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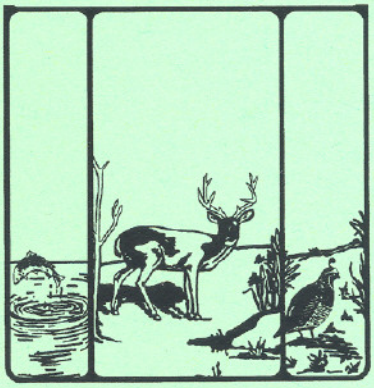

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DISTRIBUTION OF FEMALE NORTHERN PINTAILS IN RELATION TO HUNTING AND LOCATION OF HUNTED AND NON-HUNTED HABITATS IN THE GRASSLAND ECOLOGICAL AREA, CALIFORNIA

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To provide baseline information and better understand distribution of northern pintails (*Anas acuta*) in relation to hunting and distribution of hunted and non-hunted habitats in the Grassland Ecological Area (EA), we radio-tagged 191 Hatch-Year (HY) and 228 After-Hatch-Year (AHY) female pintails in the San Joaquin Valley and tracked their movements in the Grassland EA during September - March 1991-94. We investigated how the relative importance of public (National Wildlife Refuges [NWRs], California Department of Fish and Game Wildlife Areas [WAs]) vs. private areas (e.g., waterfowl hunting clubs [Clubs]), use of individual areas, and night destinations from specific day-use areas varied within and among winters and with pintail age and capture location. Overall, 64% of day and 85% of night pintail locations in the Grassland EA were on private areas. Day use of private areas was greater during nonhunting weeks (73% of all locations) and nonshoot days of hunting weeks (62% of all locations) than during shoot days (17% of all locations), when most pintails used public area sanctuaries. The effect of hunting lingered but faded, with use of private areas 1 day after hunting slightly less than 2 days after hunting (57% vs. 66%). Use of private areas on nights during nonhunting weeks and after nonshoot days of hunting weeks was identical (86%). Night use after shoot days was lower (79%), although the difference was significant only during the opening week of hunting. AHY females stayed on sanctuaries at a higher rate at dusk on shoot days and used the East Grassland (EGL) more than HY females. Use of private areas during the hunting season declined in 1993-94, possibly because newly-restored public area habitats attracted pintails. Night use of private areas during nonhunting weeks was lowest during 1991-92, the year drought prevented summer irrigations, and

probably reduced food production on most private but few public wetlands. San Luis NWR was the most important shoot day sanctuary but Kesterson NWR use increased after wetlands in its sanctuary were restored. Merced NWR was the only public area receiving high use at night during the hunting season. Most pintails that left Merced NWR at night flew to South Clubs rather than to closer East or North Clubs. Few pintails from Kesterson NWR flew to South Clubs at night but San Luis NWR and Los Banos WA pintails used both North and South Clubs at night. The percentage of San Luis NWR pintails going to South Clubs increased after the first hunting interval, except in 1993, when 10% instead went to newly restored Salt Slough WA watergrass (*Echinochloa crusgalli*) marsh. Pintails were more likely to use areas during hunting season that they frequented during August - October before hunting began, indicating that early habitat conditions influenced pintail use later in winter. Pintail distribution changed among intervals and years in response to changing hunting pressure and distribution of hunted and nonhunted habitats. Our data can serve as a baseline to evaluate response of pintails to changes in habitat management in the Grassland EA.

INTRODUCTION

The Grassland Ecological Area (EA) in the northern San Joaquin Valley (SJV) is the largest contiguous block of wetland habitat remaining in California's Central Valley and provides critical habitat for many wetland-dependent species (Grassland Water District 1999), including northern pintails (*Anas acuta*) (hereafter referred to as "pintails"). About half of the pintails in North America winter in the Grassland EA and other Central Valley habitats (Bellrose 1980, U. S. Fish and Wildlife Service[1] [USFWS]1978), arriving as early as the first week of August and remaining through March. Pintail populations in North America declined to all time lows in the early 1990s (USFWS and Canadian Wildlife Service[2] [CWS] 1995) and abundance in California during winter was about 25% of that recorded in the 1970s (Pacific Flyway waterfowl reports and USFWS, Portland, Oregon, unpublished data).

Understanding pintail distribution and movements in the Grassland EA in relation to hunting pressure and location of hunted and nonhunted areas (i.e., sanctuaries) during winter is crucial to managing pintail populations and habitats. Grassland EA is a focal point for habitat conservation efforts (USFWS and CWS[3] 1986, Central Valley

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[1]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.

[2]U.S. Fish and Wildlife Service and Canadian Wildlife Service. 1995. Waterfowl population status, 1995. U.S. Fish and Wildlife Service, Washington, D.C., USA.

[3]U.S. Fish and Wildlife Service and Canadian Wildlife Service. 1986. North American waterfowl management plan - a strategy for cooperation. U.S. Fish and Wildlife Service, Washington, D.C., USA.

Habitat Joint Venture Implementation Board[4] 1990) and knowledge of pintail movements before habitat changes occur is necessary to evaluate habitat programs. Further, most Grassland EA wetlands are privately owned and managed with funds derived largely from hunters (Gilmer et al. 1982). Changes in pintail movements that impact hunter success could impact management of many Grassland EA wetlands (Heitmeyer et al. 1989, Baldassarre and Bolen 1994).

To identify factors related to pintail distribution and provide baseline information necessary for evaluating impacts of future changes in hunting and distribution of hunted and non-hunted habitats in the Grassland EA, we radio-tagged Hatch-Year (HY) and After-Hatch-Year (AHY) female pintails throughout the SJV after their late summer arrival and monitored their movements in the Grassland EA during late August to late March, 1991-94. Waterfowl surveys (California Department of Fish and Game [CDFG], Los Banos, California, unpublished data) provide some information on diurnal distribution but most were conducted on hunting days when pintails were concentrated on Wildlife Area (WA) and National Wildlife Refuge (NWR) sanctuaries. We studied distribution of individual pintails throughout the wintering period, during both day and night (when pintails primarily feed during most of the winter [Miller 1985, Euliss[5] 1984]), relative to hunting (shoot and nonshoot days) and location of hunted and nonhunted habitats.

STUDY AREA

The Grassland EA (Fig. 1) comprised the north (NGL), south (SGL) and east grasslands (EGL) and nearby San Luis Reservoir with forebay. The NGL were comprised of public areas with some wetlands closed to hunting (San Luis NWR [532 - 570 ha wetlands in sanctuary], Kesterson NWR [99 - 138 ha wetlands in sanctuary], Los Banos WA [196 - 219 ha wetlands in sanctuary), public areas without closed zones (Volta, Salt Slough, and China Island WAs) and privately owned waterfowl hunting clubs (North Clubs). The Grassland State Park in the NGL was closed to hunting but had no flooded areas. The SGL were entirely private (South Clubs). The EGL were composed of Merced (174 - 254 ha wetlands in sanctuary) and Arena Plains NWRs (49 ha wetlands, all sanctuary) and waterfowl hunting clubs (East Clubs). Overall during 1991-94, private area flooding comprised an average of 75% of all available habitat before hunting season (i.e., Prehunt) and 82% thereafter (Fig. 2).

Most wetlands were unflooded during the summer but irrigated periodically to promote seed production, then flooded during fall and winter. Initial flooding of most wetlands occurred during mid-August to late-October. Water for irrigation, fall flood-

[4]Central Valley Habitat Joint Venture Implementation Board. 1990. Central Valley Habitat Joint Venture Implementation Plan - a component of the North American Waterfowl Management Plan. U.S. Fish and Wildlife Service, Portland, Oregon, USA.

[5]Euliss, N.H., Jr. 1984. The feeding ecology of pintail and green-winged teal wintering on Kern National Wildlife Refuge. M.S. Thesis, Humboldt State Univ., Arcata. 188 pp.

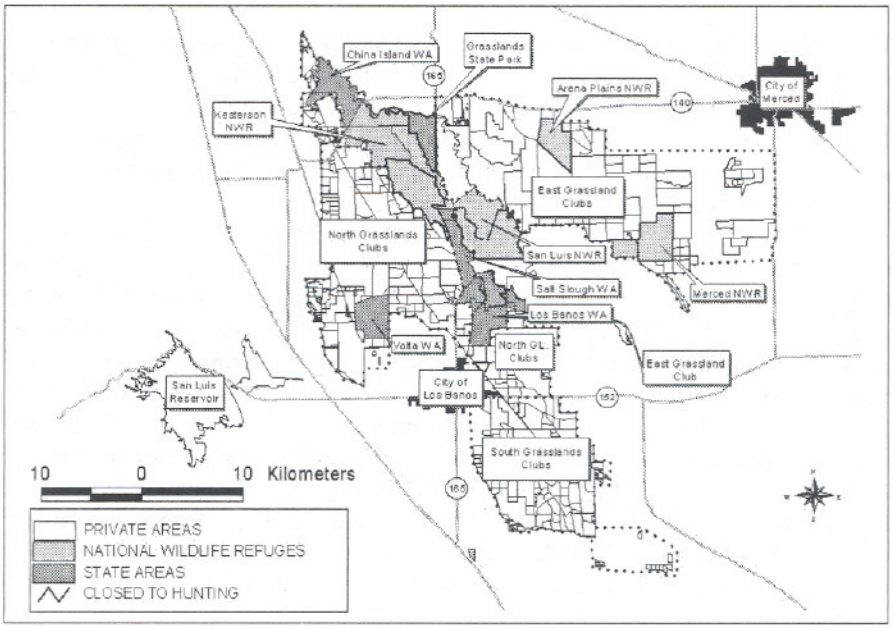

Figure 1. Grassland Ecological Area in the San Joaquin Valley, including California Department of Fish and Game Wildlife Areas (WAs), U.S. Fish and Wildlife Service National Wildlife Refuges (NWRs), private waterfowl hunting clubs, and San Luis Reservoir, during 1991-94.

up, and winter maintenance was delivered from reservoirs that stored Sierra Nevada snow-melt. Thus, the amount of early-winter habitat varied as a result of the previous winter's snowfall. Winter rains flooded additional habitat each year.

Changing precipitation, water availability, and management affected habitat availability. Drought conditions in the San Joaquin River drainage were the worst on record during 1991-92 (California Department of Water Resources[6] 1991, National Oceanic and Atmospheric Administration, Asheville, NC, unpublished data) and no water was available for May - July private wetland irrigation. Fall flood-up was delayed 2 weeks and record low August through mid-November water was delivered to private wetlands (Grassland Water District, Los Banos, CA, unpublished data). Conditions improved after January 1992 because of normal to above-average precipitation. Conditions during 1993-94 improved further because 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, CA, unpublished data)

[6]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, California, USA.

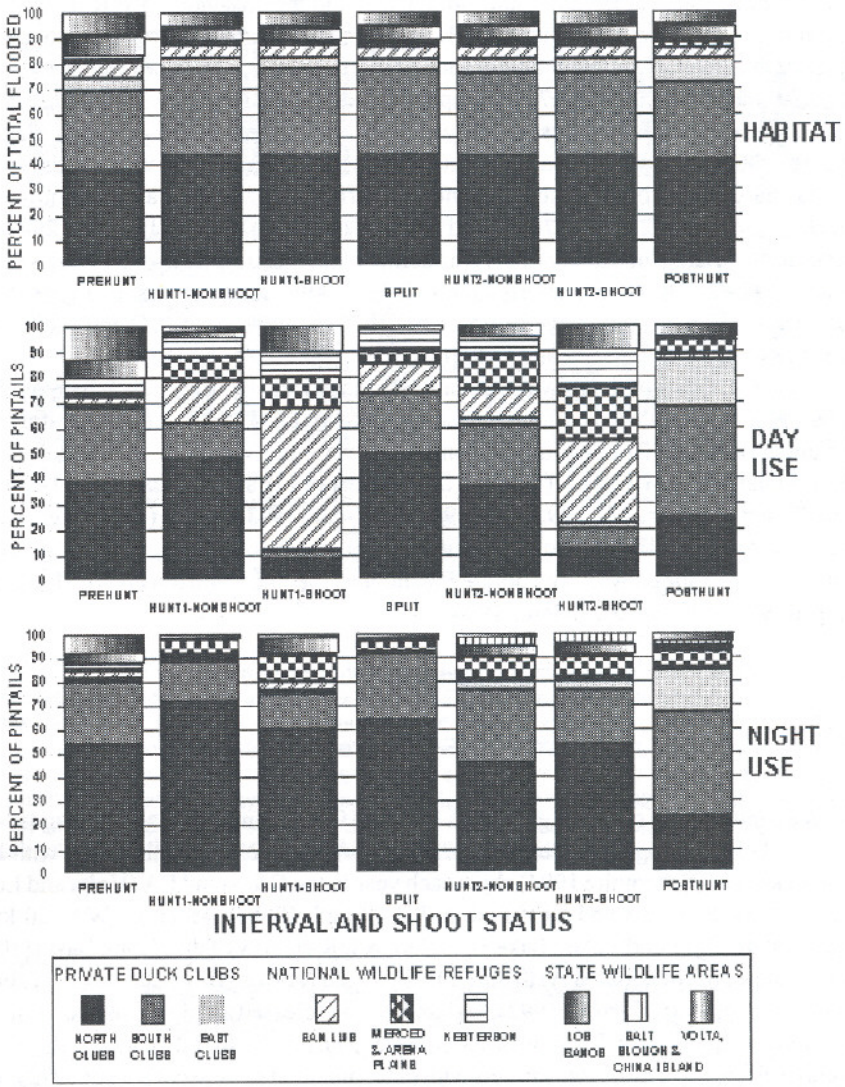

Figure 2. Percentage of total flooded habitat (excluding San Luis Reservoir and Forebay) and radio-tagged female northern pintail (*Anas acuta*) day and night locations on public areas (California Department of Fish and Game Wildlife Areas [WA], U.S. Fish and Wildlife Service National Wildlife Refuges [NWR]), and private waterfowl hunting clubs in the north, south, and east parts of the Grassland Ecological Area before (Prehunt), between (Split), after (Posthunt), and on shoot (Wednesdays and weekends) and nonshoot days during the first (Hunt1) and second (Hunt2) duck hunting seasons, 1991-94. Most pintail use was on Merced NWR but also includes use of Arena Plains NWR. Most use was on Salt Slough WA during Hunt2 but also includes use of China Island WA. San Luis Reservoir (not listed in legend) was used by only 1 or 2 birds for 3 Posthunt weeks in 1991-92 and 3 Hunt2 weeks in 1992-93.

and wetlands were restored on Salt Slough WA and the Kesterson NWR sanctuary. Mean weekly availability of marsh (89% to 96% seasonal marsh) during Prehunt was 6,088 ha in 1991-92, 7,431 ha in 1992-93 and 10,402 ha in 1993-94. These values increased to 20,106 ha, 20,815 ha and 23,723 ha respectively during the hunting season; and 20,863 ha, 22,318 ha and 24,473 ha respectively after the hunting season. Flooding of uplands and harvested fields before (46 ha, 105 ha, 207 ha) and during the hunting season (196 ha, 231 ha, 253 ha) followed similar annual patterns but availability after hunting was much greater in 1992-93 (1,178 ha) and 1993-94 (1,472 ha) than in 1991-92 (294 ha) because of variation in winter rains. Availability of reservoirs (6,348 - 6,372 ha), sewer ponds (194 - 245 ha) and evaporation ponds (1 - 39 ha) varied less among years and seasons. Habitats are described by USFWS[1] (1978), Heitmeyer et al. (1989), Johnson et al. (1993), and Baldassarre and Bolen (1994).

Daily bag limits (4 ducks with 1 either-sex pintail) and hunting season lengths (59 days) were constant but timing of seasons varied (CDFG, Sacramento, California, unpublished data). The hunting season (Hunt) was split with a 22-day first season (Hunt1) starting 26 (1991), 24 (1992) or 23 October (1993), and a 37-day second season (Hunt2) starting after a 12- (1991), 19- (1992) or 27-day (1993) closure (Split). Nearly all clubs, WAs and NWRs allowed hunting only on Wednesdays, Saturdays, and Sundays (i.e., shoot days). We define Posthunt as the interval from end of Hunt2 to 1 April 1992 and 1993 or 17 March 1994.

METHODS

Field Procedures

We captured and radio-tagged 228 AHY and 191 HY female pintails 29 August - 6 October 1991, 31 August - 5 October 1992 and 28 August - 25 September 1993 with 11 - 14 rocket-net (Schemnitz 1994) shots each year in the Grassland EA (Volta and Los Banos WAs; San Luis and Kesterson NWRs; South Clubs), Mendota WA (50 km southeast of SGL), and Tulare Lake Bed-Kern NWR vicinity of the Tulare Basin (100 km southeast of Mendota WA) (Table 1). We aged (HY or AHY, Larson and Taber 1980, Duncan 1985, Carney[7] 1992), legbanded, and released all pintails at the capture location <1 to 19 ($\bar{\chi}$ = 7.7) hours after capture. During the first 2 years we attached exclusively 20-21-g radio transmitters with back-mounted harnesses (Dwyer 1972). In 1993, we radio-tagged 98 pintails with the harness and 83 pintails with a spear-suture transmitter (similar to Pietz et al. [1995], except 8-9 g and 20 mm diameter x 12 mm high). Each transmitter had a unique signal, a mortality sensor, life expectancy ≥210 days and an initial minimum ground-to-ground range of 3.2 km using 150-db receivers and a dual 4-element Yagi null-peak telemetry system (Cochran and Lord 1963) mounted on the roof of pick-up trucks. Transmitters were imprinted with contact information which we

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

Table 1. Number of After-Hatch-Year (AHY) and Hatch-Year (HY) female northern pintails (*Anas acuta*) radio-tagged in the Grassland Ecological Area (South Clubs, Volta Wildlife Area [WA], Los Banos WA, San Luis National Wildlife Refuge [NWR], Kesterson NWR), Mendota WA, and Tulare Basin of the San Joaquin Valley, California, 1991-93.

	Year and Age Class							
	1991		1992		1993		Total	
Area	AHY	HY	AHY	HY	AHY	HY	AHY	HY
South Clubs	17	13	19	15	19(8)	20(9)	55(8)	48(9)
Volta WA	8	5	10	26	0	1(0)	18(0)	32(0)
Los Banos WA	14	17	1	1	0	0	15(0)	18(0)
San Luis NWR	2	2	0	0	0	0	2(0)	2(0)
Kesterson NWR	0	0	0	6	25(12)	18(9)	25(12)	24(9)
Mendota WA	21	4	17	4	33(14)	39(19)	71(14)	47(19)
Tulare Basin	10	2	18	6	14(6)	12(5)	42(6)	20(5)
All Areas	72	43	65	58	91(40)	90(42)	228(40)	191(42)

( )Number of spear-suture type radio-tags in parenthesis, included in cell totals. All other radio-tags were harness backpack type.

solicited by posting project descriptions at hunting check stations and in state-wide media.

We scanned the entire study area, and for each pintail present, determined their location on ≥2 shoot days and nights and ≥2 nonshoot days and nights each week during Hunt and ≥2 days and nights each week during other intervals. We conducted aerial searches (Gilmer et al. 1981) weekly to ensure we found all pintails. In addition to the pintails we radio-tagged, we also tracked 25 AHY and 24 HY female pintails radio-tagged in Suisun Marsh (Casazza[8] 1995) and 3 AHY female pintails radio-tagged in Alaska (J. B. Grand, personal communication) while they were in the Grassland EA. We obtained 2 bearings from known locations to minimize time between bearings and because preliminary testing showed more bearings did not increase accuracy. The road network allowed us to obtain >90% of all locations <1.6 km from the bird at 50-130 degree angles. Warnock and Takekawa (1995) reported an average azimuth error of 1.5° and an error polygon of 1.1 ha with location distances 0.5 - 3.0 km using a system identical to ours. We entered truck location and azimuth, bird ID and azimuth, time, date, observer and truck ID, and calculated bird locations using a modified version of XYLOG and UTMTEL (Dodge et al.[9] 1986, Dodge and Steiner 1986). We intersected pintail locations in a Geographic Information System with digitized maps and identified the polygon (average size = 20.3 ha) associated with each location.

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

[9]Dodge, W.E., D.S. Wilkie, and A.J. Steiner. 1986. UTMTEL: A laptop computer program for location of telemetry "finds" using Loran-C. Massachusetts Cooperative Research Unit. Report, U.S. Fish and Wildlife Service.

Data Analysis

We summarized pintail use in the Grassland EA for private (Clubs) vs. public areas (NWRs and WAs), individual areas (e.g., Kesterson NWR, North Clubs), and report on night destinations of pintails from specific day-use areas. We used categorical modeling (Sauer and Williams 1989) to investigate the relationship between weekly pintail distribution and diurnal period (day vs. night), study year (1991-92 vs. 1992-93 vs. 1993-94), bird age (HY vs. AHY), and bird capture location (Grassland EA vs. other [Mendota WA, Tulare Basin, Suisun Marsh, Alaska]; or NGL vs. SGL). We conducted most analyses separately for hunting and non-hunting weeks. During hunting weeks, we compared distribution on shoot vs. nonshoot days, days or nights following a shoot day vs. two days after a shoot day, and week days. We used PROC GENMOD (SAS Institute 1997) that conducts a Chi-square test for overall differences and a Z test for individual differences across weeks with a generalized estimating equations approach (McCullagh and Nelder 1989) to account for correlation between repeated measures (Liang and Zeger 1986). We used PROC CATMOD (SAS Institute 1989) by week, with a Chi-square test and the Bonferroni adjustment to maintain an alpha level of 0.05 (Johnson and Wichern 1982), to test for consistency among weeks for variables that were found to be significant across weeks. We followed Dobson (1990) and Milliken (1984) to assess the importance of explanatory variables and interactions using a step-down model selection method. To reduce bias associated with unequal and multiple sampling of individual pintails each week, we apportioned multiple day, night, shoot and nonshoot locations among areas so that each pintail had a maximum of one location per week for each day, night, shoot and nonshoot category. For instance, if during week 9 in Hunt1, a pintail was located on San Luis NWR during the day on Wednesday and on Merced NWR during the day on Saturday, we apportioned 0.5 shoot day locations to each of those areas. We grouped weekly totals into intervals (Prehunt, Hunt1, Split, Hunt2, Posthunt) and intervals into hunting (Hunt1 and Hunt2) and nonhunting (Prehunt, Split, Posthunt) for some analyses. To pool or compare weekly distribution across years, we used 1 September, 30 August, or 29 August as the start of week 1 for 1991-92, 1992-93 and 1993-94, respectively. We conducted a nearest neighbor analysis (Rosing et al. 1998) and verified that each pintail moved about independently even if captured under the same net (Fleskes[10] 1999).

We report actual use proportions for most comparisons except we report difference in relative use (with 95% CI) for the few instances (i.e., impact of capture location, age class, week day) when the magnitude of difference is more meaningful than actual use proportions. For instance, difference in relative use of private areas on Wednesdays vs. Saturdays was calculated as: (proportion of Wednesday use occurring on private areas/ 1 - proportion of Wednesday use occurring on private areas) / (proportion of Saturday use occurring on private areas/ 1 - proportion of Saturday use occurring on

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

private areas). The difference in relative use is a less biased measure of the impact of a variable than the difference in actual use proportions because relative use can range from 0 to infinity so that an equal percentage difference in relative use has the same meaning regardless of the values of relative uses being compared. In contrast, proportions are restricted to between 0 and 1, so that the meaning of a percentage change in proportions depends on the values of the proportions being compared (e.g., a 50% increase in 10% differs in meaning from a 50% increase in 20%).

RESULTS

Use of Private vs. Public Areas

Overall during September through March, 64% of day and 85% of night locations in the Grassland EA were on private areas (i.e., North, South and East Clubs). However, the relative importance of public and private areas and factors related to use patterns varied greatly among intervals with and without hunting (Fig. 2).

Nonhunting Weeks

During weeks of nonhunting intervals (Prehunt, Split, Posthunt), the relative importance of public and private areas differed between day and night ($X^2 = 200.02$, 6 df, $P < 0.0001$) and among study years ($X^2 = 30.33$, 10 df, $P = 0.0007$). Averaged across all nonhunting weeks and years, use of private areas during day was slightly less than at night (73% vs. 86% of locations; $Z \geq 4.31$, $P < 0.0001$). However, the strength of the diurnal effect varied among weeks, so that day and night use differed significantly during 3 of 5 Prehunt ($X^2 \geq 4.65$, 2 df, $P \leq 0.03$), all (3/3) Split ($X^2 \geq 13.65$, 1 df, $P < 0.001$), but no (0/5) Posthunt weeks ($X^2 \leq 0.11$, 1 df, $P \geq 0.74$) that we tested (samples too small to test other weeks). The relative importance of public and private areas during day was similar all years ($Z < 1.18$, $P > 0.24$) but night use of private areas during nonhunting weeks in 1991-92 (76.2%) was less than in 1992-93 (87.2%; $Z = 2.12$, $P = 0.034$) and 1993-94 (89.3%; $Z = 3.30$, $P = 0.0009$). The year effect was significant during 3 of 5 Prehunt, 3 of 5 Posthunt ($X^2 \geq 6.26$, 2 df, $P \leq 0.04$) but no Split weeks ($X^2 \leq 0.79$, 2 df, $P \geq 0.67$).

Hunting Weeks

The relative importance of public and private areas changed drastically once hunting began (Fig. 3), with most pintails seeking sanctuary in parts of public areas closed to hunting and flying out at dusk to private clubs (Fig. 4). Proportions of pintails on public and private areas during hunting weeks were related to diurnal period ($X^2 = 859.58$, 7 df, $P < 0.0001$), hunt status (i.e., shoot vs. nonshoot; $X^2 = 1011.88$, 7 df, $P < 0.0001$), week day ($X^2 = 42.81$, 14 df, $P < 0.0001$), study year ($X^2 = 24.81$, 12 df, $P < 0.0157$) and bird age ($X^2 = 26.99$, 7 df, $P = 0.0003$).

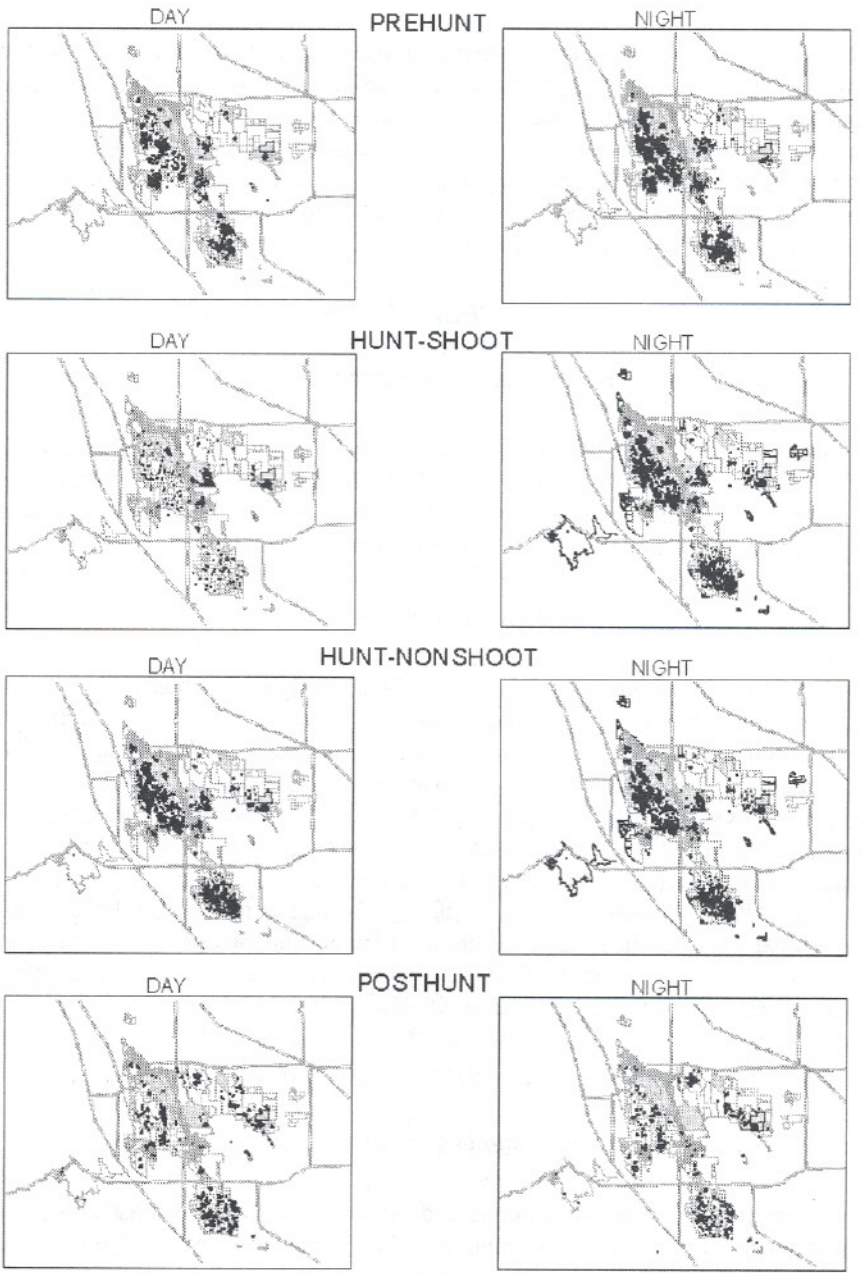

Figure 3. Day and night locations (dots) of radio-tagged female northern pintails (*Anas acuta*) in the Grassland Ecological Area before (Prehunt), after (Posthunt), and on shoot (Wednesdays and weekends) and nonshoot days during duck hunting season (Hunt), 1991-94. Locations during the Split between the first and second hunting intervals included in Hunt-Nonshoot.

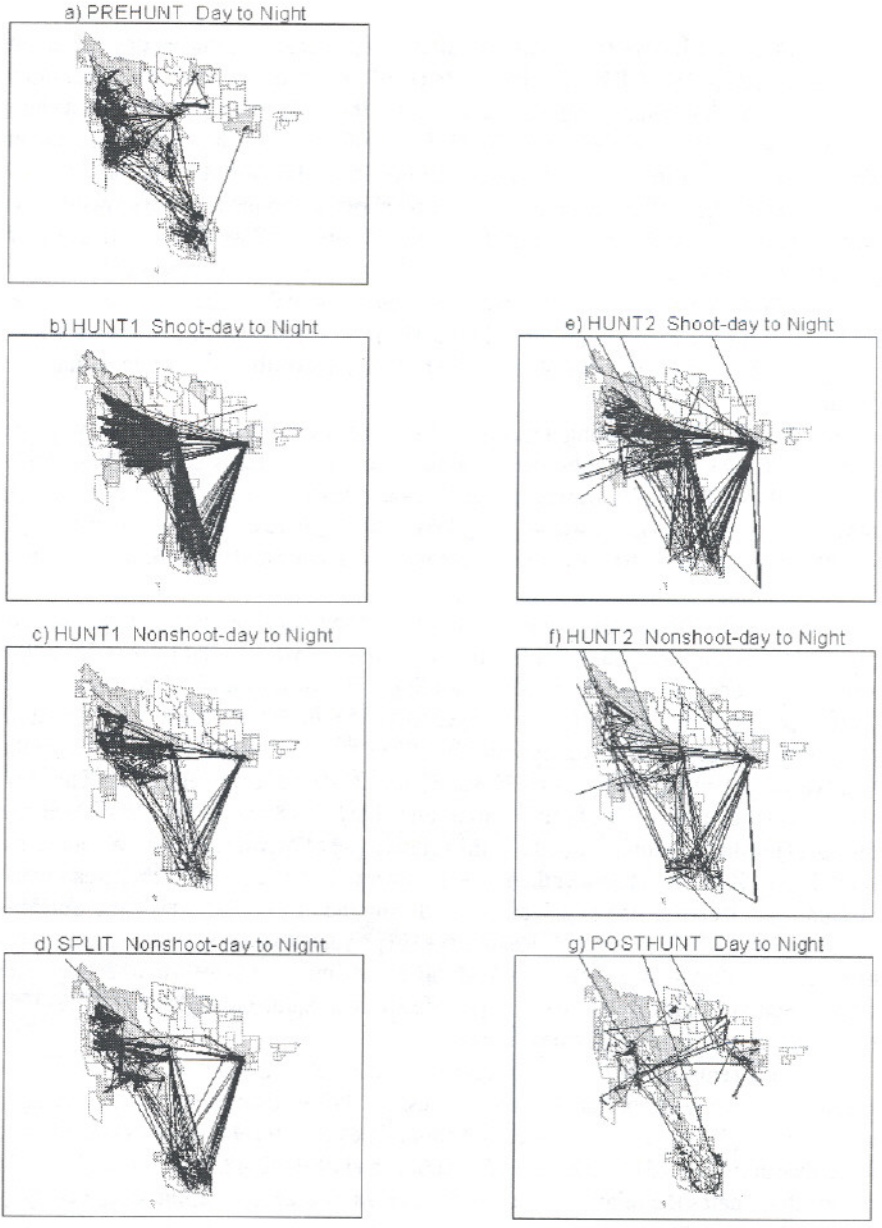

Figure 4. Movements of radio-tagged female northern pintails (*Anas acuta*) in the Grassland Ecological Area between day and night locations during Prehunt, Split, Posthunt, and on shoot (Wednesdays and weekends) and nonshoot days during Hunt1 and Hunt2, 1991-94.

Overall during hunting intervals, pintail use of private areas during day was about half that at night (42% vs. 83%; $Z = 14.83$, $P < 0.0001$). The diurnal difference was much greater than during nonhunting intervals because the difference in use between shoot and nonshoot days (17% vs. 62%; $Z = 30.35$, $P < 0.0001$) was much greater than between nights following a shoot day and nights after nonshoot days (79% vs. 86%; $Z = 4.33$, $P < 0.0001$). The difference in private use on shoot and nonshoot days was greater during Hunt1 weeks ($X^2 \geq 95.93$, 1 df, $P < 0.0001$) than Hunt2 weeks ($X^2 \geq 4.75$, 1 df, $P \leq 0.03$); at night differences between shoot and nonshoot were significant ($X^2 \geq 17.75$, 1 df, $P \leq 0.0001$) only during the first week of Hunt1. Shoot day use of private lands was similarly low ($Z = 0.75$, $P = 0.45$) for AHY and HY pintails but relative use of private areas on nights after a shoot day was 43% (16% to 61%) lower for AHY pintails than HY pintails.

The impact of hunting lingered into nonshoot days but faded over time, with use of private areas 1 day after a shoot day less than 2 days after a shoot day (57% vs. 66%; $Z = 6.22$, $P < 0.001$). The lower use of private areas 1 vs. 2 days after hunting was significant during all Hunt1 weeks ($X^2 \geq 4.61$, 1 df, $P \leq 0.03$), but no Hunt2 weeks ($X^2 \leq 1.99$, 1 df, $P \geq 0.16$). The use of private areas on the second and third night after a shoot day were similar.

Use patterns differed for some weekdays. Among nonshoot days, proportions of pintail day use on private and public areas on Mondays was similar ($X^2 = 8.74$, 7df, $P = 0.27$) to Thursdays (both 1 day after shooting) but Tuesday and Friday distribution (both 2 days after shooting) differed some years ($X^2 = 53.70$, 7df, $P < 0.0001$). Distribution on Tuesdays and Fridays was similar in 1991-92 ($Z = 0.84$, $P = 0.40$), but in 1992-93 the relative use of private areas on Friday was 53% (42% to 63%) lower than on Tuesday; in 1993-94 the relative use of private areas on Friday was 89% (39% to 157%) greater than on Tuesday. Among shoot days, the relative use of private areas on Wednesdays was 82% (35% to 146%) greater than on Saturdays and 62% (23% to 112%) greater than on Sundays. Relative use of private areas during the day on Saturdays and Sundays were similar ($Z = 0.77$, $P = 0.44$). Relative use of private areas on Wednesday night was 66% (23% to 124%) greater than on Saturday nights and 194% (89% to 622%) greater than on Sunday night. Relative use of private areas on Saturday nights was 37% (12% to 301%) greater than on Sunday nights.

Shooting reduced use of private areas all 3 years ($Z \geq 12.10$, $P < 0.0001$) but there was weak evidence that private area use was less in 1993-94 than earlier years. Averaged across day-night, use of private areas on shoot dates in 1993-94 (45.6%) tended to be lower than in 1992-93 (51.3%; $Z = 2.97$, $P = 0.0029$) and 1991-92 (48.7%; $Z = 1.80$, $P = 0.07$); on nonshoot dates the relative importance of private areas was similar each year ($Z \leq 1.41$, $P \geq 0.16$).

Use of Specific Areas

Pintail use of specific private (North Clubs, South Clubs, East Clubs) and public (Merced-Arena Plains NWRs, San Luis NWR, Kesterson NWR, Los Banos WA, Volta-Salt Slough-China Island WAs) areas in the Grassland EA varied among intervals (Fig. 2).

Prehunt

During Prehunt, 68% of day use and 80% of night use occurred on North and South Clubs (Fig. 2 and 3). The percentage of pintails using South Clubs was similar ($t = 1.68$, Bonferroni $P > 0.05$) during the day and night but use of the North Clubs was greater ($t = 7.35$, Bonferroni $P < 0.05$) at night than during the day (Fig. 2). Most of the additional pintails in North Clubs at night came from Kesterson NWR, Volta WA and Los Banos WA, where day use was roughly double ($t \geq 2.80$, Bonferroni $P < 0.05$) night use (Fig. 2). Use of other Grassland EA areas was low and similar ($t \leq 1.68$, Bonferroni $P > 0.05$) during day and night. The location within the Grassland EA where pintails were captured (i.e., NGL or SGL) was the most important factor related to their distribution during Prehunt. Relative use of the SGL was 48,900% (7,700% - 305,700%) greater for pintails radio-tagged in the SGL than pintails radio-tagged in the NGL. Likewise, relative use of the NGL was 11,600% (4,400% - 30,400%) greater for pintails radio-tagged in the NGL than pintails radio-tagged in the SGL. Thus, use of some areas varied greatly among years, reflecting differences in flooding and where we captured pintails. Relative use of the EGL during Prehunt was similar for the few pintails from NGL and SGL. Distribution within the Grassland EA during Prehunt was similar for pintails captured inside and outside (e.g., Mendota WA, Tulare Basin) the Grassland EA.

Hunt1

Pintail distribution changed drastically once hunting began (Fig. 3), with most pintails roosting on public area sanctuaries on shoot days and flying out at dusk to Clubs. San Luis NWR was the most common shoot day sanctuary (Fig. 2). Shoot day use in 1993-94 vs. earlier years was greater in San Luis NWR (61% vs. 52 to 55%) and Kesterson NWR (18% vs. 5 to 8%) but lower in Los Banos WA (6% vs. 11 to 12%) and Merced NWR (9% vs. 13 to 14%). Night and nonshoot day use shifted from areas farthest from sanctuaries (i.e., South Clubs and Volta WA) to areas closer to sanctuaries (i.e., North Clubs) (Fig. 2). North Clubs were the most common nonshoot day and night location for pintails (Fig. 2) but a greater percentage of pintails flew to the distant South Clubs in 1991-92 (21%) then later years (13 to 14%). Overall during Hunt, the relative use of the SGL was 104% (24% to 233%) greater for pintails radio-tagged in the SGL than NGL, indicating that pintails that used the SGL during Prehunt flew to the SGL from sanctuaries in the NGL and EGL more often than pintails that had not used the SGL during Prehunt. The relative use of the NGL on nonshoot nights was 103% (15% to 259%) greater for pintails radio-tagged in the NGL than those from the SGL, but because many SGL pintails remained in the NGL during Hunt, the trend was not significant on shoot days (7%, -41% to 95%), nonshoot days (58%, -9% to 175%) or shoot nights (37%, -24% to 147%). The relative use of the SGL was 51% (4% to 119%) greater for pintails radio-tagged outside the Grassland EA (e.g. Mendota WA, Tulare Basin) than for pintails captured within the Grassland EA. Use of NGL and EGL was similar for pintails captured in and outside the Grassland EA. Relative use of EGL was 60% (37% to 75%) greater for AHY than HY; relative use for AHY vs. HY did not differ significantly in NGL (39%, -2% to 97%) or SGL (-39%, -107% to 7%).

Split

During the 2-4 week Split, pintails responded to the lack of hunters by remaining on private clubs during day and night (Fig. 2). Use of South Clubs increased to near Prehunt levels but use of Volta and Los Banos WAs remained low. Day use of Kesterson and Merced NWRs was similar to Hunt1 but most birds that had been roosting on San Luis NWR did not return each morning as they did during Hunt1 and use there was lower (Fig. 2). Day use of Kesterson NWR during Split continued the trend observed during Hunt1, increasing over the 3 years from 7% to 9% to 11%. Both day (29%) and night (35%) use of the SGL in 1991-92 was greater than day (19 to 22%) and night (23 to 26%) use in later years.

Hunt2

Use patterns during Hunt2 were similar to Hunt1 except a greater percentage of shoot day locations were on private areas and importance of South Clubs, East Clubs and Merced NWR increased whereas importance of San Luis NWR and North Clubs decreased (Fig. 2). Annual trends in day use were similar to Hunt1 except shoot-day use of North Clubs during Hunt2 increased (10% to 12% to 15%) rather than decreased over the 3 years and nonshoot day use of Kesterson NWR did not increase over the 3 years. Likewise, annual trends in night use during Hunt2 were similar to Hunt1 except night use of Salt Slough WA increased greatly from <3% in 1991-92 and 1992-93 to 11% in 1993-94 and use of East Clubs declined during both day (5% to 3% to 1%) and night (10% to 5% to 1%) during the 3 years.

Posthunt

During Posthunt, the importance of South and East Clubs peaked as pintails abandoned most public areas with sanctuaries, except Merced NWR, and settled into private wetlands (Fig. 2). Although pintails used many of the same wetlands used during the hunting season, many habitats on the fringe of the Grassland EA received their first heavy use during Posthunt (Fig. 3). Most used the same area during the day and night (Fig. 3 and 4). Posthunt use over the 3 years increased on South Clubs (32% to 42% to 54%) but declined on East Clubs (32% to 18% to 5%). Use of North Clubs was lower in 1991-92 than later years (12% vs. 27 to 31%); day use of Volta WA was higher in 1991-92 than later years (8% vs. 3 to 4%).

Association Between Day- and Night-Use Areas

Night destinations of pintails in the Grassland EA differed among day-use areas, intervals, and years (Fig. 5). For private areas, 96% of the pintails using North and South Clubs and 83% using East Clubs during nonhunt and nonshoot days stayed there at night; 70% of the few that were on private areas on shoot days stayed there at night.

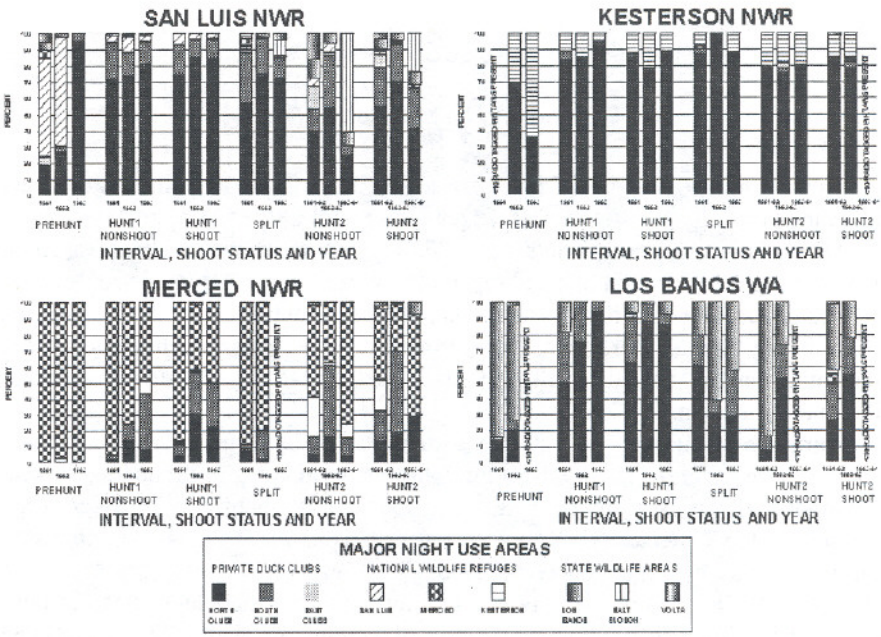

Figure 5. Percent of female radio-tagged northern pintails from 4 major day-use areas that were located at night in each area in the Grassland Ecological Area, before (Prehunt), between (Split), after (Posthunt), and on shoot (Wednesdays and weekends) and nonshoot days during the first (Hunt1) and second (Hunt2) duck hunting seasons, 1991-92, 1992-93, and 1993-94. Volta WA was a major day-use area only during Prehunt, when 69%, 57%, and 94% flew to North Clubs and 30%, 42%, and 3% stayed on Volta WA at night, during 1991, 1992, and 1993, respectively. Few pintails used private areas on shoot days; on nonhunt and nonshoot days, 96% of the pintails using North and South Clubs and 83% using East Clubs stayed there at night.

Except at Merced NWR, most pintails on public areas flew out to private areas at night (Fig. 5). Overall, a higher percentage of the Merced NWR pintails that left at night flew to South Clubs rather than to closer East or North Clubs; the percentage that left Merced for South and North Clubs during Hunt1 increased during the study (Fig. 5). Except during Prehunt, ≤10% of the pintails using San Luis NWR during the day stayed there at night. During Hunt1, >71% of the pintails on San Luis NWR went to North Clubs at night and 11-23% went to South Clubs. Thereafter, the percentage from San Luis NWR going to North Clubs decreased as the percentage going to South Clubs and, in 1993-94, to Salt Slough WA increased (Fig. 5). Few Kesterson NWR pintails went to South Clubs. During Prehunt, 31-65% of pintails using Kesterson NWR during day remained there at night and 35-69% flew to North Clubs; thereafter 67-99% flew to North Clubs at night. Night destinations of Los Banos WA pintails varied among intervals and the percentage during Hunt1 going to South Clubs decreased and to North Clubs increased over the 3-year study (Fig. 5).

DISCUSSION

Hunting and habitat distribution

Hunting and distribution of sanctuaries and other habitats were the main factors affecting pintail distribution during September - March in the Grassland EA.

During Prehunt, pintail distribution tracked distribution of flooded habitat. Variation in water supplies, location of canal repairs and other factors that impacted flooding schedules accounted for most variation in pintail distribution. Pintails that used the SGL during Prehunt were more likely to return there during the hunting season, indicating that Prehunt habitat distribution also influenced pintail distribution during the hunting season.

Variation in hunting pressure and distribution of both hunted and nonhunted habitats were important factors affecting pintail distribution during the hunting season. On shoot days, pintails were concentrated on public- area sanctuaries. Newly restored wetlands in the Kesterson NWR sanctuary attracted pintails and likely contributed to the decline in shoot-day use of private areas in 1993-94. At dusk, most pintails, except at Merced NWR, dispersed to private duck club wetlands where they remained until near dawn. This indicates that, by the start of hunting, the availability of preferred pintail food resources was lower on most public areas than on private clubs. With no sanctuaries nearby, pintail use of the SGL remained low until late winter, probably at which time food in habitats nearer sanctuaries became depleted and pintails were forced to make longer feeding flights. Restored Salt Slough WA wetlands adjacent to San Luis NWR, the main shoot-day sanctuary, likely contributed to the decline in night use of private lands in 1993-94. Most pintails remained on private areas on nonshoot days but a greater percentage returned near dawn to public sanctuaries on the day after hunting than 2 days after hunting. The higher return rate to sanctuaries the day after hunting was probably because some pintails simply continued their successful survival strategy of returning to refuges near dawn. However, we did not measure disturbance rates and disturbance due to hunters lingering on duck clubs or other factors may have been greater the day after hunting than 2 days after hunting. Other subtle differences in hunting pressure affected pintail distribution. Pintail use of private areas was greater on Wednesdays than weekends probably because most hunters were from outside the Grassland EA vicinity and fewer made the trip for a 1-day Wednesday hunt than a 2-day weekend hunt (Grassland Water District, Los Banos, California, unpublished data). Greater hunter success (CDFG and Grassland Water District, Los Banos, California, unpublished data) probably allowed hunters to bag limits and vacate wetlands earlier during Hunt2 than Hunt1, contributing to the increased pintail use of private areas that we observed during Hunt2. Fog that occurred mostly during Hunt2 (National Oceanic and Atmospheric Administration, Asheville, North Carolina, unpublished data) may have hidden pintails from hunters and also helped pintails remain on private clubs. Late-winter flooding and pintail use of EGL habitats varied with late-winter precipitation. Many habitats on the fringe of the Grassland EA received their first heavy use during Posthunt, indicating preferred foods were still available in those

habitats but had been depleted in most habitats nearer sanctuaries.

Habitat quality

In addition to habitat distribution, there was some evidence that habitat quality affected pintail distribution. Pintail use of private areas at night, when pintails primarily feed, was lowest during 1991-92. The continuing drought that year prevented summer irrigation of many private wetlands and probably reduced seed production in private wetlands below that of irrigated public wetlands. Waterfowl refuging theory predicts that when food supplies are low, feeding flight distances from sanctuaries will increase. Thus, low productivity of private wetlands in 1991-92 may also explain why a greater percentage of pintails flew to the distant South Clubs during Hunt1 and Split in that year compared to later years.

Pintail age

Age-related differences in individual experience may also have influenced pintail movements and distribution. AHY females left sanctuaries at a lower rate than HY females at dusk on shoot days, perhaps because AHY pintails were more likely to have experienced when hunters were still afield near dusk on shoot days. AHY females were also more likely than HY pintails to use the EGL, perhaps because most EGL habitats did not flood until late winter and HY females had no experience from prior years that those habitats became available with late-winter rains.

Limitations of our data

We used methods that minimized biases and allowed wide application of results. However, our findings should be considered in the light of our sampling methodology and other constraints. Logistics prevented us from studying males and applying our results to males should be done with an understanding that male and female movements may differ. We radio-tagged pintails throughout the SJV in accordance with surveyed abundance, but because it would have been difficult and disruptive to capture pintails throughout winter, we restricted trapping to Prehunt. Movements of pintails that arrive in the SJV after we trapped may differ from birds that we tracked. Our estimate of Prehunt distribution may have been biased because of our inability to capture pintails in all areas where they were abundant (i.e., Merced NWR, North Clubs; CDFG, Sacramento, California, unpublished data). However, the bias was probably not severe because radio-tagged pintails did move into the few pintail concentration areas that we did not sample. The low use of duck clubs measured on shoot days probably underestimated actual exposure of pintails to hunters. Pintails need only fly over or visit a hunted area briefly in order to risk being harvested whereas radio-tagged pintails must land in one location for several minutes for us to triangulate their location. Although missing a few minutes of use does not critically bias estimates of distribution, it does explain why

hunting mortality was high (Fleskes[10] 1999) relative to the low level of private-area use measured on shoot days.

MANAGEMENT IMPLICATIONS

Pintail distribution during this study changed primarily in response to changes in hunting pressure but also to distribution of hunted and nonhunted habitats. Our data can serve as a baseline to evaluate impacts to pintail distribution of future management changes in the Grassland EA. NWRs and WAs established during the last 30 years in the NGL and EGL have replaced San Luis Reservoir (CDFG, Sacramento, California, unpublished data) as the major pintail shoot-day roost site. Creating new sanctuaries in the future will also likely redistribute pintails. If new sanctuaries spread pintails more widely, then risk of catastrophic disease loss could be reduced. However, if pintail distribution or movements are changed in a way that reduces pintail harvest opportunity on some clubs, management of their habitats may change, impacting pintails and other wildlife dependent upon similar habitats. Understanding pintail movement can provide insight on likely impacts of habitat changes. For instance, knowing that many Merced NWR pintails fly to the SGL at night, we predict that habitat improvements in the EGL may reduce pintail abundance in the SGL. Establishing a SGL sanctuary would likely increase pintail use there.

To maximize pintail use of their areas, managers must provide attractive feeding and roosting habitats throughout the wintering period. Pintails were more likely to use areas during the hunting season that they frequented during Prehunt, indicating that early season habitat conditions influences pintail use later in winter. Opportunity to harvest pintails often arose during this study from pintails either staying in an area in the morning after feeding there at night or returning there in early evening to feed. Thus, the availability of adequate water supplies for summer irrigation to enhance production of waterfowl foods is crucial for a successful pintail hunting program. Most pintails left private clubs to roost elsewhere, even during nonhunting intervals and on nonshoot days, indicating that availability of diurnal roost sites may be limiting pintail use of private areas. Thus, providing additional undisturbed roosting sites on duck clubs would likely improve pintail use and harvest opportunity on duck clubs while also distributing pintails more widely throughout the Grassland EA and reducing risk of catastrophic disease losses.

An expanded program of nonshoot days would increase pintail use of private areas during the hunting season but may require enforced mandates. More pintails used private clubs on nonshoot than shoot days and on the second than first nonshoot day, indicating that an expanded nonshoot day program would increase pintail use of private areas. However, despite increased effort during 1992-93 to encourage voluntary compliance of nonshoot days, some clubs continued to hunt on some nonshoot days (Grassland Water District and Grasslands Resource Conservation District, unpublished data), and pintail use of private areas on nonshoot days did not increase. Thus, like other "tragedy of the commons" (Hardin 1968) situations, because the reward (i.e., duck harvest) for hunting on nonshoot days increases as duck abundance on private areas

increases, complete compliance will probably only be achieved when the penalties of hunting on nonshoot days exceed the rewards.

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