Factors influencing farmland habitat use by shorebirds wintering in the Fraser River Delta, Canada

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Abstract

Like many other coastal regions of the world, open-soil agricultural lands in the Fraser River Delta provide roosting and feeding habitat for non-breeding shorebirds that supplements intertidal habitat. Focusing on dunlin (*Calidris alpina pacifica*), black-bellied plover (*Pluvialis squatorola*), killdeer (*Charadrius vociferus*), and their avian predators (raptors), diurnal and nocturnal high tide surveys were conducted across the non-breeding period, October–April (1998–2000). All three shorebirds showed positive relationships with laser leveling, and recent manure and fertilizer application. Day length was negatively related to field use by dunlin, but positively related for black-bellied plover and killdeer. Amount of recent precipitation was positively related to dunlin and negatively related to black-bellied plover and killdeer field use. Results suggest that providing a mosaic of different crop types, autumn mowing, laser leveling, application of fertilizer and manure, and minimizing habitat fragmentation through maintenance of large fields are habitat management strategies that may enhance farmland for shorebirds during the non-breeding season in this region.
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1. Introduction

The Fraser River Delta, the largest estuary on Canada's Pacific Coast, provides valuable wildlife habitat and rich soils for agriculture. This delta has one of the mildest climates in Canada, with average daily temperatures above freezing year-round, and mean total annual rainfall of approximately 1055 mm. The delta supports internationally significant numbers of shorebirds during the non-breeding season (Butler and Campbell, 1987; Butler, 1994) including circa 40,000 dunlin (*Calidris alpina pacifica* L.) and 2000 black-bellied plovers (*Pluvialis squatorola* L.) hereafter "plover" and smaller numbers of killdeer (*Charadrius vociferus* L.). Adjacent to the approximately 257 km^2 of tidal mudflat is an approximately 127 km^2 area of farmland created in the late 1800s, when salt marshes were diked and drained. Overwintering raptors whose winter diet includes shorebirds also abound in the delta, including northern harriers (*Circus cyaneus* L.), red-tailed hawks (*Buteo jamaicencis* Gmelin), and peregrine falcons (*Falco peregrinus* Tunstall). Winter field cover ranges from bare soil to tall unharvested grasses and bushy crops that remain fairly stable for the duration of the shorebird over-wintering period. Farmland represents the largest terrestrial component (about 41%) of the Fraser Delta's landscape. Although recently designated a Western Hemisphere Shorebird Reserve Network site of hemispheric importance, less than

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5% of the delta is currently protected for wildlife. A proportion of the delta was designated as an Agricultural Land Reserve (ALR) in the 1970s in recognition of the high quality soils and the threat of encroaching urban development (BC Land Reserve Commission, unpublished data). Nevertheless provincial ALR designation does not protect the land from conversion to greenhouses, a trend that has eliminated more than 2% of previously open-soil farmland over the past decade (Corporation of Delta, unpublished data). ALR designation can also be challenged, in some cases allowing encroachment of urban development (Campbell, 2006). Motivated by the need to set conservation priorities and enhance farmland value for shorebirds, study objectives were to investigate the extent to which spatial and temporal variation in field use could be predicted by environmental, biological, landscape, and farming factors.

2. Methods

Data were collected from October to April in 1998–1999 and 1999–2000 in fields within the Fraser River Delta, British Columbia, Canada (49°10′N, 123°05′W). Eighty-one fields were surveyed in year one and 57 in year two. Over the two field seasons, 2278 (range 50–302 per month) field visits by day and 2410 (range 51–329 per month) field visits at night were made. Table 1 outlines the number of fields of each cover type, and summarizes farming practices. Cover types (type of crop or residue present) across the delta were determined by visually surveying all fields in early October, after harvesting, and later confirming crop type with farmers. During the first

year of study (1998–1999), the distribution of winter cover types across the delta in early October was as follows: grass/pasture typically comprised of orchardgrass (*Dactylis glomerata* L.) and tall fescue (*Festuca arundinacea* Schreb.) (35%), bare earth (24%), winter cover crops (typically winter cereals planted in late August or early September) (18%), grassland set-aside and old fields (comprised of senescent perennial grasses, broadleaved plants and a small amount of new growth) (8%), horticultural crops such as winter cabbage and kale (*Brassica* spp.) and strawberries (*Fragaria* spp.) (6%), corn (*Zea mays* L.) fields harvested for whole crop silage leaving approximately 15-cm tall corn stalks (3%), turf and golf courses (3%), bush berries such as currants (*Ribes* spp.), cranberries, blueberries (*Vaccinium* spp.) (2%), and greenhouses (2%). Fields in this study region are typically bounded by drainage ditches, and in some cases field margins include tall grasses or hedgerows, or both.

Data on field size and distance from shore were from an Agriculture and Agri-Food Canada GIS base map. In 1998–1999, a random sample of fields was surveyed (Cochran, 1977), stratified by field size, distance from shore, and cover type, and selected in proportion to their availability. Many of the 1998–1999 fields were never used by the shorebirds (25% for dunlin, 34% for plover, and 72% for killdeer), so 1999–2000 surveys focused on a "high use" area of fields within 1 km of the shore. In the second field season, surveys were conducted based on a transect design, with the inclusion of nearby fields that had been surveyed in the previous year. The total area surveyed over the two field seasons constituted approximately 10% of the agricultural land in the region.

Table 1
Number of fields of each cover type that were sampled in each year, and summary of farming practices data

Year/winter cover type	Fields (no.)	Field size (ha)[a]	Distance from shore (km)	Crop establishment (years)	Vegetation height (rating)[b]	Fertilizer past year (% fields)	Manure past year (% fields)	Manure past 5 years (% fields)	Laser leveled (% fields)
1									
Bare	25	8.1 (1.1)	1.96 (0.34)	1.6 (0.8)	0.04 (0.04)	24	12		20
Cover crop	17	7.0 (0.0)	1.59 (0.30)	0.3	1.02 (0.15)	29	24		24
Grassland set-aside	4	6.7 (3.3)	1.75 (0.48)		2.00 (0.00)				
Grass/pasture	21	7.4 (1.0)	2.00 (0.32)	2.9 (0.6)	1.10 (0.10)	24	33		14
Tall corn	2	1.4 (0.6)	1.00		2.00 (0.00)				
Winter vegetables	6	4.4 (1.5)	1.33 (0.33)	0.3	0.67 (0.21)	33	17		17
Berries	2	7.3 (1.0)	2.00 (1.00)	10.0	2.50 (0.50)	50	0		50
Greenhouse	1	15.5	1.00		1.00				
Turf/golf course	4	22.7 (13.5)	4.25 (1.65)		1.00 (0.00)				
2									
Bare	28	7.8 (0.9)	1	0.1 (0.0)	0.25 (0.10)	46	25	36	39
Cover crop	18	6.4 (1.0)	1	0.1 (0.1)	0.82 (0.21)	33	11	33	33
Grassland set-aside	7	7.5 (1.7)	1	0.6 (0.1)	1.70 (0.08)	14	0	0	0
Grass/pasture	7	6.5 (0.8)	1	0.4 (0.1)	0.88 (0.32)	43	43	43	0
Winter vegetables	4	4.7 (1.7)	1	1.8 (1.3)	1.50 (0.28)	50	50	50	50
Berries	2	3.9 (1.8)	1	0.5	2.00	50	50	50	50

[a] S.E.s are in bracket immediately to the right of corresponding means.
[b] Mean of vegetation height rating scale.

Environment Canada weather data (wind speed, wind direction, percent cloud cover, temperature, and precipitation) were obtained from the Vancouver International Airport, 15 km north of the study area. Data on day length and moon illumination at midnight (a measurement based on moon phase) were obtained from the U.S. Naval Observatory Astronomical Applications Department website (http://aa.usno.navy.mil/data/docs/RS_OneYear.html). Tide heights at Point Atkinson, Vancouver, to the nearest 15 min reading were obtained from the Canadian Hydrographic Service, Institute of Ocean Sciences. Average vegetation height was visually estimated for each field as one of three categories (0, 0–10 cm, or >10 cm).

Farmers were interviewed to collect farming practice histories for surveyed fields. Not all farmers agreed to be interviewed, thus these data come from a possibly less-random subset ($n = 51$ of 81) of surveyed fields. However, there was no obvious indication that farming practice in this field subset was different from the wider area.

Regular field surveys were conducted within a 5 h period pivoting around high tide, the period of highest field use by shorebirds (Butler, 1999; Shepherd, 2001). Surveys at both diurnal and nocturnal high tides involved counting numbers of feeding or roosting dunlin, plover, killdeer, and raptors seen during one complete scan of the entire field using a telescope and binoculars in daytime, or a monocular night-vision scope (ITT[TM] generation III pocketscope, with Star Tron[TM] catadioptic 4.5× lens) at night. Scans were followed by a 2 min playback of dunlin, plover and killdeer non-breeding vocalizations, with any acoustic response documented. At night, birds were flushed using a spotlight, as a final check for any previously undetected birds. At each field, the total number of birds per species was determined from the method that detected the maximum number of birds, and converted to presence/absence data (0/1).

Because not all fields could be visited within the 5 h time window (high tide ± 2.5 h), fields were divided into five survey routes in year one, and two in year two. To avoid a temporal bias of fields being visited at the same time in relation to tide, surveys were split into sub-sections, and the order in which sub-sections were visited was systematically rotated. Each field was visited approximately once every 12 days during the day, and once every 11 days at night, with surveys scheduled so that the entire route could be completed in daylight or darkness.

2.1. Statistical analyses

Analyses of variance/covariance were conducted with a binomial probability distribution and logit link function model specifications. For the analysis, each data point was converted to a binomial proportion by dividing the number of bird occurrences by the total number of assessments in a given field, thus accounting for availability of particular field types. Variance estimates from the analyses included variation among field-by-year combinations, a within field estimate (the equivalent of an across time variance estimate), and a residual estimate, which included unaccounted spatial variation and measurement error.

Multivariate analysis investigated the association between field characteristics, bird species occurrence, and winter cover (field type). The data matrix consisted of winter cover types (combining all fields of the same type) as rows and field characteristics and bird species occurrence as columns. A binomial proportion of bird species presence/absence and field characteristic (yes/no) data was calculated by summing across years, other time factors if applicable, and fields, for each winter cover type, then dividing by total fields. Continuous interval variables (e.g. field size) were averaged across years and fields for each winter cover type. A multidimensional preference analysis was conducted for day and night data separately with the PRINQUAL procedure of SAS (SAS Institute Inc., 1999). An identity transformation was used for most variables, and a monotonic transformation for variables more categorical in nature (distance from shore, vegetation height, and time from crop establishment). The results of the multidimensional preference analysis were summarized in a biplot based on standardized principal component scores for each winter cover type plotted as points in ordination space. Analysis of variance (GLIMMIX macro and the PROC MIXED procedure of SAS) was conducted to confirm if bird occurrence differed across winter months and among winter cover types (Littel et al., 1996; SAS Institute Inc., 1999). The response variable for the analysis was the number of occurrences for a bird species relative to samplings. Analysis 1 considered month and time of day as fixed effects. Analysis 2 considered winter cover type and time of day as fixed effects. Year was a random effect in both analyses. Measurements across months were repeated for each field, and consequently modeled as variation across experimental units (fields within years). Different covariance structures to model this variation were compared using corrected Akaike's Information Criterion (AICC), with a first-order autoregressive covariance structure being best for both analyses.

Covariance analysis was also conducted to determine if environmental parameters and bird occurrence affected bird preferences. Data for each bird species were not summed across time factors (e.g. month). The analysis was conducted separately for each time of the day with the GLIMMIX macro in conjunction with PROC MIXED in SAS (Littel et al., 1996; SAS Institute Inc., 1999). Environmental variables were included as independent regressors and the occurrence of other bird species and raptors were included as independent class factors. Variations across time (date) were modeled as discussed previously.

3. Results

Summarizing field use across the entire study period, 72% of the total fields sampled were used by dunlin at night, and 42% of fields were used by day. For plover, killdeer and

raptors, the diurnal pattern was reversed, with significantly greater field use by day: plover used 33% of total fields diurnally and 20% nocturnally; killdeer used 60% of fields diurnally and 46% nocturnally; raptors used 96% of fields diurnally and 62% nocturnally. Variance estimates for winter cover type use within the same fields, a surrogate for the effect of time of season, were statistically significant only for killdeer. Variance estimates among fields, an indication of the effect of landscape context, were consistently significant for all shorebird species during both day and night. Time of day was a significant factor determining field use by shorebirds as well as raptors (Table 2, analysis 1, all $P < 0.001$). Field use also differed by time of season (month) for killdeer and raptors (Table 2, analysis 1), with possibly weaker plover and dunlin seasonal differences. Cover type effects appeared stronger by day than at night (Table 2, analysis 2). Day use by plovers was relatively high in February–April and by raptors in October–February, while night use did not change seasonally.

Winter cover type was a significant factor influencing field use by all species both day and night (year as random effects, others fixed, all $P < 0.02$), with the exception of dunlin, which nevertheless showed a weak nocturnal effect ($P = 0.06$). Dunlin and killdeer winter cover preferences differed between day and night (Fig. 1) with significant interactions between winter cover and time of day (year as fixed effect, others random, all $P < 0.02$). Dunlin preferred bare and cover crop fields both day and night, but frequented berries and vegetables only at night (Fig. 1). Plovers preferred bare and cover crop fields both day and night. Killdeer preferred grass and pasture fields during the day only, and berry fields both day and night. The most preferred

Table 2
Results of analysis of variance of bird occurrence versus time of day, month, among winter cover types, and their interactions

Analysis/effect	P-value			
	DUNL	BBPL	KILL	RAP
Analysis 1				
Time of day (D)	<0.001	**<0.001**	**<0.001**	**<0.001**
Month (M)	0.075	0.061	**<0.001**	**0.003**
D × M	0.123	**0.001**	0.229	0.019
Day[a]	00.77	**<0.001**	**<0.001**	**<0.001**
Night	0.098	**0.017**	**<0.001**	0.389
Analysis 2				
D	**<0.001**	**<0.001**	0.264	**<0.001**
Winter cover (W)	**0.013**	**0.003**	**0.001**	**0.021**
D × M	**0.016**	0.878	**0.026**	0.126
Day	**0.006**	**0.007**	**0.001**	**0.045**
Night	0.060	**0.012**	**0.020**	**0.023**

Analysis 1 considered year as a random effect, and month and time of day as a fixed effects. Analysis 2 considered year as a random effect, and winter cover type and time of day as fixed effects.

[a] P-value for the contrast testing for the effect of winter cover for each time of day.
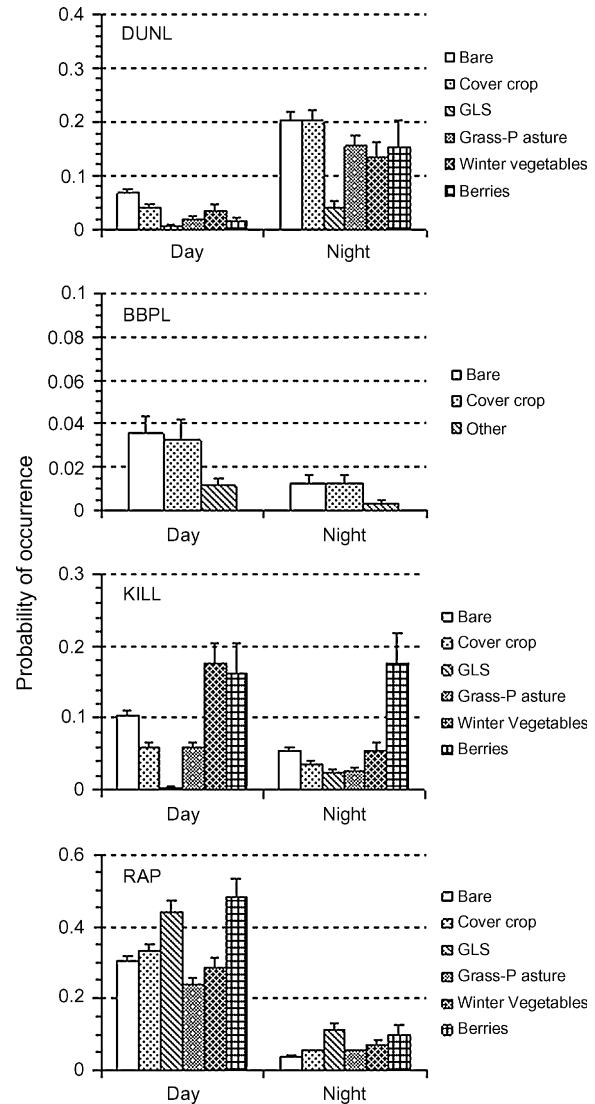

Fig. 1. Probability of occurrence of dunlin, black-bellied plover, killdeer and raptors in the six different possible crop types, averaged over the whole study period, by day and by night. GLS: Grassland set aside.

field types across both day and night for raptors were berry and grassland set aside fields.

Ordinations (Fig. 2) illustrated that during the day, dunlin and plover preferences contrasted to those of raptors. Close proximity of dunlin and plover vectors in the ordination indicated similar preferences for field characteristics both day and night, but association was closer in daytime. Raptors disproportionately occurred in fields with taller vegetation, while dunlin and plover avoided these fields. During the day, killdeer were positively associated with fields fertilized during the past year, manured during the past year, and laser leveled. Killdeer were disproportionately found in smaller fields, while dunlin and plover preferred larger fields. Dunlin were associated with fields that had been laser leveled, and manured or fertilized during the past year. At night, plover had a stronger preference for fields with short vegetation than did dunlin. Both day and night, raptors showed field
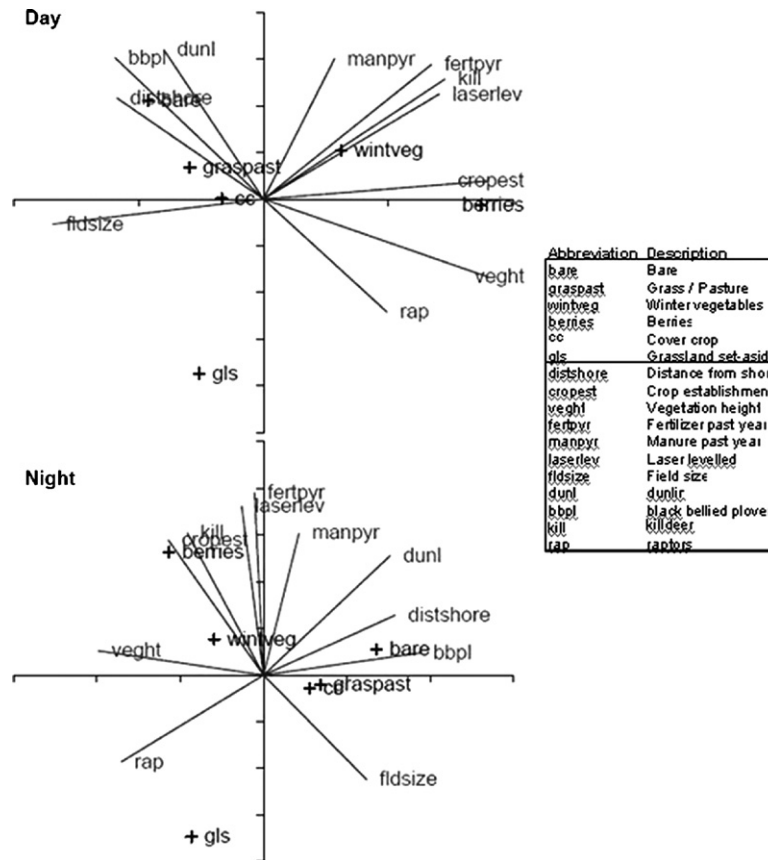
Fig. 2. Ordinations based on standardized principal component scores for each winter cover type and bird species occurrence. Each vector was calculated as the hypotenuse of the right triangle formed by the angle associated with the eigenvectors for the two principal components. Field characteristics (attributes) are represented as crosses and bird occurrences (responses) are represented by vectors.

preferences distinctly opposite to dunlin and plover. Killdeer were only weakly associated with the other two shorebird species both day and night.

At least one environmental variable affected the probability of bird occurrences for each shorebird species by day–night combination. During the day, dunlin presence in fields was positively related to tide level (covariance estimate, P-value: 0.698, 0.007), cloud cover (0.112, 0.024), precipitation (0.029, 0.001), plover (0.825, <0.001) and killdeer presence (0.496, <0.001), and negatively related to day length (−0.248, 0.001). At night, minimum temperature (0.088, <0.001), wind velocity (0.012, 0.032), and the presence of plover (0.781, <0.001), killdeer (0.706, <0.001), and raptors (0.607, 0.029) were positively related to dunlin presence.

For plover during the day, precipitation (−0.062, <0.001) and moon phase (−0.855, 0.013) were inversely associated with field use, while wind velocity (0.025, 0.045), day length (0.154, 0.023), presence of raptors (0.039, 0.011), and presence of dunlin (0.266, <0.001), were positively associated. At night, plover occurrence in fields was positively associated with tide level (0.832, <0.001), cloud cover (0.145, 0.001), wind velocity (0.028, <0.001), presence of killdeer (0.012, <0.001) and presence of dunlin (0.016, <0.001); and negatively associated with moon phase (−0.785, 0.011) and precipitation (−0.0039, 0.002).

For killdeer, day length was positively associated with field use both day (0.432, <0.001) and night (0.206, <0.001). During the day, tide level (0.641, <0.001) and presence of dunlin (0.154, <0.001) were positively related to killdeer presence. Moon phase (−0.610, 0.023), precipitation (−0.036, 0.002), and minimum temperature (−0.056, 0.034) were negatively related. At night, cloud cover (0.075, 0.034) was positively related, and moon phase weakly negatively related (−0.519, 0.063) to killdeer presence.

4. Discussion

Several lines of evidence suggest that diurnal use of farm fields, especially by dunlin, the smallest and most numerous species, was limited by the presence of substantial local populations of diurnal raptors. Plover and killdeer showed higher field usage on darker nights, closer to a new moon (Kotler et al., 1991; Colwell and Dodd, 1997; Milsom et al., 1985). Findings suggest that both diurnal and nocturnal activity must be monitored to fully characterize the habitats used (Fig. 1; cf. Shepherd and Lank, 2004; Burton and Armitage, 2005; Gillings et al., 2005).

All three shorebird species avoided long vegetation fields (e.g. Colwell and Dodd, 1997; Milsom et al., 1998; Atkinson

et al., 2004, but see Gillings et al., 2005)), despite a greater abundance and diversity of invertebrates associated with tall grass (Atkinson et al., 2004), and even grazed meadows, compared to cultivated fields (e.g. Diurez et al., 2005).

The strongest relationships between farming practices and shorebird field usage involved vegetation height and crop type effects. Close mowing or grazing of grass fields increases the attractiveness of farmland for shorebirds (Milsom et al., 1998) and may be a feasible management option to provide habitat for wintering shorebirds. Mowing itself (independent of sward height) can improve the short-term extraction efficiency of invertebrate-feeding birds (Devereux et al., 2006).

Manure had a greater positive effect than fertilizer on dunlin field use, especially at night. In the present study conducted in fall and winter, aggregations of diptera were observed on fresh cattle dung in recently grazed fields, and dipteran larvae and earthworms were prominent in dunlin stomachs (Evans Ogden, 2002, personal observation). Our results support the conclusion that fall manure spreading may benefit shorebirds by increasing invertebrate abundance (Shepherd and Lank, 2004).

Laser leveling was most positively associated with field use by killdeer and weakly with nocturnal dunlin use. While laser leveling may make fields more attractive to shorebirds that prefer shallow water depths (Safran et al., 1997; Isola et al., 2000), many waterbirds prefer deeper water, so variability in water depth should increase species diversity (Colwell and Taft, 2000). Maintaining a mosaic of winter field types that includes bare fields, grasslands, winter vegetables, and cover crops will maintain and enhance the value of farmland to dunlin, plover and killdeer. Although field preferences are species-specific, all three shorebird species also show an affinity for co-occurrence, especially dunlin and plover, thus treatments aimed at habitat enhancement for one species may in fact benefit a suite of shorebirds. Although implicated in a loss of biodiversity throughout the world (e.g. McLaughlin and Mineau, 1995), agricultural activity may have a beneficial role in sustaining populations of non-breeding shorebirds.

Acknowledgements

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