DISTRIBUTION AND MOVEMENTS OF FEMALE NORTHERN PINTAILS RADIOTAGGED IN SAN JOAQUIN VALLEY, CALIFORNIA

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Abstract: To improve understanding of northern pintail (*Anas acuta*) distribution in central California (CCA), we radiotagged 191 Hatch-Year (HY) and 228 After-Hatch-Year (AHY) female northern pintails during late August–early October, 1991–1993, in the San Joaquin Valley (SJV) and studied their movements through March each year. Nearly all (94.3%) wintered in CCA, but 5.7% went to southern California, Mexico, or unknown areas; all that went south left before hunting season. Of the 395 radiotagged pintails that wintered in CCA, 83% flew from the SJV north to other CCA areas (i.e., Sacramento Valley [SACV], Sacramento–San Joaquin River Delta [Delta], Suisun Marsh, San Francisco Bay) during September–January; most went during December. Movements coincided with start of hunting seasons and were related to pintail age, mass, capture location, study year, and weather. Among pintails with less than average mass, AHY individuals tended to leave the SJV earlier than HY individuals. Weekly distribution was similar among capture locations and years but a greater percentage of pintails radiotagged in Tulare Basin (south part of SJV) were known to have (10.3% vs. 0.9%) or probably (13.8% vs. 4.6%) wintered south of CCA than pintails radiotagged in northern SJV areas (i.e., Grassland Ecological Area [EA] and Mendota Wildlife Area [WA]). Also, a greater percentage of SJV pintails went to other CCA areas before hunting season in the drought year of 1991–1992 than later years (10% vs. 3–5%). The percent of radiotagged pintails from Grassland EA known to have gone south of CCA also was greater during 1991–1992 than later years (2% vs. 0%), but both the known (19% vs. 4%) and probable (23% vs. 12%) percent from Tulare Basin that went south was greatest during 1993–1994, when availability of flooded fields there was lowest. The probability of pintails leaving the SJV was 57% (95% CI = 8–127%) greater on days with than without rain, and more movements per bird out of SJV occurred in years with more rain and fog but fewer days with southerly winds. Movements by pintails and changes in pintail distributions, direct recovery distributions, and harvest rates suggest the disproportionate decline of pintails in Tulare Basin was due to a lower percentage of pintails moving there in fall and a greater percentage or earlier movements north and south out of Tulare Basin. With fewer in Tulare Basin to replace Grasslands EA pintails going north in December, pintail abundance in the northern SJV declined during late winter. Changes in movement patterns correspond to habitat loss in Tulare Basin and increased habitats in SACV and western mainland Mexico. Habitat improvements, especially in Tulare Basin, that increase food, sanctuary, and winter survival would probably help restore pintails throughout the SJV.

JOURNAL OF WILDLIFE MANAGEMENT 66(1):138–152

Key words: *Anas acuta*, California, Central Valley, distribution, movements, northern pintail, radiotelemetry, San Joaquin Valley.

Understanding the distribution and movements of northern pintails in the Central Valley of California, USA, and other CCA areas (Fig. 1) during winter is important for the effective management of this species. Despite loss of over 90% of Central Valley wetlands since the turn of the 20th century, about half of the pintails in North America winter there (Bellrose 1980, U.S. Fish and Wildlife Service [USFWS] 1978), arriving as early as the first week of August and remaining through March. Because of its importance to pintails and other waterfowl, the Central Valley is a priority area of the North American Waterfowl Management Plan (USFWS and Canadian Wildlife Service 1986). The Central Valley Habitat Joint Venture (CVHJV) will affect activities on 385,000 ha of wetlands and agricultural lands in the Central Valley at a capital cost of more than US$528 million and an annual cost of about US$38 million when fully implemented (CVHJV Implementation Plan 1990). Planning and managing waterfowl habitat programs such as the CVHJV requires knowledge of pintail-use patterns and how these patterns change as habitat conditions change (Williams et al. 1999). The range of wintering pintails must be delineated to manage their harvest and measure potential exposure to contaminants and disease.

Pintail breeding populations in North America were approximately 3–6 million during the 1960s,

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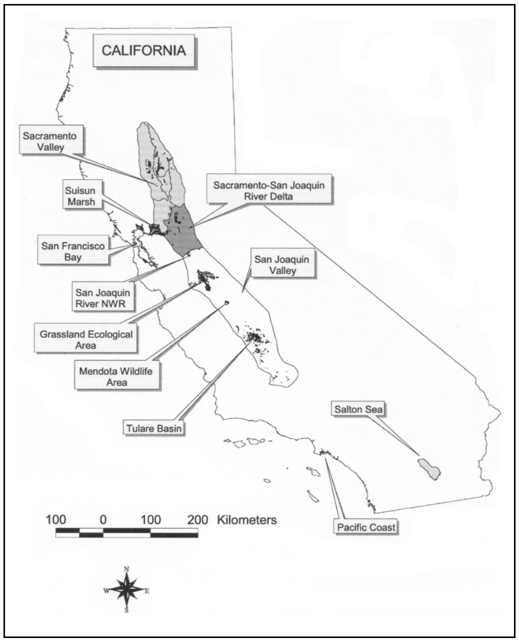

Fig. 1. Regions of California and areas within the San Joaquin Valley used by wintering northern pintails during 1991–1994. Central California includes the Central Valley (Sacramento Valley, Sacramento–San Joaquin River Delta, San Joaquin Valley), Suisun Marsh, and San Francisco Bay.

4–7 million during the 1970s, but declined from 4.5 to 2 million during the 1980s, and reached an all-time low of 1.8 million in the early 1990s (USFWS and Canadian Wildlife Service 1995). Midwinter populations in California (Pacific Flyway waterfowl reports and USFWS, Portland, Oregon, USA, unpublished data) followed similar trends, but the decline after the 1970s has been greater in the SJV (the southern part of the Central Valley) than in the SACV (the northern part of the Central Valley). For instance, the percentage of CCA pintails counted in the SJV in early January declined from 13% in the 1960s and 24% in the 1970s to 8% during 1980–1994 (Table 1; California Department of Fish and Game, Sacramento, and USFWS, Portland, Oregon, USA, unpublished data). Although incomplete coverage of the CCA during September–December surveys (Table 1) makes interpretation of early-winter distribution trends difficult, disproportionate declines in pintail abundance were apparent in the Tulare Basin throughout September–January, but only in January in the northern SJV (Fig. 2).

An understanding of individual pintail movements is needed to interpret surveys and identify factors affecting pintail distribution in CCA. Banding data provide some information on pintail movements, but differences in band recovery rates among areas and over time complicate interpretation. Also, banding data are inadequate to measure recent changes in distribution because few pintails have been banded since the 1970s (Hestbeck 1993). Pintails have been radiomarked in other California areas (Casazza 1995, Miller et al. 1995), but data for pintails from the SJV are lacking.

To obtain information important for pintail management, we radiotagged HY and AHY female pintails throughout the SJV, during late August–early October, a period of rapid influx of pintails from northern breeding areas (California Department of Fish and Game, Sacramento, and USFWS, Port-

Table 1. Percentage of Central California (CCA) northern pintails surveyed and harvested in San Joaquin Valley (SJV). CCA includes the SJV, Sacramento Valley (SACV), San Joaquin–Sacramento River Delta (Delta), Suisun Marsh, and San Francisco Bay.

	Percent of pintails surveyed in central California that occurred in the San Joaquin Valley[a]			
Period	Mid-Sep	Late Oct–early Nov	Late Dec–early Jan	Percent of CCA pintail harvest occurring in SJV[b]
1960s	<39[c]	<<20	13	33
1970s	<50	<30	24	32
1980s	<24	<<24	8	40
1991–1994	<<31	<<32	8	36

[a] Pacific Flyway reports and U.S. Fish and Wildlife Service, Portland, Oregon, USA, unpublished data.
[b] Carney et al. (1975, 1983) and U.S. Fish and Wildlife Service, Portland, Oregon, USA, unpublished data.
[c] Actual percentage of CCA pintails occurring in SJV at that time was somewhat (<) or much (<<) smaller than the percentage listed because surveys outside SJV were often incomplete. During mid-September, San Francisco Bay never surveyed, Delta not surveyed 5 years in 1980s or in 1991, and no SACV private areas surveyed in 1993. During late October–early November, San Francisco Bay never surveyed, Delta not surveyed in 1960s, and no or few SACV private lands surveyed in the 1980s or in 1991–1994.

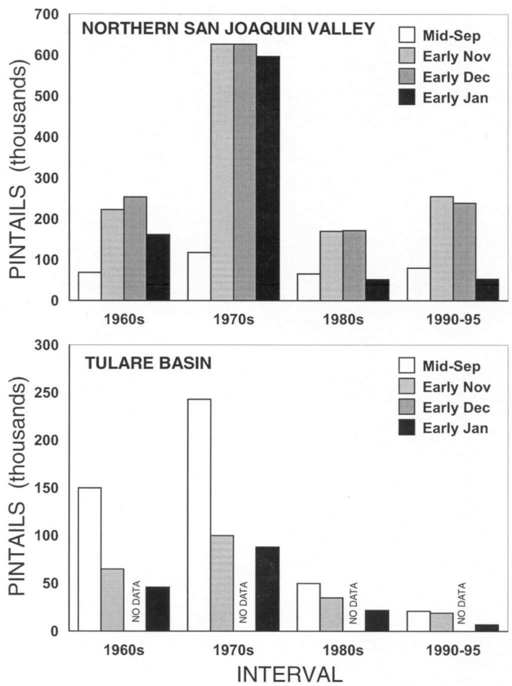

Fig. 2. Average abundance of northern pintails during mid-September, early November, early December, and early January in the northern San Joaquin Valley (includes Grassland Ecological Area and Mendota Wildlife Area) and Tulare Basin during the 1960s, 1970s, 1980s, and 1990–1995 (no Dec surveys in Tulare Basin; California Department of Fish and Game, Sacramento, USA, unpublished data).

land, Oregon, USA, unpublished data), and monitored their movements through March, 1991–1994. We radiotagged only females because they are especially important to population dynamics (Flint et al. 1998), and funding was adequate to study only 1 sex (sample sizes had to be sufficient for other study objectives [e.g., survival estimation]). We monitored pintail movements and compared results with earlier banding studies (Mclean 1950, Rienecker 1987) to determine (1) the proportion that moved to more northern and southern winter areas; (2) whether movements differed by pintail age, mass, or capture location or date; and (3) whether movement patterns differed among years and habitat conditions.

STUDY AREA

Our study area was comprised of 3 areas: (1) SJV, including the San Joaquin River National Wildlife Refuge (NWR), Grassland EA, Mendota WA, and Tulare Basin; (2) other CCA areas, including SACV, Delta, Suisun Marsh, and San Francisco Bay; and (3) areas north (i.e., northern California, Oregon, Washington, Nevada, Utah, Montana, Canada, Alaska) or south of CCA (i.e., southern California and southern states, Mexico; Fig. 1).

Southern Central Valley waterfowl habitat consisted primarily of shallow, seasonal wetlands in 3 distinct blocks (up to 23,313 ha in the Grassland EA; 2,762 ha in Mendota WA; and 2,946 ha in the Tulare Basin) that were separated by agricultural lands (Fleskes 1999). Except for ≤2,399 ha of barley–wheat, safflower, alfalfa, and cotton in the Tulare Basin that were harvested, disked, and flooded before the next planting, agricultural lands in the SJV were rarely flooded or used by waterfowl (Fleskes 1999). In contrast, the 20,000–27,000 ha of wetlands in the SACV were interspersed among 24,000–60,000 ha of rice fields flooded after harvest (CVHJV Technical Committee 1996) that provided a relatively contiguous block of waterfowl habitat. In the Delta, approximately 12,000 ha of grain fields that were flooded after harvest (CVHJV Technical Committee 1996) and 7,000 ha of wetlands (Heitmeyer et al. 1989) provided waterfowl habitat. Suisun Marsh provided 22,000 ha of brackish wetland habitat (Heitmeyer et al. 1989). Salt ponds, tidal and diked marsh, and open bay were available in the heavily industrialized and urbanized San Francisco Bay.

Most wetlands in the Central Valley were unflooded, but irrigated periodically during the summer to promote seed production and flooded during winter. Most initial flooding of wetlands and harvested croplands occurred during mid-August to late October. Water for irrigation, fall flood-up, and water-level maintenance was delivered from reservoirs that stored Sierra Mountain snowmelt. Thus, the timing and amount of early-winter habitat varied with the previous winter's snowfall. Late-winter rains flooded additional habitat each year. Study area habitats are described by USFWS (1978, 1979), Heitmeyer et al. (1989), Kadlec and Smith (1989), and Kramer and Migoya (1989).

Impacts of changing precipitation and water availability on habitat conditions varied within the SJV (Fleskes 1999). Habitat conditions in the Grassland EA were poor during 1991–1992 because 4 years of below-normal precipitation throughout California (California Department of Water Resources 1991; National Oceanic and Atmospheric Administration, Asheville, North Carolina, USA, unpublished data) prevented irrigation of private wetlands during May–July, delayed fall flood-up 2 weeks, and resulted in record low water deliveries to the Grassland

Water District (Grassland Water District, Los Banos, California, USA, unpublished data). Grassland EA wetland conditions improved after January 1992 because of above-average precipitation and higher water levels in reservoirs. Conditions in the Grassland EA were further improved during 1993–1994 when the Central Valley Project Improvement Act (Davis 1992) nearly doubled the amount of water delivered to the Grassland Water District (Grassland Water District, Los Banos, California, USA, unpublished data). Mean weekly seasonal marsh in the Grassland EA before hunting season (i.e., Prehunt) increased from 5,385 ha in 1991–1992, to 6,698 ha in 1992–1993, and 9,603 ha in 1993–1994 (Fleskes 1999).

Return of normal precipitation and reservoir levels also improved the availability of managed wetlands in the Tulare Basin during Prehunt from 490 ha during 1991–1992 and 1992–1993 to 1005 ha during 1993–1994 (Fleskes 1999). However, post-harvest flooding of agricultural fields during Prehunt declined during the study from 2,399 ha in 1991 to 1,802 ha in 1992 and 1,595 ha in 1993 (Fleskes 1999). Habitat availability in Mendota WA was similar among years because of more constant water supplies.

Duck hunting daily bag limits (4 ducks with 1 either-sex pintail) and season lengths (59 days) were identical throughout California during all years of the study (California Department of Fish and Game, Sacramento, USA, unpublished data). However, the timing of the hunting seasons differed among years and regions. The hunting season was a consecutive 59 days, starting in early to mid-November in the southern SJV zone (included Tulare Basin but not Mendota WA), and starting the second Saturday in October in the northeastern California zone. Elsewhere the season was split, with most areas (including the remainder-of-the-state zone, where almost all radiotagged pintails wintered) having a 22-day late-October to mid-November first season (Hunt1) and a 37-day second season (Hunt2) starting after a 12- (in 1991), 19- (in 1992) or 27- (in 1993) day closure (i.e., Split) of duck hunting after the end of the first season. In addition, nearly all duck clubs in the Grassland EA and WA and NWR in CCA allowed hunting only on Wednesdays, Saturdays, and Sundays (i.e., shoot days). Kern NWR allowed hunting on Wednesdays and Saturdays, and many Tulare Basin clubs adopted only Wednesdays and Saturdays as hunting days. Many clubs outside SJV allowed hunting all days of the season.

METHODS

Field Procedures

We radiomarked female pintails 29 August–6 October 1991, 31 August–5 October 1992, and 28 August–25 September 1993 in the Tulare Basin (n = 42 AHY, 20 HY), Mendota WA (n = 71 AHY, 47 HY), and Grassland EA (n = 115 AHY, 124 HY). Their movements were tracked throughout the wintering period (i.e., late Aug to late Mar). We radiotagged female pintails roughly in proportion to pintail abundance in the SJV as determined by September aerial surveys (G. Gerstenberg, California Department of Fish and Game, Los Banos, USA, unpublished data). We captured 4–275 ($\bar{x}$ = 76) pintails with each of 11–14 rocket-net (Schemnitz 1994) shots each year at rice-baited and unbaited sites on flooded agricultural fields in the Tulare Basin and in wetlands at Mendota WA and NWR, WA, and duck clubs in the Grassland EA. Age ratios were skewed heavily toward AHY in the captures, especially before late September. Thus, to radiotag pintails of both age classes during a similar period, we radiotagged all HY females that we captured until our annual goal was reached but released randomly selected AHY females without radios. Even so, mean radiotagging dates in 1991 and 1992 were about 2 weeks earlier for AHY (42 days before hunting season) than HY (27–28 days before hunting season) females because few or no HY pintails were captured until late September in those years due to poor or late production (USFWS and Canadian Wildlife Service 1991, 1992). In 1993, pintail production improved (USFWS and Canadian Wildlife Service 1993) and mean radiotagging dates were similar for AHY (35 days before hunting season opened) and HY (32 days before hunting season opened) females. We weighed (± 5 g), measured (flat wing, culmen 1, total tarsus [Dzubin and Cooch 1992] ± 0.01 mm), aged (HY or AHY; Larson and Taber 1980, Duncan 1985, Carney 1992) and legbanded some male and all female pintails that we captured. Pintails were released at the capture location from <1 to 19 ($\bar{x}$ = 7.7) hours after capture. We exclusively attached 20–21-g (2.0–3.2% of body mass) radiotransmitters with back-mounted harnesses (Dwyer 1972) in 1991 (n = 115) and 1992 (n = 123), but in 1993, we attached either harness (n = 98) or spear-suture transmitters (n = 83). Spear-suture transmitters were similar to that described by Pietz et al. (1995), except they were circular (20 mm diameter × 12 mm high) and weighed 8–9 g. Each transmitter had a unique signal, a mortality sensor, life expectancy ≥210 days, and an initial minimum range of 3.2 km ground-to-ground using a 150-db receiver and dual 4- element Yagi antennas mounted on the roof of a pickup truck. Transmitters were imprinted with contact information. We solicited information from hunters by posting project descriptions at hunting check stations and in statewide media.

We recorded status (location, alive, or dead) of each pintail 1–2 times a day during the hunting season and at least every other day during nonhunting intervals in SJV, and at least weekly in other CCA areas from the date of the first pintail capture until 20 March each year (202–205 days). We conducted aerial searches (Gilmer et al. 1981) of waterfowl habitat and urban areas for missing pintails weekly throughout CCA. We and cooperators searched other areas, including northeastern, coastal, and Salton Sea California; Malheur NWR area, Willamette and Klamath Basins in Oregon; the Carson sink in Nevada; and the western coast of Mexico, 1–10 times each winter for pintails not found in CCA. We censored (i.e., excluded data thereafter) pintails equipped with failing radios as evidenced by abnormal signals. Pintails that shed their radios were censored on the date their radios were shed. We excluded 14 of the 433 pintails that we radiotagged from analyses because they did not adjust to their radios, as evidenced by their failure to make feeding flights, and were killed by predators 1–6 days after marking.

Data Analysis

We estimated weekly distribution of pintails among SJV areas (i.e., Grassland EA, Mendota WA, Tulare Basin), other CCA areas (i.e., Delta–Suisun Marsh–San Francisco Bay [combined] and SACV), and areas north or south of CCA. To reduce bias associated with unequal and multiple sampling of individuals each week, we apportioned multiple weekly locations among areas and used a bird-week as the sample unit. For instance, if bird A was in SJV during Sunday–Wednesday but in other CCA areas during Thursday–Saturday, we apportioned 4/7 bird-weeks to SJV and 3/7 to other CCA areas that week. We grouped weekly totals into intervals (Prehunt, Hunt1, Split, Hunt2, Posthunt). We used 1 September, 30 August, or 29 August as the start of week 1 for 1991–1992, 1992–1993, or 1993–1994, respectively, to pool or compare weekly distribution across years.

We took 2 approaches in categorical modeling of repeated weekly measures to investigate the relationship of various factors to weekly distribution of radiotagged pintails among regions. The first was to use categorical modeling (Sauer and Williams 1989) by week and apply the Bonferroni adjustment to maintain $\alpha = 0.05$ when making multiple weekly comparisons (Johnson and Wichern 1982:197). The second was to use a generalized linear model (McCullagh and Nelder 1989) across weeks that accounts for correlation between repeated measures (Liang and Zeger 1986). By-week categorical modeling, implemented through PROC CATMOD (SAS Institute 1989), is suitable for comparing 2 or more response categories, but it can be cumbersome to summarize all by-week results. Generalized linear modeling (a form of logistic modeling) implemented through PROC GENMOD with a generalized estimating equations approach is suitable for describing overall effects across weeks but only between 2 response categories (SAS Institute 1997). We used PROC CATMOD (SAS Institute 1989) to compare (1) distribution each week among study years (1991–1992 vs. 1992–1993 vs. 1993–1994); (2) bird ages (HY vs. AHY); (3) bird capture locations (Grassland EA vs. other [Mendota WA and Tulare Basin]); (4) bird capture periods (<1 Sep vs. >17 Sep); (5) bird body mass at capture (above vs. below age-class mean); and (6) distribution of direct mortalities (i.e., recovered same winter as banded) of pintails we radiotagged in the SJV or Miller et al. (1995) radiotagged in SACV with direct recoveries of pintails banded earlier in the same areas (Mclean 1950, Rienecker 1987). We used PROC GENMOD to investigate effects of bird age and mass on distribution across weeks. We followed Dobson (1990:98) and Milliken (1984:990–999) to assess the importance of explanatory variables and interactions using a step-down model selection method. We conducted a nearest neighbor analysis (Rosing et al. 1998) and verified that each pintail we radiotagged moved independently even if captured under the same net (Fleskes 1999).

RESULTS

Distribution and Movements Among Regions

We estimate that 94.3% of the 419 female northern pintails that we radiotagged in the SJV wintered in CCA and 5.7% wintered south of CCA until migrating to northern breeding areas during late January–late March. We found 4 radiotagged pintails near Salton Sea, 4 along the coast of southern California, and 1 in western Mexico. We suspect that 15 birds that we lost at the same time as others that went south, wintered in parts of Mexico or in other southern areas that we did not search.

Of the 395 radiotagged pintails that wintered in CCA, 83% flew north to other CCA areas, mainly SACV and Delta, during September–January; most left the SJV during December (Fig. 3). Although 43% of the pintails that left revisited the SJV, visits averaged only 17 days and 40% were <7 days. No radiotagged pintail made regular daily or weekly flights between the SJV and other CCA areas, and none flew regularly between Grassland EA, Mendota WA, and Tulare Basin. Migration north out of CCA began in late January and peaked in early March, but 12–18% were still in CCA on 1 April (Fig. 3).

Pintail distribution during Prehunt was similar each year except that a greater ($\chi^2 = 6.82$, df = 2, $P < 0.05$) percentage of pintails moved north to other CCA areas (mainly SACV and Delta) during the dry 1991 Prehunt (10%) than during 1992 (5%) or 1993 (3%) (Fig. 3). Pintails marked at Mendota WA remained there during Prehunt, but 33% (1992–1993) to 50% (1991–1992 and 1993–1994) of those marked in Tulare Basin flew north to the Grassland EA or Mendota WA. All our pintails that wintered south of CCA left during Prehunt. Each year, 2 pintails with worn flight feathers went to northeastern California, the SACV, or Suisun Marsh, where they molted their flight feathers. By opening of Hunt1 in 1991, 20% of the radiotagged pintails were outside the SJV; in 1992 and 1993, only 7% were outside the SJV (Fig. 3).

Movements and distribution of pintails during Hunt1 also were similar each year. Approximately 95% of all pintails at Mendota WA flew to the Grassland EA on opening morning of Hunt1 each year. Most remaining there moved to the Grassland EA during the next few days and after opening of Hunt1, <10% of all radiotagged pintails were ever at Mendota WA (Fig. 3). As during Prehunt, the percentage of radiotagged pintails in Tulare Basin during Hunt1 declined (Fig. 3) as pintails there continued to move to the Grassland EA. However, in 1993–1994, some returned, and the percentage of radiotagged pintails in Tulare Basin increased (Fig. 3). During Hunt1 in 1991 and 1993, about 2–3 radiotagged pintails per week moved from the Grassland EA to the SACV; during 1992, the same number left but more abruptly during the last week of the interval. By the end of Hunt1 in 1991, 23% of the radiotagged pintails were outside the SJV, mostly in the SACV; in 1992 and 1993, 17% were outside the SJV (Fig. 3).

During the 13-day Split in 1991, pintails continued to leave the Grassland EA for the SACV, so that by the end of the interval, 31% were outside the SJV (Fig. 3). Few pintails moved among regions during the 20-day Split in 1992, and at the end of Split in 1992, 22% were outside the SJV. During the 27-day Split in 1993, the gradual exodus of pintails from the Grassland EA to the SACV continued, so that by the end of the interval, 26% were outside the SJV.

Movements to the Delta and SACV increased during Hunt2 each year, so that when hunting season closed, 77–83% were outside the SJV (Fig. 3). Mass (>10% of birds present) northerly movements began 6–11 December each year on shoot days during fog or storms. For instance, on Wednesday, 11 December 1991, the first morning of the winter with dense fog, 33% of radiotagged pintails in the Grassland EA flew to the Delta and SACV. During the later 2 years, mass northerly movements first began during opening weekend of Hunt2 during winter storms.

Distribution was similar among years during Posthunt, and few birds moved between regions until spring migration (Fig. 3). Each year, several pintails from the Delta and SACV returned to and remained in the SJV. On 1 April, when we stopped tracking in CCA in 1992 and 1993, 12% and 18%, respectively, of the pintails were still in CCA; 36% of the pintails were still in CCA on 17 March 1994 when we stopped tracking in CCA that year. Radiotagged pintails were located during February–May in northeastern California (n = 34), Nevada (n = 1), Utah (n = 1), Montana (n = 2), Idaho (n = 1), Alberta (n = 3), Oregon (n = 5), Washington (n = 4), British Columbia (n = 9), and Alaska (n = 4).

Factors Related to Regional Movements

Movements were related to pintail age, body mass, and capture location; study year; and weather. There was no significant difference ($\chi^2 \leq 9.41$, df = 2, Bonferroni $P > 0.05$) in weekly distribution among SJV, other CCA areas, and areas outside CCA, for AHY pintails captured in the Grassland EA during August versus after 17 September.

Distribution of AHY and HY pintails among the SJV, other CCA areas, and areas outside CCA dif-

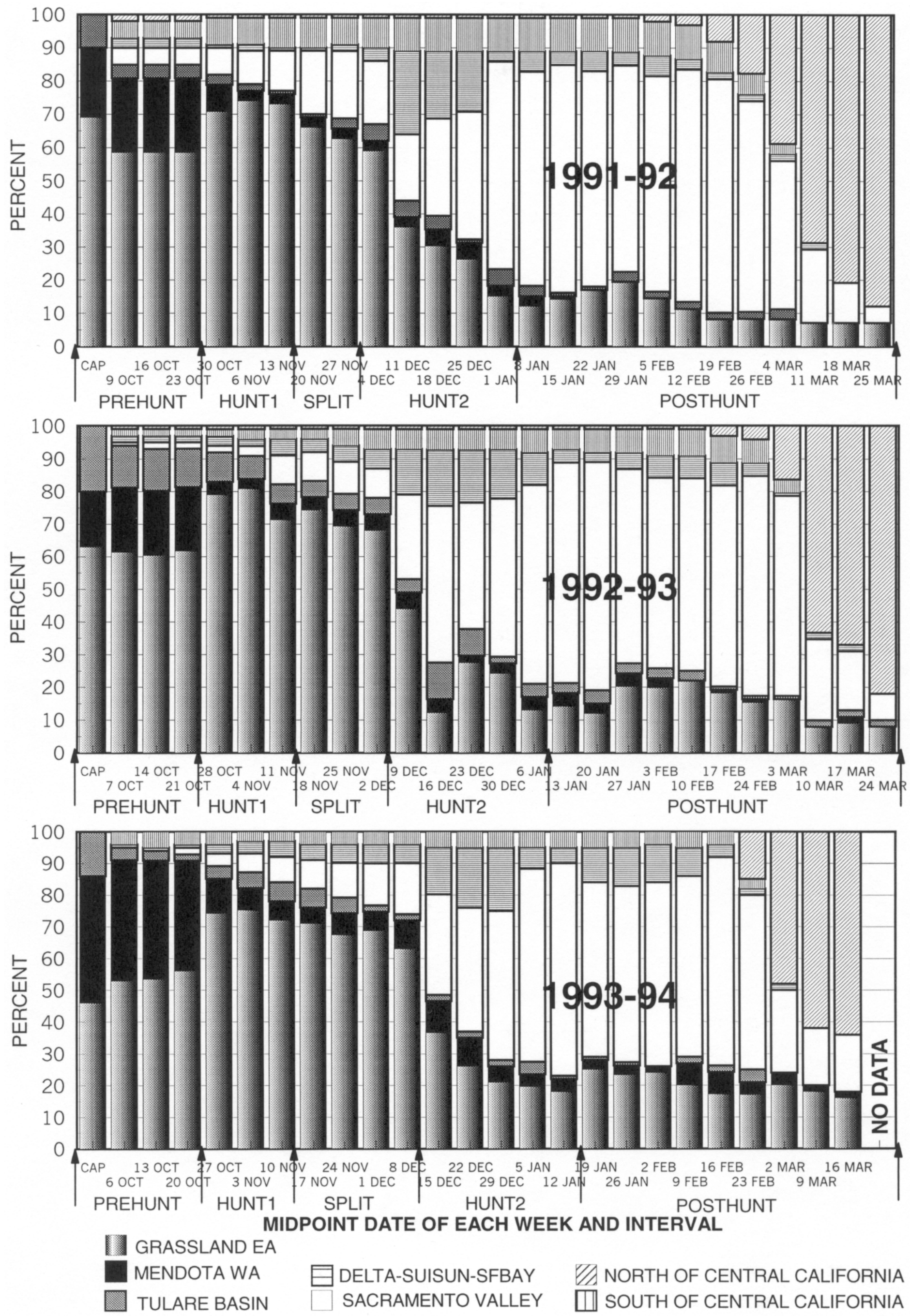

Fig. 3. Percent of live radiotagged female northern pintails present each week in the Grassland Ecological Area (EA), Mendota Wildlife Area (WA), Tulare Basin, Delta–Suisun Marsh–San Francisco Bay [combined in order of pintail use], Sacramento Valley, and areas north or south of central California, during October–April, 1991–1994. Intervals shown are for the hunting zone encompassing all central California areas except Tulare Basin. Wetland condition and availability in the Grassland EA were poor in 1991–1992 due to continued drought and low water supplies, but improved thereafter. In Tulare Basin, flooding of harvested fields, the major habitat there, peaked in 1991–1992 and declined thereafter. Elsewhere in central California, water supplies and habitat conditions were more constant. Pintails (115 in 1991, 123 in 1992, and 181 in 1993) were radiotagged during 28 August–6 October in the Grassland EA, Mendota WA, and Tulare Basin. Starting distribution of radiotagged sample is shown in the CAP (i.e., capture) column, with distribution during weeks 6–30 listed by each week's midpoint date each year.

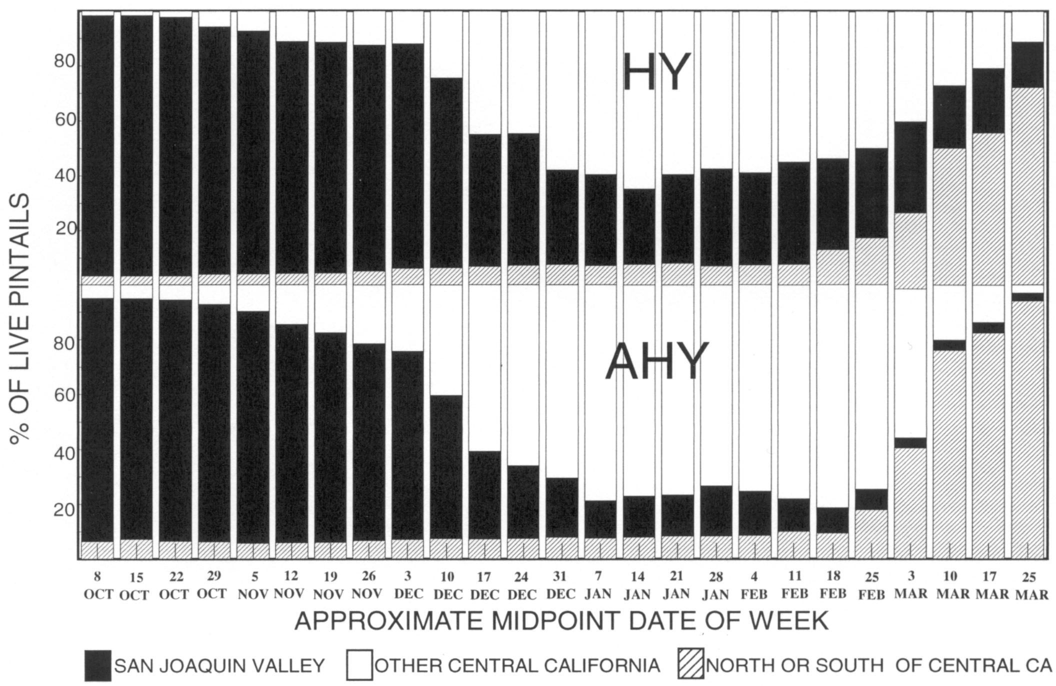

Fig. 4. Percent of live radiotagged Hatch-Year (HY) and After-Hatch-Year (AHY) female northern pintails present each week during October–March, 1991–1994, in the San Joaquin Valley, other central California areas (i.e., Sacramento Valley, Delta, Suisun Marsh, San Francisco Bay), and areas north or south of central California. A total of 191 HY and 228 AHY pintails were radiotagged 28 August–6 October in the San Joaquin Valley. Approximate midpoint date listed for weeks 6–30; capture period (weeks 1–5) not shown.

fered significantly ($\chi^2 \geq 13.13$, df = 2, Bonferroni $P < 0.05$) during weeks 17, 19, and 24–30, reflecting the lower percentage of HY females moving to other CCA areas in late December and areas north of CCA in spring, respectively (Fig. 4). Percent of both AHY and HY pintails in the SJV decreased as winter progressed, but the weekly decrease in probability of being in the SJV was greater ($Z = 2.83$, $P = 0.0046$) for AHY (23.9%, 95% CI = 20.7–26.9%) than HY (17.3%, 95% CI = 14.0–20.5%) pintails; 51% of HY but only 38% of AHY pintails that left, revisited the SJV ($\chi^2 = 2.97$, df = 1, $P = 0.085$).

After-Hatch-Year pintails tended to leave the SJV earlier than HY pintails (mean departure = 2 Dec vs. 19 Dec), but the age effect varied with capture body mass ($F = 3.77$, df = 1, $P = 0.05$). The mean departure date (27 Nov) for AHY pintails lighter than average was significantly earlier ($t = 2.58$, df = 230, $P = 0.01$) than for lightweight HY pintails (26 Dec), whereas mean departure dates of heavy birds did not differ significantly ($t = 0.41$, df = 230, $P = 0.68$) for AHY (8 Dec) and HY (12 Dec) pintails. Distribution of pintails heavier or lighter than average among SJV, other CCA areas, and areas outside CCA did not differ during any week ($\chi^2 \leq 8.32$, df = 2, Bonferroni $P > 0.05$). Likewise, averaged across weeks, the percent of heavy and light pintails that left the SJV did not differ significantly ($Z = 0.61$, $P = 0.54$).

Distribution among the SJV, other CCA areas, and areas outside CCA did not differ for pintails captured in the Grassland EA, Mendota WA, or Tulare Basin during any week ($\chi^2 \leq 13.02$, df = 4, Bonferroni $P > 0.05$). Also, averaged across weeks, the proportion from each capture site remaining in the SJV was similar ($Z = 0.51$, $P = 0.61$). However, the proportion of pintails from each capture site that are known to have ($\chi^2 = 13.06$, df = 2, $P = 0.002$) or probably ($\chi^2 = 7.95$, df = 2, $P = 0.019$) wintered south of CCA differed by capture location and was greater for pintails captured in the Tulare Basin than for pintails captured at Mendota WA or Grassland EA (Table 2). Further, capture location interacted with bird mass ($F = 4.42$, 1, df = 230, $P = 0.037$): heavy pin-

Table 2. Percentage of female northern pintails radiotagged in the Grassland Ecological Area (EA), Mendota Wildlife Area (WA), and Tulare Basin known to have (i.e., minimum [Min]) or probably (Prob) wintered south of the San Joaquin Valley (SJV), California, USA, 1991–1994.

Area where pintail was radiotagged	1991–1992			1992–1993			1993–1994			All years		
	Min[a]	Prob[b]	n[c]	Min	Prob	n	Min	Prob	n	Min	Prob	n
Grassland EA	2.6	6.5	77	0.0	3.9	76	0.0	2.4	83	0.8	4.2	236
Mendota WA	0.0	8.7	23	4.8	9.5	21	0.0	2.9	69	0.9	5.3	113
Tulare Basin	0.0	12.5	8	4.2	4.2	24	19.2	23.1	26	10.3	13.8	58
All areas	1.9	7.4	108	1.7	5.0	121	2.8	5.6	178	2.2	5.9	407

[a] Minimum percent that wintered south of SJV. Includes only those found south of SJV.
[b] Probable percent that wintered south of SJV. Includes those found south of SJV and those with no indication of impending radio failure that became missing during the same time that pintails found south of the SJV left the SJV.
[c] Sample size excludes 7 pintails in 1991–1992, 2 in 1992–1993, and 3 in 1993–1994 that died or had transmitters that failed before outcome could be determined.

tails captured in the Tulare Basin and Mendota WA tended to leave the SJV earlier than lightweight birds (mean departure = 9 Dec vs. 24 Dec), whereas heavy pintails captured in the Grassland EA left the SJV later than lightweight birds (13 Dec vs. 1 Dec).

Averaged across weeks, the percent leaving the SJV during winter was similar among years ($Z \leq 1.21$, $P \geq 0.22$). However, pintail distribution among the SJV, other CCA areas, and areas outside CCA differed ($\chi^2 > 15.15$, df = 4, Bonferroni $P < 0.05$) among years during week 15 and 27 (Fig. 3), reflecting slight differences in timing of movement to the SACV in December and northern breeding areas in March, respectively. Also, the minimum ($\chi^2 = 4.01$, df = 1, $P = 0.045$) and probable ($\chi^2 = 3.42$, df = 1, $P = 0.064$) percent of pintails radiotagged in the Tulare Basin that went south was greater in 1993–1994 than in earlier years (Table 2). The minimum ($\chi^2 = 4.16$, df = 1, $P = 0.04$) percent from the Grassland EA that went south was greater in 1991–1992 than later years but the probable percent trend, although similar, was not significant ($\chi^2 = 1.23$, df = 1, $P = 0.23$). The percent that left Mendota did not vary greatly among years (Table 2).

Slight differences among years in timing of pintail movements may have resulted from weather differences. The probability of leaving the SJV was 57% (95% CI = 8–127%) greater ($Z = 2.44$, $P = 0.015$) on days with rain than without rain, and years with more rain days had more flights per bird out of the SJV ($Z = 5.11$, $P < 0.001$). The probability of leaving the SJV on days with dense, light, or no fog did not differ significantly ($Z < 1.82$, $P > 0.07$), but years with more fog days had more flights per bird out of the SJV ($Z = 4.95$, $P < 0.001$). Likewise, the probability of leaving the SJV on days with northerly, southerly, or light–no winds did not differ significantly ($Z \leq 1.22$, $P \geq 0.15$); in 1992–1993 ($Z = 3.63$, $P < 0.001$) and 1993–1994 ($Z = 2.13$, $P = 0.03$), movements per bird out of the SJV were negatively associated with the number of days with southerly wind.

Distribution of Direct Recoveries

The percentage of direct recoveries of female pintails marked before hunting in the Grassland EA from outside the SJV during 1991–1994 was less ($\chi^2 = 15.0$, df = 1, $P < 0.001$) than during 1948–1962 (Rienecker 1987), but the percentage of direct recoveries of female pintails marked in Tulare Basin from outside the SJV was greater ($\chi^2 = 8.7$, df = 1, $P = 0.003$) during 1991–1994 than during 1939–1943 (Mclean 1950; Table 3). Only 1 of 13 (7.7%) deaths of female pintails radiotagged in the Tulare Basin during 1991–1994, but 45.3% of the direct recoveries ($n = 236$) of pintails banded in Tulare Basin during 1939–1945 (Mclean 1950) occurred in the Tulare Basin ($\chi^2 = 6.49$, df = 1, $P = 0.01$). No earlier banding data are available from Mendota WA. The percentage of direct recoveries of adult female pintails banded before hunting season in the SACV during 1949–1979 that were from the SJV (Rienecker 1987) did not differ significantly ($\chi^2 = 0.3$, df = 1, $P = 0.6$) from the percentage of adult female pintails radiotagged before hunting season in the SACV during 1987–1990 that died in the SJV (Miller et al. 1995; Table 3).

Table 3. Distribution of radiotagged female northern pintail deaths vs. direct recoveries of females banded earlier in the same area. Central California includes Sacramento Valley (SACV), San Joaquin–Sacramento River Delta, San Francisco Bay, Suisun Marsh, and San Joaquin Valley (includes Grassland Ecological Area [EA] and Tulare Basin).

	Area and period where pintails were radiotagged or banded					
	Grassland EA		Tulare Basin		Sacramento Valley	
Area where radiotagged pintail died or banded pintail was recovered	1991–1994[a] (*n* = 56)	1948–1962[b] (*n* = 461)	1991–1994[a] (*n* = 13)	1939–1943[c] (*n* = 236)	1987–1990[d] (*n* = 17)	1949–1979[e] (*n* = 191)
San Joaquin Valley	80.4%[f]	51.4%	46.2%	82.6%	5.9%	10.5%
Other central California	19.6%	39.7%	38.5%	15.7%	94.1%	88%
Non-central California	0	8.9%	15.4%	1.7%	0	1.5%

[a] This study, radiotagged females of both age classes.
[b] Rienecker (1987), banded females of both age classes.
[c] Mclean (1950), banded females, ages not reported but probably both.
[d] Miller et al. (1995), radiotagged adult females.
[e] Rienecker (1987), banded adult females.
[f] Distribution of deaths–recoveries differed among periods for Grassland EA and Tulare Basin (χ^2 > 10.9, df = 2, P < 0.004) but not SACV (χ^2 = 0.8, df = 2, P = 0.8) pintails.

DISCUSSION

Factors Affecting Pintail Movements during 1991–1994

Pintail movements patterns were fairly consistent during 1991–1994 but were related to weather; study year; and pintail age, body mass, and capture location. Numerous causal factors are possible for the patterns we observed, but differences in food and sanctuary availability among years and areas appeared to be important.

Food Availability.—The consistent timing of movements by pintails and their increased odds of leaving the SJV on rainy days suggests that food depletion may be 1 reason pintails leave the SJV during winter. Refuging theory predicts that as food resources become depleted, feeding-flight distances will increase until a critical distance is reached, at which time birds either switch roost sites (if available) or leave the area (Hamilton and Watt 1970). The mass exodus of pintails from Grassland EA in December each year (Fig. 3) coincided with a shift of roost sites, the peak in nonshoot day-to-night flight distances, and an increase in use of duck clubs farthest from sanctuaries (Fleskes 1999). Also, at the start of Posthunt, pintails dispersed into areas that had received low use during the hunting season (Fleskes 1999), indicating that food was depleted in heavy-use areas. Pintails may use rain as a proximate cue of increased food availability outside their normal daily range (Jeske et al. 1995, Cox and Afton 2000). Our observation of increased probability of pintails leaving the SJV on rainy days and <43% returning even briefly, suggests food availability in SJV was low relative to other CCA areas.

Annual variation in pintail movements corresponded to changing habitat conditions and also indicates that food supplies were an important factor. Water deliveries for wetland irrigation and flooding in the Grassland EA were lowest on record during 1991 (Grassland Water District, Los Banos, California, USA, unpublished data). The portion of our radiotagged pintails that went north during Prehunt to the less arid SACV, where better-established water rights (Gilmer et al. 1982, Heitmeyer et al. 1989) apparently maintained better habitat conditions, was 200–300% of later, more normal water delivery years. Likewise, the percentage of pintails from Tulare Basin that went south was greatest in 1993–1994, when availability of flooded agriculture, the preferred habitat in Tulare Basin (Fleskes 1999), was lowest. During dry years in the SACV, lipid content of pintails declined between February and March (Miller 1986). However, during dry years in Tulare Basin, the decline began earlier (in Sep) and averaged 7% per 100 days through March (Euliss et al. 1997).

Sanctuary Availability.—Disturbance from hunting and other causes can have major impacts on pintail distribution at a local scale (Wolder 1993, Fleskes 1999); our data suggest differences in availability of sanctuary from disturbance also affect regional distribution and favor larger populations of pintails in SACV. Most pintails left Mendota WA during opening weekend of Hunt1, and the start of mass pintail movements from the Grassland EA coincided with the opening of Hunt2 during 2 years. Jeske et al. (1995) also reported that pintail movements coincided with hunting and precipitation. Cox and Afton (2000) reported that pintails were more likely to leave during hunting than nonhunting seasons, regardless of weather. Pintails are highly mobile and can move far when disturbed. About 25% of managed wetland habitat in the SACV is sanctuary compared to 5–6% in the SJV (CVHJV Technical Committee 1996). This lower availability of sanctuary in the SJV than in the SACV may be another reason, along with lower food supplies, why only 43% of the pintails that left the SJV returned only briefly.

Changes in Pintail Movements

Movement patterns of the pintails we studied and changes in direct recovery distributions provide insight into how pintail movement patterns have changed since the 1970s and led to the disproportionate pintail decline throughout winter in Tulare Basin but only during late winter in the northern SJV. Although the decrease between 1949–1979 and 1987–1990 in the percentage of direct recoveries of SACV pintails in the SJV was not statistically significant (Table 3: 10.5% vs. 5.9%), the magnitude of the decrease was probably greater because pintail harvest rates in the SJV increased relative to other CCA areas (Table 1: e.g., 32% of the harvest and 24% of the population in the SJV during the 1970s vs. 40% of the harvest and 8% of the population in the SJV during the 1980s). Thus, a better measure of the decrease of SACV pintails going to the SJV is that only 2.9% of the use-days of adult female pintails radiotagged in the SACV during 1987–1990 occurred in the SJV (Miller et al. 1995) compared with 10.5% of the direct recoveries during 1949–1979 (Table 3). Likewise, although temporal variation in recovery probability outside CCA (e.g., Mexico) is not known, both percentage of direct band recoveries (15.4%, Table 3) and percentage wintering south from Tulare Basin (13.8%, Table 2) in 1991–1994 were much greater than the percentage of Tulare Basin direct band recoveries during 1939–1943 from outside CCA (1.7%, Table 3), indicating that movement south from Tulare Basin has increased or occurs earlier. Thus, the disproportionate decline since the 1970s in early-winter abundance of pintails in Tulare Basin (Fig. 2 and Barnum and Euliss 1991) probably is due to a combination of reduced percentage of pintails moving to Tulare Basin from more northern areas (e.g., SACV) and increased or earlier movements of Tulare Basin pintails to more southern wintering areas. Most pintails that we radiotagged in Tulare Basin moved to the northern SJV during September–November. The increase between 1939–1942 and 1991–1994 in percentage of direct recoveries of Tulare Basin pintails in more northern CCA areas (i.e., 15.7% vs. 38.5%, Table 3) and increased pintail harvest rates in the SJV relative to other CCA areas (Table 1) suggests that either a higher percentage now go north from Tulare Basin or they leave earlier. Direct recoveries of pintails banded in the Grassland EA during 1948–1962 (Rienecker 1987) show that the northerly movement of pintails from the SJV to other CCA areas during winter that we observed is also a long-term pattern (Table 3). With 83% of pintails observed going to other CCA areas during September–January, 1991–1994, the decrease between 1948–1962 and 1991–1994 in the percentage of direct recoveries of Grassland EA pintails in CCA areas outside the SJV (Table 3) was probably because pintail harvest rates in the SJV increased relative to other CCA areas (Table 1) rather than reduced or later movements of pintails out of the SJV. Surveys show that the magnitude of the decline in pintail abundance between early December and early January in the northern SJV was inversely related to the abundance of pintails in Tulare Basin (Fig. 2). Thus, we speculate that during the 1960s and 1970s, pintail abundance in the northern SJV was maintained throughout the winter, at least partially, by pintails from Tulare Basin. However, during the 1980s and 1990–1995, few pintails from Tulare Basin were available to replace those that left the Grassland EA, resulting in low pintail abundance after December in northern SJV.

Factors Related to Changes in Pintail Movements

Numerous factors probably have affected long-term changes in pintail distribution. However, landscape changes corresponding to shifts in pintail distribution suggest that changes in habitat distribution that impacted food and sanctuary availability, survival, and age ratios probably have been important.

Changes in Habitat Distribution.—Changes in pintail distribution correspond to increased flooding of harvested rice fields in SACV starting in the 1980s (CVHJV Technical Committee 1996, Elphick and Oring 1998) and freshwater habitats along the west coast of mainland Mexico during the 1950s to 1980s (Kramer and Migoya 1989), suggesting these areas now provide food and sanctuary for pintails displaced from SJV due to reduced wetland and agricultural flooding in Tulare Basin (Houghten et al. 1985, Barnum and Euliss 1991) and other SJV areas. Drought conditions in the Central Valley during 1987–1991 (California Department of Water Resources 1991; National Oceanic and Atmospheric Administration, Asheville, North Carolina, USA, unpublished data) probably exacerbated impacts of changing habitat distribution by increasing movement of SJV pintails south and shifting wintering populations to the less arid SACV, where better-established water rights (Gilmer et al. 1982, Heitmeyer et al. 1989) maintained better habitat conditions. Habitats in northern SJV apparently have remained more attractive to pintails, at least during early winter (Fig. 2).

Differential Survival.—Habitat conditions influence pintail distribution not only by affecting food and sanctuary availability but also by influencing survival. Female pintails show high fidelity to specific California wintering areas (Rienecker 1987) where overharvest can depress long-term viability of local populations (Hestbeck 1993). Hunting mortality of female pintails in SJV was greater than in SACV during 1991–1994 (Fleskes 1999). Comparisons of harvest and abundance indicate that higher pintail harvest rates in SJV than in other CCA areas have occurred long-term and as pintail abundance declined this difference increased (Table 1). Long-term lower survival for SJV pintails relative to SACV pintails (Fleskes 1999) may have contributed to the greater decline of pintails in the SJV.

Impact of Poor Recruitment.—Poor pintail recruitment after the 1970s (Miller and Duncan 1999) may also have contributed to the greater decline of pintails in the SJV during late winter. Hatch-Year pintails tended to stay longer in the SJV than AHY pintails, and in years of poor recruitment, HY females make up a smaller portion of the wintering population. The effect of wintering population age ratios may vary with habitat conditions. We found weak evidence that lightweight AHY females left the SJV earlier than heavy AHY females, whereas the reverse was true for HY females. Cox and Afton (2000) also reported that AHY females were more likely (1.9 times) than HY females to make long range northerly movements during winter to rice fields but did not find any difference by capture condition. Jeske et al. (1995) reported no apparent age differences in movement patterns. Rienecker's (1987) band recoveries show the age effect varied by marking area.

Sampled Early-Arriving Females Only

Limitations of our data should be considered when applying our results. Our telemetry data and banding data from earlier studies measured movements of female pintails that were present in SJV during late August–October. However, we have no measure of how changing conditions may have affected the number of pintails that used the SJV when habitat conditions were good but overflew or stopped too briefly in the SJV to be sampled when conditions there were poor. We speculate that trends for these pintails would be similar to trends for pintails we sampled, but winter movements of pintails marked on northern breeding or staging areas have not been studied. For instance, the additional pintails that moved south in the drought year of 1991 from the Grassland EA based on our data (e.g., 6.5% – 2.4% × ~100,000 = 4,100; Table 2, Fig. 2) was only a small percentage of the increase observed along the west coast of mainland Mexico in 1991 (i.e., 24% vs. 1975–1995 average of 18% [range = 11–24%, SE = 1.4%] of pintails in Pacific Flyway states and west coast of Mexico; USFWS, Portland, Oregon, USA, unpublished data); normal wintering areas for these pintails are unknown. Also, although our marking interval was as long (Rienecker et al. 1987, Cox and Afton 2000) or longer than other studies (Casazza 1995, Miller et al. 1995), and during the period of high influx of pintails into the SJV, movement patterns for later-arriving females may vary. Males are more likely than females to be recovered outside their banding area (Mclean 1950, Rienecker 1987), and impacts of changing conditions may differ by sex.

MANAGEMENT IMPLICATIONS

Pintail distribution has changed in the past in response to habitat changes (Michney 1979, Heitmeyer et al. 1989). This study shows that the process is ongoing. Management programs should maintain pintail abundance throughout their range. A wide distribution of pintails will minimize the risk of catastrophic disease loss and provide incentive for waterfowl hunting clubs to maintain shallow, open habitats that support pintails, shorebirds, and many other species. The greater decline in abundance of pintails wintering in the SJV seems due to a combination of factors, including improved habitat conditions elsewhere, loss of habitat in Tulare Basin, higher disturbance, lower survival, and other factors such as greater impact of drought in the SJV. Improvements that increase the carrying capacity of SJV habitats and winter survival of pintails in the SJV would likely increase SJV pintail populations. Adequate water supplies during early fall are essential to maintain SJV populations. Restoration of Tulare Basin habitats is crucial to restore pintails throughout the SJV, including the Grassland EA during late winter.

Providing adequate contaminant-free habitat in the SJV is important to minimize the risk of contaminant exposure to consumers of waterfowl throughout California. The California Department of Health Services has issued a health warning advising limited consumption of waterfowl harvested in the Grassland EA because of elevated selenium levels. Although similar warnings are absent for other Central Valley regions (California Department of Fish and Game, Sacramento, USA, unpublished data), most pintails from the Grassland EA go to other CCA areas during the hunting season. Neglect of SJV habitats could have wide-ranging impacts.

Changing agricultural and other land-use practices are continually modifying the landscape of central California, 1 of the most important waterfowl wintering areas in the world. Critical waterfowl habitat in central California is managed by a myriad of public and private interests with primary goals that sometimes diverge. The challenge to waterfowl managers is to know how waterfowl respond to habitat changes within this dynamic and complex system so that their management efforts provide the maximum benefit both for the waterfowl resource and those who enjoy it.

ACKNOWLEDGMENTS

Numerous individuals and organizations contributed to this study. C. Meslow, J. Moore, C. Pereira, and W. B. Shephard provided guidance and advice that improved all aspects. San Luis and Kern NWR, and Gray Lodge, Mendota, and Los Banos WA provided housing, habitat information, and logistical support. S. Bergerman (Mendota WA), D. Garrison (San Luis NWR), and Grassland Water District staff mapped vegetation and flooding and helped gain landowner cooperation. The Natural Resources Conservation Service provided Tulare Basin crop data. C. Kohorst, K. Lee, and G. Martinelli entered habitat data. W. Perry and J. Daugherty provided GIS support. Clear Lake and Stillbow duck clubs and Tulare Basin landowners permitted access to trap pintails. Numerous landowners allowed access to track and recover radiotagged pintails. Numerous hunters provided information about pintails they recovered. Veterinarians J. C. Franson and L. N. Locke of the National Wildlife Health Research Center conducted bird necropsies. M. Carriere of Busch Agriculture donated rice, and R. Dunston, D. Orthmeyer, and K. Mazacco helped trap pintails. L. Belt, D. Breneman, D. Buford, M. Chouinard, Jr., C. Davis, M. Humpert, P. Johnston, J. Laffitte, C. Stemler, and K. Young trapped and tracked pintails during 1 or more field seasons. California Department of Fish and Game donated aerial search costs, and D. Orthmeyer, D. Yparraguirre, S. Blankenship, M. R. Miller, M. Casazza, B. Parkin, B. Conant, J. McKay, D. Mauser, S. Boyd, W. Radke, W. Henry, R. Lowe, G. Ivey, and R. Migoya searched for radiotagged pintails throughout the Pacific Flyway. W. Newton and J. Yee provided statistical advice.

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Received 21 December 2000.
Accepted 12 June 2001.
Associate Editor: Block.