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Spring Migration of Northern Pintails from Texas and New Mexico, USA

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Abstract.—We used satellite transmitters (platform transmitting terminals or PTTs) during 2002 and 2003 to document spring migration timing, routes, stopover sites, and nesting sites of adult female Northern Pintails (*Anas acuta*) from major wintering areas of the Gulf Coast (N = 20) and Playa Lakes Regions (PLR, N = 20) in Texas, and the Middle Rio Grande Valley, New Mexico (MRGV, N = 15). Some Pintails tagged in the MRGV continued movements into Mexico. Poor winter survival or PTT failure reduced sample size to 15 for PLR Pintails, 5 for Gulf Coast Pintails, and 11 for MRGV Pintails. Apparent winter survival was 66% lower for Texas Gulf Coast PTT-tagged Pintails than for those from the PLR and MRGV. Pintails from each area used different routes to their respective breeding grounds. PTT-tagged Pintails from the MRGV followed the Rio Grande Valley north to southern Colorado, before traveling on to the Dakotas and Canada or traveled northeast and joined the migration of PLR Pintails in Texas or Kansas. The latter made initial stops in Kansas, Nebraska, Colorado, or the Dakotas. Gulf Coast Pintails traveled through north-central Oklahoma or central Kansas. Pintails that had stopped first in Kansas or Nebraska tended to settle to nest in the United States. Wetland availability in the Prairie Pothole Region of the Northern Great Plains influenced nesting destinations of PTT-tagged Pintails, but individuals settled across a wide swath of northern North America. We did not detect any consistently-used spring staging areas. Therefore, negative impacts to any of the marked populations, or their wetland habitats, may have continental implications. *Received 6 January 2006, accepted 21 February 2006.*

Key words.—*Anas acuta*, Gulf Coast, New Mexico, Northern Pintail, playa wetland, satellite telemetry, spring migration, Texas

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Spring migration routes of Northern Pintails (*Anas acuta*) that originate in wintering areas of the Central Flyway, such as Texas and New Mexico are not well delineated (Austin and Miller 1995). Although band-recovery data provide a reasonable understanding of autumn migration, northward migration during spring does not necessarily retrace autumn routes (Bellrose 1968; Wege and Raveling 1983; Ely *et al.* 1997). This lack of information on spring migration routes, timing, and relative use of stopover sites limits understanding of continental populations and efficient management of habitats for Pintails (Pederson *et al.* 1989; Anteau and Afton 2004).

Reduced annual recruitment has caused the North American population of Pintails to decline steadily since the late 1970s (Austin and Miller 1995; Miller and Duncan 1999; U.S. Fish and Wildlife Service 2005).

Although there are several factors that influence Pintail recruitment, the quantity and quality of habitat at spring migration stopovers directly affect breeding propensity and recruitment (Raveling and Heitmeyer 1989; Austin and Miller 1995). Landscape changes at these sites may decrease or eliminate foraging areas resulting in poor nutritional support for egg production and alteration of historical migration routes (Mann and Sedinger 1993; Farmer and Wiens 1998; Moon *et al.* 2006). This is especially critical following dry conditions on the wintering grounds (Raveling and Heitmeyer 1989).

Historically, the Central Flyway provided wintering habitats for approximately 25% of the continental population of Northern Pintails (Bellrose 1980), and these are divided among 3 principal wintering areas: (1) the Texas Gulf Coast, (2) the Playa Lakes Region (PLR) of northwest Texas, and (3) the middle Rio Grande Valley of New Mexico (MRGV) (Bellrose 1980). In addition, the PLR and MRGV may provide autumn migration stopover areas for birds continuing south to wintering areas in Mexico (Bellrose 1980). Based on aerial surveys, about 2/3 of the total population winters in Texas, with 30% in interior and eastern Mexico, and about 4% in New Mexico (Bellrose 1980).

After departure from wintering areas, potentially important spring migration habitats include the PLR, Rainwater Basins of south-central Nebraska, the Sandhills of northwest Nebraska, and Cheyenne Bottoms of north-central Kansas (Bellrose 1980; Pederson *et al.* 1989); however, there are no data that describe proportionate use of these areas in spring. Historically, the most critical breeding area for Central Flyway Pintails has been the western portion of the Prairie Pothole Region (PPR), principally the short-grass prairie of the Dakotas, southeastern Alberta, and southwestern Saskatchewan (Bellrose 1980; Johnson and Grier 1988). Based on band-recovery data, Texas receives about 80% of its wintering Pintails from the PPR (Bellrose 1980).

Johnson and Grier (1988) hypothesized that Pintails settled to nest when they encountered good wetland conditions in the PPR, however, they continue northward during drought (i.e., overflights of traditional nesting grounds) (Smith 1970; Henny 1973; Derksen and Eldridge 1980; Miller *et al.* 2005). Recent evidence indicates that Pintails are settling farther north than they did historically due to habitat declines in the PPR (Runge and Boomer 2005), and recruitment is decreasing in the traditional nesting areas (Hebert and Wassenaar 2005). Along with declining continental populations, this suggests a need to determine current nesting distribution for Pintails wintering in the Central Flyway. We used satellite-received transmitters (platform transmitting terminals, PTTs) to document spring migration timing, pathways, stopover sites, and nesting regions of female Northern Pintails as they migrated north from major wintering areas in Texas and New Mexico during 2002 and 2003.

STUDY AREA AND METHODS

Study Area

The study area was the mid-continent region of North America including Canada, the United States, and Mexico, and was ultimately described as the area within which all marked Pintails occurred. This region includes a vast array of wetland habitats. In winter regions, habitats include coastal marshes along the Texas Gulf Coast, commercial rice and remnant prairie areas adjacent to coastal marsh, reservoirs and livestock pasture in east and central Texas, playa wetlands of the High Plains portions of the Southern Great Plains, closed-basin wetlands in Mexico, and riparian-associated wetlands and reservoirs in New Mexico (Smith *et al.* 1989). Migration habitats include playas, prairie potholes, rainwater basins (Nebraska), reservoirs, riparian areas, livestock watering sites, and temporary sheetwater from snow melt, creek flooding, and spring rains throughout the central United States (Smith *et al.* 1989; Austin and Miller 1995).

Wetland abundance and distribution influence the timing of Pintail migration in the midcontinent (Johnson and Grier 1988), and resulting nesting effort in the PPR (Austin and Miller 1995; Miller and Duncan 1999). During spring migration 2002, precipitation was 28% below average and it was also the coldest spring temperatures since 1948 (-4.0°C below the long-term average) resulting in poor wetland conditions in the western PPR (U.S. Fish and Wildlife Service 2002). In contrast, during 2003, spring precipitation was 8% above the long-term average in the PPR, with temperatures exceeding the long-term average by 0.4°C creating excellent wetland conditions (U.S. Fish and Wildlife Service 2003).

Pintail Capture and Transmitter Attachment

Rocket nets and swim-in traps were used to capture Pintails in: (1) New Mexico's MRGV at Bosque del

Apache National Wildlife Refuge (NWR) during October and November 2001 and 2002; (2) Texas' PLR at Buffalo Lake NWR near Canyon from December 2001 to January 2002 and on two private playas north of Lubbock during November 2002; and (3) Texas' Gulf Coast on private lands south of Kingsville during November 2001 and Aransas NWR during November 2002. Timing of capture provided adequate transmitter life spans and allowed tagged Pintails to adjust to the radio-package (Cox and Afton 1998), find new mates if necessary (Miller 1985), and minimize winter mortality before migration (Miller *et al.* 1995; Moon and Haukos 2006).

Following capture, Pintails were sorted by sex and age (Carney 1992) and mass (±5 g), and attached standard numbered aluminum United States Geological Survey leg bands to each duck. PTTs were attached only to adult females because of their role in population dynamics (Flint *et al.* 1998), their likely experience with migration routes and nesting sites, and because limited funding precluded tagging other cohorts. The initial intent was to attach transmitters only to females weighing >800 g, but this threshold was lowered based on the range of mass of captured birds (Miller *et al.* 2005). During 2001-2002, we attached satellite transmitters to six adult females in the MRGV of New Mexico (12-21 November 2001), ten in the PLR of Texas (27 December 2001-21 January 2002) and ten on the Gulf Coast of Texas (6-9 December 2001) (Table 1). During 2002-2003, nine transmitters were attached to adult females in the MRGV (27 October 2005), ten in the PLR (26-27 November 2002), and ten on the Gulf Coast (23 November 2002).

Females were fitted with a Model 100 PTT (Microwave Telemetry, Inc., Columbia, Maryland, USA). Each unit weighed about 26 g (including harness and neoprene pad), which was within conventional guidelines for Pintails (Caccamise and Hedin 1985; Miller *et al.* 2005). Each unit measured 54 × 18 × 17 mm, included a 216-mm long nylon-coated flexible-stranded stainless steel antenna protruding at a 45° angle from the back, and was labeled with contact information. Each PTT was attached dorsally between the wings by fashioning a harness from 0.38-cm wide Teflon ribbon (Bally Ribbon, Bally, Pennsylvania, USA), using the design of Miller *et al.* (2005) and consisted of a single length of ribbon with knots hardened with cyanoacrylate glue. Tagged birds were released at trap sites during evening flights, or at night, together with all banded birds from the same capture (Miller *et al.* 2005).

PTTs were deployed with an initial two-day duty cycle (five-hr transmission, 48-hr inactive) for one week to verify PTT activity, followed by four to six weeks with a six-day duty cycle (repeating five-hr transmission, 144-hr inactive period) to save battery life, and finally a three-day duty cycle (five-hr transmission period) for the remainder of each season, which included the active spring migration period. Programmed life span of the PTTs extended to early July. Each PTT contained sensors to transmit calibrated indices for unit temperature, remaining battery voltage, and bird motion and used to determine if birds were alive.

Pintail Locations

The Argos location and data collection system (Argos 1996), including multisatellite service with standard and auxiliary location processing, was used to monitor tagged Pintail movements (Miller *et al.* 2005). Argos estimates PTT locations from the Doppler shift in transmitted frequency received by the satellites as they approach and then move away from the PTT and checks the plausibility of locations via (1) minimum residual effect, (2) transmission frequency continuity, (3) shortest distance covered since previous location, and (4) plausibility of velocity between locations; the number of positive checks [NOPC] ranged from zero to four and were included within each transmitted location. Argos classified each location based on estimated accuracy and the number of transmissions (messages) received from the PTT during a satellite overpass. Calculated location classes (LC) were categorized and labeled as 3, 2, 1, and 0, which had accuracies rated as <150 m, 150-350 m, 350-1000 m, and >1000 m, respectively; these were provided when >four messages were received by the satellite via standard data processing (Miller *et al.* 2005).

Argos sent raw location data to the United States Geological Survey Field Station at Dixon, California via daily electronic mail. Several criteria were used to select one location from those received to best represent each bird each transmission-day (the Selected Location) (Miller *et al.* 2005). This was necessary because Argos normally provided greater than one usable location per bird per transmission day, multiple locations are not independent (Peterson *et al.* 1999), and LC often varies among them. Normally, the Selected Location was chosen from the weight of evidence after consideration of all criteria together (Miller *et al.* 2005). Locations with LC categories 3, 2, or 1, were favored but these occurred relatively rarely (Miller *et al.* 2005). Where several locations of similar accuracy occurred in a cluster, those with the largest number of messages (Hatch *et al.* 2000) and NOPC values (Butler *et al.* 1998), those most central in homogeneous habitats (Peterson *et al.* 1999), and those closest to the previous and subsequent Selected Locations were favored (redundancy; Peterson *et al.* 1999). For positions on a heterogeneous landscape, if the previous criteria failed, locations most biologically plausible were favored (Ely *et al.* 1997).

ARC/INFO and ARCVIEW GIS software (ERSI, Inc., Redlands, CA) was used to analyze and plot Selected Locations to delineate migration routes (Miller *et al.* 2005). Data from the date of PTT-tagging and release through 30 July (Julian date 212), which would include the nesting period was used. Because PTTs did not transmit continuously, dates of departure were defined as the median date between the last Selected Location at the previous location and the first Selected Location at the new location. Dates of arrival were estimated similarly, but if the gap between dates was greater than ten days, these birds were not included in the calculation of departure or arrival dates (Martell *et al.* 2001).

Data Analyses

Because only six to ten Pintails/year were tagged in each region, years were combined to describe overall winter and spring migration movements. For PTT-tagged Pintails in each capture region (1) winter distribution prior to departure, (2) timing of spring migration (dates of departure and arrival), (3) migration routes and stopover locations, and (4) potential nesting regions were documented. Correlation analysis was used to examine the influence of body mass on date of migration. A *t*-test was used to compare the mass of birds that survived the winter and migrated with those that did not survive.

RESULTS

Tagged Texas birds tended to weigh about 9% less than those captured in New Mexico (Table 1). The PTTs comprised 2.3-3.3% of body mass in New Mexico and 2.6-3.5% in Texas. Body mass at time of capture did not influence migration date in either year (Texas r_{20} = 0.25, P = 0.29; New Mexico r_{11} = 0.05, P = 0.88). Body mass was not related to known fate in 2002 (t_{24} = 0.14, P = 0.89; N = 11 lived, $\bar{x}$ = 905 g, SE = 30; N = 15 died, $\bar{x}$ = 900 g, SE = 20); however, in 2003 mass was greater for birds that survived versus those that died (t_{18} = 2.86, P = 0.01; N = 8 lived, $\bar{x}$ = 945 g, SE = 25; N = 12 died, $\bar{x}$ = 855 g, SE = 20).

Departure Date

New Mexico PTT-tagged Pintails departed 16 and 19 days earlier than those tagged in Texas during 2003, but departure date was similar across Texas and New Mexico during 2002 (Table 2). In Texas, PLR and Gulf Coast, tagged Pintails migrated on similar dates (Table 2). In the Texas Gulf Coast, migration began 19 days earlier during 2003 than 2002 (Table 2), and this trend was evident in the other two marking areas.

Wintering Areas and Migration Routes from MRGV, New Mexico

PTT-tagged Pintails in the MRGV either remained in New Mexico during the winter after tagging and used habitats of the Rio Grande Valley (N = 7, 64%), or they moved south to the Central Highlands or West Coast of Mexico (N = 4, 36%; Fig. 1). Those that remained in the MRGV used Bosque del Apache NWR, Elephant Butte and Caballos Reservoirs to the south, or moved north along the Rio Grande to the Rio Puerco, Sevilleta NWR, La Joya State Wildlife Refuge, and Bernado and Casa Colorado State Wildlife Management Areas. Tagged Pintails in Mexico (N = 5) used the Central Highlands, Laguna Bustillos, or the West Coast of the state of Sonora prior to migration (Fig. 1).

Eleven of the 15 Pintails PTT-tagged in New Mexico survived to depart on spring migration. Two routes north from New Mexico were identified. The one used most often (45% of hens, N = 5) followed the Rio Grande Valley to south-central Colorado (San Luis Valley) and then continued on to the Dakotas and Canada (Fig. 1). Another route (27% of hens; N = 3) headed northeast from the MRGV to habitats in PLR (north of Amarillo, Texas, to southwestern Kansas) where birds apparently joined with birds from the PLR (Fig. 1). In addition, two of the 11 MRGV Pintails migrated further west, moving through Utah and western Colorado (Fig. 1). The PTT for the final MRGV bird failed just after departure and provided no useful data. New Mexico Pintails settled in nesting regions of southern Saskatchewan (64%; N = 7), northern Alberta (9%; N = 1), Nunavut (9%; N = 1), and southern Manitoba (9%; N = 1) (Table 3).

Table 1. The number and body mass of adult female Northern Pintails that received satellite transmitters in New Mexico and Texas during 2001-2002 and 2002-2003.

		Body mass (g)			
Region	*N*	$\bar{x}$	SE	Range	90% CL
New Mexico					
2001-2002	6	975	35	890-1120	920-1030
2002-2003	9	935	30	795-1065	885-985
Texas Playas					
2001-2002	10	820	15	750-880	795-845
2002-2003	10	900	15	840-960	875-925
Texas Gulf Coast					
2001-2002	10	920	25	800-1020	895-945
2002-2003	10	820	10	775-870	805-835

Table 2. Average date of departure (Julian and calendar date) of adult female Northern Pintails from wintering grounds in New Mexico and Texas during 2002 and 2003.

Region	*N*	Julian date				Calendar date
		$\bar{x}$	SE	Range	90% CL	
New Mexico						
2002	2	68	15	55-81	44-92	9 March
2003	9	58	4	45-73	52-64	27 February
Texas Playas						
2002	8	84	5	49-91	76-92	25 March
2003	7	73	4	49-83	66-80	14 March
Texas Gulf Coast						
2002	3	87	8	72-85	73-101	28 March
2003	2	68	1	67-68	67-69	9 March

Wintering Areas and Migration Routes from the PLR, Texas

All Pintails PTT-tagged in the PLR remained there throughout each winter, and moved only short distances (~60-80 km) during late winter. During winter 2001-2002, five of eight surviving birds moved south from Buffalo Lake NWR to the Dimmitt and Tulia, Texas areas during January and February (Castro and Swisher counties). During 2002-2003, six of seven surviving tagged females moved slightly northward in February to this same area prior to migrating from the region. These movements occurred because of weather events and declining playa habitats.

Three migration routes for tagged Pintails that departed the PLR in spring were identified (Fig. 1). The most prominent route (67% of birds; N = 10) was north northeast, and initial destinations included southwestern to north-central Kansas (350-700 km) or the Nebraska Sandhills Region in the west (900 km) and Rainwater Basins in the south (750 km) (Fig. 1). Stopover areas included the western Rainwater Basins (20%; N = 3) and Cedar Bluff Wildlife Area in west-central Kansas (13%; N = 2). The second route (20%; N = 3) tracked to southeastern and east-central Colorado (385-500 km). The third pathway followed that of birds stopping in Kansas and Nebraska, but instead, the first stop occurred in the Dakotas (13%; N = 2). About 80% (N = 12) of PLR tagged Pintails used the Dakotas at some time. In Canada (N = 9), tagged Pintails from the PLR used south-central Saskatchewan (Saskatoon/Regina area) (89%; N = 8), northern Alberta/British Columbia and Nunavut (56%; N = 5), northeastern Manitoba adjacent to Hudson Bay (22%; N = 2), and portions of Yukon Territory (22%; N = 2) (Table 3). Only one bird settled in Alaska, and this occurred during 2002. Pintails that stopped in Kansas and Nebraska, tended to remain in the conterminous United States during the nesting season (North Dakota, South Dakota, Nebraska, or Wyoming; N = 5; Fig. 1).

Winter Areas and Migration Routes from the Gulf Coast, Texas

During winter, all Pintails tagged on the Texas Gulf Coast either stayed near capture sites (67%; N = 12, <40 km movements) or moved northeastward along coastal habitats (33%; N = 6; Fig. 1). Those moving up the coast typically remained in the El-Campo and Eagle Lake area west of Houston, Texas, until migrating from the region. One bird moved to Louisiana in 2003, but the transmitter failed shortly after arrival. One Gulf Coast-tagged Pintail was reported shot in Texas during 2003.

Only five of 20 tagged Pintails survived, or had active transmitters at the time of departure from the Gulf Coast. Another bird's PTT failed for much of the migration period, but transmitted intermittently following arrival in Alberta. Spring migration from the Texas Gulf Coast tended to head north and follow the eastern sections of the Central Fly-

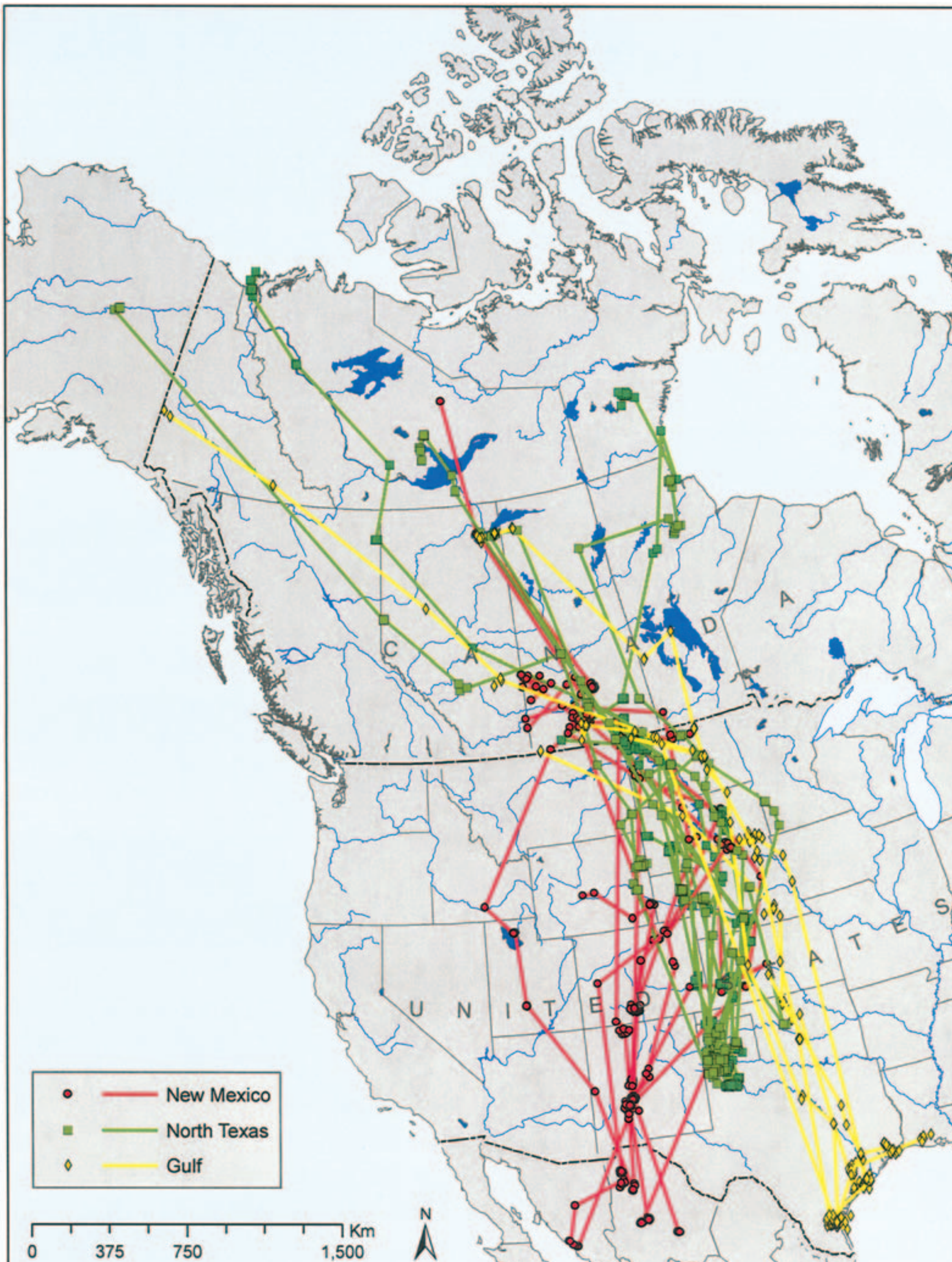

Figure 1. Winter movements and spring migration pathways used by 31 adult female Northern Pintails carrying satellite transmitters from the Middle Rio Grande Valley, New Mexico (red routes), Playa Lakes Region of Texas (green routes), and Texas Gulf Coast (yellow routes) during 2001-2002 and 2002-2003.

way (Fig. 1). North-central Oklahoma (900 km) and central Kansas (1300 km) were initial destinations for four of the five birds (Fig. 1). Upon leaving Oklahoma and Kansas, Pintails typically used the eastern Rainwater Basins or the Missouri River in north-

Table 3. Distribution of final destination (following 1 May) of adult female Northern Pintails wintering in the Central Flyway (New Mexico and Texas) during 2002 and 2003.

Final Destination	2002	2003	Overall
Prairie Pothole Region, Canada[1]	3 (23%)	8 (47%)	11 (37%)
Prairie Pothole Region, United States[2]	0	5 (29%)	5 (17%)
Alaska	1 (8%)	0	1 (3%)
Other Canada[3]	4 (31%)	3 (18%)	7 (23%)
Other United States[4]	5 (38%)	1 (6%)	6 (20%)

[1]Southern Alberta, Saskatchewan, and Manitoba.
[2]North Dakota, South Dakota, and Montana.
[3]Northwest Territories, Yukon, and Nunavut.
[4]Nebraska, Colorado, and Wyoming.

eastern Nebraska before settling in the Dakotas or Canada. Particularly important areas for Gulf Coast Pintails in Canada included southern Manitoba and Saskatchewan and northern Alberta and Saskatchewan (Table 3). One female used habitats in the Yukon Territory (Fig. 1).

DISCUSSION

Female Pintails tagged with PTTs in three Central Flyway wintering areas followed specific routes through the mid-continent of the United States and Canada. Pintails followed routes northward that differed among wintering areas, but there was considerable overlap in the nesting grounds of the Dakotas and southern Canada. Tagged Pintails that remained in areas of the United States outside of the PPR during the nesting season typically staged in Kansas or Nebraska during spring migration. In contrast, Pintails that used Canadian habitats typically overflew Kansas and Nebraska, initially staging in the Dakotas. This may indicate that pintails leaving the wintering grounds in good nutritional status proceed directly to the nesting grounds, while those with a need to replenish or increase nutrient reserves on stopover sites may not have sufficient time to travel into Canada prior to attempting to nest. Another possible explanation is that stopover habitats can no longer support the current Pintail population during spring due to habitat loss or degradation.

Weather likely played a role in our observed migration patterns; unfavorable early spring weather (i.e., cold temperatures and snowfall) during both years limited availability of potential migration stopover habitats in southern regions and delayed migration. As a result, Texas-tagged Pintails rapidly moved (median = 17 days) to their breeding grounds (either in the United States or Canada) once temperatures increased. Contrary to Bellrose's (1980) conclusions based on banding data, we observed eastward movement by Pintails from the Central Flyway once they reached Canada as two PLR Pintails moved eastward into northern Manitoba near Hudson Bay.

Negative influences on any of the populations or wetland habitats of Pintails in the three major wintering areas of the Central Flyway may have continental implications. The Central Flyway winters approximately a quarter of the continental Pintail population and these birds distribute throughout North American breeding grounds potentially mixing and contributing to populations wintering in other Flyways. Furthermore, habitat conditions in the PPR appear to have influenced final nesting destinations (Johnson and Grier 1988; Miller *et al.* 2005). Essentially, during dry years in the PPR, Pintails of the Central Flyway overfly the PPR and distribute throughout northern regions of North America, but during average or wet habitat conditions in the PPR, they settle to nest in southern Saskatchewan. During the 2002 drought (number of surveyed ponds <33% of long-term average in the traditional survey area), only 23% (N = 3) of tagged female Pintails settled in the PPR. This is lower than Smith's (1970) estimate of 38.4% of Pintails that remain in the PPR during drought conditions of the 1960s and may represent a decline in carrying capacity of the region during dry conditions since the 1960s and 1970s. In contrast, during wet 2003, 76% (N = 13) of birds remained there; the latter percentage is similar to that reported by Bellrose (1980) for birds wintering in the Central Flyway. During the drought of 2002 in the PPR, tagged Pintails either remained in the conterminous United States (Nebraska, Wyoming, and Colorado) or ventured farther north in Canada and to Alaska. Pintails tagged with PTTs in California exhibited similar responses, settling in the PPR in larger numbers during 2003 than during the previous three dryer years (Miller *et al.* 2005).

Major use of traditional (Bellrose 1980) spring staging areas by a large proportion of PTT-tagged Pintails, such as Cheyenne Bottoms in Kansas and the Rainwater Basins of Nebraska were not detected. Most commonly, individuals used different stopover areas upon exiting wintering ranges, and no individual stopover area was used by more than 16% (N = 5) of tagged Pintails. This result contrasts with data for California PTT-tagged Pintails, in which about 80% or more staged in the region consisting of southern Oregon, northeastern California and extreme northwestern Nevada (SONEC) prior to moving to nesting grounds (Miller *et al.* 2005). PLR (western portion) and Gulf Coast (eastern portion) Pintails used wetlands within the Rainwater Basin region of south-central Nebraska, but this was not proportionate to expected numbers based on previous estimates (Bellrose 1980); additionally, none of the MRGV Pintails used the Rainwater Basin or Cheyenne Bottoms regions. The lack of major stopover area for our sample of Pintails may have resulted from (1) differential body condition of individuals among wintering areas, which delayed migration and influenced migration distances; (2) wide variation in the availability and quality of spring migration habitats by year and region requiring birds to disperse (Smith 2003, Kostecke *et al.* 2004); (3) unfavorable weather delaying migration and requiring birds to accelerate once migration began; or (4) the small sample of tagged Pintails may not have been sufficient to identify any consistently-used migration stopover sites.

On average, PTT-tagged Pintails from Texas and New Mexico initiated spring migration about 25 days later than did tagged Pintails from California during the same years (Miller *et al.* 2005). Later migration by Texas and New Mexico Pintails could be related to the weather patterns that delayed migration, California Pintails are in better physical condition because of better habitat conditions just prior to migration than are Texas Pintails (Miller 1986, Smith and Sheeley 1993), or migration reflected a difference in timing of breeding between California and Texas-New Mexico Pintails. Four Texas Pintails apparently moved south in response to low temperatures, and this could be related to status of nutrient reserves (Alford and Bolen 1977). Pintails PTT-tagged in Texas and New Mexico tended to arrive later in the PPR than did those tagged in California, and this coincides with the earlier migration of California Pintails (Miller *et al.* 2005). These findings suggest the existence of differential migration strategies between the Pacific and Central Flyways. The timing of migration of California Pintails varied relative to the route used. Those migrating over the Pacific Ocean directly to Alaska delayed departure from SONEC and arrived in Alaska coincident with weather conditions favorable to survival and foraging. Others left and used inland routes to southern Alberta or other PPR locations, arriving in Canada prior to arrival of Texas and New Mexico migrants that encountered weather conditions unfavorable for migration.

PTT-tagged Pintails probably did not adequately characterize the overall spring migration and settling patterns of Pintails migrating north from Texas and New Mexico. Pintail mortalities and PTT failures limited sample sizes, which compromised inference from the data; this was especially a problem for Texas Gulf Coast birds. Most deaths or PTT failures occurred either just after PTT attachment or shortly prior to migration. Because PTT failures should have been relatively consistent among capture sites, different rates of transmitter disappearance among sites likely represented differential mortality. During the study, the percentage of PTT-tagged Pintails known to have survived and initiated spring migration was similar for New Mexico (73%; N = 11) and the PLR (75%; N = 15) birds. However, only five of 20 tagged Pintails from the Texas Gulf Coast (25%) provided migration data. We could not recover individual PTTs to determine fate. We speculate that this disparity could reflect differences in Pintail survival resulting from relative harvest rates (Moon and Haukos 2006), nutritional status relative to different physiological effects of saline versus freshwater habitats (Tietje and Teer 1988), or relatively poor coastal habitat conditions. The effects of different water salinities on the function of PTTs are unknown. However, survival of Pintails on the Texas Gulf Coast was much lower than for PLR and MRGV Pintails in recent studies using conventional VHF transmitters (Lee 2003, Moon and Haukos 2006; B. Ballard, Texas A&M-Kingsville, unpublished data) suggesting that the greater loss of our Texas Gulf Coast PTT birds was likely due to greater mortality. These findings indicate that managers and regulators should be concerned about Pintails wintering on the Gulf Coast, because conditions in this region may serve as a population sink for Central Flyway Pintails.

Additional research should be conducted on spring migration of Pintails in the Central Flyway to examine the preliminary findings of this study. In particular, larger sample sizes of PTT-tagged Pintails are needed to overcome mortality prior to migration, or PTTs could be attached after the hunting season closes. We recommend that PTTs of longer life be used to delineate both spring and autumn migration routes. The dispersed spring migration patterns of PTT-tagged Pintails suggests that investigations are needed to determine if Pintails are being displaced from traditional migration stopover sites, and if this is related to declining habitat quantity and quality in Kansas and Nebraska.

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