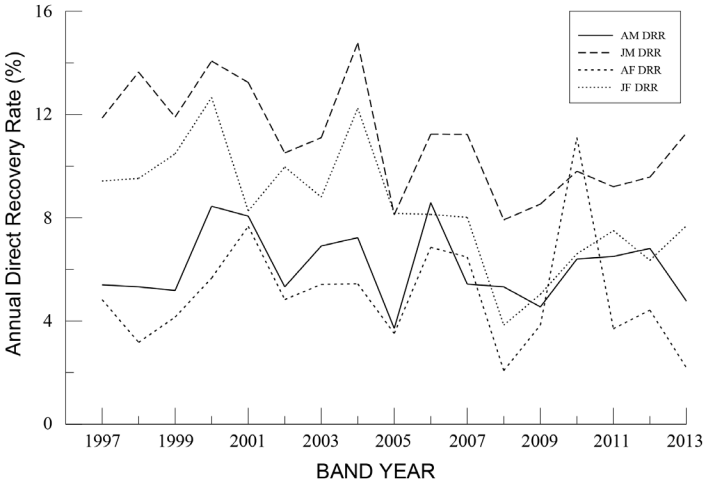

Figure 3. Annual direct recovery rate for mottled ducks banded on the Western Gulf Coast of Texas and Louisiana from 1997–2013 by age (A = Adult, J = Juvenile) and sex (M = Male, F= Female) class.

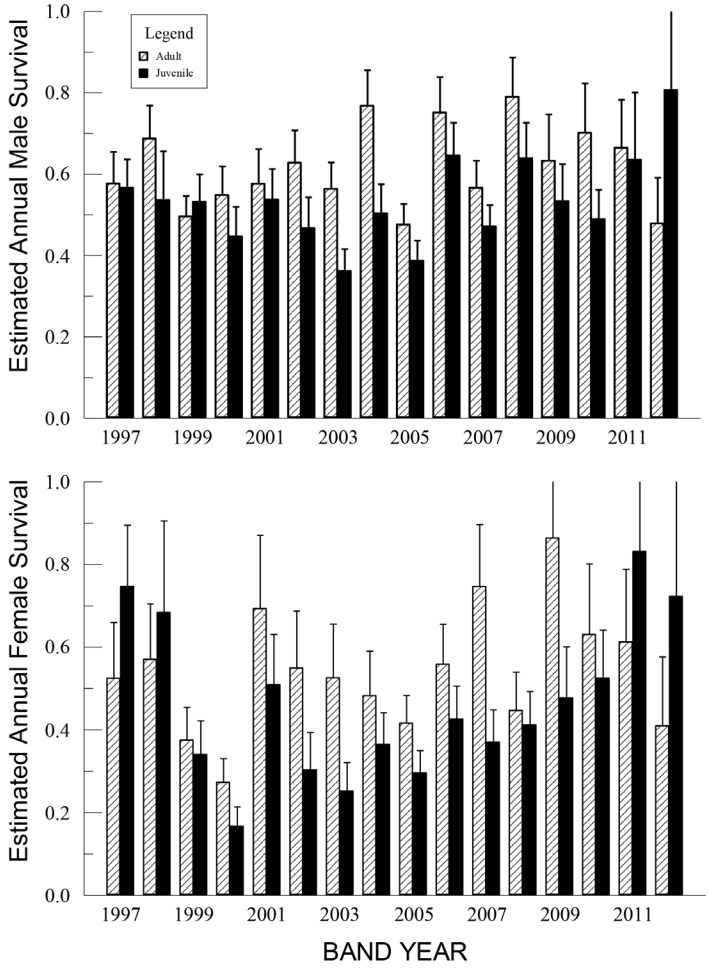

Figure 4. Estimated annual survival rate (± SE) for male and female mottled ducks banded in Texas and Louisiana from 1997–2012 by age classes.

nual survival varying by age, sex, and state but constant across years had $AIC_w = 0.0038$ and a $\Delta AIC_c = 11.15$ and was not considered a parsimonious or competing model despite the reduction in the number of parameters to 144. The global survival model had a $\Delta AIC_c = 54.36$ and no model weight. During band years 1997–2012, females exhibited greater variation in annual survival than males (Figure 4). In general, adults tended to have greater survival than juveniles; however, that trend was more apparent in males than females (Figure 4). Adult males have the greatest average annual survival, with juvenile males and adult females experiencing similar annual survival; juvenile females were represented by the lowest annual survival estimate (Figure 5).

Band recovery data were used to evaluate movements between Texas and Louisiana within the Chenier Plain geographic region. The percentage of mottled ducks banded in one state and harvested in the other suggest that a disproportionate number of birds are moving from the upper Texas Gulf Coast following the breeding season and being harvested in Louisiana compared to the converse Louisiana-to-Texas movements (Figure 6). Since 1997, an annual average of 27.5% (SE = 1.38) of birds banded in Texas and harvested as a direct recovery were shot in Louisiana compared to 6.1% (SE = 1.11) of birds banded in Louisiana and shot in Texas. Males were more likely than females to move from Louisiana to Texas prior to harvest (Figure 7). Whereas, juveniles, in particular juvenile males, were most likely to move from Texas to Louisiana prior

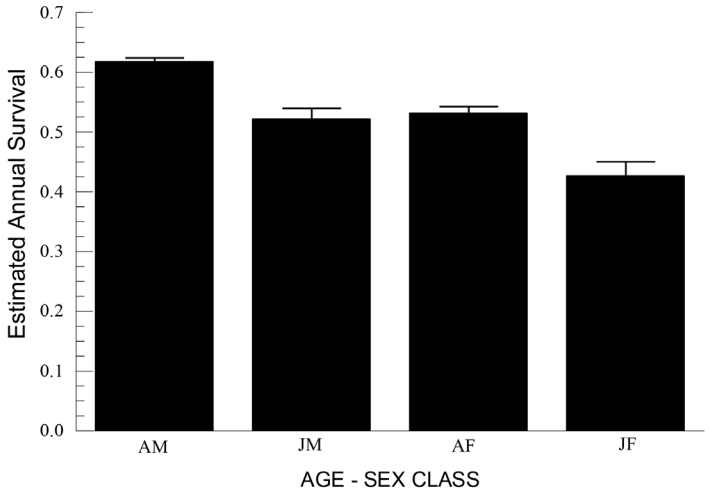

Figure 5. Estimated overall annual survival rate (± SE) for mottled ducks banded in Texas and Louisiana for 1997–2012 by age (A = Adult, J = Juvenile) and sex (M = Male, F= Female) class.

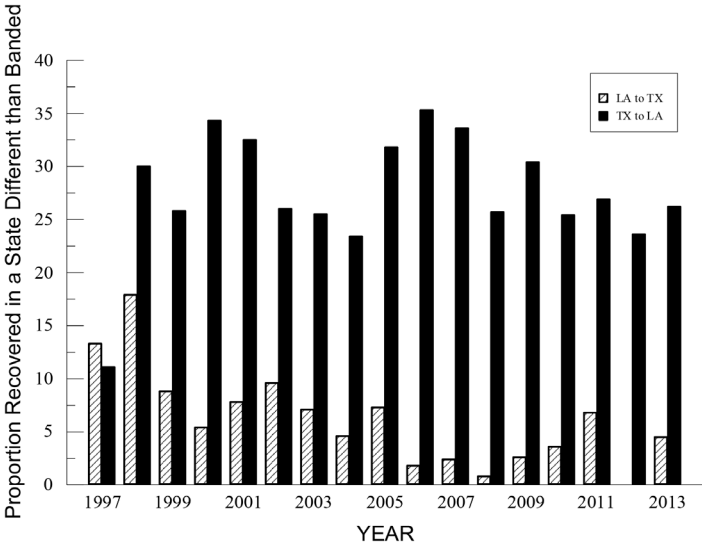

Figure 6. Percent of direct recoveries of mottled ducks banded in the Chenier Plain of Texas (TX) and Louisiana (LA) annually during 1997–2013 that were banded in one state and recovered in the other state.

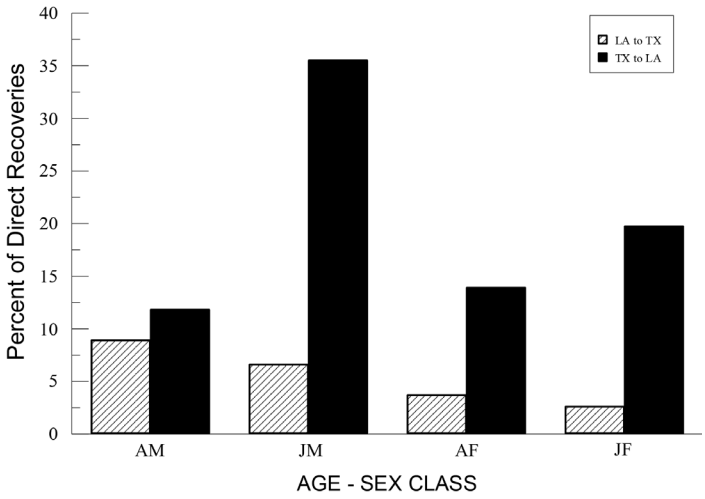

Figure 7. Percent of direct recoveries within each age (A = Adult, J = Juvenile) and sex (M = Male, F= Female) class of mottled ducks banded in the Chenier Plain of Texas (TX) and Louisiana (LA) during 1997–2013 that were banded in one state and recovered in the other state.

to harvest (Figure 7). Within age and sex class, movements between states prior to harvest was similar for adult males, but considerably greater in remaining classes for movements from Texas to Louisiana (Figure 7).

Discussion

Use of band recovery data to monitor the status and trends of Western Gulf Coast population of mottled ducks is currently limited. Upon inception of the current operational banding program, banding effort was distributed across the range of mottled ducks. However, since 2002, the majority of the birds were banded in the Chenier Plain region of Texas and Louisiana. Therefore, inference regarding population demographics beyond the range of the Chenier Plain is tenuous. Further, the relatively short timeframe of consistent banding effort precludes the development of models that might relate how changes in environmental and anthropogenic factors (i.e., harvest regulations) influence survival and recovery rates.

The highest-ranked model for annual survival rate indicated that mottled duck survival in the Western Gulf Coast population varied across time and among age and sex classes, but was not influenced by state where banded. In addition, females exhibited lower survival with greater annual variation than males. This pattern is likely due to annual variation in breeding season survival that is related to breeding propensity (Rigby and Haukos 2012). That is, increasing habitat quality results in increased reproductive effort by females, which reduces survival during the breeding season (Rigby and Haukos 2012). Variation in annual patterns of direct recovery rates were influenced by landscape-level disturbances such as drought (e.g., 2011) and Hurricanes Rita and Katrina in 2005 and Ike in 2008, which resulted in relatively steep declines in the direct recovery rate during the corresponding hunting season.

Johnson et al. (1995) reported a temporally constant survival rate for female mottled ducks in Florida. Johnson et al. (1995) also detected a lack of sex-specific differences in annual survival rates; rather, survival was influenced primarily by bird age. After removing survival estimates >1, average annual survival from band recovery data for mottled ducks in Florida (FL) from 1977–1990 (Johnson et al. 1995), was less than Western Gulf Coast (WGC) males (FL = 0.47, WCG = 0.62), but similar for juvenile males (FL = 0.55, WCG = 0.52), adult females (FL = 0.50, WCG = 0.53), and juvenile females (FL = 0.47, WCG = 0.43). However, annual

survival estimates for mottled ducks are similar or slightly lower than other waterfowl that use coastal marsh for a relatively short period of their annual cycle (e.g., migration or wintering), despite not incurring mortality risk related to long-distance migrations (Krementz et al. 1997, Rice et al. 2008).

Similar to the pattern observed by Johnson et al. (1995) for Florida mottled ducks, band recovery rates were greater for juveniles than adults in the Western Gulf Coast population. Mottled ducks were banded in Texas from 1969–1971 and 1979 in sufficient numbers to estimate a direct recovery rate. Compared to those years, contemporary direct recovery rates of females are essentially unchanged for adults, but slightly increased for juveniles despite the change in band-reporting rate between the two eras (Table 1). The banding reporting rate for waterfowl (based on mallards) prior to the change in band reporting options (i.e., prior to 1996) was 0.32 (Nichols et al. 1991). Based on the results from a recent reward band study, the contemporary band reporting rate for mottled ducks is 65% (P. Garrettson, Division of Migratory Bird Management, USFWS, personal communication). By adjusting the direct recovery rate for the band-reporting rate, an estimate of harvest is possible. Compared to the 1970s, harvest rate of mottled ducks has declined considerably for all sex and age classes (Table 1). The greatest harvest rate decline was 61% for adult females (Table 1).

The disparity between the percent of birds banded in one state and harvested in another on the Chenier Plain, with a >4-fold increase in the percent of mottled ducks banded in Texas and harvested in Louisiana compared to the reverse situation is due to movements of juveniles from Texas to Louisiana following the breeding season (i.e., when birds are banded) and prior to the end of the general waterfowl hunting season. Davis (2012) marked female mottled ducks in Texas and Louisiana using very-high frequency (vhf) radio transmitters and recorded that, on average over a three-year period, 12.8% of females (no state or age breakdown provided) were located in a state other than the one banded. This finding is slightly greater than the 9.9% average of band direct recoveries of females reported in states other than the one in which banding occurred. Moon (2014) reported that 10.6% of locations of adult female mottled ducks tagged with satellite transmitters on the Chenier Plain of Texas were in Louisiana. Davis (2012) and Moon (2014) primarily tagged adult females, which was the age and sex class least likely to move between states based on band recoveries. Further investigation into the causes and demographic ramifications of these movements could improve conservation planning to meet all of the life-cycle needs of mottled ducks in Texas.

The life-cycle requirements of mottled ducks must be met in a relatively small landscape compared to most waterfowl (Moon 2014). The relativity infrequent and short movements by female mottled ducks may limit access to unoccupied habitats across the range of the Western Gulf Coast population (Moon et al. 2015). Indeed, it is likely that the Western Gulf Coast population functions as a metapopulation, being comprised of smaller aggregations of birds that have area-specific demographic differences among the aggregations. The lack of banding effort in areas other than the Chenier Plain hampers an assessment of whether such area-specific differences exist. Low sample sizes and recoveries for adult females have considerable influence on the modeling process. Therefore, if a conservation goal is to monitor and increase understanding of population demography of the Western Gulf Coast population of mottled ducks, development of an operational banding program with abundance and distributional quotas to ensure unbiased and precise estimates of recovery and survival rates for the entire population may be beneficial. As additional years of band-recovery data accumulate, testing biologically-relevant hypotheses related to environmental conditions, harvest regulations, and spatially-defined aggregations will become possible.

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