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

A second difference between the sites was that weather

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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

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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