# NORTHERN ALASKA RESEARCH STUDIES

# Bird Use of Coastal Tundra: 1991 Report

by
Troy Ecological Research Associates

Prepared for
**BP Exploration (Alaska) Inc.**

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# 1991 Report

**November 1992**

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1991 REPORT
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This report was prepared under contract to BP Exploration (Alaska) Inc. Inquiries about this report may be addressed to:

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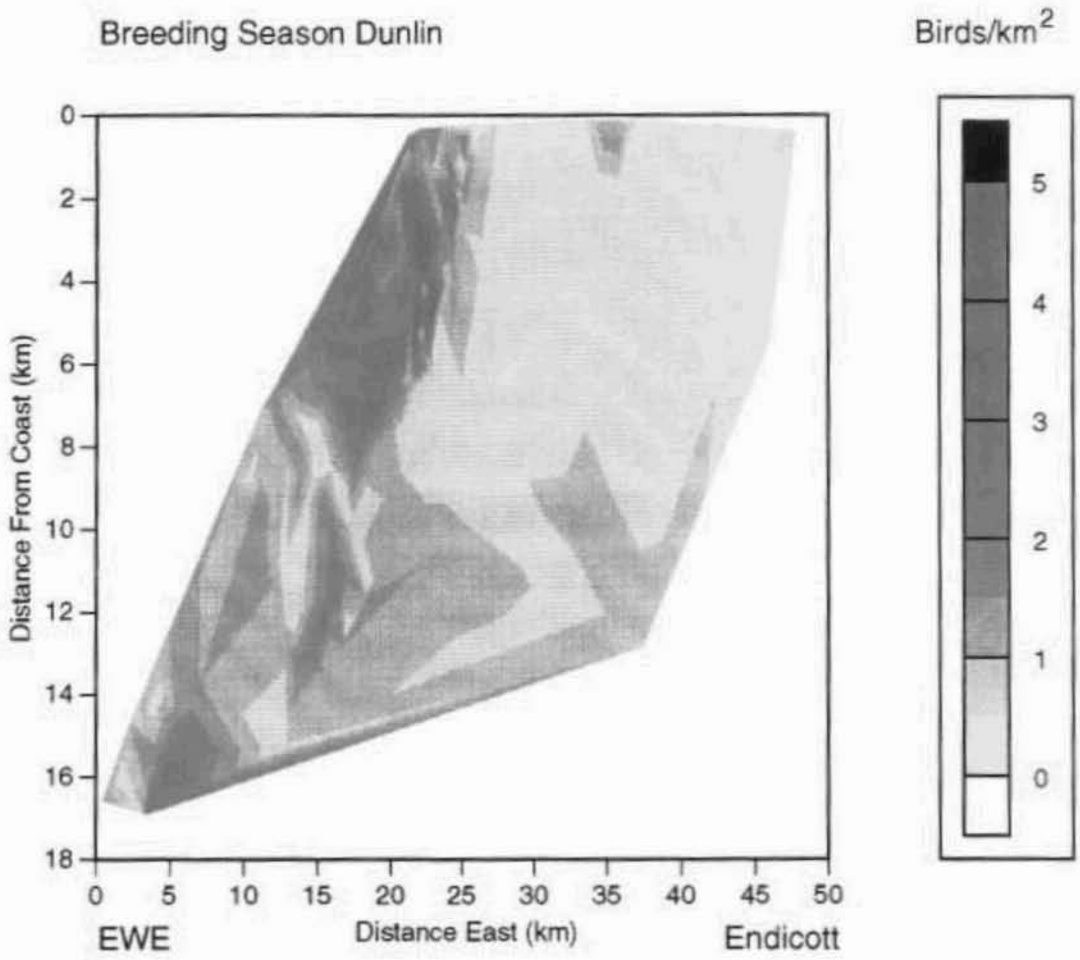

Breeding Season Dunlin
Birds/km2
Distance From Coast (km)
0
2
4
6
8
10
12
14
16
18
0
5
10
15
20
25
30
35
40
45
50
EWE
Distance East (km)
Endicott
5
4
3
2
1
0

# Executive Summary


On Alaska's North Slope, some tundra types, especially saline tundra, are restricted to areas bordering the Beaufort Sea. These wetlands are thought to be extensively used by waterfowl and shorebirds. This study was initiated to describe use of a variety coastal habitats by the predominant members of the North Slope bird community. We sampled 30 coastal plots including 10 plots in each of three classes: (1) wet saline tundra; (2) non-saline tundra, represented by areas adjacent to "salt marshes" but not influenced by salt; and (3) dry coastal tundra. Data from 10 plots sampled in the Pt. McIntyre Reference Area (PMRA) were included in our analyses as examples of noncoastal (inland) tundra. These plots were sampled from early-June through late-August. Our objectives were to compare bird use among these three types of coastal tundra and to compare use of coastal plots with plots farther inland.

Considerable variability was found in the use of the three types of coastal plots sampled. The highest nesting densities (especially Semipalmated Sandpiper and Lapland Longspur) occurred in nonsaline tundra. Saline tundra received high use by breeding-season phalaropes. During the post-breeding season, saline tundra was the single most important habitat, especially for Lapland Longspur, Red-necked Phalarope, and Dunlin. Dry habitats received low use for nesting and by breeding-season birds, but Lesser Golden-Plover and Buff-breasted Sandpiper made considerable use of dry tundra during the post-breeding season.

The species composition of coastal plots differed slightly from the rest of the Prudhoe Bay area. Ruddy Turnstone and Baird's Sandpiper are rare in the Prudhoe Bay area but were relatively numerous on the coastal plots. Overall, there was considerable similarity in the species composition of coastal plots and the Prudhoe Bay area as a whole. The three types of coastal habitats varied in their use as nest sites and by breeding-season birds. In general, there was low use of dry areas and high use of nonsaline tundra; use of saline tundra was intermediate. The species composition in coastal areas was not as diverse as in the PMRA. Following nesting there was a tendency for some species to increase use of coastal habitats. During the post-breeding season, coastal habitats, especially saline tundra, supported the highest relative densities of all species examined except King Eiders and Pectoral Sandpipers.

The results of this study were combined with those of similar plot-based studies from the Prudhoe Bay area, to document abundance gradients along east-west and distance-from-coast axes. Depending on the species, the location of a study plot could account for up to 30 percent of the variability in bird and nest densities. Species exhibiting the strongest geographic gradients were Semipalmated Sandpiper, Dunlin, Stilt Sandpiper, Red-necked Phalarope, Red Phalarope, and Lapland Longspur. Coastal gradients could go in either direction; for some species, densities were highest near the coast, but for others the converse was true. For example, during the breeding season, Dunlin densities increased near the coast, whereas Stilt Sandpiper densities generally increased inland.

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## INTRODUCTION

On Alaska's North Slope, some tundra types, especially saline tundras, are restricted to areas immediately adjacent to the Beaufort Sea coast. Bergman et al. (1977) studied water bird use of several wetland types on the Arctic Coastal Plain and found coastal wetlands to be scarce but intensively used by birds. They recommended that oil-related activities be minimized near these wetlands. Regulatory agencies have adopted this recommendation. For example, State of Alaska lease sale guidelines for coastal areas include mitigation measures requiring maintenance of buffers around key wetlands including Class VIII wetlands (the Bergman designation for coastal wetlands). Keiser and Meehan (USFWS undated) wrote that "all of this relatively scarce coastal habitat must be viewed as equally valuable bird habitat and managed conservatively."

There is widespread agreement that coastal habitats may be extensively used by arctic birds and/or may have different use patterns than inland areas. However, there is little consistency in the use of the term *coastal* by various authors. *Coastal* is used both as a specific and relative term. *Coastal* can be used very specifically to refer to littoral habitats along the Beaufort Sea (Connors 1981, Andres 1989) or salt-influenced areas (Keiser and Meehan undated). Alternatively, coastal habitats can be viewed more broadly to include all areas close to the Beaufort Sea, defined either by some distance criterion or by some other measure, for example, elevation or temperature. Temperature gradients along the Beaufort Sea coast are steep within a band about 5–7 km wide (Walker et al. 1980). Cantlon (1961) referred to the cold maritime tundra, defined as within the 7°C July normal isotherm, as "littoral tundra." In the Prudhoe Bay area this band includes most areas north of the Deadhorse airport; i.e., most of the Prudhoe Bay oil field. On an even broader scale, all of the Arctic Coastal Plain is by definition coastal. The coastal plain is of variable width, but in the central Beaufort region it extends farther inland and thus completely encompasses the Prudhoe Bay oil field. This broad definition may be the most applicable in discussions of the importance of coastal areas for breeding birds or movements of post-breeding shorebirds from foothill nesting areas to coastal areas. In the context of evaluating oil field areas and the influence of oil fields on birds, any or all of these definitions may be appropriate depending on the application.

Little quantitative sampling of bird use of strictly coastal habitats (areas under saline influence or adjacent to the Beaufort Sea) has taken place. Both Bergman et al. (1977) and Keiser and Meehan (undated) noted that the existing data base was limited. They recommended additional studies to differentiate among types of coastal habitats and to describe use patterns of a broader array of bird species than included in Bergman et al.'s study.

In 1991, Troy Ecological Research Associates, under contract to BP Exploration (Alaska) Inc., initiated the present study to characterize those areas adjacent to the Beaufort Sea in order to augment our understanding of bird distribution and abundance within the Prudhoe Bay area oil fields. Areas unique to the coast, such as those influenced by salt water, received special attention. The inland extent of the coastal area, by necessity, remains imprecisely defined. Our sampling is concentrated in the unambiguous areas in proximity of the coastline (usually <1 km, somewhat greater where low relief and river channels permit salt water intrusions farther inland). By comparison with other studies, we hope to derive a better working definition of *coastal* based on bird use.

Our primary objectives were to describe bird use of three types of coastal habitats and to contrast bird use of coastal areas with areas farther inland. Specifically our purpose was to:

- Document bird use of wet saline tundra (salt marsh) habitat,
- Compare bird use of wet saline tundra and adjacent nonsaline wetlands, and
- Document use of dry coastal habitats including coastal bluff and stabilized dunes.

Coastal wetlands as defined by Bergman et al. (1977) include all habitats bordering the Beaufort Sea that are influenced by salt water. This broad definition includes coastal lagoons, ponds, barren flats, and tundra with a characteristic vegetation dominated by *Carex subspathacea* and *Puccinellia phryganodes*. This latter type, identified as *wet saline tundra* on the Webber-Walker geobotanical maps (Everett et al. 1981), is the type of coastal wetland that we emphasized in our sampling. These habitats appear to be intensively used by brood-rearing geese, especially Brant (Bergman et al. 1977, Murphy et al. 1988) and to a lesser degree Snow Geese (Burgess and Ritchie 1987) and some species of post-breeding shorebirds (Bergman et al. 1977, Connors et al. 1979, Andres 1989). Due to the nesting failure of most Brant and Snow Geese in the Prudhoe Bay area during 1991 (Johnson 1991, Stickney et al. 1992), few data were collected pertaining to brood use of coastal habitats. We anticipate collecting additional data on this topic in 1992.

Our sampling of *nonsaline tundra* was to permit comparison of bird use of saline wet tundra and the adjacent tundra that was not salt influenced. The reason we want to make this comparison is to determine if there is a special attribute of salt-influenced tundra over tundra situated along the coast. The perceived importance of salt marshes results from frequent observations of brood-rearing geese in these habitats. Flightless geese tend to remain near escape habitat, usually large water bodies. For geese nesting along the Beaufort Sea coast, especially those that nested on coastal islands, as do most Brant and Snow Geese in the Prudhoe Bay area, low-relief wetlands close to the water are most probably saline habitats. This does not mean that being saline is a preferred habitat; indeed, if a choice was present, the converse could be true. For example, although Brant are probably considered the goose species most associated with salt marshes, their major molting area near Teshekpuk Lake is in freshwater habitat. Snow Goose brood-rearing areas near the Endicott development include wet (nonsaline) tundra as well as salt marshes (Burgess and Ritchie 1987). Therefore, we wish to compare salt and nonsalt-influenced tundra adjacent to the coast. The distribution of nonsaline plots was similar to the saline-influenced plots in an attempt to maximize similarity by all other criteria.

From a regulatory perspective, virtually the entire coastal plain is considered wetland. During the permitting phase of oil field development attempts are made to avoid wetland types that have been assigned high value by resource and regulatory agencies. The importance of wetlands and resulting attempts to avoid them have resulted in a disproportionate amount of facility construction in drier habitats. Despite the preponderance of concerns regarding *Arctophila* wetlands, drained lake basins, and coastal tundra, dry tundras are probably the rarest types of tundra on the Arctic Coastal Plain. Dry tundra comprises 0.6 to 2.0 percent of the Prudhoe Bay area, depending on the particular area sampled (Walker et al. 1983). In addition to being rare, dry habitats appear to be preferred by some species of nesting birds such as Lesser Golden-Plover and Buff-breasted Sandpiper. These species might be adversely affected by habitat losses caused by the focus on protecting wet and aquatic tundra types. The third group of plots, those sampling *dry coastal habitats*, were sampled to evaluate the importance of these rare habitats. We sampled coastal bluffs (Heald Point) and stabilized dunes (Heald Pt./East Dock area and in the Sagavanirktok delta) to maximize the representation of dry tundra in these plots.

This study monitors population trends of the entire tundra bird community. For simplicity in reporting and in realization of the limits of the statistical tests, data summaries are provided for only the ten most numerous species based on nest records in the Prudhoe Bay area (Table 1). The sampling intensity for this study is such that some of the less common species, especially their nests, are infrequently encountered, and their densities are preliminary. As more data are acquired, the reliability of the estimates will improve. The focus species selected are those monitored in detail as part of the

*Table 1. Focus species for analyses and reporting.*

| Code | Common Name | Scientific Name |
|---|---|---|
| KIEI | King Eider | *Somateria spectabilis* |
| LGPL | Lesser Golden-Plover | *Pluvialis dominica* |
| SESA | Semipalmated Sandpiper | *Calidris pusilla* |
| PESA | Pectoral Sandpiper | *C. melanotos* |
| DUNL | Dunlin | *C. alpina* |
| STSA | Stilt Sandpiper | *C. himantopus* |
| BBSA | Buff-breasted Sandpiper | *Tryngites subruficollis* |
| RNPH | Red-necked Phalarope | *Phalaropus lobatus* |
| REPH | Red Phalarope | *P. fulicaria* |
| LALO | Lapland Longspur | *Calcarius lapponicus* |

population trend monitoring in the Pt. McIntyre Reference Area (PMRA); these are thought to represent the numerically dominant breeding birds in the Prudhoe Bay area (TERA 1991).

## METHODS

### Field Methods

A total of 30 study plots similar in design to those used in most of our North Slope studies (e.g., TERA 1992a) were sampled (Fig. 1). Study plot locations are in three areas: the Sagavanirktok delta adjacent to the Endicott Road, Heald Pt./East Dock area, and the West Dock/Pt. McIntyre area. The plot design and sampling of these plots were the same as for the ten PMRA study plots that provide comparative information for this study.

The 30 coastal plots are distributed such that there are 10 plots in each of three general habitat classes:

- Wet saline tundra,
- Nonsaline coastal tundra, and
- Dry coastal tundra.

Plots were censused following the same procedures used in similar studies we have conducted (see TERA 1992a for details). The primary sampling methods were:

**Search**—A single observer walked slowly through the plot in a zigzag pattern, making four passes (a "W") through each grid. One side of the plot (even- or odd-numbered grids) was completed before the observer continued down the other side to the starting point. The "W" pattern was reduced to a "V" during census periods when nesting was unlikely (e.g., during August post-breeding censuses). The location, behavior, sex, age, and habitat of all birds seen on the plot were recorded. Attempts were made to locate any nests suspected to be present because of a bird's behavior.

**Rope drag**—Two observers, one walking the centerline and the other the outside edge of the plot, dragged a rope over the tundra, flushing birds from nests. The two biologists walked up one side of the centerline before returning down the other side to the starting point. Nests located were recorded as above.

The census schedule provided near periodic sampling from early June through late August (Table 2). All these visits are used in the report to summarize seasonal trends in use of coastal habitats. Census Periods 2 through 5 (early June, mid-June, late June/early July, and mid-July) span most of the nesting season and comprise the core of the tundra bird studies. Rope drags of each plot have been made during Census Periods 3 and 4, which encompass most of the incubation interval. Results from these four visits, averaged to provide a single value, are used to characterize breeding-season use. Similarly, results of Census Periods 8, 9, and 10 were averaged to provide a density for the brood-rearing season, and Census Periods 6 and 7 were averaged to provide a density for the post-breeding season.

Additional visits were scheduled to check nests, and as hatch dates grew closer, an attempt was made to visit the plots at least every other day.

*Table 2. Plot census periods for the Coastal Tundra study.*

| | Period | Dates | Activity |
|---|---|---|---|
| 1 | Melt | 1–8 June | Plot setup and maintenance |
| 2 | Early June | 9–13 June | Nesting—Census |
| 3 | Mid-June | 15–27 June | Nesting—Rope Drag |
| 4 | Late June – early July | 1 July –10 July | Nesting—Census, Rope-Drag |
| 5 | Mid July | 11–18 July | Nesting—Census |
| 8 | Mid July | 19–25 July | Brood-rearing—Census |
| 9 | Late July | 26 July – 1 August | Brood-rearing—Census |
| 10 | Early August | 2–9 August | Brood-rearing—Census |
| 6 | Mid August | 10–16 August | Post-breeding—Census |
| 7 | Late-August | 15–23 August | Post-breeding—Census |
| 11 | End-August | 24–29 August | Post-breeding—Census |

## Analyses

This study is primarily a descriptive one designed to document bird use patterns of coastal habitats through the summer. Coastal tundra, especially saline tundra, is perceived to be disproportionately important to birds; therefore, our focus is on comparing bird use of the various types of coastal tundra. Comparisons among habitat types are done using the Kruskal-Wallis test. This test evaluates the hypothesis that whichever measure—nest density, breeding-season density, brood-rearing density, or post-breeding-season density—is the same in all four habitat classes (PMRA, Saline, Nonsaline, Dry). Results of tests were considered significant based on a criterion of $\alpha = 0.05$.

The analyses are intended to address the following questions:

- Do coastal habitats support higher densities of birds than non-coastal habitats?
- Are saline habitats used by higher densities of birds than nonsaline habitats?
- Are wet coastal habitats used by higher densities of birds than dry coastal habitats?

To provide additional information describing differential use by birds of coastal vs. inland areas, and to determine if there is a coastal band affecting bird distribution, comparisons were made among all study plots we have sampled in the Prudhoe Bay area since 1981. In previous studies we have suspected that underlying geographic gradients along both coastal-inland and east-west axes were influencing our plot densities (Troy 1991, TERA 1992b). Stepwise regression analyses were used to attempt to determine if gradients were present and to isolate the relative importance of coastal and east-west influences. Each plot was characterized by the density of each focus species, its distance from the coast, and its position on an east-west gradient. In the case of plots sampled in multiple years (e.g., the PMRA plots), the average density over all years was used. The distance to the coast was the shortest distance from the centroid of the plot to the coast. The east-west position was measured from the plot centroid to a north-south line (UTM) west of all plots (near Z-Pad) near the westernmost boundary of the Prudhoe Bay oil field.

Stepwise regression routines select variables based on ANOVA results; therefore, testing for significance of the resultant model is circular and the associated probabilities unreliable. Selection of either distance (from coast or from the east) is taken as evidence of a gradient in densities and the order of selection as indicative of the relative importance of the two potential gradients.

# RESULTS

## Nesting

### *Species Composition*

Most nests found on the coastal plots were of the species typical of the Prudhoe Bay region as a whole. Semipalmated Sandpiper and Lapland Longspur dominated the nesting community as typically found in the region. The species composition of the coastal plots appears to exhibit some differences in the relative importance of species as compared to the overall composition of the Prudhoe Bay area (Fig. 2). Species proportionately more frequent on the coastal plots than expected based on other studies included Baird's Sandpiper, Ruddy Turnstone, and to a lesser extent, Oldsquaw. In contrast, Stilt Sandpiper, Buff-breasted

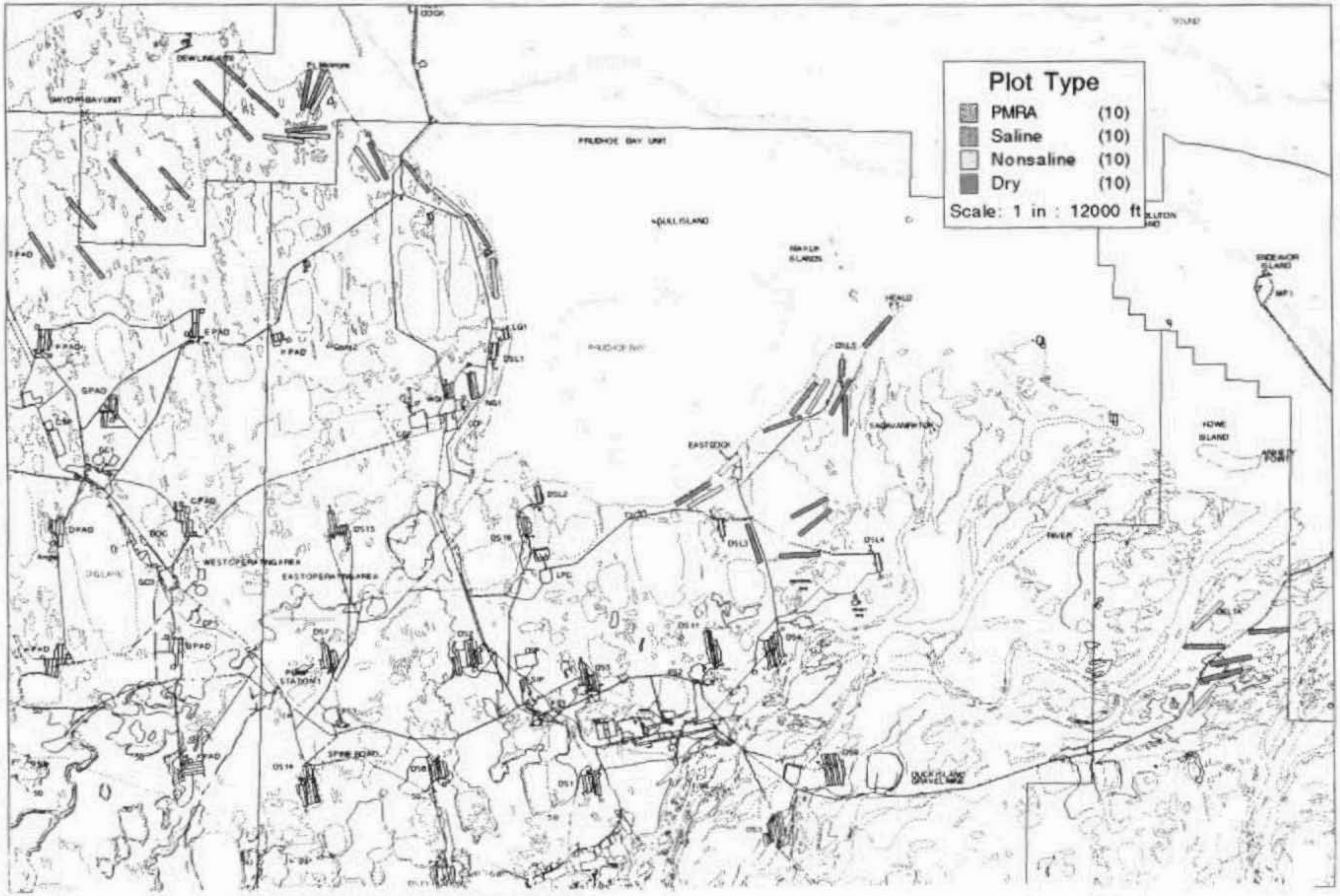


*Figure 1. Locations of study plots sampled for the Coastal Tundra Study.*

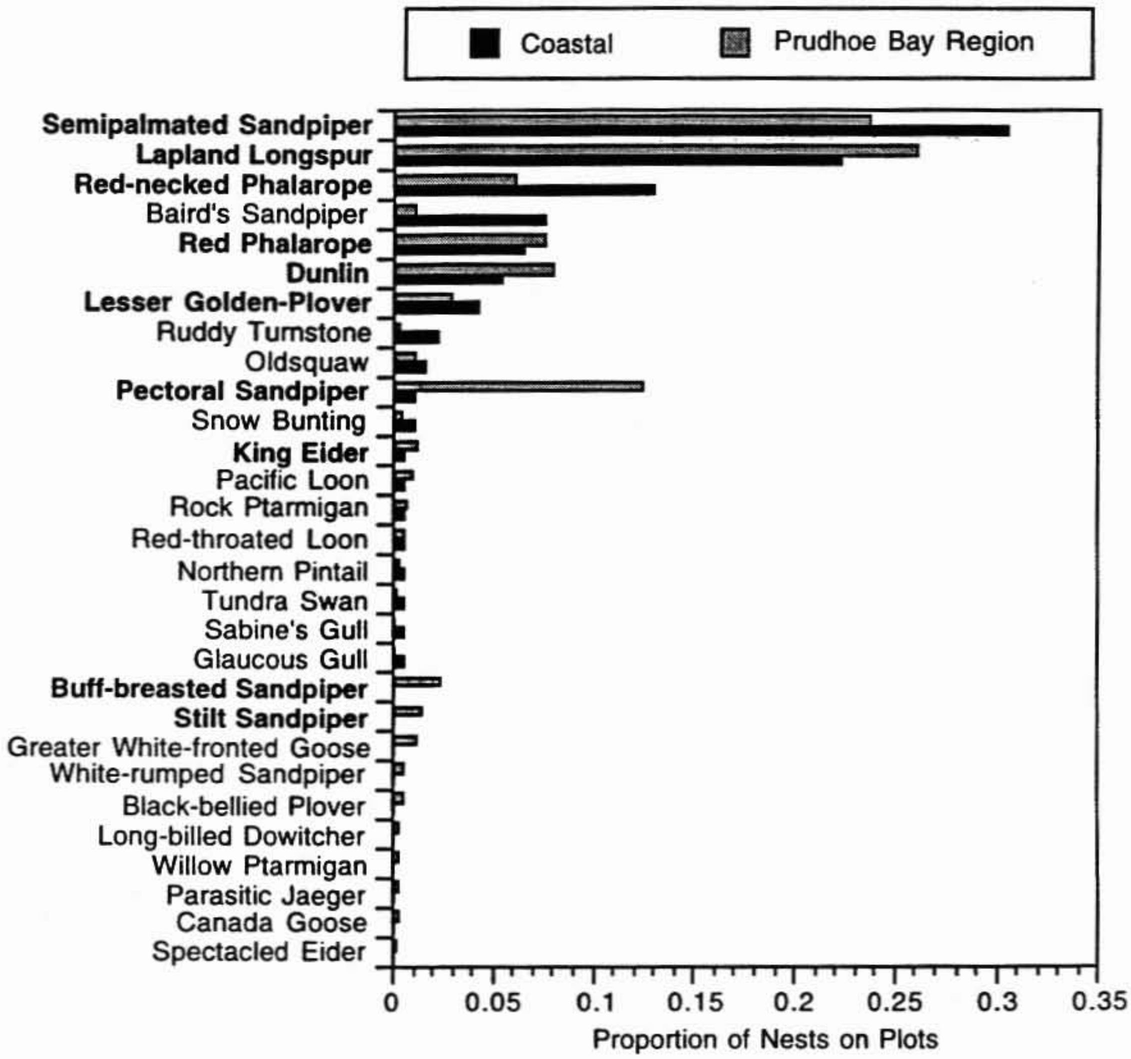


*Figure 2. Species composition of birds nesting on coastal plots in comparison to the Prudhoe Bay area tundra bird community (from TERA 1992a). Species are listed in decreasing order of abundance on coastal plots. Species shown in boldface are the species detailed in the analyses.*

Sandpiper, King Eider, and especially Pectoral Sandpiper were of lesser importance than generally found in the Prudhoe Bay area. As this investigation continues, we will see if these differences persist as more data are accumulated and the species composition is more accurately described.

### Densities

Nest densities of the key study species are shown by plot type in Table 3. More species reached their peak abundance in the PMRA (five) than in any other habitat. However, nonsaline plots had the highest density of almost as many species (four), and had a higher total density due to the extremely high density of Semipalmated Sandpiper. No key species had its peak abundance on saline or dry plots; indeed, most species had their lowest densities on dry plots.

Statistically significant differences in use of the plot types were found for Semipalmated Sandpiper and Lapland Longspur (Table 4, Fig. 3). Semipalmated Sandpiper nest density was markedly higher on nonsaline plots than any other type (Table 3). The lowest densities were found on dry plots and in the PMRA. (Although the mean density in these two plot types was the same, the median densities indicate higher use of the PMRA than dry plots.) Lapland Longspur density was also highest on nonsaline plots, although only slightly higher than in the PMRA (Table 3). The lowest density was found on saline plots.

## Seasonal Use

### Trends Over the Entire Summer

Seasonal abundance of the key species is summarized by plot type in Figure 4. These data reveal several

*Table 3. Nest densities (nests/km²) in coastal habitats and in the PMRA.*

| Species | PMRA | Saline | Nonsaline | Dry |
|---|---|---|---|---|
| King Eider | 2 | 0 | 1 | 0 |
| Lesser Golden-Plover | 4 | 2 | 4 | 2 |
| Semipalmated Sandpiper | 10 | 19 | 36 | 10 |
| Pectoral Sandpiper | 6 | 1 | 1 | 0 |
| Dunlin | 8 | 5 | 5 | 0 |
| Stilt Sandpiper | 3 | 0 | 0 | 0 |
| Buff-breasted Sandpiper | 1 | 0 | 0 | 0 |
| Red-necked Phalarope | 2 | 11 | 12 | 1 |
| Red Phalarope | 6 | 4 | 8 | 0 |
| Lapland Longspur | 22 | 8 | 23 | 10 |

*Table 4. Test results of Kruskal-Wallis analyses for among-areas differences in nest density. In all cases the degrees of freedom for the test statistics are 3 (four areas – 1). H is the Kruskal-Wallis test statistic. Significant test results are shown in boldface.*

| Species | H | p | Comments |
|---|---|---|---|
| King Eider | 0.293 | 0.9613 | |
| Lesser Golden-Plover | 1.171 | 0.76 | |
| Semipalmated Sandpiper | 16.393 | **0.0009** | High in nonsaline, low in dry |
| Pectoral Sandpiper | 4.435 | 0.2181 | |
| Dunlin | 7.582 | 0.0555 | |
| Stilt Sandpiper | 0.878 | 0.8307 | |
| Buff-breasted Sandpiper | 0.22 | 0.9744 | |
| Red-necked Phalarope | 4.674 | 0.1973 | |
| Red Phalarope | 4.926 | 0.1773 | |
| Lapland Longspur | 12.58 | **0.0056** | High in PMRA & nonsaline |

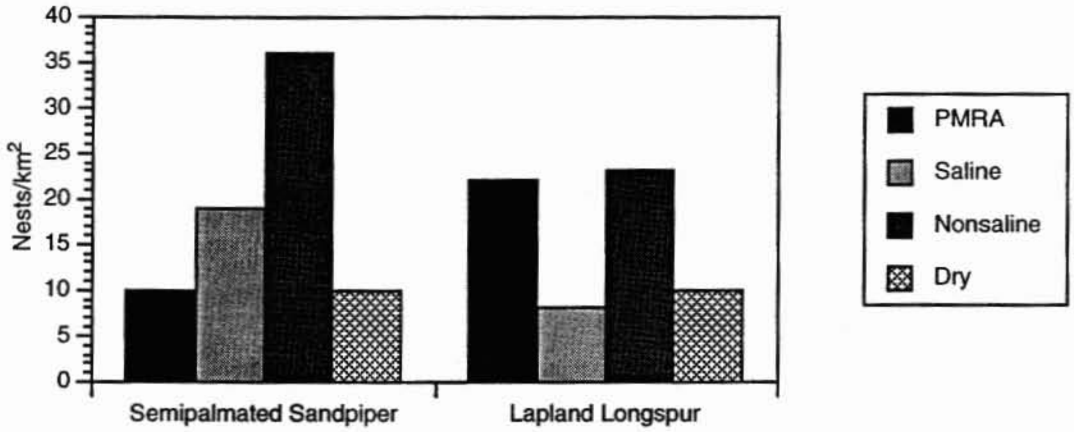


*Figure 3. Nest densities of the two species, Semipalmated Sandpiper and Lapland Longspur, having significant differences in density among plot types.*

patterns of seasonal use of the study plots. Change in species composition over the course of the summer is demonstrated by the marked diminution in abundance of Semipalmated Sandpiper after mid-July. However, post-breeding-season abundance of Stilt Sandpiper and Buff-breasted Sandpiper was much greater than during the breeding season.

King Eider was the only species that had it peak abundance in midsummer (second half of July). At this time most King Eiders were found on the nonsaline plots. Several patterns were exhibited by the shorebirds, with peaks in use occurring in any combination of early season (nesting), late July (adult migration), or mid-August (mostly juvenile migrants). Dry plots were widely used by shorebirds only during migration, especially by Lesser Golden-Plover, Dunlin, and Buff-breasted Sandpiper. Saline plots received some use throughout the summer but never supported high densities of shorebirds relative to other types of tundra. The species making the greatest use of saline plots were post-breeding Stilt Sandpiper and both species of phalaropes (especially post-breeding Red-necked Phalarope). Nonsaline plots were used by most study species, with the greatest use by Semipalmated Sandpiper and Pectoral Sandpiper. Use of nonsaline plots appears to be proportional to the abundance of these species; i.e., there did not appear to be habitat-specific variations in abundance on nonsaline plots such as the intermittent peaks in use of dry and saline plots.

All species of shorebirds used the PMRA during the breeding season, but post-breeding-season presence on these plots was species specific. Some species, such as Lesser Golden-Plover, Buff-breasted Sandpiper, and especially Semipalmated Sandpiper decreased in abundance as the summer progressed. Pectoral Sandpiper, in contrast, made increased use of the PMRA during the post-breeding season.

Lapland Longspur density was highest during the breeding season. The highest densities were in the PMRA and on the nonsaline plots. Abundance decreased in mid-July but increased during the post-breeding season to levels somewhat lower than the breeding season peak. During the post-breeding season many species shifted from use of the PMRA and nonsaline plots onto saline plots.

#### *Breeding Season*

Tests for differences in habitat use during the breeding season were based on average number of birds recorded during the four breeding-season cen-

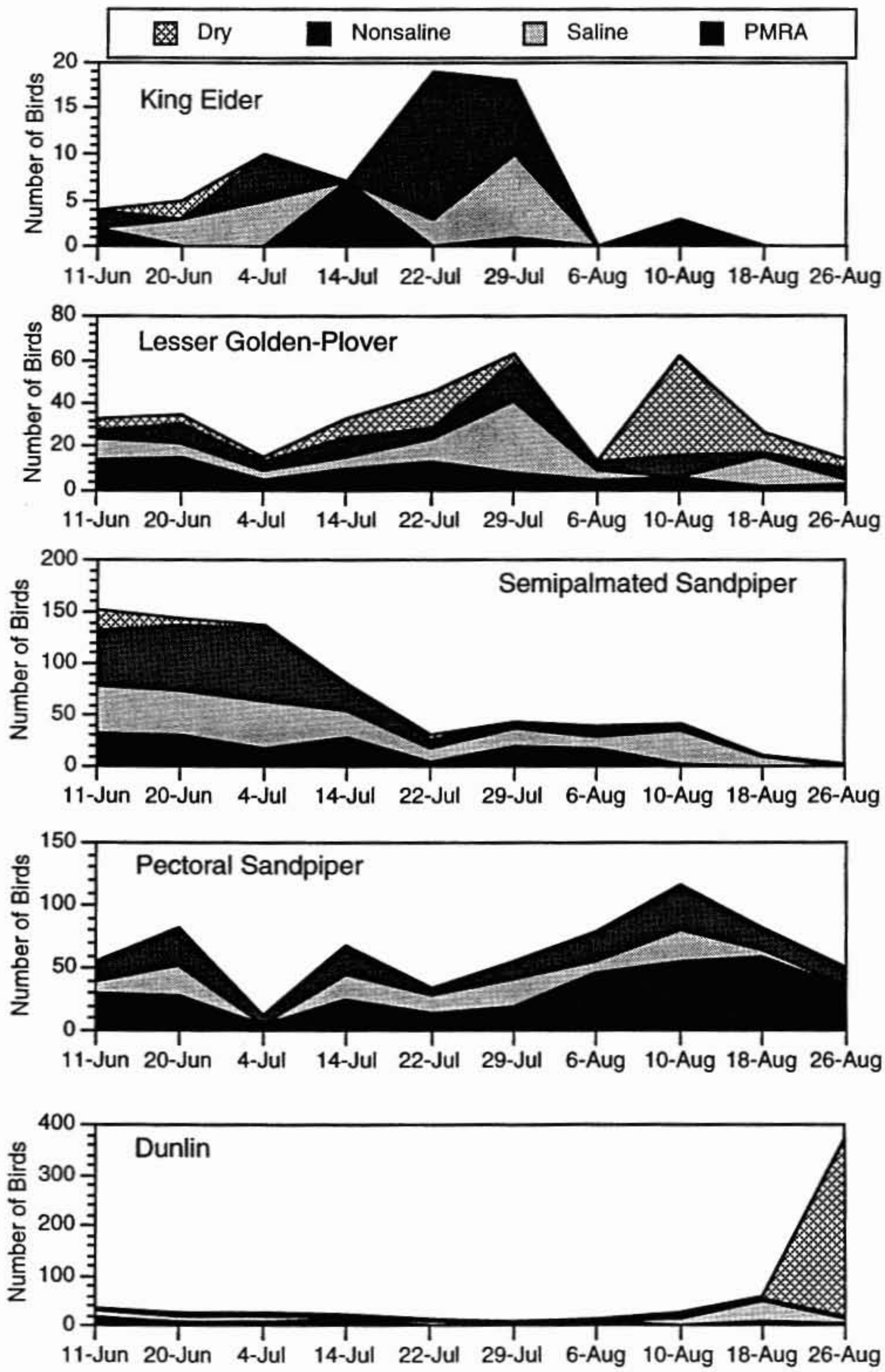


*Figure 4. Seasonal abundance of birds by plot type.*

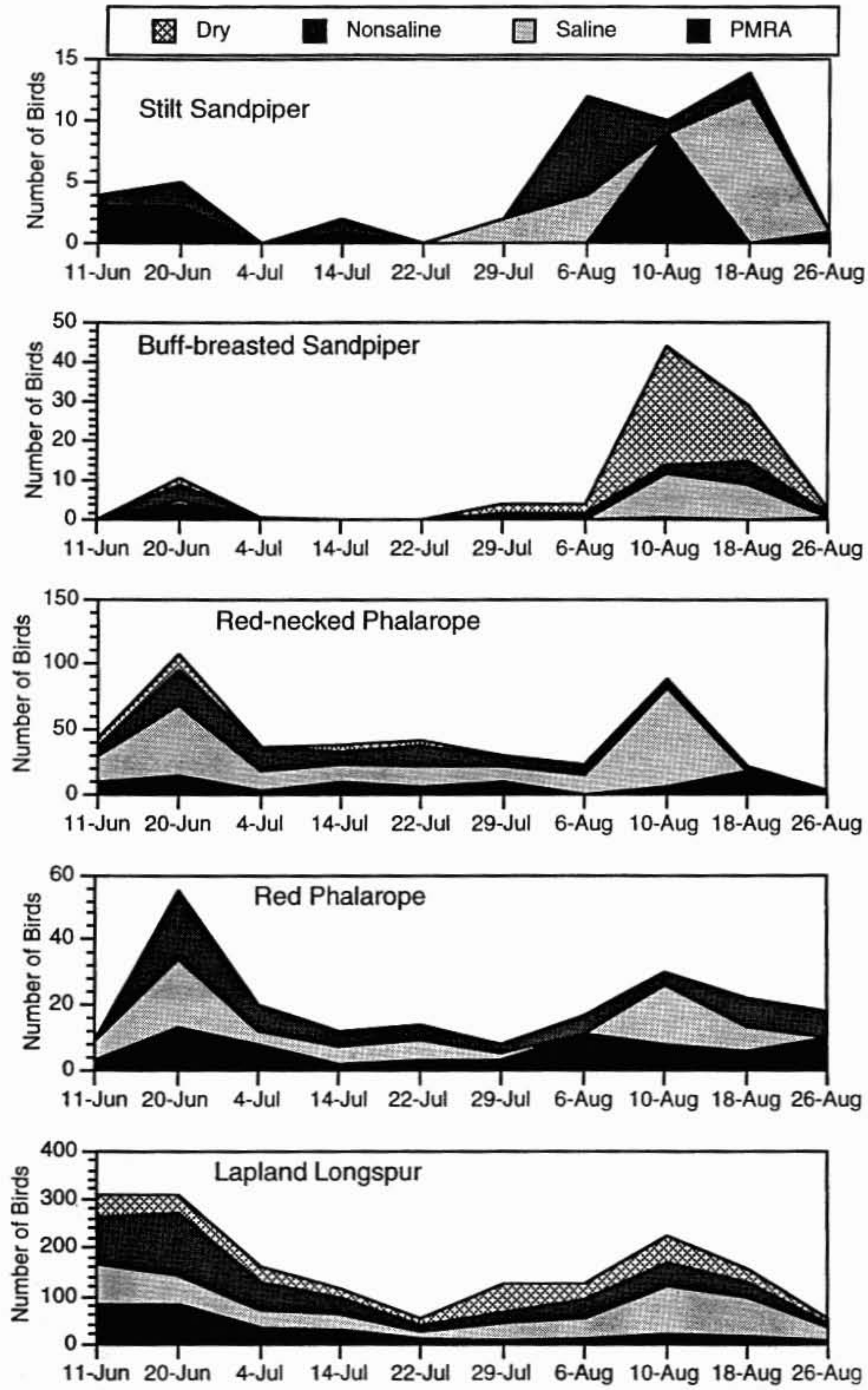


*Figure 4. Continued.*

*Table 5. Average breeding-season density (#/km²) of birds in coastal habitats and the PMRA.*

| Species | PMRA | Saline | Nonsaline | Dry |
|---|---|---|---|---|
| King Eider | 2.2 | 2.0 | 1.8 | 0.5 |
| Lesser Golden-Plover | 11.0 | 6.0 | 6.8 | 5.2 |
| Semipalmated Sandpiper | 27.5 | 40.2 | 53.5 | 7.2 |
| Pectoral Sandpiper | 22.8 | 12.5 | 18.2 | 1.8 |
| Dunlin | 14.5 | 9.2 | 6.0 | 0.0 |
| Stilt Sandpiper | 1.8 | 0.0 | 1.0 | 0.0 |
| Buff-breasted Sandpiper | 1.2 | 0.2 | 1.0 | 0.5 |
| Red-necked Phalarope | 9.0 | 26.0 | 15.2 | 6.5 |
| Red Phalarope | 6.5 | 9.0 | 8.2 | 0.2 |
| Lapland Longspur | 58.5 | 51.2 | 82.5 | 31.5 |

*Table 6. Test results of Kruskal-Wallis analyses for among-year changes in breeding-season bird density (d.f. = 3). "H" is the Kruskal-Wallis test statistic.*

| Species | H | p | Comments |
|---|---|---|---|
| King Eider | 0.552 | 0.9073 | |
| Lesser Golden-Plover | 5.613 | 0.132 | |
| Semipalmated Sandpiper | 17.652 | **0.005** | Low use of dry |
| Pectoral Sandpiper | 13.07 | **0.0045** | Low use of dry |
| Dunlin | 19.32 | **0.0002** | Low use of dry; high use of PMRA |
| Stilt Sandpiper | 5.298 | 0.1512 | |
| Buff-breasted Sandpiper | 0.718 | 0.8689 | |
| Red-necked Phalarope | 6.412 | 0.0932 | |
| Red Phalarope | 7.972 | **0.0466** | Low use of dry |
| Lapland Longspur | 17.649 | **0.0005** | Low use of dry; high use of nonsaline |

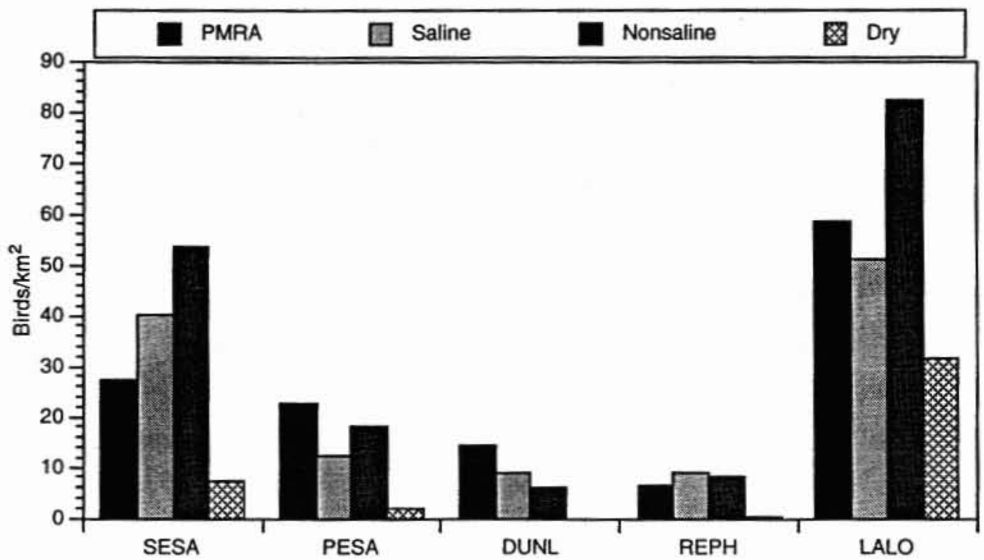


*Figure 5. Breeding-season densities of the species exhibiting significant differences among plot type.*

suses (Census Periods 2–5). Use of the four types of plots sampled differed markedly among the study species (Table 5). Differences in habitat use were statistically verified for five species—Semipalmated Sandpiper, Pectoral Sandpiper, Dunlin, Red Phalarope, and Lapland Longspur (Table 6, Fig. 5). Dry plots were little used by any of the study species during the breeding season, and this was a major contributing factor to the differences in habitat use of the five species exhibiting statistical differences in use of plot types.

There was, however, evidence of attraction to some plot types. Dunlin appeared to make disproportionately high used of the PMRA, and Lapland Longspur density was much higher on nonsaline plots than any other plot type (Table 5). In general, the most diverse area for birds during the breeding-season was the PMRA, where six of the ten study species reached their highest abundance. Nonsaline plots appear to have the highest use by birds, due to the high densities of Semipalmated Sandpiper and Lapland Longspur.

#### *Brood-Rearing Season*

The brood-rearing-period analyses are based on the average densities recorded on plots during Census Periods 8–10 (19 July through 9 August). Difference among plot types (Table 7) was much less pronounced than during the breeding season. Only two species—Semipalmated and Pectoral sandpipers—exhibited statistically significant differences among plot types (Table 8, Fig. 6). Both species made very low use of dry plots, and Pectoral Sandpiper appeared to make disproportionately high use of the PMRA during this portion of the summer.

During the breeding season, the PMRA had the highest bird diversity, with more species peaking in abundance in that area than any other plot type. This was not the situation during the brood-rearing period, when a few species peaked in each habitat type. The only tendency for a general trend was that most species had their lowest density in dry plots; however, Buff-breasted Sandpiper and Lapland Longspur were exceptions in appearing to favor dry plots.

#### *Post-Breeding Season*

The post-breeding season is defined as Census Periods 6 and 7 (10–23 August). Habitat use during this period was markedly different from earlier portions of the summer (Table 9). Pectoral Sandpiper, Buff-breasted Sandpiper, Red Phalarope, and Lapland Longspur exhibited statistically significant difference in use of the four types of plots (Table 10, Fig. 7), but all had different patterns of habitat use. Pectoral Sandpiper made high use of the PMRA but low use of dry plots. Buff-breasted Sandpiper demonstrates the opposite pattern. This species was most common in dry plots; none was found in the PMRA. Both Red Phalarope and Lapland Longspur appeared to prefer the saline plots. Red Phalarope did not occur on dry plots, and Lapland Longspur made relatively little use of the PMRA.

Overall, saline plots were the most widely used plot type during the post-breeding season. Half of the species occurred in their highest densities in this type. Dry plots continued to be little used by most species; however, densities of Lesser Golden-Plover and Buff-breasted Sandpiper were much higher in dry plots than any other habitat type.

### Gradients

#### *Nest Density*

Geographic gradients were found for nest densities of six of the ten study species (Table 11). Distance from coast was a determinant of density for five of these species: Dunlin, Stilt Sandpiper, Red-necked Phalarope, Red Phalarope, and Lapland Longspur. The sixth species, Buff-breasted Sandpiper, exhibited density trends along an east-west geographic axis. Coastal influences were most important (primary variable in regression results) for Stilt Sandpiper, Red Phalarope, and Lapland Longspur (Fig. 8). Red Phalarope density decreased at inland locations, whereas the other two species increased inland from the coast.

These results are important in that they reveal the presence of two gradients operating over relatively short distances that exert rather pronounced influences on nest densities. In the case of Dunlin, Stilt Sandpiper, and Red-necked Phalarope, 10 to 15 percent of the variability in nest densities appears to be attributable to these gradients.

#### *Breeding-Season Density*

Geographic gradients were important in describing abundance trends of eight of the study species during the breeding season (Table 12). Only Lesser Golden-Plover and Pectoral Sandpiper abundances were relatively unaffected by coastal and east-west gradients. These factors were especially important predictors of abundance of Stilt Sandpiper, Dunlin, and Lapland Longspur; for these species, 10 to 30 percent of the variability of densities is attributable to plot lo-

*Table 7. Average brood-rearing-season density (#/km²) of birds in coastal habitats and the PMRA.*

| Species | PMRA | Saline | Nonsaline | Dry |
|---|---|---|---|---|
| King Eider | 3.3 | 4.0 | 8.0 | 0.0 |
| Lesser Golden-Plover | 8.7 | 15.7 | 8.7 | 7.3 |
| Semipalmated Sandpiper | 14.0 | 14.3 | 7.7 | 2.7 |
| Pectoral Sandpiper | 26.7 | 15.3 | 13.7 | 0.3 |
| Dunlin | 5.3 | 4.0 | 3.3 | 1.0 |
| Stilt Sandpiper | 0.0 | 2.0 | 2.7 | 0.0 |
| Buff-breasted Sandpiper | 0.7 | 0.0 | 0.7 | 1.3 |
| Red-necked Phalarope | 5.7 | 13.3 | 10.0 | 2.7 |
| Red Phalarope | 5.7 | 2.7 | 4.7 | 0.0 |
| Lapland Longspur | 11.0 | 28.7 | 27.3 | 34.7 |

*Table 8. Test results of Kruskal-Wallis analyses for among-year changes in brood-rearing season bird density (d.f. = 3). "H" is the Kruskal-Wallis test statistic.*

| Species | H | p | Comments |
|---|---|---|---|
| King Eider | 3.239 | 0.3563 | |
| Lesser Golden-Plover | 0.837 | 0.8407 | |
| Semipalmated Sandpiper | 7.832 | **0.0496** | Low use of dry |
| Pectoral Sandpiper | 15.239 | **0.0016** | Low use of dry, high use of PMRA |
| Dunlin | 4.82 | 0.1855 | |
| Stilt Sandpiper | 1.672 | 0.6433 | |
| Buff-breasted Sandpiper | 0.896 | 0.8265 | |
| Red-necked Phalarope | 7.623 | 0.0545 | |
| Red Phalarope | 6.407 | 0.0934 | |
| Lapland Longspur | 5.34 | 0.1485 | |

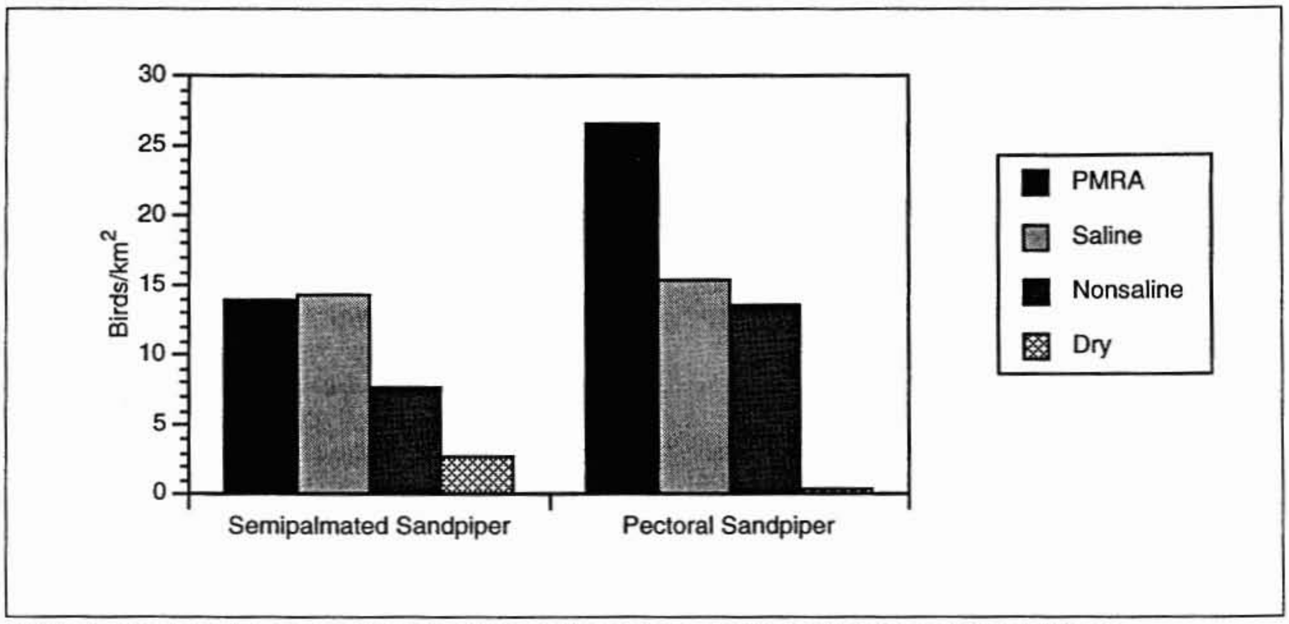


*Figure 6. Brood-rearing-season densities of the species having significant differences among plot types.*

*Table 9. Average post-breeding-season density (#/km²) in coastal habitats and in the PMRA.*

| Species | PMRA | Saline | Nonsaline | Dry |
|---|---|---|---|---|
| King Eider | 1.5 | 0.0 | 0.0 | 0.0 |
| Lesser Golden-Plover | 4.0 | 6.5 | 6.0 | 27.5 |
| Semipalmated Sandpiper | 0.5 | 2.1 | 4.5 | 0.0 |
| Pectoral Sandpiper | 55.5 | 14.5 | 24.5 | 2.5 |
| Dunlin | 5.5 | 25.0 | 10.5 | 3.5 |
| Stilt Sandpiper | 4.5 | 6.0 | 1.5 | 0.0 |
| Buff-breasted Sandpiper | 0.0 | 10.0 | 4.0 | 22.0 |
| Red-necked Phalarope | 12.5 | 38.0 | 3.5 | 1.0 |
| Red Phalarope | 6.5 | 12.5 | 6.5 | 0.0 |
| Lapland Longspur | 10.5 | 92.0 | 37.5 | 43.0 |

*Table 10. Test results of Kruskal-Wallis analyses for among-area differences in post-breeding-season bird density.*

| Species | H | p | Comments |
|---|---|---|---|
| King Eider | 0.22 | 0.9744 | |
| Lesser Golden-Plover | 4.127 | 0.2481 | |
| Semipalmated Sandpiper | 7.386 | 0.0606 | |
| Pectoral Sandpiper | 14.29 | **0.0025** | High use of PMRA |
| Dunlin | 6.766 | 0.0798 | |
| Stilt Sandpiper | 1.38 | 0.7102 | |
| Buff-breasted Sandpiper | 11.818 | **0.008** | High use of dry |
| Red-necked Phalarope | 2.375 | 0.4983 | |
| Red Phalarope | 9.765 | **0.0207** | High use of saline; low use of dry |
| Lapland Longspur | 13.25 | **0.0041** | High use of saline; low use of PMRA |

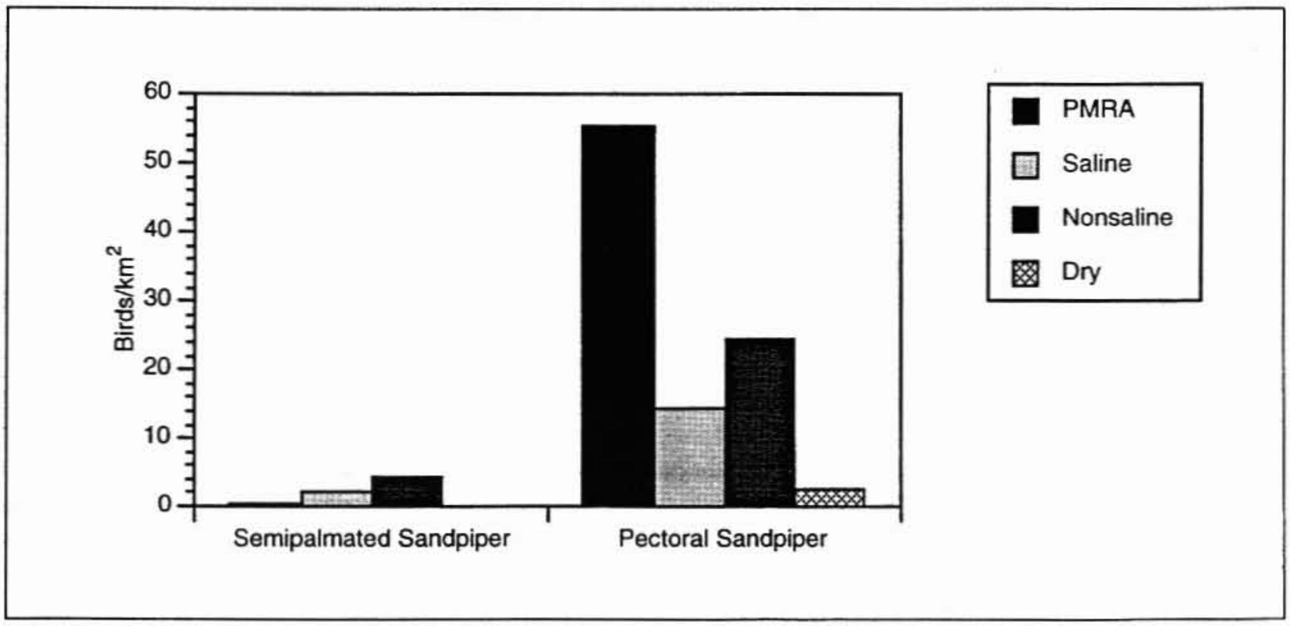


*Figure 7. Post-breeding-season densities of the species having significant differences among plot types.*

*Table 11. Results of stepwise regression analyses of nest density in relation to distance from the coast and along an east-west gradient (total d.f. = 209). The order (relative importance) that the distance from the coast or along the east-west gradient is listed if these variables participated in the regression model. If no entry is made, neither variable exhibited a demonstrable relationship with nest density.*

| Species | F | Coast | East | $r^2$ | Increasing Density |
|---|---|---|---|---|---|
| King Eider | | | | | |
| Lesser Golden-Plover | | | | | |
| Semipalmated Sandpiper | | | | | |
| Pectoral Sandpiper | | | | | |
| Dunlin | 17.275 | 2 | 1 | 0.143 | West and coastal |
| Stilt Sandpiper | 10.737 | 1 | 2 | 0.094 | Inland and west |
| Buff-breasted Sandpiper | 5.111 | | 1 | 0.024 | West |
| Red-necked Phalarope | 18.706 | 2 | 1 | 0.153 | East and inland |
| Red Phalarope | 4.679 | 1 | | 0.022 | Coastal |
| Lapland Longspur | 4.489 | 1 | | 0.021 | Inland |

*Table 12. Results of stepwise regression analyses of breeding-season densities in relation to distance from coast and along an east-west gradient (total d.f. = 209). The order (relative importance) that the distance from the coast or along the east-west gradient is listed if these variables participated in the regression model. If no entry is made, neither variable exhibited a demonstrable relationship with bird density.*

| Species | F | Coast | East | $r^2$ | Increasing Density |
|---|---|---|---|---|---|
| King Eider | 5.921 | 1 | 2 | 0.054 | Coastal and west |
| Lesser Golden-Plover | | | | | |
| Semipalmated Sandpiper | 5.171 | 1 | | 0.024 | Inland |
| Pectoral Sandpiper | | | | | |
| Dunlin | 30.437 | 2 | 1 | 0.227 | West and coastal |
| Stilt Sandpiper | 47.526 | 1 | 2 | 0.315 | Inland and west |
| Buff-breasted Sandpiper | 4.128 | | 1 | 0.019 | West |
| Red-necked Phalarope | 5.364 | 2 | 1 | 0.049 | East and inland |
| Red Phalarope | 5.987 | 1 | 2 | 0.055 | Coastal and west |
| Lapland Longspur | 26.664 | | 1 | 0.114 | West |

cation. The species most affected by distance from coast were King Eider, Semipalmated Sandpiper, Stilt Sandpiper, and Red Phalarope. Distance from the coast was also important in affecting densities of Dunlin and Red-necked Phalaropes but was secondary to location on an east-west axis.

Trends in abundance of some species whose abundance appears to be most affected by distance from the coast—Stilt Sandpiper, Dunlin, and Red Phalarope—are shown in Figure 9. Stilt Sandpiper increase in abundance inland, whereas both Dunlin and Red Phalarope were found in higher densities on plots near the coast.

### *Post-Breeding-Season Density*

Geographic location was important in determining densities for six of the ten study species during the post-breeding season (Table 13), describing up to 20 percent of the among-plot variability in density. Four of these species—Semipalmated Sandpiper, Dunlin, Red Phalarope, and Lapland Longspur—exhibited density gradients in relation to distance from the coast. Except for Lapland Longspur, all these coastal gradients involved higher densities in proximity to the coast. Trends of the species exhibiting the strongest coastal gradients are illustrated in Figure 10.

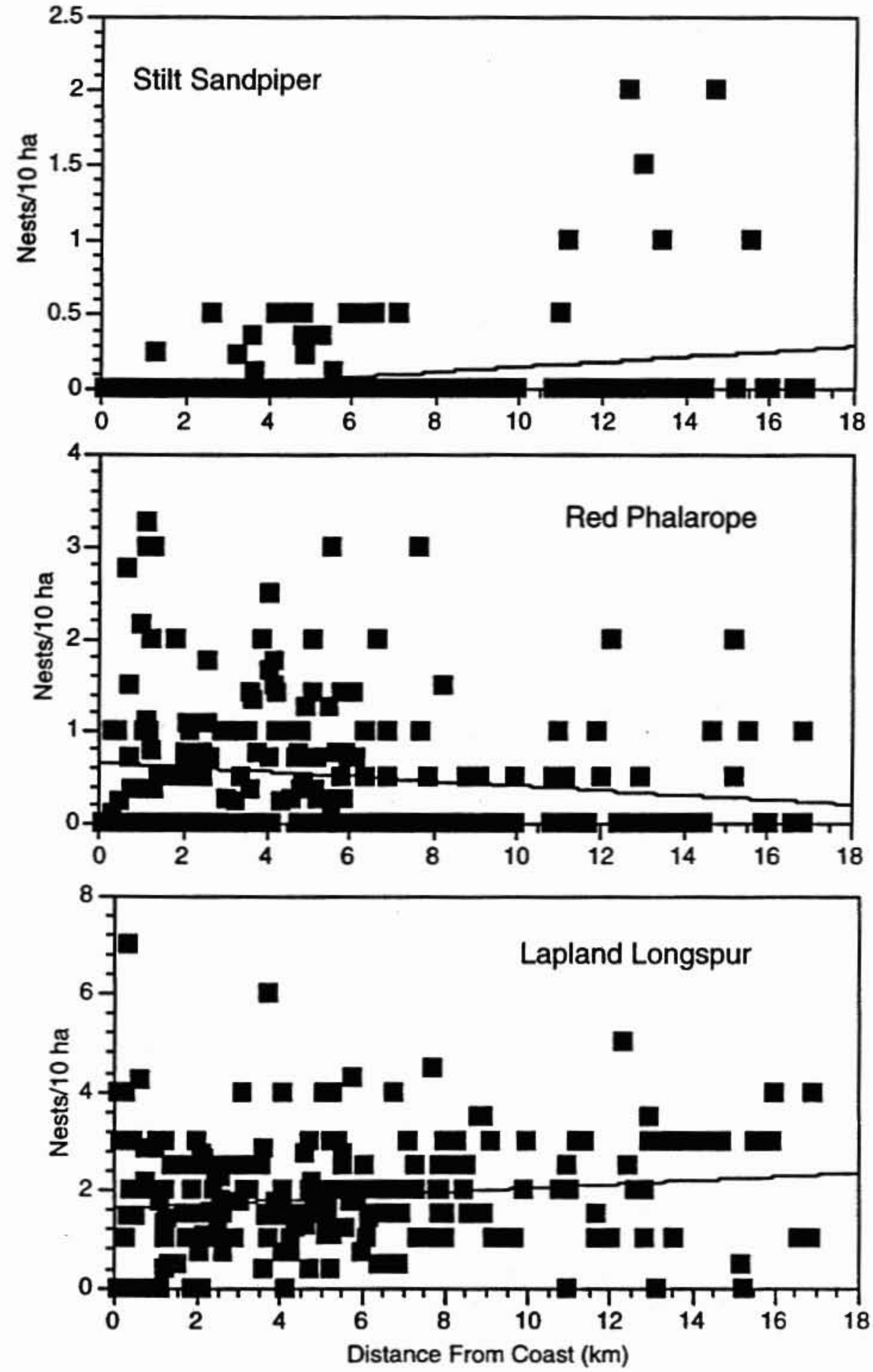


*Figure 8. Trends in nest densities in relation to distance from coast of Stilt Sandpiper, Red Phalarope and Lapland Longspur.*

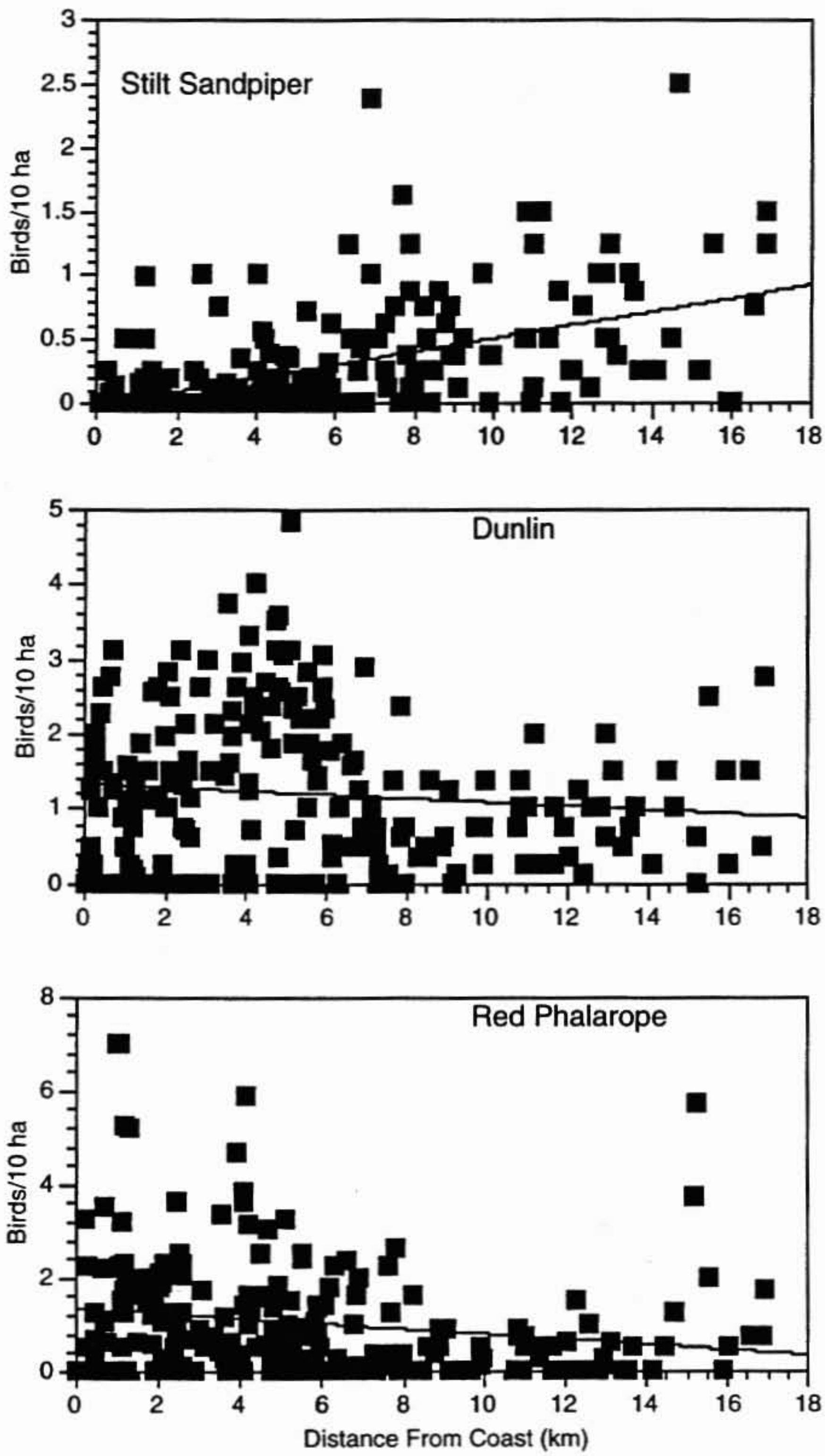


*Figure 9. Trends in breeding-season densities in relation to distance from coast of Stilt Sandpiper, Dunlin, and Red Phalarope.*

*Table 13. Results of stepwise regression analyses of post-breeding-season densities in relation to distance from coast and along an east-west gradient (total d.f. = 180). The order (relative importance) that the distance from the coast or along the east-west gradient is listed if these variables participated in the regression model. If no entry is made, neither variable exhibited a demonstrable relationship with bird density.*

| Species | F | Coast | East | $r^2$ | Increasing Density |
|---|---|---|---|---|---|
| King Eider | | | | | |
| Lesser Golden-Plover | 16.487 | | 1 | 0.084 | East |
| Semipalmated Sandpiper | 10.491 | 1 | 2 | 0.105 | Coastal and west |
| Pectoral Sandpiper | | | | | |
| Dunlin | 6.166 | 1 | 2 | 0.065 | Coastal and west |
| Stilt Sandpiper | | | | | |
| Buff-breasted Sandpiper | 23.649 | | 1 | 0.117 | East |
| Red-necked Phalarope | | | | | |
| Red Phalarope | 13.156 | 1 | 2 | 0.129 | Coastal and west |
| Lapland Longspur | 22.335 | 1 | 2 | 0.201 | Inland and east |

# DISCUSSION

## Use of Coastal Habitats

### *Nesting*

Arctic coastal tundra has rarely been described as having special attributes for nesting birds. Some arctic birds have narrow coastal distributions, especially those birds associated with islands or the ocean such as Common Eider (Schamal 1974, Wiggins and Johnson 1992) and Black Guillemot (Divoky et al. 1974), but these species are not expected to occur with any regularity in mainland tundra. Other species, such as Spectacled Eider and Red Phalarope, are often characterized as having coastal distributions. This is true only when *coast* is defined on a broad scale such as the Arctic Coastal Plain. In the central Beaufort region, the Arctic Coastal Plain is tens of kilometers wide, encompassing much of the Prudhoe Bay area. During the breeding season, most activity of birds is centered in tundra, not littoral areas (Connors et al. 1979). One of the few reported examples of selective use of coastal wetlands during the nesting season is of King Eiders (Bergman et al. 1977).

Our sampling indicates that coastal habitats are somewhat more distinctive than might have been expected based on the background summarized above. Baird's Sandpiper and Ruddy Turnstone were prominent members of the coastal nesting community, but these species occur only incidentally elsewhere in the Prudhoe Bay area and generally in disturbed habitats. That these two species were found in all three types of coastal plots suggests that proximity to the coast rather than sampling of some particular habitat type (e.g., dry plots) was important to them. Even including these specialists, the plots sampling the most strictly coastal habitats (saline and dry plots) supported relatively low nest densities. Nonsaline coastal plots sampled a habitat type that appears to have characteristics preferred by some of the common Prudhoe Bay area breeding birds, especially Semipalmated Sandpiper, Lapland Longspur, and Red-necked Phalarope. Nest density of Semipalmated Sandpiper in this plot type was almost twice as high as any other plot type sampled in 1991 (36 nests/km$^2$ on nonsaline plots vs. 19 nests/km$^2$ on saline plots). Overall, none of the coastal habitat associations sampled supported a nesting community as diverse as the PMRA, which is just slightly farther inland.

The stepwise regression analyses indicated that plot location was an important determinant of densities for several species. Although distance from the coast was involved in the regression model for more species (five) than was the east/west location (four), on the basis of the $r^2$ values the east-west gradient was stronger when it occurred. The coastal gradients indicated that Stilt Sandpiper, Red-necked Phalarope, and Lapland Longspur nest densities increased with increasing distance inland, whereas Dunlin and Red Phalarope nest densities were highest near the coast. The strongest coastal gradients were for Stilt Sandpiper, Red Phalarope, and Lapland Longspur. Based on the regression lines (Fig. 8), the expected nest densities (nests/km$^2$) of these species at the coast compared to 20

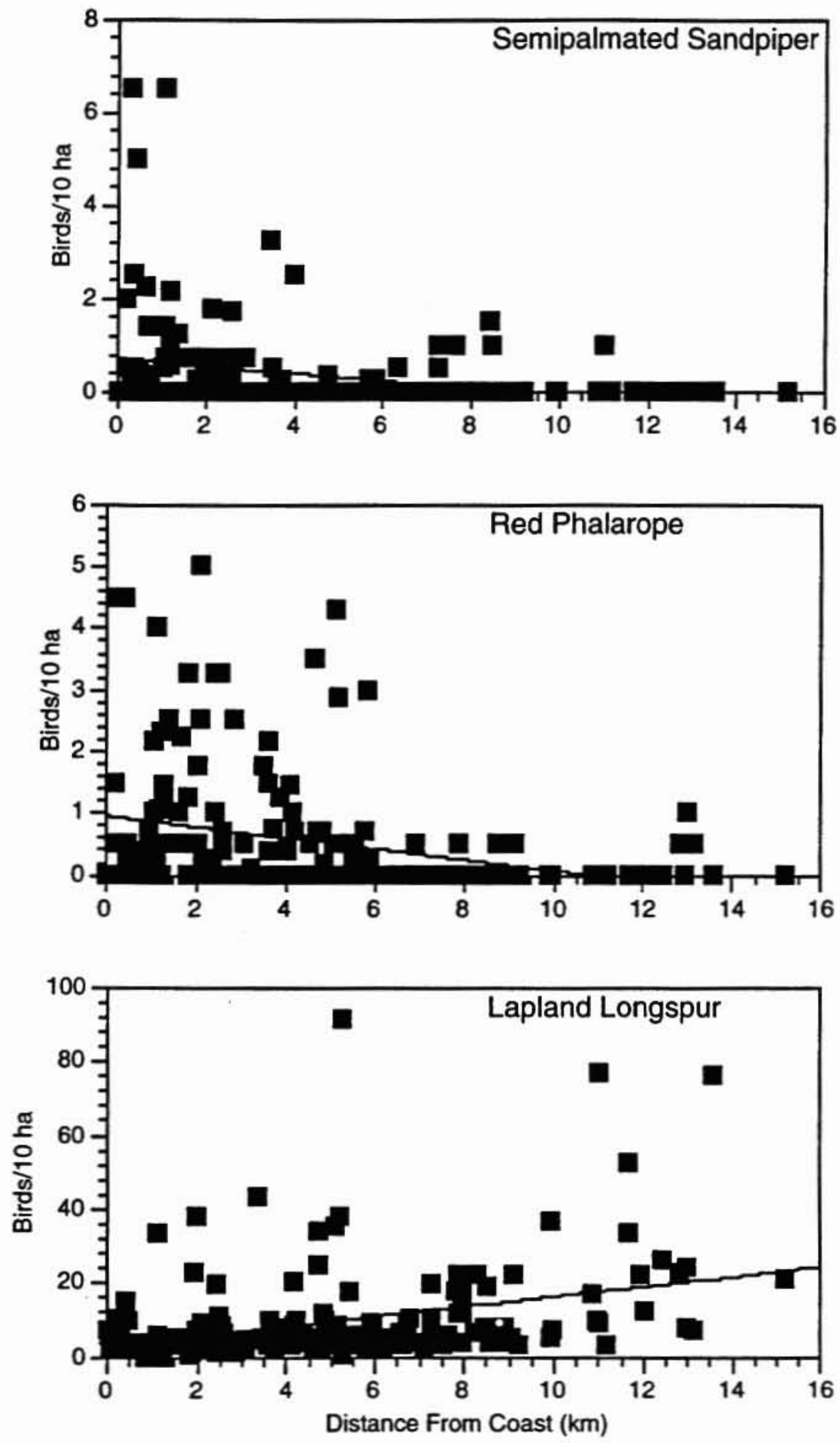


*Figure 10. Trends in post-breeding-season densities in relation to distance from coast of Semipalmated Sandpiper, Red Phalarope, and Lapland Longspur.*

km inland would be as follows: Stilt Sandpiper, 0.0 vs. 3.2; Red Phalarope, 6.6 vs. 1.6; and Lapland Longspur, 16.5 vs. 24.4. Inspection of the density profiles for these species (Fig. 8) reveals that the coastal zone is quite broad, if it can be defined at all. Stilt Sandpiper has not been found nesting at a measurable density within 1 km of the coast, and densities have been quite low within 10 km of the coast. Farther inland, Stilt Sandpiper nest densities are variable but can be considerably higher. Red Phalarope densities vary more at all distances from the coast than do Stilt Sandpiper densities; however, there is a tendency for higher Red Phalarope densities within 10 km of the coast than farther away. The trend in Lapland Longspur nest densities was the most gradual of the three and exhibited no indication of zonation along the range sampled.

The nest data provide weak evidence of coastal zonation. No species had a high degree of reliance on specific coastal habitats, but Baird's Sandpiper and Ruddy Turnstone appear to have an affinity for strictly coastal locations, generally within 1 to 2 km of the coast. On a broader scale there was some evidence of a discontinuity approximately 10 km from the coast (roughly at the Spine Road). Stilt Sandpiper nest density increased markedly inland of this demarcation, whereas Red Phalarope nest densities were highest shoreward of this distance. This corresponds to the zone of rapid temperature flux reported by Walker et al. (1980).

### *Seasonal Use by Birds*

The attachment of birds to their nest sites would lead to the expectation that densities of birds would remain stable during the nesting season. The census data, however, indicate a remarkable amount of flux in bird populations during this time period. Shorebirds provide good examples of the dynamic nature of abundance fluctuations. The basic pattern in shorebird abundance trends on the North Slope has three phases: 1) arrival and nesting, 2) a July pulse corresponding to the outbound migration of adults, and 3) an August pulse corresponding to the outbound migration of juveniles (Connors et al. 1979) (see, for example, Lesser Golden-Plover or Pectoral Sandpiper in Fig. 4). This basic pattern may be modified depending on the species. For example, species with uniparental incubation such as Pectoral Sandpiper and phalaropes may have two pulses of adult migrants, the first in June overlapping with incubation and the second following hatch.

Our analyses of bird densities divide the summer into three periods—breeding, brood-rearing, and post-breeding—based on major components of the nesting cycle. Migrants may be recorded on censuses during all these periods, especially during the brood-rearing period.

**Breeding Season.** During the breeding season the coastal habitats were not expected to be of particular significance to birds. Saline and other coastal tundras have not been described as being of particular importance to nesting birds, with the possible exception of King Eider (Bergman et al. 1977). Some species, such as Semipalmated Sandpipers, nesting in nearby areas may make use of coastal habitats (Connors et al. 1979), but no major concentrations have been reported.

The results of this study generally support the prevailing idea that coastal habitats are not especially important during the breeding season. Many significant differences were found among plot types, and all of these differences were largely because of low densities on dry plots. As was found based on the nest data, the PMRA supported the most diverse bird assemblage during the breeding season, with six of the ten study species having their highest densities in this region slightly removed from the coast. The nonsaline coastal tundra, however, had considerably higher densities of Semipalmated Sandpiper and Lapland Longspur than any other plot type.

Red and Red-necked phalaropes had the greatest affinity of any of the study species to saline plots. Densities of these species were higher on this plot type than any other, although the differences among plot types were not significant. The nest data did not indicate any particular attraction of phalaropes to saline tundra. Phalaropes have uniparental incubation, with the males performing all the incubation and early brood-rearing (Schamel and Tracy 1977). This frees the females to begin their outbound migration during late-June. Our data show a pulse in densities in late June (Fig. 4), with a disproportionate number of birds in saline tundra, at least in the case of Red-necked Phalarope. This suggests that saline tundra is being used primarily by staging or migrant phalaropes.

The analyses of broad-scale geographic patterns revealed that almost all the study species had significant density gradients in either coastal or east-west orientations. The east-west gradient affected marginally more species (seven) than the coastal gradient (six). The magnitude of geographic effect was especially high for Stilt Sandpiper (32% of the variability) and Dunlin (23% of the variability). The species exhibiting coastal gradients were King Eider, Semipalmated Sandpiper, Dunlin, Stilt Sandpiper, Red-necked Phalarope, and Red Phalarope. These gradients were evenly split in both directions; the species most common near the coast were King Eider, Dunlin, and Red Phalarope. The distributions of Stilt Sandpiper, Dunlin, and Red Phalarope were examined in greatest detail as they appeared to be the species with the strongest coastal gradients (Fig. 9). Stilt Sandpiper density trends mirrored those described for the nest data of this species, with low densities (most plots without birds) near the coast but with higher values farther inland. Based on the regression line (Fig. 9), no Stilt Sandpipers would be expected at the coast, but 10.3 birds/km$^2$ would be expected 20 km inland. The gradient between these extremes may not be linear, as there is some indication of zonation, with a boundary approximately 7 km from the coast, slightly more coastal than the 10 km estimated based on the nest data. A similar boundary can be discerned in the Dunlin and Red Phalarope data sets but with higher densities shoreward of a distance contour 7 to 8 km from the coast. The regression lines (Fig. 9) indicate expected densities of 13.5 Dunlin/km$^2$ on the coast but only 8.5 20 km inland. The corresponding densities of Red Phalaropes are 13.7 on the coast and 2.6 20 km inland.

**Brood-Rearing Season.** The brood-rearing period is the first portion of the summer when, based on prior studies, coastal habitats are expected to show concentrations in bird use relative to more typical tundra types. Reasons for this expectation are twofold—brood rearing and migration. This portion of the summer is named brood-rearing because it encompasses much of the period when young-of-the-year birds are out of the nest but prior to southbound migration. Waterfowl are generally tending their broods, while many juvenile shorebirds and longspurs are independent of their parents by this time. There is considerable evidence that waterfowl with broods, especially Brant and Snow Geese, make considerable use of coastal habitats at this time. Saline tundra has frequently been identified as being of particular importance to brood-rearing geese (Bergman et al. 1977, Murphy et al. 1988, Burgess and Ritchie 1987). We intended to evaluate how strict this reliance on saline tundra was (i.e., were coastal nonsaline plots also used?). However, in 1991 the major Brant and Snow Goose colonies in the Prudhoe Bay area (primarily Howe Island in the Sagavanirktok River delta) incurred catastrophic nest failure (Johnson 1991, Stickney et al. 1992) resulting in few brood-rearing geese using the plots, and precluded such an evaluation.

Increased reliance on coastal areas was also expected during the brood-rearing season because of the presence of migrant shorebirds. Most migrant shorebirds during this portion of the summer are adults. Post-breeding adult shorebirds of many species tend to aggregate in coastal areas; however, use of strictly coastal habitats is not as extreme as the later movement of juveniles (Connors et al. 1979). Therefore, increased use of more inland tundras such as the PMRA might be expected as well. Post-breeding Dunlin, Semipalmated Sandpiper, and Red Phalarope adults make use of coastal habitats (Connors et al. 1979).

The results of this investigation partially confirm these expectations, although they show more evidence of a shift in habitat use than major influxes of birds into the area. A distinct pulse of Lesser Golden-Plover, mostly adults, occurred during this period (Fig. 4). A pulse of Stilt Sandpiper at the end of the brood-rearing period was also recorded; however, all those that were aged were juveniles, not adults. Shorebirds were apparently on the move, but no major concentrations were recorded. Changes in habitat use were more evident. Tests revealing selection among plot types indicated that the greatest response was still due to a lack of use of dry plots, especially by Semipalmated Sandpiper and Pectoral Sandpiper. The density summaries show shifts in usage compared to earlier in the summer, although these changes are not statistically verifiable. During the breeding season most species had their peak densities in the PMRA, with a few species also occurring in highest densities on the nonsaline plots. During the post-breeding season there was greater separation of species among plot types, indicating movement into coastal areas. Lesser Golden-Plover, Semipalmated Sandpiper, and Red-necked Phalarope made most use of saline plots at this time. The high use of saline plots by Lesser Golden-Plover was unexpected based on Connors et al. (1979), who reported that this species makes little use of coastal habitats at any time during the summer. The late brood-rearing season incursion of Stilt Sandpiper, while occurring in a coastal habitat, was most concentrated in nonsaline plots—although almost as many were found on saline plots. The brood-rearing season was the first part of the summer when any of the study species made much use of the dry plots. Both Buff-breasted Sandpiper and Lapland Longspur reached their highest densities on this type of plot.

**Post-Breeding Season.** The post-breeding season is the part of the summer when the bird populations may be at their highest (except in years of nesting failure), and use of coastal habitats may be most pronounced. This is particularly true of juvenile shorebirds that tend to aggregate in coastal habitats as they start their outbound migration (Andres 1989, Connors et al. 1979, Martin and Moitoret 1981). This study has confirmed that several species have their peak abundances in coastal habitats during August; these include Lesser Golden-Plover, Pectoral Sandpiper, Dunlin, Stilt Sandpiper, and Buff-breasted Sandpiper (Fig. 4).

The tendency for species to shift into coastal plots, especially saline plots, became even pronounced during the post-breeding season. Five species—Dunlin, Stilt Sandpiper, Red-necked Phalarope, Red Phalarope, and Lapland Longspur—had their highest densities on saline plots, although differences in plot use were significant for only Red Phalarope and Lapland Longspur (Table 10). The tendency for Pectoral Sandpiper to remain on inland tundra (PMRA) and Buff-breasted Sandpiper to aggregate on the dry plots was statistically significant during the post-breeding season.

Geographic gradients continued to be important during the post-breeding season. East-west gradients were found for more species (six) than were coastal gradients (four), and none of the species had only a coastal gradient. The species exhibiting coastal influences were Semipalmated Sandpiper, Dunlin, Red Phalarope, and Lapland Longspur. The three shorebirds were most numerous near the coast, while Lapland Longspur increased in abundance inland. Zonation was moderately distinct, at least for some of the shorebirds (Fig. 10). Encounters with Semipalmated Sandpiper were primarily on plots within 4 km of the coast. The regression line (Fig. 10) indicates expected densities of Semipalmated Sandpipers of 7.1 birds/km$^2$ at the coast but none 20 km inland. Red Phalarope extended slightly farther inland, but a sharp decrease in encounters occurred approximately 6 km from the coast. The regression-based estimates for Red Phalaropes are 9.6/km$^2$ on the coast and none 20 km inland. Zonation was less distinct for Lapland Longspur, but there was a tendency for more longspurs to be present (or perhaps more accurately, it was less likely that there would be few longspurs) on plots more than 8 to 9 km inland. Despite the wide variability about the trend line, the expected density of Lapland Longspur increases substantially from 30.0 birds/km$^2$ at the coast to 297.6 birds/km$^2$ 20 km inland.

## Importance of Coastal Habitats

### *Saline Tundra*

Coastal wetlands are generally considered to be important, and relatively rare, habitats along the Beaufort Sea coast. The value of coastal wetlands to birds originates largely from the importance attributed to these habitats by Bergman et al. (1977). Bergman et al. stressed the high use of this habitat by Brant, both during migration and brood-rearing. Their analyses also indicated high use of this habitat by pre-nesting and nesting King Eiders, although other habitats (especially Deep *Arctophila)* were also used extensively. In Bergman's classification, coastal wetlands included aquatic habitats that occupy low areas bordering the Beaufort Sea and within a zone directly influenced by sea water. This type included lagoons, flats, and vegetated areas dominated by *Carex subspathacea* and *Puccinellia phryganodes*. Our saline plots approximate Bergman coastal wetlands, although our sampling was biased to sample more vegetation and less lagoon and barren flat than occur in Bergman's coastal wetland as a whole. Our nonsaline and dry plots certainly would not be included in coastal wetlands as defined by Bergman et al. (1977).

At the Canning River delta, Martin and Moitoret (1981) found saline meadows to be the most heavily used mainland shoreline habitat, especially by shorebirds and Brant during fall migration. Phalaropes and Sanderling, however, used barrier island beaches much more than other shoreline types. The use of gravel beaches by migrant phalaropes has been documented in other studies that sampled barrier islands (Johnson and Richardson 1981, Troy and Johnson 1982) and causeways (Troy and Johnson 1982). Other studies have noted extensive use of saline tundra along the Beaufort Sea coast by post-breeding shorebirds. Andres (1989) studied shorebird use of littoral zone habitats in the Colville delta during the post-breeding season (July and August) of 1987 and 1988. He distinguished five cover types—terminal shoreline silt barrens, subterminal shoreline silt barrens, interior silt barrens, sparse forb-graminoid tundra, and saline wet sedge/grass-sedge tundra. He consolidated these types into two broad classes of silt barrens (first three types) and saltmarsh (the last two types). Andres considered his saltmarsh to be encompassed by Bergman's coastal wetland class. Strictly speaking, Bergman's coastal wetland definition also included unvegetated flats, but the recognition of distinct classes for flats and saltmarshes is probably more informative. Saltmarsh was the habitat class most similar to that sampled by our saline plots. Andres concluded that Dunlin and Sanderling made extensive use of silt barrens. Other species (Semipalmated Sandpiper, Red-necked Phalarope, Western Sandpiper, Pectoral Sandpiper, and Stilt Sandpiper were the most numerous species encountered by Andres) made much more use of saltmarsh habitats. Extensive silt barrens (mud flats) are infrequent along the Beaufort Sea coast. In the Sagavanirktok delta, Troy (1982) found Semipalmated Sandpiper, Dunlin, and Stilt Sandpiper to be the species making greatest use of mudflats.

To date, our study is in agreement with other studies in failing to identify any special use of saline tundra during the breeding season. Like other investigations, we found increasing use of saline wetlands following nesting during both the brood-rearing and, especially, the post-breeding seasons. Since most of this use is by shorebirds, these periods might best be considered to represent adult and juvenile migrations. The species making most use of the saline plots during these periods were Semipalmated Sandpiper, Dunlin, Stilt Sandpiper, Red-necked Phalarope, and Red Phalarope. There is little doubt that of the areas we sampled, saline tundra may be the most heavily used by migrants of these species; however, the limitations of our sampling may give a false impression as to the relative importance of saline tundra. On the basis of the other investigations reviewed above, it appears that at least Dunlin, Red-necked Phalarope, and Red Phalarope, and perhaps Semipalmated Sandpiper and Stilt Sandpiper, may make greater use of silt barrens and gravel beaches, both of which were present near our study areas but were not sampled. Hence, compared to adjacent tundra types, saline tundra may receive greater use by migrant shorebirds, but on a slightly broader scale it may not be the most important habitat. However, along most of the Beaufort Sea coast, silt barrens are not available; therefore, in most areas saline tundra would likely be the highest use tundra type. No other study has reported the high density of post-breeding Lapland Longspur in saline wetlands. Our 1991 data indicate that this species is the most numerous saltmarsh bird.

### Nonsaline Tundra

Nonsaline coastal tundra has, to our knowledge, never been examined in isolation to determine if there is a coastal effect independent of the role of unique coastal vegetation types. The closest approximation—although the analyses were not explicitly conducted for this purpose—can be found in Troy et al. (1983), who analyzed breeding-season plot data in the Prudhoe Bay area to determine if there was a coastal influence on nest and breeding-season bird distributions. The data used in those analyses contained trivial amounts of saline habitats; thus, the analyses compared bird densities of nonsaline tundra sampled from 0.3 to 6.2 km from the coast. The species that occurred in high densities near (<1 km) the coast were Lesser Golden-Plover, Semipalmated Sandpiper, Dunlin, and Buff-breasted Sandpiper (see Fig. 7-7, Troy et al. 1983). Species appearing to occur in lower densities in this area were Oldsquaw and Red-necked Phalarope.

The nonsaline plots were located near the saline plots but largely out of the haline influence. The intent was to determine if the dominant factor affecting bird use of coastal areas was proximity to the coast or the vegetation types restricted to these areas. The results indicate that during the breeding season (including actual nest sites) nonsaline is the most heavily used coastal habitat. For some species, especially Semipalmated Sandpiper and Lapland Longspur, and to a lesser degree both phalaropes, this coastal tundra supports higher densities than inland tundra, at least to the degree that the PMRA is representative of inland tundra. It is possible that nonsaline coastal tundra is a restricted but preferred habitat type because these areas are beyond the saline influence and therefore well vegetated, yet adjacent to saline tundra that may provide better foraging areas (speculation based on attraction to these areas by staging birds).

### Dry Coastal Tundra

The dry plots were established because little sampling of dry tundras has occurred, largely because dry tundra is rare and local in the Prudhoe Bay area. Previous sampling has taken place in the Sagavanirktok delta by Troy (1982, 1991). Troy (1982) conducted a small sampling program widely scattered in the central portion of the Sagavanirktok delta. Preliminary analyses indicated that most birds made little use of dry tundra, represented in the sampling by largely stabilized dunes. The only common species that appeared attracted to dry tundra was Lapland Longspur and only during June. Sampling in the Sagavanirktok delta by Troy (1991) emphasized the heavily disturbed peat roads. Sampling was not restricted to dry tundra, but stabilized dunes were well represented in the areas sampled. This study found high densities of Red-necked Phalarope and Lapland Longspurs using these plots, although the role of increased habitat diversity due to thermokarsting may be more important that the presence of dry tundra in affecting these results.

This study shows the dry plots were little used during the breeding season. However, the dry plots were found to become more important during migration, when high densities of Lesser Golden-Plovers and Buff-breasted Sandpiper were found in these areas. Also of note was the exceptional concentration of Dunlin found in this plot type at the end of August (Fig. 4). This concentration of Dunlin was due to the occurrence of a roost on Heald Point (the birds were observed flocking to the area from the Sagavanirktok delta). Even if future censuses confirm the use of Heald Point as a roost site, it is likely to prove a site-specific phenomenon rather than a characteristic of dry tundra.

## Gradients

The magnitude of the gradients documented in the stepwise regression analyses is perhaps the most exciting result of this investigation. The scatter diagrams summarizing the plot data (Figs. 8, 9, and 10) reveal considerable scatter and require study to discern much pattern. However, much of the variability in these plots arises from the fact that these graphs are highlighting only the component of variation attributable to distance from coast, yet we know several other factors affect bird abundance. For example, many of the species exhibiting coastal gradients also had east-west gradients, frequently of greater magnitude. The distribution of our sampling within the Prudhoe Bay region has been such that the locations of plots on the coastal and east-west gradients are dependent (linear regression of distance from coast on distance east $F_{[1, 208]} = 91.246$, $p = 0.0001$); i.e., sampling in the east (Sagavanirktok delta) has been predominantly near the coast, and sampling in the west has been primarily inland. The tendency for our plots to have been located along the diagonal of these two gradients makes visual examination of either gradient in isolation difficult. Figure 11 shows patterns of variation of breeding-season Dunlin and Stilt Sandpiper, and post-breeding-season Lapland Longspur in relation to both gradients. Dunlin and Stilt Sandpiper have trends in increasing abundance in the west, but Dunlin is more numerous near the coast, whereas Stilt Sandpiper is more numerous inland. Lapland Longspur exhibit a different pattern, increasing to the east and inland.

At least three other sources of variation add to the variability in bird densities on plots: year (TERA 1992a), habitat (Troy 1986), and anthropogenic disturbances (TERA 1992b). Some species exhibit marked among-year variability in abundance (TERA 1992a). The ideal way to control for this variability is to sample all plots simultaneously, but this is impractical. Averaging densities over all years sampled minimizes this source of variation. It is conceivable that some of the plots that were sampled only one or two years may have been sampled when a species was at an extreme limit in abundance and have biased our results. Fortunately, most major highs and lows in abundances have occurred during multi-year studies; therefore, this is probably not a major concern.

Geobotanical characteristics of the tundra (habitat) are known to have a large influence on bird use of the study plots (Troy 1986, TERA 1992b). Troy (1986) estimated that differences in vegetation and surface form accounted for up to 70 percent of the variability in bird use among plots. Incorporation of geobotanical information into the regression models developed in this report would be expected to account for much of the residual variation not accounted for by plot location. Indeed, for most species, habitat type would probably emerge as the primary variable in the regressions. Some of the geographic gradients detected in the analyses presented here may have their basis in habitat availability. For example, the east-west gradient of post-breeding Buff-breasted Sandpiper may be due to the high availability of dry habitats in the Sagavanirktok River delta rather than the actual geographic location.

Although geobotanical characteristics will no doubt prove important in explaining the gradients we have detected, in some cases their influence is either subtle or secondary to other factors. For example, one might hypothesize that the gradients we observe reflect the availability of wet and aquatic tundras on the basis that drier tundra (moist and dry vegetation types) would be more frequent in the east (due to the dunes associated with the Sagavanirktok River) and inland (due to greater relief). However, birds associated with wet habitats (wet and aquatic vegetation) reach their peak abundances near the coast (King Eider and Red Phalarope) and inland (Stilt Sandpiper and Red-necked Phalarope); in the west (King Eider, Stilt Sandpiper, and Red Phalarope); and in the east (Red-necked Phalarope) (Fig. 12).

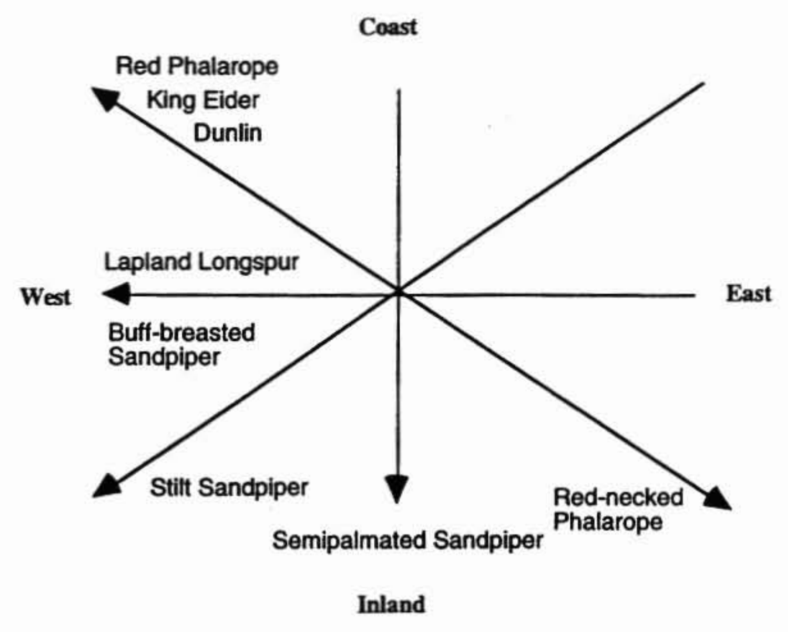


*Figure 12. Summary of abundance gradients based on breeding-season bird densities. Densities increase in the direction of the arrows.*

*Table 14. Summary of number of significant gradients selected in multiple regression analyses indicating the presence of coastal gradients, east-west gradients, or both. A total of ten species was included in each analysis.*

| Data Set | Distance From Coast | East-West | Both Gradients |
|---|---|---|---|
| Nests | 2 | 1 | 3 |
| Breeding-Season | 1 | 2 | 5 |
| Post-Breeding Season | 0 | 2 | 4 |

The final source of variation is the effect of habitat alterations and other disturbance associated with the oil field roads and pads and exploration activities (e.g., peat roads). Considerable research has shown changes in bird use of areas close to facilities (Troy 1986, TERA 1992b). In most cases, nest and breeding season abundances are lower than expected close to roads; however, some types of disturbances, such thermokarsting, may result in increased bird use of altered tundra (Troy 1991). In all these cases the densities differ from what would have been expected in unaffected tundra. The plots that formed the basis of these studies are included in the preliminary gradient analyses presented here. As these analyses are refined, we intend to incorporate a variable for distance to facilities to factor in this effect. This approach will offer a new tool to evaluate the relative importance of oil field influence in comparison to habitat and geographic location.

Coastal influences have long been known or suspected of influencing bird distribution and abundance. The gradient analyses confirm the presence of coastal influences in affecting bird distribution on the Arctic Coastal Plain. However, in reviewing the frequency of gradients detected in the analyses (summarized in Table 14), we found coastal gradients were slightly less frequent than east-west gradients. During the post-breeding season the importance of coastal gradients would have been expected to be most pronounced due to the presence of migrant birds; however, it was during this period that east-west gradients were most frequent relative to coastal gradients. Whatever the

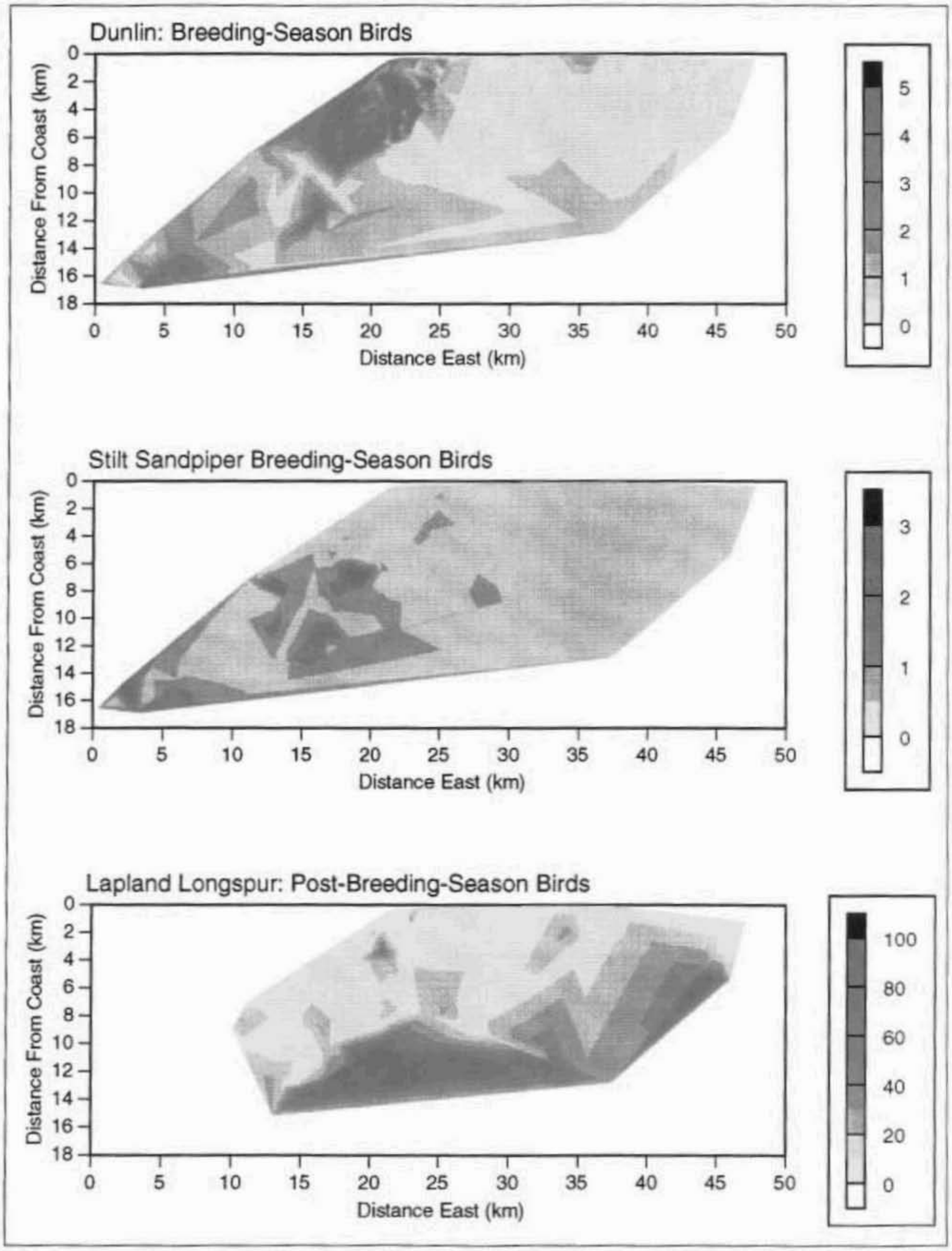


*Figure 11. Surface contour charts showing breeding-season densities of Dunlin and Stilt Sandpiper in relation to distance from coast and location on an east-west axis.*

ultimate cause of these gradients, it is apparent that there is substantial spatial variability in the distribution of tundra birds that needs to be understood in order to assess the tundra habitat values.

The presence of the gradients demonstrated in this report provides some insight into impact assessment useful in interpreting some recent studies. Meehan (1986) found differences in densities of some shorebirds on plots within developed portions of the Prudhoe Bay oil field and some of the PBU Waterflood bird plots (several of which are the PMRA study plots). This was interpreted as possible evidence of an oil field impact indicating avoidance of tundra areas within the oil field. TERA (1992b) confirmed these differences between the two study areas, finding lower densities of Dunlin and Red Phalaropes in the oil field but also the opposite trend for Stilt Sandpiper and Red-necked Phalarope. We hypothesized that these trends were not oil field influences but were probably attributable to broader-scale abundance gradients. The PMRA plots and the oil field plots used by TERA (1992b) do not differ significantly in their east-west locations, but the oil field plots were significantly farther inland than the PMRA. The results of the gradient analyses presented here support the hypothesis that the major differences in densities between the PMRA and the oil field plots were because of underlying gradients. The major differences between the two areas involved the species exhibiting the strongest coastal gradients, and the density differences were in the same direction as predicted by these gradients; i.e., species increasing in abundance near the coast were most numerous in the PMRA, while species increasing in abundance inland were more numerous in the oil field.

## CONCLUSIONS

Proximity to the coast was found to have an influence on bird use of the Prudhoe Bay area. Using a narrow definition of coastal to include all tundra adjacent to the Beaufort Sea (<1 km), the coastal effect was subtle. The species composition of coastal plots differed slightly from the Prudhoe Bay area in general. Some species that are rare in the Prudhoe Bay area, such as Ruddy Turnstone and Baird's Sandpiper, were more common in coastal areas; however, there was still considerable similarity in the species composition of coastal and other portions of the Prudhoe Bay area.

Considerable species and seasonal variability was found in the use of the three types of coastal plots sampled. The highest nesting densities (especially Semipalmated Sandpiper and Lapland Longspur) occurred in nonsaline tundra. Saline tundra received high use by breeding-season phalaropes, but overall there were more birds in nonsaline tundra. Saline tundra was the single most important habitat during the post-breeding season, especially for Lapland Longspur, Red-necked Phalarope, and Dunlin. Dry coastal habitats received low use for nesting and by breeding-season birds, while Lesser Golden-Plover and Buff-breasted Sandpiper made considerable use of these habitats during the post-breeding season. Thus, habitat type was found to play an important role in determining bird use of coastal areas. Some habitat types, such as saline tundra, are by definition restricted to coastal areas and are heavily used by some species during select periods of the summer. In general, there was low use of dry areas and high use of nonsaline tundra, but the species composition in coastal areas was not as diverse as in the PMRA. During the post-breeding season, coastal habitats, especially saline tundra, supported the highest relative densities of the study species, except King Eiders and Pectoral Sandpipers.

The strongest coastal associations were detected by analyses looking for broad-scale gradients in abundance. By combining the results of this study with those of similar plot-based studies from the Prudhoe Bay area, we documented the presence of abundance gradients along east-west and distance-from-coast axes. Depending on the species, the geographic location of a study plot could account for up to 30 percent of the variability in bird and nest densities. Species exhibiting responses to these geographic gradients were Semipalmated Sandpiper, Dunlin, Stilt Sandpiper, Red-necked Phalarope, Red Phalarope, and Lapland Longspur. Coastal gradients could go in either direction; for some species, densities were highest near the coast, but for others the converse was true. For example, during the breeding season, densities of Semipalmated Sandpiper, Stilt Sandpiper, and Red-necked Phalarope increased with distance from the coast, whereas densities of King Eider, Dunlin, and Red Phalarope decreased with increasing distance from the coast. There was little indication of a narrowly defined coastal zone receiving high use for any species. Where the analyses did indicate high use of coastal areas, the zone tended to be 4 to 10 km wide.

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