ARCTIC
VOL. 58, NO. 1 (MARCH 2005) P. 55–65

Shorebird and Passerine Abundance and Habitat Use at a High Arctic Breeding Site: Creswell Bay, Nunavut

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(*Received 29 September 2003; accepted in revised form 24 June 2004*)

ABSTRACT. Shorebirds and passerines were surveyed at Creswell Bay, Somerset Island, in the High Arctic Ecozone (Canadian Arctic Islands) during the breeding season (June and July, 1995–97) and in August 1995 (post-breeding). The study area, situated on the north and south sides of Creswell Bay, consisted of sedge marsh and sedge wetland in the lowest areas, with shrub tundra dominated by *Dryas* spp. or *Cassiope* spp. and sparse herbaceous tundra over more upland areas. Surveys were carried out on 400 × 400 m plots distributed among the vegetation types according to their relative amounts within the study areas (34 plots in 1995; 33 plus 56 new plots in 1997). Eleven shorebird and three passerine species were observed during the surveys. Densities of breeding shorebirds were similar in 1995 and 1997 (37.3 and 33.1 birds/km^2), while in 1996 a late spring with heavy snow cover resulted in reduced numbers of birds and no breeding. Shorebirds and passerines were much more numerous in sedge marsh and sedge wetland. White-rumped sandpiper (*Calidris fuscicollis*) and red phalarope (*Phalaropus fulicarius*) were the most abundant shorebirds breeding at Creswell Bay, and Lapland longspur (*Calcarius lapponicus*) was the most abundant breeding passerine. White-rumped sandpiper and sanderling (*Calidris alba*) were the most numerous species present after the breeding period. American golden-plover (*Pluvialis dominica*), red phalarope, and white-rumped sandpiper showed significant habitat preferences. An estimated 10 341 (± 6596; 95% CI) shorebirds were on the north area in 1995 and 14 840 (± 10 744) on both areas in 1997. The estimated maximum numbers over both years of white-rumped sandpiper (6769 ± 3725) and buff-breasted sandpiper (*Tryngites subruficollis*) (908 ± 1169) at Creswell Bay were more than 1% of the species' estimated national populations (1.5% and 5.1%, respectively). This abundance, along with the relatively high species diversity at this high-latitude site, warrants its continued status as a Canadian Wildlife Service "key habitat site," and every possible effort should be made to ensure its long-term protection.

Key words: Creswell Bay, High Arctic, Nunavut, shorebirds, passerines, density, numbers, habitat, species diversity, protection

RÉSUMÉ. Les oiseaux de rivage et les passereaux ont fait l'objet d'une étude menée à la baie Creswell, dans l'île Somerset située dans l'écozone de l'Extrême-Arctique (archipel Arctique canadien) durant la saison de nidification (juin et juillet, 1995–97) et en août 1995 (période post-reproductrice). La zone d'étude, située sur les rivages nord et sud de la baie Creswell, consistait en des cariçaies de terrains marécageux et humides dans les terres les plus basses, avec une toundra arbustive dominée par *Dryas* spp. ou *Cassiope* spp. et une toundra herbacée clairsemée dans les terres plus hautes. L'étude a été effectuée sur des parcelles carrées de 400 m de côté réparties dans les divers types de végétation selon l'importance relative de ces derniers dans les zones d'étude (34 parcelles en 1995; 33 parcelles plus 56 nouvelles en 1997). On a observé 11 espèces d'oiseaux de rivage et trois espèces de passereaux durant l'étude. Les densités des oiseaux de rivage qui nidifiaient étaient semblables en 1995 et en 1997 (37,3 et 33,1 oiseaux/km^2), alors qu'en 1996, un printemps tardif accompagné d'un important couvert nival a fait que le nombre des oiseaux a diminué et qu'aucun nid n'a été construit. Les oiseaux de rivage et les passereaux étaient beaucoup plus nombreux dans les cariçaies de terrains marécageux et humides. Le bécasseau à croupion blanc (*Calidris fuscicollis*) et le phalarope à bec large (*Phalaropus fulicarius*) étaient les oiseaux les plus nombreux à nidifier à la baie Creswell, et le bruant lapon (*Calcarius lapponicus*) était le passereau nidificateur le plus abondant. Le bécasseau à croupion blanc et le bécasseau sanderling (*Calidris alba*) étaient les espèces les plus nombreuses présentes après la période de nidification. Le pluvier bronzé (*Pluvialis dominica*), le phalarope à bec large et le bécasseau à croupion blanc affichaient une nette préférence quant à leur habitat. On a estimé à 10 341 (± 6596; intervalle de confiance à 95 %) le nombre des oiseaux de rivage présents sur la côte septentrionale en 1995, et à 14 840 (± 10 744) celui des oiseaux de rivage présents sur les côtes nord et sud en 1997. Au cours des deux années, le nombre maximal estimé pour le bécasseau à croupion blanc (6769 ± 3725) et celui pour le bécasseau roussâtre (*Tryngites subruficollis*) (908 ± 1169) à la baie Creswell représentaient plus de 1 % des populations nationales estimées de ces espèces (1,5 % et 5,1 % respectivement). Cette abondance, jointe à une diversité relativement forte des espèces dans cette région de haute latitude, justifie le maintien de son statut de «site d'habitat clé» du Service canadien de la faune, et toutes les mesures devraient être prises pour en garantir la protection à long terme.

Mots clés: baie Creswell, Extrême-Arctique, Nunavut, oiseaux de rivage, passereaux, densité, nombres, habitat, diversité des espèces, protection

Traduit pour la revue *Arctic* par Nésida Loyer.

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INTRODUCTION

Fifteen of the 47 species of shorebirds known to occur in Canada are exclusively Arctic breeders. Canada contains approximately 75% of their combined breeding ranges (Donaldson et al., 2000). The Arctic, therefore, plays a critical role in maintaining viable populations of these transcontinental migrants, since they all depend on Arctic wetlands either as breeding habitat or as post-breeding feeding habitat to build energy reserves for the southward migration. However, the wetland habitat required by most species is distributed very unevenly across the Arctic, especially on the northern Arctic Islands. Typically, a lowland containing well-developed wetlands is surrounded by relatively barren polar desert. In the Arctic Islands these sites are rare, and most have received no formal protection. In the early 1970s, in anticipation of extensive hydrocarbon development, considerable information was collected on shorebird species diversity and abundance at a number of wetlands across the Arctic Islands (Alliston et al., 1976; McLaren et al., 1977; Patterson and Alliston, 1978). Since then, however, scant additional information has been collected from the majority of these sites. Today, increasing evidence points to population declines in a number of shorebird species, including several Arctic breeders (Morrison et al., 2001a). Recently, there has been greater recognition of the need to include Arctic breeding areas, primarily wetlands, in international population monitoring programs for shorebirds (Skagen et al., 2003). These programs have traditionally focused on migration staging areas (Morrison et al., 1994, 1995; Harrington and Perry, 1995) and on the wintering grounds in the Southern Hemisphere (Morrison and Ross, 1989; Morrison et al., 1998; Skagen et al., 2003).

One such extensive wetland in the Canadian Arctic Islands is found at Creswell Bay, Somerset Island. The only previous shorebird surveys at Creswell Bay (Alliston et al., 1976) indicated that it supported relatively high numbers of both breeding and post-breeding shorebirds compared to other central Arctic sites. This abundance, combined with the diversity of other terrestrial and marine wildlife, gave the bay "unique" status among other similar sites in the Mid and High Arctic Islands (Alliston et al., 1976). The present study, which considered the apparent regional importance of Creswell Bay as a shorebird breeding area, was part of an overall assessment of the bay's current importance to shorebirds and passerines, particularly in light of recent population declines in a number of the species that breed there.

STUDY AREA

Creswell Bay (72˚45′ N, 93˚30′ W) is located on the southeast coast of Somerset Island in the central Canadian Arctic islands (Fig. 1). It lies on the boundary between Mid-Arctic and High Arctic ecosystems, which is defined by a mean July isotherm of 5–6˚C (Edlund, 1986), and is situated in the Northern Arctic Ecozone (Wiken, 1986). The closest weather station is at Resolute Bay, approximately 200 km to the north. The mean daily temperature at Resolute Bay is -16˚C. The coldest month is January and the warmest is July with mean annual daily temperatures of -32˚C and 4˚C, respectively. Mean annual precipitation is 139 mm, of which 47 mm falls as snow and 92 mm as rain (Environment Canada, 1993).

The study area consists of two well-vegetated lowlands, one immediately north of outer Creswell Bay (294 km^2) and one immediately south of inner Creswell Bay (143 km^2) (Fig. 1). The north area consists mainly of flat wetlands dominated by sedges (*Carex* spp.) in the lowest areas close to the coast, rising through a series of low beach ridges to drier, progressively more sparsely vegetated tundra farther inland. The entire north area consists of Quaternary sediments, while the surrounding uplands are dolostone, limestone, and sandstone of upper Silurian to lower Devonian origin, plus associated till (Stewart and Kerr, 1984). The south area consists of more localized, sedge-dominated wetlands interspersed with extensive shrub tundra. More rugged than the north area, it is composed largely of exposed dolostone and sandstone of upper Ordovician to upper Silurian origin, interspersed primarily with well-drained tundra and dissected by several small streams.

METHODS

Habitat Classification

Habitat descriptions, which included percent vegetation cover, species composition, soil moisture, standing water, and presence of frost-related surface features such as polygons or hummocks (Alliston et al., 1976), were obtained at specific sites in the wetlands and drier vegetated areas in the north area during an initial reconnaissance in July 1994. A supervised classification of Landsat Thematic Mapper imagery from 20 July 1991 (30 × 30 m pixel size; channels 2, 3, 4, 5, and 7) based on training areas from the 1994 vegetation description was then performed, using the maximum likelihood classifier on an ARIES II image analysis system. A similar supervised classification carried out for the south study area was based on qualitative vegetation descriptions obtained for a number of sites in August 1995. The classification for the north and south areas was transferred into a Geographic Information System (SPANS). A geometric correction was performed to match the Universal Transverse Mercator projection grid system (1:50 000 National Topographic System maps) and resampled to 25 × 25 m, and the subsequent image was georeferenced to the North American Datum 27. The image was smoothed by a 3 × 3 filter in which all clusters of three or fewer pixels were reassigned to the surrounding larger classes. Any number of single pixels in a line were not reassigned, however, since

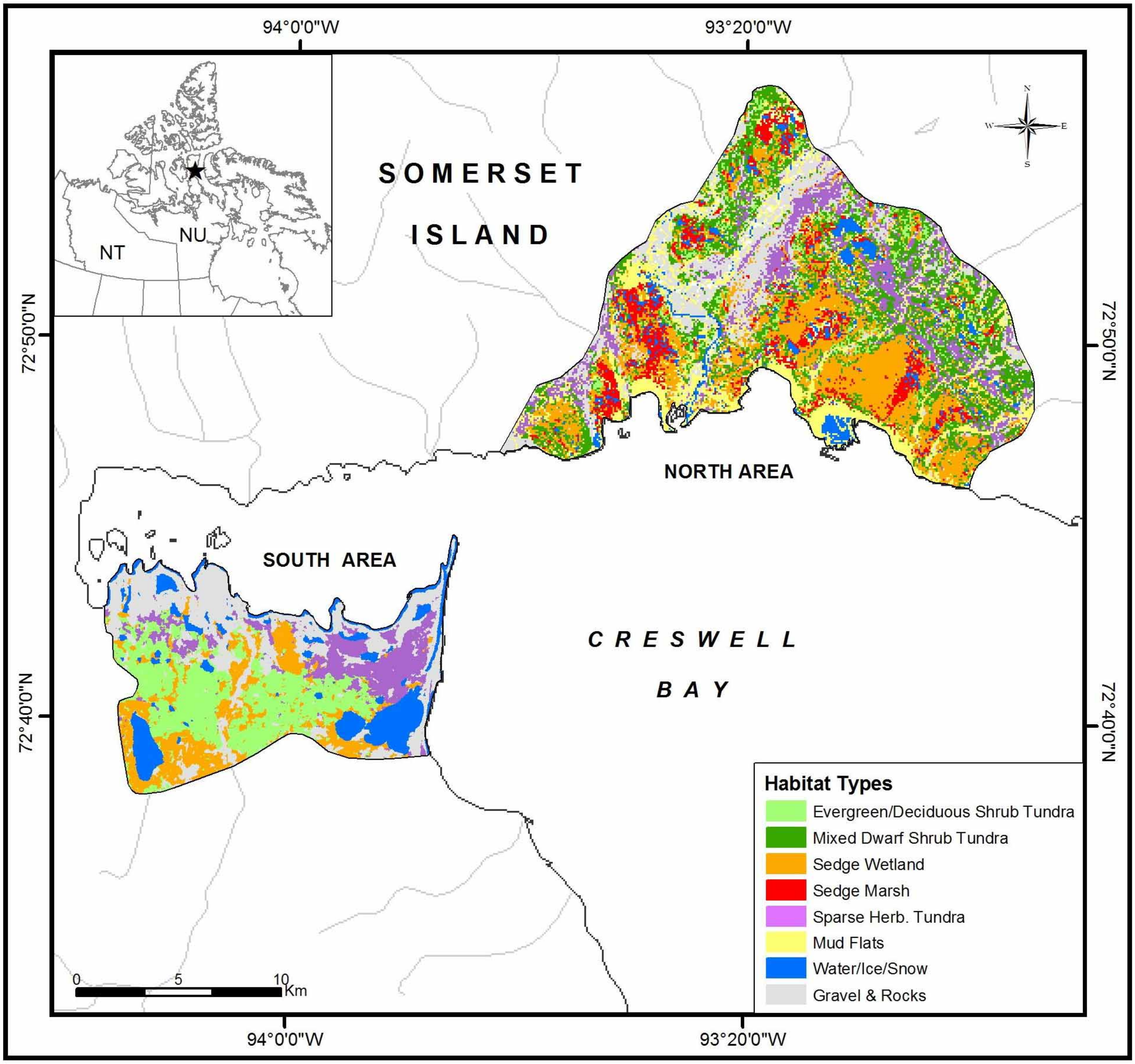

FIG. 1. The north and south areas at Creswell Bay, showing the habitat types as determined from a supervised classification of Landsat TM imagery.

they could represent a linear feature, such as a stream or ecotone, of possible importance in the classification.

Bird Surveys

To determine the number of shorebirds and passerines breeding at Creswell Bay, surveys were conducted during the breeding season in 1995 (17 June to 2 July) and 1997 (22 June to 16 July). Shorebirds and passerines were surveyed in 400 × 400 m plots (Gratto-Trevor, 1996; Johnston et al., 1999). These were drawn onto the remotely sensed vegetation maps for both the north and south areas. Each plot was located so that it was composed entirely of one vegetation or habitat type. However, the plots were not distributed across the entire two areas because of limitations associated with working from fixed base camps. For most habitats, plots were distributed according to the relative area covered by each habitat type within the two study areas. As many plots as possible were placed in sedge marsh and wetland, where higher densities of shorebirds were expected. In the field, each plot was located with a handheld Global Positioning System unit. Each plot was completely surveyed by two observers who walked back and forth at a slow pace along paired, 400 m transects spaced 25 m apart, eight pairs per plot (Gratto-Trevor, 1996). Each observer recorded all shorebirds and passerines observed on the ground or flushed within 12.5 m on either side (i.e., each transect was 25 m wide). All shorebirds and passerines observed flying into the plot and landing were also recorded. All obvious male/female pairs were noted and recorded as two individuals; however, a displaying male seen alone was not assumed to represent a breeding pair within the plot and was recorded as a single individual. If an individual showed obvious distraction behavior toward an observer, then a nest search was conducted. If a nest was found, the number of eggs or evidence of hatch was recorded. If the nest was not found after a thorough search, presence of a nest was still assumed. Plots were surveyed between 9:00 a.m. and 4:00 p.m. each day. Surveys were not conducted during periods of rain, strong winds (> 30 km/h), or restricted visibility (e.g., fog). Each plot was surveyed once in each year of the study. Densities of shorebirds and passerines were calculated as the mean number of birds per plot, which was then extrapolated to birds per square kilometre. Distributions of species among the different habitat types were compared using Kruskal-Wallis tests followed by Dunn's tests for post-hoc multiple comparisons.

To determine the number of shorebirds staging at Creswell Bay prior to migration, post-breeding surveys were carried out in August 1995. Observers walked sections of the tidal flats and ponds along 21 km of the north shore of Creswell Bay, conducting regular scans with binoculars or spotting scopes. The total daily counts of each shorebird species obtained by each observer were then tallied. Every effort possible was made not to double-count birds. These counts, however, likely represent the minimum number of shorebirds present along this coastline because on any given day, we could not view all of the numerous small tidal ponds that might have held birds. Daily counts were standardized according to the distance covered each day.

RESULTS

Habitat Classification

The supervised image produced eight distinct classes or habitat types (Fig. 1). Table 1 describes the five habitat types used by breeding shorebirds and passerines according to surface features, dominant vegetation, percent vegetation cover, moisture, and amount of standing water present in July (mud flats, water/ice/snow and gravel/rocks were excluded). The image was not tested for accuracy directly (i.e., by extensive ground truthing). However, it proved to be a highly accurate guide for placement of bird survey plots within specific habitat types on both the north and south study areas.

For subsequent analysis (e.g., determination of bird species densities), the surface area of each of the five habitat types within the study area was based on the number of pixels in each type. The north and south area classifications reflect the differences between the two in underlying geology and drainage. Although the two areas contain similar amounts of sedge-dominated vegetation (north: 22%; south: 20%; Table 1), the north area contains 7% sedge marsh habitat type, whereas the south area lacks this type of habitat. In addition, although a shrub-dominated community was the main habitat type in both areas (north: 43%; south: 24%), *Dryas* spp. dominated this habitat in the north, whereas *Cassiope* spp. dominated it in the south.

Survey Conditions

Surveys were initially planned for 1995 and 1996. In 1995, the Creswell Bay area was 90% free of snow at the beginning of the study period on 16 June, and the remaining snow disappeared by 23 June. The weather was sunny with occasional days of fog or drizzle. In 1996, the Creswell Bay area was 95% snow-covered upon our arrival on 8 June, and after two more weeks of cool, cloudy conditions, 85% snow cover remained. The field season was terminated because few shorebirds were arriving at Creswell Bay. Consequently, a third field season was mounted in 1997. Upon our arrival on 22 June 1997, conditions were very similar to those of 1995: the area was 80% snow-free, and all remaining snow was gone within a week. Weather conditions remained favourable for the majority of the survey period, with occasional days of fog, drizzle, or rain. Examination of weather records from Resolute Bay do not point to any obvious differences in average daily temperature (April–June) or total snowfall (October–May) between 1995 and 1996. However, Resolute Bay is 200 km north of Creswell Bay and may not have reflected conditions at Creswell Bay, particularly in the rate of snowmelt.

Bird Surveys

Thirty-four 400 × 400 m plots were surveyed in 1995 in the north area. In 1997, 33 of these plots were resurveyed, in addition to 26 new plots in the north area and 30 plots in the south area (Tables 2 and 3). The south area was treated separately because of the different vegetation (i.e., large amount of evergreen shrub–dominated tundra) and earlier studies (Alliston et al., 1976) that had indicated considerably lower densities of shorebirds there compared to the north area. The plots surveyed in both 1995 and 1997 in the north area did not differ significantly in the densities of shorebird species observed in either year (paired t-test, $p = .223$) (Table 2). The overall density of shorebirds in the north area was slightly higher in 1997 than in 1995 (37.3 versus 33.1/km^2). In both years, shorebirds were most abundant in sedge marsh (77.5/km^2 in 1995) followed by sedge wetland (51.4/km^2 in 1997), mixed dwarf shrub tundra (29.1/km^2 in 1997), and sparse herbaceous tundra (16.7/km^2 in 1997; Table 2). Shorebird densities were considerably higher in the north area than the south area (Tables 2 and 3), but differences in habitat (i.e., dwarf shrub tundra versus evergreen/deciduous shrub tundra;

TABLE 1. Characteristics of the habitat types at Creswell Bay.

Habitat Type	Surface Type	Dominant Vegetation	% Vegetation Cover	Moisture	% Standing Water
Sedge marsh	tussock tundra	sedge (*Carex* spp.)	100	100% saturated	10–35
Sedge wetland	tussock/hummock tundra	mainly sedge with some cotton grass (*Eriophorum* spp.)	100	60% saturated, 40% moist	< 10
Mixed dwarf shrub tundra	high/low centred polygons, finely patterned bare ground, scattered tussocks/hummocks	willow (*Salix* spp.) and dryas (*Dryas* spp.) with scattered sedge and moss	60–80	10% saturated tundra, 50% moist, 40% dry	< 5
Evergreen/deciduous shrub tundra[1]	high/low centred polygons, scattered tussocks/hummocks	heath (*Cassiope* spp.) and willow with scattered sedge	60–80	20% moist, 80% dry	< 5
Sparse herbaceous tundra	bare ground/rock, scattered tussocks and saxifrage (*Saxifraga* spp.)	saxifrage, grasses and herbs (e.g., *Papaver* spp.)	< 10	10% moist, 90% dry	< 2

[1] This habitat type is restricted to the south side of Creswell Bay.

TABLE 2. Mean densities (birds/km², by habitat type) of shorebirds and passerines observed on survey plots in the north area at Creswell Bay in 1995 and 1997.

	Sedge Marsh (21 km²)		Sedge Wetland (42 km²)		Mixed Dwarf Shrub Tundra (76 km²)		Sparse Herbaceous Tundra (50 km²)		All Habitat Types (189 km²)	
	1995 (5)[1]	1997 (11)	1995 (9)	1997 (13)	1995 (13)	1997 (26)	1995 (7)	1997 (9)	1995 (34)	1997 (59)
Shorebirds:										
Black-bellied plover	0	1.1	1.4	0.5	3.8	3.1	1.8	4.2	2.2	2.3
	0	(1.1)[2]	(1.4)	(0.5)	(1.8)	(1.4)	(1.8)	(1.8)	(0.9)	(0.8)
American golden-plover	0	0	0	0	2.4	0.9	1.8	2.1	1.3	0.8
	0	0	0	0	(2.3)	(0.8)	(1.8)	(1.1)	(1.0)	(0.4)
Buff-breasted sandpiper	0	4.0	0.7	3.4	1.0	1.7	1.8	2.8	1.0	2.6
	0	(2.3)	(0.7)	(1.5)	(0.9)	(0.8)	(1.8)	(2.1)	(0.5)	(0.7)
Baird's sandpiper	2.5	0	0.7	0.5	0.5	0	0	0	0.8	0.1
	(2.6)	0	(0.7)	(0.5)	(0.5)	0	0	0	(0.4)	(0.1)
Pectoral sandpiper	12.5	0.6	7.0	2.4	2.0	1.4	0	0	4.4	1.3
	(5.6)	(0.6)	(6.2)	(1.9)	(1.5)	(1.4)	0	0	(2.0)	(0.8)
White-rumped sandpiper	7.5	18.8	20.8	37.5	11.1	17.6	0.9	4.9	11.0	20.3
	(6.1)	(4.3)	(4.2)	(4.8)	(4.6)	(3.4)	(0.9)	(3.4)	(2.5)	(2.4)
Semipalmated sandpiper	0	0	0	0	0	0.5	0	0.7	0.2	0.3
	0	0	0	0	0	(0.3)	0	(0.7)	(0.2)	(0.2)
Sanderling	0	0.6	0	0	0	0	2.7	2.1	0.6	0.4
	0	0	0	0	0	0	(1.9)	(1.1)	(0.4)	(0.2)
Red knot	0	0.6	0	0	0	0	0	0	0	0.1
	0	(0.6)	0	0	0	0	0	0	0	0
Red phalarope	55.0	29.6	9.0	5.8	4.3	3.1	0	0	12.1	8.0
	(10.1)	(7.6)	(2.6)	(2.1)	(1.6)	(1.1)	0	0	(3.5)	(2.1)
Ruddy turnstone	0	1.8	0	1.4	1.0	(0.5)	(2.7)	0	(0.8)	(0.4)
All shorebirds	77.5	56.8	39.6	51.4	26.0	29.1	13.4	16.7	33.1	37.3
	(10.6)	(9.8)	(6.0)	(6.5)	(6.5)	(6.1)	(5.2)	(5.2)	(4.5)	(4.1)
Passerines:										
Horned lark	0	0	0	0	0.5	1.7	4.4	0.7	1.1	0.9
	0	0	0	0	(0.5)	(0.9)	(2.3)	(0.7)	(0.6)	(0.4)
Lapland longspur	17.5	9.7	13.9	13.0	20.2	16.6	3.6	5.6	14.7	12.8
	(5.4)	(2.3)	(5.1)	(2.7)	(4.1)	(2.6)	(2.7)	(2.4)	(2.4)	(1.4)

[1] Number of plots in each vegetation type.
[2] Standard error.

lack of sedge marsh in the south area) precluded statistical comparison of the two areas. In all habitat types on the north area, detectability of shorebirds and passerines showed a downward trend during the 1997 survey period (24 June–6 July), but this trend was not statistically significant ($p \geq .103$ for each habitat type).

TABLE 3. Mean densities (birds/km^2, by habitat type) of shorebirds and passerines observed on survey plots in the south area at Creswell Bay in 1997.

	Sedge Wetland (30 km^2) (10)[1]	Evergreen/Deciduous Shrub Tundra (34 km^2) (14)	Sparse Herbaceous Tundra (18 km^2) (6)	All Habitat Types (82 km^2) (30)
Shorebirds:				
Black-bellied plover	0.6	2.3	0	1.3
	(0.6)[2]	(2.3)	0	(1.1)
American golden-plover	1.3	0.4	0	0.6
	(0.8)	(0.4)	0	(0.4)
Buff-breasted sandpiper	1.3	1.3	0	1.1
	(0.6)	(0.6)	0	(0.6)
Baird's sandpiper	0.6	0	0	0.2
	(0.6)	0	0	(0.2)
Pectoral sandpiper	0	0	0	0
	0	0	0	0
White-rumped sandpiper	5.6	8.1	0	5.6
	(2.4)	(5.9)	0	(2.9)
Semipalmated sandpiper	4.4	4.0	2.1	3.8
	(2.6)	(3.1)	(2.1)	(1.7)
Sanderling	0	0	0	0
	0	0	0	0
Red knot	0	0	0	0
	0	0	0	0
Red phalarope	0	0	0	0
	0	0	0	0
Ruddy turnstone	0	0	0	0
	0	0	0	0
All shorebirds	13.8	16.1	2.1	12.5
	(3.3)	(7.4)	(2.1)	(3.7)
Passerines:				
Horned lark	5.0	0	0	1.7
	(2.8)	0	0	(1.0)
Lapland longspur	17.5	7.6	5.2	10.5
	(3.7)	(2.4)	(3.4)	(2.0)
Snow bunting	0	0	1.1	0.2
	0	0	(1.1)	(0.2)

[1] Number of plots in each vegetation type.
[2] Standard error.

Species abundance on the north area differed in the two study years. In 1995, the red phalarope was the most common species, followed by white-rumped sandpiper, pectoral sandpiper (*Calidris melanotos*), black-bellied plover (*Pluvialis squatarola*), and American golden-plover (Table 2). In 1997, the white-rumped sandpiper was the most common species, followed by red phalarope, buff-breasted sandpiper, black-bellied plover, and pectoral sandpiper. Of the most frequently observed species, white-rumped sandpipers increased by 102% in 1997 ($p = .002$) compared to 1995 and red phalaropes decreased by 32%, although this decrease was not significant (Table 4). Buff-breasted sandpipers increased by 140% in 1997 ($p = .017$). Most notable on the south area in 1997 was the complete lack of red phalaropes, sanderlings, and ruddy turnstones (*Arenaria interpres*). Semipalmated sandpipers (*Calidris pusilla*) and Baird's sandpipers (*Calidris bairdii*) occurred in low numbers in both areas in both years. Lapland longspurs were by far the most common passerine observed in both years in both the north and south areas.

Shorebirds and passerines were noticeably absent from the north area in 1996 because of the nearly complete snow cover that remained through June, including in its extent all the plots surveyed in 1995. During 11–22 June, small numbers of shorebirds, primarily white-rumped sandpipers, sanderlings, and semipalmated sandpipers, were observed around the limited snow-free areas, and some display behaviour was seen. Other shorebirds noted in small numbers were black-bellied plover, American golden-plover, pectoral sandpiper, purple sandpiper (*Calidris maritima*), red phalarope, ruddy turnstone, and red knot (*Calidris canutus*). On 20 June, we conducted a transect survey (four observers 25 m apart) of a small, snow-free "sedge wetland" (8.9 ha) and adjacent beach ridges (20.9 ha, primarily "sparse herbaceous tundra"). The density of shorebirds observed was 449 birds/km^2 in the sedge wetland and 57 birds/km^2 for the beach ridges, but no evidence of nesting was obtained.

White-rumped sandpipers and sanderlings were the two shorebirds observed most frequently on surveys along the north area coast during the post-nesting period in August 1995 (Table 5). Both species increased in abundance during the study period: highest numbers were reached on

TABLE 4. Changes (± %) in shorebird and passerine species numbers on 34 plots surveyed in 1995 and 1997 on the north area (paired t-test, 33 df).

	Change
Shorebirds:	
Black-bellied plover	+50%
American golden-plover	-43%
Baird's sandpiper	-75%
Buff-breasted sandpiper	+140%
Pectoral sandpiper	-50%
White-rumped sandpiper	+102%
Semipalmated sandpiper	+200%
Sanderling	-33%
Red phalarope	-32%
Ruddy turnstone	-33%
All shorebirds	+18%
Passerines:	
Horned lark	-17%
Lapland longspur	-11%
All passerines	-12%

20 August, when 6431 white-rumped sandpipers and 1427 sanderlings were recorded. Nine other shorebird species were also observed during the study period, although numbers were less than 50 (Table 5). Purple sandpipers were not observed during the spring surveys, and those present in August were likely passage migrants from farther north.

Habitat Use

For analysis of habitat use by shorebirds, the 1997 survey data (north area only) were used since, as already noted, there was little difference between 1995 and 1997, and sample size was considerably larger in 1997 (59 versus 34 plots). Four of 10 shorebird species showed significant differences in their densities between the various habitat types (Table 6). American golden-plovers and sanderlings were significantly more abundant in sparse herbaceous tundra. Red phalaropes were significantly more abundant in sedge marsh, while white-rumped sandpipers were more abundant in sedge wetland. For all shorebirds, sedge marsh and sedge wetlands were equal in terms of shorebird abundance, followed by sparse herbaceous tundra and mixed dwarf shrub tundra, which were also equal. Lapland longspurs were similar in abundance in all well-vegetated habitat types (p = .07), with smaller numbers in sparse herbaceous tundra. A similar analysis of habitat use on the south area was not attempted because of the small samples of birds observed for some of the habitat types.

Population Estimates

Estimated numbers of the 10 shorebird species and three passerines observed during surveys are presented in Table 7. There were an estimated 10 341 (± 6596) shorebirds on the north area during the breeding season in 1995 and 13 545 (± 8190) in 1997. The difference between the two years reflects the significantly lower numbers of buff-breasted sandpipers and white-rumped sandpipers observed in 1995. The estimated total number of shorebirds using the north and south areas during the 1997 breeding season was 14 840 (± 10 774) (Table 7). There were an estimated 5823 ± 3650 Lapland longspurs on the north and south areas as well as 566 ± 563 horned larks (*Eremophila alpestris*). White-rumped sandpipers and Lapland longspurs were the most abundant species on the study area.

TABLE 5. Counts of shorebirds during daily coastal surveys at Creswell Bay in August 1995. Parentheses show mean number of individuals of each species observed per linear kilometre on a given survey date.

Date	13 Aug	14 Aug	15 Aug	16 Aug	17 Aug	18 Aug	19 Aug	20 Aug
Survey length (km)	6.0	9.5	14.0	13.5	10.0	20.5	23.5	21.7
Black-bellied plover	46 (8)		22 (2)			12 (1)		4 (0.2)
American golden-plover								6 (0.3)
Buff-breasted sandpiper				2 (0.2)	2 (0.2)			2 (0.1)
Pectoral sandpiper				1 (0.1)	1 (0.1)	10 (0.5)		40 (1.8)
White-rumped sandpiper	311 (51)	522 (55)	20 (2)	1166 (86)	1105 (111)	2985 (15)	3380 (14)	6431 (296)
Semipalmated sandpiper	2 (0.3)							
Sanderling	236 (39)	50 (5.3)	31 (3.2)	200 (15)	280 (28)	851 (42)	785 (33)	1427 (65)
Purple sandpiper							7 (0.3)	17 (0.8)
Red knot	1 (0.2)							3 (0.2)
Red phalarope				1 (0.1)	1 (0.1)			1 (0.1)
Ruddy turnstone	21 (3.5)				11 (1.1)	5 (0.2)	4 (0.2)	14 (0.7)

TABLE 6. Results of comparing species' distribution on five habitat types (1997–north area only). All species were tested, but only species with significant differences in abundance between habitats are listed.

	$\chi^{2‡}$	p	Location of Significant Differences[1]
American golden-plover	8.92	0.03	sparse herbaceous tundra = mixed dwarf shrub tundra > sedge marsh and sedge wetland
Red phalarope	23.97	< 0.001	sedge marsh > all others
Sanderling	12.75	0.005	found only in sparse herbaceous tundra
White-rumped sandpiper	18.77	< 0.001	sedge wetland = sedge marsh > sparse herbaceous tundra and mixed dwarf shrub tundra
All shorebirds	17.51	0.001	sedge marshland = sedge wetland > sparse herbaceous tundra = mixed dwarf shrub tundra

‡ Statistic from a Kruskal-Wallis test: sedge marsh, n = 11; sedge wetland, n = 13; mixed dwarf shrub tundra, n = 26; sparse herbaceous tundra, n = 9.

[1] Results of Dunn's statistic (non-parametric post-hoc multiple comparisons test, corrected for ties).

Nesting Chronology

In 1995, nesting was well underway for the two most common species on the study area (white-rumped sandpiper and red phalarope) by 17–19 June, when several nests from each species were observed with full clutches. Nests of both these species were still under incubation with no evidence of hatching up to 3 July. In 1997, in contrast, laying was only partially complete by 25–26 June, at which time several nests of both white-rumped sandpipers and red phalaropes contained only two eggs each. The first full clutches for white-rumped sandpipers and red phalaropes were observed on 27 and 29 June, respectively. Nests under incubation were observed up until 12 July, and on 16 July a brood of recently hatched white-rumped sandpipers was observed.

DISCUSSION

Species Richness

The species richness of breeding shorebirds and passerines observed at Creswell Bay in this study—11 and 3 species, respectively—is generally higher than in most other areas of concentrated breeding in the Mid and Low Arctic and exceeds that of all other sites north of Creswell Bay. For example, sites on the Yukon and Alaska North Slope (Richardson and Gollop, 1974; TERA, 1991) and the Mackenzie Delta (Gratto-Trevor, 1994) typically supported 7 to 11 shorebird species. Other sites in the Mid Arctic and closer to Creswell Bay, such as on the Boothia and Melville peninsulas, supported at most eight species. One exception was the Rasmussen Lowlands, 600 km south of Creswell Bay, where Johnston et al. (1999) reported 12 breeding species. It would appear that the series of concentrated shorebird breeding sites in the central Canadian Arctic extending from southern Boothia Peninsula to Creswell Bay on Somerset Island represent the northern limit of the breeding ranges of species such as the buff-breasted sandpiper (Lanctot and Laredo, 1994), pectoral sandpiper (Holmes and Pitelka, 1998), and semipalmated sandpiper (Gratto-Trevor, 1992). Sites with concentrations of breeding shorebirds and passerines become increasingly rare north of Creswell Bay, and species richness decreases markedly. For example, at Polar Bear Pass, Bathurst Island (350 km NE of Creswell Bay), four species of shorebird breed regularly (Parmelee and Payne, 1973; Mayfield, 1983), while at Truelove Lowland, Devon Island (200 km NW of Creswell Bay), eight breeding species have been recorded (Hussell and Holroyd, 1974; Pattie, 1990).

Species Density and Numbers at Creswell Bay

The densities of shorebirds and passerines reported here for the north area in 1997 were not significantly affected by decreasing detectability. The survey was conducted during a restricted period of the breeding season, and decreasing detectability—caused by individuals' becoming more secretive during the breeding season (Meltofte, 2001) and by the early departure of non-incubating parents in uniparental species, failed nesters, and non-breeders (Gratto-Trevor et al., 1998)—was likely not a factor. This was also likely the case in 1995, since in both years surveys were initiated immediately after snowmelt and conducted during a restricted period. However, for the south area, the relative lateness of surveys (12–16 July) may have meant there were fewer birds there compared to earlier in the season.

The overall density of nesting shorebirds on the north area is similar to that observed in 1975 for the same area (Alliston et al., 1976). At that time, 63 shorebirds/km^2 were recorded in "thermokarst," which is composed of sedge marsh and sedge wetland habitat types. In the present study, these two habitat types contained 67 and 45 shorebirds/km^2 respectively (average = 56 shorebirds/km^2). Comparisons with Alliston et al. (1976) must be made cautiously since their estimates were based on a smaller sample size obtained in mid to late July, when lower counts would be expected because a portion of the breeding population would have already departed (Gratto-Trevor et al., 1998). The species densities at Creswell Bay, in particular the north area, equal densities found at some sites in the Low and Mid Arctic, where typically the breeding density of all shorebird species ranges from 14–98 shorebirds/km^2 (cf. Patterson and Alliston, 1978; Dickson et al., 1988; TERA, 1991; Gratto-Trevor, 1996; Morrison, 1997; Johnston et al., 1999). At Polar Bear Pass, shorebird densities recorded in the 1970s (Mayfield, 1983) were 8–15 breeding pairs/km^2, or a minimum of 16–30 shorebirds/km^2, in "sedge-moss meadow" (compared to 51 shorebirds/km^2 in sedge wetlands in 1997, this study). At Truelove Lowland, at the same latitude as Polar Bear Pass, shorebird densities were reported as 2–6 shorebirds/km^2. Farther north, at Lake Hazen and Alexandra Fiord on Ellesmere Island, shorebird densities were in the range of 1–3 shorebirds/km^2 (Savile and Oliver, 1964; Freedman and Svoboda, 1982). The breeding densities of passerines at Creswell Bay were similar to those at Rasmussen Lowlands, where densities of Lapland longspurs and horned larks were 22/km^2 and 1.0/km^2, respectively. However, on the North Slope of Alaska the density of Lapland longspurs was considerably higher (66/km^2; TERA, 1991).

The estimated maximum number of shorebirds nesting at Creswell Bay was 14 840 (13 545 in north + 1295 in south, Table 7). The white-rumped sandpiper (5968) and red phalarope (3557) were the two most numerous species, far exceeding the next closest, the pectoral sandpiper. However, these two species switched in abundance between 1995 and 1997. Red phalaropes are non-philopatric; thus, considerable variability in their annual abundance at specific Arctic breeding sites is typical (Tracy et al., 2002). Annual variability in breeding numbers at Creswell Bay may reflect these species' being on the edge of their main breeding range (Parmelee, 1992; Tracy et al., 2002). Alliston et al. (1976) also reported that white-rumped sandpiper and red phalarope were the most numerous species at Creswell Bay. They reported a density of white-rumped sandpipers (24.4/km^2) in "thermokarst" similar to that found in the present study (28.1/km^2). Red phalarope density in 1975 (19.2/km^2), however, was considerably lower than in the present study (32.0/km^2). Alliston et al. did not observe the pectoral sandpiper and buff-breasted sandpiper, the next most numerous species in the present study. These two species are also non-philopatric, and considerable annual variability in their numbers has been observed in Arctic breeding areas (Lanctot and Laredo, 1994; Holmes and Pitelka, 1998).

There does not appear to have been a major decline in the numbers of breeding shorebirds at Creswell Bay between the mid 1970s and 1990s, such as that seen at Rasmussen Lowlands (500 km south), the closest large area of concentrated shorebird nesting, where overall shorebird densities have declined by 50% since the mid 1970s (Johnston et al., 1999). Unfortunately, trend data are lacking for shorebirds at breeding sites comparable in

TABLE 7. Estimated numbers and 95% C.I. for shorebirds, by species, in the north and south areas at Creswell Bay. Estimates are based on the maximum density observed in 1995 and 1997 within each habitat type for each species, except buff-breasted sandpiper and white-rumped sandpiper (see footnote).

	North Area	South Area
Shorebirds:		
Black-bellied plover	676 ± 508	185 ± 1021
American golden-plover	382 ± 399	86 ± 147
Buff-breasted sandpiper	764 ± 899	144 ± 270
Baird's sandpiper	235 ± 167	29 ± 69
Pectoral sandpiper	1293 ± 630	–
White-rumped sandpiper	5968 ± 2468 (3224 ± 1572)[1]	801 ± 1077
Semipalmated sandpiper	88 ± 129	357 ± 636
Sanderling	176 ± 164	–
Red knot	29 ± 55	–
Red phalarope	3557 ± 2304	–
Ruddy turnstone	377 ± 467	–
Total all shorebirds	13545 ± 8190 (10341 ± 6596)[2]	1295 ± 2584
Passerines:		
Horned lark	323 ± 257	243 ± 306
Lapland longspur	4321 ± 1530	1502 ± 2120
Snow bunting	–	157 ± 372
Total all passerines	4644 ± 1787	1902 ± 2798

[1] Significantly fewer buff-breasted sandpipers and white-rumped sandpipers were observed in 1995 than in 1997; therefore, 1995 estimates are given in brackets.

[2] Estimate of total shorebirds is based on maximum densities and, for buff-breasted sandpipers and white-rumped sandpipers, the significantly higher densities observed in 1997 (1995 in parentheses).

latitude to Creswell Bay, and indeed across much of the northern limit of shorebird breeding range. Recently, however, steps are being taken at the international level to address this situation (Skagen et al., 2003).

In 1996, although several species were observed to 'pack' into the small amount of available breeding habitat, there appeared to be almost no shorebird and passerine breeding at Creswell Bay because of prolonged snow cover over much of the area that year. This phenomenon has been documented elsewhere on northern breeding areas, and indications are that these events probably occur every several years at Arctic breeding sites (Green et al., 1977; Mayfield, 1978). The two- to three-week difference between 1995 and 1997 in nesting chronology likely indicates the maximum leeway shorebirds breeding at Mid to High Arctic latitudes have in order to achieve successful fledging of young before the first fall storms.

In addition to being a regionally important shorebird breeding site, Creswell Bay appears to be an important post-breeding staging site. The north shore supported large numbers of white-rumped sandpipers and sanderlings at post-breeding time. The greater numbers of these species observed in August 1995 compared to the numbers estimated during the breeding season that same year may have resulted from locally hatched fledglings' swelling the total number of individuals. It may also indicate that Creswell Bay is an important stopover site for individuals of a number of species migrating through from farther north.

Significance of Creswell Bay

This study indicates that Creswell Bay continues to be an important shorebird breeding site in the Canadian Arctic Islands. Although other concentrations of breeding shorebirds occur at points farther north, Creswell Bay is the most northern large area of exceptional shorebird breeding density in the Canadian Arctic Islands. While some species breeding there are well within their known breeding range, others, such as the white-rumped sandpiper, semipalmated sandpiper, and sanderling, are at the northern limit.

Since the early 1960s, the Canadian Wildlife Service (CWS) has created protected areas (Migratory Bird Sanctuaries and National Wildlife Areas) in northern Canada to protect important habitat for migratory birds. CWS uses specific criteria (Fuller, 1980; Alexander et al., 1991; Frazier, 1996) to assess the importance of candidate protected areas hosting a migratory bird species or a suite of species, which are based on the known, estimated national populations of these species and whether at least 1% of these populations use the site at some point during the year. Using the estimated breeding numbers determined from maximum breeding densities (1997 versus 1995) at Creswell Bay (Table 7), two species exceed the 1% criterion based on estimated population sizes (Morrison et al., 2001b). White-rumped sandpiper and buff-breasted sandpiper numbers represent 1.5% and 5.1%, respectively, of the estimated North American populations. These high breeding densities, together with the exceptional diversity of breeding shorebirds and the passerine species present, means that this high-latitude site should be accorded a high degree of protection from activities causing disturbance to either the habitat or the birds themselves. All of the lowlands around Creswell Bay, including the north and south areas, were selected as private lands by the Inuit during the negotiation of the Nunavut Final Agreement in 1993. The Inuit chose these lands primarily because of their ecological and cultural importance. Their sense of Creswell Bay's value, in concert with conservation-focused land-use planning for the surrounding area, including the marine offshore, will help ensure the long-term protection of this important site for breeding and staging migratory birds.

ACKNOWLEDGEMENTS

We thank S. Barry, H. Butler, M. d'Entremont, and P. Shepherd for valuable and dedicated assistance in the field. The Canadian Wildlife Service and the Polar Continental Shelf Project provided financial and logistical support for this study. The Northwest Territories Centre for Remote Sensing, in particular H. Epp, provided thorough and efficient analysis and interpretation of the satellite imagery. P. Smith provided valuable criticism of an earlier draft. We appreciate the comments of three anonymous reviewers, which improved the manuscript considerably.

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