ARCTIC SHOREBIRDS *in* NORTH AMERICA

A Decade of Monitoring

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CHAPTER FOUR

North Slope of Alaska

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Abstract. We used a combination of ground and aerial surveys to characterize the abundance and distribution of shorebirds and other birds on the North Slope of Alaska. The double sampling method, which we used for the ground surveys, is described in Bart et al. (chapter 2, this volume). The aerial surveys were conducted during 1992–2005 and covered most of the study area. We present numbers recorded, estimated densities and population sizes, and habitat relationships for shorebirds and other species. Most species occurred in higher density, and had much larger populations, in the National Petroleum Reserve–Alaska than west of the Colville River. The most abundant shorebirds were Semipalmated Sandpipers and Pectoral Sandpipers, with estimated populations of about 1.2 million birds each; and Long-billed Dowitchers, Red and Red-necked Phalaropes, and Dunlin, with estimated populations of 500,000–700,000 each. The most abundant waterfowl were Northern Pintails, Greater White-fronted Geese, and Long-tailed Ducks, with estimated populations of 200,000–300,000 each. Glaucous and Sabine's Gulls, Arctic Terns, and Parasitic and Long-tailed Jaegers each had estimated populations of about 30,000–100,000. Lapland Longspurs, Savannah Sparrows, and Willow Ptarmigan were the most common landbirds, with estimated populations of about 1 million each. All but a few species were most common in wetlands and least common in uplands.

Key Words: Alaska, landbirds, North Slope, population estimates, shorebirds, surveys, waterbirds, waterfowl.

The North Slope of Alaska is a major nesting area for a wide variety of bird species, including shorebirds, waterfowl, gulls and terns, and landbirds (National Research Council 2003, Johnson et al. 2007). However, there has never been an analysis of the density of these species across the entire range of habitats in the region. Previous studies have provided either descriptions of the ranges of these species within the region or densities for some species in some parts of this larger area (Mallek et al. 2004, Larned et al. 2005, Brown et al. 2007, Johnson et al. 2007,

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unpublished U.S. Fish and Wildlife Service reports). This monograph provides the results of the first such analysis, for all arctic-nesting birds that occur on the North Slope.

The primary goals of this study were (1) to collate and present results from bird surveys conducted during many years, and provide graphic displays of bird numbers recorded; (2) to estimate the density of each species, and calculate estimates of total population size in the study area; and (3) to examine interrelationships among habitat types and nesting densities by species to determine which habitats are most important for each species.

Measurements of density and total population are important for understanding both the biology of these species and the relative importance of the region for their global populations. Many conservation systems use the relative contribution of a specific area to total population size to determine importance for conservation. For example, the Western Hemisphere Shorebird Reserve Network (WHSRN; www.whsrn.org) and the Ramsar Convention on Wetlands of International Importance, especially as waterfowl habitat (Ramsar Convention; www.ramsar.org), both use the percentages of a flyway population as a conservation threshold. Similar criteria have been developed by the Important Bird Areas Program of Birdlife International (www.birdlife.org/action/science/sites). All of these programs rely on having both accurate overall population size estimates for each species and estimates of the proportion of the population using particular areas of interest. The development of accurate population estimates for the North Slope region of Alaska will contribute significantly to both of these goals by providing the first regional population estimates and by providing a context against which to evaluate total population size estimates published for various species.

Major threats to breeding birds in the North Slope region include oil and gas development and climate change. Understanding the current densities of breeding birds in the region is a prerequisite to determining impacts of any future changes in the wetland and tundra habitats supporting these birds.

Oil and gas development have been under way on the North Slope since 1977, and development has expanded to the point that assessments of cumulative impacts on the biology of arctic birds and mammals are warranted (Gilders and Cronin 2000, National Research Council 2003). Significant oil and gas development has been proposed for the Arctic National Wildlife Refuge and is already under way in parts of the National Petroleum Reserve–Alaska and the state lands in between (National Research Council 2003). Impacts from these developments on nesting birds may occur from a variety of factors, including direct loss of habitat from development of roads, drilling pads, pipelines and related infrastructure, and supporting activities such as gravel mining. In addition, indirect impacts may occur from increases in dust or changes in hydrology including snow accumulation patterns (Auerbach et al. 1997, National Research Council 2003). Other indirect impacts may include changes in predator populations that could negatively affect nesting birds (Eberhardt et al. 1983, National Research Council 2003, Liebezeit et al. 2009).

Climate change impacts are expected to be severe in the arctic compared to other regions (ACIA 2005). A variety of different types of impacts may be important. Northward expansion of shrub habitats has already been documented in the arctic, and is expected to increase with the rising temperature in the region (Sturm et al. 2001, ACIA 2005). The resulting loss of tundra habitats may reduce breeding areas for many species dependent on graminoid tundra. Sea level rise projected to occur may reduce coastal habitat availability or quality for species that nest or forage in coastal areas (Jorgensen and Ely 2001, Rehfisch and Crick 2003). Changes in the seasonal availability of food sources such as invertebrates may also change, affecting the ability of each species to time their life history to coincide with peaks in available food (the "match/mismatch" hypothesis; Durant et al. 2007).

The population size estimates presented here are the first for the entire North Slope region, and will be critical in determining future impacts from ongoing development and climate change.

METHODS

Regions

We distinguished between the Arctic Coastal Plain (ACP) and the Foothills to the south (Fig. 4.1). The ACP was the area covered by U.S. Fish and Wildlife

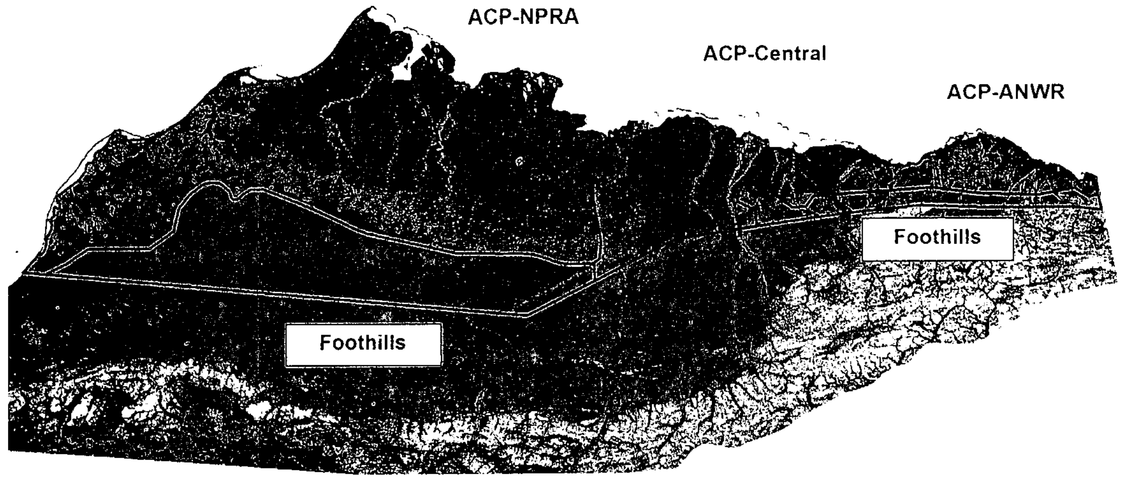

Figure 4.1. Regions used in the study. Light gray indicates drier areas (source for vegetation: Muller et al. 1999). Sampling intensity in the ACP-NPRA was much higher in the northeast in the delta of the Colville River and along Fish Creek. This area is delineated above (and in Fig. 4.2), but separate estimates for the area are not reported in the tables because it did not have ecological significance. A fifth area for which estimates are reported, the Colville River, includes the riparian areas along the Colville River upstream from the delta. It is too small to show on the figure.

Service aerial surveys; the Foothills included our study area south of these regions. We also subdivided the ACP into the National Petroleum Reserve of Alaska (NPRA), the Central region, and the Arctic NWR. A small region in the northeastern part of the NPRA was also distinguished because sampling intensity was particularly high there. The areas of the regions were ACP-NPRA (34,489 km^2), ACP-Central (10,825 km^2), ACP-Arctic NWR (4,793 km^2), Foothills (23,254 km^2), and Colville River (30 km^2). In the analyses below, results from this region are combined with the rest of the ACP-NPRA region.

Results from both ground and aerial surveys were depicted using a grid of square cells, 6 km on a side (Fig. 4.2). For both data sets, we simply calculated the overall density of observations. For the aerial surveys, this provided an unbiased estimate because locations for the aerial surveys were selected without regard to habitat. For the ground surveys, the simple average ignored habitat within the cell, whereas the plots were usually concentrated in wetlands and moist habitat. However, the purpose of producing these maps was simply to show the general distribution of sightings using a method that involved the least possible manipulation of the data and that produced a comprehensible image (which displaying the counts in each plot did not due to the large number of plots). Three density categories were defined for each map using zero for one category and an intermediate threshold to define the other two categories. The threshold was chosen so that about one-third of the cells were in the high-density category. This approach produced maps that highlighted the areas of highest

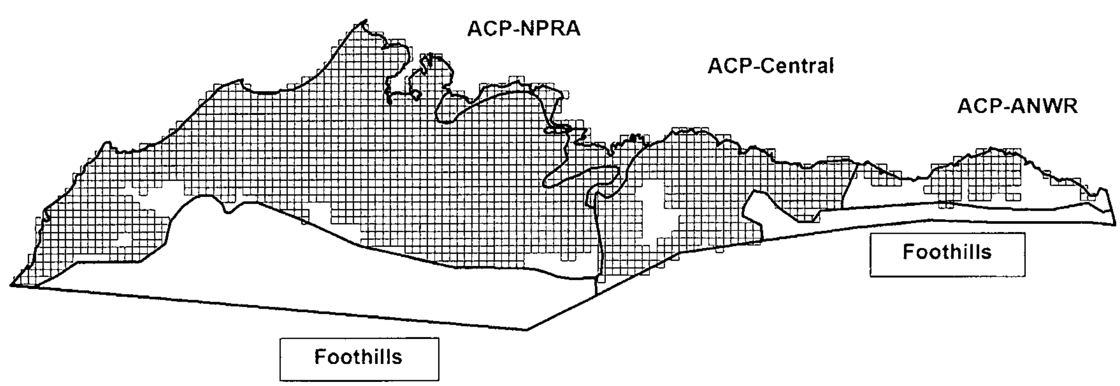

Figure 4.2. Cells used to display results from ground and aerial surveys.

density. We used these maps for various purposes, including a description of the distribution of each common species within our study areas. Our descriptions update those of Johnson et al. (2007), which were based solely on our ground surveys and on presence (rather than density) data.

Ground Surveys

Bart et al. (chapter 2, this volume) discuss methods used to select and survey the plots and analyze the resulting data. Here, we discuss only the methods that are specific to this chapter.

Habitats (wetland, moist, upland, unsuitable) were defined using the landcover map by Muller et al. (1999). At the time the study was initiated, the Muller et al. (1999) landcover map was the only GIS layer available that covered the entire North Slope region. The pixel size was 100 m; eight classes were identified, which we combined to four classes. More recently, other landcover maps have become available with 30-m pixels and more classes (e.g., National Land Cover Dataset, Landfire, Ecosystems of Northern Alaska), but the more general coverage was adequate and perhaps even an advantage for our work. The cross-walk between our categories and the Muller categories (and codes) was: wet = wet (5); moist = moist-grass prostrate (2) or moist-tussock grass shrub (9); uplands = tussock tundra (3) or moist-low shrub (4); unsuitable = dry prostrate barrens (1), water (6), or ice (7). Muller category eight, clouds, was rare in our study area but was classified as moist (because that was the most common type). Plots were assigned to habitat types based on whichever habitat was most common. For example, if the proportions of suitable habitat covered by wetlands, moist areas, and uplands were 0.3, 0.4, and 0.3, respectively, then the plot was assigned to the moist type. It is thus important to realize that the habitat in plots was heterogeneous, even though we refer to them using terms like "moist." This is perhaps especially important in interpreting numbers in plots classified as upland. Pure upland, in this area, usually had very few shorebirds. But plots classified as upland—because that was the most common type—often had small wetlands with shorebirds. It must also be recognized that different studies, using different definitions to classify plots, might produce different densities in, for example, "moist" plots. The assignments were thus of greatest use in letting us concentrate survey efforts in areas with the most birds rather than in elucidating habitat relationships (a task better done with the models we constructed).

We used the Arctic PRISM extension (see Bart et al., chapter 2, this volume) to partition the entire study area into 197,279 plots, most of which covered approximately 16 ha. We assigned plots to zones for logistic reasons. Plots were also assigned to strata based on region and habitat. Ideally, plots to be surveyed would have been selected using the comprehensive sampling frame. The process for partitioning the entire study area, however, was only worked out in the later years of the study. During the earlier years, plots were selected using a variety of random selection methods. On the Colville Delta and surrounding areas, plots were selected by partitioning that part of the survey area into plots manually (i.e., using GIS methods but without automatic creation and modification of plots) and plots to be surveyed were then selected randomly. Elsewhere, the most common method for choosing plots was to randomly select a point and partition the surrounding area of a predetermined size and shape into plots, each assigned to a habitat type. Plots to be surveyed were then randomly selected, with a restriction to yield the desired number of plots in each habitat type. Rapid surveys were conducted on 637 plots (Table 4.1). Sampling intensity varied substantially between regions (Fig. 4.3; Table 4.1).

We estimated detection ratios using six camps and 28 intensive plots (Table 4.2). Intensive plots were usually surveyed four times by rapid surveyors (range 1–8, Table 4.2). We calculated species-specific detection ratios for the 13 shorebird species encountered most often (Table 4.3). All detection ratios based on more than five birds were between 0.75 and 0.90. The only statistically significant $P < 0.05$) differences between species were for Buff-breasted and Pectoral Sandpipers (for scientific names, see Appendix C); however, the sample size for Buff-breasted Sandpipers was small, so the SE estimate is unreliable. Furthermore, with 13 species being compared, it is hardly surprising that one contrast was significant. The remaining estimates varied widely, as expected with small sample sizes. We therefore used all shorebirds combined to estimate an overall detection ratio. The estimate was 0.81,

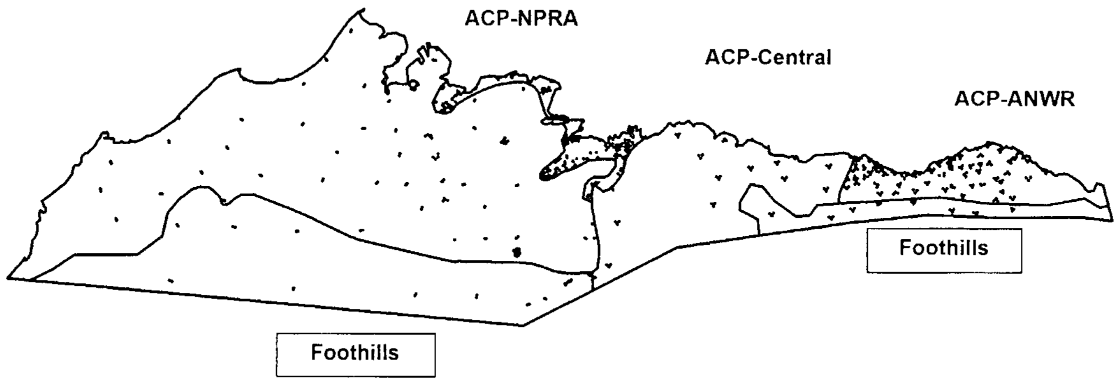

Figure 4.3. Plots in the ground survey (dots indicate groups of up to several plots).

TABLE 4.1

Areas and numbers of plots in each stratum.

	Area (km^2)				Number of plots surveyed			
Region	Wetlands	Moist	Uplands	Total	Wetlands	Moist	Uplands	Total
ACP-Arctic NWR	1,207	2,233	1,353	4,793	85	70	24	179
ACP-Central	2,398	8,162	266	10,825	15	26	1	42
ACP-NPRA	8,804	15,324	10,362	34,489	205	142	10	357
Foothills	152	3,612	3,486	7,250	2	8	28	38
Colville River	10	10	10	30	0	2	19	21
Totals	12,570	29,342	15,476	57,388	307	248	82	637

TABLE 4.2

Number of intensive plots, indicated shorebird pairs, and rapid surveys of the intensive plots.

Camp				
Region	Year	No. of plots	No. of indicated pairs	No. of rapid surveys
ACP-ANWR	2002	4	27	16
ACP-ANWR	2004	4	14	13
ACP-NPRA	1998	8	143	30
ACP-NPRA	1999	4	65	28
ACP-NPRA	2000	4	84	16
ACP-NPRA	2001	4	59	32

with a SE of 0.08. We used these estimates in estimating densities and population sizes and their SEs for all shorebird species. Not using species-specific rates in our main analysis, however, certainly does not mean the rates are all identical. They undoubtedly do vary. For species with relatively large sample sizes, we therefore also present estimates with the species-specific detection ratio.

Although the PRISM surveys were designed for shorebirds, we recorded all species encountered. During intensive surveys, however, surveyors did not attempt to find all species; they only surveyed for shorebirds. As a result, we do

TABLE 4.3

Detection ratios for shorebirds, their standard errors (SE), and 95% confidence intervals (95% CI).

Species	Number on intensive plots	Detection ratio	SE	95% CI Lower bound	95% CI Upper bound
Semipalmated Sandpiper	111	0.75	0.13	0.50	1.00
Pectoral Sandpiper	96	0.83	0.06	0.71	0.95
Red-necked Phalarope	68	0.80	0.14	0.53	1.07
Red Phalarope	43	0.77	0.17	0.44	1.10
Dunlin	24	0.90	0.16	0.59	1.21
Black-bellied Plover	10	0.85	0.17	0.52	1.18
American Golden-Plover	9	0.88	0.26	0.37	1.39
Ruddy Turnstone	9	0.83	—	—	—
Long-billed Dowitcher	5	2.16	1.20	0.00	4.51
Buff-breasted Sandpiper	5	0.60	0.03	0.54	0.66
Stilt Sandpiper	4	0.61	0.11	0.39	0.83
Western Sandpiper	4	0.78	—	—	—
Bar-tailed Godwit	3	0.75	0.26	0.24	1.26

not have detection ratios for non-shorebirds. For non-shorebirds, we therefore report the total number of birds seen and the estimated number of pairs on rapid plot surveys. We assumed that a single indicated a pair (unless it was considered to be breeding off the plot). We calculated uncorrected, relative densities using these data.

Habitat Analyses

Habitat associations were investigated using regression analyses of the results from rapid plots. Most species occurred throughout our study area, but for a few (e.g., Western Sandpiper) that clearly occurred only in part of the study area, we deleted plots that were outside the range as depicted on the maps prepared by Ridgely et al. (2007). This section describes our modeling process.

We recorded spatial and habitat variables for each surveyed plot. The spatial variables were longitude (*ew*), mean (among pixels) elevation (*elev*), mean distance to the nearest wetland pixel (*diswet*), and smallest distance from the center of the plot to the coast (*discoa*). The habitat variables were recorded at three scales: micro (within the plot), meso (within 1 km of the center of the plot, and macro (within 10 km of the center of the plot). At each scale we recorded the proportion of the suitable area covered by pixels classified as wetlands, moist areas, and uplands. We thus had nine habitat variables: *micwet*, *micmoi*, and *micupl* at the micro scale; *meswet*, *mesmoi*, and *mesupl* at the meso scale; and *macwet*, *macmoi*, and *macupl* at the macro scale.

Habitat relationships were explored by building regression models that predicted density as a function of spatial and habitat variables. We used SAS (ver. 8.2, SAS Institute, Cary, NC) for the analysis. The response variable—number of birds recorded—was distinctly non-normal. Errors were correlated and random effects were present due to the selection of clusters. The recommended SAS procedure for such cases is GLIMMIX (Littell et al. 2006:16). GLIMMIX uses residual maximum likelihood to estimate parameters. With this approach, models that differ in their fixed effects cannot legitimately be compared using log likelihoods or AICs (Littell et al. 2006:754). We therefore compared models on the basis of the *P*-values of their regression coefficients.

Although we had relatively few variables for our sample size (637 plots), the number of possible models, with squared terms and interactions, far exceeds our sample size. It was thus necessary to reduce the number of models considered using biological knowledge. Below, we use a standard notation to describe the models in which only the names of the independent variables are provided. For example, consider the model

$$d_i = b_0 + b_1 ew_i + b_2 elev_i + b_3 ew_i{*}elev_i$$

where d_i, ew_i, and $elev_i$ are the observed density, longitude measured as the distance west from a north–south line at the east edge of the study area, and elevation, respectively, on the *i*th plot. This model would be described as *ew*, *elev*, and *ew**elev*. In listing models below, we generally start with the most complex model. Our model selection process depended in part on the number of positive counts. For abundant species we proceeded as follows:

1. Select the best model using the spatial variables *ew* and *elev*. The models were *ew ewsqd elev ewsqd**elev*, *ew ewsqd elev*, *ew elev ew**elev*, *ew elev*, *ew ewsqd*, *ew*, and *elev*. We included *ewsqd* because some species were most abundant in the middle (east to west) of the study area. *Elevsqd* was not included because the relationship between density and elevation appeared always to be monotonic (usually decreasing density with increasing elevation) and in most cases was not clearly different from linear. We followed the standard practices of calculating interactions with the highest-order terms of the main effects and of not including interactions unless the main effects were significant. Based on many years in the study area, we expected *ew*, *elev*, and *ew**elev* to be important correlates of density for many species.
2. Select the best model that adds habitat variables. We only considered the proportion of the plot covered by wetlands and moist areas since also including uplands would have been redundant. In these models, the intercept gives the predicted density if the plot was entirely upland (because then *x*-values for wetlands and moist areas are both zero) and the coefficients for wetlands and moist habitats express the change in density due to changing some of the upland to wetlands or moist areas. We did not consider higher-order terms or interactions in part because we doubted they would have much explanatory power and in part to keep the number of models relatively small. We therefore needed to consider three models at each spatial scale. Let *spatial* indicate the variables selected in Step 1. Then the models evaluated would be *spatial micwet micmoi*, *spatial micwet*, *spatial micmoi*, and so on for the meso and macro scales. This stage thus involved considering an additional nine models. We deleted any nonsignificant variables. Thus, *elev* might have been included at Step 1 but might be omitted from the model selected at Step 2.
3. Add distance to the coast. For a few species found only near the coast, we added *discoa*. The range for such species only included areas near the coast, so *discoa* was not necessarily significant for such species. This variable was added as the last step in the model-building process.

The process described above involves comparing approximately 20 models, though the model sets varied between species depending on which variables were selected in Step 1. This number seemed reasonable when we had hundreds of positive counts and all or nearly all of our 637 plots were within the species range. When we had only a few dozen positive counts, however, evaluating 20 models seemed likely to result in over-fitting (i.e., obtaining a model unlikely to have been chosen had we obtained a different random sample). Since we could not use AICs to compare models, it was difficult to know how serious this potential problem was. We elected only to consider habitat variables at the meso and macro scale when we had at least 100 positive counts. Thus for species with fewer than 100 positive counts, we compared roughly a dozen models (depending on the number compared in Step 3) rather than roughly 20 models.

Correlations between the independent variables were generally small (Table 4.4), as were correlations between density and independent variables (Table 4.5). These weak relationships meant that we could not expect habitat models to have high

TABLE 4.4

Correlation coefficients between independent variables.

Variable	Plot area	*ew*	*elev*	*micwet*	*micmoi*	*micupl*	*meswet*	*mesmoi*	*mesupl*	*macwet*	*macmoi*	*macupl*
ew	0.08											
elev	−0.08	−0.18										
micwet	0.1	0.06	−0.48									
micmoi	−0.04	−0.05	−0.08	−0.62								
micupl	−0.08	−0.02	0.66	−0.58	−0.28							
meswet	0.06	0.06	−0.61	0.76	−0.3	−0.62						
mesmoi	0.03	−0.03	−0.16	−0.27	0.66	−0.36	−0.4					
mesupl	−0.08	−0.03	0.74	−0.56	−0.22	0.91	−0.69	−0.38				
macwet	0.06	0.13	−0.67	0.63	−0.15	−0.61	0.87	−0.21	−0.71			
macmoi	0.08	−0.1	−0.22	−0.05	0.47	−0.43	−0.14	0.8	−0.48	−0.19		
macupl	−0.1	−0.05	0.74	−0.53	−0.16	0.82	−0.69	−0.32	0.95	−0.78	−0.47	
discoa	0.03	0.41	0.13	−0.1	0.06	0.07	−0.18	0.1	0.1	−0.22	0.1	0.13

TABLE 4.5

Correlation between density and independent variables for selected species (all species had >40 records).

Variable	AMGP	BARG	BBPL	BBSA	DUNL	LBDO	PESA	REPH	RNPH	RUTU	SESA	STSA	WESA
ew	−0.08	0.08	0.17	−0.04	0.28	0.17	0.04	0.12	0.02	0.02	0.13	−0.01	0.43
elev	0.06	−0.05	−0.11	−0.06	−0.20	−0.11	−0.18	−0.18	−0.12	−0.06	−0.19	−0.05	−0.08
micwet	0.05	0.05	0.17	−0.02	0.23	0.16	0.21	0.21	0.17	0.02	0.27	0.12	0.07
micmoi	−0.02	0	−0.10	0.06	−0.13	−0.07	−0.12	−0.11	−0.11	0.01	−0.15	−0.08	0.07
micupl	−0.04	−0.06	−0.11	−0.05	−0.16	−0.12	−0.14	−0.14	−0.09	−0.04	−0.18	−0.08	−0.11
meswet	−0.05	0.10	0.20	0.14	0.25	0.17	0.18	0.19	0.13	0.06	0.29	0.10	−0.07
mesmoi	0	−0.04	−0.13	−0.13	−0.12	−0.07	−0.07	−0.07	−0.07	−0.02	−0.13	−0.05	0.18
mesupl	0.05	−0.07	−0.12	−0.05	−0.17	−0.11	−0.13	−0.15	−0.08	−0.05	−0.19	−0.07	−0.07
macwet	−0.06	0.12	0.23	0.12	0.31	0.18	0.18	0.17	0.13	0.07	0.31	0.08	−0.13
macmoi	−0.01	−0.05	−0.14	−0.11	−0.14	−0.08	−0.03	−0.02	−0.07	−0.03	−0.11	−0.02	0.17
macupl	0.06	−0.07	−0.14	−0.05	−0.20	−0.12	−0.14	−0.15	−0.08	−0.05	−0.20	−0.07	−0.02
discoa	0.01	0.07	0.03	−0.04	−0.08	0.12	−0.12	−0.15	−0.04	−0.06	−0.02	0.06	−0.09

NOTE: Species are displayed with AOU 4-letter codes. See Appendix C.

explanatory power even if their coefficients were highly significant.

Aerial Surveys

Data from two aerial surveys were used in this analysis. The Arctic Coastal Plain Survey was flown in late June and early July. The survey area covered 61,645 km^2 including most of the area surveyed on the ground, but not extending into the foothills. A systematic sample of transects 18.8 km apart was flown with two observers. The plane flew 38 m above ground at 176 km/hr. Birds within 200 m of the airplane, on both sides of the transect, were recorded. The North Slope Eider Survey was similar, but the survey area was smaller, transects were half as far apart, and the survey was conducted during the middle part of June. We used data collected on both surveys during 1992–2005.

Survey results were summarized by determining, for each cell in the grid (Fig. 4.2), the total area surveyed (in all years) and the total number of birds recorded, defined as two times the number of singles plus the number in pairs and groups. We then calculated the density of observations (per km^2) of each species in each cell as "number recorded in all years/area surveyed in all years." Maps were then prepared for each species showing the numbers detected in each cell.

SPECIES ACCOUNTS

Shorebirds

Black-bellied Plover

Black-bellied Plovers were encountered on 142 plots and were judged to be breeding on 119 plots. Nearly all records were from the ACP-NPRA region (Fig. 4.4a). Sightings were split about equally between pairs (including nests and probable nests) and single birds. They were strongly associated with wetlands and almost never occurred in uplands (Table 4.6). The numbers of plots with four, five, and six sightings were seven, one, and one, and no plots had more than six sightings. Thus, they rarely occurred in high density. The estimated number of breeding pairs on surveyed plots was 175.

Ten Black-bellied Plovers were breeding in the intensive plots, all at one camp (Table 4.7). At that camp, the species was present on six of seven plots. Surveyors recorded a few birds on plots where the species was not breeding. The overall detection ratio was 0.85.

Estimated densities were highest in wetlands, lowest in uplands, and averaged a little less than 3 birds/km^2 with a CV of 0.23 (Table 4.6). Population size for the entire study area was estimated to be about 200,000 birds, the majority in the ACP-NPRA region.

The variables *ew*, *elev*, and *ewsqd* were each highly significant in at least one model and were therefore selected as the spatial variables. Both *wet* and *moi* were significant in the univariate models (models with one independent variable) and had about the same significance at the micro and meso scales but lower significance at the macro scale. When *wet* and *moi* were both in the model, *moi* was nonsignificant. We therefore used *micwet* as the only habitat variable. Adding *discoa* improved the fit, but adding *diswet* did not. All the variables and the intercept were highly significant in the final model (Table 4.8). According to the final model, density was higher in the west, at higher elevation, in wetlands, and farther from the coast.

The range map in the Birds of North America (BNA) species account is generally consistent with our results, though it shows the range extending farther east than we found birds (Paulson 1995). The BNA also states, "where tundra varies from low and wet to higher and drier, latter preferred." This would probably suggest to most readers that our upland habitat should have been preferred, whereas it was strongly avoided in our study area and even the density in moist areas was less than half the density in wetlands (Table 4.6). The BNA also makes it clear that habitat preferences vary across the range depending on the environment.

American Golden-Plover

American Golden-Plovers were encountered on 180 plots and were judged to be breeding on 122 plots. Records were widely distributed across the study area but were markedly less common in the western NPRA, although this may have been an artifact caused by small sample size (Fig. 4.4b). They were found in every region (Table 4.6). More than half were found in wetlands and most of the remaining records came

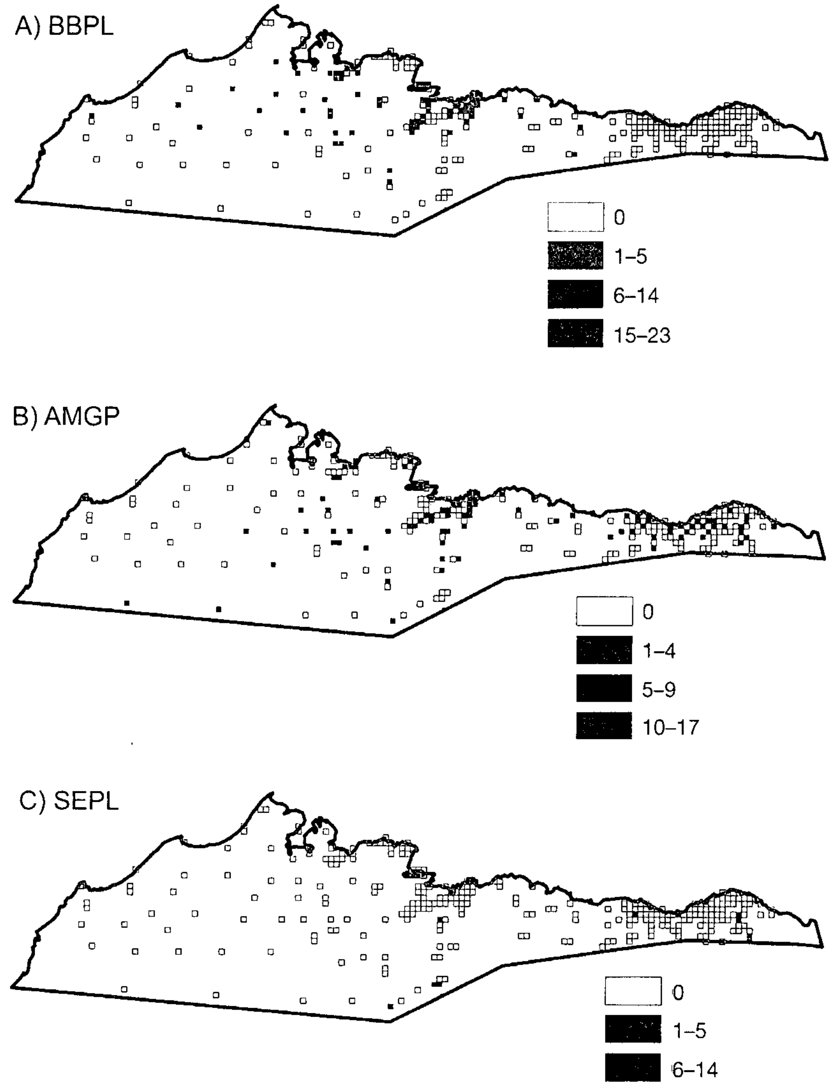

Figure 4.4. Densities (birds/km^2) of Black-bellied Plovers (a), American Golden-Plovers (b), and Semipalmated Plovers (c) recorded on the rapid surveys.

from moist habitat. The number of plots with three, four, and more than four indicated pairs were three, one, and zero. We did find one intensive plot with four pairs (all verified by nests); the other five plots with this species had one pair each. Thus, the species was generally distributed evenly rather than in a clumped fashion, but clusters of nesting pairs did exist at least rarely. The estimated number of breeding pairs on surveyed plots was 159.

Nine American Golden-Plovers were present on the intensive plots. The overall detection ratio was 0.88 (Table 4.7). As with most species, low numbers (including zero) tended to be overestimated and the high count of five actually present was underestimated.

The estimated densities, within regions, were highest in moist habitats in the ACP, though not in the Foothills region (Table 4.6). This is one of the few species that had substantial densities in uplands, though this was true only for the Foothills region. Densities in uplands in the ACP were low. The density across all areas was 3.75 birds/km^2. The estimated population size was about 275,000 for the entire study area. The Foothills region had a substantial estimated population but with a large CV.

None of the spatial parameters had clear predictive power. The only significant term in all of the models was *ew*elev* in the model *ew elev ew*elev*. We therefore did not include any spatial parameters in subsequent models. Among the habitat parameters, *wet* was not significant in any models but *moi* was significant at the micro and meso scales, and nearly significant at the macro scale, in both the univariate and bivariate models.

TABLE 4.6

Number of shorebirds recorded on rapid surveys, estimated densities and population size (with SEs).

Refer to Appendix C for common and scientific names of species 4-letter codes.

Species	Region	Total recorded	Est. *n* pairs	Birds/km² (SE) Wetlands	Moist areas	Uplands	All habitats	Population size Estimate (SE)	CV
AMGP	ACP-NPRA	113	114	2.52 (0.74)	8.63 (2.67)	0 (0)	3.82 (1.08)	131,827 (37,373)	0.28
	ACP-Central	19	8	1.05 (1.10)	3.34 (1.24)	0 (0)	2.22 (0.71)	24,061 (7,652)	0.32
	ACP-ANWR	59	29	2.44 (0.78)	4.27 (1.16)	0.41 (0.32)	2.46 (0.56)	11,805 (2,690)	0.23
	Foothills	10	6	0 (0)	0.7 (0.66)	5.1 (4.04)	4.93 (3.81)	114,564 (88,647)	0.77
	Colville River	2	2	0 (0)	0 (0)	1.77 (1.4)	0.99 (0.72)	20 (14)	0.73
	All	203	159	2.05 (1.05)	6.72 (0.95)	2.46 (2.92)	3.75 (1.15)	275,506 (84,298)	0.31
BBPL	ACP-NPRA	168	166	10.54 (2.18)	3.24 (1.28)	1.32 (1.43)	4.13 (1.03)	142,288 (35,599)	0.25
	ACP-Central	13	6	5.03 (2.97)	1.65 (1.15)	0 (0)	3.09 (1.41)	33,485 (15,285)	0.46
	ACP-ANWR	2	0	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0
	Foothills	3	3	0 (0)	1.01 (1.00)	0 (0)	0.16 (0.16)	3,699 (3,684)	1.00
	Colville River	0	0	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0
	All	186	175	8.13 (0.53)	2.59 (0.89)	0.61 (2.84)	2.74 (0.62)	201,162 (45,530)	0.23
BARG	ACP-NPRA	75	55	1.18 (0.65)	0.75 (0.39)	3.17 (3.23)	1.81 (1.30)	62,494 (44,797)	0.72
	ACP-Central	13	1	0 (0)	0.40 (0.40)	0 (0)	0.21 (0.21)	2,247 (2,272)	1.01
	ACP-ANWR	0	0	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0
	Foothills	1	0	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0.77
	Colville River	0	0	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0
	All	89	56	0.72 (0.59)	0.57 (0.47)	1.47 (1.04)	1.03 (0.73)	75,602 (53,252)	0.7

WHIM	ACP-NPRA	13	12	0.01 (0.01)	1.04 (0.79)	0 (0)	0.39 (0.30)	13,520 (10,375)	0.77
	ACP-Central	0	0	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0
	ACP-ANWR	5	2	0 (0)	0.54 (0.42)	0 (0)	0.22 (0.18)	1057 (847)	0.80
	Foothills	4	2	0 (0)	0.10 (0.11)	0.05 (0.05)	0.05 (0.04)	1232 (974)	0.79
	Colville River	1	1	0 (0)	0 (0)	0.40 (0.39)	0.22 (0.22)	4 (4)	0.98
	All	23	17	0.01 (0.15)	0.73 (0.17)	0.03 (0.23)	0.25 (0.17)	18,243 (12,529)	0.69
RUTU	ACP-NPRA	42	26	0.10 (0.06)	0.08 (0.06)	0 (0)	0.06 (0.04)	2,240 (1,216)	0.54
	ACP-Central	0	0	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0
	ACP-ANWR	6	5	0.39 (0.23)	0.59 (0.49)	0 (0)	0.33 (0.21)	1,602 (1,019)	0.64
	Foothills	0	0	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0.74
	Colville River	0	0	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0
	All	48	31	0.08 (0.02)	0.10 (0.03)	0 (0)	0.05 (0.02)	3,419 (1,430)	0.42
DUNL	ACP-NPRA	303	350	30.37 (5.41)	5.6 (1.92)	4.83 (3.47)	10.91 (2.29)	376,370 (79,094)	0.21
	ACP-Central	19	14	8.21 (3.57)	3.89 (1.88)	0 (0)	5.68 (2.01)	61,451 (21,711)	0.35
	ACP-ANWR	22	14	2.87 (1.21)	0.04 (0.05)	0 (0)	0.67 (0.30)	3,232 (1,449)	0.45
	Foothills	0	0	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0
	Colville River	0	0	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0
	All	344	378	21.74 (1.01)	4.44 (1.92)	2.25 (4.66)	6.82 (1.34)	500,161 (98,089)	0.20
SESA	ACP-NPRA	1,127	1,174	66.24 (11.39)	24.72 (6.68)	4.77 (3.86)	26.18 (4.77)	902,819 (164,476)	0.18
	ACP-Central	87	59	28.86 (11.06)	18.66 (4.8)	0 (0)	22.57 (5.99)	244,309 (64,890)	0.27
	ACP-ANWR	143	100	15.22 (3.57)	8.09 (2.42)	0.18 (0.19)	6.87 (1.52)	32,941 (7,281)	0.22
	Foothills	4	2	0 (0)	2.38 (2.28)	0 (0)	0.37 (0.37)	8,708 (8,532)	0.98
	Colville River	0	0	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0
	All	1,361	1,335	51.17 (2.54)	20.97 (3.55)	2.23 (13.58)	17.98 (2.98)	1,319,225 (218,761)	0.17

TABLE 4.6 (*continued*)

TABLE 4.6 (CONTINUED)

Species	Region	Total recorded	Est. n pairs	Birds/km^2 (SE)				Population size	
				Wetlands	Moist areas	Uplands	All habitats	Estimate (SE)	CV
WESA	ACP-NPRA	51	44	5.63 (2.7)	5.33 (2.82)	15.25 (6.57)	9.29 (2.99)	320,451 (103,233)	0.32
	ACP-Central	0	0	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0
	ACP-ANWR	1	1	0.14 (0.14)	0 (0)	0 (0)	0.03 (0.03)	153 (153)	1
	Foothills	0	0	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0.98
	Colville River	0	0	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0
	All	52	45	3.58 (2.44)	3.44 (2.68)	7.08 (2.1)	5.21 (1.65)	382,443 (120,837)	0.32
PESA	ACP-NPRA	947	982	36.7 (6.57)	10.65 (2.14)	23.14 (10.08)	21.61 (4.81)	745,179 (165,849)	0.22
	ACP-Central	81	47	22.44 (6.21)	18.96 (5.32)	0 (0)	19.88 (4.42)	215,272 (47,842)	0.22
	ACP-ANWR	224	111	17.58 (4.02)	7.74 (2.11)	2.35 (1.5)	8.04 (1.65)	38,552 (7,922)	0.21
	Foothills	8	4	0 (0)	3.39 (2.27)	0.10 (0.10)	0.61 (0.38)	14,294 (8,780)	0.61
	Colville River	6	5	0 (0)	0 (0)	4.92 (5.87)	2.75 (3.05)	55 (61)	1.11
	All	1,266	1,149	30.82 (2.02)	12.07 (2.23)	10.93 (6.30)	15.23 (2.92)	1,117,937 (214,529)	0.19
BBSA	ACP-NPRA	21	14	1.36 (1.20)	0.87 (0.62)	0 (0)	0.63 (0.36)	21,788 (12,398)	0.57
	ACP-Central	12	3	2.28 (2.31)	0.91 (0.65)	0 (0)	1.49 (1.08)	16,081 (11,733)	0.73
	ACP-ANWR	27	8	1.09 (0.79)	0.04 (0.05)	0 (0)	0.27 (0.19)	1,284 (894)	0.70
	Foothills	0	0	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	1
	Colville River	0	0	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0
	All	60	25	1.61 (0.36)	0.76 (0.31)	0 (0)	0.57 (0.25)	41,541 (18,538)	0.45
LBDO	ACP-NPRA	372	350	26.99 (5.24)	11.28 (2.60)	10.51 (5.17)	14.47 (2.95)	499,030 (101,783)	0.20
	ACP-Central	31	13	5.19 (2.30)	5.09 (2.28)	0 (0)	4.97 (1.61)	53,818 (17,429)	0.32
	ACP-ANWR	38	9	1.03 (0.74)	0.98 (0.57)	0.43 (0.45)	0.79 (0.34)	3,802 (1,634)	0.43
	Foothills	1	1	0 (0)	1.01 (1.00)	0 (0)	0.16 (0.16)	3,699 (3,684)	1
	Colville River	1	1	0 (0)	0 (0)	0.98 (1.17)	0.55 (0.61)	11 (12)	1.11
	All	443	374	18.66 (1.51)	8.61 (1.58)	4.90 (4.13)	8.83 (1.68)	647,695 (123,559)	0.19

	All	445	374	18.66 (1.51)	8.61 (1.58)	4.90 (4.13)	8.83 (1.68)	647,695 (123,559)	0.19
STSA	ACP-NPRA	138	119	6.01 (1.65)	1.97 (0.99)	0 (0)	2.09 (0.55)	72,130 (18,891)	0.26
	ACP-Central	17	8	3.89 (2.51)	2.39 (1.32)	0 (0)	2.98 (1.30)	32,209 (14,033)	0.44
	ACP-ANWR	25	16	4.22 (1.56)	1.38 (0.79)	0 (0)	1.53 (0.53)	7,331 (2,559)	0.35
	Foothills	1	0	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0.98
	Colville River	0	0	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0
	All	181	143	5.24 (0.39)	1.90 (0.60)	0 (0)	1.65 (0.37)	121,213 (27,381)	0.23
RNPH	ACP-NPRA	544	458	17.75 (3.91)	9.62 (3.04)	10.21 (6.71)	11.67 (3.13)	402,491 (108,068)	0.27
	ACP-Central	30	14	8.09 (4.28)	3.70 (3.38)	0 (0)	5.52 (2.50)	59,775 (27,064)	0.45
	ACP-ANWR	167	78	14.94 (4.02)	2.88 (1.23)	2.48 (1.43)	5.49 (1.43)	26,295 (6,833)	0.26
	Foothills	2	2	0 (0)	1.19 (1.14)	0.10 (0.10)	0.27 (0.20)	6,241 (4,637)	0.74
	Colville River	3	3	0 (0)	0 (0)	2.95 (3.52)	1.65 (1.83)	33 (37)	1.11
	All	746	555	14.59 (1.41)	7.40 (2.04)	4.91 (4.77)	7.63 (1.82)	560,092 (133,782)	0.24
REPH	ACP-NPRA	632	672	38.22 (7.11)	9.91 (3.50)	0 (0)	12.41 (2.30)	427,952 (79,473)	0.19
	ACP-Central	42	17	10.57 (5.34)	3.81 (2.04)	0 (0)	6.67 (2.57)	72,246 (27,811)	0.38
	ACP-ANWR	75	46	6.38 (2.67)	1.44 (0.72)	0 (0)	2.05 (0.78)	9,825 (3,726)	0.38
	Foothills	0	0	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0.61
	Colville River	0	0	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0
	All	749	735	27.58 (1.23)	7.30 (2.37)	0 (0)	7.82 (1.39)	573,979 (102,199)	0.18

TABLE 4.7

The number of shorebirds recorded on rapid surveys of intensive plots ("Estimate"), the number determined to be present through intensive surveys ("Actual"), the detection ratio, and its standard error (SE).

Refer to Appendix C for common and scientific names of species 4-letter codes.

		Region and year							
Species	Count	ACP-NPRA 1998	ACP-NPRA 1999	ACP-NPRA 2000	ACP-NPRA 2001	ACP-ANWR 2002	ACP-ANWR 2004	Total	Detection ratio (SE)
BBPL	Estimate	7.25	0.14	0	0.88	0.25	0	8.52	0.85 (0.17)
	Actual	10	0	0	0	0	0	10	
AMGP	Estimate	2.75	0.14	3	0	1	1	7.89	0.88 (0.26)
	Actual	2	0	5	0	2	0	9	
BARG	Estimate	2	0	0.25	0	0	0	2.25	0.75 (0.26)
	Actual	2	0	1	0	0	0	3	
RUTU	Estimate	7.5	0	0	0	0	0	7.5	0.83 (—)
	Actual	9	0	0	0	0	0	9	
DUNL	Estimate	9.5	1.7	4	6.5	0	0	21.7	0.90 (0.16)
	Actual	11	1	2	10	0	0	24	
SESA	Estimate	37.5	16.3	19	5.1	3.8	2	83.7	0.75 (0.13)
	Actual	38	26	37	5	4	1	111	
WESA	Estimate	0	0	0	3.1	0	0	3.1	0.78 (—)
	Actual	0	0	0	4	0	0	4	
PESA	Estimate	37	8.4	13	15.1	3	2.8	79.3	0.83 (0.06)
	Actual	41	10	17	16	6	6	96	
BBSA	Estimate	2.5	0	0	0	0.5	0	3	0.60 (0.03)
	Actual	4	0	0	0	1	0	5	
LBDO	Estimate	1.5	0.3	1.5	5.3	2.3	0	10.8	2.16 (1.20)
	Actual	1	0	0	1	3	0	5	
STSA	Estimate	0.3	0.4	0.8	0	0	1	2.4	0.61 (0.11)
	Actual	0	1	1	0	0	2	4	
RNPH	Estimate	23.25	12.43	8.25	3.63	3.25	3.25	54.1	0.80 (0.14)
	Actual	21	16	12	4	11	4	68	
REPH	Estimate	7.75	4.57	4.75	16	0	0	33.1	0.77 (0.17)
	Actual	4	11	9	19	0	0	43	

Clear evidence thus existed that *moi* had explanatory power and that it was most powerful at the micro scale.

American Golden-Plovers usually breed in uplands, and usually close to wetlands. We thought that *diswet* therefore might strengthen the model. The *P*-value for *diswet*, with *micmoi* in the model, however, was 0.42, clearly indicating that this variable did not improve the model. In contrast, we did not expect *discoa* to contribute significantly but included it with *micmoi* and found that it was significant. The intercept was

TABLE 4.8

Parameter estimates and their significance from habitat models predicting counts of shorebirds on rapid surveys.

Refer to Appendix C for common and scientific names of species 4-letter codes.

Species		Variable[a]							
		Intercept	*ew*	*ew*^{2}	*elev*	*ew*elev*	*micwet*	*micmoi*	*discoa*
BBPL	Value	1.221	0.148	−0.030	−0.016		−1.230		0.016
	Sig.	<0.001	0.002	<0.001	0.003		<0.001		0.004
AMGP	Value	−0.265						0.742	0.010
	Sig.	0.151						0.021	0.013
BARG	Value	−0.490	0.102		−0.013				
	Sig.	0.027	0.023		0.033				
RUTU	Value	−0.846							−0.106
	Sig.	0.040							0.013
DUNL	Value	2.316	0.182	−0.011	−0.043		−0.439		
	Sig.	<0.001	<0.001	0.026	<0.001		0.094		
SESA	Value	0.325	0.077		−0.015		2.854	2.067	
	Sig.	0.508	<0.001		<0.001		<0.001	<0.001	
WESA	Value	−0.943	0.368						
	Sig.	0.369	0.022						
PESA	Value	2.548	0.093		−0.024	−0.002	0.397		
	Sig.	<0.001	<0.001		<0.001	<0.001	0.006		
LBDO	Value	0.949	0.172	−0.009	−0.004		0.855		
	Sig.	<0.001	<0.001	0.021	0.081		<0.001		
STSA	Value	0.407			−0.009			−2.206	0.030
	Sig.	0.084			0.017			<0.001	<0.001
RNPH	Value	0.385			−0.011		1.390		0.019
	Sig.	0.060			<0.001		<0.001		<0.001
REPH	Value	1.768	0.203		−0.028		1.242		−0.024
	Sig.	<0.001	<0.001		<0.001		<0.001		0.002

[a] Variables not found to be significant in any model are excluded from table.

not significant; *micmoi* and *discoa* were significant, though not highly significant. In the final model, density was higher in moist areas and farther from the coast (Table 4.8).

The range map in the BNA shows its range covering our entire study area, which is consistent with our study except that we did not find it in the western NPRA (Johnson and Connors 1996a). The BNA summarized habitat preferences saying that "rocky, dry tundra" is generally preferred for nesting "but in some areas moist habitat with taller vegetation" is also used. In our study area, plots classified as moist were strongly preferred, which seems more consistent with the second habitat above than the first.

Semipalmated Plover

Semipalmated Plovers were encountered on 14 plots and were judged to be breeding on ten plots. The sightings were all on the Colville River or in the Arctic NWR (Fig. 4.4c). Throughout the

North Slope they occurred only in gravel stream beds, a relatively rare habitat that we did not focus on. For example, they occurred commonly on gravel bars along the Colville River upstream from the delta (where the substrate is silt). Our study does not provide a good basis for describing habitat associations quantitatively or for estimating population size.

The range map in the BNA shows this species occurring throughout our study area (Nol and Blanken 1999). That is probably accurate in the sense that the species probably does occur wherever gravel beds occur. Such areas, however, occur on much less than 1% of the North Slope.

Lesser Yellowlegs

One pair and one single Lesser Yellowlegs were encountered on one plot near the Colville River, about 70 km upstream from Umiat. They were judged to be breeding on the plot. The range map in the BNA is thus correct in showing that this species does not breed extensively on the North Slope (Tibbitts and Moskoff 1999).

Spotted Sandpiper

A single Spotted Sandpiper was recorded on a plot along the Colville River near Umiat. It was judged to be breeding off the plot. The range map in the BNA is thus correct in showing that the species does not breed extensively on the North Slope, except perhaps at its extreme southern edge (Oring et al. 1997).

Whimbrel

Whimbrels were encountered on 21 plots and were judged to be breeding on 15 plots. The records were widely distributed across the study area south of the coast (Fig. 4.5a). The species may have been less common in the western NPRA, or the lack of records there may have been due to the lower sampling intensity. Most detections were of single birds, and most were in moist areas (Table 4.6). The species did not occur on intensive plots. The estimated number of pairs breeding on surveyed plots was 17.

The estimated densities were much higher in moist areas than in wetlands or uplands, and this pattern was consistent across regions. Population size was estimated at about 18,000 (Table 4.6). Due to the small number of birds recorded, we did not attempt to characterize habitat relationships.

The BNA range map shows this species extending throughout the North Slope, which may be correct, or there may be a gap in its range in the western NPRA but we had too few samples there to be certain (Skeel and Mallory 1996). The BNA describes breeding habitat as "variable ranging from dry heath uplands to poorly drained hummocky, grass-sedge, dwarf shrub, and mossy lowlands." Breeding sites for this species elsewhere in Alaska are described as "wet, flat, dwarf-shrub tundra," "dry dwarf-shrub ridges and steep slopes," and "rolling, open, usually moist tundra." These descriptions seem consistent with the very strong association in our study area of Whimbrels with moist habitat. Many of the sites where we found breeding Whimbrels had low (and occasionally moderate height) shrubs.

Bar-tailed Godwit

Bar-tailed Godwits were encountered on 59 plots and were judged to be breeding on 43 plots, widely distributed across the study area (Fig. 4.5b). All but one of the birds judged to be breeding were in the ACP-NPRA region (Table 4.6). About half the records came from the Colville Delta and most were of single birds in either wetlands or moist areas. Five counts of four or more occurred, but all but three of the birds were judged to be non-territorial. Thus, the species was distributed fairly evenly across the surveyed plots. The estimated number of pairs breeding on the surveyed plots was 56.

Only three Bar-tailed Godwits were present on the intensive plots (Table 4.7). An average of 2.25 birds was recorded on rapid surveys for a detection ratio of 0.75. The species was not recorded on rapid surveys of any intensive plots where it was absent.

The estimated density was nearly 2 birds/km^2 in the ACP-NPRA region but low or zero in all other regions (Table 4.6). The point estimate was highest in uplands, but the estimate is not close to significantly different from the estimate for the wetlands and moist areas. Population size was estimated at about 75,000 with a large CV.

The variables *ew* and *elev* were significant alone and in combination. The only other significant spatial variable was *ewsqd*, and it was only significant when *ew* was not in the model. Neither

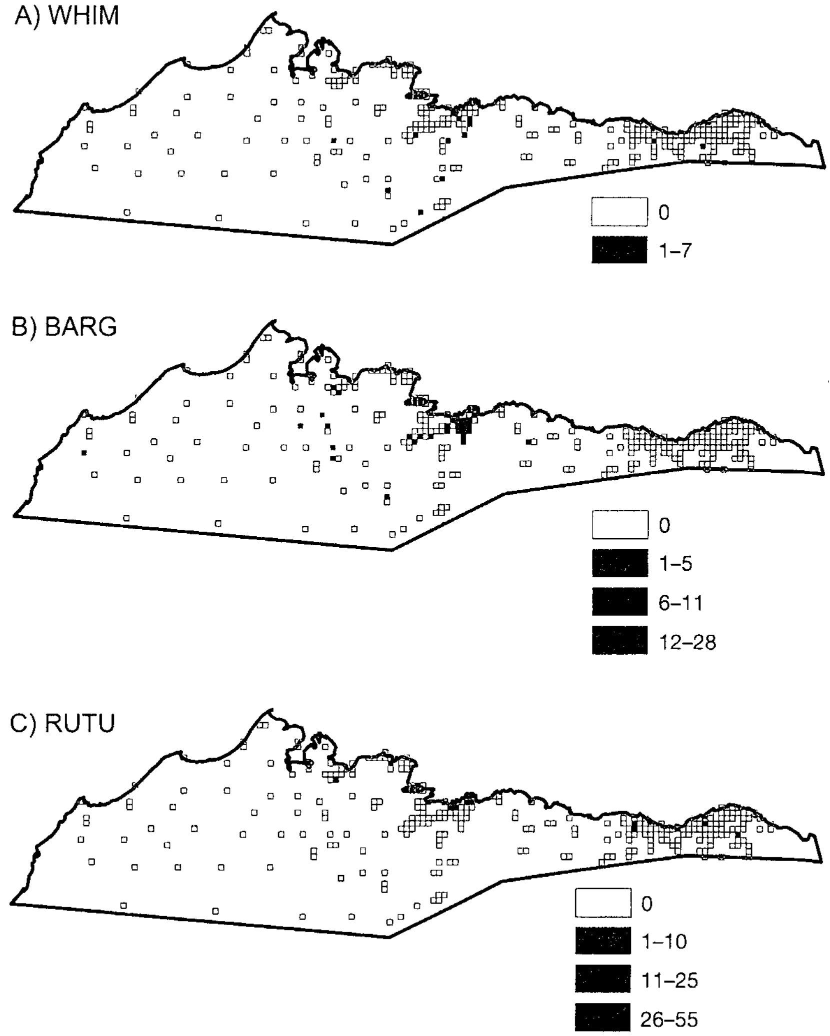

Figure 4.5. Densities (birds/km^2) of Whimbrels (a), Bar-tailed Godwits (b), and Ruddy Turnstones (c) recorded on the rapid surveys.

wet nor *moi* was significant at any spatial scale. Both of these variables and the intercept were significant (though not highly significant) predictors of the number obtained on counts. In the final model, density was higher in the west and at low elevations (Table 4.7).

The range map in the BNA shows the range ending before the Alaska–Canada border, which is consistent with our results (McCaffery and Gill 2001). This species was unusual in our study in not showing much association with habitat (no contrasts between habitats were close to significant). The BNA also refers to its use of many different habitats.

Ruddy Turnstone

Ruddy Turnstones were encountered on 22 plots and were judged to be breeding on 16 plots. Birds judged to be breeding were encountered largely in the ACP-NPRA region, though five indicated pairs were recorded in ANWR (Fig. 4.5c; Table 4.6). The species was notable for the high proportion (25%) of sightings that were nests or probable nests. Although nests were often on partially vegetated dunes, sightings were exclusively on plots classified as wetlands or moist areas. Most plots with the species present had one or two sightings, but 24 of the 48 sightings occurred on just two plots, one of which had 16 sightings. The species thus showed a highly clumped distribution on the surveyed plots. The estimated number of breeding pairs on surveyed plots was 31.

Nine Ruddy Turnstones were present on the intensive plots, all at one camp, and surveyors recorded an average of 7.5 birds for a detection ratio of 0.83 (Table 4.7). Since the species only occurred at one camp, we could not calculate a camp-to-camp variance and thus could not obtain a SE for the estimated detection ratio.

Estimated densities were less than 1 bird/km^2 in all regions and habitats (Table 4.6). All of the records were from wetlands or moist areas. The estimated population size was about 3,400. Despite a large CV, the results show that population size on the North Slope is fairly small (e.g., <10,000 birds).

None of the spatial or habitat variables was consistently significant. The factor *discoa* was nearly significant, and we thought it was justified on the basis of biological evidence (the species normally occurs close to the coast). In the final model, density was higher close to the coast (Table 4.8).

The BNA range map shows this species distributed in a narrow band throughout our study area (Nettleship 2000). Our finding of five to ten locations, nearly all right on the coast, is consistent with this description. We had too little data for a quantitative description of habitat associations, but our impression was that this species occurred in sites that were unusually barren (e.g., halophytic and sparsely vegetated) for our study area, consistent with their habitat use elsewhere.

Sanderling

A single Sanderling was recorded in the Arctic NWR. The BNA range map shows a small patch of range at Barrow (MacWhirter et al. 2002). We did not find Sanderlings there but could have missed such a small area.

Dunlin

Dunlin were encountered on 188 plots and were judged to be breeding on 175 plots. Most records were within 50 km of the coast (Fig. 4.6a). Nearly all the records were from the ACP-NPRA region and none were from the Foothills (Table 4.6). The range appeared to stop at the western edge of the Arctic NWR. Most records were from wetlands and hardly any were from uplands. The number of plots with seven, eight, and nine sightings were four, one, and one. No plot had more than nine sightings. They were thus one of the more abundant shorebird species. The estimated number of breeding pairs on the surveyed plots was 378.

Intensive plots had 24 territorial Dunlin, 21 of which were at two camps on the Colville Delta (Table 4.7). Surveyors recorded an average of nearly 22 birds/survey, for a detection ratio of 0.90.

Estimated densities were consistently highest in wetlands by a considerable margin (Table 4.6). Density in wetlands across all regions was significantly higher than in moist areas. Dunlin were rarely found in uplands. Overall density was nearly 7 birds/km^2. Population size was estimated at 500,000 birds with a CV of just 0.20. More than 70% of the birds were estimated to occur in the NPRA-coast region.

The variables *ew*, *elev*, and *ewsqd* were significant predictors of Dunlin counts in rapid plots. *Wet* was significant alone and in combination with *moi*. Its significance level was about the same for the micro and meso scales and lower at the macro scale. The factor *moi* was generally not significant either alone or in combination with *wet*. Neither *discoa* nor *diswet* improved the fit. All variables but *micwet* were significant. In the final model, density was higher in the west, at lower elevation, and in drier areas (Table 4.8).

The range map in the BNA is consistent with our findings except that we found few birds in the Arctic NWR, whereas the BNA map suggests they occur throughout the ACP (Warnock and Gill 1996). The BNA includes a detailed description of habitat for Dunlin near Prudhoe Bay, which is similar to our finding that density was highest in wetlands, intermediate in moist areas, and low in uplands.

Semipalmated Sandpiper

Semipalmated Sandpipers were encountered on 351 plots and were judged to be breeding on 325 plots. They occurred throughout the ACP but were rare in the Foothills (Fig. 4.6b). Among the 1,361 records (Table 4.6) were 174 nests and probable nests. The largest number of birds was found on the Colville Delta. Most records were in wetlands and few were in uplands. The species was often abundant on plots; 29 plots had ten or more sightings, and four had 20 or more sightings. The estimated number of pairs breeding on surveyed plots was 1,335.

More than 100 Semipalmated Sandpipers occurred on the intensive plots, and the species was present at every camp (Table 4.7). The overall detection ratio was 0.75 with a small CV of 0.13.

The estimated density in wetlands was >50 birds/km^2, more than twice as many as in moist areas ($P < 0.001$; Table 4.6). Even fewer birds were seen in uplands. The overall density was

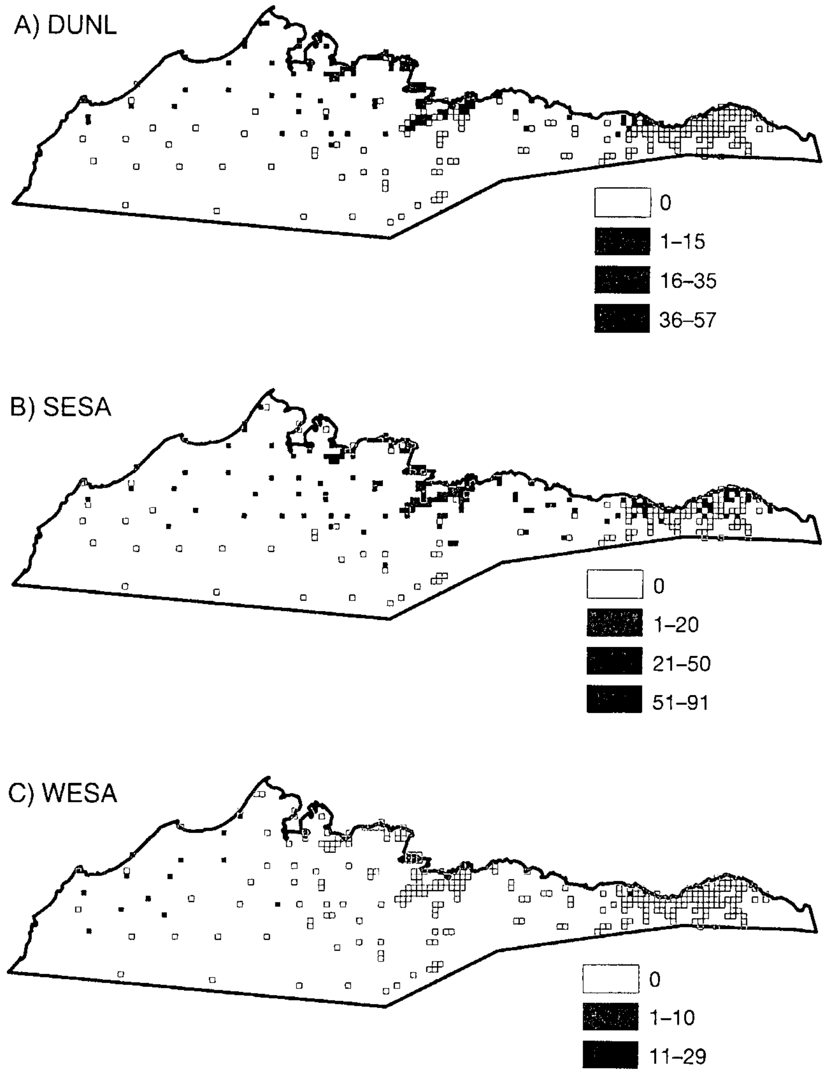

Figure 4.6. Densities (birds/km^2) of Dunlin (a), Semipalmated Sandpipers (b), and Western Sandpipers (c) recorded on the rapid surveys.

nearly 20 birds/km^2. The estimated population size was about 1.3 million birds. Most of the birds were estimated to be in the ACP-NPRA. Unlike many species, significant numbers (>240,000) were estimated to occur in the Central region.

The spatial variables *ew* and *elev* were highly significant alone and in combination. When we added *ewsqd*, it was significant but *ew* became nonsignificant. We thus used *ew* and *elev* as the spatial variables. When we added *wet*, *moi*, or *wet moi* to *ew elev*, *wet* and *moi* were both significant. The factors *wet* and *moi* were highly significant at the micro and meso scale. Convergence did not occur when *discoa* was added to *ew elev micoi micwet*. Adding *diswet* to *ew elev micmoi micwet* was not significant. All variables were highly significant. According to the final model, density was higher in the west, at lower elevations, and in wetlands or moist areas (Table 4.8).

The range map in the BNA is consistent with our findings as are the descriptions of this species' habitat as "moist or wet sedge-grass or heath tundra" (Gratto-Trevor 1992).

Western Sandpiper

Western Sandpipers were encountered on 23 plots and were judged to be breeding on 20 plots. They were encountered almost exclusively in the western part of the ACP-NPRA region, with a single record in the Arctic NWR (Fig. 4.6c). They were unusual among shorebirds in occurring regularly in uplands, although they were not found in the Foothills region (Table 4.6). More sightings occurred in wetlands than in uplands or moist areas. The numbers per plot were almost always four or fewer, although one plot had eight sightings. The number of estimated pairs breeding on surveyed plots was 45.

Four Western Sandpipers were present on the intensive plots, all at one camp (Table 4.7). The mean number recorded/survey was 3.13 for a detection ratio of 0.78. Since the species occurred only at one camp, we could not estimate the SE of the point estimate.

The estimated density in the ACP-NPRA region, 9.29, is not very meaningful because the species occurred only west of Barrow (excluding the single bird recorded in the Arctic NWR). The high estimated density in uplands is unusual for shorebirds. The estimated population size was nearly 400,000.

The only significant spatial or habitat variable, including *discoa* and *diswet*, was *ew*. According to the final model, density was higher in the west (Table 4.8).

The BNA range map shows three small, discrete patches of range for Western Sandpipers, whereas we found it regularly west of Barrow (especially close to the coast, Wilson 1994). A review using all available data now would probably be worthwhile. The BNA says this species breeds in areas dominated by prostrate woody plants and dwarf shrubs. This is consistent with our finding that they were most common in moist and upland areas.

White-rumped Sandpiper

White-rumped Sandpipers were encountered on six plots and were judged to be breeding on four plots mainly between Barrow and Cape Halkett (Fig. 4.7a). The other two records were in the Arctic NWR and were probably migrants. The estimated number of breeding pairs in surveyed plots was five.

The BNA range map shows this species' range extending from the Canadian border to Barrow, whereas we found only five pairs of White-rumped Sandpipers (all along the coast near Barrow, Parmelee 1992b).

Baird's Sandpiper

Baird's Sandpipers were encountered on 12 plots and were judged to be breeding on six plots. Two pairs and ten single Baird's Sandpipers were encountered, but only seven of the sightings were considered to be of birds nesting on the surveyed plots. Seven of the 12 sightings were in the Arctic NWR and two were in the Central region. Only three sightings were west of the Colville River. The records were obtained mainly in wetlands; four were from moist areas and none were in uplands. The BNA range map shows the range for this species extending along the coast throughout our study area (Moskoff and Montgomerie 2002). Our results suggest the range may be less extensive.

Pectoral Sandpiper

Pectoral Sandpipers were encountered on 376 plots and were judged to be breeding on 345 plots. They were widely distributed north of the Foothills (Fig. 4.7b). Most sightings were of single birds in wetlands (Table 4.6). Only about 1% of the sightings were in uplands. This species was often quite abundant on plots; 23 plots had ten or more sightings and five plots had 20 or more sightings. The estimated number of breeding pairs on surveyed plots was 1,149.

Nearly 100 Pectoral Sandpipers were present on the intensive plots and the species occurred at all six camps (Table 4.7). Surveyors recorded an average of 79 birds/survey for a detection ratio of 0.83. The mean numbers recorded/survey were less than the actual numbers present at each of the six camps.

Estimated densities were about 30 birds/km^2 in wetlands and about 12 birds/km^2 in moist areas (Table 4.6). The difference between the two habitats was highly significant ($P < 0.001$). Estimated densities in uplands were more variable. The overall estimate for uplands (10.93) was not significantly different from 0.0. The estimated population size was greater than 1 million. Nearly all birds were in the ACP, with nearly 75% in the NPRA.

The variables *ew* and *elev* were significant in several models, as was their interaction. The interaction *ewsqd*elev* was significant, but *ew* was not significant. We therefore used *ew*, *elev*, and *ew*elev* as the spatial parameters. With these variables included, *wet* was generally significant, sometimes highly so, whereas *moi* was either not significant or at least not highly significant. The factor *wet* was equally significant at the micro and meso scale and not significant at the macro scale. When *discoa* and *diswet* were added, neither was significant. The model selected was thus *ew elev*

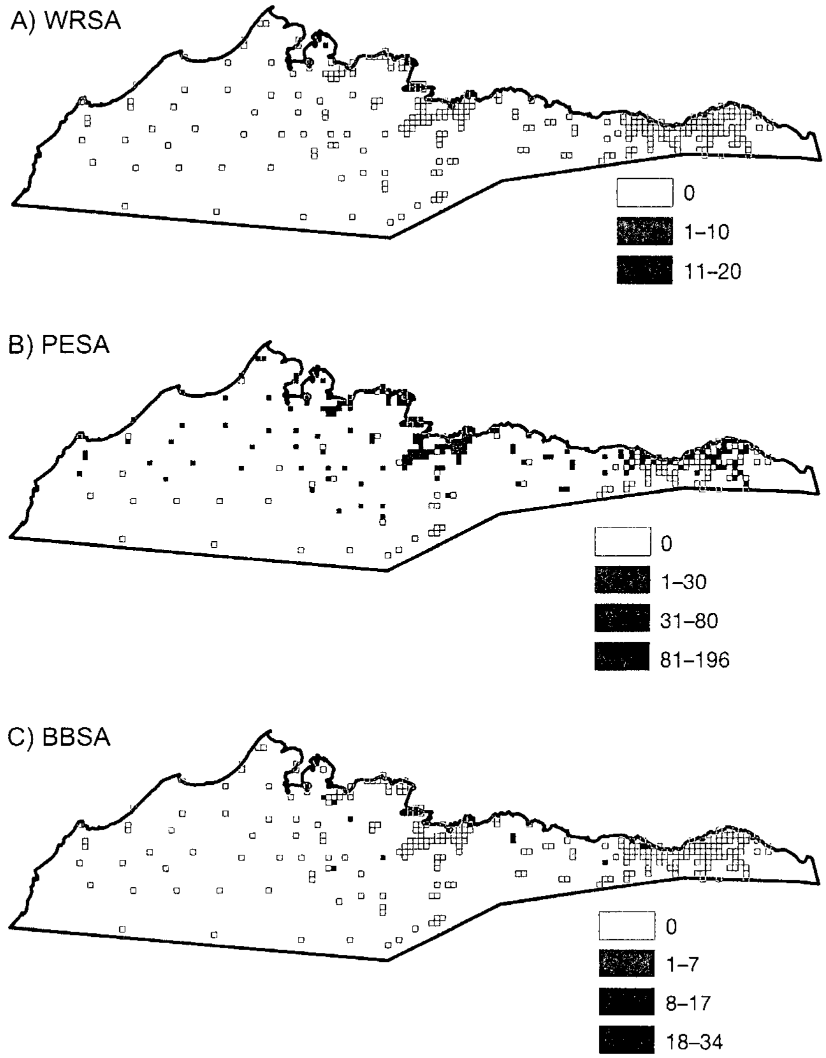

Figure 4.7. Densities (birds/km^2) of White-rumped Sandpipers (a), Pectoral Sandpipers (b), and Buff-breasted Sandpipers (c) recorded on the rapid surveys.

*ew*elev micwet*. According to the final model, density was higher in the west, at lower elevations, and in wetlands (Table 4.8).

The BNA range map and descriptions of breeding habitats are consistent with our results (Holmes and Pitelka 1998).

Buff-breasted Sandpiper

Buff-breasted Sandpipers were encountered on 28 plots and were only judged to be breeding on 16 plots. They were recorded widely across the ACP (Fig. 4.7c) east of Barrow. Most records were of single birds in wetlands, but a substantial number of records occurred in moist areas as well (Table 4.6).

Few birds were recorded on the intensive plots (Table 4.7). No birds were recorded when the species was actually absent. The observed detection ratio was 0.6. The low SE results from only two intensive plots having birds and the detection ratio happening to be similar (0.5 and 0.63). We do not consider this a reliable estimate of the true SE.

Estimated densities were highest in wetlands, intermediate in moist areas, and zero in uplands (Table 4.6). All CVs were large. Population size was estimated at a little over 40,000 but with a large CV of 0.45. The BNA range map for our study area is consistent with our observations (Lanctot and Laredo 1994).

Long-billed Dowitcher

Long-billed Dowitchers were encountered on 229 plots and were judged to be breeding on 198 plots. They were recorded throughout the ACP,

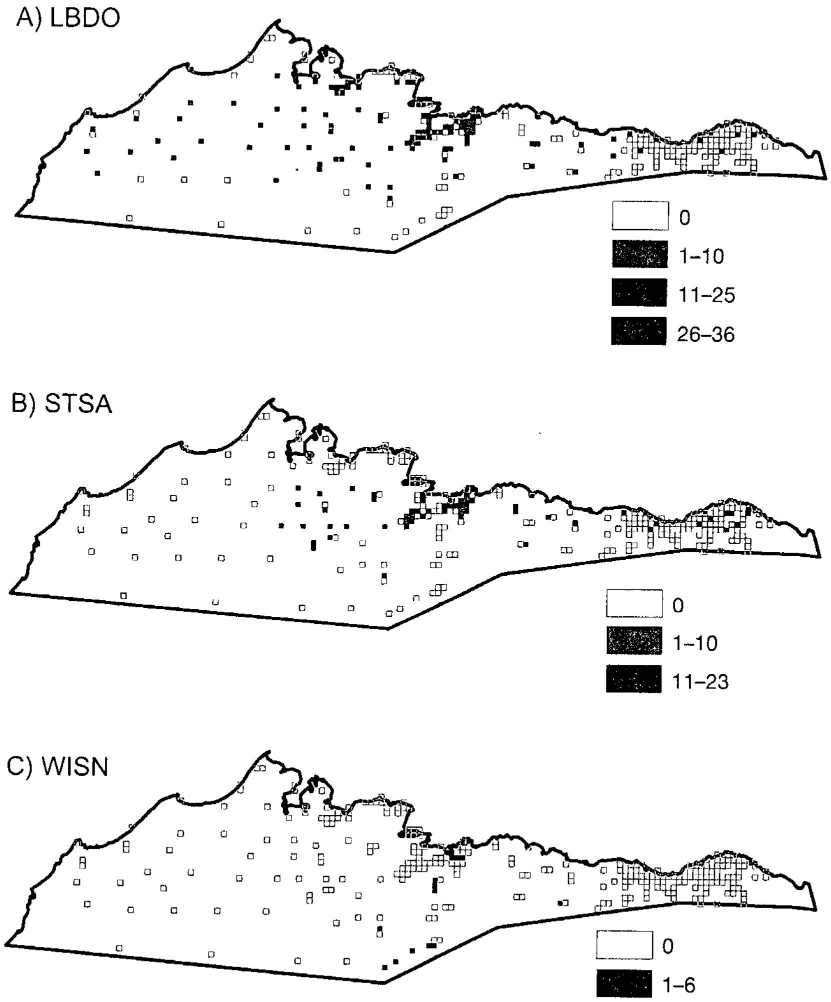

Figure 4.8. Densities (birds/km^2) of Long-billed Dowitchers (a), Stilt Sandpipers (b), and Wilson's Snipe (c) recorded on the rapid surveys.

but relatively few records came from the Arctic NWR (Fig. 4.8a; Table 4.6). About a third of the sightings were of nests, probable nests, or pairs; the rest were of single birds. About two-thirds of the sightings were in wetlands, and nearly all the remaining sightings were in moist areas. Single plots had 10, 11, 12, and 13 sightings each and 18 plots had four or more sightings. Thus, detecting multiple birds per plot was not uncommon. The estimated number of pairs breeding on surveyed plots was 374.

Only five Long-billed Dowitchers were present on the intensive plots (Table 4.7). Surveyors consistently recorded this species in larger numbers than were present. The overall detection ratio was 2.16, but due to the small sample size the confidence interval for the estimate extended almost to zero. Our subjective impression is that this species was secretive at nests and moved around a lot. It may often have been counted on plots where it was not breeding. If this is true, then our estimated densities and population sizes (which used the combined detection rate, not 2.16) could have substantial positive bias.

Estimated region-wide densities were highest in wetlands and lowest in uplands (Table 4.6). The difference between densities in wetlands and moist areas was highly significant. The estimated population size was about 650,000, making this one of the most abundant shorebirds. The estimate was quite precise (CV = 0.19) but, as noted above, we are concerned that the detection ratio might have been substantially underestimated. Most of the birds were estimated to occur in the ACP-NPRA region. A small population was estimated to occur in the Foothills and on the Colville River.

The variables *ew*, *elev*, and *ewsqd* were all significant when included together in the model. No other variables were significant. With these variables in the model, *wet* was significant, especially at the micro scale. The factor *moi* was far from significant alone but was significant when *wet* was included. Because *moi* was not significant alone, we did not include it. When *discoa* was added to this model, the estimator did not converge. When *diswet* was added instead, *diswet* was significant but the significance level for *elev* dropped to 0.21, which, overall, seemed like a less satisfactory model. The final model was thus *ew elev ewsqd micwet* (Table 4.8). In this model, all variables except *elev* were significant. According to the final model, density was higher in the west, at lower elevations, and in wetlands (Table 4.8).

The BNA range map is consistent with our results (Takekawa and Warnock 2000). The description of habitat as "wet, grassy meadows" (assuming grass includes sedge) is consistent with our finding that density was highest in wetlands and moist areas.

Stilt Sandpiper

Stilt Sandpipers were encountered on 103 plots and were judged to be breeding on 86 plots. They were widely distributed, though never abundant, across the ACP but were not encountered in the southern or western parts of the study area (Fig. 4.8B; Table 4.6). They were strongly associated with wetlands, though about a third of the sightings were in moist areas. Only one sighting was in uplands. Most plots on which the species occurred had relatively few birds. Seven plots had five or more birds. The largest numbers of sightings were individual plots with 10, 10, and 14 sightings. The estimated number of pairs breeding on surveyed plots was 143.

Four pairs were present at three intensive camps (Table 4.7). The mean number recorded per survey was 2.43 for an overall detection ratio of 0.61. The SE was fairly small, but we suspect this was just due to the camp-specific rates being similar by chance. We do not place high confidence in an estimate of the detection ratio based on only four birds.

Densities were much higher (P = 0.001) in wetlands than in moist areas, and the species was never recorded in uplands (Table 4.6). Densities were highest in wetlands in all three ACP regions. Estimated population size was about 120,000 with a moderate CV of 0.23. More than half the birds were in the NPRA.

The only significant spatial variable was *elev* with no other spatial variables included. The habitat variables *wet* and *moi* were both significant when added to *elev*, but only *wet* was significant in *elev wet moi*. Significance values were slightly higher at the micro scale than at the meso scale. In *elev micmoi discoa*, *discoa* was significant. In *elev micmoi diswet*, *diswet* was significant but *elev* was then not significant (P = 0.83). The final model was thus *elev micmoi discoa* (Table 4.8). All variables were significant; *micmoi* and *discoa* were highly significant. According to the final model, density was higher at lower elevations, lower in moist areas, and higher farther from the coast (Table 4.8).

The BNA range map for our study is fairly accurate except that we found the species farther south than shown in the BNA (see Fig. 4.8b, Klima and Jehl 1998). The BNA's description of this species' habitat, especially near Prudhoe Bay, is consistent with our results.

Wilson's Snipe

Wilson's Snipe were encountered on 24 plots and were judged to be breeding on 18 plots. Most records occurred along the Colville River (Fig. 4.8c). About equal numbers were recorded in wetlands and moist areas. The estimated number of pairs breeding on surveyed plots was 21.

The BNA range map shows our entire study area as within the range of Wilson's Snipe (Mueller 1999). This may be accurate, depending on how low density can be within the range, but our results suggest that only the central part of our study area, and especially the Colville River, was within the range. The tundra is an unusual breeding habitat for this species and is not explicitly acknowledged in the BNA.

Red-necked Phalarope

Red-necked Phalaropes were encountered on 247 plots and were judged to be breeding on 220 plots. They were widely distributed across the ACP but were nearly absent from the Foothills (Fig. 4.9a; Table 4.6). Nests and probable nests were uncommon, but about a third of the sightings were pairs. They were encountered mainly in wetlands, but a substantial number were found in moist areas. Large groups were uncommon, but 12 plots

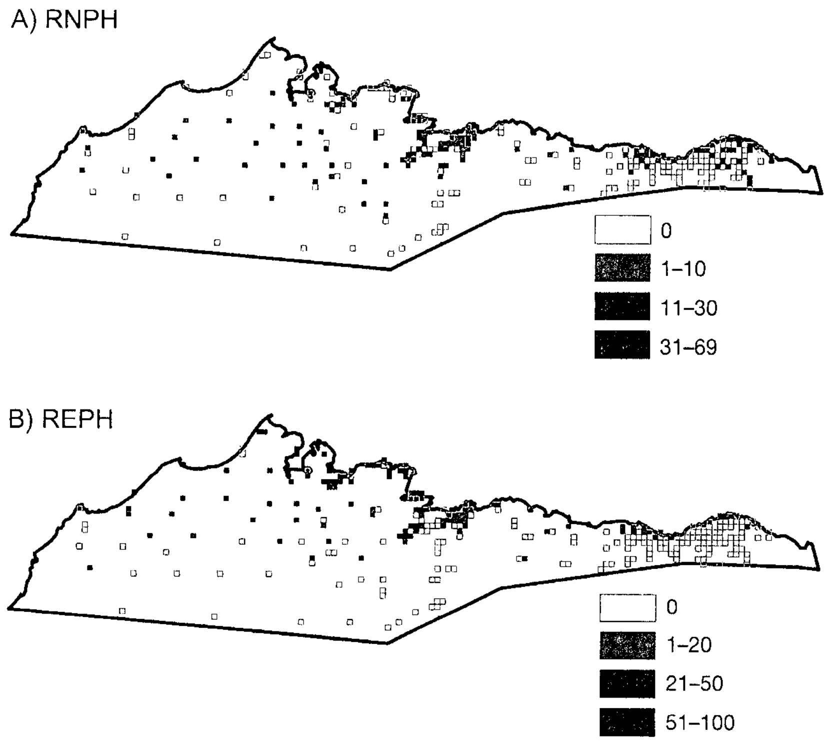

Figure 4.9. Densities (birds/km^2) of Red-necked Phalaropes (a) and Red Phalaropes (b) recorded on the rapid surveys.

had ten or more sightings and individual plots had 21, 22, and 27 sightings. The estimated number of pairs breeding on surveyed plots was 555.

Sixty-eight Red-necked Phalaropes were present on the intensive plots, and the species was present at all of the six camps (Table 4.7). Surveyors recorded an average of 54 birds/survey for a detection ratio of 0.80.

Densities were much higher in wetlands than in moist areas and were lowest in uplands (Table 4.6). The difference in density between wetlands and moist areas was highly significant. The overall density was 7.6 birds/km^2. The estimated population size was more than half a million birds, with the great majority in the ACP-NPRA region.

The spatial variable *ew* was significant alone but was not significant when *elev* was in the model. The factor *elev* was highly significant in all models. No other spatial variables were significant. With *elev* in the model, *wet* and *moi* were both significant alone, but only *wet* was significant when both were in the model. The factor *wet* was only significant at the micro scale. This led us to the model *elev micmoi*. Adding *discoa* to this model, was significant but *diswet* was not. The final model was thus *elev micwet discoa* (Table 4.8). All variables were significant but the intercept was just nonsignificant. According to the final model, density was higher at lower elevations, in wetlands, and farther from the coast (Table 4.8)

The BNA range map includes all of our study area, which is consistent with our results (Rubega et al. 2000). The habitat description, especially for populations in the Mackenzie Delta, is consistent with our results.

Red Phalarope

Red Phalaropes were encountered on 219 plots and were judged to be breeding on 193 plots. They were widely recorded across the ACP, though they were noticeably rare in the Arctic NWR (Fig. 4.9b; Table 4.6). More than half of the sightings were of nests, probable nests, or (especially) pairs. They were more restricted to wetlands (77% of the sightings) than most other shorebirds. None were recorded in uplands. They were sometimes abundant on plots; 14 plots had ten or more sightings, and two plots had 35 and 51 sightings. The estimated number of pairs breeding on surveyed plots was 735.

Forty-three Red Phalaropes occurred on the intensive plots, with four of six camps having the species present (Table 4.7). Surveyors recorded an average of 33 birds/survey for a detection ratio of 0.77.

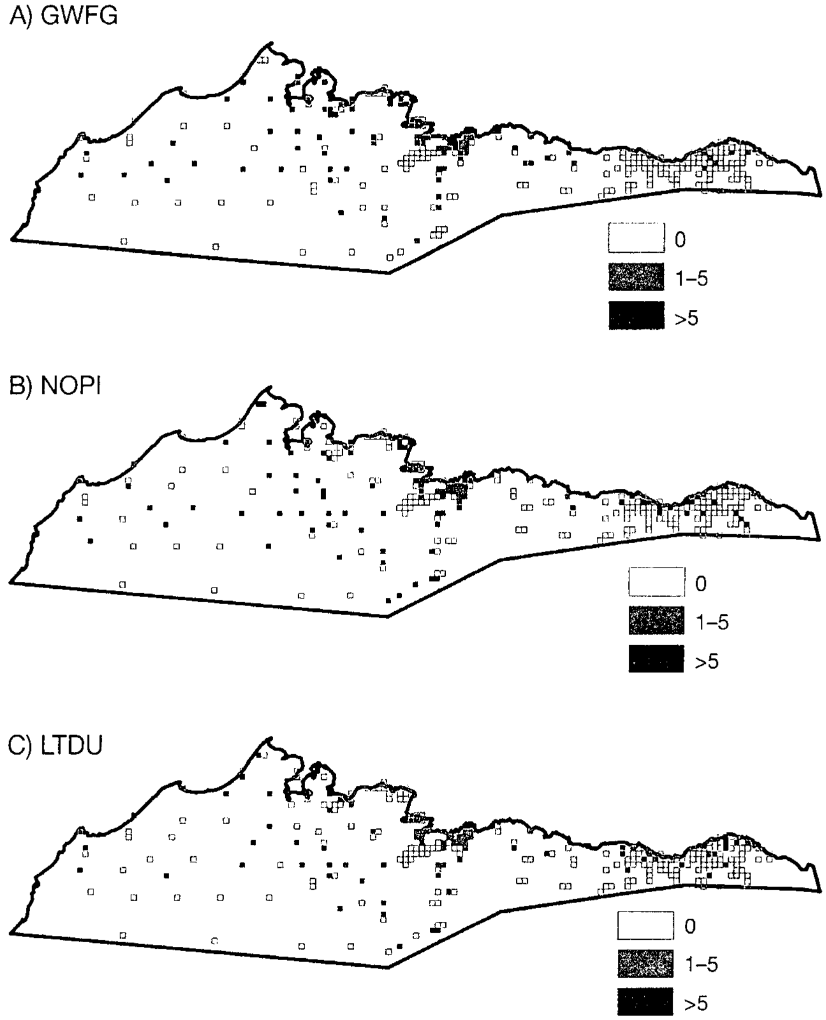

Figure 4.10. Densities (birds/km^2) of Greater White-fronted Geese (a), Northern Pintail (b), and Long-tailed Ducks (c) recorded on the rapid surveys.

Estimated densities were highest in wetlands in the ACP and were 0.0 in uplands in the other regions (Table 4.6). The region-wide density in wetlands was significantly higher than in moist areas. Overall density was nearly 8 birds/km^2. Estimated population size for all regions was about 570,000. Most of the estimated population was in the NPRA.

The only significant spatial variables were *ew* and *elev*, and they were highly significant in all combinations. The habitat variables *wet* and *moi* were both significant alone but *moi* was not significant with *wet*. The factor *wet* was equally significant at the micro and meso scale but not at the macro scale. The factor *discoa* was significant when added to *ew elev wet* but *diswet* was not. The final model was thus *ew elev micwet discoa* (Table 4.8). All variables and the intercept were highly significant. According to the final model, density was higher in the west, at lower elevations, in wetlands and closer to the coast (Table 4.8).

The BNA range map includes all of our study area, which is consistent with our results (Tracy et al. 2002). The habitat description is consistent with our results.

Other Species

Greater White-fronted Goose

Greater White-fronted Geese were encountered during ground surveys on 206 plots and were judged to be breeding on 135 plots. They occurred mainly west of Prudhoe Bay and north of the Foothills (Fig. 4.10a). This species was recorded on 1,583 cells during the aerial surveys. Results were similar to the ground surveys, though the patterns were much easier to discern (Fig. 4.11a). Few birds were recorded east of Prudhoe Bay. The aerial surveys suggest a band of high density extending west and a little north from Prudhoe Bay.

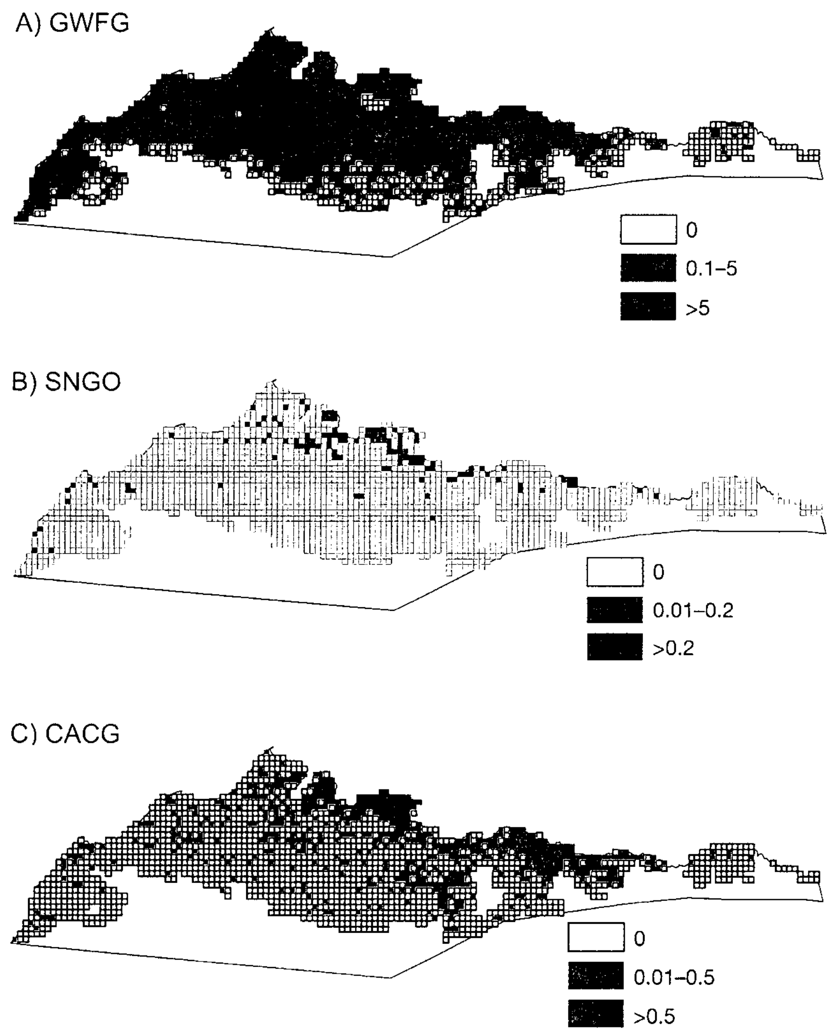

Figure 4.11. Densities (birds/km^2) of Greater White-fronted Geese (a), Snow Geese (b), and Cackling Geese (c) recorded on the aerial surveys.

On ground surveys, most records were of single birds in wetlands (Table 4.9). About one-third of the birds were in moist areas, and only about 1% were in uplands. The estimated number of pairs breeding on surveyed plots was 347.

Density estimates from the ground surveys were approximately 8, 3, and 3 birds/km^2 in wetlands, moist areas, and uplands, respectively, with an overall density of 4.1. The uncorrected estimate of population size was about 300,000 with a moderate CV of 0.29 (Table 4.9). Nesting birds of this species often leave a survey plot when the surveyor is still far away and it is difficult to know whether departing birds were on the survey plot. Incubating birds usually do not flush unless the surveyor comes within 10–20 m. For both reasons, it seems likely that the detection ratio achieved on ground surveys was less than 1, which would suggest the population was probably even larger than the estimate based on the ground surveys.

The range and habitat relationships as described in the BNA are consistent with our results (Ely and Dzubin 1994).

Snow Goose

Aerial surveys recorded Snow Geese in 124 cells (Fig. 4.11b). During ground surveys, Snow Geese were encountered on ten plots and were judged to be breeding on three plots. Flocks of non-breeders were observed on four plots. Most records were close to the coast between just east of the Colville Delta and Dease Inlet. Other records were widely scattered.

Detection ratios for this species are probably close to 1.0. The estimated population size was 485 (0.70). This estimate, however, does not include birds judged to be non-breeders.

The BNA range map has a dashed line along the southern border of our study site (Mowbray

TABLE 4.9

Number of waterfowl, waterbirds, and landbirds recorded on rapid surveys, estimated densities, and population size (with SEs).

Refer to Appendix C for common and scientific names of species 4-letter codes.

Species	Region	Total recorded	Est. *n* pairs	Birds/km² (SE)				Population size	
				Wetlands	Moist areas	Uplands	All habitats	Estimate (SE)	CV
GWFG	ACP-NPRA	636	326	11.07 (1.69)	3.68 (1.18)	6.87 (5.14)	6.61 (2.11)	228,112 (72,914)	0.32
	ACP-Central	190	10	4.18 (2.08)	2.7 (1.37)	0 (0)	3.27 (1.14)	35,362 (12,301)	0.35
	ACP-ANWR	140	9	1.42 (0.70)	0.91 (0.63)	0 (0)	0.70 (0.31)	3,344 (1,485)	0.44
	Foothills	2	0	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	1.02
	Colville River	2	2	0 (0)	0 (0)	1.12 (0.99)	0.63 (0.51)	13 (10)	0.81
	All	970	347	8.19 (0.64)	3.03 (1.12)	3.19 (3.14)	4.13 (1.2)	303,028 (87,860)	0.29
CACG	ACP-NPRA	97	26	0.10 (0.06)	0.32 (0.32)	0 (0)	0.14 (0.12)	4,945 (4,127)	0.83
	ACP-Central	14	3	1.31 (0.99)	0.45 (0.45)	0 (0)	0.81 (0.46)	8,791 (5,014)	0.57
	ACP-ANWR	39	21	2.00 (0.76)	1.65 (0.89)	0 (0)	1.13 (0.42)	5,439 (2,019)	0.37
	Foothills	2	0	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	1.00
	Colville River	8	8	0 (0)	0 (0)	5.45 (5.72)	3.04 (2.95)	61 (59)	0.97
	All	160	58	0.59 (0.14)	0.43 (0.15)	0.02 (0.23)	0.27 (0.09)	19,539 (6,937)	0.36
TUSW	ACP-NPRA	71	21	0.20 (0.12)	0.01 (0.01)	0 (0)	0.05 (0.03)	1,750 (943)	0.54
	ACP-Central	3	1	0 (0)	0.45 (0.45)	0 (0)	0.23 (0.24)	2,542 (2,592)	1.02
	ACP-ANWR	12	1	0 (0)	0.19 (0.18)	0 (0)	0.08 (0.08)	366 (374)	1.02
	Foothills	0	0	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0.28
	Colville River	0	0	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0
	All	86	23	0.12 (0.04)	0.12 (0.05)	0 (0)	0.06 (0.04)	4,483 (2,616)	0.58
NOPI	ACP-NPRA	442	224	10.41 (2.17)	4.87 (1.21)	3.89 (2.05)	5.71 (1.10)	196,961 (38,044)	0.19
	ACP-Central	24	12	13.02 (11.45)	1.40 (1.08)	0 (0)	6.49 (5.17)	70,307 (55,973)	0.80

TABLE 4.9 *(continued)*

TABLE 4.9 (CONTINUED)

Species	Region	Total recorded	Est. n pairs	Birds/km^2 (SE)				Population size	
				Wetlands	Moist areas	Uplands	All habitats	Estimate (SE)	CV
	ACP-ANWR	147	51	2.67 (2.07)	3.37 (1.91)	4.92 (1.79)	3.77 (1.17)	18,071 (5,619)	0.31
	Foothills	3	0	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0.16
	Colville River	10	14	0 (0)	0 (0)	11.69 (4.49)	6.53 (1.99)	131 (40)	0.31
	All	626	301	10.67 (1.51)	3.71 (0.94)	2.07 (1.93)	4.30 (0.93)	315,559 (68,429)	0.22
GRSC	ACP-NPRA	67	37	1.75 (1.03)	1.17 (0.65)	0 (0)	0.83 (0.40)	28,692 (13,892)	0.48
	ACP-Central	5	2	0 (0)	0.62 (0.44)	0 (0)	0.33 (0.23)	3,547 (2,510)	0.71
	ACP-ANWR	9	5	0.31 (0.23)	0.07 (0.07)	1.42 (1.37)	0.61 (0.51)	2,930 (2,422)	0.83
	Foothills	0	0	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	1.02
	Colville River	3	4	0 (0)	0 (0)	4.36 (1.85)	2.44 (1.05)	49 (21)	0.43
	All	84	48	1.13 (0.32)	0.90 (0.26)	0.08 (0.44)	0.55 (0.23)	40,534 (16,844)	0.42
SPEI	ACP-NPRA	27	21	0.80 (0.49)	0.01 (0.01)	0 (0)	0.18 (0.11)	6,369 (3,802)	0.6
	ACP-Central	1	1	1.85 (1.87)	0 (0)	0 (0)	0.82 (0.82)	8,868 (8,891)	1
	ACP-ANWR	0	0	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0
	Foothills	0	0	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0.28
	Colville River	0	0	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0
	All	28	22	1.06 (0.13)	0.01 (0.15)	0 (0)	0.21 (0.13)	15,584 (9,333)	0.60
LTDU	ACP-NPRA	195	131	4.77 (1.27)	3.93 (1.17)	1.07 (1.15)	2.97 (0.72)	102,345 (24,791)	0.24
	ACP-Central	20	14	16.78 (7.52)	1.03 (1.02)	0 (0)	7.96 (3.42)	86,173 (36,983)	0.43
	ACP-ANWR	61	30	4.09 (1.33)	0.75 (0.52)	1.42 (1.37)	1.76 (0.60)	8,415 (2,897)	0.34
	Foothills	1	0	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0.16
	Colville River	6	7	0 (0)	0 (0)	8.13 (4.17)	4.54 (2.23)	91 (45)	0.49
	All	283	182	8.35 (0.84)	2.82 (0.79)	0.59 (2.52)	2.85 (0.62)	208,928 (45,327)	0.22

ROPT	ACP-NPRA	41	34	1.81 (0.53)	3.56 (1.09)	0 (0)	1.73 (0.44)	59,828 (15,259)	0.26
	ACP-Central	4	3	0.52 (0.50)	1.28 (0.97)	0 (0)	0.90 (0.56)	9,727 (6,032)	0.62
	ACP-ANWR	19	14	0.55 (0.31)	1.59 (0.74)	1.92 (1.73)	1.47 (0.70)	7,050 (3,346)	0.47
	Foothills	9	9	1.3 (1.97)	1.78 (1.59)	1.7 (1.64)	1.89 (1.57)	44,032 (36,527)	0.83
	Colville River	1	1	0 (0)	0 (0)	1.38 (1.34)	0.77 (0.76)	15 (15)	0.98
	All	74	61	1.35 (0.46)	2.96 (0.44)	0.90 (1.44)	1.66 (0.46)	121,592 (34,046)	0.28
WIPT	ACP-NPRA	329	303	9.27 (1.88)	20.11 (2.92)	18.69 (6.64)	17.01 (2.96)	586,801 (102,249)	0.17
	ACP-Central	16	11	2.13 (1.53)	3.81 (1.36)	48.31 (0)	4.51 (0.96)	48,771 (10,356)	0.21
	ACP-ANWR	30	22	0.67 (0.41)	1.22 (0.53)	7.01 (2.92)	3.18 (1.13)	15,224 (5,428)	0.36
	Foothills	10	11	0 (0)	0 (0)	7.46 (3.80)	7.03 (3.59)	163,472 (83,458)	0.51
	Colville River	30	30	0 (0)	0 (0)	18.77 (5.45)	10.48 (2.82)	210 (56)	0.27
	All	415	377	6.51 (2.41)	13.9 (1.82)	13.07 (3.35)	12.04 (1.90)	883,500 (139,683)	0.16
PALO	ACP-NPRA	102	67	1.79 (0.62)	0.96 (0.60)	0 (0)	0.76 (0.26)	26,341 (9,128)	0.35
	ACP-Central	7	0	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0
	ACP-ANWR	28	16	2.27 (0.89)	0.15 (0.15)	0.35 (0.36)	0.70 (0.28)	3,372 (1,319)	0.39
	Foothills	0	0	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0.97
	Colville River	5	5	0 (0)	0 (0)	3.52 (3.81)	1.97 (1.96)	39 (39)	1.00
	All	142	88	1.27 (0.15)	0.63 (0.29)	0.03 (0.32)	0.47 (0.15)	34,426 (10,932)	0.32
GLGU	ACP-NPRA	102	67	1.79 (0.62)	0.96 (0.60)	0 (0)	0.76 (0.26)	26,341 (9,128)	0.35
	ACP-Central	7	0	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0
	ACP-ANWR	28	16	2.27 (0.89)	0.15 (0.15)	0.35 (0.36)	0.70 (0.28)	3,372 (1,319)	0.39
	Foothills	0	0	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0.97
	Colville River	5	5	0 (0)	0 (0)	3.52 (3.81)	1.97 (1.96)	39 (39)	1.00
	All	142	88	1.27 (0.15)	0.63 (0.29)	0.03 (0.32)	0.47 (0.15)	34,426 (10,932)	0.32

TABLE 4.9 *(continued)*

TABLE 4.9 (CONTINUED)

Species	Region	Total recorded	Est. *n* pairs	Birds/km² (SE)				Population size	
				Wetlands	Moist areas	Uplands	All habitats	Estimate (SE)	CV
SAGU	ACP-NPRA	20	18	1.38 (0.53)	0.88 (0.67)	0 (0)	0.64 (0.28)	21,978 (9,559)	0.43
	ACP-Central	0	0	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0
	ACP-ANWR	17	9	0.27 (0.27)	0.29 (0.29)	0 (0)	0.18 (0.14)	870 (654)	0.75
	Foothills	0	0	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0.83
	Colville River	0	0	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0
	All	37	27	0.89 (0.14)	0.59 (0.27)	0 (0)	0.37 (0.15)	26,949 (11,349)	0.42
ARTE	ACP-NPRA	112	76	4.59 (1.85)	3.00 (1.95)	0 (0)	2.15 (0.83)	74,275 (28,733)	0.39
	ACP-Central	13	1	1.49 (1.44)	0 (0)	0 (0)	0.66 (0.65)	7,122 (7,009)	0.98
	ACP-ANWR	59	9	0.77 (0.42)	0.18 (0.18)	0 (0)	0.25 (0.12)	1,202 (588)	0.49
	Foothills	0	0	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0
	Colville River	0	0	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0
	All	184	86	3.40 (0.48)	1.95 (0.85)	0 (0)	1.30 (0.47)	95,594 (34,824)	0.36
PAJA	ACP-NPRA	46	27	1.14 (0.55)	0.90 (0.66)	0 (0)	0.59 (0.28)	20,344 (9,612)	0.47
	ACP-Central	20	7	2.44 (1.26)	1.19 (0.66)	0 (0)	1.70 (0.61)	18,413 (6,613)	0.36
	ACP-ANWR	61	9	0.58 (0.27)	1.07 (0.57)	0 (0)	0.57 (0.25)	2,737 (1,194)	0.44
	Foothills	3	1	0 (0)	0.97 (0.92)	0 (0)	0.15 (0.15)	3,538 (3,447)	0.97
	Colville River	0	0	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0
	All	130	44	1.49 (0.22)	1.06 (0.28)	0 (0)	0.64 (0.18)	46,761 (13,379)	0.29
LTJA	ACP-NPRA	44	22	0.43 (0.32)	1.12 (0.71)	1.4 (1.40)	1.07 (0.62)	36,830 (21,242)	0.58
	ACP-Central	11	3	0.99 (1.00)	1.57 (1.10)	0 (0)	1.26 (0.73)	13,636 (7,905)	0.58
	ACP-ANWR	40	6	0 (0)	0.79 (0.48)	0.58 (0.42)	0.53 (0.25)	2561 (1,209)	0.47
	Foothills	2	0	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0.16

	Colville River	0	0	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0
	All	97	31	0.56 (0.51)	1.13 (0.37)	0.68 (0.77)	0.80 (0.36)	58,673 (26,377)	0.45
YEWA	ACP-NPRA	51	48	1.47 (0.60)	2.62 (1.27)	2.12 (1.53)	2.15 (0.78)	74,104 (26,935)	0.36
	ACP-Central	8	3	0 (0)	1.45 (1.07)	48.31 (0.00)	2.32 (0.57)	25,153 (6,146)	0.24
	ACP-ANWR	18	12	0.11 (0.12)	1.39 (0.88)	3.83 (2.53)	1.98 (1.02)	9,473 (4,873)	0.51
	Foothills	5	4	7.39 (3.57)	1.70 (1.59)	0 (0)	0.34 (0.27)	7,988 (6,177)	0.77
	Colville River	16	16	0 (0)	0 (0)	14.99 (6.66)	8.37 (3.31)	167 (66)	0.40
	All	98	83	1.05 (0.67)	2.36 (0.67)	1.65 (0.75)	1.76 (0.45)	129,399 (33,330)	0.26
SAVS	ACP-NPRA	285	258	3.73 (1.08)	7.28 (1.78)	27.55 (7.72)	14.55 (3.37)	501,727 (116,155)	0.23
	ACP-Central	6	3	0 (0)	2.08 (1.37)	48.31 (0)	2.65 (0.72)	28,737 (7,827)	0.27
	ACP-ANWR	49	45	1.39 (0.84)	5.54 (2.13)	11.95 (3.98)	6.90 (1.75)	33,073 (8,404)	0.25
	Foothills	43	41	23.48 (8.74)	4.16 (1.88)	14.8 (4.32)	14.80 (4.09)	344,276 (95,204)	0.28
	Colville River	28	28	0 (0)	0 (0)	16.05 (3.14)	8.96 (2.24)	179 (45)	0.25
	All	411	375	2.68 (3.34)	6.16 (2.52)	20.90 (2.52)	12.52 (2.15)	919,060 (157,607)	0.17
LALO	ACP-NPRA	450	405	11.88 (4.62)	15.62 (5.20)	6.64 (2.31)	11.24 (2.53)	387,694 (87,123)	0.22
	ACP-Central	62	56	23.27 (8.26)	17.13 (5.62)	0 (0)	19.29 (4.50)	208,860 (48,769)	0.23
	ACP-ANWR	538	484	57.52 (17.62)	47.37 (5.13)	43.07 (9.49)	48.14 (5.60)	230,734 (26,848)	0.12
	Foothills	38	44	14.79 (7.14)	8.52 (2.67)	9.89 (1.72)	10.72 (1.68)	249,322 (39,173)	0.16
	Colville River	1	1	0 (0)	0 (0)	0.93 (0.87)	0.52 (0.50)	10 (10)	0.96
	All	1,089	990	18 (2.91)	18.67 (2.74)	9.75 (2.04)	14.27 (1.53)	1,047,043 (112,027)	0.11

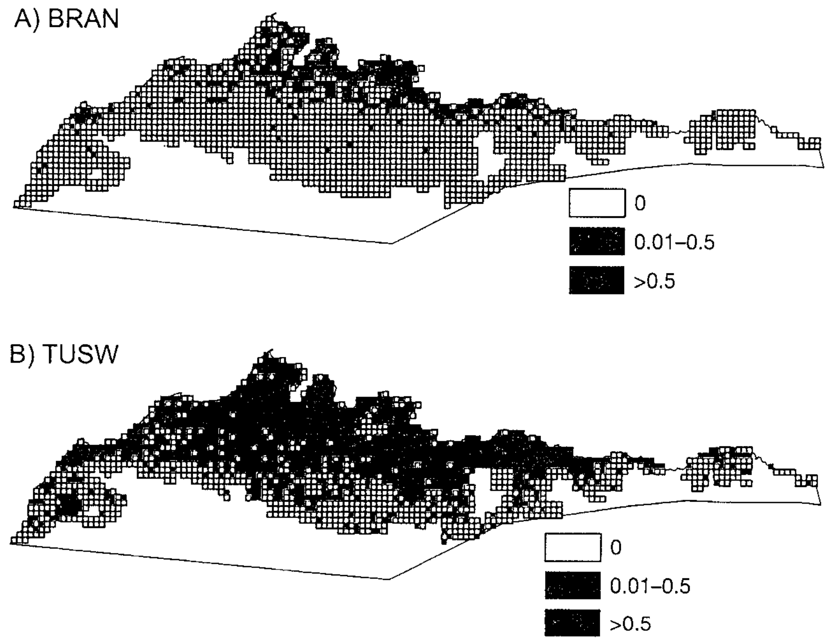

Figure 4.12. Density (birds/km^2) of Brant (a) and Tundra Swans (b) recorded on the aerial surveys.

et al. 2000). Results from the aerial surveys suggest that most of this area should be included in the range.

Cackling Goose

For this description, we assume all small geese resembling the Canada Goose were the Cackling Goose, though a few may have been *Branta hutchinsii hutchinsii* or *B. canadensis parvipes* (Mlodinow et al. 2008). During aerial surveys, Cackling Geese were recorded in 578 cells (Fig. 4.11c). They were particularly dense along the coast from Prudhoe Bay to Barrow, but they were also recorded widely across the ACP. They were uncommon in the Arctic NWR.

During ground surveys, Cackling Geese were encountered on 55 plots and were judged to be breeding on 32 plots. Most records were of single birds on wetlands. The species was rarely recorded in uplands (Table 4.9). The estimated number of pairs breeding on surveyed plots was 58.

Estimated densities from the rapid surveys were similar in wetlands and moist areas and much lower on uplands (Table 4.9). It seems likely that detection ratios were less than 1.0. The uncorrected, estimated population size was about 20,000 with a medium CV of 0.36.

The range map in the BNA for this species is consistent with our results (Mowbray et al. 2002).

Brant

During ground surveys, Brant were encountered on 22 plots and were judged to be breeding on 15 plots. All of the records were within several kilometers of the coast. Although 55 indicated pairs were recorded, 36 were on just two plots. The ground surveys thus provided relatively little information about this species' distribution. In contrast, during the aerial surveys Brant were recorded in 368 cells (Fig. 4.12a). Most records were between Prudhoe Bay and Barrow and within 50 km of the coast. Density was highest right along the coast.

The range map in the BNA is consistent with our results, except that we found them farther south than depicted in the BNA map, especially in the central NPRA (Reed et al. 1998).

Tundra Swan

During aerial surveys, Tundra Swans were recorded in 1,183 cells (Fig. 4.12b). Records occurred widely across the study area, though they were much less common in the Arctic NWR and near the southern edge of the coastal plain.

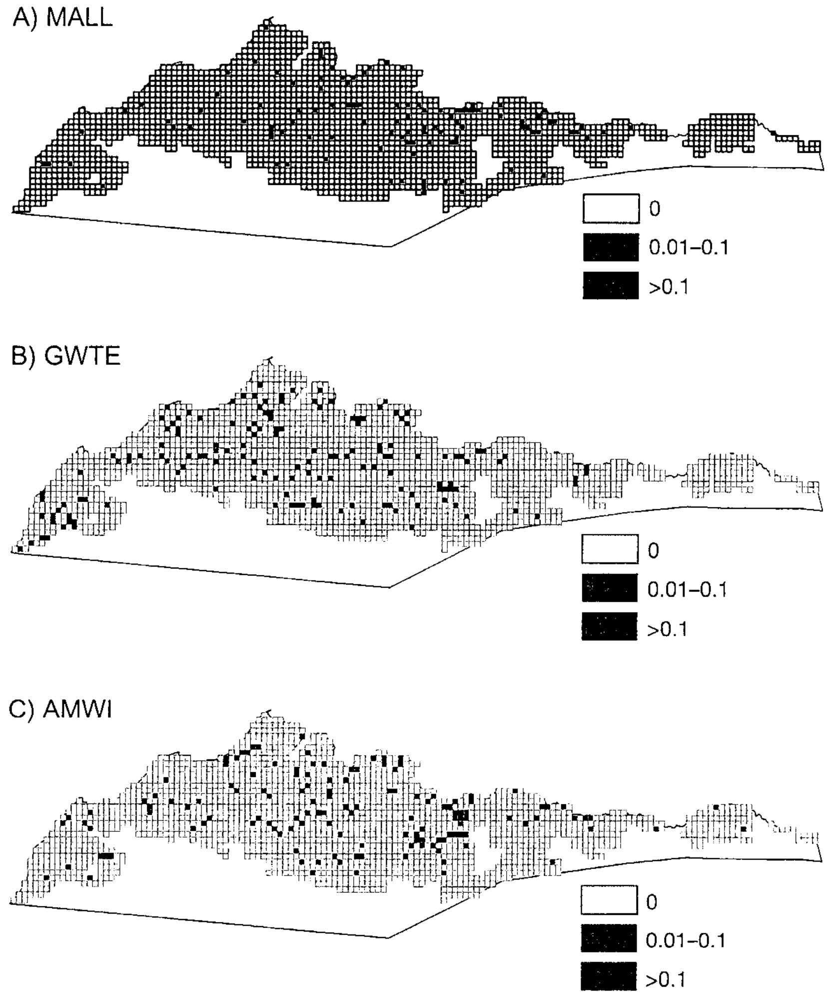

Figure 4.13. Densities (birds/km^2) of Mallards (a), Green-winged Teal (b), and American Wigeon (c) recorded on the aerial surveys.

On ground surveys, Tundra Swans were encountered on 45 plots and were judged to be breeding on 21 plots. Too few records were obtained for meaningful comparisons with the aerial survey data.

We suspect detection ratios for swans were close to 1.0. The uncorrected population estimate was 4,483 (Table 4.9). This estimate did not include non-breeding flocks, which are common on the North Slope.

The range map in the BNA is consistent with our results, except that we found them farther south than depicted in the BNA in the central NPRA (Limpert and Earnst 1994).

Mallard

During aerial surveys, Mallards were recorded in 107 cells (Fig. 4.13a). Records were widely distributed across the study area west of Prudhoe Bay. Density was perhaps slightly higher well south of the coast.

During ground surveys, Mallards were encountered on 11 plots and were judged to be breeding on eight plots. Only nine pairs were judged to be breeding.

The range map in the BNA for this species shows our entire study area as being within the range (Drilling et al. 2002). This seems reasonable, despite the low density with less than 1,500 pairs even if detection ratios are only 10%.

Green-winged Teal

During aerial surveys, Green-winged Teal were recorded in 149 cells (Fig. 4.13b). The records were almost entirely from west of the Colville River. Density was highest in the southern part of the coastal plain.

During ground surveys, Green-winged Teal were encountered on nine plots in the NPRA and were judged to be breeding on all of them. Most sightings were of pairs or single birds in wetlands. The estimated number of birds breeding in surveyed plots was 12.

The region- or habitat-specific SEs were too large to make useful comparisons between regions or habitats. The estimated population size was 5,950 with a large CV of 0.73. Results indicate that population size was probably less than 15,000.

The BNA range map is consistent with our results, except that we found them in the western part of the ACP-NPRA region, whereas the BNA map does not include this area (Johnson 1995).

American Wigeon

During aerial surveys, American Wigeon were encountered on 135 cells (Fig. 4.13c). Nearly all records were obtained from west of the Colville River. Records were widely distributed across the ACP-NPRA region, but density appeared to be slightly higher in the southern part of the coastal plain.

During ground surveys, American Wigeon were encountered on six plots and were judged to be breeding on all of them. All records were in the ACP-NPRA region. The estimated number of pairs breeding on surveyed plots was seven. The estimated population size was 407 with a large CV of 0.71.

The BNA range map does not include any of our study area (Mowbray 1999). The number of records for this species on aerial surveys was similar to results for Mallard and Green-winged Teal, both of which are depicted in the BNA as occurring across most or all of the North Slope. It may therefore be more appropriate that the range map for American Wigeon include all of our study area, or at least the ACP-NPRA region portion.

Northern Pintail

During aerial surveys, Northern Pintails were recorded in 1,613 cells (Fig. 4.14a). Records were obtained from throughout the study area including the Arctic NWR. Density appeared to be highest west of the Colville River and in the northern portion of the ACP.

During ground surveys, Northern Pintails were encountered on 219 plots and were judged to be breeding on 139 plots (Fig. 4.10b). Results were similar to results on the aerial survey. Records were widely distributed across the study area, including in the Arctic NWR (Table 4.9). Ground surveys revealed only a few birds in the Foothills, but 14 indicated pairs were recorded in the Colville River region. The estimated number of breeding birds was often much less than the observed number because non-breeding birds, often in flocks, were common. The estimated number of pairs breeding on surveyed plots was 301 (Table 4.9).

Data from the ground surveys suggested that densities were highest in wetlands but were substantial even in uplands (Table 4.9). Variation in density between ACP regions appeared to be small. The uncorrected estimate of population size was about 315,000 with a moderate CV of 0.22 (Table 4.9). We suspect the detection ratio was less than 1.0. The estimated population size excludes birds judged to be non-breeders.

The BNA range map includes all of our study area, which is consistent with our results (Austin and Miller 1995).

Northern Shoveler

During aerial surveys, Northern Shovelers were recorded in 96 cells (Fig. 4.14b). Records occurred almost exclusively west of the Colville River and were widely distributed across the NPRA.

Northern Shovelers were encountered on 15 plots and were judged to be breeding on 13 plots. They were observed almost exclusively on the Colville Delta, though a probable nest was recorded in the Arctic NWR and two pairs were recorded on one plot in the western part of the study area. They were recorded mainly as pairs or single birds in wetlands. The estimated number of pairs breeding on the surveyed plots was 22. The uncorrected estimate of population size was 1,110 with a large CV of 0.42.

The BNA range map excludes most of the NPRA, whereas we found this species sparsely distributed throughout the NPRA (Dubowy 1996).

Canvasback

Canvasbacks were not recorded on the ground surveys and were seen in only three cells, widely distributed across the study area, on the aerial survey. The BNA range map, which excludes the North Slope, is thus consistent with our results (Mowbray 2002).

Redhead

Four pairs of Redheads were encountered on one plot west of Fish Creek but were judged to

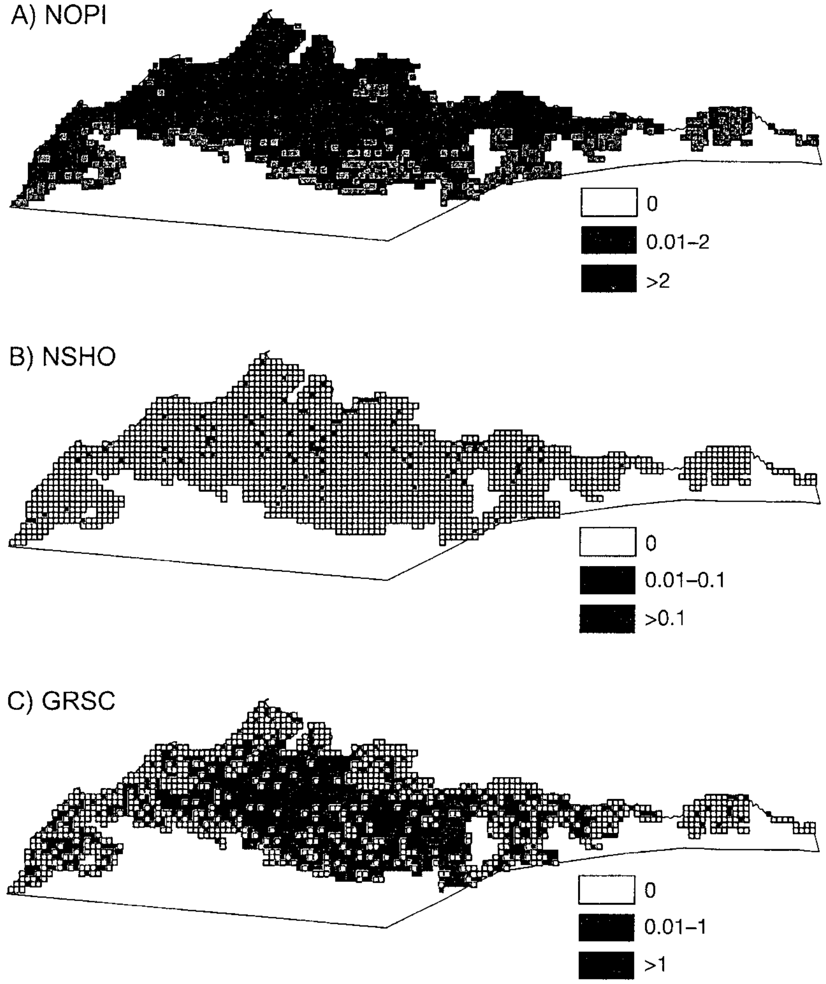

Figure 4.14. Densities (birds/km^2) of Northern Pintails (a), Northern Shovelers (b), and Greater Scaup (c) recorded on the aerial surveys.

be breeding off the plot. They were not recorded on the aerial survey. The BNA range map, which excludes the North Slope, is thus consistent with our results (Woodin and Michot 2002).

Greater Scaup

During the aerial surveys, Greater Scaup were recorded in 1,090 cells (Fig. 4.14c). Records were obtained from throughout the study area but were less common east of Prudhoe Bay and more common at the southern edge of the coastal plain in the eastern half of the NPRA.

During ground surveys, Greater Scaup were encountered on 46 plots and were judged to be breeding on 35 plots. Results were similar to the aerial survey, with birds being recorded widely across the study area, including in the Arctic NWR (Table 4.9). No birds were recorded in the Foothills. Most records were of pairs in wetlands or moist areas. Nearly half the detections were considered to be birds not breeding on the plot. The estimated number of pairs breeding on the surveyed plots was 48.

The uncorrected, estimated population size was about 40,000 with a large CV of 0.42 (Table 4.9). We suspect the detection ratio was below 1.0, though perhaps not far below it given the large sample size.

The BNA range map portrays the study area as being occupied by "isolated nest site(s) or small, isolated breeding populations(s) of uncertain persistence" (Kessel et al. 2002). Our results suggest the entire study area should be considered within the species' range.

Common Eider

None of the surveys reported in this chapter covered the primary breeding grounds for this

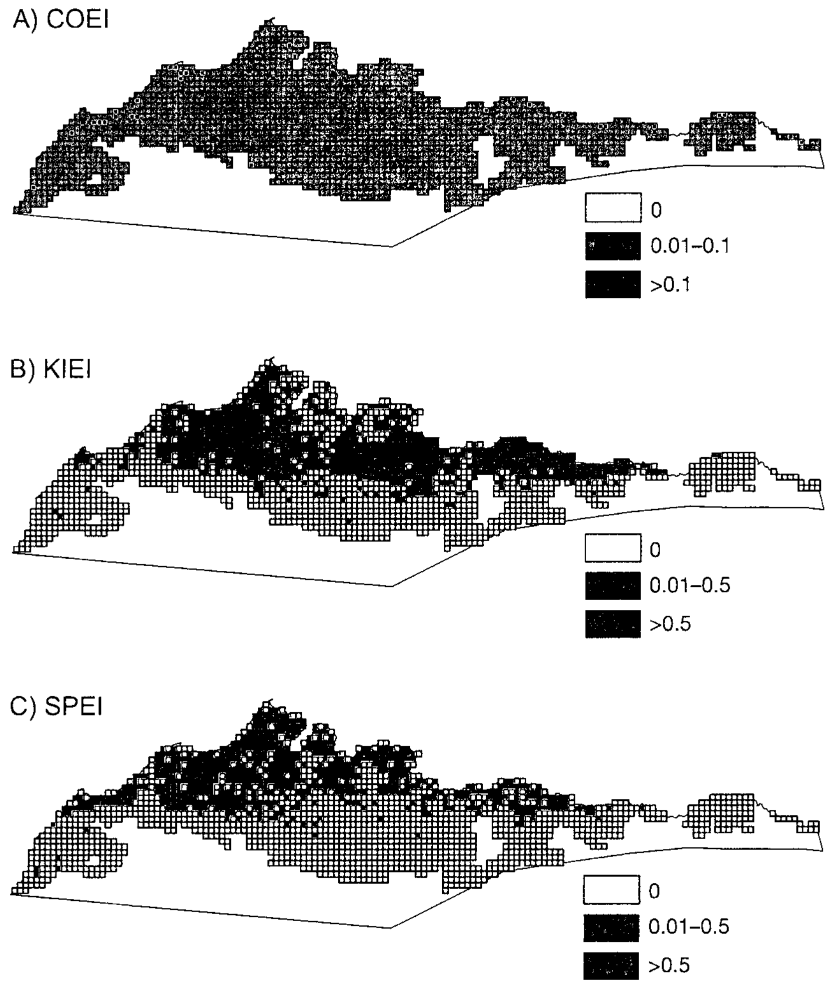

Figure 4.15. Densities (birds/km^2) of Common Eiders (a), King Eiders (b), and Spectacled Eiders (c) recorded on the aerial surveys.

species (offshore islands, covered by a separate USFWS survey). During aerial surveys, Common Eiders were recorded in 57 cells (Fig. 4.15a). They were observed along the entire coast including in the Arctic NWR but appeared to be most common southwest of Wainwright. A few records were obtained from inland areas. Only one Common Eider was observed during ground surveys.

The BNA range map shows the species occurring in a narrow band along the entire coast in our study area (Goudie et al. 2000). This is probably the only way to depict its range, but it should be realized that all or nearly all nests are on the barrier islands, not on the mainland.

King Eider

During aerial surveys, King Eiders were recorded in 853 cells (Fig. 4.15b). Nearly all records came from west of Prudhoe Bay. Density was highest in a band extending west from Prudhoe Bay into the NPRA. Few birds were seen in the southern third of the coastal plain.

During ground surveys, King Eiders were encountered on 37 plots and were judged to be breeding on 22 plots. The pattern was similar, with nearly all records being in the band of high density evident from the aerial surveys. Most records were of pairs in wetlands. The estimated number of pairs breeding on surveyed plots was 40 (Table 4.9).

Males were present for most of the survey period, so detection ratios were probably quite high. The uncorrected, estimated population size was 38,531 with a moderate CV of 0.42 (Table 4.9).

The range map in the BNA is consistent with our results, except that we found the species

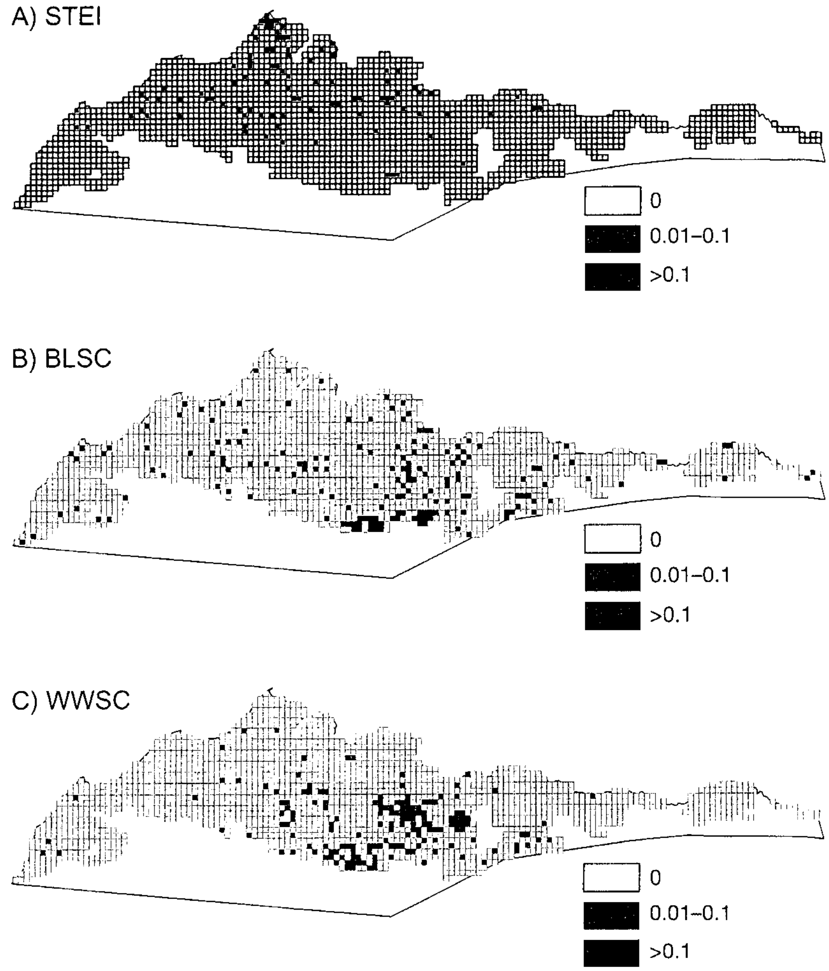

Figure 4.16. Densities (birds/km^2) of Steller's Eiders (a), Black Scoters (b), and White-winged Scoters (c) recorded on the aerial surveys.

farther south in the NPRA than indicated on the BNA range map (Suydam 2000).

Spectacled Eider

During aerial surveys, Spectacled Eiders were recorded in 629 cells (Fig. 4.15c). Records occurred almost exclusively west of Prudhoe Bay and were most common in the northwestern quarter of the NPRA. Almost no birds were recorded in the southern portion of the coastal plain.

During ground surveys, Spectacled Eiders were encountered on 20 plots and were judged to be breeding on 15 plots. Most of the indicated breeding birds were on the Colville Delta (Table 4.9).

Males were present during most of the surveys, so we suspect the detection ratio was close to 1.0. The uncorrected population estimate was 15,584 birds but the CV (0.60) was so large that this estimate is of little value (Table 4.9). Furthermore, more than half the estimate is due to a single bird observed in the ACP-Central region. If this bird had not been seen, the estimate would have been 6,369. This species provides a good example of why measures of precision should not be ignored.

The range map in the BNA corresponds closely to our results, except that we found it farther south in the NPRA than depicted on the BNA map (Petersen et al. 2000).

Steller's Eider

During aerial surveys, Steller's Eiders were recorded in 97 cells (Fig. 4.16a). Records occurred almost exclusively in the NPRA. They were widely distributed across the coastal plain. This species was not recorded on ground surveys.

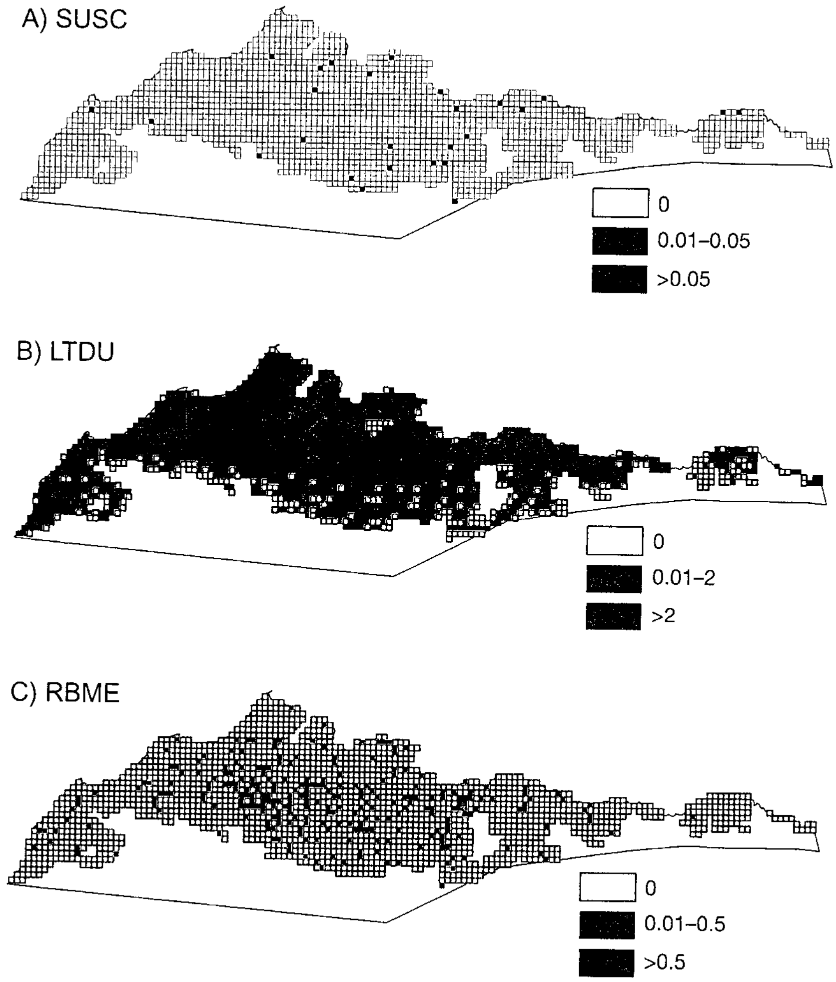

Figure 4.17. Densities (birds/km^2) of Surf Scoters (a), Long-tailed Ducks (b), and Red-breasted Mergansers (c) recorded on the aerial surveys.

The BNA range map is consistent with our results (Frederickson 2001).

Black Scoter

During aerial surveys, Black Scoters were recorded in 171 cells (Fig. 4.16b). They were recorded throughout the study area but were uncommon east of Prudhoe Bay. They were most common in the southern part of the coastal plain.

The BNA range map classifies the entire study area as "breeding probable" (Bordage and Savard 1995). We found the species throughout the study area, especially in the southern half of the NPRA and ACP-Central region, but we do not have evidence for or against breeding.

White-winged Scoter

During aerial surveys, White-winged Scoters were recorded in 158 cells (Fig. 4.16c). Most records were from the southern part of the coastal plain in a broad band along the Colville River. During ground surveys, White-winged Scoters were encountered on only four plots.

The BNA range map includes only the ACP-Arctic NWR region in our study area (Brown and Frederickson 1997). In contrast, we did not record in that region but did find it commonly in the south-central part of the study area and occasionally elsewhere in the western two-thirds of the study area.

Surf Scoter

During aerial surveys, Surf Scoters were recorded in 28 cells (Fig. 4.17a). Most records were from the eastern half of the NPRA, though a few came from the western NPRA and the Arctic NWR. The species was not recorded on the ground surveys.

The BNA stated that breeding on the North Slope was not confirmed except for one nest close to the Colville River (Savard et al. 1998). We found the species widely, but sparsely distributed across the entire study area (though we did not confirm breeding). Density may have been slightly higher in the south-central region, similar to the White-winged Scoter.

Long-tailed Duck

During aerial surveys, Long-tailed Ducks were recorded in 1,689 cells (Fig. 4.17b). They occurred throughout the study area. They were less common in the Arctic NWR and perhaps more common in the southern part of the coastal plain.

During ground surveys, Long-tailed Ducks were encountered on 156 plots and were judged to be breeding on 106 plots. Results were similar to results from the aerial surveys. The species was not recorded breeding in the Foothills (Table 4.9). Most records were pairs or single birds on wetlands. The estimated number of birds breeding in surveyed plots was 182 (Table 4.9).

Long-tailed Ducks were conspicuous for most of the survey period, so we suspect that detection ratios were close to 1.0. Densities were much higher on wetlands, but some birds were encountered in uplands (Table 4.9). The overall density was nearly 3 birds/km^2. The uncorrected, estimated population size was about 200,000 (Table 4.9).

The BNA range map includes the entire study area, which is consistent with our results (Robertson and Savard 2002).

Common Goldeneye

During aerial surveys, Common Goldeneyes were recorded in 11 cells, mainly in the central NPRA. They were not recorded on ground surveys. The range map in the BNA excludes our study area, which is consistent with our results (Eadie et al. 1995).

Red-breasted Merganser

During aerial surveys, Red-breasted Mergansers were recorded in 262 cells (Fig. 4.17c). Nearly all records were in the NPRA. Density appeared to be somewhat higher in the southern part of the coastal plain. Red-breasted Mergansers were encountered on only 11 plots and were judged to be breeding on six plots.

The BNA range map includes the entire study area, which is consistent with our results except perhaps in the Arctic NWR (Titman 1999).

Rock Ptarmigan

Rock Ptarmigan and Willow Ptarmigan were neither consistently recorded nor distinguished during the aerial surveys. On ground surveys, Rock Ptarmigan were encountered on 62 plots and were judged to be breeding on 53 plots (Fig. 4.18a). Nearly all records were from the ACP regions (Table 4.9). Most detections were of single birds. Female ptarmigan rarely flush (surveyors occasionally stepped on incubating birds), so nests, probable nests, and pairs were rarely encountered. The species occurred in all habitats. The estimated number of pairs breeding on surveyed plots was 61 (Table 4.9).

Male Rock Ptarmigan kept their winter plumage throughout the survey period and were nearly always conspicuous. We therefore suspect the detection ratio during ground surveys was close to 1.0. On this assumption, it appears that density is approximately the same across habitats and regions (1–3 birds/km^2) and that the population size is probably around 100,000–150,000 birds (Table 4.9).

The BNA range map includes the entire study area, which is consistent with our results (Montgomerie and Holder 2008).

Willow Ptarmigan

During ground surveys, Willow Ptarmigan were recorded on 211 plots and were judged to be breeding on 193 plots (Fig. 4.18b). Most records were single birds in wetlands or moist areas, but many records were also obtained in uplands. The estimated number of pairs breeding on surveyed plots was 377 (Table 4.9).

Male Willow Ptarmigan retained their winter plumage throughout the survey period and were conspicuous on their territories. We therefore suspect that detection ratios were close to 1.0. The estimated density across all habitats was 12 birds/km^2, making it one of the most abundant species (Table 4.9). Density was higher in moist areas and uplands than in wetlands. Population size was estimated at nearly 900,000 birds with a low CV of 0.16.

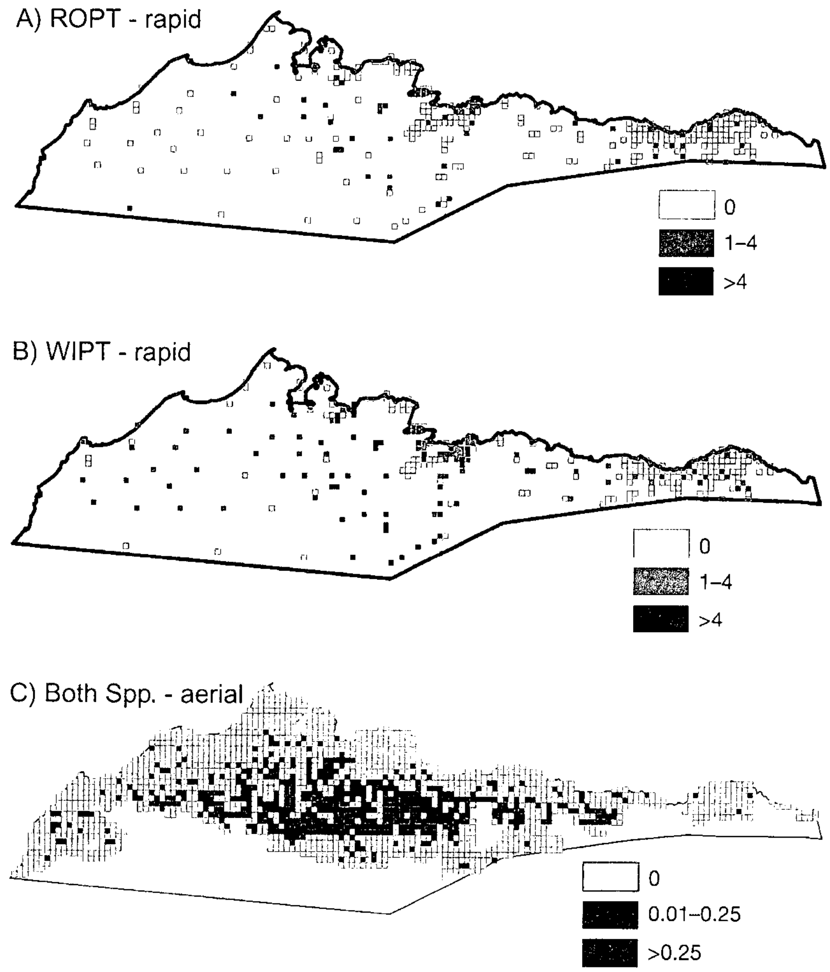

Figure 4.18. Densities (birds/km²) of Rock Ptarmigan (a) and Willow Ptarmigan (b) recorded on the rapid surveys, and of both species recorded on the aerial surveys (c).

Although ptarmigan were not generally classified to species or recorded consistently on the aerial surveys, records of ptarmigan were obtained from 520 cells (Fig. 4.18c). Most records were from west of Prudhoe Bay. They were uncommon or absent in the northern part of the NPRA and appeared to be less common at the southern edge of the coastal plain.

The BNA range map includes the entire study area, which is consistent with our results (Hannon et al. 1998).

Red-throated Loon

During aerial surveys, Red-throated Loons were recorded in 850 cells (Fig. 4.19a). Sightings were distributed fairly evenly across the study area, except that they were less common in the Arctic NWR and along the southern edge of the coastal plain.

During ground surveys, Red-throated Loons were encountered on 35 plots and were judged to be breeding on 21 plots. Most records were from the Colville Delta or immediately west of there along the coast, though a few records were from the Arctic NWR. The estimated number of pairs breeding on surveyed plots was 24. Because most of our records came from the Colville Delta, and yet the species obviously occurred widely across the study area, we did not estimate densities from the ground surveys.

The BNA range map includes our entire study area, which is consistent with our results (Barr et al. 2000).

Pacific Loon

During aerial surveys, Pacific Loons were recorded in 1,575 cells (Fig. 4.19b). Sightings came from throughout the surveyed area but were least common in the Arctic NWR and may have been slightly more common in the west-central portion of the NPRA.

During ground surveys, Pacific Loons were encountered on 94 plots and were judged to be

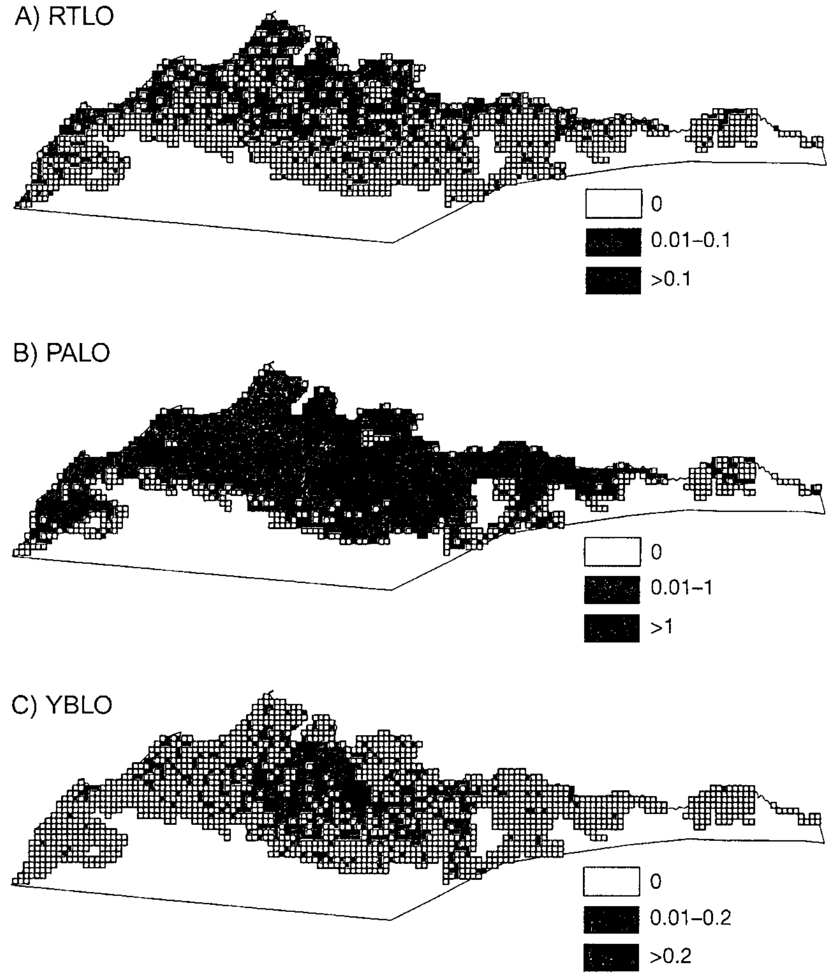

Figure 4.19. Densities (birds/km^2) of Red-throated Loons (a), Pacific Loons (b), and Yellow-billed Loons (c) recorded on the aerial surveys.

breeding on 66 plots. Nearly all sightings were in the ACP (Table 4.9). Most observations were pairs and almost all were in wetlands. The estimated number of pairs breeding on surveyed plots was 88.

We suspect detection ratios were close to 1.0, though birds at nests often hid from surveyors and could be hard to detect. Densities were highest in wetlands and almost zero in uplands (Table 4.9). Most of the population was estimated to occur in the ACP-NPRA. Population size was estimated at about 35,000 with a moderate CV of 0.32 (Table 4.9).

The BNA range map includes the entire study area, which is consistent with our results (Russell 2002).

Common Loon

During aerial surveys, Common Loons were recorded in nine cells, mainly in the NPRA, and widely distributed across it, but including three cells near the coast close to Prudhoe Bay. The species was not recorded on the ground surveys. The BNA does not include any of our study area, which is consistent with our results (Mcintyre and Barr 1997).

Yellow-billed Loon

During aerial surveys, Yellow-billed Loons were recorded in 575 cells (Fig. 4.19c). Sightings were concentrated in the central and eastern NPRA and appeared to be less common both close to the coast and close to the Foothills. Few sightings occurred east of Prudhoe Bay.

This species was only encountered during ground surveys on 14 plots and was only judged to be breeding on five plots. All but one of the records was from the Colville Delta.

The BNA range map includes our entire study area, which is consistent with our results (North 1994).

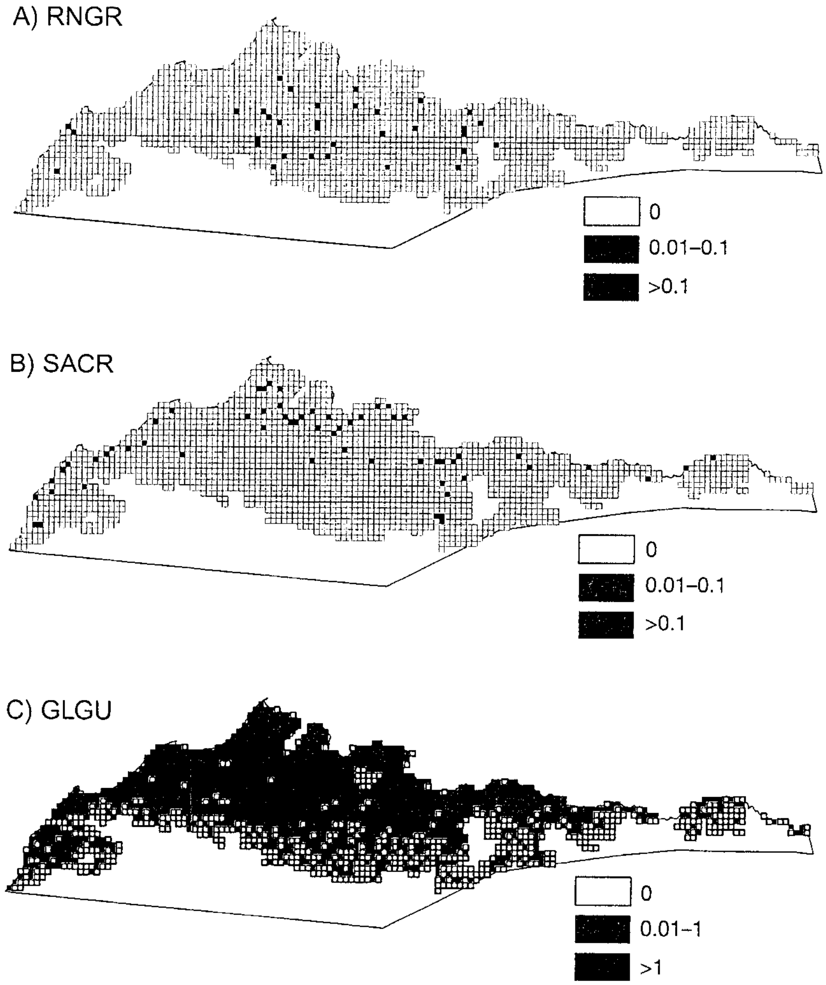

Figure 4.20. Densities (birds/km^2) of Red-necked Grebes (a), Sandhill Cranes (b), and Glaucous Gulls (c) recorded on the aerial surveys.

Red-necked Grebe

During aerial surveys, Red-necked Grebes were recorded in 33 cells (Fig. 4.20a). The sightings were mainly in the central and eastern part of the NPRA. Only a few sightings were east of the Colville. Density appeared to be lower close to the coast and in the southern part of the coastal plan. The species was not encountered on ground surveys.

The BNA range map does not include any of our study area (Stout and Nuechterlein 1999). Even though the species was recorded in the central part of the study area, it could be argued that density was too low to include this region in the range.

Northern Harrier

On the ground surveys, surveyors recorded six single Northern Harriers, three in the Arctic NWR and one each in each of the three NPRA regions. None of the birds was judged to be breeding. They were not recorded on aerial surveys. The BNA range map excludes the entire study area, which is consistent with our results (MacWhirter and Bildstein 1996).

Golden Eagle

During aerial surveys, Golden Eagles were recorded in 140 cells (Fig. 4.21a). The sightings were widely distributed across the survey area but were a little more common in southern parts. The species was only encountered on three plots during the ground surveys.

The BNA range map excludes our study area (Kochert et al. 2002). We suspect many of the birds recorded on aerial surveys were not breeding, so whether to include our study area in the species' range depends on whether birds summering (or visiting) north of their usual breeding range are to be included.

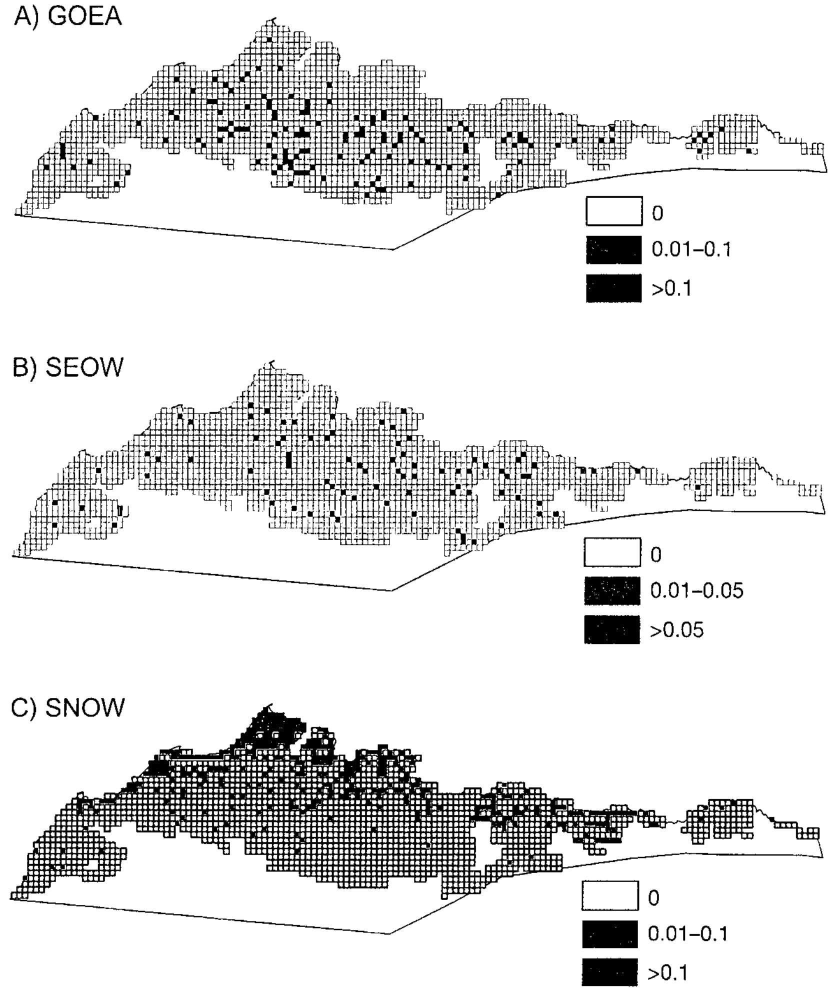

Figure 4.21. Densities (birds/km^2) of Golden Eagles (a), Short-eared Owls (b), and Snowy Owls (c) recorded on the aerial surveys.

Rough-legged Hawk

Rough-legged Hawks were observed breeding outside our plots on the Colville River upstream from Umiat. They were also recorded on seven plots: two in the Arctic NWR and five in the NPRA. They were not judged to be breeding on any of these plots. They were not recorded on the aerial surveys. We suspect that few pairs breed within our survey area except along the Colville River. The BNA includes our entire study area as within the range (Bechard and Swem 2002). Based on our results, excluding most of our study area except the upper Colville River may be more appropriate.

Peregrine Falcon

Peregrine Falcons were encountered on ten plots and were judged to be breeding on one plot. They were observed along the Colville River, where they breed, and once in the Arctic NWR. They were not recorded on the aerial survey, which seems odd given the number of flights that crossed the Colville River. The BNA shows most of our study area in the range (White et al. 2002). Based on our results, excluding most of our study area, other than the Colville River upstream from Ocean Point, might be more appropriate.

Gyrfalcon

Two Gyrfalcons were recorded, one in the Arctic NWR at the southern edge of the study area and one along the coast at the extreme western edge of the study area. None were recorded on the aerial survey. The BNA excludes most our study area from the range, which is consistent with our results (Booms et al. 2008).

Sandhill Crane

During aerial surveys, Sandhill Cranes were recorded in 59 cells (Fig. 4.20b). Sightings occurred mainly within 50 km of the coast and up the Colville River. During ground surveys, Sandhill Cranes were encountered on 13 plots and were judged to be breeding on three plots. We assume the detection ratio was close to 1.0. The estimated population size was 212 with a large CV of 0.74. The results indicate that the breeding population is almost certainly less than 500 birds.

The BNA range map does not include any of the North Slope, but our results suggest that the species occurs regularly in the northern portion of the study area and along the Colville River (Tacha et al. 1992).

Mew Gull

Aerial surveyors recorded Mew Gulls in seven cells in the southern part of the NPRA. The species was not encountered during ground surveys. The BNA excludes our entire study area, which is consistent with our results (Moskoff and Bevier 2002).

Herring Gull

A single Herring Gull was recorded in the NPRA-Coastal region on the ground surveys but was not thought to be breeding on the plot. The species was not recorded on aerial surveys. The BNA excludes our entire study area (Pierotti and Good 1994).

Glaucous Gull

During aerial surveys, Glaucous Gulls were recorded in 1,401 cells (Fig. 4.20c). Sightings were recorded throughout the surveyed area, though they were less common in the Arctic NWR and along the southern border of the coastal plain.

Glaucous Gulls were encountered on 138 plots and were judged to be breeding on 46 plots. They occurred widely across the study area during ground surveys (Table 4.9). They were most frequently recorded in the ACP-NPRA region. They often came to surveyors from great distances and so were encountered far more often (232 records) than they were recorded as breeding pairs (56 records).

Glaucous Gulls are one of the most conspicuous and easy to count species on the tundra. We suspect detection ratios were close to 1.0. Densities were similar in wetlands and moist areas (Table 4.9). Region-specific estimates were of low precision. Population size was estimated at about 35,000 with a moderate CV of 0.27 (Table 4.9).

The BNA range map includes most of our study area, but we found the species farther south in the NPRA than depicted on the BNA map (Gilchrist 2001).

Sabine's Gull

During aerial surveys, Sabine's Gulls were recorded in 831 cells (Fig. 4.22a). Most sightings were west of Prudhoe Bay and well north of the Foothills region. There was a slight suggestion that density was lower close to the coast, west of Barrow.

During the ground surveys, Sabine's Gulls were encountered on 22 plots and were judged to be breeding on 16 plots (Table 4.9). Most records were of single breeding pairs, but small colonies occurred occasionally and two were on surveyed plots (eight and five pairs). The estimated number of pairs breeding on surveyed plots was 27.

Sabine's Gulls were generally conspicuous. Where groups occurred, especially if some were on and some were off the plot, estimating the number of pairs could be difficult, but this happened rarely and probably had little impact on estimated densities. We therefore suspect the detection ratio was close to 1.0. The estimated population size was about 27,000 with a moderate CV of 0.42 (Table 4.9).

The BNA range map is consistent with our results (Day et al. 2001).

Arctic Tern

During the aerial surveys, Arctic Terns were encountered in 1,226 cells (Fig. 4.22b). They were widespread across the ACP-NPRA region but were most dense in the south-central part. They occurred in only a few cells in the Arctic NWR.

During the ground surveys, Arctic Terns were encountered on 100 plots and were judged to be breeding on 54 plots (Table 4.9). Most records were of single birds in wetlands. Foraging groups

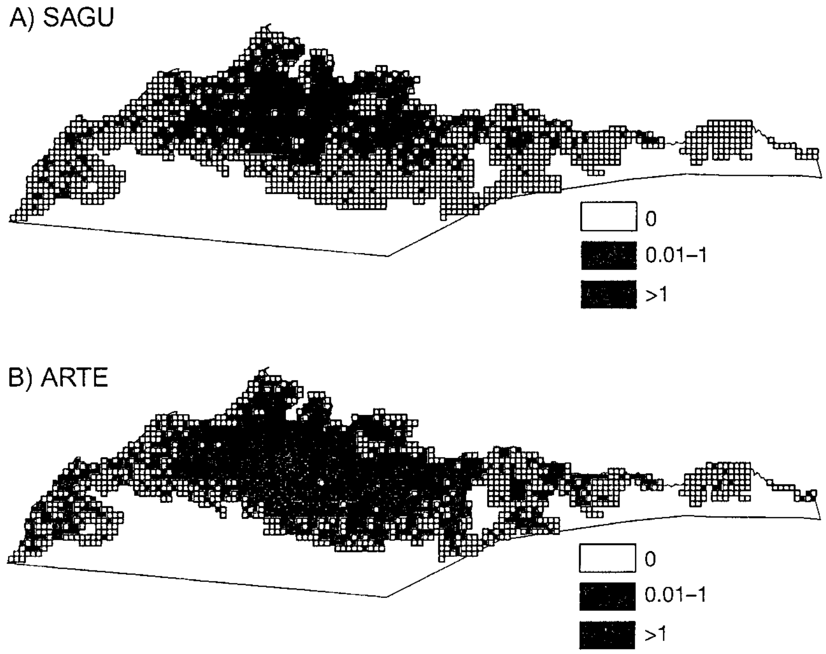

Figure 4.22. Densities (birds/km^2) of Sabine's gulls (a) and Arctic Terns (b) recorded on the aerial surveys.

were often encountered, so the total number observed (184) on all plots was much higher than the number (86) estimated to be breeding on these plots.

Arctic Terns are usually obvious foraging above wetlands. We therefore suspect the detection ratio is close to 1.0. Relative densities were highest in wetlands (Table 4.9). Most of the estimated population was in the ACP-NPRA region. The estimated, uncorrected population size was nearly 100,000 with a moderate CV of 0.36 (Table 4.9).

The BNA range map includes the entire study area, which is consistent with our results (Hatch 2002).

Pomarine Jaeger

Pomarine Jaegers were encountered on 25 plots and were judged to be breeding on six plots. The other records were of foraging birds. The species migrates eastward across the study area throughout most of June, but birds that were clearly migrating were not recorded. Jaegers were counted but not identified to species on the aerial surveys. The BNA range map shows the species breeding in a narrow band along the coast throughout our study area (Wiley and Lee 2000). This may be a reasonable depiction, but the species certainly does not breed throughout this area each year. For example, we never found it breeding on the Colville Delta during ten years of intensive study there.

Parasitic Jaeger

Parasitic Jaegers were encountered on 129 plots and were judged to be breeding on 42 plots (Fig. 4.23a). Records were widely distributed across the study area except possibly in the westernmost part of the NPRA (Table 4.9). The most common records were single birds in wetlands; however, they occurred frequently in moist areas. They often approached surveyors from considerable distances, so the estimated number of breeding birds (44) was much smaller than the number encountered (130).

The estimates of relative densities show that the species achieved highest densities in wetlands but was also common in moist areas (Table 4.9). Parasitic Jaegers are usually conspicuous when surveyors are near to the nest. We therefore suspect the detection ratio is fairly close to 1.0. The estimated population size was nearly 50,000 birds with a CV of 0.29 (Table 4.9).

The BNA range map includes the entire study area, which is consistent with our results (Wiley and Lee 1999).

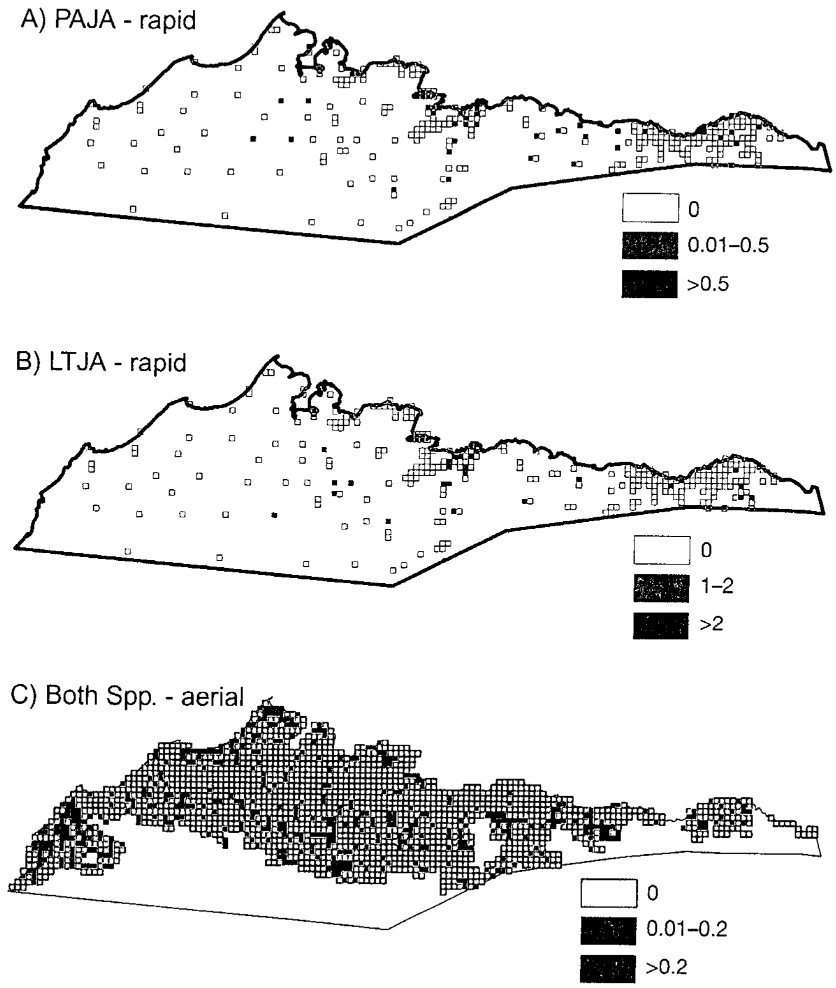

Figure 4.23. Densities (birds/km^2) of Parasitic Jaegers (a) and Long-tailed Jaegers (b) recorded on the rapid surveys, and of both species recorded on the aerial surveys (c).

Long-tailed Jaeger

During ground surveys, Long-tailed Jaegers were encountered on 90 plots and were judged to be breeding on 27 plots (Fig. 4.23b). The records were widely distributed across the study area but were concentrated in the Colville River Delta and were absent from the western two-thirds of the NPRA (Table 4.9). As with other jaegers, birds flying over the plot, often clearly coming to investigate the surveyor, were common, with the result that many more birds were recorded than were judged to be breeding within the plot. The estimated number of birds breeding on surveyed plots was 31.

We suspect detection ratios for jaegers are close to 1.0. Uncorrected densities were similar across habitats and regions (Table 4.9). Population size was estimated at about 60,000 birds.

As noted above, jaegers were seldom identified to species on the aerial survey. Combined results for jaegers (Fig. 4.23c) showed that they were widely distributed across the study area and were somewhat more common near the south border of the study area. Jaegers were recorded in 1,424 cells.

The BNA range map includes nearly all of our study area, which is consistent with our results (Wiley and Lee 1998). The map shows a small, unoccupied area in the vicinity of Barrow. We do not know whether that is accurate.

Short-eared Owl

During the aerial surveys, Short-eared Owls were recorded in 86 cells (Fig. 4.21b). Sightings were widely distributed across the surveyed areas but were least common in the Arctic NWR and appeared to be more common in the southern part of the ACP. During ground surveys, Short-eared Owls were encountered on 21 plots and were only judged to be breeding on three plots.

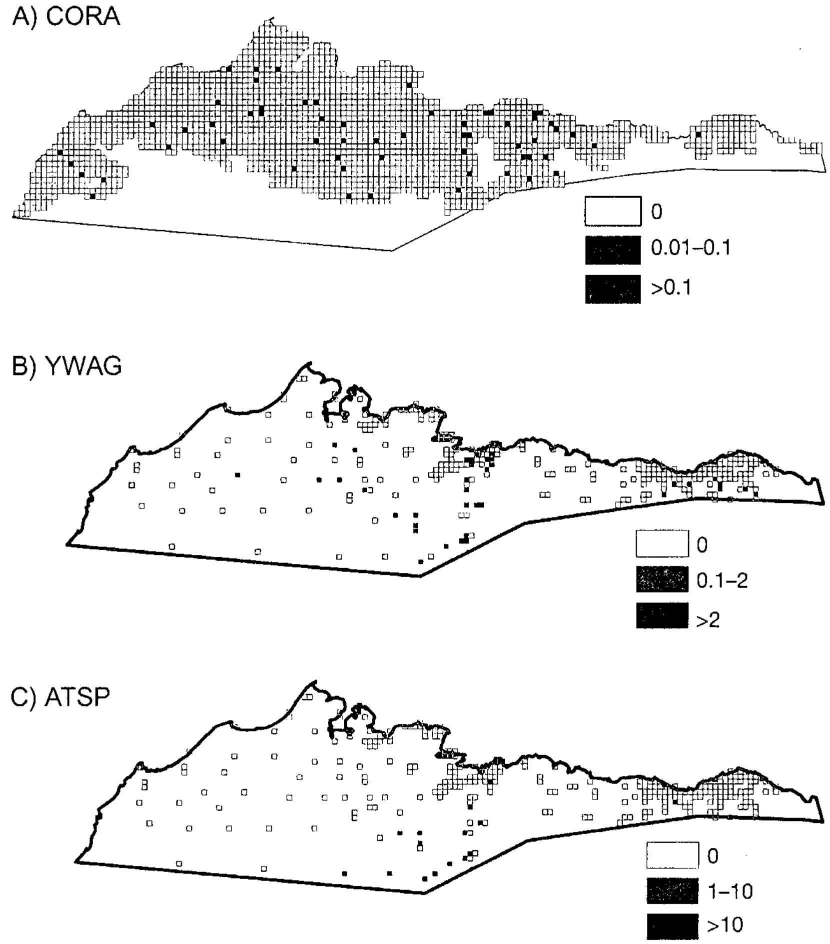

Figure 4.24. Densities (birds/km^2) of Common Ravens recorded on the aerial surveys (a), and Eastern Yellow Wagtails (b) and American Tree Sparrows (c) recorded on the rapid surveys.

The BNA range map includes the entire study area, which is consistent with our results (Wiggins et al. 2006).

Snowy Owl

During the aerial surveys, Snowy Owls were recorded in 384 cells (Fig. 4.21c). They were recorded widely across the surveyed area but were most abundant along the coast from Barrow to Wainwright. During the ground surveys, Snowy Owls were encountered on four plots and were not judged to be breeding on any of them.

The BNA range map includes the entire study area, which is consistent with our results (Parmelee 1992a).

Common Raven

During the aerial surveys, Common Ravens were recorded in 59 cells (Fig. 4.24a). Sightings were widely distributed across the surveyed area but were most common in the southern part of the coastal plain and least common close to the coast. During the ground surveys, the species was encountered on 17 plots but was not judged to be breeding on any of them.

The BNA range map includes the entire study area, which is consistent with our results (Boarman and Heinrich 1999).

Tree Swallow

Tree Swallows were encountered on nine plots and were judged to be breeding on seven plots. All but one record was from the Colville River upstream from Umiat. The BNA shows the species occurring only south of the Brooks Range (Robertson et al. 1992). Our results suggest that they also regularly occur in the upper Colville River near the southern border of our study area.

Arctic Warbler

Arctic Warblers were encountered on only one plot (three birds estimated to indicate three breeding pairs) on the Colville River near Umiat. The BNA shows the range extending into our study area mainly in the upper Colville River, which is consistent with our results (Lowther and Sharbaugh 2008).

Bluethroat

Bluethroats were encountered on ten plots and were judged to be breeding on all ten of them. They were encountered frequently in low shrub along the Colville river and occasionally elsewhere. Thirteen indicated pairs were recorded. The BNA includes our entire study area within the range (Guzy and McCaffery 2002). Our results suggest that the species occurs rarely away from the Colville River upstream from Ocean Point.

Gray-cheeked Thrush

Gray-cheeked Thrushes were encountered on four plots and were judged to be breeding on all of them. They were recorded only along the Colville River in tall shrubs. They were abundant on two of these plots (17 indicated pairs on each plot). The BNA excludes most of our study area except for a small portion of the upper Colville River, which is consistent with our results (Lowther et al. 2001).

American Robin

American Robins were encountered on three plots in the southern NPRA and were judged to be breeding on all of them. The BNA excludes all our study area, which is consistent with our results (Sallabanks and James 1999).

Eastern Yellow Wagtail

Yellow Wagtails were encountered on 57 plots and were judged to be breeding on 51 plots (Fig. 4.24b). The records were widely distributed in areas with shrubs at least 1 m tall. Single birds were the most common record. About equal numbers of records were obtained in wetlands and moist areas (Table 4.9). The estimated number of pairs breeding in surveyed plots was 83.

Yellow Wagtails sang actively throughout the survey period and have a distinctive note, given in flight and detectable from considerable distances. They remain largely on territory and are easy to count. We suspect the detection ratio was close to 1.0. Overall density was an impressive 1.8 birds/km^2 (Table 4.9). Densities were highest in moist areas. Population size was estimated at about 130,000 birds with a moderate CV of 0.26 (Table 4.9).

The BNA includes our entire study area within the range (Badyaev et al. 1998). This may be correct, though our results suggest that densities are low in the northwestern part of the NPRA and close to the coast throughout our study area.

American Pipit

American Pipits were encountered on two plots in the Arctic NWR and were not judged to be breeding on either of them. The BNA excludes most of our study area, which is consistent with our results (Verbeek and Hendricks 1994).

Yellow Warbler

Yellow Warblers were common on three plots on the Colville River upstream from Umiat. The estimated number of pairs breeding in these plots was 24. The BNA range map excludes our entire study area, whereas our results suggest that the species may breed commonly, if locally, on the upper Colville River (Lowther et al. 1999).

American Tree Sparrow

Tree Sparrows were encountered on 23 plots and were judged to be breeding on 22 plots (Fig. 4.24c). They were encountered commonly along the Colville River in the shrubs and occasionally elsewhere in the southern part of the study area. They were nearly always single birds, though a few nests and probable nests were found. They occurred exclusively in moist areas and uplands. The estimated number of pairs breeding in the surveyed plots was 80.

The BNA range map excludes our study area, whereas we found the species breeding commonly along the Colville at least as far north as

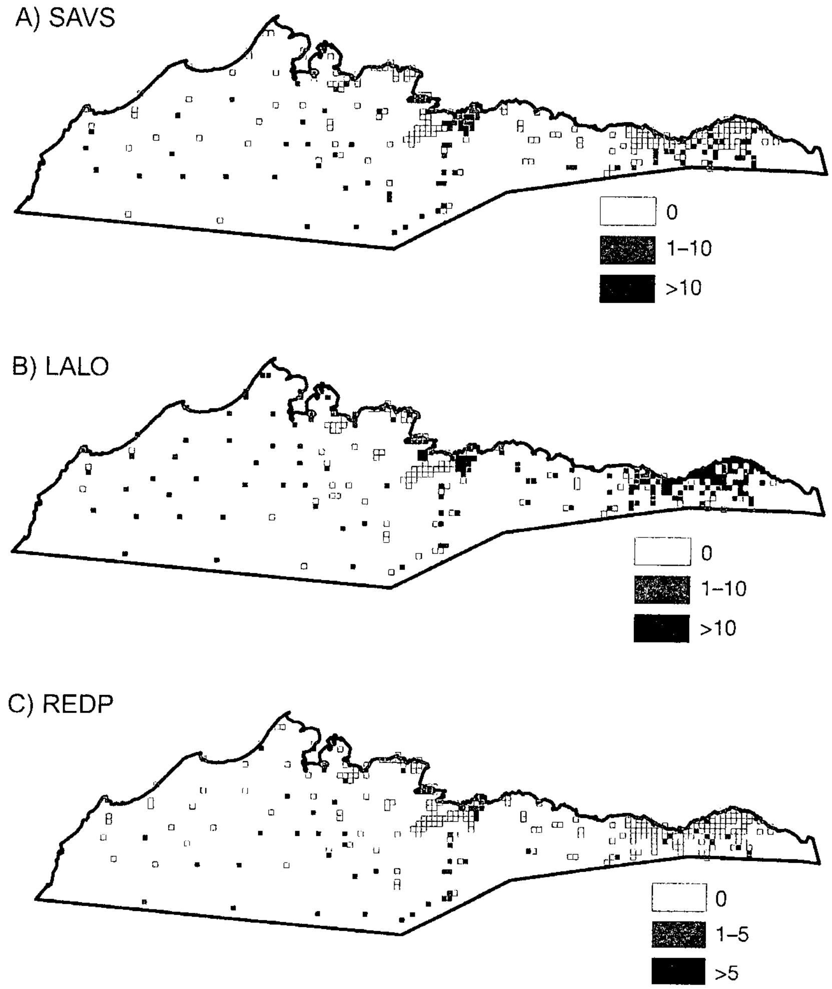

Figure 4.25. Densities (birds/km^2) of Savannah Sparrows (a), Lapland Longspurs (b), and Redpolls (c) recorded on the rapid surveys.

Ocean Point and sporadically almost to the coast (Naugler 1993).

Fox Sparrow

Fox Sparrows were encountered on eight plots (23 indicated pairs) along the Colville River about 100 km upstream from Umiat. They occurred in medium and tall shrubs. The range map in the BNA is consistent with our results (Weckstein et al. 2002).

Savannah Sparrow

Savannah Sparrows were encountered on 153 plots and were judged to be breeding on all but two of them (Fig. 4.25a). Most plots had zero to three pairs, but 28 plots had four or more pairs. They were recorded commonly in all habitats and in all regions (Table 4.9). The estimated number of pairs breeding on surveyed plots was 375.

Savannah Sparrows sang frequently throughout the survey period and unlike the other two common landbirds, Lapland Longspurs and Redpolls, were easy to count because their density was low and they generally sang from within their territories rather than covering large areas as both Longspurs and Redpolls frequently do. We suspect the detection ratio was slightly less than 1.0. Density was much higher in uplands than in other habitats (Table 4.9). The estimated density for all habitats was an extremely high 12.5 birds/km^2. The estimated population size was about 920,000 with a small CV of 0.17 (Table 4.9).

The BNA includes all of the study area, which is consistent with our results (Wheelwright and Rising 2008).

White-crowned Sparrow

White-crowned Sparrows were encountered on nine plots and were judged to be breeding on all of them. All records were from the Colville River, mainly above Umiat. The BNA shows the species breeding throughout the southern quarter of our study area, whereas we found it only along the Colville River upstream from Ocean Point (Chilton et al. 1995).

Lapland Longspurs

Lapland Longspurs were encountered on 318 plots and were judged to be breeding on 306 plots (Fig. 4.25b). Density appeared to be highest in the Arctic NWR. Single birds in wetlands or moist areas were the most common record. The estimated number of birds breeding on surveyed plots was 990 (Table 4.9).

Intensive work with banded birds on the Colville Delta showed that Longspur density was often 2–3 pairs/ha. At these densities, it was difficult to count them when all other species were being counted. As a result, surveyors often just indicated "present" rather than trying to estimate numbers present. This occurred on 108 plots out of 299 plots on which positive values were recorded. We converted these values to "1" for estimates of relative density.

Even with these sources of negative bias, the estimated densities in the Arctic NWR exceeded $40/km^2$ and the estimated population size was over 1 million (Table 4.9). Given the substantial degree to which actual numbers were underestimated, it is plausible that the study area might hold 5 million Lapland Longspurs.

The BNA range map includes the entire study area, which is consistent with our results (Hussell and Montgomerie 2002).

Snow Bunting

Snow Buntings occurred on only three plots, all in the Colville Delta near buildings. The BNA shows the species breeding throughout all but the southernmost part of our study area, whereas we found it almost exclusively near settlements and other man-made features (Lyon and Montgomerie 1995).

Redpolls

We did not attempt to distinguish between Common and Hoary Redpolls, though the full range of color variations was encountered. Redpolls were encountered on 94 plots and were judged to be breeding on 74 plots (Fig. 4.25c). They were hard to count because they were mainly detected from flight calls and they traveled widely. As a result, we did not try to estimate densities. They were found widely across the study area wherever brush occurred, especially when it was one or more meters tall. They were particularly common along the Colville River in the taller brush there.

The BNAs for the redpolls show both species occurring throughout our study area, which is consistent with our results, though they may be uncommon in the northwestern part of the NPRA (Knox and Lowther 2000a, 2000b).

DISCUSSION

Geographic Patterns

Results in the species accounts may be used to compare regions and species. We do this below by examining patterns in density and abundance for waterfowl, waterbirds, shorebirds, and landbirds, using the most reliable survey data (i.e., ground or aerial) available. To estimate the proportions of the populations in each region from the aerial surveys, we multiplied the density of observations in each cell by 36 to obtain an estimate of the number of birds that would have been recorded in a single survey covering the entire cell. We referred to the sum, across all cells, of these estimates as the "aerial population index." We used the proportion of the index in each region as an estimate of the proportion of the population in the region and the density of observations as an estimate of the relative density among regions.

Waterfowl and Waterbirds

By far the most abundant species (based on the aerial surveys) were Northern Pintails, Greater White-fronted Geese, and Long-tailed Ducks, which together comprised 81% of the common waterfowl (Table 4.10). The estimates for Spectacled and Steller's Eiders and for Yellow-billed Loons have high CVs, which is unfortunate given the conservation concerns for these species.

For all waterfowl combined, 80% of the population was in the NPRA and only 5% was in the Arctic NWR (Table 4.11). Most of this difference is due to the much larger size of the NPRA, but most densities were also lower in the Arctic

TABLE 4.10

Ranked estimates of abundance and density for selected waterfowl and waterbirds, shorebirds, and landbirds based on the ground surveys.

Taxa	Species	*n* birds recorded	Estimated population size	Estimated density (birds/km^2)	CV
Waterfowl and waterbirds	Northern Pintail	301	315,559	4.3	0.22
	Greater White-fronted Goose	347	303,028	4.13	0.29
	Long-tailed Duck	182	208,928	2.85	0.22
	Arctic Tern	86	95,594	1.3	0.36
	Long-tailed Jaeger	31	58,673	0.8	0.45
	Parasitic Jaeger	44	46,761	0.64	0.29
	Greater Scaup	48	40,534	0.55	0.42
	King Eider	40	38,531	0.53	0.42
	Glaucous Gull	56	35,132	0.48	0.27
	Pacific Loon	88	34,426	0.47	0.32
	Sabine's Gull	27	26,949	0.37	0.42
	Cackling Goose	58	19,539	0.27	0.36
	Spectacled Eider	22	15,584	0.21	0.60
	Brant	55	11,045	0.15	0.51
	White-winged Scoter	2	8,338	0.11	1.00
	Green-winged Teal	12	5,950	0.08	0.73
	Tundra Swan	23	4,483	0.06	0.58
	Red-breasted Merganser	12	3,722	0.05	0.87
	Yellow-billed Loon	5	2,570	0.04	0.85
	Red-throated Loon	24	1,737	0.02	0.41
	Mallard	9	1,465	0.02	0.75
	Northern Shoveler	22	1,110	0.02	0.42
Shorebirds	Semipalmated Sandpiper	1,335	1,319,225	17.98	0.17
	Pectoral Sandpiper	1,149	1,117,937	15.23	0.19
	Long-billed Dowitcher	374	647,695	8.83	0.19
	Red Phalarope	735	573,979	7.82	0.18
	Red-necked Phalarope	555	560,092	7.63	0.24
	Dunlin	378	500,161	6.82	0.20
	Western Sandpiper	45	382,443	5.21	0.32
	American Golden-Plover	159	275,506	3.75	0.31
	Black-bellied Plover	175	201,162	2.74	0.23
	Stilt Sandpiper	143	121,213	1.65	0.23
	Bar-tailed Godwit	56	75,602	1.03	0.70
	Buff-breasted Sandpiper	25	41,541	0.57	0.45

TABLE 4.10 *(continued)*

TABLE 4.10 (CONTINUED)

Taxa	Species	*n* birds recorded	Estimated population size	Estimated density (birds/km²)	CV
	Baird's Sandpiper	7	22,252	0.3	0.69
	Whimbrel	17	18,243	0.25	0.69
	Wilson's Snipe	21	14,599	0.2	0.58
Landbirds	Lapland Longspur	990	1,047,043	14.27	0.11
	Savannah Sparrow	375	919,060	12.52	0.17
	Willow Ptarmigan	377	883,500	12.04	0.16
	Redpolls	89	225,699	3.08	0.14
	American Tree Sparrow	80	194,539	2.65	0.39
	Eastern Yellow Wagtail	83	129,399	1.76	0.26
	Rock Ptarmigan	61	121,592	1.66	0.28
	Bluethroat	13	39,163	0.53	0.51

NWR. For all waterfowl, density was more than twice as high in the NPRA as in the Arctic NWR. The Central region was intermediate with respect to both population size and density.

Among gulls, terns, and jaegers, five species were common and widespread, with CVs ≤ 0.45 from the ground surveys (Table 4.9). Other members in this group, including Pomarine Jaeger, were much rarer. Regional estimates of distribution and relative density, based on the aerial surveys, were similar to results for waterfowl (Table 4.11). Most of the population of each species occurred in the NPRA, and densities were lower on the Arctic NWR. The difference was small, however, for Glaucous Gulls and the jaegers. Results from the ground surveys were generally similar (Table 4.9); however, the small samples within regions made comparisons difficult.

Shorebirds

Fifteen species of shorebirds had estimated population sizes of 14,000 or more based on the ground surveys (Table 4.10). The two most abundant of these comprised about half of all shorebirds.

The aerial surveys also recorded shorebirds, though not to species level. Results were fairly similar to the results for waterfowl. The NPRA contained 87% of all shorebirds, with 10% in the Central region and the remainder in the ANWR. Densities were more than twice as high in the NPRA as in the ANWR (0.56 sightings/km² vs. 0.23 sightings/km²). Results from the ground surveys showed similar patterns (Table 4.12). Most species were highly concentrated in the NPRA. Density was markedly higher in the NPRA for nearly all species.

Landbirds

Ground surveys demonstrated that eight species of landbirds were common and widespread (Table 4.9). Most other landbirds were restricted to shrubs, especially along the Colville River. Regional patterns were generally similar to other groups, with the majority of the ACP population in the NPRA, and densities being highest there (Table 4.12). Lapland Longspurs were the only exception. Density for this species was much higher in the Arctic NWR, though it is possible that this pattern was due to surveyors recording estimated densities (rather than a "1" indicating "present") in the Arctic NWR.

Upper Colville River

The upper Colville River, above Ocean Point, contains the tallest shrubs in the study area and supports a diverse bird fauna quite unlike the rest of the study area (Table 4.13). During our brief surveys of this area, we recorded 34 species on plots plus several additional species off plots. Tree Sparrows were by far the most abundant species.

TABLE 4.11

Regional estimates of relative population size and relative density for selected waterfowl and waterbirds in the Arctic Coastal Plain based on the aerial surveys.

Species	*n* cells with positive counts	Proportion of population[a]			Relative density[b]		
		ACP-NPRA	ACP-Central	ACP-ANWR	ACP-NPRA	ACP-Central	ACP-ANWR
All waterfowl	1,858	0.80	0.15	0.05	5.43	3.97	2.50
Greater WF Goose	1,583	0.80	0.19	0.01	1.72	1.57	0.17
Long-tailed Duck	1,689	0.75	0.14	0.11	0.80	0.56	0.90
Northern Pintail	1,613	0.88	0.09	0.03	1.17	0.47	0.29
Pacific Loon	1,575	0.83	0.15	0.02	0.44	0.29	0.08
Glaucous Gull	1,401	0.80	0.13	0.08	0.28	0.17	0.21
Greater Scaup	1,090	0.76	0.22	0.02	0.23	0.26	0.04
Arctic Tern	1,226	0.89	0.09	0.02	0.32	0.12	0.06
Brant	368	0.74	0.08	0.17	0.15	0.06	0.27
Cackling Goose	578	0.81	0.17	0.02	0.20	0.16	0.04
Tundra Swan	1,183	0.73	0.18	0.10	0.13	0.12	0.13
Black Scoter	171	0.41	0.13	0.46	0.03	0.04	0.30
King Eider	853	0.74	0.25	0.01	0.15	0.19	0.01
Jaegers	1,424	0.77	0.19	0.04	0.11	0.10	0.05
Sabine's Gull	831	0.97	0.03	0	0.15	0.02	0.01
Spectacled Eider	629	0.91	0.08	0	0.12	0.04	0
Red-throated Loon	850	0.82	0.12	0.05	0.06	0.03	0.03
Snow Goose	124	0.83	0.17	0	0.06	0.05	0
White-wgd. Scoter	158	0.83	0.17	0	0.05	0.04	0
Common Eider	57	0.38	0.06	0.56	0.01	0	0.07
Yellow-billed Loon	575	0.91	0.08	0	0.04	0.01	0
Red-br. Merganser	262	0.83	0.16	0.01	0.02	0.02	0
Mallard	107	0.66	0.24	0.10	0.01	0.01	0.01
American Wigeon	135	0.76	0.18	0.07	0.01	0.01	0.01
Steller's Eider	97	0.96	0.04	0	0.01	0	0
Northern Shoveler	96	0.85	0.15	0	0.01	0	0
Green-winged Teal	149	0.91	0.09	0	0.01	0	0
Red-necked Grebe	33	0.80	0.20	0	0	0	0

[a] Proportion of the aerial population index in each region.
[b] Sightings/km^2.

TABLE 4.12

Regional estimates of relative population size and relative density for selected shorebirds and landbirds in the Arctic Coastal Plain based on the ground surveys.

Species	Proportion of population[a]			Relative density[b]		
	ACP-NPRA	ACP-Central	ACP-ANWR	ACP-NPRA	ACP-Central	ACP-ANWR
Lapland Longspur	0.47	0.25	0.28	11.26	19.29	48.14
Semipalmated Sandpiper	0.77	0.21	0.03	26.19	22.57	6.87
Pectoral Sandpiper	0.75	0.22	0.04	21.62	19.88	8.04
Willow Ptarmigan	0.90	0.07	0.02	17	4.51	3.18
Savannah Sparrow	0.89	0.05	0.06	14.54	2.65	6.90
Red-necked Phalarope	0.82	0.12	0.05	11.67	5.52	5.49
Red Phalarope	0.84	0.14	0.02	12.42	6.67	2.05
Long-billed Dowitcher	0.90	0.10	0.01	14.46	4.97	0.79
Dunlin	0.85	0.14	0.01	10.92	5.68	0.67
Western Sandpiper	1.00	0	0	9.28	0	0.03
American Golden-Plover	0.79	0.14	0.07	3.82	2.22	2.46
Black-bellied Plover	0.81	0.19	0	4.13	3.09	0
Stilt Sandpiper	0.65	0.29	0.07	2.09	2.98	1.53
Eastern Yellow Wagtail	0.68	0.23	0.09	2.15	2.32	1.98
Redpoll	0.72	0.22	0.05	2.25	2.22	1.21
Rock Ptarmigan	0.78	0.13	0.09	1.73	0.90	1.47
Baird's Sandpiper	0.17	0.14	0.70	0.11	0.29	3.36
American Tree Sparrow	0.81	0.19	0.01	1.47	1.09	0.08
Buff-breasted Sandpiper	0.56	0.41	0.03	0.63	1.49	0.27
Bar-tailed Godwit	0.97	0.03	0	1.81	0.21	0
Bluethroat	0.99	0	0.01	0.59	0	0.03
Whimbrel	0.93	0	0.07	0.39	0	0.22
Wilson's Snipe	1	0	0	0.04	0	0

[a]Proportion of the aerial population index in each region.
[b]Sightings/km^2.

Several other species were found only on the Colville River.

Summary

The main geographic pattern demonstrated in this study was that birds on the North Slope occurred mainly in the ACP. Few species were present in the Foothills. Within the ACP a distinct east–west gradient existed, with higher densities, for most species, in the west. This trend, in combination with the much larger areas in the west, resulted in the great majority of the birds of most species being in the NPRA, with the fewest in the Arctic NWR.

Habitat Relationships

The analysis allowed us to determine which spatial scale (plot, area within 1 km, and area within 10 km) was most useful for predicting abundance. Detailed results are presented in the shorebird accounts. Combining results (Table 4.14) shows

TABLE 4.13

Species recorded on the Colville River upstream from Ocean Point.

Species	n birds recorded	Estimated population size	Estimated density (birds/km^2)	CV
American Tree Sparrow	50	3134	156.69	0.82
Tree Swallow	45	482	24.10	0.46
Gray-cheeked Thrush	40	519	25.94	0.57
Willow Ptarmigan	30	210	10.48	0.27
Savannah Sparrow	28	179	8.96	0.25
Yellow Warbler	24	339	16.95	0.65
Fox Sparrow	22	250	12.48	0.43
Eastern Yellow Wagtail	16	167	8.37	0.40
Northern Pintail	14	131	6.53	0.31
Redpoll	14	134	6.71	0.35
White-crowned Sparrow	11	668	33.41	0.72
Wilson's Snipe	9	774	38.68	0.77
Bluethroat	8	47	2.37	0.43
Cackling Goose	8	61	3.04	0.97
Long-tailed Duck	7	91	4.54	0.49
American Robin	6	70	3.51	0.48
Pectoral Sandpiper	5	55	2.75	1.11
Arctic Warbler	5	71	3.57	0.67
Pacific Loon	5	39	1.97	1.00
Greater Scaup	4	49	2.44	0.43
Red-necked Phalarope	3	33	1.65	1.11
Semipalmated Plover	3	43	2.16	0.49
American Golden-Plover	2	20	0.99	0.73
Lesser Yellowlegs	2	9	0.44	0.98
Glaucous Gull	2	18	0.89	1.11
Greater White-fronted Goose	2	13	0.63	0.81
King Eider	2	18	0.89	1.11
Mallard	2	28	1.40	0.64
Long-billed Dowitcher	1	11	0.55	1.11
Whimbrel	1	4	0.22	0.98
Lapland Longspur	1	10	0.52	0.96
Red-breasted Merganser	1	10	0.52	0.96
Rock Ptarmigan	1	15	0.77	0.98
Sandhill Crane	1	4	0.18	0.98

TABLE 4.14

Significance levels of habitat variables, measured at three spatial scales, in a multiple regression to predict bird density.

Species	Variable	Scale			Best scale
		Micro	Meso	Macro	
Black-bellied Plover	Wetlands	0.0001	0.0001	0.0008	???
	Moist areas	0.0017	0.01	0.0052	micro
American Golden-Plover	Wetlands	0.568	0.719	0.837	micro
	Moist areas	0.01	0.031	0.063	micro
Bar-tailed Godwit	Wetlands	0.0935	0.1753	0.3607	micro
	Moist areas	0.1194	0.2546	0.7601	micro
Ruddy Turnstone	Wetlands	0.6496	0.1323	0.2512	meso
	Moist areas	0.7673	0.2849	0.2512	macro
Dunlin	Wetlands	0.0153	0.0154	0.0485	micro
	Moist areas	0.0939	0.3682	0.8067	micro
Semipalmated Sandpiper	Wetlands	0	0	0	???
	Moist areas	0	0.0001	0.3715	micro
Western Sandpiper	Wetlands	0.3412	0.1786	0.1052	macro
	Moist areas	0.5816	0.18	0.3631	meso
Pectoral Sandpiper	Wetlands	0.0059	0.0058	0.8266	meso
	Moist areas	0.048	0.0814	0.1842	micro
Long-billed Dowitcher	Wetlands	0.0005	0.0173	0.0551	micro
	Moist areas	0.1986	0.9504	0.7053	micro
Stilt Sandpiper	Wetlands	0	0.0039	0.8896	micro
	Moist areas	0	0.0876	0.3149	micro
Red-necked Phalarope	Wetlands	0	0.0508	0.9989	micro
	Moist areas	0	0.0205	0.3125	micro
Red Phalarope	Wetlands	0	0	0.4788	micro
	Moist areas	0	0.0001	0.0307	micro

that in 17 of 24 cases the significance level was highest when habitat was measured at the micro scale. In three cases the meso scale had the highest significance level, in two analyses the macro scale was best, and in two the issue was uncertain because significance was extremely high at all scales. In our analysis, there was thus little advantage to be gained by measuring habitat at a scale larger than the plot. When the analyses can all be completed using GIS methods, as was the case for us, there is little harm in carrying out analyses at the other scales. If fieldwork were required, our analysis suggests that confining the work to the plot would be prudent.

The analysis also permits a crude comparison of whether spatial or habitat variables were more useful in predicting density (Table 4.8). Among the 12 models, spatial variables were used in all models, and a total of 27 times. In contrast, habitat variables were used in only nine of the models, and a total of ten times. Furthermore, spatial variables usually dominated the model so that predicted numbers varied in a smooth manner across the landscape, showing little influence of habitat. This does not mean, of course, that habitat is unimportant to these species, as any field biologist knows. Instead, it shows that our level of resolution (100-m pixels) and small number of

TABLE 4.15

Estimated detection ratios on aerial surveys.[a]

Species	Ground surveys Estimate	Ground surveys CV	Aerial surveys Estimate	Aerial surveys CV	Detection ratio	SE
Jaegers	105,435	0.28	5,647	0.14	0.05	0.02
Short-eared Owl	11,084	0.90	204	0.45	0.02	0.02
Long-tailed Duck	208,928	0.22	46,328	0.10	0.22	0.05
Northern Pintail	315,559	0.22	68,180	0.12	0.22	0.05
Green-winged Teal	5,950	0.73	397	0.55	0.07	0.06
Arctic Tern	95,594	0.36	23,036	0.14	0.24	0.09
Gr. Wh.-fronted Goose	303,028	0.29	129,879	0.11	0.43	0.13
Glaucous Gull	35,132	0.27	16,216	0.16	0.46	0.15
King Eider	38,531	0.42	12,216	0.24	0.32	0.15
Northern Shoveler	1,110	0.42	238	0.61	0.21	0.16
Greater Scaup	40,534	0.42	16,626	0.21	0.40	0.19
Sabine's Gull	26,949	0.42	11,758	0.25	0.44	0.21
Pacific Loon	34,426	0.32	25,331	0.08	0.74	0.24
Red-necked Grebe	264	1.00	50	1.18	0.19	0.29
Spectacled Eider	15,584	0.60	6,706	0.70	0.43	0.40
Mallard	1,465	0.75	633	0.57	0.43	0.41
White-winged Scoter	8,338	1.00	3,806	0.43	0.46	0.50
Red-breasted Merganser	3,722	0.87	2,018	0.56	0.54	0.56
Brant	11,045	0.51	9,861	0.63	0.89	0.73
Cackling Goose	19,539	0.36	21,693	0.62	1.11	0.80
Yellow-billed Loon	2,570	0.85	2,440	0.22	0.95	0.83
Sandhill Crane	212	0.74	221	0.58	1.04	0.98
Red-throated Loon	1,737	0.41	3,955	0.16	2.28	1.00
Tundra Swan	4,483	0.58	11,717	0.17	2.61	1.58
American Wigeon	407	0.71	845	0.51	2.08	1.81
Snow Goose	485	0.70	5,296	1.43	10.92	17.35

[a]Estimated from aerial surveys provided by Dr. R. S. Stehn and were based on the Arctic Coastal Plain surveys (Mallek et al. 2004) except for Spectacled and King Eiders, which were based on the North Slope eider survey (R. S. Stehn, pers. comm.).

categories (wetland, moist, upland) largely failed to capture the important variation, another indication that small- rather than large-scale variation was important to our species.

Range Map Adjustments

This study provides a great deal of new information that may be useful in adjusting range maps. These adjustments should be made by the biologists most familiar with the species in our study area. Our results suggest that consideration be given to expanding the ranges for American Wigeon, Red-necked Grebe, Golden Eagle, and Sandhill Crane and that consideration be given to contracting the ranges for Least Sandpiper, Baird's Sandpiper, Wilson's Snipe, Rough-legged Hawk, and Bluethroat. Smaller adjustments might be made for about two dozen other species, as described in the species accounts.

Detection Ratios on Aerial Surveys

We compared our estimates from ground surveys of population size with the indices of population size published by the USFWS (Mallek 2006). A summary of 26 species, sorted by CV of the detection ratio (Table 4.15), suggests that detection ratios vary widely between species. Large, white, monomorphic species such as Tundra Swans and Snow Geese, and obvious species such as loons, had detection ratios above 0.5. Many other species had lower rates, often <0.3. CVs for the detection ratios, however, were often large, indicating that these data do not lend themselves to estimating species-specific detection ratios, nor do the aerial surveys provide a good basis for estimating population size except for the most obvious species. As stated in Bart et al. (chapter 2, this volume), bias in population size estimates, in this case based on the aerial survey index, does not necessarily cause any bias in trend estimates; it only makes such bias possible.

CONCLUSIONS

This is one of the first avian studies in the arctic to combine results from aerial and ground surveys and to have large samples collected over a large area in both programs. The fact that well-defined sampling plans were used in both surveys meant the results could be compared and combined when appropriate. Although the aerial surveys did not include estimation of detection ratios, they still revealed spatial patterns and proportions of the population in different areas, assuming only that detection ratios were fairly uniform across the study area. This chapter has presented hundreds of estimated densities and population sizes, most of them for the first time ever for this region. These estimates, all of which are accompanied by measures of precision, will help managers identify the most important species in a given region and the most important region for a given species. Major findings applicable to groups of species are that (1) density was generally higher, and population size much higher, in the western ACP than east of the Colville River; (2) in predicting density, habitat variables measured at the plot level were consistently better than, or as least as good as, measurements at a larger scale; (3) spatial variables were consistently more useful than habitat variables in predicting density; (4) many distribution maps can now be revised using our findings; and (5) detection ratios on the aerial survey probably varied widely, approaching 1.0 for large, white birds, but being substantially lower for most other species.

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