

Vocalization activity of breeding shorebirds: documentation of its seasonal decline and applications for breeding bird surveys

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Abstract: We documented vocalization activity of breeding shorebirds at two sites in northern and western Alaska, on the Colville River Delta and on the Yukon – Kuskokwim Delta. At both sites, number of calling individuals decreased throughout the season. Variation in vocalization activity was significantly higher at the Colville River Delta towards the end of the season, while weather variables affected vocalization activity only on the Yukon – Kuskokwim Delta. Our results highlight the importance of timing, weather, and site-specific attributes on number of birds detected. We discuss our findings in the context of different methods to monitor breeding shorebirds.

Résumé : Nous avons étudié les émissions de vocalises des oiseaux de rivage pendant la période de reproduction à deux sites du nord et de l'ouest de l'Alaska, le delta du fleuve Colville et le delta des fleuves Yukon et Kuskokwim. Aux deux endroits, le nombre d'individus qui font des vocalises diminue au cours de la saison. La variation de l'émission de vocalises est significativement plus élevée à delta du fleuve Colville vers la fin de la saison, alors que les variables climatiques n'affectent ces activités qu'à delta des fleuves Yukon et Kuskokwim. Nos observations mettent en évidence l'influence du moment, du climat et des caractéristiques spécifiques au site sur le nombre d'oiseaux recensés. Nous discutons de nos résultats en fonction des différentes méthodes de recensement des oiseaux de rivage pendant la période de reproduction.

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Introduction

Tundra-nesting shorebirds perform breeding displays that typically include conspicuous auditory elements (Pitelka et al. 1974; Miller 1984, 1992). These displays can provide cues to researchers conducting surveys to determine distribution, community composition, habitat relationships, and population size (e.g., Johnston et al. 2000; Bart and Earnst 2002). Shorebirds on their arctic breeding grounds can be visually cryptic, and observers frequently detect them first by acoustic signals. Even when visually detected, initial species identification is frequently based on vocalizations. Such cues, however, are not produced uniformly through time. The vocal activity of breeding individuals varies diurnally, seasonally, and with weather conditions. For example, Least Sandpipers (*Calidris minutilla*) display less often during fog and display rates vary with time of day (Miller 1979). In most sandpipers, the majority of calls related to display or territory virtually cease in the later stages of the breeding season (Miller 1986). Because detectability of these birds

changes through time, a comparison of results from surveys conducted at different times of the day or season can be misleading. Understanding the temporal pattern of vocalization is crucial for determining when and how to carry out surveys of breeding birds (e.g., Bart and Herrick 1984; Bart and Schoultz 1984; Bart 1985; Meltofte 2001).

Optimal timing for shorebird surveys in the arctic is of practical importance because the program for Regional and International Shorebird Monitoring calls for periodic surveys of breeding shorebirds in the arctic and boreal regions (Skagen et al. 2003). These surveys will provide baseline information on shorebird abundance throughout their range. If surveys during the nonbreeding period indicate declines, then the breeding area surveys will be repeated to confirm or refute the suggested trends. Proper design of these surveys thus requires information on when during the season the surveys should be conducted to maximize detection rates and (or) minimize variation in those rates.

Our objectives in this study were to (i) determine the factors influencing vocalization rates in several species of breeding shorebirds at two different sites in the North American arctic, (ii) evaluate any differences between the sites, and (iii) evaluate the implications of our findings for developing shorebird survey protocols in tundra environments.

Materials and methods

Study site

The study was carried out on the Colville River Delta (CRD) in northern Alaska during 1997 and on the Yukon – Kuskokwim Delta (YKD) in western Alaska during 2001.

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Table 1. Mean number of individual breeding shorebirds recorded per 3-min period on the Yukon-Kuskokwim Delta (17 May – 17 June 2001) and the Colville River Delta (12 June – 16 July 1997).

Species	Mean no. of breeding shorebirds per 3-min interval	
	Yukon site	Colville site
All	3.95	2.53
Black-bellied Plover (<i>Pluvialis squatarola</i>)	0.09	0.27
Pacific Golden-Plover (<i>Pluvialis fulva</i>)	0.002	0.00
Bar-tailed Godwit (<i>Limosa lapponica</i>)	0.12	0.02
Ruddy Turnstone (<i>Arenaria interpres</i>)	0.03	0.05
Black Turnstone (<i>Arenaria melanocephala</i>)	0.003	0.00
Semipalmated Sandpiper (<i>Calidris pusilla</i>)	0.00	1.05
Western Sandpiper (<i>Calidris mauri</i>)	2.49	0.00
Pectoral Sandpiper (<i>Calidris melanotos</i>)	0.00	0.19
Rock Sandpiper (<i>Calidris ptilocnemis</i>)	0.40	0.00
Dunlin (<i>Calidris alpina</i>)	0.03	0.22
Buff-breasted Sandpiper (<i>Tryngites subruficollis</i>)	0.00	0.03
Long-billed Dowitcher (<i>Limnodromus scolopaceus</i>)	0.05	0.03
Wilson's Snipe (<i>Gallinago delicata</i>)	0.54	0.02
Red-necked Phalarope (<i>Phalaropus lobatus</i>)	0.19	0.27
Red Phalarope (<i>Phalaropus fulicarius</i>)	0.00	0.39

The CRD study site (70°N, 151°W) was 100 km west of Prudhoe Bay on the Beaufort Sea coast. The area was flat and covered primarily by herbaceous vegetation (especially *Carex aquatilis* and *Eriophorum* sp.) and numerous wetlands. The YKD study site was at the Kanaryarmiut Field Station located near the Aphrewn River on the Yukon Delta National Wildlife Refuge (61°21.80' N, 165°07.53' W). The study site consisted of upland heath tundra; dominant species included dwarf birch (*Betula nana*), Labrador tea (*Ledum palustre*), and several species of sedge (*Carex* spp.), moss (*Sphagnum* spp.), and lichen (genera *Cladonia*, *Cladonia*, and *Certraria*). Permanent water bodies bordered the site along 85% of its perimeter.

Survey design

Surveys were conducted for 1 h each day during the breeding season by a single observer on the CRD (12 June – 16 July 1997) and by two observers (one on each day) on the YKD (17 May – 17 June 2001). On the CRD, we conducted surveys between 0730 and 1630 and on the YKD between 0715 and 1815. A systematic random design was used to select starting times for each daily survey to avoid confounding seasonal and diurnal trends in display behavior. We used the North American Breeding Bird Survey methodology as a template for our study (Bystrak 1981). At each site and on each day, a 3-min survey period was the primary sampling unit within which vocalizing shorebirds were detected. Three-minute survey periods were used because our experience with the North American Breeding Bird Survey protocol made us confident that we could keep track of separate displaying individuals (using both auditory and visual cues) for an interval of that length; we suspected that surveying for much longer intervals, however, would have increased the probability of double-counting individuals. Surveys were conducted as point surveys, and during each of 20 consecutive 3-min periods, surveyors listened for and re-

corded all shorebirds within an area of about 30 ha on the CRD and 16 ha on the YKD within which they could hear most or all vocalizing shorebirds. Because detection of Western Sandpiper (*Calidris mauri*) vocalizations can be problematic at distances >100 m, vocalizing individuals of this species on the YKD were only recorded within a 4-ha core area centered on the observation point.

For analytical purposes, study periods were divided into the early, middle, and late parts of the season: early, clutch initiation through early incubation, i.e., period before middle; middle, 14 days before beginning of hatch through first shorebird hatch; late, period after first hatch. Observations on the YKD included only the first two periods and ended just prior to hatch. Hatch began on 22 June on the YKD and on 5 July on the CRD. The durations of the periods were as follows: YKD, 22 and 10 days; CRD, 8, 14, and 12 days. To reduce the potential for interobserver variation on the YKD, we jointly conducted up to twenty 3-min training sessions a day for several days. After each survey bout, we compared observations to ensure that our skill levels and interpretations were as comparable as possible.

The following auxiliary variables were recorded each day: starting time, temperature, cloud cover, cloud density and precipitation, wind speed, and wind direction. The cloud density / precipitation score was as follows: 0 is cloud cover <20%, 1 is light clouds, 2 is medium clouds, 3 is dense clouds, 4 is light fog, 5 is medium fog, 6 is heavy fog, 7 is light rain, 8 is medium rain, 9 is heavy rain, and 10 is light snow.

Statistical analysis

We calculated the mean number of birds detected per 3-min interval for all species and individual species on each day. These means were then regressed against combinations of the independent variables, namely time of season, wind speed, and a cloud / precipitation index, using SYSTAT 10.2

(Systat Software Inc. 2002) general linear model techniques. Simple correlations between number of singing birds per 3-min interval and auxiliary variables were used to guide the multiple regression analyses. We entered date (the first day of the study period is defined as day 1) and date squared, testing for a U-shaped relationship, and retained one or both of these variables if the regression model was significant ($P < 0.05$). We then evaluated the other auxiliary variables starting with the one most highly correlated with mean number recorded and not including any with absolute correlations < 0.20 . Variables were retained in the model only if their coefficients were statistically significant ($P < 0.05$). The test for homogeneity of coefficients of variation (CV) was used to detect whether variance differed between samples (Zar 1999).

Results

We recorded 15 shorebird species during the surveys (Table 1). Analyses were conducted for the five most commonly recorded species, and for all species combined, at each site except that we did not analyse Red-necked Phalaropes (*Phalaropus lobatus*) on the YKD because they did not show any clear pattern, probably because only a few individuals passed through the study site during the surveys.

The mean number of calling individuals decreased seasonally at both sites (YKD: $F = 4.95$, $P = 0.034$; CRD: $F = 35.88$, $P < 0.001$) (Fig. 1A). Maximum numbers recorded showed the same trend as the means (Fig. 1B). Regression analyses also indicated that the mean number of shorebirds detected per 3-min interval generally declined, although the trend was not always significant (Figs. 2 and 3).

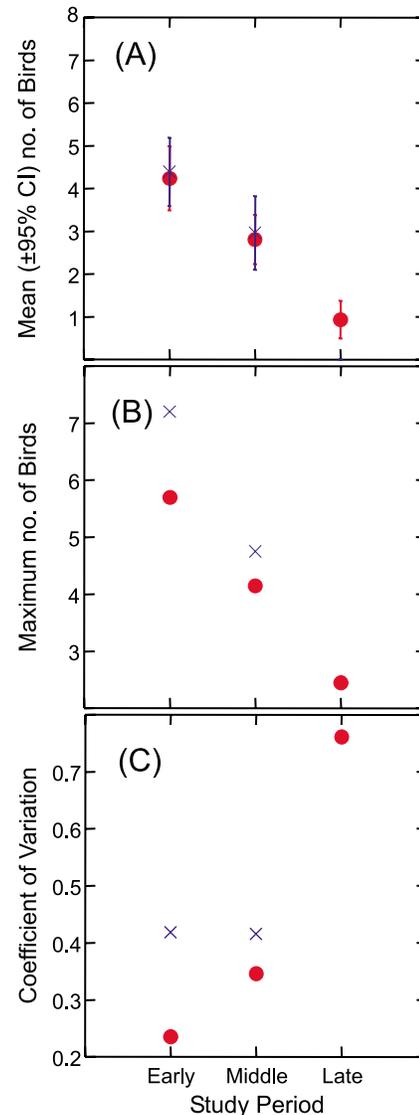
Time of season was significant in 9 of the 12 models. A linear trend provided the best fit in six of nine analyses, while date squared improved the fit for Western Sandpipers and for all species (which were dominated by Western Sandpipers) on the YKD and for Red Phalaropes on the CRD. Weather variables were only significant on the YKD (Table 2). Wind speed was significant in three models and the cloud density / precipitation index was significant in one model (Table 3). CVs differed significantly between periods at the Colville site ($\chi^2_{0.05,2} = 10.5$, $P < 0.025$) but not at the Yukon site ($\chi^2_{0.05,2} = 0.0005$, not significant) (Fig. 3C).

Discussion

On both the CRD and the YKD, we recorded a seasonal decline in the number of shorebirds detected per 3-min period. This relationship held for both the shorebird community overall at each site and for most species – site combinations. Such declines in shorebird displays and (or) detectability across the incubation period have been reported previously (e.g., Meltofte 2001).

There were several differences between the two sites, however. First, the shape of the curve describing the seasonal pattern of display activity varied between the YKD and the CRD. This was likely due to the earlier start of sampling on the YKD, which apparently preceded the peak of shorebird detectability. Had we truncated the YKD data set to include only the last 8 days of the early period (as on the

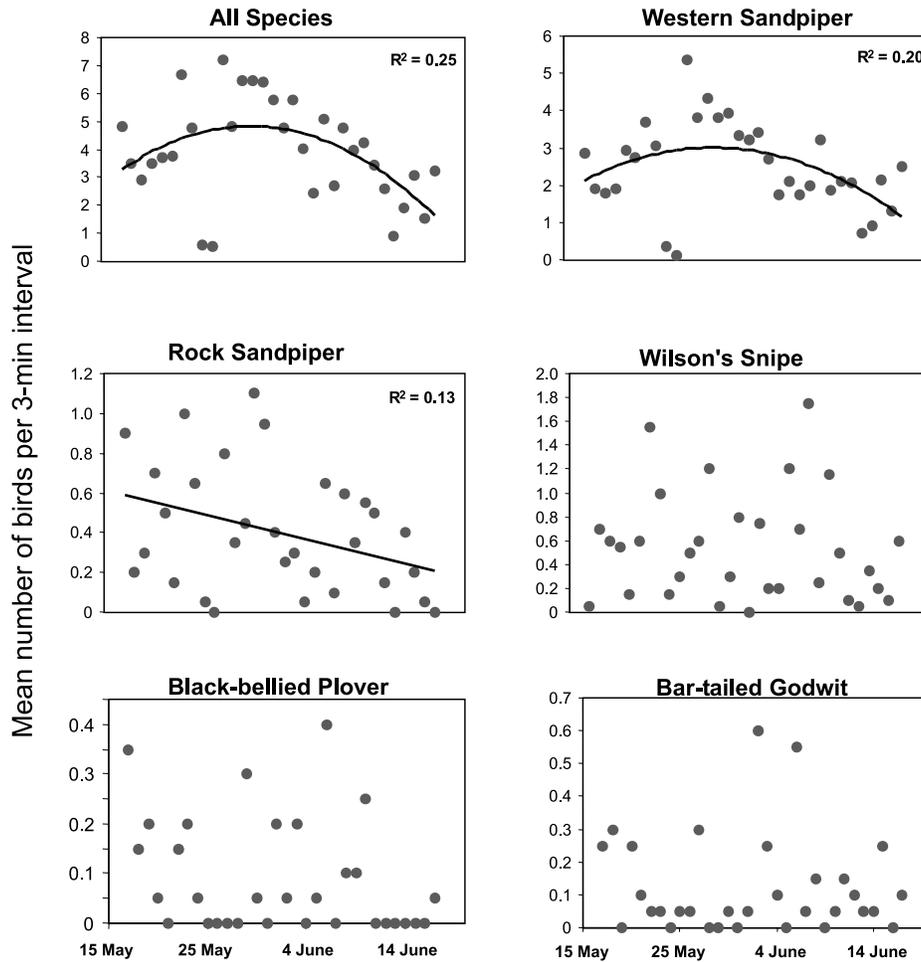
Fig. 1. Mean ($\pm 95\%$ confidence interval (CI)) number (A), maximum number (B), and coefficient of variation (C) in number of shorebirds detected per 3-min interval during the three study periods on the Colville River Delta (●) and Yukon – Kuskokwim Delta (×).



CRD), a strong declining linear trend would have been described.

A second difference between the sites was that weather factors (particularly wind) contributed only to models on the YKD. Wind significantly reduced display behavior and (or) detectability for Black-bellied Plover (*Pluvialis squatarola*), Rock Sandpiper (*Calidris ptilocnemis*), and Wilson's Snipe (*Gallinago delicata*). Winds on the YKD may be more variable in intensity, duration, and direction than on the CRD. In contrast, winds on the North Slope of Alaska (including the CRD) are much more consistent. In such a region, where it is almost always windy, breeding shorebirds may simply have less opportunity and (or) flexibility to respond to variation in wind; in other words, they may have to display whether it is windy or not. On the other hand, displaying birds on the somewhat more benign tundra of the subarctic

Fig. 2. Mean number of shorebirds detected per 3-min interval for surveys on the Yukon – Kuskokwim Delta. Trend lines indicate cases in which the mean number recorded was significantly related to date. The best one- or two-parameter model is shown.



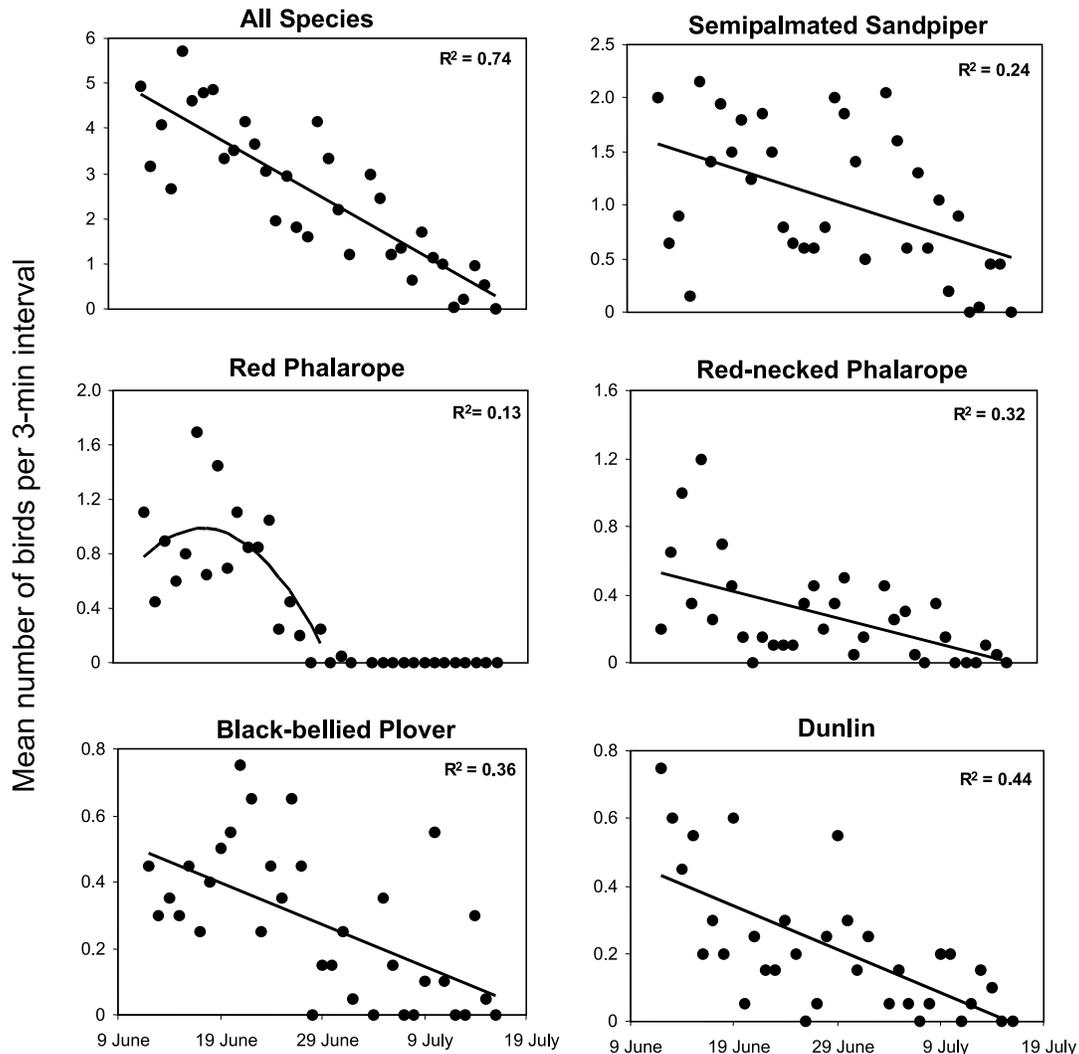
YKD may have more flexibility and may be able to choose to display at optimal times. Surprisingly, wind was not a significant component of the model for Western Sandpipers. Initially, this seems counterintuitive because this small-bodied sandpiper may be more susceptible to the physical effects of wind during aerial displays, and its weaker calls are less likely to carry well during strong winds than are the calls of larger, stronger, and higher flying shorebirds. This apparent paradox may be at least partially resolved by consideration of the special sampling protocol for Western Sandpipers on the YKD. Only those birds within a 4-ha core sampling zone were recorded during the surveys, while for other species, the study area was 16 ha. Even if winds reduce the transmissibility, and thus detectability, of distant Western Sandpiper vocalizations, our smaller sampling area for this species may have precluded our ability to detect such reductions because only those birds closest to us were being monitored.

A final difference between the sites was the difference in CV trends across the season. On the YKD, there was no change between the first two periods, while on the CRD, CV increased across all three periods. The increasing trend in CV on the CRD was not unexpected. As clutches become complete and males begin incubating (at least among those

species with some level of male parental care), the number of males displaying should decline because males are on the nest much of the time and respond less frequently to displaying neighbors. The variance of display rate might be expected to increase, however, because (i) the display behavior of unpaired males may become less consistent later in the season as the probability of finding a mate decreases and (ii) males with complete clutches occasionally do respond to their unpaired neighbors, but more sporadically than during the period prior to clutch completion.

The stability of the CV on the YKD was not initially expected. Several hypotheses might explain this pattern. First, the breeding season at this subarctic site is somewhat longer than in the arctic, and unpaired birds may have a greater window of opportunity for securing a mate. Thus, unpaired males could display longer and more consistently than at sites farther north where breeding decisions must be made more quickly. In addition, early failed breeders frequently re-nest, and this decision is usually accompanied by a renewed surge of display behavior. Both of these phenomena would result in a more gradual overall decline in the frequency of male display and a less dramatic rise in the CV as the season progresses. The pattern that we found on the YKD, however, may simply be an artifact of the sampling

Fig. 3. Mean number of shorebirds detected per 3-min interval for surveys on the Colville River Delta. Trend lines indicate cases in which the mean number recorded was significantly related to date. The best one- or two-parameter model is shown.



regime. The CV in the early period on the YKD was calculated over a 3-week interval, while on the CRD, the early period was only 1 week long. As a result, the early period on the YKD incorporated a much wider range of variation in display behavior, which may have resulted in an inflated estimate of CV for that period. Similarly, we only collected 10 days of data from the middle period on the YKD versus 14 days on the CRD. If variation in display behavior is actually increasing during that phase of the breeding season (as the CRD data suggest), the YKD data set may have been collected over too brief a time to reveal such an increase relative to the first period. In effect, the CV estimate for the YKD may be too high for the first period and too low for the second, thereby obscuring any pattern of seasonal increase.

Regardless of the effects of differential sampling during the early and middle parts of the season at the two sites, the increase in CV late in the season on the CRD is dramatic. Coupled with the evidence for a seasonal decline in detectability at both sites, our findings support those of other researchers (Meltofte 2001; Bart and Earnst 2002) who have

highlighted the crucial importance of timing when scheduling shorebird surveys on the breeding grounds. Our Western Sandpiper data from the YKD provide a particularly illuminating example. Consider the 12 consecutive survey data points that follow the peak value during the early season sampling (Fig. 2). They cluster into three groups of four each, with no values overlapping between the clusters and means of approximately four, three, and two individuals detected per 3-min interval, respectively. Because of the rapid decline in detectability over that interval, population size estimates derived from survey data collected an average of just 8 days apart could have differed by a factor of 2.

Whenever possible, breeding shorebird surveys in arctic regions should be scheduled so that detections are maximized and variance is minimized (Bart and Earnst 2002; Thompson 2002). The potential impact on survey results of phenomena described in this paper depend on the survey objectives and methodologies. Index surveys (e.g., raw point count data such as collected in the North American Breeding Bird Surveys) may be particularly vulnerable to seasonal

Table 2. Correlation coefficients between mean number of breeding shorebirds recorded and temporal and weather variables on the Yukon – Kuskokwim Delta and the Colville River Delta.

Species	Correlation coefficient				Cloud density / precipitation	Wind speed
	Date	Start time	Temperature	Cloud cover		
Yukon – Kuskokwim Delta						
All	-0.27	0.07	0.20	-0.28	-0.36	-0.34
Black-bellied Plover	-0.28	-0.03	0.04	-0.16	-0.31	-0.37
Bar-tailed Godwit	-0.05	-0.07	0.20	-0.27	-0.19	-0.04
Western Sandpiper	-0.25	0.05	0.16	-0.26	-0.30	-0.13
Rock Sandpiper	-0.36	0.07	-0.01	-0.17	-0.19	-0.51
Wilson’s Snipe	-0.09	0.00	0.11	-0.04	-0.24	-0.59
Colville River Delta						
All	-0.86	-0.34	0.00	0.07	0.20	-0.54
Black-bellied Plover	-0.60	-0.27	-0.29	0.27	0.11	-0.21
Semipalmated Sandpiper	-0.49	-0.10	0.25	-0.19	-0.06	-0.60
Dunlin	-0.67	-0.18	-0.09	0.08	0.23	-0.12
Red-necked Phalarope	-0.56	-0.20	-0.03	0.02	0.06	-0.33
Red Phalarope	-0.79	-0.44	-0.19	0.29	0.31	-0.30

Table 3. Best regression models (see text) for mean number of breeding shorebirds detected per 3-min interval on the Yukon – Kuskokwim Delta and the Colville River Delta.

Species	Model	P	Adjusted r ²
Yukon – Kuskokwim Delta			
All	$y = 3.00 + 0.27(\text{day}) - 0.001(\text{day}) - 0.01(\text{day}^2)$	0.016	0.20
Black-bellied Plover	$y = 0.17 - 0.01(\text{wind})$	0.039	0.11
Bar-tailed Godwit	$y = 0.05 - 0.0002(\text{day})$	<0.001	0.40
Western Sandpiper	$y = 1.98 + 0.15(\text{day}) - 0.01(\text{day}^2)$	0.042	0.14
Rock Sandpiper	$y = 0.93 - 0.01(\text{day}) - 0.03(\text{wind})$	<0.001	0.38
Wilson’s Snipe	$y = 1.18 - 0.05(\text{wind}) - 0.06(\text{precipitation})$	<0.001	0.40
Colville River Delta			
All	$y = 5.66 - 0.13(\text{day})$	<0.001	0.73
Semipalmated Sandpiper	$y = 1.79 - 0.03(\text{day})$	0.004	0.21
Red Phalarope	$y = -0.5 + 0.16(\text{day}) - 0.007(\text{day}^2)^a$	<0.001	0.61
Red-necked Phalarope	$y = 0.64 - 0.02(\text{day})$	0.001	0.29
Black-bellied Plover	$y = 0.58 - 0.01(\text{day})$	<0.001	0.34
Dunlin	$y = 0.52 - 0.01(\text{day})$	<0.001	0.43

^aRegression line calculated only for the period during which the species was present (see Fig. 2).

changes in detectability. Index surveys have been criticized because they rest on the often untested assumption that the number of detections is consistently proportional to the actual number of individuals in the population of interest through space and time (Nichols et al. 2000). The violation of this assumption would be exacerbated if surveys were conducted over periods when detectability is changing as rapidly as we have documented in this study. Standardization in the timing of such surveys to maximize detections and minimize variance may reduce (but not eliminate) these biases. Our data (Figs. 2 and 3) suggest that, for at least some species at some sites, there may not be an extended window of either constant high detectability or low variance.

We note, however, that even survey methods that estimate the probability of detection are not immune to the effects of seasonal changes in detectability. For example, a primary assumption of the double-sampling approach (e.g., Bart and Earnst 2002) is that all items of interest (e.g., territories, nests) are found on the subset of intensively surveyed plots

(Thompson 2002). Because the probability of locating and accurately delineating a territorial male shorebird is at least partially a function of the frequency and duration of his vocalizations, it is important to conduct the intensive surveys of a double-sampling approach when breeding displays are most frequent. Distance sampling, on the other hand, makes no assumption about the proportion of birds detected by the observer, but to develop robust models for detection functions, large numbers of detections are required (Buckland et al. 1993; Rosenstock et al. 2002). Given the low densities at which many shorebird species occur, sufficient detections for generating precise density estimates through distance sampling may only be feasible if sampling is conducted during the period of greatest vocal activity. Finally, recent developments in double-observer methods also allow for the estimation of detection probability; such an approach does not work, however, when the detectability of some classes of the population approaches zero (Nichols et al. 2000). Among breeding shorebirds, incubating adults and off-duty

parents that leave the territory may both have detectabilities approaching zero. Recognition of these seasonal changes would allow sampling to be scheduled before most members of the population shift to these behaviors.

Pilot fieldwork on temporal patterns of display behavior can be important in determining when to conduct shorebird surveys in subsequent years. Researchers in the arctic must concede, however, that the vagaries of spring weather and the complexities of logistic support often preclude arriving and conducting fieldwork during the optimal survey window. Thus, surveys based on observations of displaying birds on single visits to study plots or regions are most susceptible to error, particularly if the objective is to derive either population estimates or accurate indices of population size. Other types of single-visit studies, however, are also vulnerable, including those that attempt to determine local density, species diversity, and habitat use patterns.

Alternative approaches to generating density or abundance estimates on single visits, such as rope-dragging, may seem preferable because a nest is fixed in time and space, while display behavior is more labile and less predictable. Just like behavior, however, the number of nests present on a study plot changes through time and is affected by numerous factors, including annual variation in the timing of nest initiation, the degree of synchrony among nests, and the magnitude and temporal pattern of nest loss. In addition, rope-dragging does not find all nests, and the probability of an incubating bird flushing may vary seasonally, diurnally, and (or) with weather, just as display behavior does.

Descriptions of shorebird biology that are contingent upon single or brief visits to plots or regions should be scrutinized very carefully, particularly if inferences are being made to areas beyond the area(s) actually sampled. Either repeatedly surveyed plots (e.g., season-long area searches) or a combination of rapidly and intensively surveyed plots (e.g., Bart and Earnst 2002) is superior to single-visit surveys for elucidating most aspects of shorebird breeding biology. Even with these latter techniques, however, it is important to schedule surveys as carefully as possible to maximize detections and reduce variance. While our data were collected in only a single year at each of our two study sites, researchers should probably anticipate similar temporal patterns in other northern regions. Unless there are site-specific data to the contrary, sampling designs should account for rapid seasonal declines in detectability among displaying shorebirds.

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