Predictable Interregional Movements by Female Northern Pintails During Winter

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Abstract.—Factors influencing initiation of regional and interregional movements by nonbreeding ducks are poorly understood, especially during winter. During winters 1990-1991 through 1992-1993, we radiotagged 347 female Northern Pintails (Anas acuta) in southwestern Louisiana and monitored their movements to three regions: (1) the Gulf Coast Region of Louisiana and Texas (outside of southwestern Louisiana), (2) the Rice Prairie Region of Texas, and (3) the Mississippi Alluvial Valley. We found that adult females were 1.9 times more likely than were immatures to emigrate from southwestern Louisiana during winter. During winters 1990-1991 and 1991-1992, females were more likely to emigrate during stormy than during fair weather, whereas they were more likely to emigrate during fair weather in 1992-1993. Females were more likely to emigrate during duck-hunting seasons than during nonhunting seasons, regardless of weather. Daily emigration probabilities did not differ in relation to body condition when released (body mass adjusted for body size) or to number of previous emigration events. Each winter, large numbers of females consistently moved from the Gulf Coast Region to areas with abundant rice (Oryza sativa) agriculture within the Mississippi Alluvial Valley. We conclude that destination of interregional movements by this population of Northern Pintails is highly predictable, and that initiation of such movements is influenced by female age and long-term winter precipitation patterns in the Mississippi Alluvial Valley. Furthermore, timing of these movements is predictable, based not on calendar date, but rather on duck-hunting seasons and, usually, the environmental cues to habitat availability provided by stormy weather. Received 5 January 2000, accepted 1 April 2000.

Key words.—Anas acuta, Gulf Coast, interregional movements, Mississippi Alluvial Valley, Northern Pintail, Oryza sativa, rice, Rice Prairie, winter.

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Northern Pintails (Anas acuta; hereafter pintails) are circumpolar in distribution (Bellrose 1976). In North America, pintails breed or winter over much of the continent (Bellrose 1976; Palmer 1976; Austin and Miller 1995). Pintails show considerable flexibility in breeding distribution, typically overflying the Prairie Pothole Region of the U.S. and Canada to more northern areas during drought years (Hansen and McKnight 1964; Smith 1970; Johnson and Grier 1988; Hestbeck 1995). Wintering areas for pintails breeding in North America include the Pacific Coast from Alaska to Mexico, Hawaii, the Gulf Coast from Mexico through Louisiana, the Atlantic Coast from Massachusetts to Florida, Cuba, Bermuda, and Central and South America (Low 1949; Bellrose 1976; Palmer 1976; Austin and Miller 1995).

Movements by pintails and other waterfowl have been studied more at continental and local scales than at intermediate scales (i.e., regional and interregional). Wide-ranging intra- and intercontinental movements by pintails have been documented by direct and indirect band recoveries (Low 1949; Baysinger and Bauer 1971; Palmer 1976; Rienecker 1987, 1988). Analyses of banding data indicate that pintails show varying degrees of site-fidelity to wintering areas in North America (Hestbeck 1993). However, pintails, particularly females, display strong fidelity to major wintering areas (e.g., Central Valley of California and Gulf Coasts of Texas and Louisiana; Rienecker 1987; Hestbeck 1993), and these areas consistently attract large numbers of pintails annually (U.S. Fish and Wildlife Service [USFWS] unpubl. mid-winter surveys). These findings suggest that on a
continental scale, individual pintails select the same broad wintering region each year, despite the overall cosmopolitan wintering distribution of this species. Indeed, Hestbeck (1993) convincingly argued that wintering populations of pintails are more stable spatially than are breeding populations. However, pintails and other ducks undoubtedly maintain some flexibility in selecting wintering regions based on environmental conditions or other factors. For example, Nichols et al. (1983) demonstrated that proportionately more Mallards (Anas platyrhynchos) wintered in the Mississippi Alluvial Valley (MAV) during years characterized by high precipitation or low Mallard population levels.

Movements and spatial distribution of individual ducks within or among regions have received little study, particularly during winter. Mallards wintering in the MAV move south during extended periods of extremely cold temperature (Nichols et al. 1983; Reinecke et al. 1987). Reinecke et al. (1987) documented northward shifts of 50 km by radiotagged Mallards, evidently in response to heavy rains and subsequent flooding of major rivers in the MAV of Arkansas. Analyses of direct recoveries of pintails banded prior to hunting season in California suggest that incidence of regional and interregional movements by pintails varies considerably among banding sites, and that movements are extensive for pintails banded at some sites (Rienecker 1987).

Movements of wintering waterfowl have been studied most frequently on study areas of 80-km radii or less (e.g., Morton et al. 1989). At this scale, site selection by wintering pintails generally is highly flexible. Variation in food availability, often mediated by abundance of shallowly flooded natural or agricultural habitats, and disturbance from hunting influence local-scale distribution (i.e., use of habitats) of wintering pintails (Euliss and Harris 1987; Euliss et al. 1991; Cox and Afton 1997; 1998b; Cox et al. 1998). Pintails concentrate on refuges in many wintering regions (e.g., California [Miller et al. 1995] and Louisiana [Cox and Afton 1997; Cox et al. 1998]). However, unlike feeding sites, use (high or low) of specific refuges by pintails tends to be consistent among years (Cox and Afton 1998b). Pintails often make extensive daily flights between refuges and feeding sites (Miller 1985, 1987; Cox and Afton 1996).

There are at least four potential problems with using banding data to investigate within-winter movements by pintails and other ducks. First, banding data are biased toward movements prior to or during hunting seasons because most information is obtained from birds shot, retrieved, and reported by hunters. Consequently, movements by individuals that are not recovered and reported will not be detected. Second, pintail banding effort has been relatively small and highly localized compared to that for Mallards (Hestbeck 1993). Therefore, selected reference areas may encompass regions with considerable heterogeneity in distribution and movements, but this within-reference-area heterogeneity may not be apparent in banding data. Third, geographic variation in hunting pressure and, subsequently, direct recovery or band reporting rates can give misleading results regarding incidence of movements among regions (Hestbeck 1993). Finally, timing of movements is measured crudely because only dates and locations of bandings and recoveries are known; consequently, movements could have occurred long before or immediately prior to recoveries.

For these reasons, we used radiotelemetry to investigate intra- and interregional movements by wintering female pintails from the Gulf Coast Region in southwestern Louisiana. Our primary objective was to identify factors associated with initiation of movements by pintails to three regions: (1) the Gulf Coast Region (outside of southwestern Louisiana), (2) the Rice Prairie Region, and (3) the MAV. We also report timing, incidence, and destination of movements by radiotagged pintails during winter to assist development, implementation, and spatial resolution of habitat management plans within and among these regions.

**STUDY AREA AND METHODS**

**Physiographic Regions, Primary Study Area, and Extended Search Area**

The Gulf Coast Region herein collectively refers to the Gulf Coastal Plain of the Mississippi Flyway
(Chabreck et al. 1989) and the Texas Gulf Coastal Zone of the Central Flyway (Stutzenbaker and Weller 1989; Fig. 1). The Gulf Coast Region is comprised of extensive coastal marshes of varying salinity and is one of the most important freshwater wetland areas in North America (Chabreck et al. 1989; Stutzenbaker and Weller 1989). The Rice Prairie Region consists of four areas of intensive rice (Oryza sativa) production in southeastern Texas (Hobaugh et al. 1989; Fig. 1). Over 1.5 million waterfowl, particularly geese, have wintered in this region since the 1980s (Hobaugh et al. 1989). Finally, the MAV is a vast alluvial floodplain formed by the Mississippi River (Reinecke et al. 1989; Fig. 1). This region hosts large numbers of wintering waterfowl, but is best known as a primary wintering area for Mallards (Nichols et al. 1983; Reinecke et al. 1989).

Our primary study area included all lands within 80 km of the perimeter of Lacassine Pool, Lacassine National Wildlife Refuge (NWR), in southwestern Louisiana, and extending 8 km into the Gulf of Mexico (see Cox and Atton 1997). This area, which comprises the entire southwestern portion of Louisiana, is part of the Gulf Coast Region (Chabreck et al. 1989; Stutzenbaker and Weller 1989), an important pintail wintering area (Reinecke 1987; Fig. 1). Our extended search area (see below) included the remainder of the Gulf Coast Region of Louisiana, the Rice Prairie Region and Gulf Coast of Texas as far west as Matagorda Bay, and all but southeastern Missouri in the MAV (Fig. 1).

Field Procedures


We previously described trapping (Cox and Atton 1994) and handling procedures (Cox and Atton 1998a). We classified captured females as adult or immature using cloacal and tail-and-wing feather characteristics (Hochbaum 1942; Carney 1964; Duncan 1985). We weighed (± 5 g) each female and measured (± 0.01 mm): (1) culmen, (2) bill width at nares, (3) total tarsus (Daubin and Cooch 1992), and (4) middle toe length. We legbanded and fitted females with 21-g backpack-type radio-transmitters (Dwyer 1972) that had mortality sensors and expected battery lives of 100 days (1990-1991) or 150 days (1991-1992 and 1992-1993). Transmitters had minimum ground-to-ground ranges of 7 km to truck-mounted four-element null-peak antennas, and ground-to-air ranges of 60-100 km to aircraft flown at 1300-2900 m altitudes (Cox and Atton 1996, 1997).

During 26 October 1990-20 February 1991, 5 October 1991-19 February 1992, and 8 October 1992-20 Feb-

Figure 1. Primary study area (short-dashed polygon), with Lacassine Pool in the center, and extended search area (long-dashed polygon) in which radiotagged female Northern Pintails were tracked during winters 1990-1991 through 1992-1993. Regions include Gulf Coast (dark shading; Chabreck et al. 1989; Stutzenbaker and Weller 1989); Mississippi Alluvial Valley (light shading; Reinecke et al. 1992), and Rice Prairie of southeastern Texas (horizontal hatches; Hobaugh et al. 1989).
January 1993, we attempted to locate radiotagged females and assess their status (alive or dead) once daily within our primary study area. Each day that weather permitted, we used aircraft to search the entire primary study area (Gilmer et al. 1981). When weather prohibited use of aircraft, we assessed status using ground vehicles and permanent towers (Cox and Afton 1996, 1997). At monthly (1990-1991 and 1991-1992) or weekly (1992-1993) intervals, we used aircraft to locate radiotagged pintails outside of our primary study area, but within our extended search area. We estimated point locations for birds located aerially using LORAN-C.

Statistical Analysis

Body size and condition.—We used size-adjusted body mass at the time females were released as an index of body condition (Dufour et al. 1993). We first performed principal components analysis (PROC PRINCOMP; SAS Institute 1990) on the correlation matrix of the four morphometric variables from all instrumented females. We subsequently used PCI scores as a measure of body size for each female (Alisauskas and Ankeny 1987). We then used least-squares regression (PROC GLM; SAS Institute 1990) to test for a relation between body mass and size of females (winters combined). Given a significant (P < 0.05) relation (see Cox and Afton 1998a for details), we adjusted body mass of each female for her size by adding the overall mean body mass to each female’s residual from the regression (Ankeny and Afton 1988).

Movements.—We divided each winter into five non-overlapping time periods based on duck-hunting seasons in southwestern Louisiana: (1) pre-hunting season (PRE); max range of dates for all winters = 1 October-20 November), (2) first hunting season (IFHUNT); 16 November-6 December), (3) time between split hunting seasons (SPLIT); 6-27 December), (4) second hunting season (ISHUNT); 26 December-9 January), and (5) post-hunting season (POST); 6 January-20 February). We obtained monthly weather reports for Lake Charles, Louisiana (about 35 km from the center of our primary study area), from the Louisiana Office of State Climatology (1990-1993), wherein weather was classified as one of eight synoptic weather types (Muller and Willis 1983) each day at 0600 and 1500 h CST (Table 1). For each day, we pooled weather types into two categories: (1) stormy (if either weather type for a day was classified as Frontal Overrunning, Frontal Gulf Return, or Gulf Tropical Disturbance), or (2) fair (if neither weather type for a day was classified as such; Table 1).

For each exposure day for each bird, we constructed a binary response variable representing whether or not an emigration event occurred (i.e., female departed the primary study area). When an individual’s emigration date was not known exactly, we estimated it by randomly selecting a date from the interval between the last date the bird was known to be in the primary study area and the first date the bird could not be located within the primary study area on a complete flight or was located outside the primary study area. Most instances where exact dates of emigration were not known occurred during periods of uninterrupted stormy weather within time periods; thus, we believe little error occurred in assigning time-dependent covariates from our random assignment of dates within intervals. We similarly estimated dates of return to the primary study area when exact dates were not known. We excluded (i.e., right-censored) females while they were alive but located out of the primary study area, and re-included them in the risk set if they later returned. We also right-censored females that died in the primary study area on their date of death. When the exact date of death was not known, we estimated it as the midpoint between the last date that the bird was noted alive and the first date that the mortality signal was detected.

Our approach was similar to a survival analysis, except that the event of interest was emigration rather than mortality. Unlike mortality, however, individual females could emigrate on multiple occasions (up to three times in our study). We thus included the number of previous emigration events for each female (since radiotagging) as an explanatory variable to assess the plausibility of considering multiple emigration events by an individual to be independent. We used logistic regression (PROC GENMOD; SAS Institute 1997) with a complementary log-log link (Allison 1995) to test for variation in daily emigration probability in relation to

Table 1. Synoptic weather types used by Louisiana Office of State Climatology.

<table>
<thead>
<tr>
<th>Weather type</th>
<th>Characteristics</th>
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<tbody>
<tr>
<td>Pacific High</td>
<td>Fair, mild, and dry; winds west to northwest</td>
</tr>
<tr>
<td>Continental High</td>
<td>Fair, cold, and dry; winds north to northwest</td>
</tr>
<tr>
<td>Coastal Return</td>
<td>Fair and mild; winds northeast, east, or southeast</td>
</tr>
<tr>
<td>Gulf High</td>
<td>High barometric pressure; maritime tropical air; winds southwest</td>
</tr>
<tr>
<td>Gulf Return</td>
<td>Cold front approaching, but too far away to affect weather yet; variable cloudiness and becoming warm; winds east, southeast, or south</td>
</tr>
<tr>
<td>Frontal Gulf Return</td>
<td>Turbulent and stormy as cold front approaches; winds typically southwest</td>
</tr>
<tr>
<td>Frontal Overrunning</td>
<td>Cloudy and rainy conditions associated with a cold front that has become stationary; winds northeast</td>
</tr>
<tr>
<td>Gulf Tropical Disturbance</td>
<td>Stormy, turbulent weather associated with approaching tropical depressions or hurricanes</td>
</tr>
</tbody>
</table>

1See Muller and Willis (1983) for complete descriptions.
2Classified as stormy for analysis; remainder classified as fair.
female age (categorical; adult or immature), winter (categorical; 1990-1991, 1991-1992, or 1992-1993), time period within winters (categorical, time-dependent; PRE, FHUNT, SPLIT, SHUNT, or POST), body condition when released (continuous; body mass adjusted for body size), weather (categorical, time-dependent; stormy or fair), and number of previous emigration events (continuous, time-dependent; 0, 1, or 2). Our fully specified model included the number of previous emigration events as a main effect only and all other main effects and two-way interactions among remaining explanatory variables except time period-by-winter; we did not include this interaction because no females emigrated during SPLIT in 1990-1991 (i.e., there was a missing cell). We used backward, stepwise procedures to eliminate nonsignificant (P > 0.05) terms, beginning with the two-way interactions. We assessed fit of our final model using Hosmer and Lemeshow's (1989) goodness-of-fit test (PROC LOGISTIC; SAS Institute 1997). We compared emigration probabilities within levels of interactions remaining in our final models using orthogonal contrasts (Littell et al. 1991). We calculated product-limit estimates (Kaplan and Meier 1958) of emigration rates using PROC PHREG (SAS Institute 1997). Two females were shot and reported by hunters after their transmitters had failed; we right-censored these individuals following their last radio contact.

To investigate temporal trends in relative numbers of pintails wintering in Arkansas and Louisiana, we obtained mid-winter waterfowl survey data for the Mississippi Flyway during 1980-1995 (U.S. Fish and Wildlife Service unpubl. data). We used least-squares regression (PROC GLM; SAS Institute 1990) to test for a linear relation among years in the percentage of pintails counted in Arkansas and in Louisiana. Weather prevented completion of the mid-winter survey in Louisiana during 1993; consequently, we excluded this year from analysis. We obtained data on land area planted in rice during 1980-1995 in each state in the U.S. and during 1992 in each county or parish in the U.S. from the National Agricultural Statistics Service, U.S. Department of Agriculture. We used least-squares regression (PROC GLM; SAS Institute 1990) to test for a linear trend among years in the percentage of land area planted in rice in Arkansas during 1980-1995 relative to that planted in Arkansas and Louisiana combined.

RESULTS

We radiotagged 347 females during our study, including 29 adults and 12 immatures during 1990-1991, 96 adults and 58 immatures during 1991-1992, and 108 adults and 44 immatures during 1992-1993. During 1990-1991 through 1992-1993, we recorded 197 emigration events during 20,107 exposure days. One hundred and seventy (86%) emigration events were by females that had not emigrated since radiotagging, 25 (13%) were by females that had emigrated once previously, and two (1%) were by females that had emigrated twice previously.

Our final fitted model indicated that daily emigration probabilities differed in relation to female age ($\chi^2_1 = 15.36, P < 0.0001$). Further, weather effects on emigration were not consistent among winters (weather-by-winter interaction; $\chi^2_2 = 33.99, P < 0.0001$) or time periods (weather-by-time period interaction; $\chi^2_2 = 16.61, P = 0.002$). Effects of body condition when released, number of previous emigration events, and other interactions were not significant ($P > 0.24$ for all tests). Our final model fit the observed data (Hosmer and Lemeshow goodness-of-fit statistic = 10.94, df = 8, $P = 0.21$).

Adults (daily emigration probability = 0.0047; 95% CI = 0.003-0.0074; N = 233) were 1.9 times more likely than were immatures (0.0025; 95% CI = 0.0015-0.0042; N = 114) to emigrate on any given day of the wintering period. Females were more likely to emigrate during stormy than during fair weather in 1990-1991 (orthogonal contrast; $\chi^2_1 = 8.28, P = 0.004$) and 1991-1992 ($\chi^2_1 = 4.53, P = 0.03$), whereas they were more likely to emigrate during fair weather in 1992-1993 ($\chi^2_1 = 9.61, P = 0.002$; Table 2). Pintails were more likely to emigrate during stormy than during fair weather during FHUNT, SPLIT, and POST (orthogonal contrasts; $P < 0.04$ for all tests), but emigration probabilities did not differ in relation to weather during PRE and SHUNT (orthogonal contrasts; $P > 0.14$ for both tests; Table 3). During both stormy and fair weather, females were more likely to emigrate during hunting seasons (FHUNT and SHUNT) than during nonhunting seasons (PRE, SPLIT, and POST; orthogonal contrasts; $P < 0.0001$ for both tests; Table 3).

Table 2. Daily emigration probabilities and 95% confidence intervals for female Northern Pintails captured and radiotagged in southwestern Louisiana in relation to weather for each winter.

<table>
<thead>
<tr>
<th>Winter</th>
<th>Weather</th>
<th>Probability</th>
<th>95% confidence interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>1990-1991</td>
<td>Stormy</td>
<td>0.0035</td>
<td>0.0014-0.0086</td>
</tr>
<tr>
<td></td>
<td>Fair</td>
<td>0.0005</td>
<td>0.0001-0.0037</td>
</tr>
<tr>
<td>1991-1992</td>
<td>Stormy</td>
<td>0.0049</td>
<td>0.0022-0.0108</td>
</tr>
<tr>
<td></td>
<td>Fair</td>
<td>0.0033</td>
<td>0.0020-0.0054</td>
</tr>
<tr>
<td>1992-1993</td>
<td>Stormy</td>
<td>0.0024</td>
<td>0.0011-0.0055</td>
</tr>
<tr>
<td></td>
<td>Fair</td>
<td>0.0086</td>
<td>0.0060-0.0122</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Time period</th>
<th>Weather</th>
<th>Probability</th>
<th>95% confidence interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>PRE</td>
<td>Stormy</td>
<td>0.0003</td>
<td>0.0001-0.0022</td>
</tr>
<tr>
<td></td>
<td>Fair</td>
<td>0.0019</td>
<td>0.0010-0.0035</td>
</tr>
<tr>
<td>FHUNT</td>
<td>Stormy</td>
<td>0.0282</td>
<td>0.0217-0.0367</td>
</tr>
<tr>
<td></td>
<td>Fair</td>
<td>0.0118</td>
<td>0.0076-0.0183</td>
</tr>
<tr>
<td>SPLIT</td>
<td>Stormy</td>
<td>0.0078</td>
<td>0.0050-0.0121</td>
</tr>
<tr>
<td></td>
<td>Fair</td>
<td>0.0046</td>
<td>0.0020-0.0107</td>
</tr>
<tr>
<td>SHUNT</td>
<td>Stormy</td>
<td>0.0227</td>
<td>0.0153-0.0335</td>
</tr>
<tr>
<td></td>
<td>Fair</td>
<td>0.0204</td>
<td>0.0109-0.0379</td>
</tr>
<tr>
<td>POST</td>
<td>Stormy</td>
<td>0.0147</td>
<td>0.0105-0.0207</td>
</tr>
<tr>
<td></td>
<td>Fair</td>
<td>0.0039</td>
<td>0.0019-0.0081</td>
</tr>
</tbody>
</table>

1PRE = pre-hunting season; FHUNT = first hunting season; SPLIT = time between hunting seasons; SHUNT = second hunting season; POST = post-hunting season.

The timing of major movements by radiotagged female pintails varied markedly among winters (Fig. 2). In 1990-1991, emigration occurred primarily during late December, particularly during SHUNT. In 1991-1992, most emigration occurred during November, beginning immediately following initiation of FHUNT. Emigration was more protracted in 1992-1993, being most frequent from mid-December to early January (Fig. 2).

Interregional movements by female pintails were common during winter. Emigration rates (ages combined) exceeded 50% by 8 January in 1990-1991, by 3 December in 1991-1992, and by 27 December in 1992-1993 (Fig. 2).

During each winter, emigrating females consistently moved north-northeasterly to the MAV (Fig. 3). Pintail locations were concentrated along the western edge of the MAV in central and northeastern Louisiana, and in southeastern, central, and northeastern Arkansas (Fig. 3). Females rarely moved westward within the Gulf Coast Region or to the Rice Prairie Region of Texas (ten of 556 locations, eight of 152 females for these regions combined), or eastward within the Gulf Coast Region to marshes or major river deltas in Louisiana (two of 556 locations, two of 152 females; Fig. 3).

The percentage of Mississippi Flyway pintails observed in Louisiana during midwinter surveys during 1980-1995 declined by 1.7 ± 0.8% (X ± SE) each winter (F1,15 = 4.93, P = 0.04, r2 = 0.28; Fig. 4). When we excluded 1991 (an obvious outlier; Fig. 4), we found that the percentage of Mississippi Flyway pintails observed in Louisiana declined by 1.1 ± 0.3% each winter (F1,12 = 13.04, P = 0.004, r2 = 0.52). Concurrently, the percentage of pintails counted in Arkansas increased by 1.6 ± 0.8% each winter (F1,15 = 4.24, P = 0.06, r2 = 0.25; Fig. 4), or increased by 1.0 ± 0.3% each winter when 1991 was excluded (F1,12 = 9.14, P = 0.01, r2 = 0.43). During 1980-1995,
70% (range = 68-72%) of the land area planted in rice each year in Arkansas and Louisiana combined was found in Arkansas, and we found no evidence that this percentage varied linearly among years ($F_{1,16} = 1.99$, $P = 0.18$).

**DISCUSSION**

Our results indicate that early-migrant pintails observed in southwestern Louisiana during October apparently moved first to areas with dependable water and food, such as coastal marshes, and then moved northward to agricultural areas later in winters, as these habitats were flooded. Because October typically is the driest month in the MAV (Reinecke et al. 1988), most agricultural habitats in the MAV to which pintails moved later in winter likely were dry in October. On average, rains begin increasing in November, and December typically is one of the wettest months in the MAV (Reinecke et al. 1988). Pintails in our study were more likely to emigrate during stormy than during fair weather in two of three winters and in three of five time periods. By emigrating during stormy weather (a possible proximate cue to wetland availability), pintails probably increase the likelihood of finding flooded agricultur-
al habitats upon their arrival in more northern areas. However, we found that pintails were more likely to initiate movements during fair rather than stormy weather during 1992-1993. Pintails may respond to more specific environmental cues than the coarse weather classifications used in our study; consequently, more detailed studies of weather factors influencing initiation of interregional movements might be fruitful.

We found that pintails were more likely to emigrate during hunting seasons than during nonhunting seasons, regardless of weather. Pintails that remained in southwestern Louisiana shifted their diurnal use of habitats from privately owned agricultural areas to refuges in response to hunting (Cox and Afton 1997). Thus, hunting not only influences habitat and site use by pintails on a local scale, but also increases the likelihood that pintails initiate larger scale, interregional movements.

During each winter, the majority of female pintails in our study consistently moved northward well before mid-winter, and major emigrations occurred as early as November in one winter. We believe that northward movements were not related to temperature or to initiation of spring migration, but to availability of shallowly flooded agricultural habitats in the MAV.

During 1981-1995, the Gulf Coast Region of southwestern Louisiana was the primary wintering area for pintails found east of Texas, hosting 58% of the pintails in the Mississippi Flyway (Cox 1996). Few pintails were counted during mid-winter surveys (conducted approximately 1 January) in Arkansas during the early 1980s (Fig. 4). Since that time, the proportion of Mississippi Flyway pintails found in Arkansas during mid-winter surveys has increased, while that in Louisiana has decreased. This apparent change in winter distribution could have occurred because: (1) a greater proportion of pintails now migrate only as far south as Arkansas, (2) pintails from Louisiana recently have begun to move northward to Arkansas during winter, (3) pintails have always moved from Louisiana to Arkansas during winter, but now do so earlier (i.e., prior to mid-winter surveys), or (4) over time, winter survival rates have increased or hunting mortality rates prior to mid-winter surveys have decreased in Arkansas relative to Louisiana. Our finding that the majority of pintails that we radiotagged in southwestern Louisiana during October moved to the MAV prior to mid-winter suggests that at least part of this change in winter distribution between Louisiana and Arkansas is related to movements by pintails, particularly adults, prior to midwinter surveys. Regardless of the factors responsible for the apparent shift in winter distribution, mid-winter survey data indicate that habitats in the mid- to upper MAV are increasing in importance to pintails in the Mississippi Flyway.

Extensive clearing of bottomland hardwood forests in the MAV for conversion to agriculture occurred during 1944-1972 (Reinecke et al. 1988), well before pintails in Arkansas began to increase. Thus, wintering pintails did not make extensive use, at least by 1 January, of greatly expanded agriculture in the MAV until long after these habitats first became available. Land area planted in rice in Arkansas and Louisiana was stable during 1980-1995; consequently, the apparent recent shift in wintering pintails from Louisiana to Arkansas is not related to changes in rice agriculture during this period. Thus, a considerable time lag may exist between major changes in habitat and extensive redistribution among regions by pintails. However, deteriorating waterfowl habitat quality in Louisiana coastal marshes (e.g., Stone et al. 1978; Craig et al. 1979) and increased waterfowl management (e.g., artificial flooding) of rice fields in Arkansas (M. E. Heitmeyer, pers. comm.) also may have influenced pintail distribution over time.

Radiotagged pintails relocating to the MAV were found in areas along the western edge of this region containing abundant rice agriculture (Fig. 5). Our finding that pintails relocated to areas with abundant rice is not surprising considering the high use of flooded rice fields by pintails in southwestern Louisiana (Cox and Afton 1997) and in other important wintering areas (Miller 1987; Migoya et al. 1994). Rice is an important food
of pintails wintering in California, accounting for up to 97% of their diet (Miller 1987). Although numbers of pintails wintering at Pabellón, Mexico, were positively correlated with rice availability (Migoya et al. 1994), rice comprised only 3% of the diet of hunter-killed pintails in that region (Migoya and Baldassarre 1993). A variety of moist-soil plants that produce seeds considered desirable to pintails also occur in rice fields (Hohman et al. 1996). A recent study (Manley 1999) of waterfowl food densities in rice fields in the MAV indicates that rice-seed density is low by early winter, and that invertebrates and moist-soil seeds may comprise a considerable proportion of overall biomass of potential waterfowl foods in these habitats. Because of the coarse resolution of our high-altitude aerial locations, further research is needed to document the extent to which pintails in the mid- to upper MAV actually use rice agriculture, and the dietary importance of rice and other foods to pintails in these habitats.

Comparison of Site-Selection at Various Scales

In much the same way that large numbers of pintails in North America routinely occur in the same broad wintering regions each winter, large numbers of pintails in our study routinely moved from the Gulf Coast Region to the MAV each winter. Marked seasonality in long-term precipitation patterns (i.e., dry in October vs. wet in December and January) coincides with apparent pintail overflights of the MAV to the Gulf Coast during early fall, and northward movements to the MAV later in winter when conditions are wetter and shallowly flooded agricultural habitats are more abundant. Female pintails, particularly adults, captured and radiotagged in southwestern Louisiana during October predictably relocated to the MAV each winter. However, we found that specific timing of interregional movements varied among winters with respect to calendar date, but typically was associated with disturbance from duck-hunting seasons and stormy weath-
er. Consequently, timing of movements appears to be influenced by much the same factors that influence use of particular sites on a local scale, primarily wetland availability and disturbance from hunting. We conclude that destination of interregional movements by this population of pintails is highly predictable, and that initiation of such movements is influenced by female age and long-term winter precipitation patterns in the MAV. Furthermore, timing of these movements is predictable, based not on calendar date, but rather on duck-hunting seasons and, usually, the environmental cues to habitat availability provided by stormy weather.

Management Recommendations

Our results indicate that the "wintering area" for pintails found in southwestern Louisiana during October extends primarily from the southwestern Louisiana Gulf Coast Region to the upper-MAV in northeastern Arkansas. Consequently, winter habitat management for pintails in the Mississippi Flyway should be planned and coordinated on a broad scale and integrated between the Gulf Coast and Lower Mississippi Valley Joint Ventures of the North American Waterfowl Management Plan (USFWS and CWS 1986). Moreover, our results indicate that waterfowl habitat management in the MAV will be increasingly important to pintails in the future.

We found that pintails radiotagged in southwestern Louisiana rarely moved longitudinally along the Gulf Coast or to the Rice Prairie Region of Texas, despite considerable numbers of pintails in these nearby areas. For example, peak numbers of pintails at Atchafalaya Delta, located only 55 km east of our primary study area, averaged 35,424 (range = 18,691-64,856) during winters 1988-1989 through 1994-1995 (R. G. Linscombe, Louisiana Department of Wildlife and Fisheries, New Iberia, unpubl. aerial survey data), yet only one of 152 radiotagged female pintails moved to this area during our study. Thus, our results are consistent with Hestbeck's (1993) conclusion, based on analyses of winter bandings, that pintails winter in distinct populations. However, our results are unique in that pintails wintering in close proximity (southwestern Louisiana vs. Atchafalaya and Mississippi River deltas and Gulf Coast and Rice Prairie Regions of Texas) apparently are highly segregated. The frequency, timing, and destinations of interregional movements by pintails wintering in these nearby areas are unknown. Consequently, we recommend that movements of pintails be studied elsewhere along the Gulf Coast and in the Rice Prairie Region, and that future management plans consider distinctiveness of various wintering populations of pintails.

Acknowledgments

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