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MICROHABITAT VARIABLES INFLUENCING NEST-SITE SELECTION BY TUNDRA BIRDS[1]

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Abstract. Studies were performed to determine what types of microhabitat characteristics attract the most common bird species to nest at particular sites on tundra habitats in the Prudhoe Bay oil field. Microhabitat variables of 2 × 2 m plots centered on bird nests were measured and compared with those of plots centered on random points. Results indicated differences in amount of microrelief, graminoid and shrub/forb cover, roughness of topography, and presence of water among species. These differences have implications for management of abandoned gravel sites as oil production declines in the Prudhoe Bay oil field. The amount and variability of microrelief plays an important role in influencing nest-site selection. Birds do not require total coverage by graminoid and shrub/forb plant species at nest sites. Water plays an important role by influencing plant growth at disturbed gravel sites.

Key words: forb; graminoid; gravel; longspur; microrelief; nest sites; oil field; phalarope; Prudhoe Bay; rehabilitate; restoration; sandpiper; shorebirds; shrub.

INTRODUCTION

Since the late 1960s, habitat studies have been conducted in the Prudhoe Bay region. In recent years some of these efforts have focused on habitat restoration in industrial development areas. In the future, oil companies and regulatory agencies may attempt to rehabilitate abandoned gravel sites in the Prudhoe Bay oil field by restoring or enhancing their value as nesting habitat for birds. To restore abandoned sites, it is necessary to know what habitat characteristics influence birds to nest at particular sites.

A common method for determining habitat preference is to estimate the numbers of birds occupying various habitat types and to correlate those numbers with the average characteristics of the habitats (Bond 1957, Beals 1960, MacArthur et al. 1966). This has been done for bird species in a number of locations on the Arctic Coastal Plain (Holmes 1966, Martin and Moitoret 1981, Spindler and Miller 1983, Troy 1985; J. P. Myers and F. A. Pitelka, *unpublished manuscript*). Another method, which may better enable managers to determine specific habitat characteristics preferred by bird species, is to measure habitat characteristics on small plots centered on individual birds. James (1971) and Whitmore (1975) used plots centered on the perches of singing males in Utah and in Arkansas, and compared habitat characteristics among species. Larson and Bock (1986) compared traditional sampling methods with bird-centered habitat analysis in shrubsteppe communities in New Mexico, and found that bird-centered analysis was a more powerful tool for examining habitat relationships than traditional methods.

In this study, microhabitat characteristics of plots centered on nests of the four most common bird species (Lapland Longspur [*Calcarius lapponicus*], Semipalmated Sandpiper [*Calidris pusilla*], Pectoral Sandpiper [*C. melanotos*], and Red-necked Phalarope [*Phalaropus lobatus*]) were measured and compared with the characteristics of plots centered on random points. Microhabitat variables were also measured at the nests of other species, but sample sizes were too small for analysis. The microhabitat variables measured were percent graminoid cover, percent shrub/forb cover, presence or absence of water, and overall amount and variability of microrelief. These features could possibly be influenced or controlled when rehabilitating abandoned gravel sites.

METHODS

Data collection

Bird nests were located on 10-ha study plots in the Prudhoe Bay and Kuparuk oil fields on the Arctic Coastal Plain of Alaska during the summers of 1990 and 1991 (Rodrigues 1992). Each 10-ha study plot was divided into 36–40 cells by a grid system, and one random point was located in each grid cell using a computerized random-number generator. Points that fell in a lake or pond were discarded. Nests were revisited and data were collected from late July to mid-August 1991, after completion of the nesting season to insure that birds would not be disturbed at nest sites.

Plots measuring 2 × 2 m (4 m^2), centered on each nest (irrespective of nest success) and on random points on undisturbed tundra, were established using 1/2 cm

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diameter nylon rope to outline the plot. The diagonal of the plot (also 1/2-cm rope) was marked in the center. This center marker was placed directly over the nest or random point and a 30-cm spike attached to each corner was pushed into the ground to hold the rope in place.

Graminoid (grass and sedge) and shrub/forb cover were measured using the Daubenmire cover class system (Daubenmire 1959). Four estimates for both graminoid and shrub/forb cover were made for each 2-m square plot by tossing two Daubenmire boxes into the plot on one side of the diagonal, recording the cover class values, and repeating this procedure on the other side of the diagonal. Water cover also was recorded for each plot. Because of the high percentage of zero values, water was designated either as present on a plot if it occurred on any of the cover class records, or absent if it did not.

The vertical distance from the high point to the low point was measured to determine the amount of relief for each plot. A 2-m carpenter's level was used to measure differences in relief by placing one end on the high point while holding the other end over the low point and measuring down to the low point with a tape measure to the nearest 0.5 cm. The location of the high and low points could usually be determined visually, but sometimes several measurements were taken.

The amount of microrelief did not yield information regarding the variability of relief (or roughness) within the plots. Two plots could differ substantially in the amount of relief, but the variability within each plot could be similar. For example, a plot located on the flat top of a high-centered polygon might have a low amount of relief with little variability. By contrast, a plot located on a wide trough of a high-centered polygon might have a high amount of relief due to the slope of the trough, but if the surface area was relatively uniform, then the variability of relief of this plot also would be low.

Since the amount of relief is not necessarily correlated with the variability of relief within a plot, a subjective measurement of plot roughness was developed. Plots were designated as having low, medium, or high roughness based on a visual assessment. Generally, a plot with a small amount of relief was relatively flat and roughness was low. A plot having one ridge or trough would be designated as having medium roughness. A plot having several ridges or troughs, or abundant tussocks, would be designated as having high roughness. These designations were subjective and plots did not always fit precisely into a particular category. Nevertheless, since all observations were made by a single observer, the designations of plot roughness were thought to be sufficiently consistent.

The height of the nest within the plot was measured in the same manner as the microrelief. One end of the level was placed on the high point of the plot and the vertical distance to the nest cup was measured.

Nests of Lapland Longspurs were often located behind a ridge or tussock. The compass direction from the ridge to the nest was recorded to determine if there was a preference for a particular side of these ridges.

Data analysis

The means of the habitat variables from nest and random plots were combined using a principal components analysis to characterize nesting habitat. It was assumed that the values of these variables for nest plots in 1990 had not changed by 1991. Two separate principal components analyses of the data using SYSTAT version 5.1 for DOS (Wilkinson 1989) were used to characterize the nesting habitat of each species. Variables included in the initial analysis were relief, percent graminoid and shrub/forb cover, and presence or absence of water. The measure of plot roughness was not developed until the study was underway, so this variable was not present in the data set for all nest and random plots. A second analysis, which incorporated roughness, was performed on data including this variable. Two data sets were excluded from the analyses: nest height was not included because this variable was not present for plots centered on random points, and orientation of nests was not included because these data pertained only to Lapland Longspurs.

In addition, the individual microhabitat variables associated with bird nests were compared for each year between nest plots of each species and random plots. For presence or absence of water only data from 1991 were used in this analysis. Table 1 lists the type of statistical test used and test score for each variable. Results of statistical tests are discussed at the .05 and .01 confidence levels.

Results

The initial principal components analysis (Fig. 1) extracted two factors that accounted for ≈42 and 25% of the variance, respectively. The first factor described a positive association for water and graminoid cover, and was negatively associated with shrub/forb cover. The second factor described a positive association for relief. Species were consistent in their loadings between years. Red-necked Phalarope was strongly positive for factor one, indicating a strong preference for water and graminoid cover, and a negative association for shrub/forb cover. Strong preferences for particular habitat characteristics were not shown by other species or random points, although longspurs, and Red-necked Phalaropes to a lesser extent, were moderately associated with high relief.

The second principal components analysis (Fig. 2) also extracted two factors, which accounted for ≈36 and 24% of the variance, respectively. The first factor described a positive association for high roughness and relief, and a negative association for water. The second factor described a positive association for graminoid cover and a negative association for shrub/forb cover.

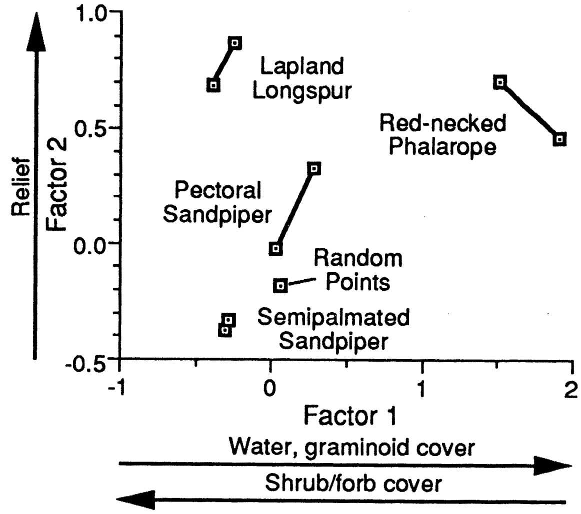

FIG. 1. Principal components analysis of microhabitat variables (not including roughness) of plots centered on nests of bird species and on random points, Prudhoe Bay, Alaska. Data include plots for nests in 1990 and 1991.

Lapland Longspurs were positive for factor one, indicating a preference for high relief and roughness. Red-necked Phalaropes were strongly negative for factor one, indicating a positive association with water and a negative association with roughness and relief. Phalaropes were also strongly positive for factor two, indicating a positive association for graminoid cover and a negative association for shrub/forb cover.

The principal components analyses were consistent with analyses of the individual variables. The data suggest that several habitat variables are important in the selection of nest sites by some species. These variables should be considered if abandoned gravel sites are to be restored as nesting habitat.

Graminoid cover

At the .05 confidence level, mean percent graminoid cover was significantly different between nest-centered and random plots for all species except Semipalmated Sandpipers in 1990 (Table 1). However, some of these differences may not be biologically meaningful due to the large standard deviations and ranges (Fig. 3A). At the .01 confidence level, mean percent graminoid cover was significantly higher on nest plots of Red-necked Phalarope in both years and on plots centered on Lapland Longspur and Pectoral Sandpiper nests in 1991 than on random plots. Red-necked Phalaropes selected nest sites with a high degree of graminoid cover; this cover value was approximately twice that of random plots (Fig. 3A).

Shrub/forb cover

Mean percent shrub/forb cover was lower than mean percent graminoid cover on nest plots of all four species studied and on random plots (Fig. 3B). Mean percent shrub/forb cover was significantly higher on nest plots of Semipalmated Sandpiper than on random plots, but was significantly lower on nest plots of Red-necked Phalaropes than on random plots for both years (Fig. 3B).

At the .05 confidence level, mean percent shrub/forb cover on nest plots of Lapland Longspurs was significantly higher than that of random plots (Table 1), but this difference may not be biologically meaningful (Fig. 3B). There was no significant difference in mean percent shrub/forb cover between plots centered on Pectoral Sandpiper nests and random plots.

Microrelief

Mean amount of microrelief of plots centered on the nests of Pectoral and Semipalmated Sandpipers and Red-necked Phalarope did not differ from that of plots centered on random points (Table 1), indicating that there may not have been any particular selection of nest sites based on microrelief for these species. For these species, variation in selection for microrelief demonstrated that many individuals selected flat areas with little microrelief, while others selected plots with higher than average microrelief (Fig. 3C). For the species studied, only nest plots of Lapland Longspurs had significantly higher microrelief than was found on random plots.

Nest height

At the .05 confidence level, nest height (mean distance from the high point in the plot to the nest cup) was significantly different between species for all combinations tested (Table 1). Mean nest height of Lapland Longspurs was lower than that of any other species (Fig. 3D). The lower nest height of Lapland Longspurs

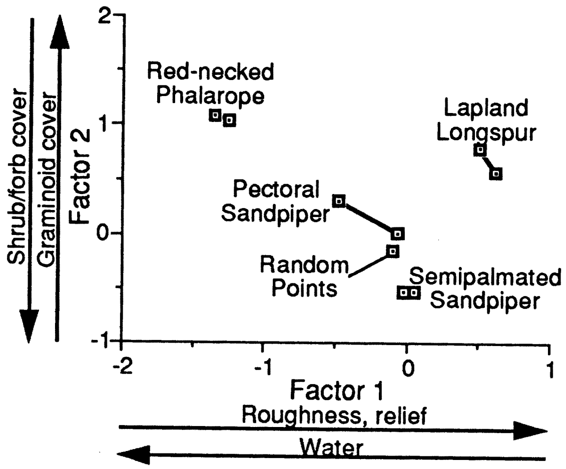

FIG. 2. Principal components analysis of microhabitat variables (including roughness) of plots centered on nests of bird species and on random points, Prudhoe Bay, Alaska. Data include plots for nests in 1990 and 1991.

TABLE 1. Type of test and test scores of statistical analyses for comparisons of means of individual habitat variables. In most cases, comparisons are between plots centered on nests of bird species in 1990 and 1991 and random plots. Abbreviations are: LALO = Lapland Longspur, PESA = Pectoral Sandpiper, RNPH = Red-necked Phalarope, SESA = Semipalmated Sandpiper, RAND = Random Plots.

Variable	Comparison	Test type	Test score
Graminoid cover	LALO(1990) vs. RAND	two-sample t test	$t = 2.46, P = .014$
	LALO(1991) vs. RAND	two-sample t test	$t = 4.31, P < .001$
	PESA(1990) vs. RAND	two-sample t test	$t = 2.06, P = .040$
	PESA(1991) vs. RAND	two-sample t test	$t = 4.16, P < .001$
	RNPH(1990) vs. RAND	two-sample t test	$t = 4.91, P < .001$
	RNPH(1991) vs. RAND	two-sample t test	$t = 7.93, P < .001$
	SESA(1990) vs. RAND	two-sample t test	$t = 0.72, P = .471$
	SESA(1991) vs. RAND	two-sample t test	$t = 2.02, P = .044$
Shrub/forb cover	LALO(1990) vs. RAND	two-sample t test	$t = 2.28, P = .023$
	LALO(1991) vs. RAND	two-sample t test	$t = 2.25, P = .025$
	PESA(1990) vs. RAND	two-sample t test	$t = 1.23, P = .220$
	PESA(1991) vs. RAND	two-sample t test	$t = 0.71, P = .476$
	RNPH(1990) vs. RAND	two-sample t test	$t = 3.01, P = .003$
	RNPH(1991) vs. RAND	two-sample t test	$t = 3.91, P < .001$
	SESA(1990) vs. RAND	two-sample t test	$t = 3.58, P < .001$
	SESA(1991) vs. RAND	two-sample t test	$t = 4.31, P < .001$
Relief	LALO vs. RAND	two-sample t test	$t = 0.00, P < .001$
	PESA vs. RAND	two-sample t test	$t = 0.49, P = .627$
	RNPH vs. RAND	two-sample t test	$t = 0.89, P = .376$
	SESA vs. RAND	two-sample t test	$t = 0.91, P = .363$
Nest height	PESA vs. SESA	two-sample t test	$t = 2.31, P = .023$
	LALO vs. SESA	two-sample t test	$t = 6.67, P < .001$
	RNPH vs. SESA	two-sample t test	$t = 4.55, P < .001$
	PESA vs. RNPH	two-sample t test	$t = 2.70, P = .008$
Roughness	LALO vs. RAND	chi-square	$\chi^2 = 121.04$, df = 2, $P < .001$
	PESA vs. RAND	chi-square	$\chi^2 = 4.07$, df = 2, $.10 < P < .25$
	RNPH vs. RAND	chi-square	$\chi^2 = 8.34$, df = 2, $.01 < P < .025$
	SESA vs. RAND	chi-square	$\chi^2 = 11.03$, df = 2, $.001 < P < .005$
Water presence/absence	LALO vs. RAND	chi-square	$\chi^2 = 0.72$, df = 1, $.25 < P < .50$
	PESA vs. RAND	chi-square	$\chi^2 = 0.27$, df = 1, $.50 < P < .75$
	RNPH vs. RAND	chi-square	$\chi^2 = 37.58$, df = 1, $P < .001$
	SESA vs. RAND	chi-square	$\chi^2 = 4.66$, df = 1, $.025 < P < .05$
Nest orientation	Compass direction (observed vs. expected)	chi-square	$\chi^2 = 114.75$, df = 7, $P < .001$

seemed significant because longspurs often place their nests in concealed areas on the sides of ridges or polygon rims. The shorebird species generally nest in open areas, often on the tops of ridges or polygon rims.

Variability of relief (roughness)

At the .05 confidence level, variability of microrelief (or plot roughness) was significantly different between random plots and nest plots of all species except Pectoral Sandpiper (Table 1). At the .01 confidence level, only nest plots of Lapland Longspur and Semipalmated Sandpiper differ from random plots. Because of the high degree of overlap in plot roughness (Fig. 4), these differences may be biologically meaningful only for Lapland Longspur. Red-necked Phalaropes had the highest percentage of plots classified as having low roughness, and no plots were classified as having high roughness.

Orientation of longspur nests

Of 165 nests of Lapland Longspurs, 101 clearly were placed on the side of a ridge, a polygon rim, or a tussock. The remaining 64 longspurs' nests were located in open areas and no direction of orientation could be determined. Longspurs tended to select nest sites on the south and southwest sides of these ridges (Fig. 5). Few nests were located on the north and northeast sides. The null hypothesis that nests have an equal probability of falling in any compass direction was rejected (Table 1).

Water regime

At the .05 confidence level, the occurrence of water was significantly different on nest plots of Red-necked Phalarope and Semipalmated Sandpiper compared to random plots (Table 1). At the .01 confidence level, only nest plots of Red-necked Phalarope differed from random plots. The occurrence of water on nest plots of Red-necked Phalarope was much greater than for nest plots of other species or random plots (Fig. 6).

DISCUSSION AND CONCLUSIONS

Troy (1985) reported that most species select drier habitats for nesting than for other activities and stated that the Pectoral Sandpiper was extreme in this regard. He also reported that Red-necked Phalaropes were as-

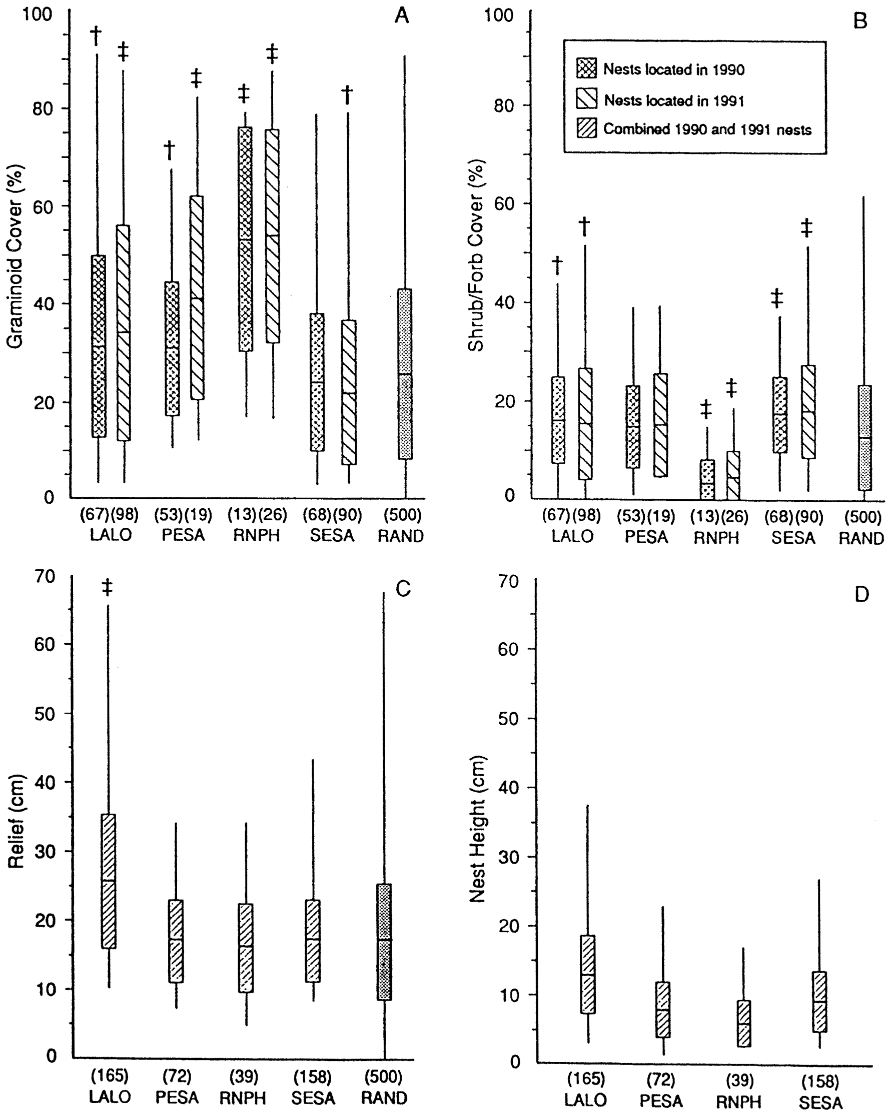

FIG. 3. Values of variables selected to characterize plots centered on nests of bird species and on random points. The horizontal line is the mean, the vertical line is the range, and the rectangle encloses ±1 SD. Significant differences between the means of bird-centered plots and random plots at the .05 confidence level are indicated by †, and at the .01 confidence level by ‡. Number in parentheses is the sample size. Abbreviations are: LALO = Lapland Longspur, PESA = Pectoral Sandpiper, RNPH = Red-necked Phalarope, SESA = Semipalmated Sandpiper, RAND = random plots.

sociated with ponds with emergent vegetation at all times of the year. If dry sites do represent preferred nesting habitat for most species, then abandoned gravel sites may be prime candidates for manipulation in an effort to restore or enhance nesting habitat. Knowledge of the habitat characteristics associated with bird nests should provide some insight about how to best restore these habitats.

Measurements of microhabitat variables of plots centered on bird nests with plots centered on random points has yielded information that will be useful when managers begin to restore disturbed habitats. A high percentage of graminoid cover is not necessary to attract some bird species to nest. Of the species studied, graminoid cover is probably most important for Pectoral Sandpiper and Red-necked Phalarope. For both of these species, mean percent graminoid cover was higher on nest plots than on random plots. This tendency may be related to the moisture regime as nest sites are often located on flat, wet areas with poor drainage where graminoid cover is well developed. Although the general area may be wet, the nest site itself is frequently located on a small, well-drained mound or ridge. Pitelka (1959) reported that nest sites of Pectoral Sandpipers at Barrow occurred in all variants of tundra vegetation as long as there was a continuous cover of grass or sedge. On study plots in the Arctic National Wildlife Refuge (ANWR), Martin (1983) found higher

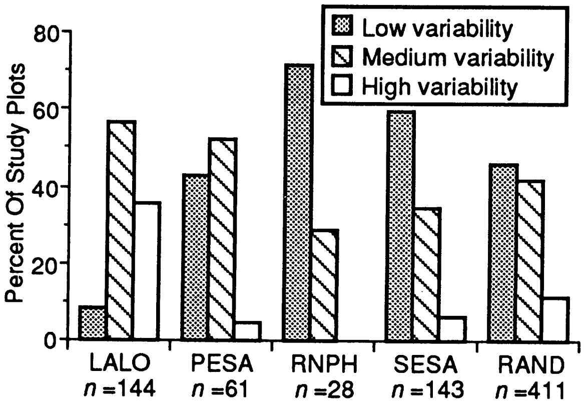

FIG. 4. Percent of study plots with low, medium, and high variability of microrelief for the four study species and for random plots in the Prudhoe Bay oil field, Prudhoe Bay, Alaska, 1991. (*n* is the total number of nest or random plots.) Abbreviations as in Fig. 3.

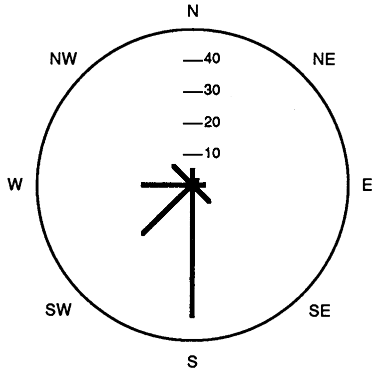

FIG. 5. Number of nests of Lapland Longspur oriented in various compass directions on the sides of ridges, troughs, or tussocks in the Prudhoe Bay oil field, Prudhoe Bay, Alaska, 1991.

densities of Pectoral Sandpiper nests on lowland and mesic plots that had higher moisture content than an upland plot. For Lapland Longspur and Semipalmated Sandpiper, graminoid cover on nest plots was usually closer to that of random plots, which averaged ≈25%.

Mean percent shrub/forb cover was less than graminoid cover on nest plots of all species and on random plots. For the species studied, Red-necked Phalarope would probably benefit least from revegetation of gravel sites with shrub and forb species, and Semipalmated Sandpiper the most. Nests of Semipalmated Sandpipers often were surrounded by low, prostrate willows (*Salix* spp.). It is possible that Semipalmated Sandpipers are not selecting nest sites with higher shrub and forb cover as much as they are selecting nest sites in drier habitats where this vegetation occurs.

These species, and Pectoral Sandpiper, are predatory species that feed on adult and larval insects. Shrub and forb vegetation does not serve as a food source for these species, and the primary function may be as an aid in nest concealment. Lapland Longspurs feed not only on insects, but also on seeds of forb species, particularly after the breeding season when birds are beginning to stage for fall migration (Custer and Pitelka 1977, Pollard et al. 1990, Rodrigues and Miller 1991). The presence of shrub and forb vegetation could benefit longspurs, not only during the breeding season by helping to provide cover for nest sites, but also as a food source after the breeding season.

The amount of microrelief and the variability of relief, or surface roughness, appear to be important factors influencing nest-site selection, particularly for Lapland Longspurs. At nest sites of other species, measurements of amount and variability of microrelief did not differ from that of randomly selected plots, however, the presence of some relief, similar to that which occurs on the tundra, also may be important for these species.

Although some gravel pads, particularly older pads with thinner gravel, have developed some thermokarsting that has produced troughs and polygons, the surface of most gravel pads is flat with little or no relief. When rehabilitating abandoned gravel sites, it will be important to construct a series of ridges and troughs, and also flat, sloping areas. Troy (1991) also believed that heterogeneity of terrain should be a consideration when rehabilitating disturbed sites. Lapland Longspur, which nests predominantly on the south and southwest sides of ridges or polygon rims, would probably benefit from ridges oriented in a northwest to southeast direction. The height of ridges should vary such that trough depths reach ≈40 cm for the highest ridges. This is approximately the mean amount of microrelief plus 1 SD for plots centered on nests of Lapland Longspurs. If longspurs were not a species of concern, the height of the ridges could probably be reduced.

Although water was generally not present on nest plots of most species, moisture is important because of its effect on the plant community, and is considered

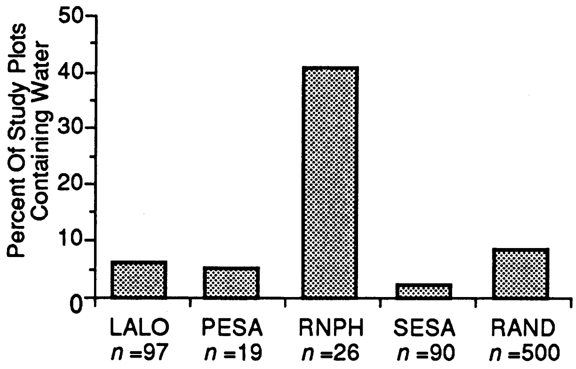

FIG. 6. Percent of study plots centered on bird nests and on random points on which water was present in the Prudhoe Bay oil field, Prudhoe Bay, Alaska, 1991. (*n* is the total number of nests or random plots.) Abbreviations as in Fig. 3.

to be a limiting factor in determining plant growth on disturbed gravel sites (Jorgenson 1988). The addition of water to abandoned gravel sites would be beneficial to plant species trying to colonize these sites, thus increasing the probability that birds may use these sites for nesting. Moisture content at abandoned gravel sites could be increased in several ways. Reduction of gravel thickness would bring the surface of the gravel closer to the water table thus allowing for more efficient transfer of water by capillary action. "Snow fences," constructed to concentrate drifting snow and thereby provide increased water during the growing season, have been used successfully on gravel pad enhancement projects on the North Slope (BP Exploration 1991). Additionally, the construction of ditches, troughs, or other low areas that could trap precipitation would probably encourage plant colonization.

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Literature Cited

BP Exploration. 1991. 1990 BP pad progress report. On file at BP Exploration (Alaska), Anchorage, Alaska, USA.

Beals, E. W. 1960. Forest bird communities in the Apostle Islands of Wisconsin. Wilson Bulletin **72**:156–181.

Bond, R. R. 1957. Ecological distribution of breeding birds in the upland forests of southern Wisconsin. Ecological Monographs **27**:351–384.

Custer, T. W., and F. A. Pitelka. 1977. Seasonal trends in summer diet of the Lapland longspur near Barrow, Alaska. Condor **80**:295–301.

Daubenmire, R. 1959. A canopy-coverage method of vegetation analysis. Northwest Science **33**:43–66.

Holmes, R. T. 1966. Breeding ecology and annual cycle adaptations of the red-backed sandpiper (*Calidris alpina*) in northern Alaska. Condor **68**:3–46.

James, F. 1971. Ordinations of habitat relationships among breeding birds. Wilson Bulletin **83**:215–236.

Jorgenson, M. T. 1988. Revegetation of the Lake State 1 exploratory well site, Prudhoe Bay Oilfield, Alaska, 1987. Report prepared for ARCO Alaska, and Kuparuk River Unit by Alaska Biological Research, Fairbanks, Alaska, USA.

Larson, D. L., and C. E. Bock. 1986. Determining avian habitat preference by bird-centered vegetation sampling. Pages 37–43 *in* J. Verner, M. Morrison, and C. Ralph, editors. Wildlife 2000. University of Wisconsin Press, Madison, Wisconsin, USA.

MacArthur, R. H., H. Recher, and M. Cody. 1966. On the relation between habitat selection and species diversity. American Naturalist **100**:319–332.

Martin, P. D. 1983. Bird use of arctic tundra habitats at Canning River Delta, Alaska. Thesis. University of Alaska, Fairbanks, Alaska, USA.

Martin, P. D., and C. S. Moitoret. 1981. Bird populations and habitat use, Canning River Delta, Alaska. On file at United States Department of the Interior Fish and Wildlife Service, Fairbanks, Alaska, USA.

Pitelka, F. A. 1959. Numbers, breeding schedule, and territoriality in pectoral sandpiper of northern Alaska. Condor **61**:233–264.

Pollard, R. H., R. Rodrigues, and R. C. Wilkinson. 1990. Wildlife use of disturbed habitats in arctic Alaska: 1989 final report. Report by LGL Alaska Research Associates, Anchorage, to BP Exploration (Alaska), Anchorage. On file at BP Exploration (Alaska), Anchorage, Alaska, USA.

Rodrigues, R. 1992. Bird use of abandoned gravel pads in arctic Alaska: 1990 and 1991. Final report prepared by LGL Alaska Research Associates for BP Exploration (Alaska). On file at BP Exploration (Alaska), Anchorage, Alaska, USA.

Rodrigues, R., and M. E. Miller. 1991. Bird use of abandoned gravel pads in arctic Alaska. Report prepared by LGL Alaska Research Associates for BP Exploration (Alaska). On file at BP Exploration (Alaska), Anchorage, Alaska, USA.

Spindler, M. A., and P. A. Miller. 1983. Terrestrial bird populations and habitat use on coastal plain tundra of the Arctic National Wildlife Refuge. Pages 107–200 *in* G. W. Garner and P. E. Reynolds, editors. 1982 update report baseline study of the fish, wildlife, and their habitats. United States Department of the Interior Fish and Wildlife Service, Anchorage, Alaska, USA.

Troy, D. M. 1985. Prudhoe Bay waterflood environmental monitoring project terrestrial studies. Report by LGL Alaska Research Associates for Envirosphere Company, Anchorage, Alaska, USA. On file at BP Exploration (Alaska), Anchorage, Alaska, USA.

———. 1991. Bird use of disturbed tundra at Prudhoe Bay, Alaska: bird and nest abundance along the abandoned peat roads, 1988–1989. Report to BP Exploration (Alaska) by Troy Ecological Research Associates, Anchorage, Alaska, USA. On file at BP Exploration (Alaska), Anchorage, Alaska, USA.

Whitmore, R. C. 1975. Habitat ordination of passerine birds of the Virgin River valley, southwestern Utah. Wilson Bulletin **87**:65–74.

Wilkinson, L. 1989. SYSTAT: the system for statistics. SYSTAT, Evanston, Illinois, USA.