SEPTEMBER–MARCH SURVIVAL OF FEMALE NORTHERN PINTAILS RADIOTAGGED IN SAN JOAQUIN VALLEY, CALIFORNIA

JOSEPH P. FLESKES,[1] U.S. Geological Survey, Biological Resources Division, Western Ecological Research Center, 6924 Tremont Road, Dixon, CA 95620, USA
ROBERT L. JARVIS, Department of Fish and Wildlife, 104 Nash Hall, Oregon State University, Corvallis, OR 97331, USA
DAVID S. GILMER, U.S. Geological Survey, Biological Resources Division, Western Ecological Research Center, 6924 Tremont Road, Dixon, CA 95620, USA

Abstract: To improve understanding of pintail ecology, we radiotagged 191 hatch-year (HY) and 228 after-hatch-year (AHY) female northern pintails (*Anas acuta*) in the San Joaquin Valley (SJV), and studied their survival throughout central California, USA, during September–March, 1991–1994. We used adjusted Akaike Information Criterion (AIC_c) values to contrast known-fate models and examine variation in survival rates relative to year, interval, wintering region (SJV, other central California), pintail age, body mass at capture, capture date, capture area, and radio type. The best-fitting model included only interval × year and age × body mass; the next 2 best-fitting models also included wintering region and capture date. Hunting caused 83% of the mortalities we observed, and survival was consistently lower during hunting than nonhunting intervals. Nonhunting and hunting mortality during early winter was highest during the 1991–1992 drought year. Early-winter survival improved during the study along with habitat conditions in the Grassland Ecological Area (EA), where most radiotagged pintails spent early winter. Survival was more closely related to body mass at capture for HY than AHY pintails, even after accounting for the later arrival (based on capture date) of HY pintails, suggesting HY pintails are less adept at improving their condition. Thus, productivity estimates based on harvest age ratios may be biased if relative vulnerability of HY and AHY pintails is assumed to be constant because fall body condition of pintails may vary greatly among years. Cumulative winter survival was 75.6% (95% CI = 68.3% to 81.7%) for AHY and 65.4% (56.7% to 73.1%) for HY female pintails. Daily odds of survival in the cotton–agriculture landscape of the SJV were –21.3% (–40.3% to +3.7%) lower than in the rice–agriculture landscape of the Sacramento Valley (SACV) and other central California areas. Higher hunting mortality may be 1 reason pintails have declined more in SJV than in SACV.

JOURNAL OF WILDLIFE MANAGEMENT 66(3):901–911

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

Northern pintails (hereafter pintails) have been the most abundant duck in the Pacific Flyway (U.S. Fish and Wildlife Service [USFWS] 1978) and the most important duck to California hunters (Gilmer et al. 1989). On average, about half of the pintails in North America migrate to and winter in central California (USFWS 1978, Bellrose 1980), arriving as early as the first week of August and remaining through March.

Pintail breeding populations in North America reached all-time lows in the early 1990s (USFWS and Canadian Wildlife Service [CWS] 1995) and midwinter pintail populations in California are still only about 25% of those recorded in the 1970s (Pacific Flyway Waterfowl Reports and USFWS, Portland, Oregon, USA, unpublished data). The decline of pintails has been especially prevalent during late winter in the SJV, the southern part of central California (Fig. 1). For instance, during central California surveys in the 1970s, about 50% of pintails counted in mid-September and 24% of the pintails counted in early January occurred in the SJV. However, during the 1980s, the SJV accounted for only 24% of central California pintails in mid-September and 8% in early January (California Department of Fish and Game [CDFG], Sacramento, and USFWS, Portland, Oregon, USA, unpublished data).

Most data indicate that low recruitment because of persistent drought and poor nest success are the main reasons for the decline of continental pintail populations (Miller and Duncan 1999). However, because pintails (especially females) exhibit high fidelity to some wintering grounds (Rienecker 1987*a*, Hestbeck 1993*a*), high mortality during winter also may depress long-term viability of local populations (Hestbeck 1993*a*). Past increases in Pacific Flyway pintail populations were associated with high annual survival rates for females (Hestbeck 1993*b*), and models of pintail population dynamics in Alaska were most sensitive to variation in female survival (Flint et al. 1998). Thus, female mortality, both on breeding and wintering areas, may be a key determinant of population trends. Data on the

[1] E-mail: joe_fleskes@usgs.gov

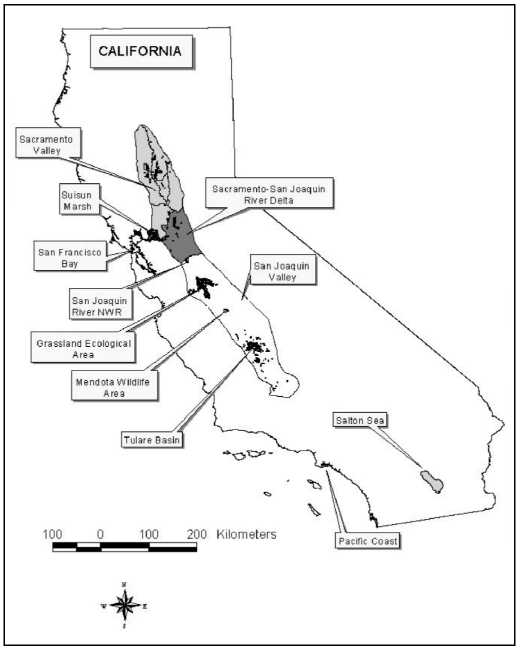

Fig. 1. Regions of California and areas within the San Joaquin Valley used by northern pintails during Sep–Mar, 1991–1994.

magnitude, timing, and causes of female pintail mortality during winter are needed to effectively manage continental pintail populations (USFWS and CWS 1986, Reynolds et al. 1995).

Miller et al. (1995) radiotagged pintails in the SACV, the northern part of central California (Fig. 1), and studied their survival during winter, 1987–1990. Overwinter survival of AHY females during that study was high (88%; Miller et al. 1995). However, HY females were not studied, and little was learned about survival in the SJV because few SACV pintails visited the SJV.

To obtain information important for management of pintails, we radiotagged HY and AHY female pintails throughout the SJV after their late-summer arrival, and monitored their survival throughout central California during winter, 1991–1994. We identified causes, location, and timing of female pintail mortalities and examined variation in survival rates in central California relative to year, interval, wintering region, pintail age, body mass, capture date, capture area, and radio type.

STUDY AREA

We studied pintail survival in the SJV (includes the San Joaquin River National Wildlife Refuge [NWR], Grassland EA, Mendota Wildlife Area [WA], and Tulare Basin) and other central California areas (composed of SACV, Sacramento–San Joaquin River Delta [Delta], Suisun Marsh, and San Francisco Bay [Fig. 1; USFWS 1978]).

San Joaquin 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), which 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 (USFWS 1979).

Most wetlands in the Central Valley were not flooded, but were 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. Rains during late winter flooded additional habitat each year.

Habitat conditions improved during the study due to increased precipitation and water availability (Fleskes 1999). Habitat conditions were poor during 1991–1992 because of 4 years of below-normal precipitation throughout California (California Department of Water Resources 1991; National Climatic Data Center, Asheville, North Carolina, USA, unpublished data). The impact of drought was most severe in the SJV, with record-low water deliveries to the Grassland Water District in 1991–1992 that prevented irrigation of private wetlands during May–July and delayed fall flood-up 2 weeks (Grassland Water District, Los Banos, California, USA, unpublished data). 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 (Fleskes 1999) 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 availability in the Grassland EA before hunting season (i.e., Prehunt) increased from 5,385 ha in 1991, to 6,698 ha in 1992, and 9,603 ha in 1993 (Fleskes 1999).

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 (CDFG, Sacramento, California, USA, unpublished data). However, the timing of the hunting seasons differed among years and regions. The hunting season was 59 consecutive days, starting in early to mid-November in the southern SJV zone (includes 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 balance 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 wildlife areas and national wildlife refuges in central California allowed hunting only on Wednesdays, Saturdays, and Sundays. 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) roughly in proportion to pintail abundance in the SJV as determined by September aerial surveys (G. Gerstenberg, CDFG, Los Banos, California, 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 national wildlife refuges, wildlife areas, and duck clubs in the Grassland EA. Female age ratios were skewed heavily toward AHY in the captures, with only 11.4%, 19.5%, and 37.1% HY before 26 September, and 27.6%, 22.2%, and 37.1% HY overall in 1991, 1992, and 1993, respectively. 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 attached 20- to 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 that 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, dead) of each pintail 1–2 times a day during the hunting season and at least every other day during non-hunting intervals in SJV, and at least once a week (for most at least every other day) in other central

California areas, from the date of the first pintail capture until the end of March each year (approx. 215 days). We conducted aerial searches (Gilmer et al. 1981) of waterfowl habitat and urban areas for missing pintails weekly throughout central California. With cooperators, we also 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 west coast of Mexico, 1–10 times each winter for pintails not found in central California. We censored (i.e., excluded data thereafter) pintails that left central California and any equipped with failing radios as evidenced by abnormal signals. Pintails that shed radios were censored on the date their radios were shed. We excluded 14 of the 433 pintails 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. We determined the timing and cause of death by site and carcass evidence and a review of the bird's movements (Fleskes 1999). We also recorded deaths reported by hunters and others.

Data Analysis

We conducted known fate modeling using program MARK (White and Burnham 1999) to examine variation in female pintail daily survival in central California relative to year (1991–1992, 1992–1993, 1993–1994), interval (Prehunt, Hunt1, Split, Hunt2, Posthunt), pintail wintering region (SJV, other central California), pintail age (HY, AHY), body mass at capture (standardized by age class), capture date (days before start of Hunt1), capture area (Grassland EA, Mendota WA, Tulare Basin) and radio type (harness, spear-suture). We used AIC_c values (Akaike 1985, Burnham and Anderson 1992) to compare support for 80 candidate models, including models with only single main effects, combinations of main effects without interactions, main effects with individual 2-way interactions, models with interval × year and age × body mass plus 1 other 2-way interaction, and other candidate models. We estimated survival using the best-fitting model and effects of covariates for models within 2 units of AIC_c of the best-fitting model (Burnham and Anderson 1992). For modeling the effect of wintering region, we treated birds as censored when they left a region of interest and as captured when they entered a region of interest. We estimated change in daily odds of survival (with 95% confidence intervals) for important model factors directly in program MARK (White and Burnham 1999), by manipulating the design matrix if necessary and transforming Beta values. We computed hunting and nonhunting mortality rates by considering natural or hunting mortalities, respectively, as censored observations (Conroy et al. 1989).

RESULTS

Causes, Location, and Timing of Pintail Mortalities

Of the 419 pintails that we successfully radiotagged, 101 died during the winter in which they were radiotagged. However, 7 of those were censored because of failing radios before being reported shot (in the SJV), and 2 were censored when they left central California before being shot near Salton Sea. Thus, we estimated survival from 92 deaths among the 419 radiotagged pintails.

Hunting was the major cause of death (76/92 = 83%); 7 were killed by avian predators, 1 died with several unmarked pintails from a collision with a power line during a late December period of dense fog, and 8 died from other nonhunting causes (4 avian cholera, 1 aspergillosis [*Aspergillus* sp.], 3 undetermined disease or poison). Of the 76 pintails shot in central California with functioning transmitters, 61 were shot in the SJV, 11 in the SACV, 2 in the Delta, and 1 each in Suisun Marsh and San Francisco Bay. All predator kills occurred in the SJV, with all but 1 being killed during Prehunt and 4 of 7 on private lands. All disease deaths occurred after late December with 5 of 8 dying in the SACV and all but 1 on private lands.

Factors Related to Pintail Survival in Central California

Interval × year and age × body mass were the only factors present in the best model (Table 1) and were present in the best-fitting 13 models of the 80 we contrasted. Early-winter (i.e., before Hunt2) survival was lowest during the 1991–1992 drought year because of higher nonhunting and hunting mortality but survival increased during the 3-year study (Table 2). Survival was consistently lower during hunting than nonhunting intervals because of hunting mortality. Daily odds of survival for an average-mass AHY female pintail were 28.3% (95% CI = 3.9% to 58.4%) greater than for an average-mass HY female pintail. Cumulative winter survival was 75.6% (68.3% to 81.7%) for AHY, 65.4% (56.7% to 73.1%) for HY, and 71.9% (66.3% to 77.0%) for females, overall. Daily odds of survival increased 35.9% (3.0% to

Table 1. Akaike Information Criterion (AIC_c) values, adjusted for small sample size, for the 3 best-fitting models and others selected to display covariate importance on survival of female northern pintails in central California, USA, Sep–Mar, 1991–1994.

Model	AIC_c weight	ΔAIC_c
(1) year × interval, age × mass	0.419	0
(2) year × interval, age × mass, capture date, age × winter region	0.198	1.5
(3) year × interval, age × mass, capture date, winter region	0.170	1.8
(4) year × interval, age × mass, capture area	0.108	2.7
(5) year × interval, age × mass, capture date	0.038	4.8
(6) year × interval, age × mass, winter region	0.036	4.9
(7) year × interval, age × mass, age × winter region	0.015	6.6
(8) year × interval, age × mass, radio type	0.008	7.9
(9) year × interval, age	0.005	8.6
(10) year × interval	0.001	12.0
(11) year × interval, mass	0	13.5
(12) interval, age	0	17.4
(13) year, interval, age	0	19.2
(14) year, interval, age, mass, winter region, capture date	0	19.9
(15) year, interval, age, mass, winter region, capture date × mass	0	20.8
(16) year, interval, age, mass, winter region, capture date × age	0	21.9
(17) age	0	106.7

79.3%) for HY females with each additional gram of body mass at capture. The relationship of capture mass and survival of AHY females was less consistent (–18.4%, –40.1% to +11.1%).

In addition to interval × year and age × body mass, wintering region (with or without an interaction with age) and capture date were present in the 2 other models with AIC_c values <2 units higher than the best model (Table 1). Early capture date improved survival regardless of the body mass or age of pintails (model 14 vs. 15, 16; Table 1). Averaged across intervals and years, the daily odds of survival in SJV for an average-mass HY were –26.7% (–49.8% to +7.2%) lower, and for an average-mass AHY were –15.7% (–41.5% to +21.5%) lower than the odds of survival in other central California areas. In SJV, daily odds of survival for an average-mass AHY were 20.1% (–8.6% to +59.4%) greater than for an average-mass HY. Elsewhere in central California, the daily odds of survival for an average-mass AHY were only 4.4% (–34.5% to +66.4%) greater than for HY. Survival increased 14.6% from –12.1% to +49.5% for each additional day before hunting the bird was captured. Capture area (model 4 vs. 1) and radio type (model 8 vs. 1) were not closely related to survival of female pintails in central California (Table 1).

DISCUSSION

Geographic Variation in Hunting Mortality

Pintails radiotagged in the SJV survived winter at rates (HY = 0.654, SE = 0.042; AHY = 0.756, SE = 0.034) similar to pintails radiotagged in Suisun Marsh (HY = 0.625, SE = 0.045; AHY = 0.775, SE =

Table 2. Survival with 95% CI, and hunting (Hmort) and nonhunting (NHmort) mortality rates of female northern pintails radiotagged in San Joaquin Valley and wintering in central California, USA. Intervals based on “balance of state” hunting regulations.

Winter	Interval	Days	Survival	95% CI Lower	95% CI Upper	Hmort	NHmort
1991–1992	Prehunt	58	0.957	0.873	0.986	0.000	0.047
	Hunt1	22	0.794	0.695	0.864	0.201	0.000
	Split	13	0.986	0.904	0.998	0.000	0.015
	Hunt2	37	0.938	0.843	0.976	0.060	0.000
	Posthunt	85	1.000	0.999	1.000	0.000	0.000
	Overall	215	0.693	0.583	0.785	0.249	0.076
1992–1993	Prehunt	54	0.977	0.910	0.994	0.000	0.024
	Hunt1	22	0.879	0.804	0.927	0.120	0.000
	Split	20	0.990	0.932	0.999	0.000	0.010
	Hunt2	37	0.869	0.780	0.924	0.109	0.023
	Posthunt	80	0.962	0.856	0.990	0.000	0.039
	Overall	213	0.710	0.614	0.790	0.216	0.094
1993–1994	Prehunt	56	1.000	0.999	1.000	0.000	0.000
	Hunt1	22	0.904	0.847	0.941	0.095	0.000
	Split	27	1.000	0.999	1.000	0.000	0.000
	Hunt2	37	0.874	0.792	0.925	0.115	0.011
	Posthunt	74	0.908	0.773	0.965	0.000	0.095
	Overall	216	0.721	0.619	0.804	0.199	0.101

0.062; M. R. Miller, U.S. Geological Survey, personal communication), slightly higher than pintails radiotagged in Louisiana (HY = 0.550, SE = 0.068; AHY = 0.714, SE = 0.045; Cox et al. 1998) but lower than pintails radiotagged in the SACV (AHY = 0.874, SE = 0.03; Miller et al. 1995) and Sinaloa, Mexico (HY and AHY = 0.91, SE = 0.02; Migoya and Baldassarre 1995). Further, daily odds of survival were greater for pintails in this study after they moved to other central California areas (mainly SACV; Fleskes 2002). Survival varied among these areas mainly because hunting mortality varied; nonhunting mortality was low in all areas (Migoya and Baldassarre 1995, Miller et al. 1995, Cox et al. 1998).

Our observation of higher hunting mortality in the SJV than elsewhere in central California is consistent with other data. Rienecker's (1987*b*) banding data show higher ($P \leq 0.007$) direct recovery rates for HY and AHY female pintails banded during 1950–1961 in the Grassland EA than for those banded during 1949–1963 in the SACV. Also, comparisons of regional abundance and harvest of pintails show that the portion of the central California pintail harvest that occurred in the SJV was greater than the portion of the central California pintail population that occurred there (e.g., during 1991–1994, 36% of central California harvest but only 8% of central California midwinter population occurring in SJV; see Fleskes 1999). Hestbeck (1993*b*) found no geographic variation in annual survival rates of female pintails banded post-season but grouped all of central California when comparing survival rates between Louisiana and other areas; he did not compare them to survival rates of pintails in Mexico.

Differences in pintail hunting mortality among central California regions were probably due to differences in the amount of sanctuary, types of feeding habitats, waterfowl populations, and hunter pressure. About 25% of wetland habitat on wildlife areas and national wildlife refuges in the SACV was closed to waterfowl hunting compared to only about 6% of wetland habitat on wildlife areas and national wildlife refuges in the northern SJV (CVHJV Technical Committee 1996). Pintail habitat in the Grassland EA during much of the hunting season was almost exclusively seasonal wetlands provided by duck clubs, national wildlife refuges, or wildlife areas managed specifically for waterfowl and hunting (Fleskes 1999). In contrast, crop fields that were flooded mainly to promote straw decomposition (Elphick 1998) or weed control (Casazza 1995) were available in the SACV and Delta. Some of these flooded fields were not regularly hunted and provided sanctuary. Also, pintails may have had an easier time fulfilling their energetic requirements and avoiding hunters in the SACV, where they could feed on rice, than in northern SJV, where only wetlands were available. Invertebrates make up a larger portion of the diet of pintails during winter in the SJV (Beam and Gruenhagen 1980, Connelly and Chesemore 1980, Euliss 1984) than in the SACV (Miller 1987), and although invertebrates have similar metabolizable energy per gram as rice (see Miller 1987), the time and effort required to gather the same amount of energy probably is much greater for invertebrates than rice (Miller 1985, Paulus 1988). Other waterfowl, especially species preferred by hunters (e.g., mallards [*Anas platyrhynchos*]), are less abundant in the SJV than in the SACV (Pacific Flyway Waterfowl Reports and USFWS, Portland, Oregon, USA, unpublished data), which may also increase the relative harvest pressure on SJV pintails. Migoya and Baldassarre (1995) theorized that the large habitat area and low numbers of hunters in Sinaloa resulted in light hunter pressure relative to California and Louisiana. Our data suggest that hunting pressure also varies within California. Hunting pressure was high in Louisiana, and like in the SJV, HY females were much more likely than AHY females to be shot (Cox et al. 1998). Hunting pressure was low in Mexico, and like in the SACV, differences in survival of AHY and HY pintails were small (Migoya and Baldassarre 1995).

Pintail Age, Arrival Condition, and Date

Like others reporting a direct relation between body condition and survival (Greenwood et al. 1986, Hepp et al. 1986, Reinecke and Shaiffer 1988, Conroy et al. 1989, Dufour et al. 1993, Heitmeyer et al. 1993), we speculate that pintails in poor condition had reduced survival because they were more focused on feeding rather than avoiding hunters and predators, more attracted to decoys they perceived as ducks feeding in preferred sites, and at greater risk to disease. We theorize fall body condition was more closely related to survival of HY than AHY because HY condition changed less before hunting started. Based on capture date, most HY pintails in the SJV arrived on the wintering grounds later than AHY pintails and had less time to improve their condition before being exposed to hunters. Also, age ×

body mass was important even after accounting for capture date, suggesting that HY pintails may be less adept than AHY pintails at finding or competing for resources. Further, the direct relation we observed between capture date and survival, even after accounting for age and body mass differences, suggests that early arrival in a region may allow pintails to acquire local information (e.g., sanctuary and hunter locations) that improves their chance of survival. Cox et al. (1998) found no relationship between survival and fall body condition for either HY or AHY female pintails and theorized fall body condition may not adequately reflect later status. However, pintails that Cox et al. (1998) studied fed primarily in rice fields which may allow for more rapid improvement in body condition.

Nonhunting Mortality

Nonhunting mortality of female pintails that we observed was similar to other reports in California. Avian predators killed 1.7% of the pintails we radiotagged, similar to 2.1%–3.6% loss to predators in other central California areas (Miller et al. 1993, 1995). We agree with Miller et al. (1995), who theorized that depredation was highest during Prehunt because of increasing pintail abundance on limited wetlands. Avian cholera, unknown in California until 1944 but with almost annual winter epizootics since (Botzler 1991), killed 1% (1.4% if unspecified disease losses were cholera) of the female pintails we radiotagged. This level of disease mortality was identical to female pintails radiotagged in SACV (Miller et al. 1995) and Suisun Marsh (Miller et al. 1993). Estimates of avian cholera losses calculated by extrapolating numbers of carcasses picked up, ranged from 0.2% to 2.0% of the wintering duck population in California (see Botzler 1991) and 4.5% for midcontinent mallards (Samuel 1992).

Are Our Survival Estimates Representative of Central California?

Our estimates of survival are representative of most female pintails that started winter in SJV, but because most pintails wintering in central California do not start winter in SJV and survival varies among central California regions, our estimates do not represent average pintail survival in central California. We radiotagged pintails in SJV during the period that most arrived there (Pacific Flyway Waterfowl Reports and USFWS, Portland, Oregon, USA, unpublished data). Pintail abundance in other central California areas peaks later than in SJV (Dec vs. Oct–Nov; Pacific Flyway Waterfowl Reports and USFWS, Portland, Oregon, USA, unpublished data) and pintails we radiotagged moved to other central California areas throughout September–December (Fleskes 2002). Thus, our sample does provide a valid measure of relative odds of survival in the 2 central California regions (i.e., –21.3% [–40.3% to 3.7%] lower in SJV than other central California areas). However, <32% of the pintails in central California during early winter were in SJV (Pacific Flyway Waterfowl Reports and USFWS, Portland, Oregon, USA, unpublished data), so our estimate of early-winter and overall survival for central California is overweighted for SJV pintails. Survival of pintails starting winter in Suisun Marsh (M. R. Miller, U.S. Geological Survey, personal communication) was similar, but survival of pintails starting winter in SACV was higher (Miller et al. 1995) than in SJV. Thus, early-winter survival for an average female pintail in central California probably was higher than what we estimated. Average pintail survival in central California could be estimated by weighting survival estimates for pintails starting winter in each region by the portion of central California pintails present there at the start of winter. However, although survival of the many pintails that migrate directly from northern areas to SACV during October–December is probably similar to SJV pintails that moved there during the same period, actual rates are unknown.

Most data indicate that female northern pintail winter survival rates based on our radiotagged sample are not severely biased. Calculations dividing mean annual survival estimates by our winter survival estimates produce biologically reasonable estimates of female pintail survival during the nonwintering period (1 Apr–29 Aug). For instance, a mean spring–summer survival estimate of 0.80 for both HY (range = 0.63 to 0.98) and AHY (range = 0.67 to 0.86) female pintails results from using annual survival estimates from 1950 to 1961 preseason banding in the SJV (Rienecker 1987*b*), 1970–1990 preseason banding in northern Alberta–Northwest Territories, southwestern Alberta, southwestern Saskatchewan, northern California, High Plains and Missouri River Basin (i.e., unweighted mean of breeding areas 2, 3, 4, 10, 12, and 13; F. A. Johnson, USFWS, personal communication), 1952–1956 postseason banding in the SJV (Rienecker 1987*b*), and 1957–1978 postseason banding in central California (Hestbeck 1993*a*). Our estimate is similar to the spring–summer survival estimate of 0.75 for AHY female pintails wintering in the SACV (Miller et al. 1995). Other estimates of spring–summer survival for female pintails are lacking (Carlson et al. 1993), but most for female mallards are similar to our estimates for pintails and also range widely (0.574 to 0.914; Johnson and Sargeant 1977, Cowardin et al. 1985, Kirby and Cowardin 1986, Reynolds et al. 1995). Although body mass dynamics (Miller 1986) of some pintails may have been altered by radiotagging (Fleskes 1999), the flight and social status of radiotagged pintails appeared normal (Fleskes 1999). Further, the regional differences in survival we observed are consistent with banding data (Rienecker 1987*b*).

MANAGEMENT IMPLICATIONS

The decline in abundance of pintails wintering in the SJV is obviously related to poor habitat conditions compared with other wintering areas in the Central Valley. About 90% of the estimated 4 to 5 million acres of wetlands originally present in the Central Valley have been lost (USFWS 1978, Gilmer et al. 1982). This loss has been especially detrimental to waterfowl in SJV, where wetlands primarily have been converted into cotton fields or other crops that have little value to waterfowl. In contrast, rice and corn fields that have replaced many SACV and Delta wetlands are heavily used by waterfowl (Miller et al. 1993, 1995; Elphick 1998). Recent water-conserving preirrigation practices in the Tulare Basin have further lowered the value of SJV agricultural lands to waterfowl (Houghten et al. 1985, Barnum and Euliss 1991), and agricultural drain water contaminated with trace elements and heavy metals (e.g., selenium) has degraded some SJV wetlands (Ohlendorf et al. 1986, Barnum and Gilmer 1988). The loss and degradation of SJV habitat coupled with high harvest rates appear to have altered pintail distribution (Fleskes 2002) and reduced winter survival below that of pintails elsewhere in the Central Valley.

Female pintails exhibit high wintering fidelity to central California (Hestbeck 1993*a*) and SJV (e.g., 36% of indirect recoveries from pintails banded preseason and 50% of indirect recoveries from pintails banded postseason in SJV were from SJV; Rienecker 1987*a*). Thus, habitat improvements in SJV that increase the carrying capacity and winter survival of pintails would likely increase SJV pintail populations. Pintail survival would likely be enhanced by increasing the amount of flooded agricultural lands in the SJV to disperse wintering birds and provide refuge from hunting pressure.

Pintail survival was higher in the SACV landscape that included an abundance of winter-flooded rice fields than in the cotton–agriculture SJV landscape. The main differences between these regions is the amount of agricultural habitat and refuge available to pintails. Both could be increased by providing incentives to flood rice and other SJV grain fields currently being left dry. Some of these fields could be left unhunted, with long-term easements provided to maintain the benefit. Conversely, recent expansion of cotton agriculture into SACV will likely be detrimental to pintails if it reduces rice agriculture.

Adequate early-winter habitat is important to improve survival of female pintails in the SJV, especially for HY birds in drought years. Early-winter survival improved during this study along with early-winter habitat conditions in the Grassland EA (where most of the pintails we radiotagged resided). Hatch-year female pintails in poor condition were especially vulnerable to hunting. Poor condition of HY females and high early-season mortality occurred during a year when drought delayed nesting on the breeding grounds (USFWS and CWS 1991) and delayed and reduced water deliveries on the wintering grounds (Grassland Water District, Los Banos, California, unpublished data). This implies that if pintail production is delayed or drought conditions prevail on the breeding or wintering grounds, special efforts should be made to improve habitat conditions during August–October to promote weight gain of HY pintails. Delaying the opening date of hunting also may reduce hunting mortality by allowing more time for birds to improve their condition, but not if poor habitat conditions prevent weight gain.

Our finding of a stronger relationship between fall body condition and harvest vulnerability of HY than AHY pintails should be considered if age ratios of harvested pintails are used as indices of recruitment. If relative vulnerability of AHY and HY pintails to harvest is assumed to be constant among years, our finding indicates recruitment indices based upon harvest age ratios would overstate production in years that HY pintails arrive in poor body condition on wintering areas (e.g., drought years and years of late production) and understate production when HY pintails arrive in good condition on wintering areas.

The SJV once provided a vast area of prime wintering habitat for pintails (Johnson et al. 1993) and still represents about half the wintering range of pintails in California. Pintails are highly mobile, and a significant proportion of the population could be exposed to hazardous elements (e.g., selenium; Ohlendorf et al. 1986) if the quality of SJV habitats is not maintained. Restriction of range could increase crowding and probability of catastrophic disease losses. Thus, although pintail survival is lower in the SJV than SACV, continued management of the entire central California wintering range is important to maintain a healthy pintail population.

ACKNOWLEDGMENTS

Numerous individuals and organizations contributed to the success of this study. C. Meslow, J. Moore, C. Pereira, and W. B. Shephard provided guidance and advice that improved all aspects of this project. We thank the staffs of San Luis NWR, Kern NWR, Gray Lodge WA, Mendota WA, and Los Banos WA for providing housing, habitat information, and logistical support. S. Bergerman mapped vegetation and weekly flooding at Mendota WA. D. Garrison (San Luis NWR) mapped vegetation in most duck clubs in the Grassland EA. Grassland Water District staff mapped controlled flooding of habitats during August–October and helped gain landowner cooperation in the Grassland EA. The Natural Resources Conservation Service provided crop information in the Tulare Basin. C. Kohorst, K. Lee, and G. Martinelli entered habitat information into computer files. W. Perry and J. Daugherty provided GIS support.

We thank Clear Lake and Stillbow duck clubs and Tulare Basin landowners for permitting access to trap pintails, and all landowners for permitting access to track and recover radiotagged pintails on their lands. We thank the hunters who reported and provided information about pintails they recovered. Doctors of veterinary medicine, J. C. Franson and L. N. Locke of the National Wildlife Health Research Center, conducted bird necropsies. R. Dunston, D. Orthmeyer, and K. Mazacco helped trap pintails. M. Carriere of Busch Agriculture donated rice for trapping.

L. Belt, D. Breneman, D. Buford, M. Chouinard, Jr., C. Davis, M. Humpert, P. Johnston, J. Laffitte, C. Stemler, and K. Young helped trap and track radiotagged pintails during 1 or more of the 8-month field seasons. California Department of Fish and Game donated pilot and airplane costs for aerial searches 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. P. L. Flint and 2 anonymous referrees provided comments that improved the manuscript.

LITERATURE CITED

AKAIKE, H. 1985. Prediction and entropy. Pages 1–24 *in* A. C. Atkinson and S. E. Fienberg, editors. A celebration of statistics: the ISI centenary volume. Springer-Verlag, New York, USA.

BARNUM, D. A., AND N. H. EULISS, JR. 1991. Impacts of changing irrigation practices on waterfowl habitat use in the southern San Joaquin Valley, California. California Fish and Game 77:11–22.

———, AND D. S. GILMER. 1988. Selenium levels in biota from irrigation drain water impoundments in the San Joaquin Valley, California. Lake & Reservoir Management 4:181–186.

BEAM, J., AND N. GRUENHAGEN. 1980. Feeding ecology of pintails (*Anas acuta*) wintering on the Los Banos Wildlife Area, Merced County, California. Federal Aid Wildlife Restoration Progress Report, Project W-40-D-1, California Department of Fish and Game.

BELLROSE, F. C. 1980. Ducks, geese and swans of North America. Stackpole Books, Harrisburg, Pennsylvania, USA.

BOTZLER, R. G. 1991. Epizootiology of avian cholera in wildfowl. Journal of Wildlife Diseases 27:367–395.

BURNHAM, K. P., AND D. R. ANDERSON. 1992. Data-based selection of an appropriate biological model: the key to modern data analysis. Pages 16–30 *in* D. R. McCullough and R. H. Barrett, editors. Wildlife 2001: populations. Elsevier Applied Science, New York, USA.

CALIFORNIA DEPARTMENT OF WATER RESOURCES. 1991. California's continuing drought, 1987–1991: a summary of impacts and conditions as of December 1, 1991. State of California, Sacramento, USA.

CARLSON, J. D., JR., W. R. CLARK, AND E. E. KLAAS. 1993. A model of the productivity of the northern pintail. U.S. Fish and Wildlife Service Biological Report 7, Washington, D.C., USA.

CARNEY, S. M. 1992. Species, age and sex identification of ducks using wing plumage. U.S. Fish and Wildlife Service, Washington, D.C., USA.

CASAZZA, M. L. 1995. Habitat use and movements of northern pintails wintering in the Suisun Marsh, California. Thesis, California State University, Sacramento, USA.

CENTRAL VALLEY HABITAT JOINT VENTURE TECHNICAL COMMITTEE. 1996. Hunting success in the Central Valley, California during 1995–96 compared with previous years. Central Valley Habitat Joint Venture Special Technical Report 1, Sacramento, California, USA.

CONNELLY, D. P., AND D. L. CHESEMORE. 1980. Food habits of pintails, *Anas acuta*, wintering on seasonally flooded wetlands in the northern San Joaquin Valley, California. California Fish and Game 66:233–237.

CONROY, M. J., G. R. COSTANZO, AND D. B. STOTTS. 1989. Winter survival of female American black ducks on the Atlantic coast. Journal of Wildlife Management 53:99–109.

COWARDIN, L. M., D. S. GILMER, AND C. W. SHAIFFER. 1985. Mallard recruitment in the agricultural environment of North Dakota. Wildlife Monographs 92.

COX, R. R., JR., A. D. AFTON, AND R. M. PACE, III. 1998. Survival of female northern pintails wintering in southwestern Louisiana. Journal of Wildlife Management 62:1512–1521.

DAVIS, P. A. 1992. Omnibus western water law. Congressional Quarterly, November 21:3687–3690.

DUFOUR, K. W., C. D. ANKNEY, AND P. J. WEATHERHEAD. 1993. Condition and vulnerability to hunting among mallards staging at Lake St. Clair, Ontario. Journal of Wildlife Management 57:209–215.

DUNCAN, D. C. 1985. Differentiating yearling from adult northern pintails by wing-feather characteristics. Journal of Wildlife Management 49:576–579.

DWYER, T. J. 1972. An adjustable radio-package for ducks. Bird-Banding 43:282–284.

DZUBIN, A., AND E. G. COOCH. 1992. Measurements of geese: general field methods. California Waterfowl Association, Sacramento, USA.

ELPHICK, C. S. 1998. Waterbird conservation and ecology: the role of rice field management in habitat restoration. Dissertation, University of Nevada, Reno, USA.

EULISS, N. H., JR. 1984. The feeding ecology of pintail and green-winged teal wintering on Kern National Wildlife Refuge. Thesis, Humboldt State University, Arcata, California, USA.

FLESKES, J. P. 1999. Ecology of female northern pintails during winter in the San Joaquin Valley, California. Dissertation, Oregon State University, Corvallis, USA.

———, R. L. JARVIS, AND D. S. GILMER. 2002. Distribution and movements of female northern pintails radiotagged in San Joaquin Valley, California. Journal of Wildlife Management 66:138–152.

FLINT, P. L., J. B. GRAND, AND R. F. ROCKWELL. 1998. A model of northern pintail productivity and population growth rate. Journal of Wildlife Management 62:1110–1118.

GILMER, D. S., L. M. COWARDIN, R. L. DUVAL, L. M. MECHLIN, C. W. SHAIFFER, AND V. B. KUECHLE. 1981. Procedures for the use of aircraft in wildlife biotelemetry studies. U.S. Fish and Wildlife Service Resource Publication 140, Washington, D.C., USA.

———, J. M. HICKS, J. P. FLESKES, AND D. P. CONNELLY. 1989. Duck harvest on public hunting areas in California. California Fish and Game 75:155–168.

———, M. R. MILLER, R. D. BAUER, AND J. R. LEDONNE. 1982. California's Central Valley wintering waterfowl: concerns and challenges. Transactions of the North American Wildlife and Natural Resources Conference 47:441–452.

GREENWOOD, H., R. G. CLARK, AND P. J. WEATHERHEAD. 1986. Condition bias of hunter-shot mallards (*Anas platyrhynchos*). Canadian Journal of Zoology 64:599–601.

HEITMEYER, M. E., D. P. CONNELLY, AND R. L. PEDERSON. 1989. The Central, Imperial, and Coachella valleys of California. Pages 475–505 *in* L. M. Smith, R. L. Pedersen, and R. M. Kaminski, editors. Habitat management for migrating and wintering waterfowl in North America. Texas Tech University Press, Lubbock, USA.

———, L. H. FREDRICKSON, AND D. D. HUMBURG. 1993. Further evidence of biases associated with hunter-killed mallards. Journal of Wildlife Management 57:733–740.

HEPP, G. R., R. J. BLOHM, R. E. REYNOLDS, J. E. HINES, AND J. D. NICHOLS. 1986. Physiological condition of autumn-banded mallards and its relationship to hunting vulnerability. Journal of Wildlife Management 50:177–183.

HESTBECK, J. B. 1993*a*. Overwinter distribution of northern pintail populations in North America. Journal of Wildlife Management 57:582–589.

———. 1993*b*. Survival of northern pintails banded during winter in North America. Journal of Wildlife Management 57:590–596.

HOUGHTEN, C. J., J. E. HOUK, AND T. J. CHARMLEY. 1985. Waterfowl population objectives for the southern San Joaquin Valley and Kern National Wildlife Refuge: issues and strategies. U.S. Fish and Wildlife Service, Portland, Oregon, USA.

JOHNSON, D. H., AND A. B. SARGEANT. 1977. Impact of red fox predation on the sex ratio of prairie mallards. U.S. Fish and Wildlife Service Wildlife Research Report 6, Washington, D.C., USA.

JOHNSON, S., G. HASLAM, AND R. DAWSON. 1993. The great Central Valley: California's heartland. University of California Press, Berkeley, USA.

KIRBY, R. E., AND L. M. COWARDIN. 1986. Spring and summer survival of female mallards from northcentral Minnesota. Journal of Wildlife Management 50:38–43.

LARSON, J. S., AND R. T. TABER. 1980. Criteria of age and sex. Pages 143–202 *in* S. D. Schemnitz, editor. Wildlife management techniques manual. Fourth edition. The Wildlife Society, Washington, D.C., USA.

MIGOYA, R., AND G. A. BALDASSARRE. 1995. Winter survival of female northern pintails in Sinaloa, Mexico. Journal of Wildlife Management 59:16–22.

MILLER, M. R. 1985. Time budgets of northern pintails wintering in the Sacramento Valley, California. Wildfowl 36:53–64.

———. 1986. Northern pintail body condition during wet and dry winters in the Sacramento Valley, California. Journal of Wildlife Management 50:189–198.

———. 1987. Fall and winter foods of northern pintails in Sacramento Valley, California. Journal of Wildlife Management 51:405–414.

———, AND D. C. DUNCAN. 1999. The northern pintail in North America: status and conservation needs of a struggling population. Wildlife Society Bulletin 27:788–800.

———, J. P. FLESKES, D. L. ORTHMEYER, W. E. NEWTON, AND D. S. GILMER. 1995. Survival of adult female northern pintails in Sacramento Valley, California. Journal of Wildlife Management 59:478–486.

———, D. L. ORTHMEYER, M. L. CASAZZA, M. R. MCLANDRESS, AND D. P. CONNELLY. 1993. Survival, habitat use, and movements of female northern pintails radiomarked in the Suisun Marsh, California. Final report. National Fish and Wildlife Foundation and California Waterfowl Association, Sacramento, USA.

OHLENDORF, H. M., D. J. HOFFMAN, M. K. SAIKI, AND T. W. ALDRICH. 1986. Embryonic mortality and abnormalities of aquatic birds: apparent impact of selenium from irrigation drain water. Science of the Total Environment 52:49–63.

PAULUS, S. L. 1988. Time-activity budgets of nonbreeding Anatidae: a review. Pages 135–151 *in* M. W. Weller, editor. Waterfowl in winter. University of Minnesota Press, Minneapolis, USA.

PIETZ, P. J., D. A. BRANDT, G. L. KRAPU, AND D. A. BUHL. 1995. Modified transmitter attachment method for adult ducks. Journal of Field Ornithology 66:408–417.

REINECKE, K. J., AND C. W. SHAIFFER. 1988. A field test for differences in condition among trapped and shot mallards. Journal of Wildlife Management 52:227–232.

REYNOLDS, R. E., R. J. BLOHM, J. D. NICHOLS, AND J. E. HINES. 1995. Spring–summer survival rates of yearling versus adult mallard females. Journal of Wildlife Management 59:691–696.

RIENECKER, W. C. 1987*a*. Migration and distribution of northern pintails banded in California. California Fish and Game 73:139–155.

———. 1987*b*. Survival and recovery rate estimates of northern pintail banded in California, 1948–79. California Fish and Game 73:230–237.

SAMUEL, M. D. 1992. Influence of disease on a population model of mid-continent mallards. Transactions of the North American Wildlife and Natural Resources Conference 57:487–498.

SCHEMNITZ, S. D. 1994. Capturing and handling wild animals. Pages 106–124 *in* T. A. Bookhout, editor. Research and management techniques for wildlife and habitats. Fifth edition. The Wildlife Society, Bethesda, Maryland, USA.

U.S. FISH AND WILDLIFE SERVICE. 1978. Concept plan for waterfowl wintering habitat preservation, Central Valley, California. U.S. Fish and Wildlife Service, Portland, Oregon, USA.

———. 1979. Concept plan for waterfowl wintering habitat preservation, California Coast. U.S. Fish and Wildlife Service, Portland, Oregon, USA.

———, AND CANADIAN WILDLIFE SERVICE. 1986. North American waterfowl management plan—a strategy for cooperation. U.S. Fish and Wildlife Service, Washington, D.C., USA.

———, AND ———. 1991. Status of waterfowl and fall flight forecast. U.S. Fish and Wildlife Service, Washington, D.C., USA.

———, AND ———. 1992. Status of waterfowl and fall flight forecast. U.S. Fish and Wildlife Service, Washington, D.C., USA.

———, AND ———. 1993. Status of waterfowl and fall flight forecast. U.S. Fish and Wildlife Service, Washington, D.C., USA.

———, AND ———. 1995. Waterfowl population status, 1995. U.S. Fish and Wildlife Service, Washington, D.C., USA.

WHITE, G. C., AND K. P. BURNHAM. 1999. Program MARK: survival estimation from populations of marked animals. Bird Study 46 (Supplement):S120–S138.

Received 30 October 2000.
Accepted 30 January 2002.
Associate Editor: Flint.