University of Alberta

The effects of seismic lines and drill pads on breeding migratory birds in the Kendall Island Migratory Bird Sanctuary, NWT.

by

Amber Renee Ashenhurst ©

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CHAPTER 1. THESIS INTRODUCTION

Arctic Ecosystems

Arctic ecosystems are fragile (Dunbar 1973; Reynolds and Tenhunen 1996) and have a short growing season (50 to 80 days), low plant productivity, cold annual temperatures, the presence of permafrost (which inhibits movement of water both above and below ground), high wind erosion, low annual precipitation, salinization and little organic matter (Bliss and Wein 1972; Babb and Bliss 1974; Walker and Walker 1991; Walker 1996; Truett 2000; Forbes *et al.* 2001). In concert, these factors make arctic ecosystems less resilient to disturbance and contribute to slower recovery times than temperate ecosystems (Babb and Bliss 1974; McKendrick 2000; Forbes *et al.* 2001). Anthropogenic disturbances in the arctic such as mining, oil and gas exploration and extraction, road building, road dust, airstrips, hydrocarbon spills and trash are increasing (Walker and Walker 1991; Felix *et al.* 1992; Walker 1996; Truett 2000). These disturbances may change soil thermal regimes, geochemistry, hydrology, vegetation structure and nutrient levels in soil and water (Babb and Bliss 1974; Felix and Raynolds 1989; Raynolds and Felix 1989; Walker and Walker 1991; Felix *et al.* 1992; Emers *et al.* 1995; Walker 1996; Forbes *et al.* 2001). Even minimal disturbances, that do not damage the substrate and slightly damage the vegetation, may take 5-20 years to recover (Babb and Bliss 1974; Walker 1996). If both the substrate and vegetation are impacted recovery usually takes more than 100 years, if at all (Babb and Bliss 1974; Walker and Walker 1991; Walker 1996). Recovery, as defined by the Canadian Wildlife Service and their industrial partners, is the restoration of an impact through natural processes or human assistance to its natural state, which is the combination of flora and fauna at a particular site that is similar (no significant difference) to that which existed prior to industrial activity (Canadian Wildlife Service 2004).

Hydrocarbon Exploration and Development

Hydrocarbon exploration and development has been ongoing in the Canadian arctic since the early 1960's. Oil and gas exploration and extraction introduces drill pads, pipelines, roads, airstrips, winter roads, seismic lines and hydrocarbon spills to the arctic. Gravel drill pads, airstrips and roads are the most conspicuous disturbances and represent a permanent change to the ecosystem if they are not fully reclaimed (Walker 1996). These dry, elevated, artificial features disrupt natural drainage, alter snow drift patterns and do not revegetate naturally to the original vegetation type (Walker 1996; Forbes *et al.* 2001). Winter roads and seismic lines crush vegetation and disrupt the active layer depths (Felix and Raynolds 1989; Felix *et al.* 1992; Walker 1996). A single pass of a vehicle can also drain a wetland due to the ruts left behind (Forbes *et al.* 2001). Dust accumulation from roads eliminates plant species with low dust tolerance (e.g., mosses), thus creating a niche for an alternative community (e.g., willows) (McKendrick 2000). Wet sites tend to recover faster than dry sites after an oil spill as oil disperses in wet sites whereas it is absorbed in dry sites, killing the vegetation (Walker 1996). Diesel spill recovery is very slow as diesel affects vegetation re-growth and creates lasting impressions in permafrost depth (Walker 1996).

Disturbance

Disturbance has four elements that affect the structure and recovery time of the vegetation: frequency, intensity, scale and timing (White and Pickett 1985; Hobbs and Huenneke 1992; Troy 2000; Forbes *et al.* 2001). In the context of hydrocarbon exploration, frequency is the number of seismic lines or other disturbances (e.g., drill pads) per unit area. As exploration begins, the habitat is bisected by seismic lines or perforated by drill pads and/or camps (Hunter 1996). As frequency increases the habitat becomes more fragmented, possibly reducing the quality or availability of habitat for wildlife. Intensity is the level of disturbance to the ground and vegetation. For example, soil compaction and crushing of vegetation by seismic activity in summer would be more intense than seismic activity conducted in winter over snow. Scale is the grain of the disturbance (e.g., width of seismic lines) and the spatial extent of the disturbance. Scale of hydrocarbon exploration and development is usually microscale ($<1km^2$) and often microsite ($<100m^2$) (Walker and Walker 1991). However, these small-scale disturbances may affect species abundance and diversity by creating microscale heterogeneity (Truettt *et al.* 1994). Timing is when the exploration and development occurs. For example, when seismic lines are created in winter they have less impact on the vegetation (Bliss and Wein 1972; Felix and Raynolds 1989; Raynolds and Felix 1989), and occur when all migratory bird species are absent. Since bird abundance, distribution and diversity is related to vegetation structure and composition (Truettt *et al.* 1994; Troy 2000), disturbances that alter vegetation communities are predicted to affect bird populations and communities. In particular, obligate arctic species might be expected to be most susceptible to changes in vegetation (Coppedge *et al.* 2001), due to their restricted habitat preferences.

Arctic Birds

The arctic ecosystem provides important habitat for birds. Some species breed only in the arctic (e.g., arctic tern (*Sterna paradisaea*), greater white-fronted goose (*Anser albifrons*), stilt sandpiper (*Calidris himantopus*) and Lapland longspur (*Calcarius lapponicus*); Sibley 2000) and are considered rare due to their narrow geographic range, habitat specificity and/or local population size (Rabinowitz *et al.* 1986). As well, the breeding ranges of many North American shorebirds are restricted to the arctic (Gratto-Trevor 1994; 1996). The allure of the arctic for breeding birds is the 24-hours of daylight in which to feed young, ample food supply of insects and larvae (Troy 2000), islands free of mammal predators on which to nest, diversity in habitat types, and a limited number of predators. However, nest initiation is not until after the snow melts in the early part of June, which results in a very short nesting season (Troy 2000). In fact, in shorebird species where only one parent incubates the eggs, the other parent begins southward migration as soon as incubation begins, less than a month after arrival (Troy 2000).

Kendall Island Migratory Bird Sanctuary

There has been a lot of biological interest in the outer Mackenzie River Delta, Northwest Territories since the turn of the twentieth century. From 1927 to 1935 A.E. Porsild studied the birds in the Delta and in 1943 he published "Birds of the Mackenzie Delta" in the Canadian Field Naturalist. Porsild noted earlier authors that described fauna in the Delta, i.e., Preble (1908), MacFarlane (1908), and Anderson (1913). In 1949 and 1951, Soper studied the area in the vicinity of Kendall Island to determine "outstanding bird habitats with sanctuary possibilities" (Soper 1952, page 1). The area he outlined (Figure 1.1) was the best bird habitat he had found in the western arctic based on high bird populations, particularly for lesser snow geese

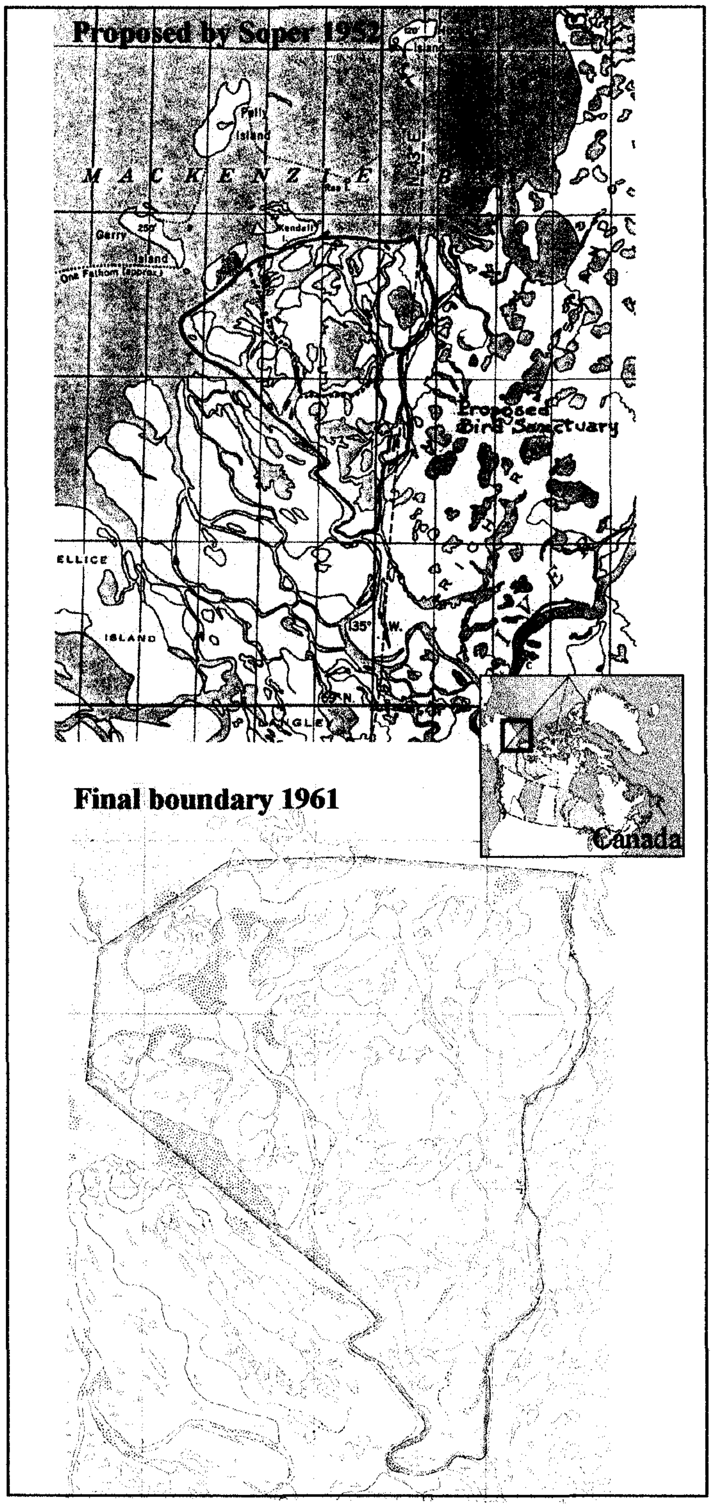

Figure 1.1. Left - Sanctuary boundary as proposed by Soper in 1952 (solid line was proposed for the sanctuary to be within easily recognizable boundaries, dotted line was considered vital for protection of lesser snow geese) (Soper 1952). Right – current sanctuary boundary as established in 1961 (Energy, Mines and Resources Canada 1988).

(*Anser caerulescens).* T. Barry (1961) proposed migratory bird sanctuaries for the Anderson River Delta and Kendall Island and vicinity. He argued that there were no migratory bird sanctuaries in the western arctic and it was the policy of the Canadian Wildlife Service to establish areas to protect migrating and breeding waterfowl. Barry also felt that the Anderson and Kendall areas were the most threatened by development and that the outer Mackenzie Delta was especially threatened because of the potential hydrocarbon opportunities (Barry 1961). In a press release dated December 1961, under the government of Prime Minister Diefenbaker, the Kendall Island Migratory Bird Sanctuary was declared.

The present day Kendall Island Migratory Bird Sanctuary encompasses 623 km^2 (Figure 1.1) and its boundary closely resembles the original boundary proposed by Soper in 1952. The justification for the sanctuary was for long-term protection of colonies of lesser snow geese on some of the outer islands (Canadian Wildlife Service 1992). However, this area also protected key nesting and staging habitats for 84 other bird species including waterfowl, waterbirds, shorebirds, grouse, raptors and passerines (Canadian Wildlife Service 1992). This outer part of the Mackenzie River Delta has high species diversity and abundance of breeding birds (Alexander *et al.* 1988) due to the diversity of habitats in this arctic estuary.

Discoveries of oil and gas under the sanctuary have raised concerns about the effects of hydrocarbon development on sensitive tundra ecosystems and the bird populations they support (Dickson 1992). Taglu and Niglingtak are two proven natural gas fields that lie under the sanctuary. Taglu (100% held by Imperial Resources Ventures Limited) has the largest discovered on-shore gas resources in the Mackenzie Delta with a mean of 58,617.62 million m^3 of marketable gas resources (non-associated and associated[1]) and a mean of 6,227.32 thousand m^3 of recoverable condensate[2] (National Energy Board 1998). Niglingtak (100% held by Shell Canada) has the third largest discovered gas resources in the Mackenzie Delta with a mean of 13,620.98 million m^3 of marketable gas resources (non-associated and associated) and a mean of 22.51 thousand m^3 of recoverable condensate (National Energy Board

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[1] Associated gas is the "gas cap" on the top of the oil in an oil reservoir; non-associated gas is gas in a gas reservoir or formation. (K. Ashenhurst, personal communication).

[2] Condensate in "gas production terms" or hydrocarbon condensate (HC) is the liquid component insitu with the non-associated gas. Condensate should not be mistaken as oil. (K. Ashenhurst, personal communication).

1998). Niglingtak also has the fifth largest discovered oil resources in the Mackenzie Delta with a mean of 3,392.39 thousand m^3 of recoverable oil (National Energy Board 1998). Presently there are six companies that hold Significant Discoveries and/or Exploration licences within these lands.

In 1966, one summer seismic line (9 km of the line was on land) was completed in the sanctuary. Since then, all seismic activities have been completed in winter to minimize the impact to the land (Felix and Raynolds 1989). From 1967 to 1992, there were 891 km of winter seismic exploration on land in the sanctuary. There was relatively little hydrocarbon related activities in the Mackenzie Delta during the 1990's (Bergquist *et al.* 2003), but seismic activities resumed in the sanctuary in 2001. In the winters of 2001 and 2002 there were 102 km of seismic exploration on land in the sanctuary.

The Canadian Wildlife Service has a mandate of allowing a ≤1% anthropogenic footprint on the land within the sanctuary (Canadian Wildlife Service 2004). This footprint fluctuates between 0% and 1% as old impacts recover and new impacts are created. There is 335 km^2 of land in the sanctuary and on this land there is 891km of old seismic lines and 102 km of new seismic lines (993 km total) each 6m wide, 21 drill pads, a gravel pile, two staging areas, and a permanent camp that includes buildings and an airstrip. The seismic lines may affect 6.0 km^2 or 1.8% of the land and the remaining features may affect 2.4 km^2 or 0.72% of the land. There have been no impact studies and thus no determination of the footprint or analysis of recovery completed in the sanctuary.

Vegetation in the Sanctuary

There have been multiple studies in and adjacent to the sanctuary to attempt to classify the vegetation. The first was by Corns (1974) who classified the vegetation on the east side of the Mackenzie Delta (including areas east of the sanctuary). The second was by Gratto-Trevor (1994; 1996) who used a 1986 Landsat Thematic Mapper (TM) image to determine priority shorebird habitat in and adjacent to the sanctuary (Table 1.1). Most recently is by Kemper (in preparation) who studied the effects of seismic exploration on vegetation communities in and adjacent to the sanctuary. The Canadian Wildlife Service uses the classification derived by Gratto-Trevor (1994; 1996), thus I used her terms to define my habitat types (Table 1.1).

Table 1.1. Vegetation classification in the outer Mackenzie River Delta by Corns (1974), Gratto-Trevor (1994; 1996), Ashenhurst (2004) and Kemper (in preparation).

I.G.W. Corns (1974)	**C.L. Gratto-Trevor (1994)**	**A.R. Ashenhurst (2004)**	**J.T. Kemper (in preparation)**
n/a	mudflats	n/a	n/a
herb type aquatic subgroup	emergents	n/a	n/a
tall shrub herb type	wet sedge/willow	sedge/willow	tall shrub herb type wet grammanoid type
tall shrub herb type medium shrub heath	dense willow	dense willow	tall shrub herb type
herb type sedge subgroup herb type aquatic subgroup	Sedge/low centre polygons	low centre polygons	wet grammanoid type
low shrub heath type herb low shrub heath type medium shrub heath type	upland tundra	upland tundra	low shrub heath type/herb low shrub heath type medium shrub heath type

I used the following habitats in my study area: 1) upland tundra (Figure 1.2a) is a Pleistocene upland with short (<3m) alder (*Alnus* spp.) and willow (*Salix* spp.) and variable amounts of sedge (*Carex* spp.) tussocks; 2) low-centre polygon (Figure 1.2b) has a patterned shaped ground with a wet interior dominated by sedges and a moist ridge with willows and sedge; and, 3) sedge/willow (Figure 1.2c) has the same vegetation as low-centre polygon, but does not have the polygonal structure, varies from being very wet to moist and muddy and has varying densities of willow and sedge. Areas closer to the river channels have a higher density of willow than areas farther away (Gratto-Trevor 1994; 1996). I did not study the other habitats found in Table 1.1, as they were either not abundant enough in the sanctuary (emergents and mudflats) or not conducive to my sampling methods (dense willow). The dense willow primarily follows river channels and since seismic lines bisected this habitat type, it was not appropriate for transect sampling and a reference line in the same habitat would not fit parallel to the disturbed transect.

Thesis Objectives

In Chapter 2 my objective was to determine if seismic lines affect the abundance and distribution of breeding migratory birds and, if so, to determine the area of the footprint of seismic lines in the sanctuary. If the seismic lines have recovered, there should be no statistical difference in bird abundance and distribution as compared with unaffected areas. Seismic lines that have not recovered will have birds that either avoid, select for, or increase their territory sizes around affected areas. In Chapter 3 my objective was to examine the effect of drill pads (a permanent anthropogenic feature) on the abundance and distribution on birds. In Chapter 4 I provide conclusions and management recommendations based on my study.

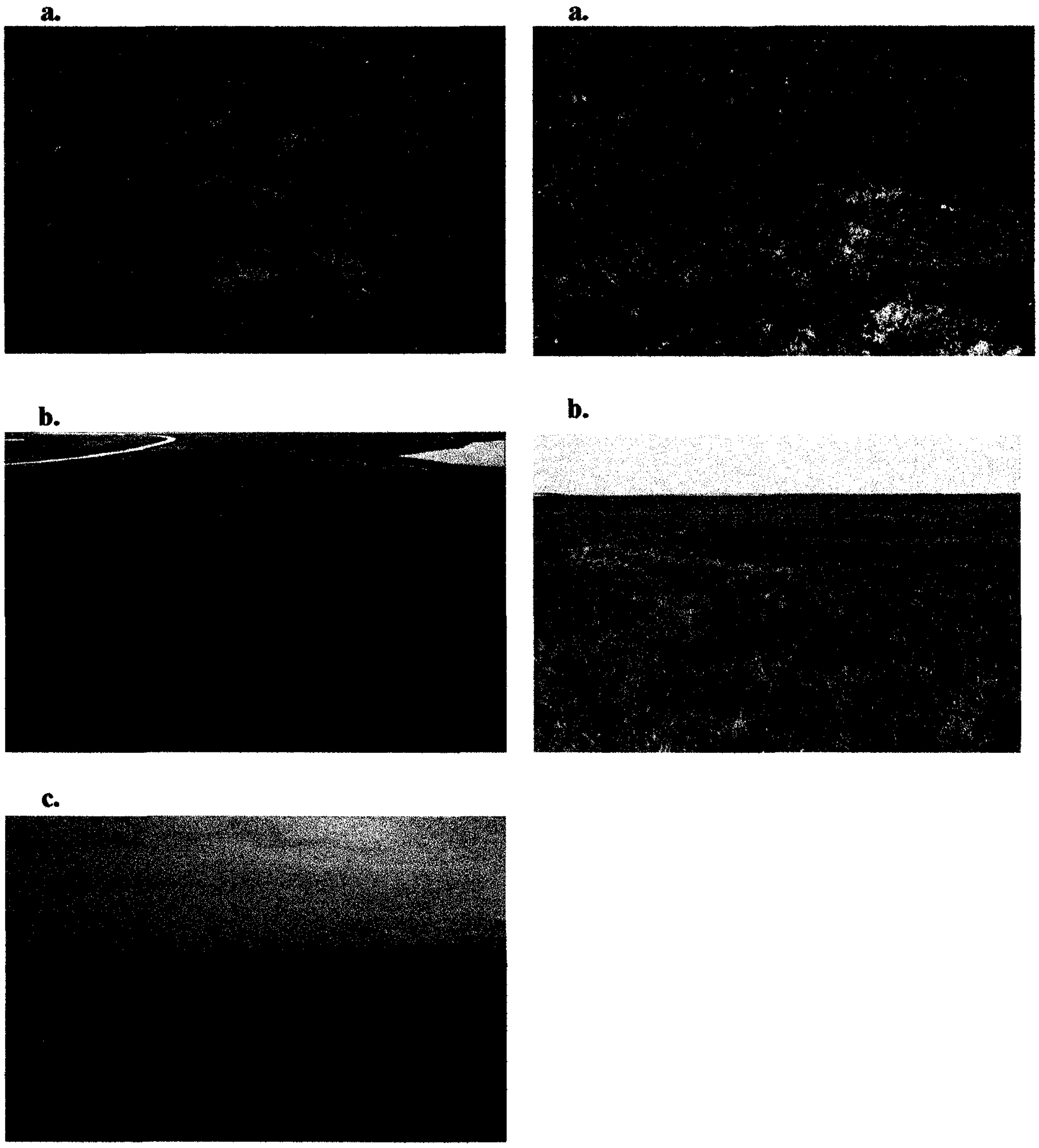

Figure 1.2. Photographs of the three habitat types I studied in the Kendall Island Migratory Bird Sanctuary (a. upland tundra, b. low-centre polygon and c. sedge/willow (with a seismic line)) (all photos by A. Ashenhurst).

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CHAPTER 2. OLD AND NEW SEISMIC LINES AFFECT THE ABUNDANCE AND DISTRIBUTION OF BREEDING MIGRATORY BIRDS IN THE KENDALL ISLAND MIGRATORY BIRD SANCTUARY, NWT

INTRODUCTION

Arctic ecosystems are fragile (Dunbar 1973; Reynolds and Tenhunen 1996), and recover slowly from anthropogenic disturbances (Babb and Bliss 1974). Despite this, human activities, including petroleum development, continue to increase in the arctic (Walker *et al.* 1987, Walker and Walker 1991; Truett *et al.* 1994; Truett 2000; Forbes *et al.* 2001). The arctic has high faunal species richness (Chernov 1995), and provides critical breeding habitat for several species of migratory birds (Alexander *et al.* 1988; Gratto-Trevor 1994, 1996; Chernov 1995). Most North American shorebirds, for example, are restricted to breeding in Arctic Canada and Alaska and habitat destruction or alteration could result in declines of many species (Gratto-Trevor 1994, 1996).

The Kendall Island Migratory Bird Sanctuary was established by the Canadian Wildlife Service (CWS) in 1961 for long-term protection of colonies of breeding lesser snow geese *(Anser caerulescens)* on some of the outer islands of the Mackenzie River Delta, NWT (Canadian Wildlife Service 1992). This area also protects key nesting and staging habitats for 84 other bird species including waterfowl, waterbirds, shorebirds, grouse, raptors and passerines (Canadian Wildlife Service 1992). However, discoveries of oil and gas under the Sanctuary have raised concerns about the effects of hydrocarbon development on sensitive tundra ecosystems and the bird populations they support (Dickson 1992). Some development results in permanent removal of habitat (e.g., drill pads, airstrips, camps), whereas activities such as seismic exploration leave linear features on the landscape due to soil compaction and alteration of vegetation. Summer seismic activities began in the Canadian Arctic in 1965, however this changed to winter seismic activities in the late 1960's to decrease damage to tundra plant communities (Bliss and Wein 1972).

In three studies within the northeast coastal plain of Alaska, vegetation on seismic lines created in winter did not recover 1-2 summers after disturbance (Felix and Raynolds 1989), 4-5 summers after disturbance (Felix *et al.* 1992) or 7-8 summers after disturbance (Emers *et al.* 1995). All three studies were competed in upland and wetland areas. Removal of vegetation or alteration of plant communities may affect the distribution and abundance of breeding birds; in particular habitat obligate species (Coppedge *et al.* 2001). In addition, if habitat is fragmented by high densities of seismic lines, populations of birds that avoid lines may decline. Although the effects of seismic line fragmentation have not been studied in the arctic, densities of ground nesting birds decrease with increasing fragmentation in other open habitats (e.g., grassland (Winter and Faaborg 1999) and marsh habitats (Benoit and Askins 2002)). There have been some small-scale studies completed on birds in the arctic. For example, Barry (1976), Barry and Spencer (1976), found active drill pads negatively affected 43% of the bird species whereas Troy and Carpenter (1990) found that a gravel P-pad (production-well or drill pad) displaced some bird species while other species were attracted to the disturbance. Troy (1991) found a more diverse group of avian species on abandoned peat roads (roads created by bulldozers in summer but used in winter as roads) than the surrounding area due to the resulting heterogeneity of terrain.

In this study, I examine the impacts of new (0.5-1.5 years old) and old (>10 years, created on or before 1992) seismic lines in the Kendall Island Migratory Bird Sanctuary on the abundance and distribution of birds during the breeding season in three habitat types. The CWS and their industrial partners define a "long-term impact" as the alteration, disruption, removal, covering or degradation of wildlife habitat, which is not restored through natural processes or human assistance to its natural state within three years. A "temporary impact" is defined as the alteration, disruption, removal, covering or degradation of wildlife habitat, which may be restored through natural processes or human assistance to its natural state within three years. A "natural state" is defined as that combination of flora and fauna at a particular site that is similar (no significant difference) to that which existed prior to oil and gas industrial activities (Canadian Wildlife Service 2004).

To determine the effects of the seismic lines, I measured abundance of birds on and distances from the centre of transects on and adjacent to seismic and paired reference lines. Birds could be affected by the seismic line in five ways. They could: 1) select for habitat on the seismic line. In this case, bird abundance should be higher and distance from the centre should be closer on the seismic than on the reference transect; 2) avoid habitat on the seismic line. In this case, bird abundance would be lower on the seismic line transect than on a reference transect and no birds would be detected directly on the seismic line; 3) avoid both habitat on the line and the edge of the line. In this case, bird abundance would be lower and bird distance from the centre of the seismic line transect higher on the seismic than the reference transect; 4) enlarge their territories to compensate for reduced habitat suitability on the seismic line. In this case, bird abundance would be lower, however distance from the centre of the seismic line transect may not be different than the reference transect; or 5) they could be unaffected by the line. In this case, distance from the centre of the line and abundance should not differ between seismic and reference transects.

I also predicted that new seismic lines should have more of an impact on bird abundance and distribution than old seismic lines since old seismic lines have had more time for vegetation to recover. I also predicted that species that were arctic obligates (i.e., full time arctic residents or migratory species that breed only in the arctic) would be more affected than others, because of their narrow habitat requirements and thus dependence on the arctic tundra as place to breed. Finally, I used my results to determine whether seismic lines are part of the permanent anthropogenic footprint in the sanctuary and if so, whether or not the total footprint is within or beyond the 1% allowable by the Canadian Wildlife Service (Canadian Wildlife Service 2004).

METHODS

Study Area

Field research took place in 2002 and 2003, in and adjacent to the Kendall Island Migratory Bird Sanctuary, NWT (69° 15"N and 135° 00"W, Figure 2.1). This area has six habitat types as used by Gratto-Trevor (1994, 1996); mudflats, emergents, dense willow (*Salix* spp.), wet sedge/willow, low-centre polygon, and upland tundra (see Chapter 1 for habitat comparison to Corns (1974) and Kemper (in preparation)). Mudflats have no vegetative cover and emergent habitat has sparse *Equisetum* cover. Dense willow habitat has dense cover of alder (*Alnus* spp.) and tall willow (*Salix* spp.) and is most often adjacent to river channels in the sanctuary. Upland tundra habitat is a dry Pleistocene upland with dwarf shrubs and forbs, and sedge tussocks. Low-centre polygon habitat is a wetland with a patterned ground structure where the interior of the polygon is wet and dominated by sedges (*Carex* spp.) and the ridges are moist and

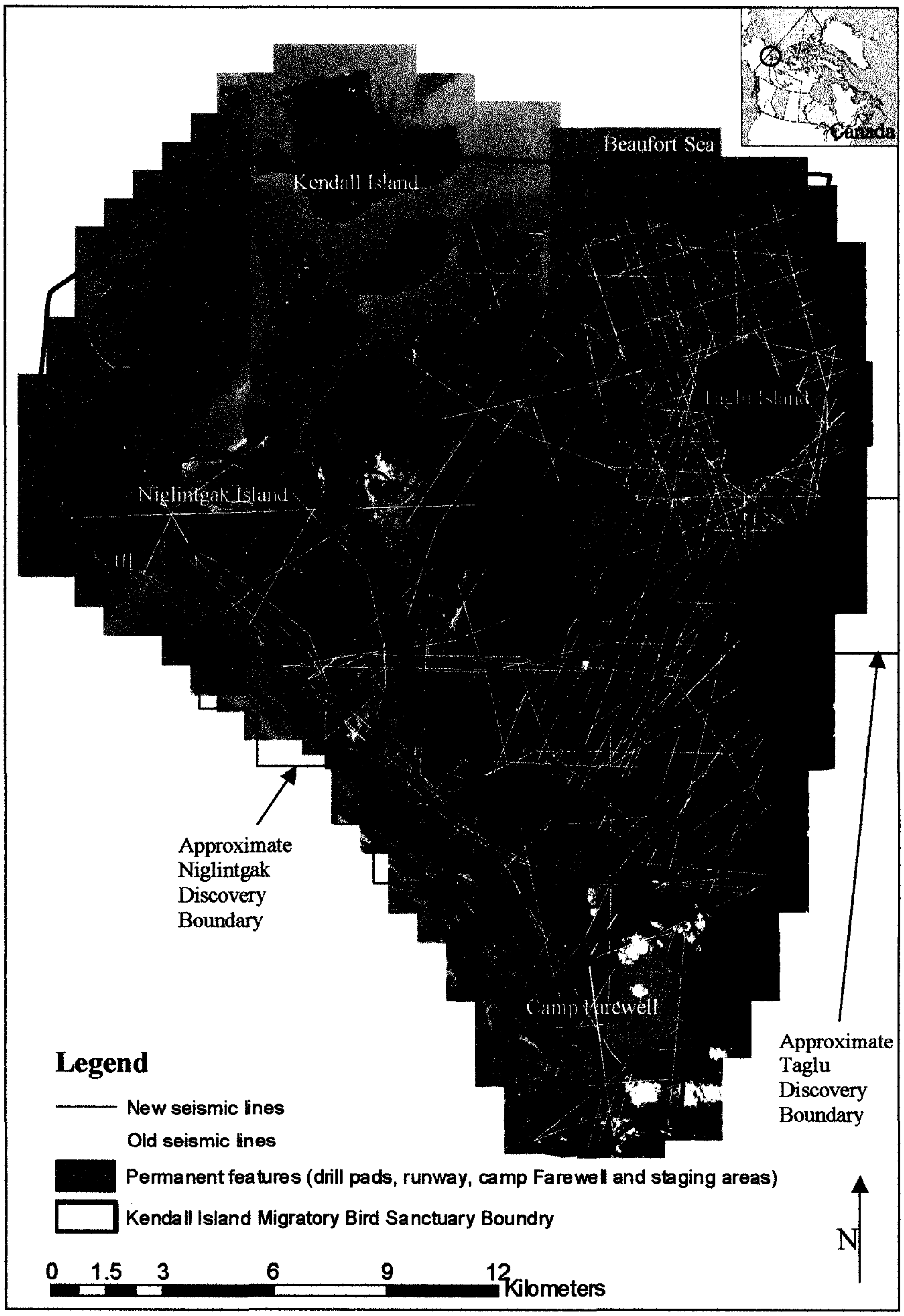

Figure 2.1. GIS layer of the location and boundary of the Kendall Island Migratory Bird Sanctuary, NWT as well as the two largest Significant Discoveries, all terrestrial new and old seismic lines and permanent features.

vegetated with willows and sedges. Wet sedge/willow (herein called sedge/willow) habitat is also a wetland with the same vegetation as low-centre polygon but without the patterned ground, has gradients of short to medium willow cover, and varies from being very wet (~50cm water) to moist and muddy. I studied upland tundra, low-centre polygon and sedge/willow habitats (Figure 2.2). Dense willow habitat was too variable (e.g., quantity and height of willows), indistiguishable from the LANDSAT Thematic Mapper (TM) or IKONOS images, did not leaf out due to flooding, and since it followed the river channels it was too narrow a habitat structure for the sampling technique used.

Habitat types were initially determined and described by Jaques (1991) using the classified 1986 LANDSAT TM image used by Gratto-Trevor (1994, 1996). The map has 25 LANDSAT Classification Units which were grouped into 6 terrestrial habitats by Gratto-Trevor (1994, 1996). She noted that the map was not always accurate, especially at distances more than 10 km from the original, intensively ground-truthed study area of Dickson *et al.* (1989); Dickson and Smith (1991). Therefore, habitat types had to be ground-truthed in the field. To determine the habitat types for the second field season, I used both the LANDSAT TM image and an IKONOS image taken in August of 2002.

The seismic lines studied were 2-dimensional[3], averaged 6 m wide and were produced in the winter by a series of vehicles, each independently powered. Sometimes vehicles drove side by side creating a 13 m wide line but this was not monitored or mapped by CWS, thus 6 m was the average width for this study. There were old (>10 years old or prior to 1992) and new (0.5-1.5 years old) seismic lines in and adjacent to the sanctuary. The old lines and the new lines created in 2001 were constructed by: a Caterpillar for clearing snow, a survey vehicle, an energy source vehicle (dynamite), a receiver (geophone and recording) vehicle and sometimes a camp vehicle in which the workers lived (Coffeen 1986; Raynolds and Felix 1989; Felix *et al.* 1992). Starting around 1971, the blade on the Caterpillar had 'mushroom shoes' to reduce the impact to the vegetation (Bliss and Wein 1972). The new lines created in 2002 were completed with ~4 - 42,000lbs vibroseis vehicles as the energy source vehicle and did not use a Caterpillar to clear the snow. The CWS currently

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[3] 2-dimensional seismic has source and receiver lines on the same line as compared to 3-dimensional seismic where source lines are perpendicular to receiver lines.

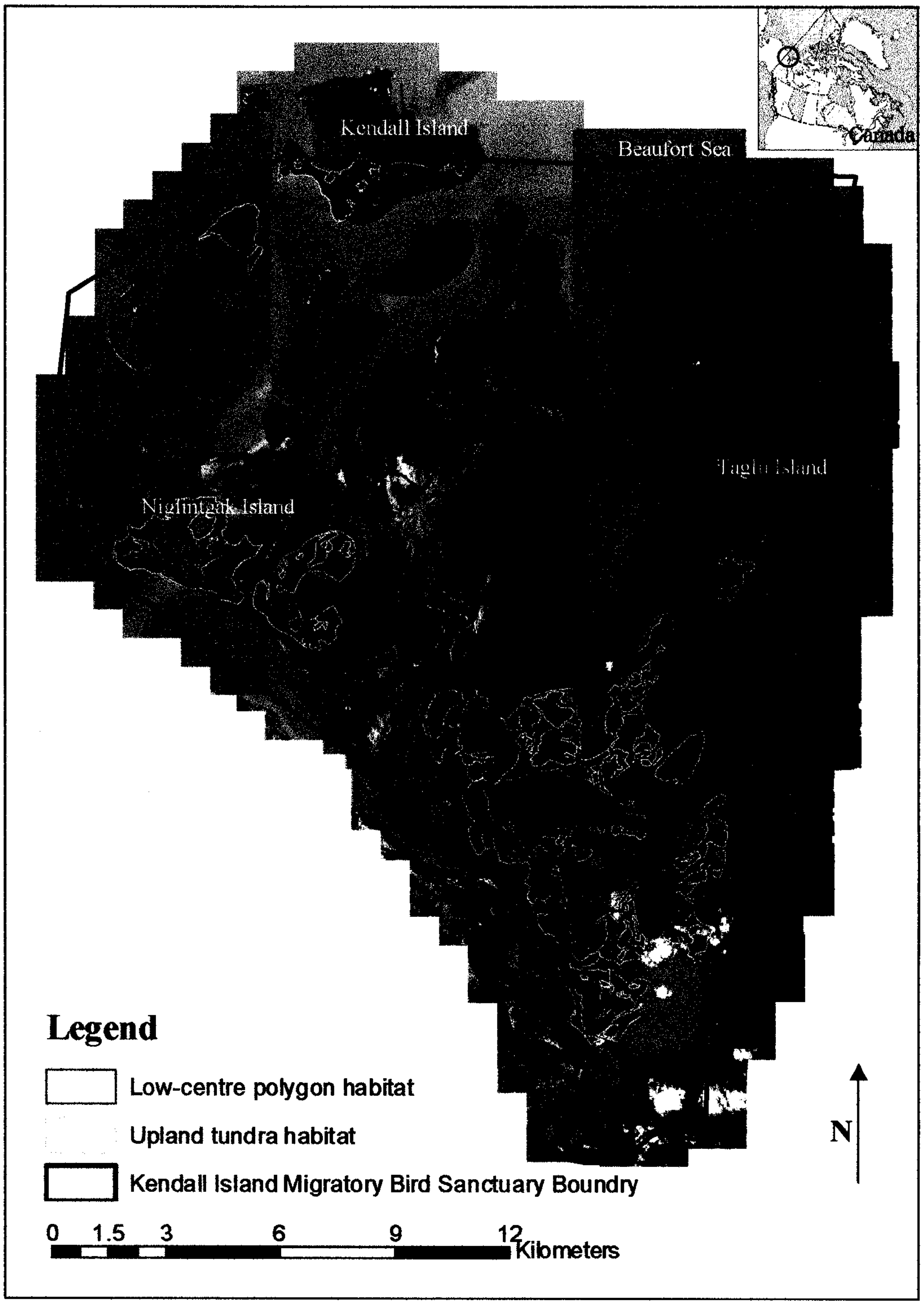


Figure 2.2. GIS layer of the upland tundra and low-centre polygon habitats within the Kendall Island Migratory Bird Sanctuary, NWT.

dictates that seismic companies use the vibroseis technique as it is thought to be less harmful than blading by Caterpillars. Seismic companies targeted subsurface geology and therefore the seismic lines are not randomly distributed throughout the sanctuary. Seismic lines are denser in low-centre polygon habitat than any other habitat (Table 2.1).

Paired Transect Design

We sampled birds using a paired design of treatment and reference transects, each 100m wide. The treatment transect was centered on the seismic line and the reference was parallel to it (either right or left) and offset by 150m (2002) or 200m (2003) from the centre of the treatment transect (Figure 2.3). The position of the reference transect with respect to the seismic line was randomly chosen, except in situations where the reference was too close to a different habitat type or another seismic line. The distance between the treatment and reference was widened in 2003 to avoid double sampling the same bird. The distance was based on the average radius of a small passerine's or shorebird's home range (e.g., 30m radius for savannah sparrow; Wheelwright and Rising 1993; all scientific names are in Table 2.3). All new seismic line transects sampled in 2002 were approximately 500m long to detect statistical differences in bird abundance, as suggested in Hanowski *et al.* (1990). This was an acceptable distance for highly abundant species, however to detect statistical differences in less abundant bird species and in habitats with lower bird densities, old seismic line transects were longer than 500m in 2003 (Table 2.1).

To determine the location of potential transects within the three habitat types, I first used both the classified LANDSAT TM image (see above) and a 2002 IKONOS image to locate the habitat types. To locate seismic lines I used both a Geographic Information software (GIS) layer of old seismic lines (National Energy Board 2002) and a map obtained from Anadarko Canada Corporation showing locations of new seismic lines. I chose new seismic lines that were further than 50m from each other and old lines that were farther than 300m from all other seismic lines, and then located these lines in the field. The new lines were closer as they were not abundant enough to allow a greater separation. If the habitat type corresponded to the mapped habitat type, I chose to sample these lines. I was able to visually locate all new lines in the field. However, since the old seismic lines were often inaccurate on the GIS layer

Table 2.1. Area of terrestrial habitats, proportions of each habitat in the sanctuary and length of seismic lines (km) in the Kendall Island Migratory Bird Sanctuary, NWT.

Habitat	km^2 area	% of total area[1]	km of new lines	% of all new	km of old lines	% of all old	total km of lines	% total	km of lines/1km^2
Upland tundra	49.3	15%	7.0	7%	121.0	14%	128.0	13%	2.6
Low-centre polygon	71.6	21%	29.7	29%	319.4	36%	349.1	35%	4.9
Other (sedge/willow, dense willow, mudflats, emergents, polygonal upland tundra)	214.3	64%	65.5	64%	450.3	50%	515.8	52%	2.4
Total	**335.2**	**100%**	**102.2**	**100%**	**890.7**	**100%**	**992.9**	**100%**	**3.0**

[1] Percent of the total land area.

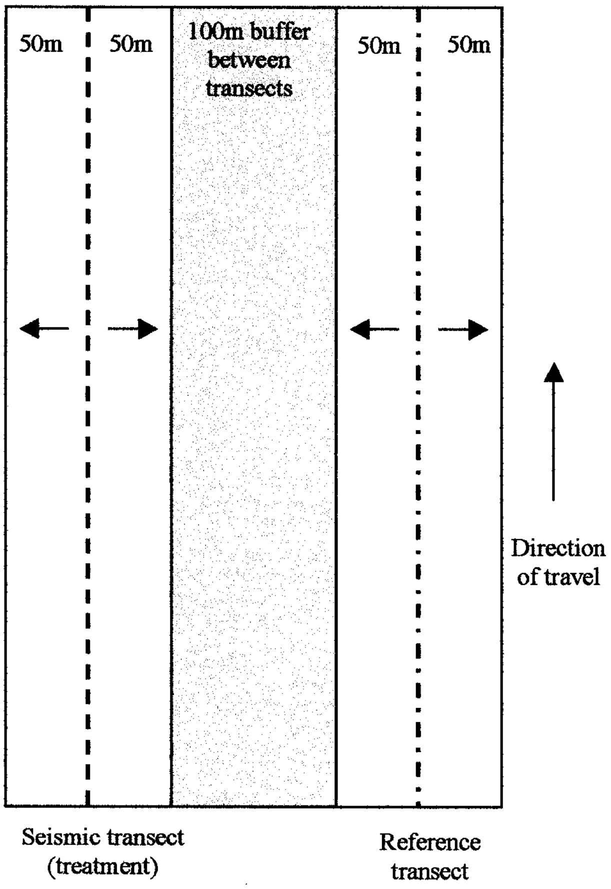


Figure 2.3. Paired line transect design for 2003 field season. In 2002 (and new lines in 2003) the buffer between transects was 50m.

(e.g., 0-~100m displaced), all the old seismic lines sampled had to be seen in order to ensure that the transect was on a seismic line. Some old lines sampled were barely visible and some were highly visible. All lines sampled had to have an area parallel to them within the same habitat that was large enough for the reference transect.

Sampling on Transects

Transects were sampled starting in early June and ending when the breeding season was over and the young birds had fledged (early July). Treatment and reference transect pairs were sampled simultaneously and to avoid bias, observers alternated every other treatment and control transect. In 2002, there were four observers, two per transect. In 2003 there were two observers, one per transect. All observers were well trained in bird identification. At the start of a survey, we recorded the date, time, habitat type, compass direction of the line, GPS location of the start of the line, percent cloud cover, precipitation, temperature, and wind speed using the Beaufort scale (Atmospheric Environment Service 1970). Sampling was not done during heavy rain, fog, snow or strong winds (greater than 4 (20-29km/hour) on the Beaufort scale). During the survey, we walked at approximately 1km/hour and recorded bird species, sex, perpendicular distance in metres from the centre of the transect (using a hip chain) and distance along the transect from the start (using a GPS). Birds flying above were not recorded and waterfowl were not used in the analysis, due to their rarity or use of water in habitats sampled. Bird behaviour (e.g., foraging, nest material gathering, and singing) was recorded using Bibby's (1992) standard symbols for bird activities. In 2002 we measured the distance and angle of the bird from the centre of the line (Anderson *et al.* 1979; Krebs 1999) using a hip chain and compass and I calculated the perpendicular distance. This sampling technique was very time consuming, so in 2003 we estimated distance perpendicular to the line for savannah sparrows (the most common bird) and measured it for the rest of the birds. This allowed us to complete more transects in 2003.

Between Year Sampling

Over the two summers, I sampled 81 paired transect lines totaling 62.1km: 46 new lines (0.5-1.5 yr old) in upland tundra, low-centre polygon and sedge/willow in 2002, and 35 old lines (>10 yr old) in upland tundra and low-centre polygon in 2003

Table 2.2). In 2003 I resampled 7 new lines (4.1km) in sedge/willow to determine whether effects noted in 2002 had persisted. In 2003 I focused on old lines because I suspected that older lines, made using different technology than new lines, would have vegetation disturbances that persisted longer than new lines. I did not have time to sample old lines in the sedge/willow habitat as I wished to get a large sample size in upland tundra and low-centre polygon habitats. I focused on these two habitats as visual impacts were still apparent on old upland tundra lines and because low-centre polygon habitat is preferred by shorebirds (Gratto-Trevor 1994, 1996), many of which are obligate arctic nesters.

Analysis

Transect Level Analysis

Abundance data were not normally distributed and could not be transformed to normality. Hence, I analyzed these data using a generalized linear model with the quasi-likelihood function (link=log; variance=mu) in S-Plus 2000 (Math Soft 1999). Dispersion parameters were checked but were not close to 1, hence Poisson distributed errors could not be used. The dependant variable was abundance of each species with sufficient data (savannah sparrow, Lapland longspur, tree sparrow, common redpoll, red-necked phalarope and Whimbrel) or species combined (all passerines excluding savannah sparrows and all shorebirds excluding Whimbrel). I removed savannah sparrows from all passerines and Whimbrel from all shorebirds since they were the most abundant passerine and shorebird respectively, and hence highly influenced the outcome of the analysis. Factors in the analysis were habitat (habitat type, age (new and old)), treatment (reference or seismic line), habitat x treatment interaction, and block. Data were blocked by transect location since the reference and seismic lines were paired at each location. Because I sampled new lines in 2002 and old lines in 2003, the effect of line age was confounded by year. Hence to try to isolate line age effects from year effects, I subtracted the abundance of birds on the seismic line from the number on its paired reference line and since the data were normally distributed, I compared the mean difference across ages within habitat type using a two-sample t-test in SYSTAT Version 10 (SPSS Inc. 2000). I assumed that although the overall abundance of birds might change over years, their relative response to the seismic and reference lines should be the same.

Table 2.2. Number of paired transects, average transect length (m) and distance (km) sampled for each year and each habitat type.

Year	Habitat type	# paired transects	Average transect length in metres	Total distance in km
2002	upland tundra - new lines	17	506	8.6
	low-centre polygon - new lines	14	500	7.0
	sedge/willow - new lines	15	487	7.3
2003	upland tundra - old lines	21	1271	26.7
	low-centre polygon - old lines	14	893	12.5
	sedge/willow - new lines	7	700	4.9

Distance data were not normally distributed and could not be transformed to normality. Hence, I analyzed the distance data of each species with sufficient data (savannah sparrow, Lapland longspur, tree sparrow and common redpoll) using the Mann-Whitney U test. The program Distance 4.0 was not used for distance analysis as birds were not abundant enough on new lines and only two species in one habitat on old lines were abundant enough to use the program. I used SYSTAT Version 10 (SPSS Inc. 2000) for distance analysis.

To determine if birds avoided the actual seismic line, the number of birds on and off the 6m wide seismic line was compared with the number of birds on (the equivalent of the 6m footprint) and off the reference transect using a G-test in RC Rand. The 6m equivalent on the reference was 3m on either side of the centre of the transect. For the G-test, I used the same species as used in the abundance calculations.

For all statistical tests, I concluded that differences were significantly different if $p<0.1$. I used this conservative value of P since sample sizes for some species were small and variation was high and I wanted to avoid making a type II error (accepting the null hypothesis when it is actually false); which could be detrimental for conservation within a federal bird Sanctuary.

Landscape Level Analysis

The purpose of this analysis was to extrapolate data from the transects to potential impacts of seismic activity over the whole sanctuary. Using ArcMap^{TM} GIS, I determined the area of land and water in the sanctuary. I created polygon GIS layers for low-centre polygon and upland tundra (Figure 2.2, Table 2.1). Sedge/willow habitat was not distinguishable from the LANDSAT TM or IKONOS images and thus I could not create a layer for it. However, sedge/willow habitat is most of the remaining habitat in the "other" category (Table 2.1). I created a line layer for all new seismic lines and used a National Energy Board GIS layer of old seismic lines and superimposed these on the IKONOS image (Figure 2.1). This provided the kilometers of new and old seismic lines on land in each habitat type (Table 2.1).

I created three scenarios of impact of seismic lines on bird abundance in upland tundra and low-centre polygons habitats within the sanctuary: 1) abundance of birds with no seismic lines; 2) abundance of birds under current seismic line density; and 3) possible bird abundance if the current density of new seismic lines was doubled or tripled. For scenario 1, I determined how many birds of certain species would be in each habitat by extrapolating from the density of birds found on my reference lines. For scenario 2, I subtracted the number of birds lost due to the current density of old and new lines in each habitat, based on the effects seen on the treatment transects. For scenario 3, the area of old seismic lines remained the same, but I either doubled or tripled the number of new lines within the two habitat types and calculated loss of each species based on effects seen on the treatment transects. For the current scenario, the mean, best and worst case scenarios for each species were calculated using the upper and lower 95% confidence intervals of the current scenario compared to the no seismic scenario. For example, if a species was denser on the reference transect than the seismic transect, then the best case scenario for reduction in density due to the seismic lines was the lower confidence interval from the reference transect minus the upper confidence interval of the seismic transect. The worst case scenario was the upper confidence interval from the reference transect minus the lower confidence interval from the seismic transect.

RESULTS

Thirty-two species were observed during the surveys (Table 2.3). In general, more birds were observed in 2003 than 2002. For most species, abundances per km walked were not high and species were absent from many transects (Figures 2.4 to 2.6). Table 2.4 indicates the species, habitats and line age categories for which I had sufficient data to test statistically.

Passerines

All passerines (excluding savannah sparrows)

All passerines (excluding savannah sparrows) were more abundant on reference lines than on seismic lines across each habitat type (Figure 2.7, Table 2.5). In 2003, passerines were more abundant on old upland tundra transects than old low-centre polygon transects, but there was no difference between new upland tundra and new low-centre polygon transects in 2002. Neither the treatment x habitat/age/year interaction (Table 2.5), nor the effect of line age in low-centre polygon habitat were significant (Table 2.6), suggesting that differences between reference and seismic transects were similar on new and old lines. However, the effect of line age in upland

Table 2.3. Species list from seismic line and control transects for 2002 and 2003 (* indicates obligate arctic passerines and shorebirds).

Species	Scientific Name	Species Code
Waterfowl		
Northern shoveler	*Anas clypeata*	NOSH
Canada goose	*Branta canadensis*	CAGO
Greater white-fronted goose	*Anser albifrons*	GWFG
Red-throated loon	*Gavia stellata*	RTLO
Green-wing teal	*Anas crecca*	GWTE
Lesser scaup	*Aythya affinis*	LESC
Greater scaup	*Aythya marila*	GRSC
Pacific loon	*Gavia pacifica*	PALO
Northern pintail	*Anas acuta*	NOPI
Tundra swan	*Cygnus columbianus*	TUSW
Long-tailed duck	*Clangula hyemalis*	LTDU
Seabirds		
Arctic tern	*Sterna paradisaea*	ARTE
Grouse		
Willow ptarmigan	*Lagopus lagopus*	WIPT
Passerines		
American tree sparrow	*Spizella arborea*	TRSP
Savannah sparrow	*Passerculus sandwichensis*	SASP
*Lapland longspur	*Calcarius lapponicus*	LALO
Common redpoll	*Carduelis flammea*	CORE
White-crowned sparrow	*Zonotrichia leucophrys*	WCSP
Fox sparrow	*Passerella iliaca*	FOSP
*Hoary redpoll	*Carduelis hornemanni*	HORE
Yellow warbler	*Dendroica petechia*	YEWA
Cliff swallow	*Petrochelidon pyrrhonota*	CLSW
Shorebirds		
Red-necked phalarope	*Phalropus lobatus*	RNPH
Common snipe	*Gallinago gallinago*	COSN
*Stilt sandpiper	*Calidris himantopus*	STSA
*Pectoral sandpiper	*Calidris melanotos*	PESA
*Least sandpiper	*Calidris minutilla*	LESA
*Whimbrel	*Numenius phaeopus*	WHIM
*Hudsonian godwit	*Limosa haemastica*	HUGO
Lesser yellowlegs	*Tringa flavipes*	LEYE
*Semipalmated sandpiper	*Calidris pusilla*	SESA
American golden plover	*Pluvialis dominica*	AGPL

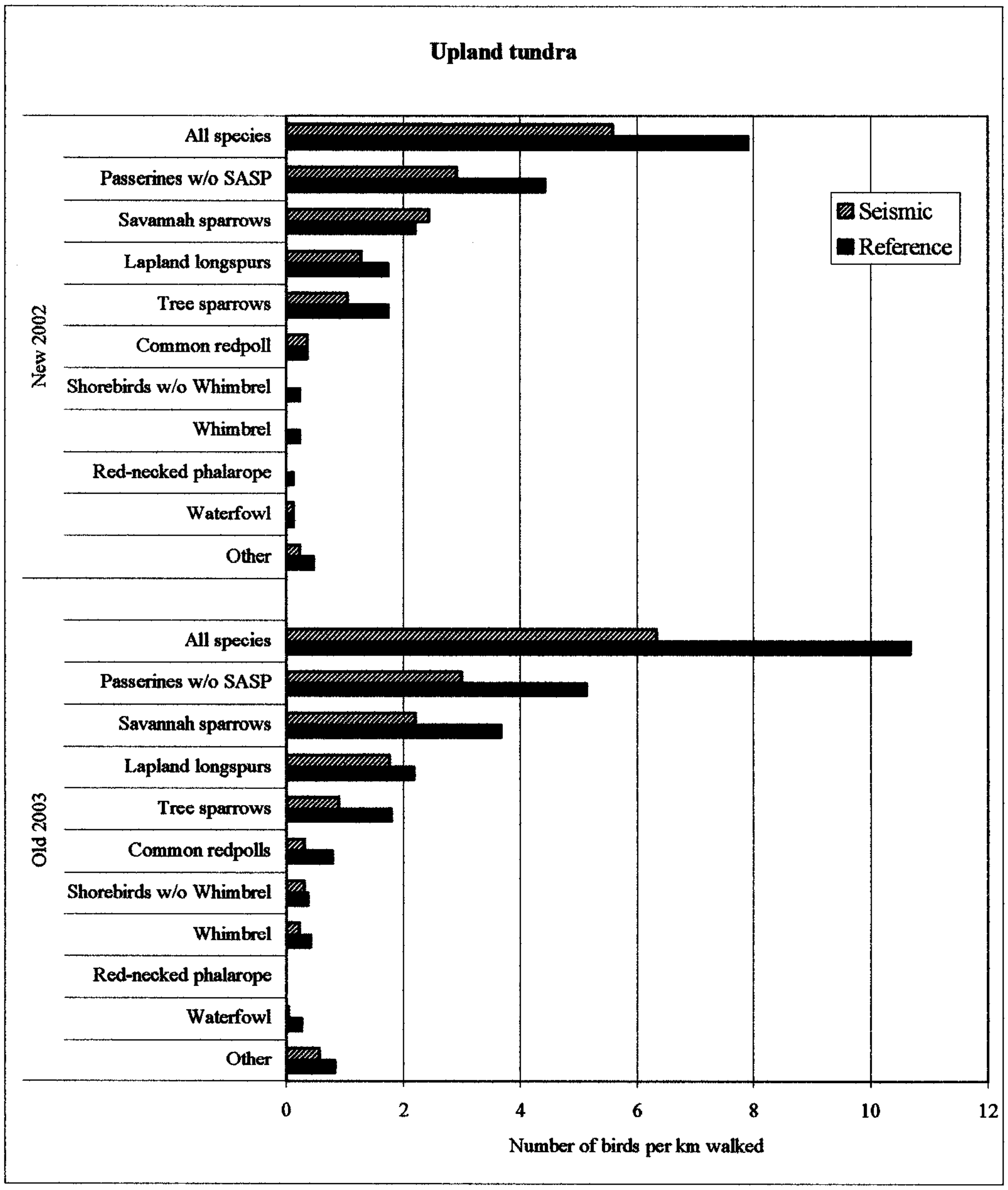


Figure 2.4. Total number of birds observed per km walked in upland tundra habitat for old and new seismic lines and respective reference lines (all species=all species from Table 3; w/o=without; Other=willow ptarmigan).

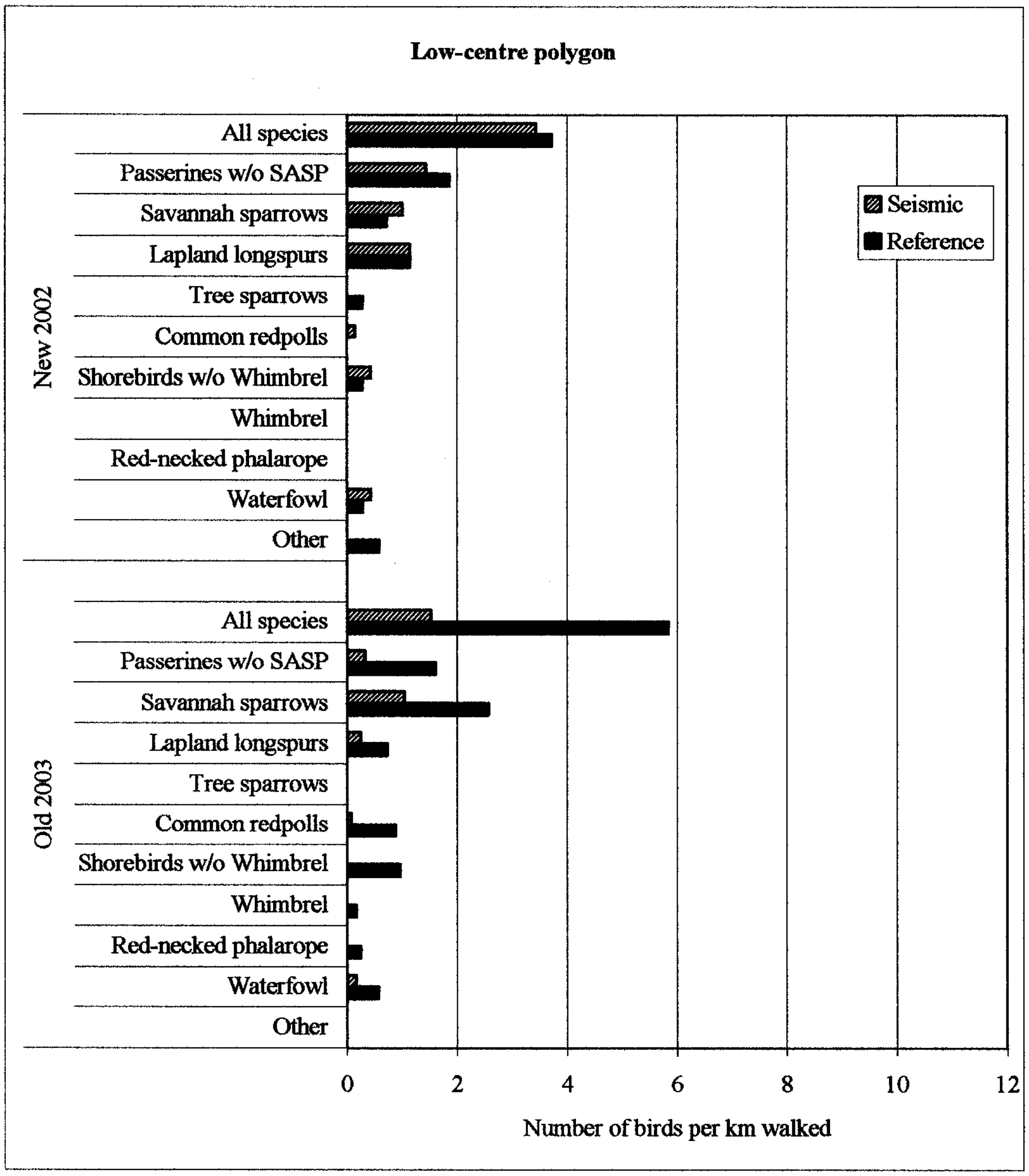


Figure 2.5. Total number of birds observed per km walked in low-centre polygon habitat for old and new seismic lines and respective reference lines (all species=all species from Table 3; w/o=without; Other=willow ptarmigan).

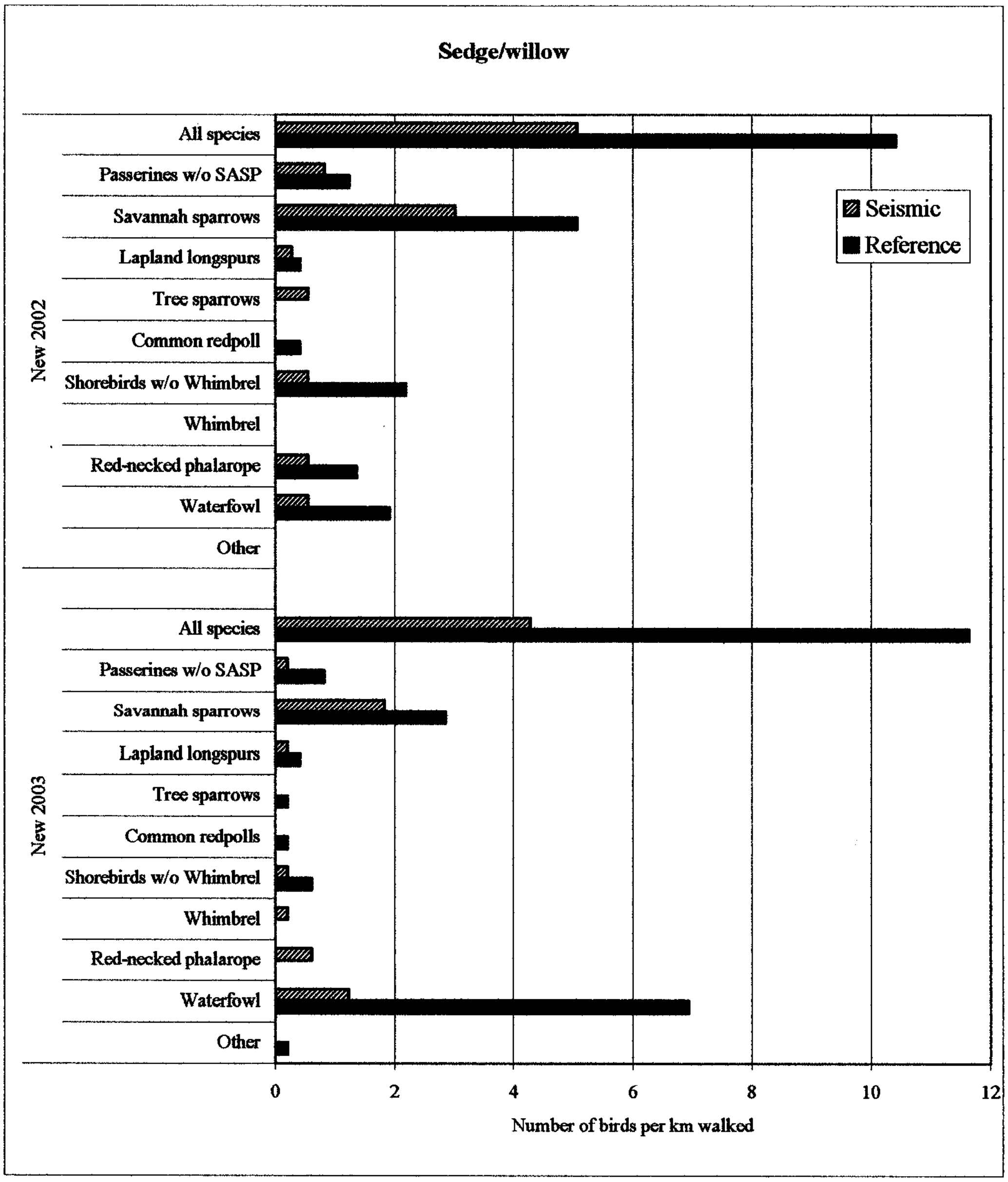
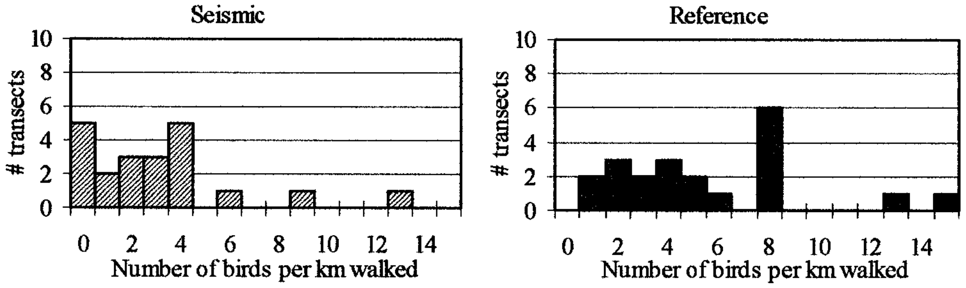


Figure 2.6. Total number of birds observed per km walked in sedge/willow habitat for new seismic lines and respective reference lines in 2003 and 2003 (all species=all species from Table 3; w/o=without; Other=one Arctic tern).

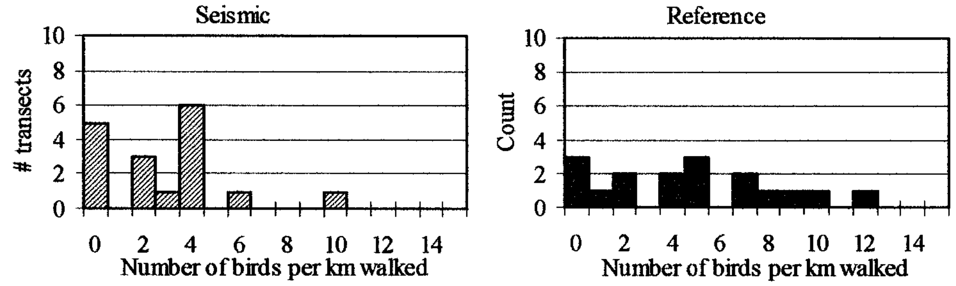
Table 2.4. Abundant species and groups of birds in respective habitat types (UT=upland tundra, LCP=low-centre polygon and SW=sedge/willow; SASP=savannah sparrow, LALO=Lapland longspur, CORE=common redpoll, TRSP=tree sparrow, WHIM=Whimbrel, and RNPH=red-necked phalarope,). Columns with x's indicates the statistical comparisons made across habitat types and line ages for each species.

Species	**Old seismic lines (2003)**		**New seismic lines (2002 UT and LCP, 2002 and 2003 for SW)**		
	UT	LCP	UT	LCP	SW
Passerines w/o SASP	x	x	x	x	
SASP	x	x	x		x x
LALO	x	x	x		
TRSP	x		x		
CORE	x	x			
Shorebirds w/o WHIM	x	x			
WHIM	x	x			
RNPH					x

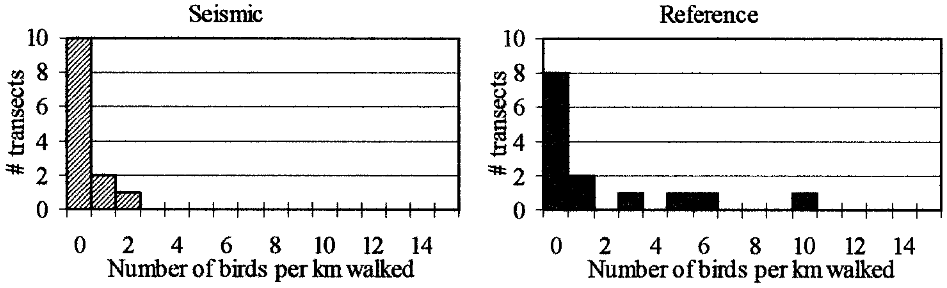
All passerines (w/o SASP) - Upland tundra old 2003



All passerines (w/o SASP) - Upland tundra new 2002



All passerines (w/o SASP) - Low-centre polygon old 2003



All passerines (w/o SASP) - Low-centre polygon new 2002

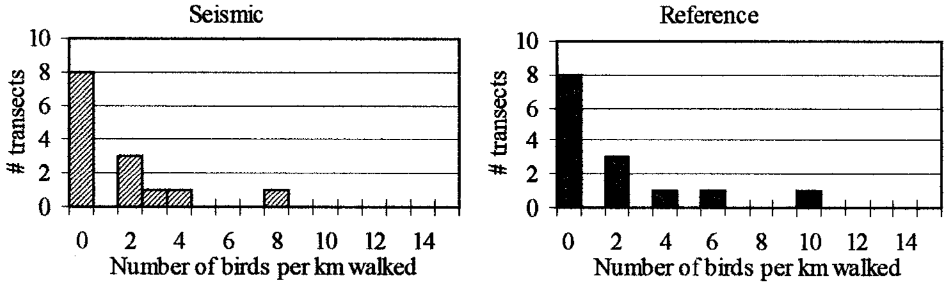


Figure 2.7. Histograms of the number of all passerines (excluding savannah sparrows) observed per km walked (w/o=without and SASP=savannah sparrow).

Table 2.5. Statistics for generalized linear models using quasi-likelihood function by species and grouped species (w/o=without; n/a=not applicable (only found in one habitat type); df=degrees of freedom, dev=deviance; SASP=savannah sparrow, LALO=Lapland longspur, TRSP=tree sparrow, CORE=common redpoll, RNPH=red-necked phalarope; WHIM=Whimbrel). Habitat includes habitat type and line age.

Species		df	dev	F	p	% dev explained by model
All Passerines w/o SASP	null					61.7%
	habitat	3	180.7	36.2	<0.0001	
	treatment	1	24.5	14.7	<0.0001	
	block	20	96.3	2.9	<0.0001	
	treatment x habitat	3	5.4	1.1	0.36	
SASP	null					42.3%
	habitat	4	62.7	11.2	<0.0001	
	treatment	1	18.4	13.1	<0.001	
	block	20	49.4	1.8	0.03	
	treatment x habitat	4	5.2	0.9	0.45	
LALO	null					81.9%
	habitat	2	67.1	37.6	<0.0001	
	treatment	1	3.1	3.5	0.07	
	block	49	173.0	4.0	<0.0001	
	treatment x habitat	2	2.1	1.1	0.33	
TRSP	null					44.2%
	age/year	1	16.0	11.9	0.001	
	treatment	1	9.5	7.1	0.01	
	block	20	37.3	1.4	0.17	
	treatment x habitat	1	0.1	0.1	0.75	
CORE	null					47.7%
	habitat	1	0.7	1.5	0.22	
	treatment	1	4.8	9.9	0.003	
	block	20	13.3	1.3	0.19	
	treatment x habitat	1	0.1	0.2	0.62	
All Shorebirds w/o WHIM	null					66.4%
	habitat	1	0.2	0.32	0.57	
	treatment	1	8.4	14.3	<0.0001	
	block	20	40.6	3.5	<0.0001	
	treatment x habitat	1	11.3	19.3	<0.0001	
WHIM	null					73.9%
	habitat	1	8.2	19.4	<0.0001	
	treatment	1	2.6	6.2	0.02	
	block	20	46.9	5.5	<0.0001	
	treatment x habitat	1	1.6	3.8	0.06	
RNPH	null					90.8%
	habitat	n/a	n/a	n/a	n/a	
	treatment	1	2.7	10.0	0.007	
	block	14	42.4	11.3	<0.0001	
	treatment x habitat	n/a	n/a	n/a	n/a	

Table 2.6. Mean difference across ages within habitat type using a two-sample t-test (SASP=savannah sparrow).

Species	**Habitat**	$\bar{x} \pm$ **SE**	**N**	**t**	***p*-value**
All passerines w/o SASP	Low-centre polygon	-0.68, 0.34	28	1.40	0.17
All passerines w/o SASP	Upland tundra	-1.84, 0.59	38	1.69	0.10
Savannah Sparrow	Upland tundra	-0.97, 0.33	38	3.40	0.002
Lapland longspur	Upland tundra	-0.40, 0.39	38	0.37	0.72
Tree sparrow	Upland tundra	-0.79, 0.34	38	1.17	0.25

tundra was significant (Table 2.6): the differences between seismic and reference transects were larger on old seismic lines. There was no difference in whether birds were on or off the 6m seismic footprint in any habitat type (Table 2.6). The distance of grouped species was not compared due to detectability differences between species.

Savannah Sparrows

Across all habitats, savannah sparrows were more abundant on reference lines than on seismic lines (Figure 2.8, Table 2.5). They were not abundant enough to analyze on new lines in low-centre polygon habitat (Table 2.4). In 2003, they were more abundant in upland tundra than low-centre polygon and sedge/willow and within upland tundra were more abundant in 2003 than 2002 (Figure 2.8). The treatment x habitat/age/year interaction was not significant (Table 5), however the effect of line age in upland tundra was significant (Table 2.6): the differences between seismic and reference transects were larger on old seismic lines. There were significantly more birds off the 6m seismic footprint on new lines in sedge/willow in 2003; however this was not significant in the rest of the habitats (Table 2.7). There was no difference between seismic and reference transects in the distance that savannah sparrows were from the transect lines in any habitat (Table 2.8).

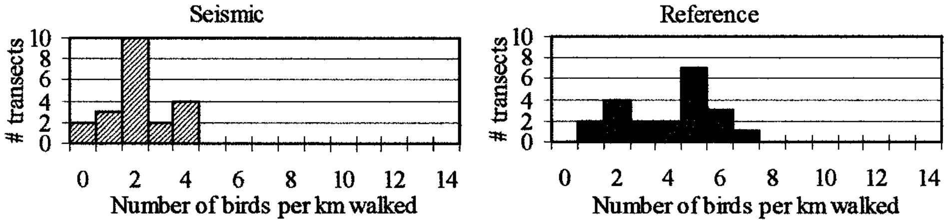
Lapland Longspurs

Across both years, seismic line ages and all habitats, Lapland longspurs were more abundant on reference than seismic transects (Figure 2.9, Table 2.5). In 2003, they were more abundant in upland tundra than low-centre polygon and within upland tundra were more abundant in 2003 than 2002 (Figure 2.9). Neither the treatment x habitat/age/year interaction (Table 2.5) nor the effect of line age were significant (Table 2.6) suggesting that differences between reference and seismic transects were similar on old and new lines. There were significantly more birds off the 6m seismic footprint on old lines in upland tundra; however this was not significant on old lines in low-centre polygon (Table 2.7). Lapland longspurs were significantly farther (9.2m) from the centre of old upland tundra seismic transects than from the centre of reference transects (Table 2.8). They did not occur on enough transects in other habitats to analyze distance.

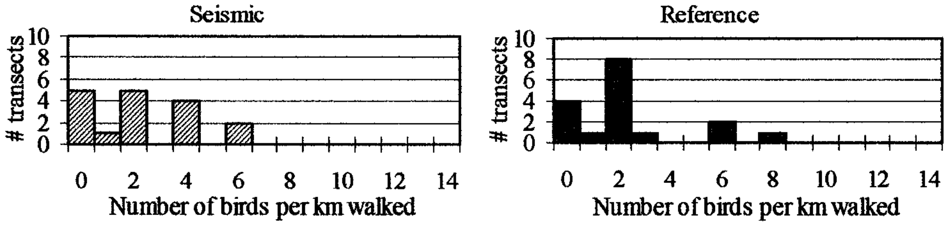
Table 2.7. Proportion on birds on or off either the 6m footprint of the seismic line or the 6m equivalent of the reference line analyzed with a G-test (UT=upland tundra, LCP=low-centre polygon and SW=sedge/willow; w/o=without; SASP=savannah sparrow, LALO=Lapland longspur, TRSP=tree sparrow, CORE=common redpoll, WHIM=Whimbrel, RNPH=red-necked phalarope).

Habitat	Age/Year	Species	Treatment		Reference		G-statistic	p-value
			On	***Off***	***On***	***Off***		
UT	**NEW 2002**	*All passerines w/o SASP*	1	24	4	34	0.96	0.35
		SASP	3	18	4	15	0.32	0.61
		LALO	0	11	0	15	0.00	1.00
		TRSP	1	8	2	13	0.03	0.91
	OLD 2003	*All passerines w/o SASP*	7	73	19	118	1.31	0.28
		SASP	8	51	13	85	0.00	0.98
		LALO	1	46	8	50	5.21	0.03
		TRSP	4	20	7	41	0.05	0.86
		CORE	1	7	2	19	0.05	0.87
		WHIM	0	6	1	10	0.90	0.68
		Shorebirds w/o WHIM	1	7	3	7	0.82	0.40
LCP	**NEW 2002**	*All passerines w/o SASP*	1	9	3	13	0.38	0.59
	OLD 2003	*All passerines w/o SASP*	1	3	6	14	0.04	0.88
		SASP	1	12	5	27	0.55	0.51
		LALO	0	3	3	6	2.04	0.27
		CORE	1	0	2	8	2.88	0.11
		WHIM	0	0	0	2	n/a	n/a
		Shorebirds w/o WHIM	0	0	0	12	n/a	n/a
SW	**NEW 2002**	*SASP*	4	18	7	31	0.00	0.99
		RNPH	1	3	1	9	0.48	0.73
	NEW 2003	*SASP*	0	9	4	10	4.50	0.07

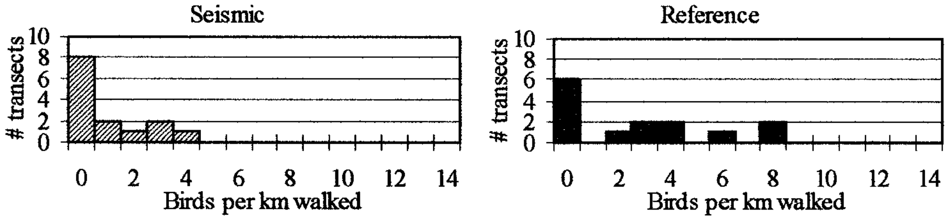
Savannah sparrows - Upland tundra old 2003



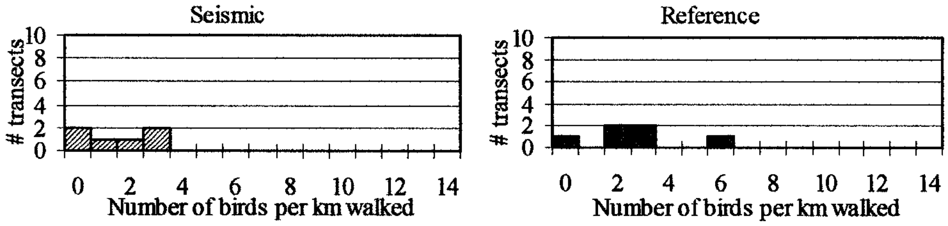
Savannah sparrows - Upland tundra new 2002



Savannah sparrows - Low-centre polygon old 2003



Savannah sparrows - Sedge/willow new 2003



Savannah sparrows - Sedge/willow new 2002

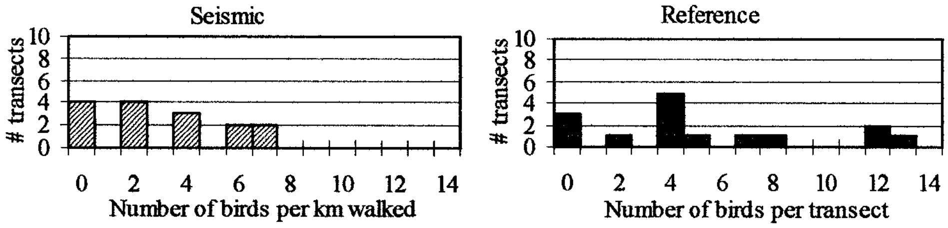
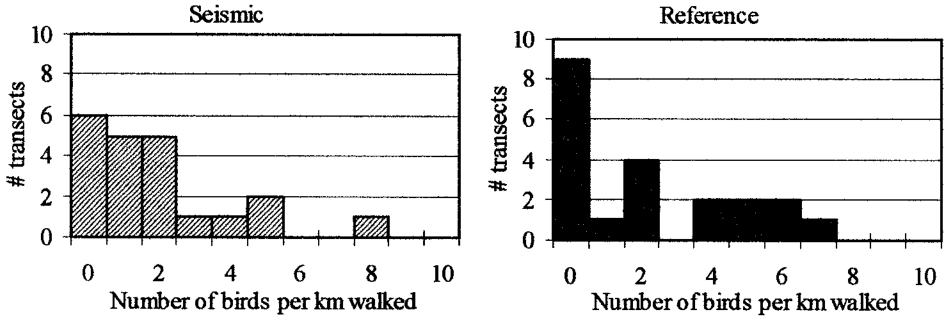


Figure 2.8. Histograms of the number of savannah sparrows observed per km walked.

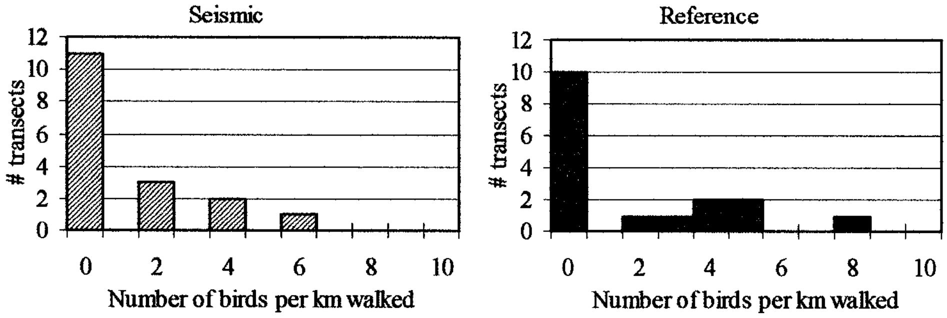
Table 2.8. Difference between the distance (metres) of birds from the centre of the transect line on new or old seismic lines and reference transects calculated using the Mann-Whitney U test (n=number of transects; UT=upland tundra, LCP=low-centre polygon, SW=sedge/willow; SASP=savannah sparrow, LALO= Lapland longspur, TRSP=tree sparrow, CORE=common redpoll).

Habitat type	Age/year	Species	Treatment			Reference			U-statistic	p-value
			Mean	***Range***	***n***	***Mean***	***Range***	***n***		
UT	**NEW 2002**	*SASP*	25.1	1.0,59.6	11	23.7	1.9,42.0	13	72.0	0.98
	OLD 2003	*SASP*	24.3	6.0,48.0	19	23.4	11,46	21	206.5	0.85
		LALO	31.5	11.0,59.0	15	22.3	9.0,43.4	12	50.5	0.05
		TRSP	20.8	4.0,43.0	10	28.3	8.0,49.0	19	130.0	0.11
		CORE	14.9	2.0,27.0	6	15.8	3.0,29.5	9	28.5	0.86
LCP	**NEW 2002**	*n/a*								n/a
	OLD 2003	*n/a*								n/a
SW	**NEW 2002**	*SASP*	24.2	3.4,55.0	11	21.1	0,36.7	12	60.5	0.74
	NEW 2003	*n/a*								n/a

Lapland longspurs - Upland tundra old 2003



Lapland longspurs - Upland tundra new 2002



Lapland longspurs - Low-centre polygon old 2003

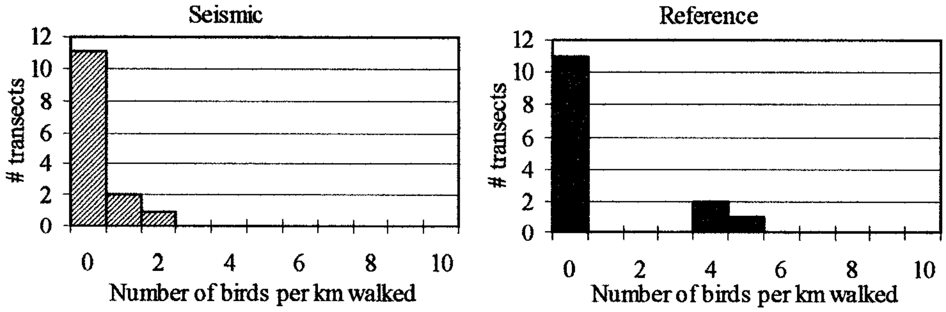


Figure 2.9. Histograms of the number of Lapland longspurs observed per km walked.

Tree Sparrows

Tree sparrows were only abundant enough to analyze in upland tundra, where they were more abundant on reference transects than seismic lines and were more abundant in 2003 than 2002 (Figure 2.10, Table 2.5). However, neither the treatment x habitat/age/year interaction (Table 2.5) nor the effect of line age were significant (Table 2.6) suggesting that differences between reference and seismic transects were similar on old and new lines. There was no difference in whether they were on or off the 6m seismic footprint (Table 2.7). Tree sparrows were a similar distance from seismic and reference transects on old lines in upland tundra (Table 2.8). They did not occur on enough transects on new lines in upland tundra to analyze distance.

Common Redpolls

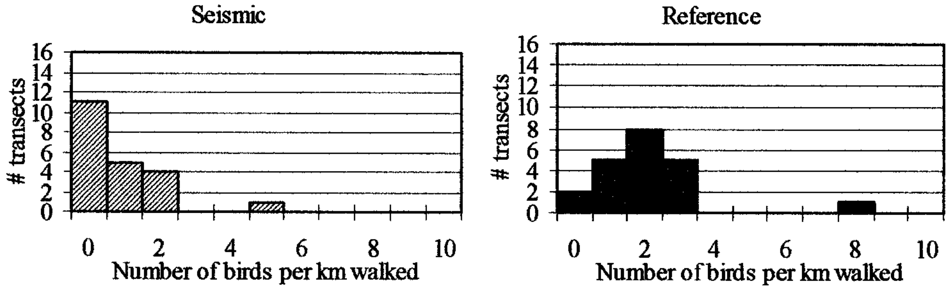
Common redpolls were equally abundant in upland tundra and low-centre polygon habitats (Figure 2.10, Table 2.5) and were not abundant enough in sedge/willow habitat to analyze (Table 2.4). Across all habitats, they were more abundant on reference lines than on seismic lines (Figure 2.7, Table 2.5). There was no difference on or off the 6m seismic footprint as compared to the reference in either habitat type (Table 2.7). Redpolls were equally distant from the transect line on old lines in upland tundra (Table 2.8). They did not occur on enough transects to compare the distance on new lines in upland tundra or old lines in low-centre polygon.

Shorebirds

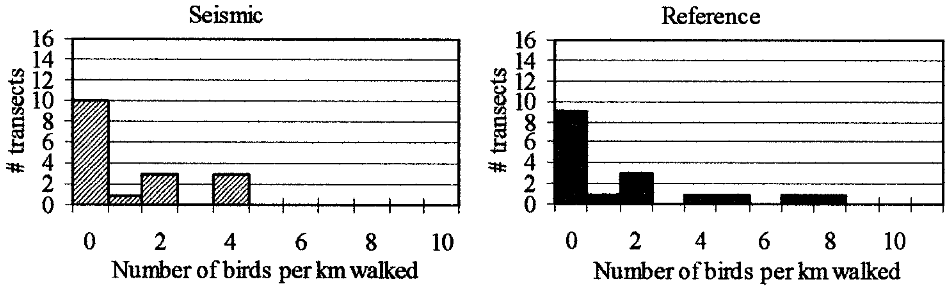
All Shorebirds (excluding Whimbrel)

All shorebirds were not abundant in sedge/willow or on any new lines to analyze, but were equally abundant on old lines in upland tundra and low-centre polygon habitats (Figure 2.11, Table 2.5). Across these two habitats, shorebirds (excluding Whimbrel) were more abundant on reference lines than on seismic lines (Figure 2.11, Table 2.5), however they were significantly more abundant on reference transects in low-centre polygon. There was no difference between the number of birds on and off the 6m seismic footprint versus the reference on old lines in upland tundra (Table 2.7). Shorebirds were not present on old seismic line transects in low-centre polygon habitat (Figure 2.11), however for all the shorebirds that did occur on the

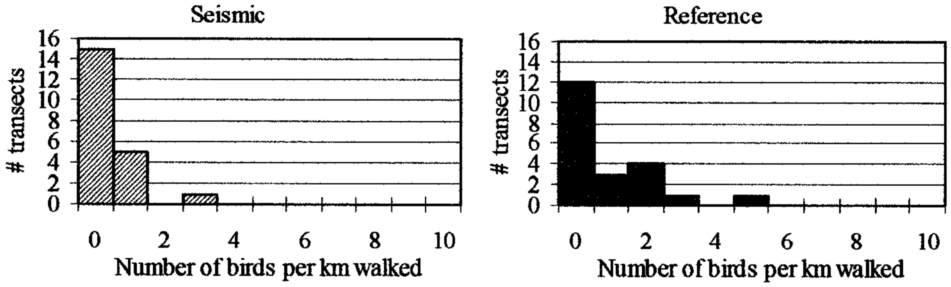
Tree sparrows - Upland tundra old 2003



Tree sparrows - Upland tundra new 2002



Common redpolls - Upland tundra old 2003



Common Redpolls - Low-centre polygon old 2003

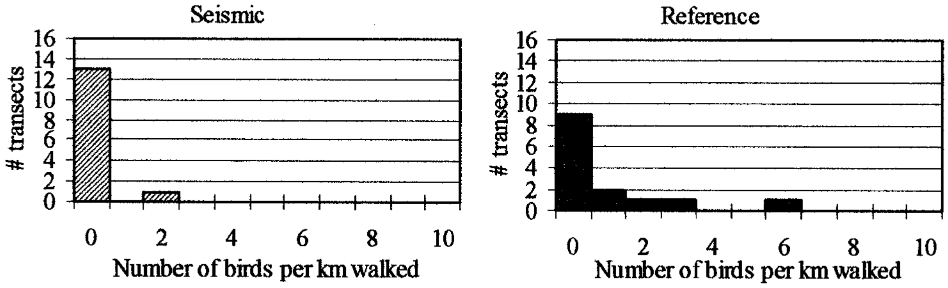
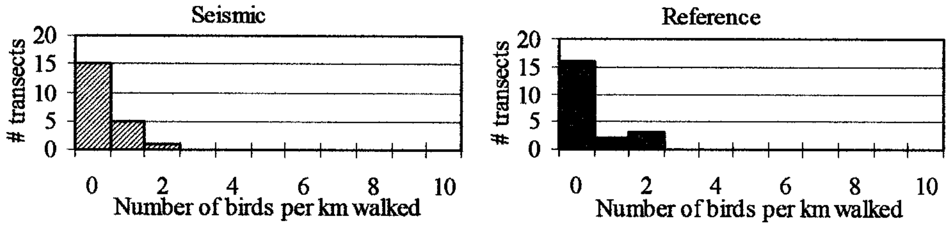
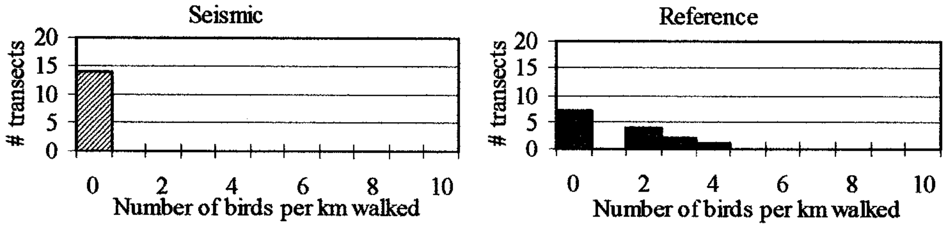


Figure 2.10. Histograms of the number of tree sparrows and common redpolls observed per km walked.

All shorebirds (w/o WHIM) - Upland tundra old 2003

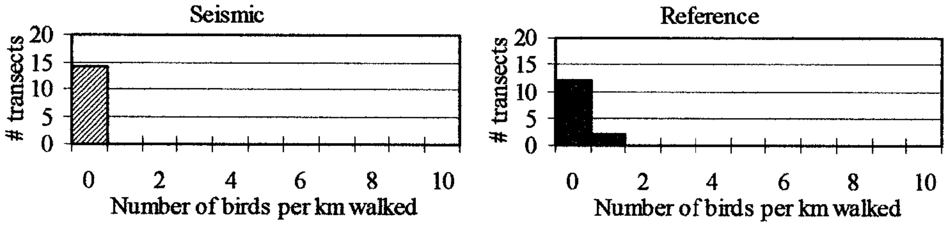


All shorebirds (w/o WHIM) - Low-centre polygon old 2003



Whimbrel - Upland tundra old 2003

Whimbrel - Low-centre polygon old 2003



Red-necked phalaropes - Sedge/willow new 2002

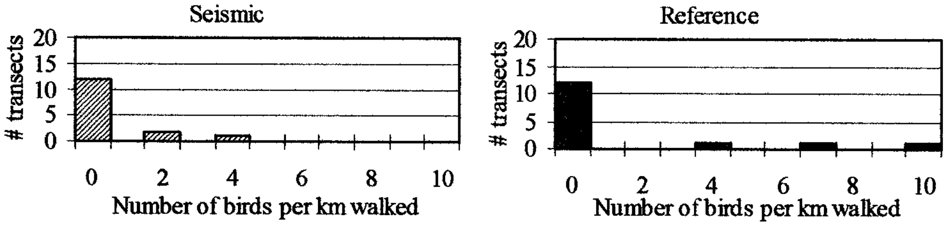


Figure 2.11. Histograms of the number of shorebirds (excluding Whimbrel), Whimbrel and Red-necked phalaropes observed per km walked (w/o=without and WHIM=Whimbrel).

reference transects in this habitat, the minimum distance to any seismic line was 55m. They were observed on the centre of the reference transect. The distance from the centre of the transects for grouped species was not analyzed.

Whimbrel

Whimbrel were more abundant in upland tundra than low-centre polygon (Figure 2.11, Table 2.5), and were not abundant enough to analyze in sedge/willow (Table 2.4). Across both habitats, Whimbrel were more abundant on the reference transects than on old seismic lines (Figure 2.11, Table 2.5). They were significantly more abundant on reference transects as compared to seismic transects in upland tundra (Figure 2.11). There was no difference in the number of birds on and off the 6m footprint versus the reference area in upland tundra (Table 2.7) and they were not present on old seismic line transects in low-centre polygon habitat (Figure 2.11). Whimbrel did not occur on enough transects to compare distance from the centre of the transects in either habitat.

Red-necked phalaropes

Red-necked phalaropes were only abundant enough to analyze in the sedge/willow in 2002 (Figure 2.11, Table 2.5) and there were no other shorebirds abundant enough to test in this habitat. They were more abundant on reference lines than on seismic lines (Figure 2.11, Table 2.5). There was no difference on or off the 6m seismic footprint as compared to the reference on new lines in sedge/willow in 2002 (Table 2.7) and phalaropes did not occur on enough transects to compare distance from the centre of the transects.

Landscape Level Effects

Seismic lines were not random with respect to habitat types (Table 2.1): there were about twice as many lines per km^2 in low-centre polygon than in upland tundra. Landscape level effects for each species or group were calculated using the mean density of birds and the 95% confidence intervals over upland tundra and low-centre polygon habitats.

Passerines

Based on densities of birds on reference sites and the current density of old and new seismic lines, passerines (excluding savannah sparrows) would have declined by an average of 11% (best case 43% increase - worst case 60% decrease) in upland tundra and by 35% (best case 65% increase - worst case 100% decrease) in low-centre polygon (Figure 2.12). Savannah sparrows had an average decline of 12% (best case 27% increase - worst case 46% decrease) in upland tundra and an average decline of 27% (best case 58% increase - worst case 90% decrease) in low-centre polygon (Figure 2.12). Lapland longspurs would have declined by an average of 4% (best case 71% increase - worst case 76% decrease) in upland tundra and by 32% (best case 69% increase - worst case 100% decrease) in low-centre polygon (Figure 2.12). Tree sparrows had an average decline of 15% (best case 46% increase - worst case 67%) in upland tundra (Figure 2.12). Common redpolls would have declined by an average of 16% (best case 74% increase - worst case 91%) in upland tundra and by 38% (best case 66% increase - worst case 100%) in low-centre polygon (Figure 2.12). If new seismic line density was doubled or tripled, this would further decrease abundance by only 1% to 2% for each species or group within each habitat type, since the largest effects on bird abundance come from old seismic lines due to the quantity of old lines.

Shorebirds

Based on densities of birds on reference sites and the current density of old and new seismic lines, shorebirds (excluding Whimbrel) would have declined by an average of 2% (best case 97% increase - worst case 100% decrease) in upland tundra, and by 45% (best case 44% increase - worst case 94%) in low-centre polygon (Figure 2.12). Whimbrel had an average decline of 6% (best case 95% increase - worst case 100%) in upland tundra and an average decline of 45% (best case 55% increase - worst case 100%) in low-centre polygon (Figure 2.12). Red-necked phalaropes were only analyzed in sedge/willow habitat and could therefore not be extrapolated to the landscape level. I was not able to extrapolate the effects of new lines on shorebirds and Whimbrel, as they were not abundant enough on new lines.

Summary

Old and new seismic lines in upland tundra and low-centre polygon have not

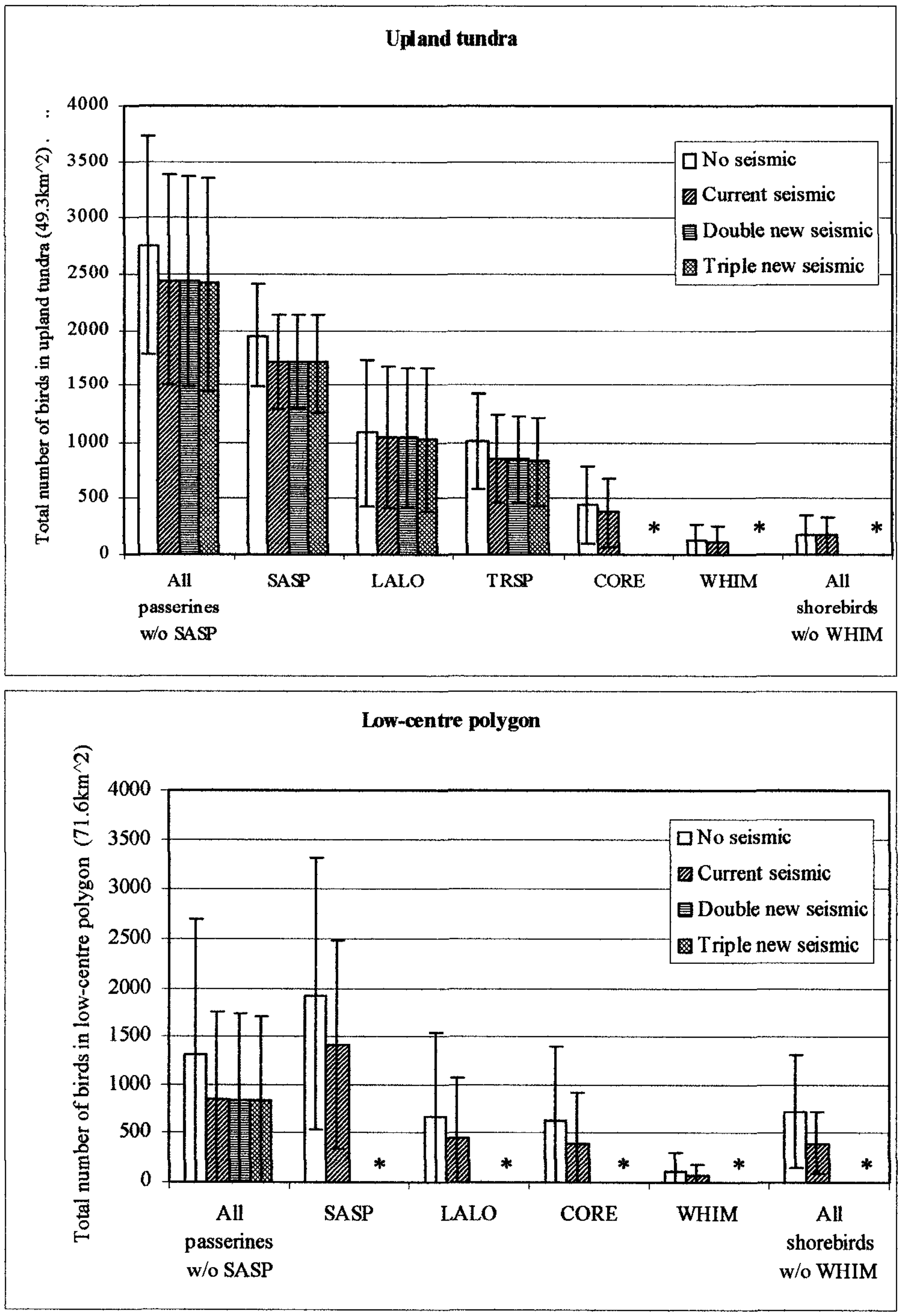


Figure 2.12. Mean density of birds in each habitat type with 95% confidence intervals (to determine best and worst case scenarios). No seismic scenario is extrapolated from the reference transects, current seismic scenario is based on the effects of both new and old seismic lines, double and triple new seismic scenarios are extrapolated based on the effects of the old lines plus either double or triple the current amount of new lines. Best and worst case scenarios based on no seismic and current seismic scenarios and 95% confidence intervals (w/o=without; SASP=savannah sparrow; LALO=Lapland longspur, CORE=common redpoll, WHIM=Whimbrel; * birds were not present or not abundant enough on new lines to analyze and could not be extrapolated onto double or triple new seismic lines).

completely recovered, however, most of the observed reduction in bird abundance is due to the old seismic lines. There are marginal decreases in bird abundance with the addition of double and triple the amount of new seismic lines (Figure 2.12). Birds are more affected by seismic lines in the low-centre polygon habitat than upland tundra at the landscape scale.

DISCUSSION

Alteration of habitat by seismic exploration could increase, decrease or not affect bird abundance and distribution on and adjacent to seismic lines. My analysis indicated that seismic lines in the Kendall Island Migratory Bird Sanctuary supported lower abundances of birds than reference areas for all habitats surveyed. Most species, however, did not avoid the seismic lines themselves (Table 2.7), nor were bird locations significantly farther from the seismic lines as compared to the reference lines on transects where birds were present (Table 2.8). This suggests that bird abundance on seismic lines was lower because bird territories were larger on the transects that contained seismic lines.

O'Leary and Nyger (2000) and Coppedge *et al.* (2001) found that grassland nesting birds had an aversion to woody vegetation and arctic ground nesting passerines (e.g., savannah sparrow) tend to prefer denser grasses and dwarf willows or birches (*Betula* spp.; Wheelwright and Rising 1993). Thus, the taller and denser shrubs that Kemper (in preparation) found on the old seismic lines in upland tundra may be unsuitable habitat for most tundra nesting birds. These birds may have increased their territory size to compensate for shrub cover. For example, Siffezyk *et al.* (2003) found that willow tits (*Parus montanus*) and Storch (1993) found that capercaillie (*Tetrao urogallus*) increased their territory size if the vegetation composition within their habitat was unsuitable. Also notable in my study was that savannah sparrows and all passerines (excluding savannah sparrows) were more sensitive to the effects of old lines than new lines in upland tundra, and the old lines have taller, denser woody vegetation (Kemper in preparation) and thus exhibit these unsuitable habitat characteristics.

Three notable exceptions to the above pattern occurred, two of which involved obligate arctic avifauna. First, savannah sparrows, a non-arctic obligate, appeared to avoid new seismic lines in sedge/willow habitat. Generally, these new lines have compressed sedges, damaged shrubs and an increase in water (Felix and Raynolds 1989) and there are also decreases in total vascular plant cover, shrubs, sedges and horsetails (*Equisetum* spp.; Kemper in preparation). Since savannah sparrows prefer denser grasses and dwarf willows or birches during breeding (Wheelwright and Rising 1993) these impacts create undesirable habitat for savannah sparrows, and thus could be a reason why these birds do not use new lines in sedge/willow habitat.

Second, Lapland longspurs, the quintessential Arctic bird, were located farther from the centre of old lines than from the centre of adjacent reference lines in upland tundra and only one bird was observed on an old seismic line. Chestnut-collared longspurs (*Calcarius ornalus*), an obligate grassland nesting bird, are known to prefer more sparsely vegetated habitats (Owens and Myers 1973) and are more frequent in native grasslands as opposed to seeded (disturbed) pastures (Davis *et al.* 1999). Sutter *et al.* (2000) found that chestnut-collared longspurs avoided more physically disturbed areas. Old seismic lines in upland tundra have denser forbs and shrubs while the new lines have decreased vegetative cover (Kemper in preparation) than the reference tundra. Thus, since Lapland longspurs prefer undisturbed hummocky ground with grasses, mosses, sedges and some shrubby plants (Hussell and Montgomerie 2002), they may avoid the dense vegetation and disturbed habitat on seismic lines, which exhibit these habitat characteristics. Lapland longspurs also perform a "flight song display" (Hussell and Montgomerie 2002) and while in the air, they may be able to see the seismic line and thus use this visual cue to delineate the edge of their territories.

The third exception was shorebirds (excluding Whimbrel), which did not use seismic lines in low-centre polygon habitat. In fact, results from the second field season showed that the closest shorebird to any seismic line was 55m, as compared to zero metres to a reference line. There could be a couple of factors influencing this reaction of shorebirds to seismic lines. First, Willets (*Catoptrophorus semipalmatus*) select nest sites within clumped vegetation that also has low cover (Benoit and Askins 2002). However, old seismic lines in sedge dominated habitats, such as low-centre polygon, have denser vegetation/cover than unaffected habitat (Emers *et al.* 1995). This is due to the compression of sedges from seismic equipment which results in a nutrient flush and subsequent increase in plant productivity (Chapin and Shaver 1981;

Emers *et al.* 1995). Since sedges on the old seismic lines become denser, shorebirds could be sensitive to the impacted area and choose not to nest in those areas. Benoit and Askins (2002) also found that Willets appear to be area sensitive and only nest in large marshes unaffected by artificial barriers. Since the density of seismic lines is highest in the low-centre polygon habitat, this could be reducing the amount of unaffected areas in which shorebirds could breed.

Another of my predictions was that the presence of new seismic lines would have a greater impact on bird abundance than old lines. On old seismic lines in upland tundra, the forbs and shrubs were generally denser and taller (Kemper in preparation) than new lines where Felix and Raynolds (1989) found that tussocks and shrubs were shorter and more damaged. Sedges on new seismic lines in the wetland communities tended to be compressed and lower in abundance than the reference lines (Kemper in preparation), however Emers *et al.* (1995) found that these plants grow denser over time. I found that, despite the differences in vegetation, birds were negatively affected by both new and old seismic lines and therefore, new lines did not have a greater impact on birds than old lines. However, since the quantity of old seismic lines is much greater than new seismic lines, the old lines are creating the larger loss of habitat at the landscape level. While new seismic lines did not appear to have a large effect on birds, it is also not clear whether changes in habitat on these lines will occur over time, due to soil compaction. Ultimately it may not matter what technique was used to make the seismic lines, the tundra vegetation is fragile and the impacts to the vegetation from the equipment used to create seismic lines changes bird habitat for the worse.

Finally, I predicted that obligate arctic bird species (i.e., full time arctic residents or migratory species that breed only in the arctic; Table 2.3) would be more negatively affected than other species. The seismic lines reduced abundance of all birds analyzed; however Lapland longspurs and shorebirds were more abundant off old seismic lines and other species (e.g., savannah sparrow, tree sparrow, common redpoll and red-necked phalarope) frequently used seismic lines, with the exception of savannah sparrows on new sedge/willow seismic lines. Population declines in the low-centre polygon habitat negatively affected shorebirds the most, but affected both the non-obligate and Lapland longspurs equally. Shorebirds may not use old seismic lines in low-centre polygon because the denser, taller vegetation may inhibit their ability to see, move and nest (Benoit and Askins 2002). Coppedge *et al.* (2001) found that changes in landscape structure (e.g., increased woody vegetation within grasslands) decreased the habitat suitability and the resource base for obligate grassland avian species. However, all the ground-nesting passerines (obligate and non-obligate) may be affected in upland tundra because of the woody vegetation on the old seismic lines and thus have unsuitable habitat in which to nest (O'Leary and Nyger 2000).

Although I found statistically significant differences in bird abundance between reference and seismic transects, is the reduction in abundance biologically significant? At the current level of seismic lines in upland tundra, average bird abundance decreased between 2% and 16% and the worst case scenario was between 27% and 45%, relative to the pristine state. Additional new seismic lines (double or triple) would only marginally decrease abundances. However, bird abundances were more affected in low-centre polygon habitat than upland tundra (Figure 2.12). In low-centre polygon habitat, bird abundances decreased between 27% and 45% and the worst case scenario was between 90% to 100%. Again, additional new seismic lines would only marginally decrease abundances. Although there were marginal decreases in bird abundance due to new seismic lines as compared to old seismic lines at the landscape level, 90% of the seismic lines in the sanctuary are old, have not recovered and thus account for most of the loss in bird habitat. New lines do impact bird abundance and distribution, however since there are very few new lines within the sanctuary, the magnitude of the loss of birds at the landscape level is currently not as great as compared to old lines. The decreases in abundance of shorebirds in low-centre polygon habitat are the most substantial of any species or group and although shorebirds may not have a biologically significant decline in upland tundra, there could be detrimental population declines in low-centre polygon.

Based on the CWS definition of a long-term impact (Canadian Wildlife Service 2004), I calculated that with a current 6m wide seismic line, there is a 1.8% footprint over the entire sanctuary. Since the sedge/willow habitat accounts for most of the remaining habitat (Table 2.1) and seismic lines negatively affected bird abundance and distribution in this habitat, these seismic lines are included in the sanctuary wide footprint. Permanent deletion of habitat by drill pads (see chapter 3) creates a further 0.6% to the footprint. Hence, the total footprint in the sanctuary is currently 2.4%. This total footprint, however, does not include other permanent features (e.g., runway and camp), since they were not studied, or habitat loss due to avoidance by birds.

Within upland tundra there is a 1.0% footprint and within low-centre polygon there is a 2.7% footprint (Table 2.9). Also Lapland longspurs avoided old seismic lines in upland tundra by 6.2m, and therefore 4.6% of this habitat was unusable for this species (Table 2.9). However, there is an abundance of upland tundra in and beyond the region of the outer delta that can be utilized by the birds. In addition, shorebirds were not closer than 55m to seismic lines in low-centre polygon habitat and this resulted in 38.2% of this habitat being unusable for shorebirds (Table 2.9). There is very little low-centre polygon habitat in and beyond the region of the outer delta and this loss of habitat could have detrimental effects on shorebird populations.

Seismic lines that were sampled did not have to be seen well, but they still had to be visible to ensure treatment sampling was on a seismic line. There may be some seismic lines in the sanctuary that are no longer visible and have thus recovered. The visible footprint of seismic lines within the sanctuary is currently being examined and this may decrease my estimates of the loss of usable habitat for birds. Also, the analysis was based on a 6m wide seismic line. There were some areas, for both new and old seismic lines, where the seismic machinery drove side-by-side creating a 13m wide seismic line. This enlarged the actual area of industrial footprint, but since these doublewide lines were not mapped by CWS or industry, they were not part of the final footprint analysis. Habitats may not be saturated and this could be affecting the distribution of the birds. There is an abundance of upland tundra in the outer delta in which birds that breed in this habitat can use. However, there is a very limited amount of low-centre polygon and the birds that breed in this habitat do not have other unaffected areas to breed in within the outer delta. There was also a lot of variability at the landscape level due to the variation in the number of birds on each transect sampled. Sanctuary managers and industry need to decide where within the mean, best and worst case scenarios they which to manage the sanctuary and the potential outcomes of their decisions. Finally, there were a number of species that were not abundant enough to statistically analyze and the impacts of seismic lines may affect these species in similar or different ways. A larger sample size (particularly for new seismic lines) may aid in assessing how other species react to seismic lines.

Table 2.9. Area and percent of habitat lost due to seismic lines in the entire sanctuary and in upland tundra and low-centre polygon habitats.

	Area of habitat (km^2)	**km of seismic lines**	**Area of seismic lines (km^2)**	**Percent footprint**
Entire sanctuary (6m wide line)	335.2	992.9	6.0	1.8%
Upland tundra (6m wide line)	49.3	128.0	0.50	1.0%
Low-centre polygon (6m wide line)	71.6	349.1	1.90	2.7%
Lapland longspurs in upland tundra (9.2m from seismic line centre)	49.3	128.0	2.3	4.6%
Shorebirds in low-centre polygon (55m from seismic line centre)	71.6	349.1	27.4	38.2%

This research assessed a broad perspective of the reaction of birds to seismic lines. Future research could ask: 1) how do birds react to different densities of seismic lines? This could reveal the density of seismic lines at which bird populations begin to dramatically decline (see Bayne *et al.* in press for a study on a seismic line density threshold affecting bird populations); 2) would samples on old seismic lines in sedge/willow and/or dense willow reveal similar trends in avifaunal reactions to seismic lines? I was not able to sample old lines in these habitats and this should be done; 3) will new seismic lines recover better over time due to the use of vibroseis machinery as opposed to blading and dynamite? Vibroseis machinery is new technology being used in the sanctuary and over time these methods may be either better or worse on the vegetation. In addition, detailed vegetation mapping of sedge/willow and dense willow habitats needs to be completed in order to extrapolate results in avian abundance to the landscape level.

Conclusions

Habitats for birds along new and old winter seismic lines have not yet recovered and are now part of the permanent anthropogenic footprint in the sanctuary. Seismic lines currently account for more than 1% of the allowable industrial footprint, as mandated by the CWS (Canadian Wildlife Service 2004). There are very few new seismic lines in the sanctuary and effects to birds of adding more new seismic lines is relatively low. Thus, the largest effects to birds are from old seismic lines along which habitat has not recovered. Since the habitat types vary in their bird species abundance and composition, the sanctuary needs to be managed on a habitat-by-habitat basis. Upland tundra currently has a density of seismic lines that meets the 1% footprint allowed by the CWS, based on a 6m footprint. Lapland longspurs avoid seismic lines and there is a 4.6% footprint in upland tundra. More seismic exploration in upland tundra will also increase the industrial footprint above the allowed 1%. Therefore, any further exploration and development should be planned carefully to minimize effects in this habitat, which has the highest density of passerines in the sanctuary. Shorebirds are extremely sensitive to seismic line impacts in low-centre polygon habitat and there may already be detrimental population effects to shorebirds, which may be increased if hydrocarbon exploration is permitted to continue. Taglu Island, Fish Island and vicinity are the critical breeding areas for shorebirds in the outer delta (Gratto-Trevor 1994; 1996), which makes preservation of this habitat in the sanctuary even more crucial.

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CHAPTER 3. THE EFFECT OF OIL AND GAS DRILL PADS ON AVIAN ABUNDANCE AND DISTRIBUTION WITHIN THE KENDALL ISLAND MIGRATORY BIRD SANCTUARY, NWT.

INTRODUCTION

Arctic landscapes are becoming increasingly subjected to anthropogenic disturbances caused by hydrocarbon exploration and development (Walker *et al.* 1987; Walker 1996; Forbes *et al.* 2001). Once disturbed, these systems are very slow to recover and if these anthropogenic features are not fully reclaimed, these ecosystems will be permanently altered (Walker 1996). A common permanent anthropogenic disturbance associated with oil and gas exploration (for test drilling) and extraction is the drill pad. A drill pad is a surface land area that averages 4ha and is usually leased from the Landowner or Crown. They typically contain; drilling equipment, drill pipe lay down area, mud sump and associated pumps, rig escape area, living quarters and support facilities, office, safety equipment, fuel storage, septic system, garbage disposal, power generation, warehousing, a perimeter bermed area to contain spills, and large truck vehicle parking area. More remote sites can be larger requiring additional areas for survival equipment, recreation room, additional food, water and fuel storage, warehousing, two power generators, and often a helicopter pad or airstrip.

Oil and gas companies have been developing drill pads in the Canadian Arctic since the 1960's. Such development disrupts the natural drainage patterns, alters snow drift patterns, and fails to revegetate naturally to the original habitat type (Walker 1996; Forbes *et al.* 2001). Plant productivity is enhanced (e.g., willows (*Salix* spp.); Figure 3.1) on drill pads (Truett and Kertell 1992) and there are also ponds on or adjacent to drill pads (Figure 1). For the most part, these disturbances are small, microscale (<1km^2) or microsite (<100m^2) in size (Walker and Walker 1991), however the landscape becomes perforated (Hunter 1996). Birds can respond to disturbances at relatively small spatial scales (Rodrigues 1994; Truett *et al.* 1994) and these disturbances may either be detrimental or beneficial (Truett *et al.* 1994). Many bird species are arctic obligates (i.e., full time arctic residents or migratory species that breed only in the arctic), are thus dependant on arctic ecosystems during reproduction (Gratto-Trevor 1994, 1996) and drill

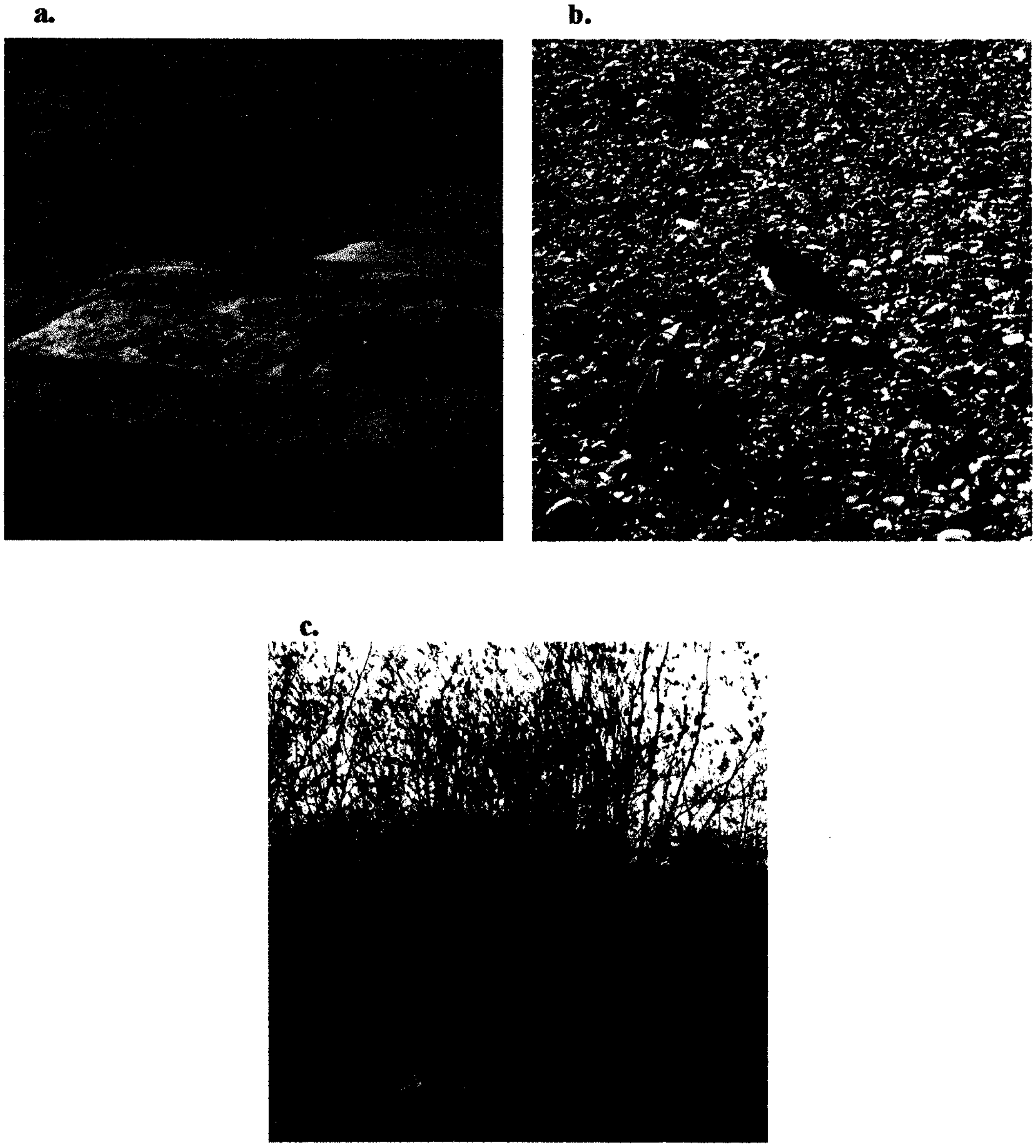

Figure 3.1. Habitat associated with drill pads in the Kendall Island Migratory Bird Sanctuary, NWT. a. Aerial view of a drill pad with adjacent ponds (used by red-necked phalaropes). b. Gravel drill pad (used by semipalmated plover). c. Taller shrubs on a drill pad (all photos by A. Ashenhurst).

pads can either provide or reduce habitat for breeding birds (Barry 1976). A few bird species, such as the semipalmated plover[4] (Barry 1976), are attracted to drill pads for nesting, however others such as the Lapland longspur may be displaced because of the lack of nesting habitat (Rodrigues 1994).

The Kendall Island Migratory Bird Sanctuary (623km^2) is north of tree line in the outer Mackenzie River Delta of the Northwest Territories. The Canadian Wildlife Service established the Sanctuary in 1961 for the long-term protection of lesser snow geese (*Anser caerulescens)* on some of the outer islands (Canadian Wildlife Service 1992). This area is also critical for nesting, rearing of young (Barry and Spencer 1976) and staging habitats for 85 other bird species (Canadian Wildlife Service 1992). Oil and gas exploration and development has occurred in the sanctuary since the early 1960's. Presently, there are 21 drill pads, a camp, airstrip, a gravel pile, and two staging areas for transferring equipment within the sanctuary. All of these anthropogenic features together total 0.72% (241ha) of the total land area of the sanctuary (drill pads are 0.60% (202ha) of these disturbed areas in the sanctuary). The Canadian Wildlife Service has a mandate that ≤1% of the sanctuary will consist of a permanent anthropogenic footprint where the footprint fluctuates between 0% and 1% as old impacts recover and new impacts are created (Canadian Wildlife Service 2004). My objective was to determine if there was a difference in bird abundance between drill pads and unimpacted areas.

METHODS

Study area

My study site was located in the Kendall Island Migratory Bird Sanctuary located at 69° 15" N and 135° 00"W (Figure 3.2). The drill pads in the Sanctuary lie within three habitat types: 1) upland tundra, a dry upland habitat with dwarf willows (*Salix* spp.), alders (*Alnus* spp.) and sedge (*Carex* spp.) tussocks; 2) low-centre polygon, a wetland with patterned ground consisting of sedges, and willows and sedges on the polygon rims; and 3) sedge/willow, a wetland with variable densities of

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[4] All Latin names of species are in Table 3.2.

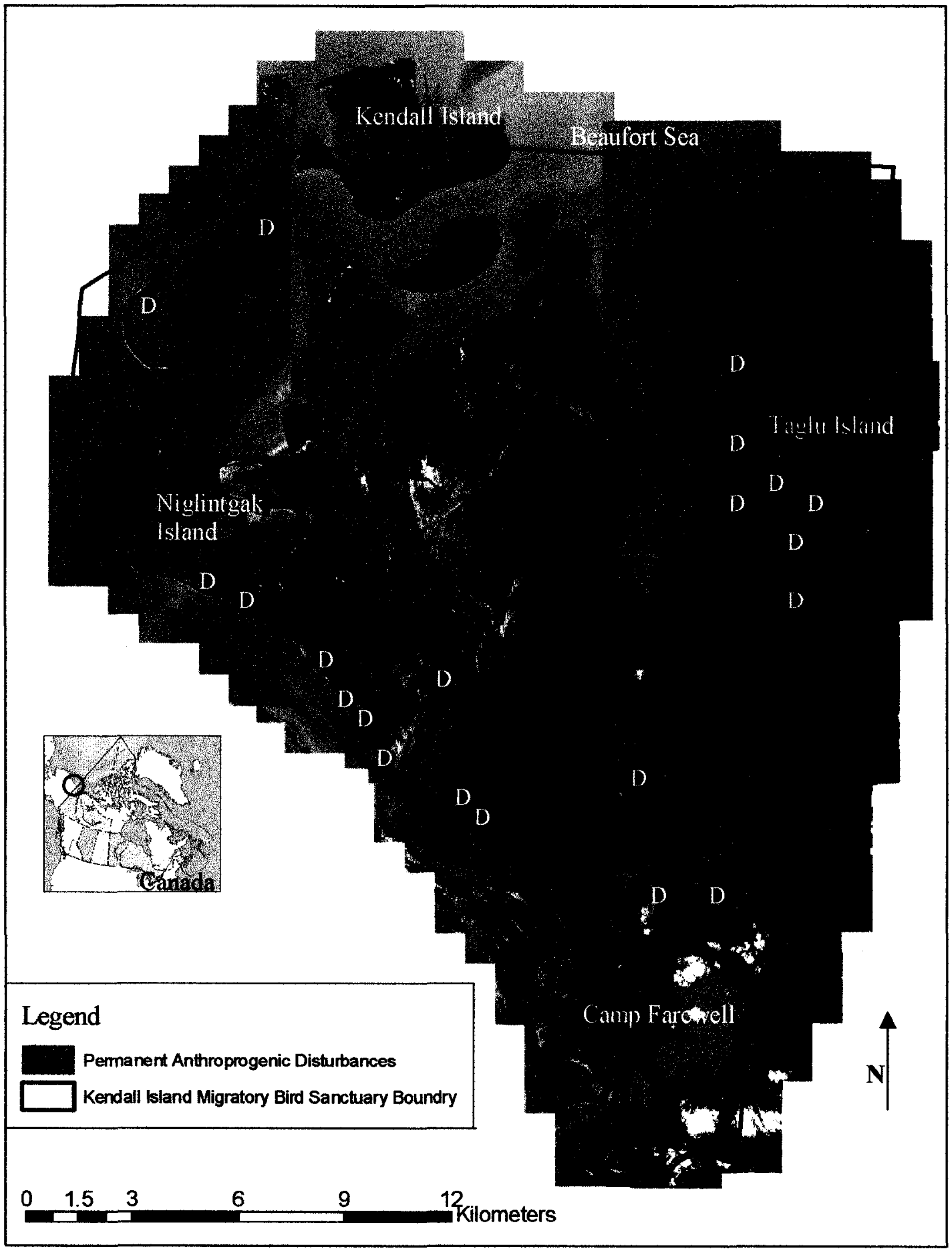

Figure 3.2. GIS layer of permanent anthropogenic disturbances (i.e., drill pads (indicated with a "D"), staging areas, gravel pile, camp and airstrip) within the Kendall Island Migratory Bird Sanctuary, NWT.

sedges and willows (see Chapter 1 for more detailed habitat descriptions). Twenty of the 21 drill pads in the study area were created by hauling gravel from another site outside the Sanctuary and piling the gravel up to 2m high (Barry and Spencer 1976; Streever 2002) over an area of approximately 0.6-3.5ha for gas pads and approximately 3.5-6.5ha for oil pads. These raised gravel pads protect the drill site from storm tides and help protect the permafrost from melting (Barry and Spencer 1976; Walker 1996). Once drilling is finished, the drilling equipment and buildings are removed and either the gravel is left behind or the gravel is removed as an attempt to restore the area (Jorgenson and Joyce 1994). One drill pad in the sanctuary was constructed of steel I-beams (supports) and heavy-duty steel grating (platform) encompassing ~0.17ha, but the impacted habitat was 5.2ha and resembled the affected habitat of restored drill pads. The drill pads studied were flat, had no micro-topographic relief (e.g., tussocks or ridges), had artificial ponds and very little vegetation (Figure 1). The vegetation on the drill pads consisted of shrubs (e.g., *Salix alaxensis*) and sparsely distributed forbs and grasses all of which were native to the region, although many of the species were not found elsewhere in the sanctuary itself. There were also some exotic plant species (e.g., Dandelion (*Taraxacum officinale*)). None of the drill pads were active during my study.

Experimental design

In late June and early July 2002, we sampled eight drill pads that ranged from 0.6ha to 9.3ha (mean of 4.3ha; Table 3.1). Seven drill pads were inside and one drill pad was outside the Sanctuary. We sampled birds using line transects (Bibby 1992) at the edge and/or on the drill pad. If visibility was high with (i.e., little or no vegetation on the drill pad) two observers simultaneously walked along parallel lines on the perimeter of the affected area and mapped the birds inside the plot. If the drill pad had dense vegetation and low visibility, we simultaneously walked along the parallel perimeter line and then simultaneously walked along parallel internal lines inside the drill pad. There was one large drill pad that had very little vegetation so we only walked the perimeter lines as any birds between us could be easily seen. None of the parallel lines were close enough that we would count the same bird twice.

Table 3.1. Drill pads studied in respective habitats, area and date (in 2002) sampled (UT=upland tundra, LCP=low-centre polygon, S/W=sedge willow).

Drill pad #	Habitat	Area (ha)	Date sampled
1	UT	5.2	June 26
2	S/W	0.9	July 05
3	S/W	3.3	July 05
4	S/W	5.5	July 05
5	S/W	0.6	July 05
6	LCP	9.3	July 06
7	LCP	6.3	July 06
8	UT	3.7	July 06

Immediately after sampling the drill pad, we sampled a paired reference plot at a distance of 100m from the drill pad. This distance was far enough away to avoid double sampling birds (e.g., average radius of the home range of a small passerine or shorebird) and was outside the influence of the drill pad (e.g., perimeter trees and ponds). The direction of the reference plot was randomly chosen but represented the habitat type occupied by the drill pad. The reference plot was the same size and was subject to the same sampling effort as the drill pad. Both drill pads and reference plots were surveyed once. We determined and noted each bird species, sex, location and behaviour (e.g., foraging and singing).

Statistical Analysis

I calculated mean density per 1ha and the 95% confidence intervals of bird abundance over the eight drill pads and eight reference sites. Paired densities were analyzed using the Wilcoxon Signed-ranks test since the data were not normal and could not be transformed to normality. My sample size was small (n=8 drill pads and 8 reference plots), so I only statistically compared the density of species with sufficient data (i.e., savannah sparrows and Lapland longspurs) or species combined (all shorebirds and all[5] passerines as a group (excluding savannah sparrow)). I removed savannah sparrows from all passerines as they were the most abundant species and influenced the outcome of the analysis. My sample size was too small to separate out the habitat types for more detailed analysis, so I analyzed them all together. I used SYSTAT Version 10 (SPSS Inc. 2000) for the analysis.

Total area of all the drill pads (202ha) in the Sanctuary was determined using ArcMap™ Geographic Information software (GIS). I extrapolated the mean density of birds I found on the 8 drill pads and 8 reference plots to determine the number of birds gained or lost on the 202ha of habitat covered by all drill pads in the sanctuary. I then determined a best and worst case scenario for each species using the 95% confidence intervals of the means. For example, if a species was denser on the drill pad than the reference, then the best case scenario for the reduction in density due to the drill pad was the lower confidence interval from the reference minus the upper confidence interval from the drill pad. The worst case scenario was the upper

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[5] All passerines indicates all passerines in Table 3.2.

confidence interval from the reference minus the lower confidence interval from the drill pad.

For all statistical tests, I concluded that abundances were significantly different if $p<0.1$. I used this conservative value of P since sample sizes for some species were small and variation was high and I wanted to avoid making a type II error (accepting the null hypothesis when it is actually false); which could be detrimental for conservation within a federal bird Sanctuary.

RESULTS

We identified 14 species seen on the drill pads and/or control plots (Table 3.2). The density of savannah sparrows was significantly higher on drill pads than reference plots (Table 3.3). Over the whole sanctuary, drill pads would add, on average, habitat for an additional 438 savannah sparrows (Figure 3.3). This was a 92% average increase of savannah sparrows (best case was 100% increase and worst case was a 3% decrease; Figure 3.3). Lapland longspurs were significantly denser on references than drill pads (Table 3.3) and over the sanctuary, drill pads would cause habitat loss for 102 birds on average (Figure 3.3). This was a 97% average decrease of Lapland longspurs (best case was an 8% increase and worst case was a 100% decrease; Figure 3.3). The density of all shorebirds as a group and all passerines (excluding savannah sparrows) on or off drill pads was not significantly different (Table 3.3).

DISCUSSION

Drill pads leave a permanent footprint in the Kendall Island Migratory Bird Sanctuary and have altered the available breeding habitat for some avian species. Lapland longspurs generally do not use drill pads. Microrelief and high surface roughness (e.g., tussocks) are important for nesting and foraging Lapland longspurs (Rodrigues 1994). Chestnut-collared longspurs (*Calcarius ornalus*), an obligate grassland nesting bird, are known to prefer more sparsely vegetated habitats (Owens and Myers 1973), and Sutter *et al.* (2000) found that chestnut-collared longspurs have

Table 3.2. Bird species seen on drill pads and reference plots (D=at least one seen on drill pad, R=at least one seen on reference).

Species	Scientific name	Species Code
Waterfowl		
Greater white-fronted goose	*Anser albifrons*	GWFG ^{D}
Passerine		
American tree sparrow	*Spizella arborea*	ATSP ^{D}
Savannah sparrow	*Passerculus sandwichensis*	SASP $^{D/R}$
Lapland longspur	*Calcarius lapponicus*	LALO $^{D/R}$
Common redpoll	*Carduelis flammea*	CORE $^{D/R}$
White-crowned sparrow	*Zonotrichia leucophrys*	WCSP ^{D}
Yellow warbler	*Dendroica petechia*	YEWA ^{D}
Grouse		
Willow ptarmigan	*Lagopus lagopus*	WIPT $^{D/R}$
Shorebirds		
Red-necked phalarope	*Phalropus lobatus*	RNPH $^{D/R}$
Pectoral sandpiper	*Calidris melanotos*	PESA ^{R}
Lesser yellowlegs	*Tringa flavipes*	LEYE ^{R}
Semipalmated sandpiper	*Calidris pusilla*	SESA ^{R}
Long-billed dowitcher	*Limnodromus scolopaceus*	LBDO ^{D}
Semipalmated plover	*Charadrius semipalmatus*	SEPL ^{D}

Table 3.3. Median, range and number of birds/ha and 95% confidence intervals on drill pads and reference plots (SASP=savannah sparrow and LALO=Lapland longspur); p-value from a Wilcoxon Signed-ranks test; n=8 drill pads and 8 paired controls.

	Drill Pad			**Reference**			**Z value**	**p-value**
Species	**Median**	**Range**	**Density ±95% CI**	**Median**	**Range**	**Density ±95% CI**		
SASP	4	1-22	2.37±1.94	0	0-6	0.20±0.20	-2.52	0.01
LALO	0	0-1	0.013±0.013	2	0-9	0.52±0.52	1.83	0.07
All shorebirds	0	0-9	0.36±0.36	0.5	0-3	0.12±0.12	-0.67	0.50
All passerines (excluding SASP)	4	0-10	1.13±1.13	4	0-10	1.20±1.20	0.81	0.42

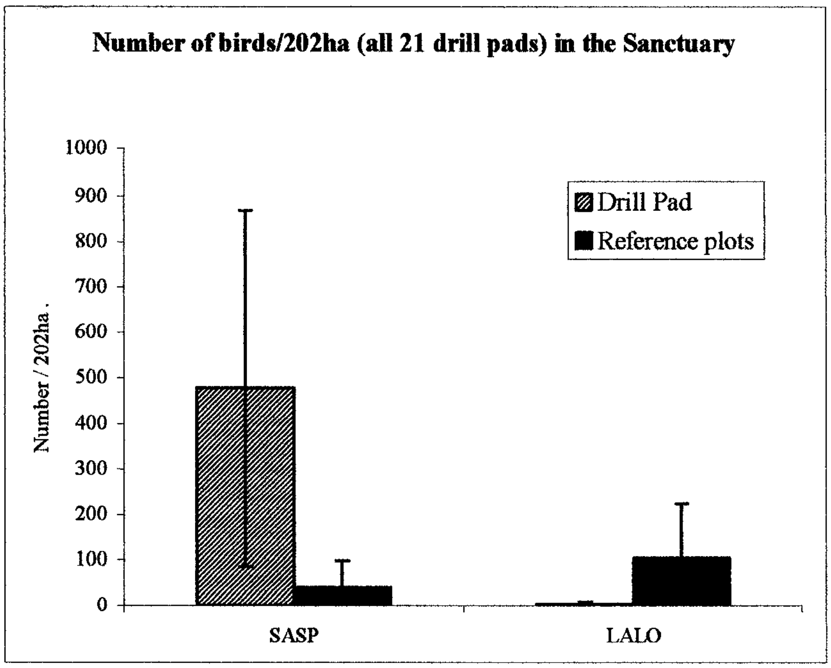

Figure 3.3. Mean density of savannah sparrows (SASP) and Lapland longspurs (LALO) (with 95% CI) extrapolated to all 21 drill pads (202ha) in the sanctuary.

an aversion to more physically disturbed areas. Since drill pads are disturbed habitat that are flat, often graveled, do not have tussocks and have taller shrubs, they therefore do not provide appropriate breeding habitat for Lapland longspurs. Although my results for shorebird distribution were not significant, the dominant shorebirds that use drill pad sites in my study were semipalmated plovers and red-necked phalaropes. Semipalmated plovers build their nests on the gravel (Barry 1976; Troy 2000) and red-necked phalaropes use the water adjacent to the gravel pads for foraging (Rodrigues 1994), hence these birds have a natural attraction to the disturbances resulting from drill pads.

Grassland nesting birds, such as the savannah sparrow, have an aversion towards woody vegetation (O'Leary and Nyger 2000; Coppedge *et al.* 2001). Therefore, it is not clear why savannah sparrows were so much more abundant on drill pads. One reason may be that they are better able to adapt to the disturbance created by drill pads, since the habitat requirements of generalist species (e.g., savannah sparrow) are often more flexible than obligate species (e.g., Lapland longspur; Sutter *et al.* 2000). Bakker and Higgins (2003) found that for avian habitat generalists, species richness was higher in human modified areas of their study area while species richness of obligates was higher in the natural areas. Thus, drill pads can be utilized by generalist species (savannah sparrows) and drill pads are generally not used by Lapland longspurs, an obligate species.

The effect from drill pads is local and small as there is only a loss of habitat for some Lapland longspurs. However, since the drill pads affect the abundance and distribution of some bird species, there is an industrial footprint that represents 0.60% of the sanctuary caused by these permanent anthropogenic features.

My study examined unused drill pads, however from personal observations the change in bird distribution is similar for the staging areas, airstrip and camp within the sanctuary. These other features are also composed of gravel, have taller shrubs and usually have ponds adjacent to them. The camp has buildings and these may have a different effect on avian species distribution. While camped for six weeks near the airstrip and camp, I did not observe any Lapland longspurs on or adjacent to these disturbances. Three examples of birds, all of which breed in broad geographic ranges beyond the arctic coastlands (Sibley 2000), were not seen anywhere else in the sanctuary and nested in the disturbed area of the camp were; varied thrush (*Ixoreus* *naevius*), American robin (*Turdus migratorius*), and northern shrike (*Lanius excubitor*).

Bird distribution in my study may also be affected if the drill pads were active (see Barry 1976 and Barry and Spencer 1976 for results from an active drill pad study adjacent to the Sanctuary). As well, the noise (Slabbekoorn and Peet 2003) from compressor stations, the direct effects of flare stacks on birds (Bjorge 1987), indirect effects of flare stacks on habitat, human disturbance and other activities around active drill pads that affect birds should be considered before further development occurs in the sanctuary. Currently, drill pads cause a 0.60% permanent footprint in the sanctuary. If further development is to take place in the sanctuary (see www.mackenziegasproject.com for current proposals), I recommend that creating new drill pads, runways and gathering building materials (e.g., gravel) inside the sanctuary should not be permitted.

Recommendations

To decrease the permanent footprint currently caused by drill pads in the sanctuary, complete reclamation must take place. Simply removing the gravel is not sufficient reclamation for arctic avifauna. Troy (1991) and Rodrigues (1994) recommended that reclamation tailored to arctic breeding birds should have topographic diversity with a ridges and troughs (approximately 40cm for the tallest ridges) on a combination of flat and sloping aspects. These ridges would most beneficial if they were oriented northwest to southeast because Lapland longspurs nest on the south/southwest sides of ridges (Rodrigues 1994). Thus, the microrelief created should be designed to replicate natural features in the area. Shorebirds are sparse in the sanctuary and they prefer the patterned ground herb type habitat (Gratto-Trevor 1994, 1996), which is very limited in the outer Mackenzie River Delta. However, these birds are very dependant on this area for breeding and a more detailed study within this habitat type could better determine the effect of drill pads on shorebirds. Complete, proper and maintained reclamation of drill pads could provide arctic dependant birds with breeding habitat.

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CHAPTER 4. MANAGEMENT OPTIONS AND RESEARCH NEEDS

Summary of findings

The abundance and distribution of breeding migratory birds has been altered due to the effects of hydrocarbon exploration and development in the sanctuary. Drill sites (i.e. gravel pads, sumps, disturbed vegetation) currently make a 0.6% footprint on the land with the remaining permanent features (e.g., airstrip or camp) possibly accounting for 0.12% more. Drill pads might be restored so that Arctic obligate breeding birds can make better use of those areas (see Chapter 3). Since the seismic lines have not recovered completely they account for 1.8% of the footprint. Therefore, there is an industrial footprint within the sanctuary that affects the birds in excess of the 1% allowable by the Canadian Wildlife Service (CWS; Canadian Wildlife Service 2004). This footprint affects avian species differently, thus management goals should be dictated by: 1) what birds and habitats are crucial an/or unique in the area (e.g., Arctic obligates); and, 2) what habitats are crucial for those species.

Management options

The Canadian Wildlife Service will have to prioritize management goals for the sanctuary. The sanctuary was established prior to oil and gas development for the protection of breeding migratory birds, but hydrocarbon exploration and development have occurred within the sanctuary with the potential for more. Since the total industrial footprint (including seismic lines) is above the minimum 1% allowable by CWS, most of the options include suggestions for no further development that will create a permanent footprint. I have also included suggestions as to how CWS can minimize potential future increases in the industrial footprint size within the sanctuary:

1. Two-dimensional seismic is done for exploration purposes and the sanctuary has been explored with these techniques for 38 years. Additionally, two 3-dimensional surveys have been conducted in regions near the two largest significant discoveries in the sanctuary. Thus, it is possible that the position and abundance of hydrocarbon resources in the sanctuary have been thoroughly mapped to date. Therefore, further exploration should be well justified by industry.

2. Further exploration or development that will add to the permanent impact in the sanctuary should not be conducted until habitat has sufficiently recovered so that birds are no longer affected and the industrial footprint is below 1% as required by the CWS. While new seismic lines did not appear to have a large effect on birds, it is not clear whether changes in habitat on these lines will occur over time, due to the effects of soil compression. Hence, new lines should be monitored to determine whether they will become permanent footprints.
3. Further exploration should be avoided in low-centre polygon habitat because this habitat is essential to breeding habitat for arctic obligates. Although my sample size was small, the data indicated a negative impact on shorebirds and passerines. In addition, under the Northwest Territories Wildlife and Fisheries species monitoring infobase (Resources, Wildlife and Economic Development 2004), 70% of the shorebirds I observed are listed as sensitive and 20% are listed as undetermined status. Therefore, populations of shorebirds are not secure in the Northwest Territories and attempts to preserve their breeding habitat should be paramount.
4. Further exploration and development in upland tundra should not be conducted until the industrial footprint associated with permanent impacts is below 1% in this habitat.
5. Additional studies to determine effects of seismic lines in sedge/willow and dense willow habitat are required before any recommendations for exploration and development can be made for this habitat.
6. Companies should consider other methods, such as helicopters, to survey for gas resources. This would eliminate or greatly reduce the requirement for land-based vehicles and ultimately, the degradation of habitat. Platforms for the workers could be placed on the tundra adjacent to the helicopter to minimize damage to vegetation. To further reduce any possible impacts created during helicopter seismic exploration, any new seismic lines should follow the existing routes of seismic lines.
7. Presently, CWS does not have a snow depth regulation for activities in the sanctuary. However, the Department of Indian and Northern Affairs has a minimum criterion of 10cm before they permit operations in the area (R. Walker personal communication), and CWS thus defaults to this regulation. Therefore, CWS should first establish a minimum snow depth within their own regulations and second, this should be, at a minimum, the same 15cm that is regulated within the Arctic National Wildlife Refuge (U.S. Department of Interior 1983). However, 25cm was originally recommended within the Arctic National Wildlife Refuge and this should

be considered by CWS before making a final decision on this matter. This is because deeper snow greatly reduces vegetation damage, thus seismic exploration should only be done during times of deep snow and only in areas with deep snow (e.g., not in areas where wind has exposed vegetation).

8. The proposed development of a runway at Taglu in the low-centre polygon habitat (Mackenzie Gas Project 2004) should not be permitted.
9. The proposed well sites, processing facilities operations and other permanent features should be built on existing permanent features in the sanctuary (e.g., drill pads) (Mackenzie Gas Project 2004). If these proposed developments are larger in area than the existing disturbances, then they should be established adjacent to the sanctuary.
10. The possibility of directional drilling for hydrocarbon resources from outside the sanctuary should be considered before permitting drilling within the sanctuary.
11. We noticed that seismic machines were sometimes driven side-by-side in the sanctuary creating a 13m wide footprint (this has occurred on both old and new lines). Vehicular traffic should be single file to help keep the footprint to a minimum and alterations to the route should not be permitted.
12. Improved seismic technology will enable managers to reduce the environmental impact of exploration and these devices should be sought after continually.

Future Studies

This study was designed to determine if seismic lines affected the abundance and distribution of breeding migratory birds. Chapter 2 and Chapter 3 outlined the top priority studies that could be done. However, questions addressed by other studies could include:

1. If seismic line age categories were partitioned into separate decades (or 5 year time spans), could there be a better detection of recovery over time (as opposed to all old lines being grouped together)? This would, however, require a much larger sample size of seismic lines than in my study and would thus have to go far beyond the borders of the sanctuary.
2. What are the long term and short term effects on vegetation of vibroseis machines compared to dynamite techniques. From the helicopter I observed a greater footprint on new seismic lines created by vibroseis

machines as opposed to dynamite outside the sanctuary. Therefore, a study outside the sanctuary to compare the short term and long term effects of the two methods is recommended.

3. Do seismic lines affect less abundant avian species in similar ways as abundant species?
4. Is there a difference in invertebrate density/diversity between seismic and reference transects? The seismic lines may have affected the distribution of this food source for birds.
5. Do Lapland longspurs and shorebirds avoid old lines in low-centre polygon and upland tundra respectively, or new seismic lines in all habitats? Since these birds avoided old lines in upland tundra and low-centre polygon respectively, perhaps a larger sample size in the other habitats and/or on other seismic line ages will help determine the answer to this question.
6. How might active winter seismic programs affect non-migratory birds such as willow ptarmigan (*Lagopus lagopus*) and hoary redpolls (*Carduelis hornemanni*) (e.g., helicopters, disturbance, noise, and/or harassment from other aircraft, snowmobiles or people)?
7. How does air traffic affect avian abundance and distribution (fixed wing and helicopter)? If there is to be an increase in activities in and adjacent to the sanctuary, these modes of transportation will most likely be the primary ones and may affect birds.
8. Do the runway, staging areas and camp have the same effect on bird distribution as the drill pads? These possibly account for 0.12% of the permanent footprint and if they cause bird habitat loss, then they are part of the footprint and perhaps there are ways they can be properly restored.

There are many suggestions for future research, but much of this has not been completed in the sanctuary, in the arctic, or in relation to hydrocarbon exploration and development. If further exploration and development is to proceed in the sanctuary, then some of these questions need to be answered before the activities take place. Further research to expand the knowledge of bird responses to anthropogenic disturbances in the arctic will benefit the area of avian ecology and conservation.

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