Regional Fidelity and Movement Patterns of Wintering Killdeer in an Agricultural Landscape

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Abstract.—Killdeer (*Charadrius vociferus*) is a common and widespread North American species for which there are few studies of residency patterns and movements. We quantified fidelity and movement patterns of 24 radio-tagged Killdeer in the Willamette Valley of Oregon during the winter of 1999-2000. Results from telemetry surveys and census efforts revealed that the group monitored was composed of winter residents (63%), winter transients (26%), and year-round residents (11%). Movements were localized with birds detected at an average distance of 5.15 ± 0.91 (SE) km from the site of capture. Mean home range size (95% kernel) was 7.73 ± 3.19 km^2. However, results also indicated periodic exploratory movements, with some birds detected up to 30 km from marking sites. Overall, individuals exhibited a low degree of fidelity to specific sites and were detected at an average of 11.9 ± 1.1 sites. No differences were found in monthly movement patterns. In almost all cases, year-round residents were more sedentary than winter residents and winter transients. Results indicate a complex regional population structure and highlight the need to consider both migrant and resident birds, as well as seasonal differences in habitat needs and space use requirements, in future conservation planning efforts. *Received 29 August 2001, accepted 20 October 2001.*

Key words.—Agricultural landscape, *Charadrius vociferus*, home range, Killdeer, movements, Oregon, Willamette Valley, wintering.

Waterbirds 25(1): 16-25, 2002

Killdeer (*Charadrius vociferus*) are one of the commonest shorebird (suborder: Charadrii) species in North America. The range of this predominantly temperate breeding species extends from the southern edge of the Arctic Circle to the Caribbean and northern areas of South America (Bent 1929; Jackson and Jackson 2000). Recent data summaries from large-scale avian surveys indicate long-term declines in Killdeer throughout segments of their range, with the most severe declines occurring in parts of Canada and the western United States (Page and Gill 1994; Sanzenbacher and Haig 2001). However, there has been a general lack of concern regarding their status, presumably because they are a visible species that often occur in altered and degraded habitats (e.g., urban and industrial developments). Efforts to determine causes of decline and identify populations at risk are further complicated by a general lack of information on basic Killdeer ecology.

Most Killdeer research has focused on breeding behavior (Mace 1971; Nol 1980; Schardien 1981; Mundahl 1982; Nol and Lambert 1984; Brunton 1988a,b,c, 1990; Powers 1998; Plissner *et al.* 2000). The few nonbreeding studies have been limited to aspects of social organization (Myers *et al.* 1979; Heck 1985) and habitat use (Brush 1995; Colwell and Dodd 1997) during winter. Killdeer winter in large numbers in northern temperate regions; thus a major segment of the population is exposed to pressures associated with adverse weather conditions, such as increased costs of thermoregulation (Castro *et al.* 1992), decreased foraging opportunities (Dugan *et al.* 1981), and enhanced risk of predation (Whitfield *et al.* 1988).

Killdeer occur in a range of open wetland and upland habitats; however, these habitats are some of the most threatened in North America. As a result of the conversion of native habitats to urban and agricultural areas, less than half of the wetlands that existed prior to European settlement remain today (Dahl 1990) and losses of upland habitats, such as native prairies, are even more extensive (Samson and Knopf 1994). Furthermore, the continued degradation and alteration of these habitats have been implicated in widespread declines of numerous avian species, including shorebirds (Haig

1992; Knopf 1994, 1996; Page *et al.* 1995; Brown *et al.* 2000). The potential effect of these changes across the landscape on Killdeer numbers is not well understood (Sanzenbacher and Haig 2001).

The Willamette Valley in western Oregon is a heavily altered landscape in which most native upland and wetland habitats have been converted for agricultural purposes (Hulse 1998). Regardless, vast areas of seasonally flooded agricultural fields attract large numbers of nonbreeding shorebirds and other waterbird species (Gabrielson and Jewett 1940; Budeau 1992). The region is an important area for Killdeer that winter at northern latitudes and supports high densities of birds. In some cases, Killdeer occur in single, loose flocks of up to 1,000 birds. Previous studies of breeding Killdeer have suggested a latitudinal gradient in the proportion of migrant versus resident individuals (Jackson and Jackson 2000). Further, there may be differences in winter movements of migrants versus year-round residents (Schardien 1981; Heck 1985). However, there is little quantitative information on residency patterns or seasonal movements across most of the species range. Thus, we radio-tracked Killdeer wintering in the Willamette Valley to determine their fidelity, movement patterns, and space use.

STUDY AREA

We studied Killdeer during the winter months (December-March) of 1999-2000 in the Willamette Valley of Oregon (45°N, 123°W; Fig. 1). The Willamette Valley is a lowland area of northwest Oregon, located approximately 60-km inland from the Pacific Coast and bordered by the Coast Range to the west and Cascade Mountains to the east. Winter climate is characterized by average temperatures of 3-5°C and extensive rain. The majority of the annual precipitation (30-year mean = 104.8 cm) occurs from December through February (Taylor 2000). Regional land cover consists of large tracts of cultivated grass-seed fields interspersed with various row crops, pasture, and areas of urban and industrial development (Hulse 1998). As a result of land use practices, precipitation levels, and occurrence of hydric soils, dominant waterbird habitats during winter months are a dynamic assemblage of agricultural wetlands with a high degree of annual and seasonal variation in distribution and site characteristics. Vegetation at sites varies with crop type as well as the stage of the winter growing season and there is frequent formation of sheet water and ponds. However, drainage practices, such as construction of artificial waterways and tiling,

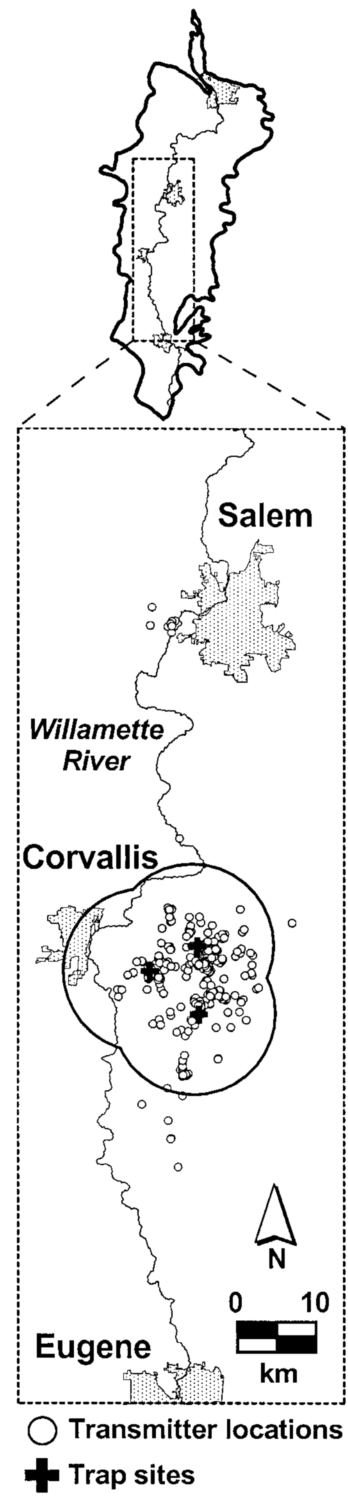

Figure 1. The Willamette Valley ecoregion and areas covered during aerial surveys (dotted line) and ground surveys (solid line) for radio-marked Killdeer during the winter months of 1999-2000. Capture sites and all detections of radio-marked birds are indicated.

are widespread. The result is a complex and shifting mosaic of saturated soils and flooded agricultural fields during winter months. In addition, there are numerous moist-soil managed wetland refuges and hunt clubs located throughout the region.

METHODS

Surveys

Weekly roadside shorebird counts were conducted as part of associated studies of shorebirds in the Willamette Valley. Census efforts covered ten focal areas that were approximately 15 km^2 each and were selected as representative of the distribution and spatial array of local habitats (O. Taft, pers. comm.). Protocol used was to drive all roads within designated areas on a weekly basis. Observers scanned all sites with potential shorebird habitat and counted all shorebirds. For each census period, results were summed across all focal areas. These counts represent an index of shorebird numbers within a representative segment of the Willamette Valley and provide information on temporal changes of winter Killdeer numbers.

Radio-telemetry

We captured and radio-marked 20 Killdeer from 29 November to 3 December 1999, and an additional four birds on 2 February 2000. Killdeer were captured with leg-noose traps (G. Page, pers. comm.) during daylight hours on three agricultural sites, located approximately 8 km apart (Fig. 1). Birds were fitted with 2.75-g radio-transmitters with individual frequencies and an estimated lifespan of 16 weeks (model PD-2, 2.75 g, Holohil Systems, Canada). Transmitters were attached using a leg-loop harness (Rappole and Tipton 1996; Sanzenbacher *et al.* 2000). In addition, birds were banded with a U.S. Fish and Wildlife Service aluminum band and an unique combination of ultra-violet resistant Darvic color bands. Total weight of transmitters and auxiliary markers averaged 3.93 g and did not exceed 4% of a bird's body weight. Sexing and aging of birds at time of capture was not possible due to a lack of reliable morphological characteristics to differentiate groups (Jackson and Jackson 2000).

We conducted surveys for radio-marked birds for the duration of the transmitter lifespan, approximately December through March. Tracking efforts included daily ground surveys that each week covered all areas within a 10-km radius of trap sites. Sites with large flocks of Killdeer and areas with previous detections of radio-marked birds were visited with greater frequency. In addition, bi-weekly aerial surveys and periodic exploratory ground surveys covered extensive areas of the Willamette Valley (Fig. 1). Most tracking efforts occurred during daylight hours (approx. 08.00-18.00 h); however, night ground surveys were conducted at least once per week.

Ground telemetry involved use of two trucks fitted with four-element dual-Yagi antennas and null-peak systems. Survey protocol was to scan for all frequencies at two-second intervals in each of four cardinal directions. This process was repeated every 1.6-3.2 km in order to ensure complete coverage of areas. Following detection of a transmitter, observers determined the location of the radio-marked bird based on the intersection of signal bearings taken from two or more points. All location information was collected within a 10-min period in order to reduce the probability of a bird moving during data collection. Program LOAS (Ecological Software Solutions, http://www.ecostats.com) was used to derive location estimates and the associated error (error polygons, error ellipses). In some cases, it was possible to get visual sightings of radio-marked birds or associated flocks and record information such as flock size and habitat type (e.g., crop type). As weather permitted, bi-weekly aerial surveys were conducted in a Cessna 182-RG with an H-element antenna attached to each wing strut. Survey protocol was to fly latitudinal transects at 2 to 4 km intervals and at an altitude of approximately 457 m (1,500 feet). Locations of radio-marked birds were plotted on topographic maps. Field trials were conducted with test transmitters to determine the range of transmitter detection and accuracy of estimated locations for both ground and aerial surveys.

Statistical Analyses

We used multiple approaches to examine fidelity, movement patterns, and space use of Killdeer. Data were evaluated for potential biases prior to calculation of parameter estimate. A minimum of 45 min separated locations for a given individual to reduce effects of autocorrelation. This interval was determined as a sufficient time for an individual to traverse the extent of its home range (Swihart and Slade 1997; De Solla *et al.* 1999; Otis and White 1999) and was based on observations of Killdeer movements within the study area. An exception to this rule was when observers tracked direct movements of birds between sites. In addition, no more than three locations were permitted for an individual in a single day. For cases that violated these criteria, a random subset of data was selected for inclusion in calculations.

To assess the regional fidelity of Killdeer during the wintering period, we determined the departure date of each radio-marked bird from the study area. Departure was estimated as the last date each radio-marked bird was detected. Fidelity of birds to local areas was evaluated based on the number of sites at which individuals were detected. We used a geographic information system (GIS; ArcView, ESRI Inc.) to plot bird locations on digital map layers with road systems and general habitat classes (O. Taft and S. Haig, unpubl. data). Sites were differentiated based on physical borders (e.g., roads) and habitat types.

Killdeer movements were quantified as the sum of linear distances an individual traveled between successive locations. In addition, we calculated the mean and maximum distance each bird was detected from its capture site. Finally, we calculated home ranges based on two different methods. Home range has been defined as the area utilized by an individual during normal activities for a given period of its life cycle (Burt 1943). We calculated minimum convex polygons (MCPs), using ArcView GIS software and the Animal Movement extension (Hooge and Eichenlaub 1997), to estimate the total area encompassed by movements of each individual (White and Garrot 1990). These estimates do not imply actual utilization of space due to the inclusion of large areas that separate bird locations. We determined actual space use of birds with a non-parametric fixed kernel method (Worton 1989). Previous work has established that fixed kernel estimators result in less bias relative to other home range procedures (Seaman and Powell 1996). Estimates were calculated with KERNELHR software (Seaman *et al.* 1998) using least squares cross-validation to determine smoothing parameters and automatic selection of grid cell size (Worton 1995). We selected contour levels to represent home ranges with 95% of an individual's locations and derived core use areas based on 50% of locations for an individual.

Estimates of site fidelity, movements, and home ranges were summarized across the entire winter and for each monthly period. Sample size requirements of individuals for inclusion in summaries were based on visual assessments of scatterplots and simple regression analyses of each parameter versus sample size. Estimates of number of sites visited, total distance traveled, mean distance detected from capture site, and maximum distance located from capture site were calculated for birds with at least ten locations across the entire winter. Monthly estimates were derived for birds with at least five locations within a given period. Winter home ranges and core use areas were summarized for individuals with at least 20 locations; however, sample size constraints prevented calculation of monthly estimates (Seaman *et al.* 1999).

We used one-way analysis of variance (ANOVA) tests to investigate potential monthly differences in sites visited and movements of wintering Killdeer (SAS/ASSIST/INSIGHT, SAS Institute Inc. 1997). In models with a significant overall F-statistic ($P < 0.05$), Fisher's least-significant-difference (LSD) tests were used to determine group differences. Sample size constraints prevented statistical comparisons of migrants versus residents so all birds were lumped for analyses.

Assumptions of independence of observations were violated in some cases due to the fact that certain individuals ($N = 11$) were represented in more than one monthly period. Therefore, we also conducted repeated measure ANOVAs, using an unstructured covariance structure, for birds with data across all monthly periods ($N = 9$). Results of these tests did not differ from the outcome of previous ANOVAs that included all data. Estimates of average and maximum distances from band sites were log transformed for analyses to meet assumptions of normality and homogenous variance. All values were reported as means with associated standard errors (±SE).

RESULTS

Killdeer Surveys

Sixteen shorebird surveys were conducted from 24 November 1999 to 28 March 2000 (Fig. 2). Killdeer totals summed across all census areas ranged from 119 to 8,162 birds per survey period. Numbers fluctuated in early winter, with an overall increase throughout December and peak winter counts occurring in the final two weeks of the month. A decline in numbers was observed in the latter part of January and continued for the duration of surveys.

Tracking Effort

Tracking efforts were initiated immediately after deployment of radios and continued until transmitters ceased operation or individuals departed the study area. Approximately 932 h of ground surveys and 29 h of aerial surveys resulted in 453 locations of radio-marked birds (mean 18.9 ± 2.9 locations per bird). Whereas the majority of radio-marked birds were located in areas of intensive ground surveys, scattered detections of Killdeer outside focal areas (Fig. 1) and aerial survey efforts suggested a high degree of coverage across the study area. Field trials indicated average transmitter detection range from telemetry trucks was 1.59 ± 0.06 km with a standard bearing error of 1.7° ± 0.2°. The mean distance from estimated locations of test transmitters ($N = 8$ transmitters) to actual locations was 24.2 ± 2.7 m. Detection range during aerial surveys was approximately 1.6-3.2 km and the accuracy of location estimates was 0.48 ± 0.14 km ($N = 4$ transmitters).

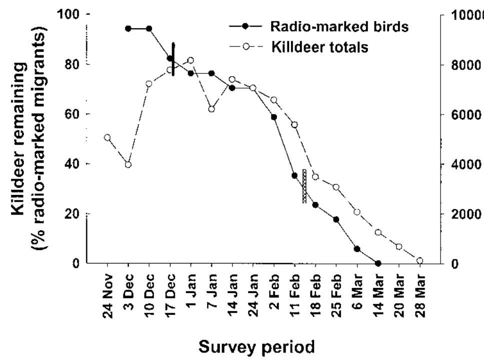

Figure 2. Proportion of radio-marked birds, excluding year-round residents and birds marked in late winter, remaining in the Willamette Valley (solid circles) and total numbers of Killdeer summed across all shorebird census blocks (empty circles) throughout the winter of 1999-2000. The primary axis (left) corresponds to proportion of radio-marked birds and the secondary axis (right) corresponds to Killdeer count totals. Mean departure date of radio-marked winter residents is indicated by hatched vertical bar and mean departure date of winter transients is signified by solid vertical bar.

Regional Fidelity

Most radio-marked birds were relocated in the study area following initial capture (23/24; 96%); however, individuals exhibited varying degrees of fidelity to the Willamette Valley over the winter. Most birds monitored from the beginning of the winter sampling period were *winter residents* (63% of radio-marked birds; 12/19) that were detected in the study area for extended periods prior to departing the region in February and March. In contrast, several radio-marked birds (26%; 5/19) departed the region earlier in winter during December and mid-January, and hereafter are referred to as *winter transients*. Fluctuations in Killdeer survey numbers over the same period support the contention that a proportion of the wintering birds departed the region (Fig. 2). Overall, the mean departure date of winter residents was 15 February and that of winter transients was 18 December. Based on the date of final detection and observations of nesting activities, we determined that two radio-marked Killdeer (11%, 2/19) were *year-round residents*. Another individual radio-marked in February also remained to breed in the study area.

Local Movements

Radio-marked birds were detected at 139 distinct sites and an average of 12.2 ± 1.0 sites per bird (Table 1). There were no differences in the number of sites individuals visited each month ($F_{2,27}$ = 1.43, n.s.). Similar numbers of sites were used by year-round residents and winter residents (Fig. 3). In some cases, birds exhibited greater site tenacity and used specific sites over extended periods. For example, winter resident #151.391 was detected at the same site on eleven different days.

The minimum total distance radio-marked birds traveled during the winter period averaged 52.4 ± 7.16 km. Estimates did not differ with respect to month ($F_{2,27}$ = 0.01, n.s.), but there was considerable individual variation. Whereas sample size constraints prevented statistical comparisons of winter residents and year-round residents, there were apparent differences between groups for monthly estimates, with year-round residents more sedentary than winter residents (Fig. 3).

In general, movements occurred within discrete areas, as the mean distance of locations from respective capture sites averaged 4.6 ± 0.85 km. Exceptions were two winter residents that shifted to more distant areas shortly after capture (see Fig. 1). Monthly period was not a significant factor in distance from capture site analyses ($F_{2,27}$ = 1.23, n.s.), although distances winter residents were observed from capture site gradually increased as the winter progressed. In contrast, year-round residents exhibited no apparent difference in movements over time (Fig. 3). Estimates of maximum distances that winter residents were detected from the capture site were as much as twice the average distance and suggest the occurrence of exploratory movements during the tracking period. Average maximum distance across all periods was 8.6 ± 1.29 km. These distances did not differ by month ($F_{2,27}$ = 1.91, n.s.).

Winter movements of Killdeer encompassed a mean area of 34.3 ± 8.0 km^2 (100% MCP). In contrast, home range estimates (95% kernel) were considerably smaller, with a mean utilization area of 6.7 ± 2.6 km^2. Similarly, core use areas (50% kernel) averaged 1.65 ± 0.70 km^2. In all cases, results indicated considerable individual variation and were suggestive of differences between winter residents and year-round residents (Table 2).

Table 1. Movements of wintering Killdeer in the Willamette Valley of Oregon, USA (1999-2000). Data presented are means ± SE.

Month[a]	N birds	N obs.	Sites visited	Total distance traveled (km)	Mean distance from capture site (km)	Max. distance from capture site (km)
December	11	102	6.1 ± 0.6	14.52 ± 2.73	2.57 ± 0.38	4.87 ± 0.84
January	13	117	5.9 ± 0.6	16.00 ± 3.50	5.03 ± 1.00	7.87 ± 1.32
February	14	150	4.8 ± 0.4	15.86 ± 2.28	3.87 ± 0.78	8.86 ± 2.61
Total[b]	13	375	12.2 ± 1.0	52.41 ± 7.16	4.61 ± 0.85	8.58 ± 1.29

[a]Calculated based on individuals with ≥5 locations within a monthly tracking period.
[b]Calculated based on individuals with ≥10 locations across entire tracking period.

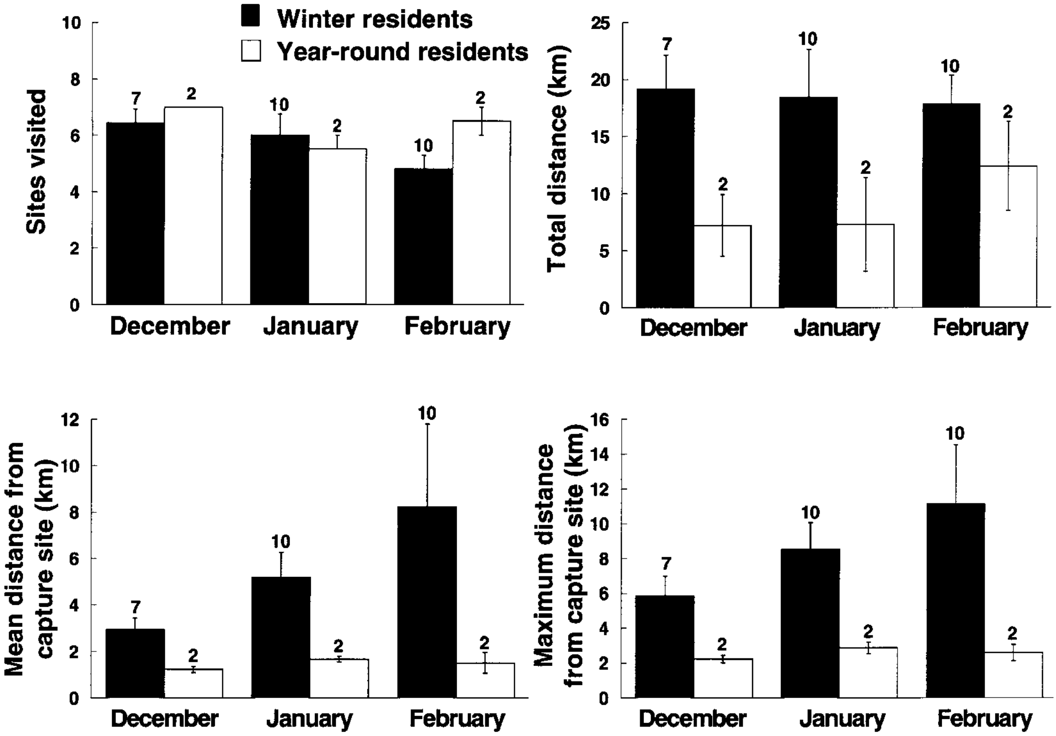

Figure 3. Comparison of sites visited, minimum total distance traveled, mean distance located from capture site, and maximum distance located from capture site for winter resident and year-round resident Killdeer during the winter months of 1999-2000 in the Willamette Valley, Oregon. Data presented are means with standard error bars.

Daily Activity Patterns

All locations of radio-marked Killdeer were in agricultural habitats, with greater than 50% of habitat observations (N = 191 observations) occurring in fields actively farmed for grass seed. Other crop types used by Killdeer included clover, peas, and sugar beets, as well as fallow fields and pasture. Killdeer showed a tendency to congregate in relatively large, loose flocks as average flock size associated with radio-marked birds was 82 ± 9.7 individuals (N = 149 observations). Movements were detected at all times of day; however, birds were relatively sedentary during diurnal and nocturnal periods. In contrast, dawn and dusk were periods of major movement activity, as birds located in afternoon hours and then relocated at night moved an average distance of 1.47 ± 0.25 km between sites (range = 0.34 to 3.54 km, N = 46 observations). For some individuals, use of specific diurnal and nocturnal sites was predictable over time, with crepuscular movements between particular diurnal and nocturnal sites.

DISCUSSION

Knowledge of avian movement provides insight into various aspects of the life history of a species and an array of ecological relationships, yet difficulties associated with detecting and quantifying movements have resulted in limited studies of movement behavior (Hansson *et al.* 1995; Haig *et al.* 1998; Webster *et al.*, in press). Killdeer exhibit complex and variable patterns of residency and timing of migration across the range of the species; however, knowledge of population structure is limited for most geographical areas and phases of the annual cycle. This information is most often derived from scattered observations of marked individuals or indirect methods such as census data (except see Plissner *et al.* 2000). Our results from tracking of radio-marked individuals

Table 2. Area encompassed by movements (100% MCP), home range size (95% kernel), and core use areas (50% kernel) of winter resident and year-round resident Killdeer in the Willamette Valley during the winter months of 1999-2000. Data presented are means ± SE.

	N radios	N obs.	Area encompassed by movements (km^2)	Home range (km^2)	Core use area (km^2)
Winter residents	8	249	39.18 ± 8.99	7.73 ± 3.19	1.92 ± 0.84
Year-round residents	2	86	14.73 ± 11.70	2.28 ± 2.05	0.58 ± 0.54

and concurrent surveys indicate considerable variation in winter residency status, timing of departure, and local movements of Killdeer in the Willamette Valley.

Regional Fidelity

Previous studies of Killdeer reported the occurrence of partial migration, in which both resident and migratory individuals occur in a given area, and suggest a latitudinal gradient in frequency of occurrence (Schardien 1981; Heck 1985). For example, Schardien (1981) determined that the majority of Killdeer at study sites in the southeastern United States were year-round residents. Our findings indicated that year-round residents accounted for a minority of Killdeer wintering in the Willamette Valley and thus was consistent with the proposed hypothesis that the proportion of migrants increases at more northern latitudes (Jackson and Jackson 2000). We found that year-round residents were relatively sedentary and nested within winter home ranges. Thus, the proportion of resident birds that we detected may reflect the fact that we only trapped birds at three sites. In addition, our findings relate to a specific sample marked in early winter and may differ depending on the timing of investigation.

Whereas we were unable to confirm the status of transients that departed the region in early winter (i.e., December and January), there are numerous competing, but not mutually exclusive hypotheses to explain the departure of these birds. For instance, it is likely that some individuals represent the delayed migration of local breeders and fledged juveniles. In some areas (e.g., Illinois, Nevada) Killdeer remain at breeding sites until forced south by local environmental conditions, such as lack of water or onset of harsh winter weather (Jackson and Jackson 2000; Plissner *et al.* 2000). In this case, it is possible that juvenile birds constitute the majority of late autumn and early winter migrants, because in many shorebird species that breed in temperate regions adults depart breeding grounds prior to juveniles (Haig 1992; Paulson 1995; Nol and Blanken 1999).

Early winter departures may represent a protracted or facultative migration, in which birds annually winter as far north as possible but retain the ability to move further south as environmental conditions deteriorate (Terrill and Ohmart 1984). Previous reports indicate that numbers of Killdeer overwintering in Oregon decline during winters with severe weather (Nehls 1994) and shorebird surveys in the Central Valley of California have detected mid-winter increases in Killdeer numbers (Shuford *et al.* 1998). The winter climate of the Willamette Valley is generally mild; however, periods of intense rains as well as temperatures below 0°C occur and are known to influence shorebird movements (Warnock *et al.* 1995; Sanzenbacher and Haig, in press).

An additional explanation for early winter departure of Killdeer is that a segment of the winter population is composed of wandering individuals (Matthysen 1993; Reed *et al.* 1999). In a study of wintering Killdeer in North Carolina, Heck (1985) suggested the presence of mobile winter visitors. Dispersal patterns of Killdeer are not well understood, but studies suggest that like most shorebirds, they exhibit low rates of philopatry (Lenington and Mace 1975; Colwell and Oring 1989; Powers 1998), yet strong breeding site fidelity (Jackson and Jackson 2000). Also, both sexes can breed at one year of age

(Jackson and Jackson 2000). Thus, juvenile birds may represent the major proportion of winter transients as the extended winter movements of these birds provides a mechanism to prospect for and evaluate potential breeding sites (Reed *et al.* 1999).

Local Fidelity and Movements

At a local scale, individual Killdeer visited numerous agricultural fields in the Willamette Valley throughout the winter period, such that the degree of local site fidelity was relatively low. In contrast, other studies of wintering shorebirds reported a high degree of local site fidelity (Warnock and Takekawa 1996; Drake *et al.* 2001). However, these studies inferred site fidelity based on scale of local movements, not persistence at specific sites as defined in our study. Using a similar scale, Killdeer wintering in the Willamette Valley are site faithful. Observed fidelity of nonbreeding shorebirds at coastal sites has been attributed to occurrence of predictable and abundant resources (Skagen and Knopf 1993; Drake *et al.* 2001). Conversely, agricultural land use practices and variation in winter precipitation at inland sites in the Willamette Valley result in a highly fragmented and changing landscape. For example, crop types, planting regimes, and growing conditions influence the density and height of vegetation at different sites. Therefore, use of multiple agricultural sites within a relatively small home range is likely a response to the complex spatial and temporal variation in the distribution of resources. In addition, Killdeer at inland sites tend to congregate in loose flocks. Whereas flocking behavior has been identified as a strategy that lessens vulnerability to predators (Creswell 1994; Barbosa 1997), switching sites over time may also prevent predators from cueing in on specific sites where birds congregate.

The total distance Killdeer traveled did not indicate seasonal differences in the scale of movements; however, average distances that birds were detected from capture sites suggest that areas of use shifted and expanded as the winter progressed, in particular for winter residents. A similar trend was observed for radio-marked Dunlin over the same period (Sanzenbacher and Haig, in press). These movement patterns likely reflect both physiological factors related to the onset of spring (e.g., premigratory restlessness), as well as changes in the spatial array and distribution of local resources (e.g., food). For example, precipitation levels decrease as spring approaches and wetland mapping conducted concurrent with our studies revealed a reduction in the area of saturated soils that are indicative of shorebird habitats (O. Taft and S. M. Haig, unpub. data).

Seasonal movements and space use suggested differences between migrants and resident birds; however, small sample sizes prevented direct statistical comparisons. Regardless, year-round residents tended to remain closer to the capture site, with smaller home ranges than winter residents (i.e., migrants). In addition, at least one of the two individuals identified as a year-round resident nested near the centroid of its winter home range. Similarly, year-round resident Killdeer in other regions often remain on breeding territories during winter (Schardien 1981; Heck 1985).

Finally, a comparison of movements and space use from other Killdeer studies indicate that breeding birds in other regions exhibit movements at a much smaller scale than Killdeer wintering in the Willamette Valley (Schardien 1981; Plissner *et al.* 2000). Our estimate of home ranges (95% kernel) for wintering birds were an order of magnitude greater than that reported for breeding birds in the Great Basin (Plissner *et al.* 2000). Thus, differences in movements among breeding and wintering birds highlight the need to consider seasonal differences in habitat needs and space use requirements.

ACKNOWLEDGMENTS

Funding and logistical support was provided by the USGS Forest & Rangeland Ecosystem Science Center, U.S. Fish and Wildlife Service, Oregon Department of Fish and Wildlife, and Bureau of Land Management. We thank Jen Dhundale, Matthew Henschen, Wendy Jensen, Heidi Packard, and Michael Taft for assistance with all aspects of data collection. The expertise of pilot Wayne Moreland was greatly appreciated. Numerous landowners provided access to properties and information on natural history and land use practices in the region. We also thank Dylan Kesler, Lewis Oring, Dan Roby, Oriane Taft, and an anonymous reviewer for insightful comments on the manuscript.

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