1017

NORTHERN ALASKA RESEARCH STUDIES

Bird Use of Abandoned Gravel Pads in Arctic Alaska: 1990 and 1991

by

Robert Rodrigues

LGL Alaska Research Associates, Inc.

Prepared for

BP Exploration (Alaska) Inc.

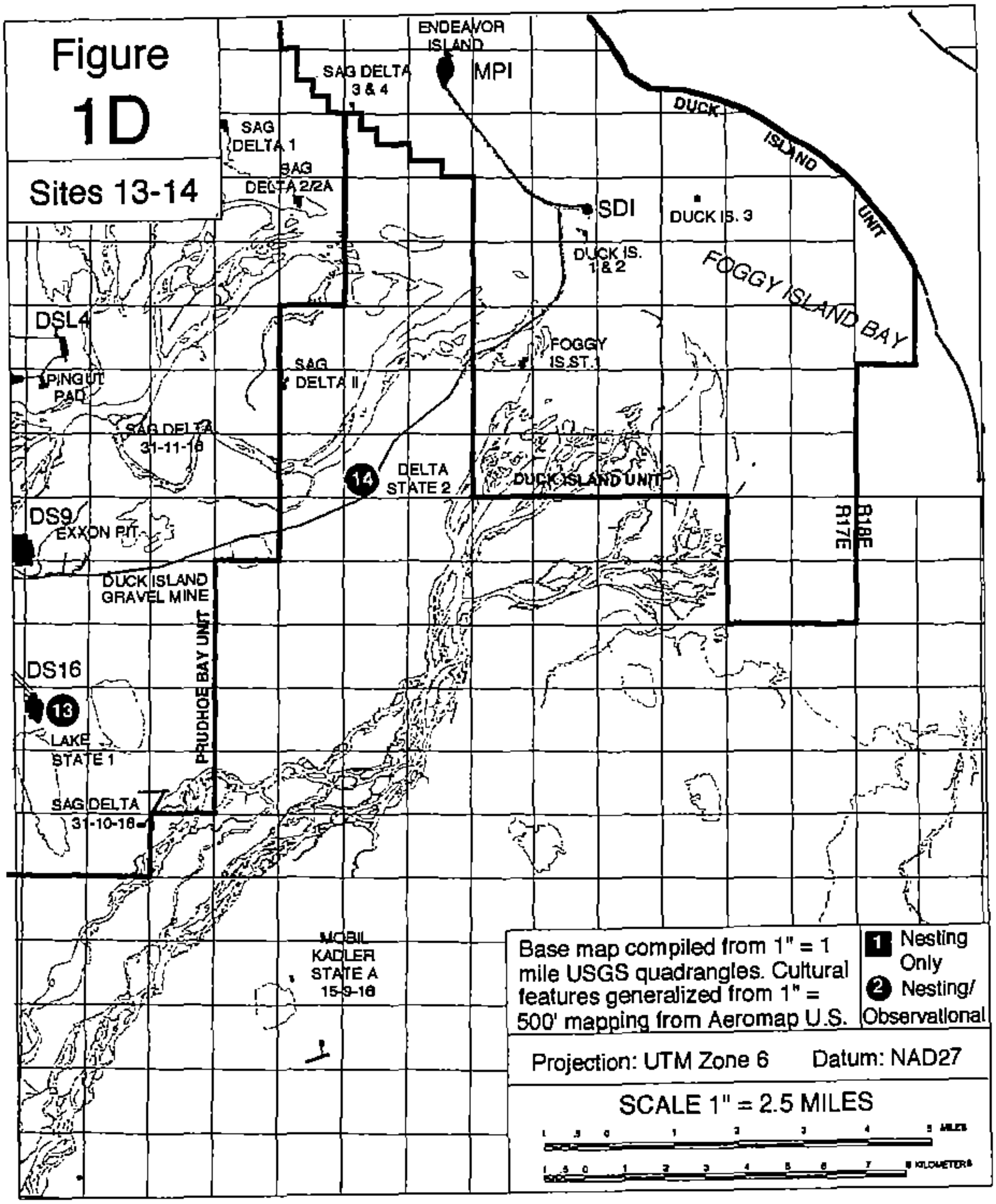


Figure
1D
Sites 13-14
ENDEAVOR ISLAND
MPI
SAG DELTA 3 & 4
SAG DELTA 1
SAG DELTA 2/2A
SDI
DUCK IS. 3
DUCK IS. 1 & 2
DUCK ISLAND UNIT
FOGGY ISLAND BAY
DSL4
PINGUT PAD
SAG DELTA II
FOGGY IS.ST.1
SAG DELTA 31-11-16
DELTA STATE 2
14
DUCK ISLAND UNIT
DS9
EXXON PIT
DUCK ISLAND GRAVEL MINE
R17E
R18E
DS16
13
LAKE STATE 1
PRUDHOE BAY UNIT
SAG DELTA 31-10-16
MOBIL KADLER STATE A 15-9-16
Base map compiled from 1" = 1 mile USGS quadrangles. Cultural features generalized from 1" = 500' mapping from Aeromap U.S.
1 Nesting Only
2 Nesting/ Observational
Projection: UTM Zone 6
Datum: NAD27
SCALE 1" = 2.5 MILES

Bird Use of Abandoned Gravel Pads in Arctic Alaska: 1990 and 1991

by

Robert Rodrigues

May 1992

Prepared by

LGL Alaska Research Associates, Inc.
4175 Tudor Center Drive, Suite 101
Anchorage, Alaska 99508-5917

Prepared for

BP Exploration (Alaska) Inc.
Environmental and Regulatory Affairs Department
P.O. Box 196612
Anchorage, Alaska 99519-6612

BIRD USE OF ABANDONED GRAVEL PADS IN ARCTIC ALASKA: 1990 AND 1991

by
Robert Rodrigues

May 1992

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

BP Exploration (Alaska) Inc.
Environmental and Regulatory Affairs Department
Special Studies
P.O. Box 196612
Anchorage, Alaska 99519-6612

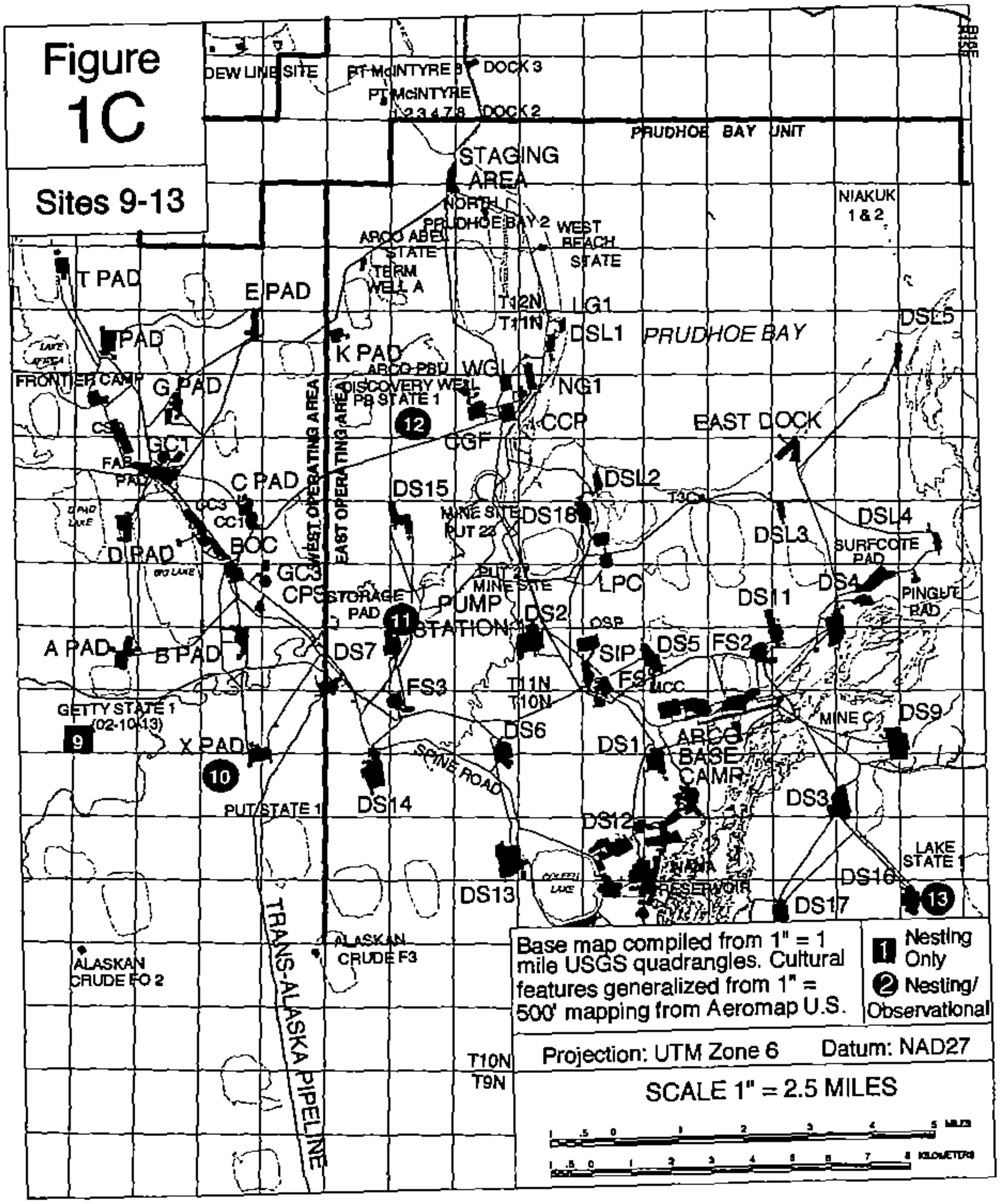


Figure 1C

Sites 9-13

Executive Summary

In 1989, BP Exploration (Alaska) Inc. and LGL Alaska Research Associates, Inc. initiated a series of studies of wildlife use of disturbed habitats in Arctic Alaska. A major goal of these studies was to assess the impacts of gravel fill, which is required to insulate tundra permafrost, on the wildlife community in and around the Prudhoe Bay oil field. An additional objective was to collect information useful for rehabilitating habitats affected by gravel fill. The findings of the 1989 work (Pollard et al. 1990) indicated that abandoned gravel pads were used by wildlife to a surprising extent. Levels and types of uses varied by species and habitat type, but gravel pads almost always attracted more individuals per time period than did undisturbed tundra plots.

The 1989 results interested agencies, and a more detailed analysis was planned. In 1990 and 1991, one experiment (the "nesting study") was designed to explore the effects of abandoned gravel pads on the nesting density, success, and diversity of tundra-nesting bird species. Another experiment (the "post-breeding observational study") was designed to compare several different microhabitat types present on and adjacent to abandoned gravel pads in terms of their post-breeding use by bird species. In 1991, a third study was initiated to investigate habitat characteristics associated with bird nests to gain insight on ways of rehabilitating abandoned gravel sites.

For the nesting study, 13 study sites were used for most comparisons. At each site a 10-hectare plot was established surrounding an abandoned gravel pad (the "disturbed" plot), and another plot was placed on adjacent undisturbed tundra (the "undisturbed" plot). Data on bird nesting densities, nesting success, and species diversity within plots were collected, and comparisons were made between disturbed and undisturbed plots. One site, Ugnu 1, could possibly be considered an outlier because of the thinner gravel and higher degree of plant colonization compared to that of other sites. Therefore, results of the nesting study are presented both with and without data from Ugnu 1. These results indicate that:

- More nests were initiated on undisturbed plots than on disturbed plots when data for all sites for each year are considered, but the difference between the two in mean nest densities was not statistically significant (P=0.17 and 0.56).
- When data from Ugnu 1 are deleted, more nests were initiated each year on undisturbed plots than on disturbed plots. Nest density was significantly higher in undisturbed plots in 1990 (P=0.05), but not in 1991 (P=0.84).
- There was no statistically significant difference in nest success between the two plot types for either year (P=0.31 and P=0.84 for all sites, and P=0.25 and P=0.96 when Ugnu 1 is excluded).
- More species nested in the disturbed plots (16) than in the undisturbed plots (13) in 1990. In 1991, the number of species nesting in undisturbed plots remained the same (13), but declined in disturbed plots (12). However, the difference was not statistically significant for either year (P=0.43 and 0.27).
- Of the four most common nesting species, there were significantly more nests of Pectoral

Sandpiper in undisturbed than in disturbed plots in 1990 (P=0.01). Over twice as many Red-necked Phalaropes nested in disturbed plots than undisturbed plots each year, but the difference was significant only in 1991 (P=0.05). Lapland Longspur and Semipalmated Sandpiper showed no significant differences in nest numbers between the two plot types for either year.

- Less common species generally nested more frequently on undisturbed than on disturbed plots. However, the numbers were too small to determine whether these differences were significant.
- The density of nests (all species and plots combined) on the non-graveled portions of disturbed plots was not significantly different from nest density on the undisturbed plots for either year (P=0.70 and 0.35). This suggests that the value of tundra as nesting habitat was not diminished by the presence of gravel pads. Thermokarsting may enhance the tundra adjacent to pads as nesting habitat for some species.
- Although the number of birds using disturbed plots was higher than the number using undisturbed plots during three plot-use surveys, the differences were not significant for the first two surveys (P=0.75 and 0.29), and only marginally significant during the third (P=0.06).

The post-breeding observational study of bird use was carried out at abandoned gravel pad sites for approximately one month following the end of nesting. Birds were observed on plots established on various disturbed habitats. At some sites, plots were also established on adjacent undisturbed tundra to give an indication of bird use of natural habitats. Systematic observations of bird use were made from elevated blinds during 2.5-hour sessions in the mornings and afternoons. Data were collected regarding numbers of each species, type of behavior, and the microhabitat used.

Results of these observations in 1990 and 1991 indicated that:

- Levels of bird use were highest at two sites which had been the objects of experimental rehabilitation.
- Lapland Longspur was by far the most frequently observed species at gravel sites, although Snow Bunting was the most common species at a site at which gravel had been removed. Gravel plots with some water present attracted more shorebird species than plots without water.
- The levels of bird use on gravel plots appeared to be related to presence or absence of vegetation and to vegetation type. The results in 1991 confirmed observations in 1990 that levels of use were higher on plots with natural plant colonization than on plots with seeded cultivars. Fertilization may play an important role in encouraging plant colonization. Gravel plots with no vegetation attracted few birds.
- Of 34 study plots, 5 were aquatic (i.e., reserve pits, impoundments, and a pond). Aquatic plots generally had relatively high levels of use and high species diversity compared with gravel and tundra plots.
- Birds were observed feeding more than 50 percent of the time on most gravel plots.
- On gravel plots, it appeared that birds were feeding primarily on seeds of forb species which had colonized those sites.

To study the microhabitat characteristics associated with bird nests, small, 2 m by 2 m square plots centered on bird nests were compared with plots centered on random points on undisturbed tundra. Variables measured included microrelief, variability of relief (or roughness) within plots, percent graminoid cover, percent shrub/forb cover, and presence or absence of water. For Lapland Longspurs, nests were often located behind a small ridge or polygon rim; thus, orientation of nests in relation to these ridges was recorded. It was felt that these habitat characteristics could be influenced or controlled when rehabilitating abandoned gravel sites.

Results of the study of these variables indicate that:

- Of the four species studied, only Lapland Longspur selected nesting sites with higher amounts of relief and roughness than occur randomly on the tundra.
- Lapland Longspurs tended to orient their nests on the south and southwest sides of ridges, polygon rims, and tussocks.
- Percent graminoid cover was higher on nest plots of Red-necked Phalaropes and Pectoral

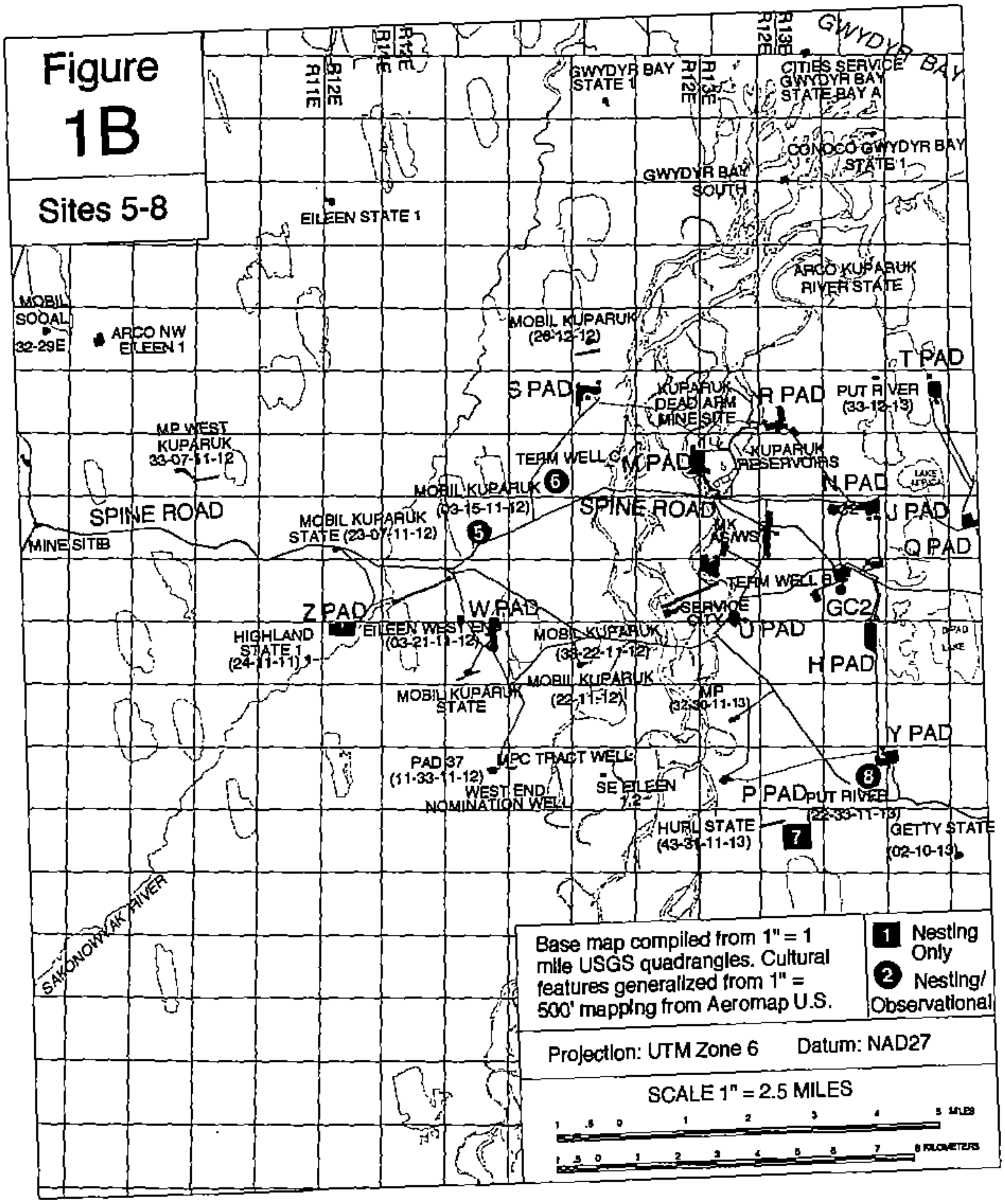


Figure 1B
Sites 5-8

Sandpipers than on nest plots of other species and random plots.

- Percent shrub/forb cover was highest on nest plots of Semipalmated Sandpiper and lowest on nest plots of Red-necked Phalarope.
- A higher percentage of plots centered on nests of Red-necked Phalarope contained water than plots centered on nests of other species or random points.

The association of some nests with natural vegetation and thermokarst on abandoned gravel fill suggests that habitat manipulation may improve the value of abandoned pads as nesting habitat for some birds.

During the post-breeding season, Lapland Longspurs were observed more often at sites undergoing experimental revegetation. Levels and types of post-breeding uses of abandoned pads depended on the amount and type of vegetation and water present. The use of fertilizers at these sites may be helpful in encouraging plant colonization.

Abandoned gravel sites may be enhanced as nesting habitat by manipulating the surface to form a series of ridges and troughs interspersed with flat, slightly sloping areas. Some ridges should be oriented in a northwest to southeast direction. High graminoid cover (to 50 percent) would most benefit Red-necked Phalarope and Pectoral Sandpiper; other species may need less. Shrub/forb cover might be most beneficial to Lapland Longspurs because it may be a potential food source after the nesting season. The presence of water at the nest site does not seem to be necessary for most bird species. However, the effect of water on plant growth makes it an important consideration in rehabilitation of abandoned gravel sites.

Table of Contents

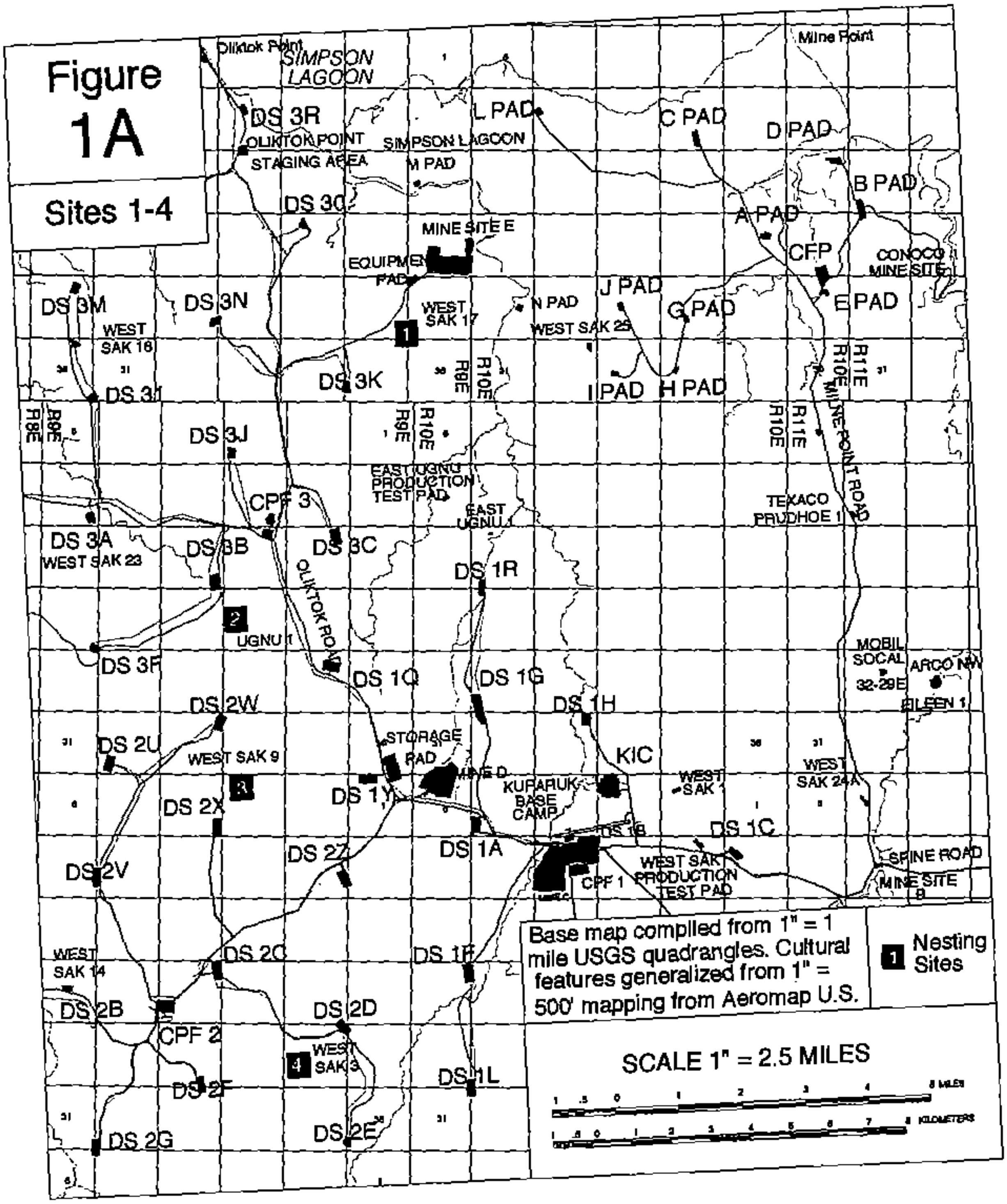
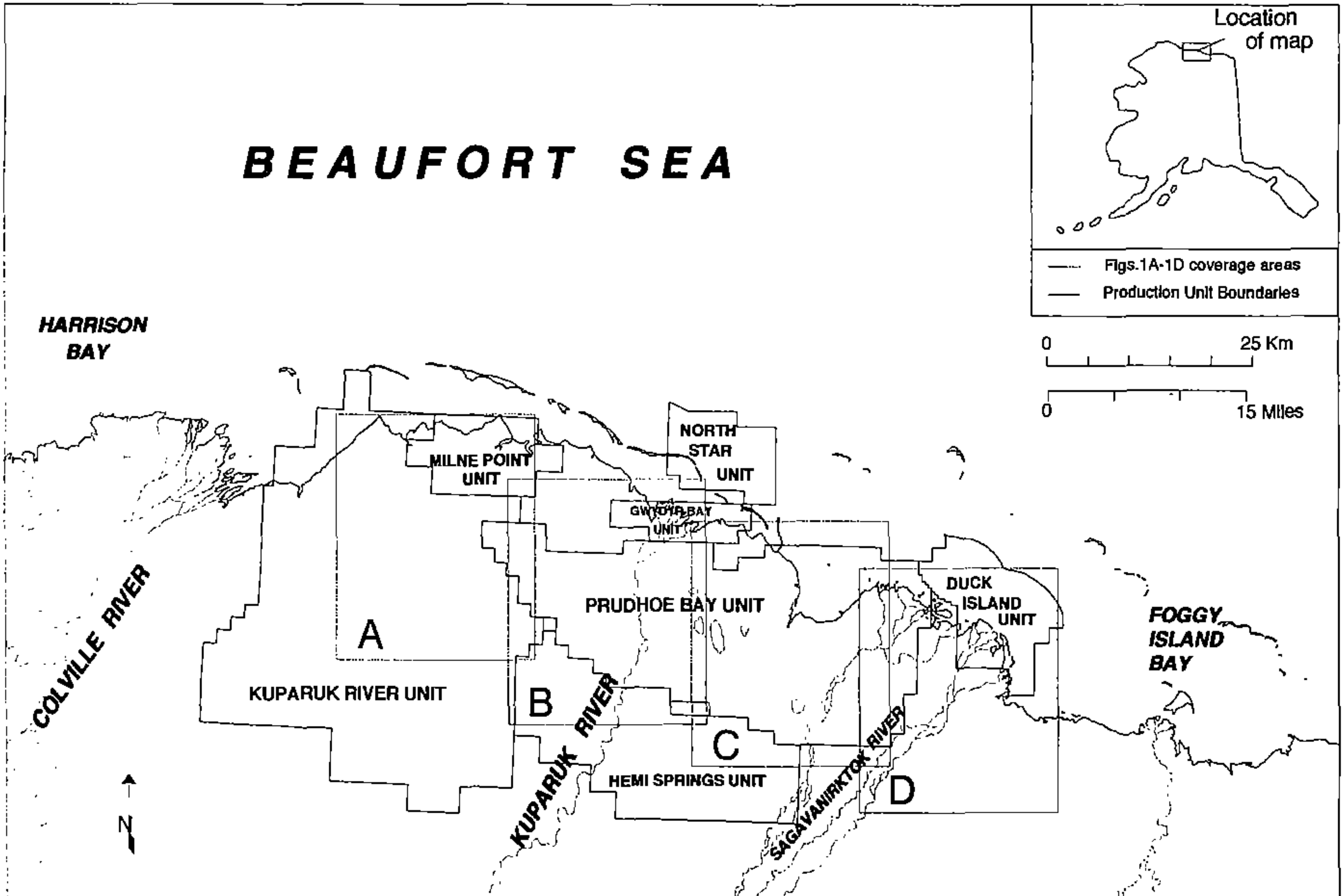


Figure 1A
Sites 1-4
Oliktok Point
SIMPSON LAGOON
Milne Point
DS 3R
OLIKTOK POINT STAGING AREA
SIMPSON LAGOON
M PAD
L PAD
C PAD
D PAD
B PAD
A PAD
CFP
CONOCO MINE SITE
E PAD
DS 3O
MINE SITE E
EQUIPMENT PAD
WEST SAK 17
N PAD
J PAD
G PAD
WEST SAK 25
I PAD
H PAD
DS 3M
WEST SAK 16
DS 3N
DS 3K
DS 3I
R9E
R8E
R10E
R11E
MILNE POINT ROAD
DS 3J
EAST UGNU PRODUCTION TEST PAD
EAST UGNU 1
TEXACO PRUDHOE 1
CPF 3
DS 3A
WEST SAK 23
DS 3B
DS 3C
OLIKTOK ROAD
DS 1R
UGNU 1
DS 3F
MOBIL SOCAL 32-29E
ARCO NW EILEEN 1
DS 1Q
DS 1G
DS 2W
DS 1H
DS 2U
STORAGE PAD
WEST SAK 9
KIC
MINE D
KUPARUK BASE CAMP
WEST SAK 1
WEST SAK 24A
DS 2X
DS 1Y
DS 1B
DS 1C
DS 2Z
DS 1A
DS 2V
WEST SAK PRODUCTION TEST PAD
CPF 1
SPINE ROAD
MINE SITE B
WEST SAK 14
DS 2C
DS 1F
DS 2B
CPF 2
DS 2D
WEST SAK 3
DS 2F
DS 1L
DS 2G
DS 2E
Base map compiled from 1" = 1 mile USGS quadrangles. Cultural features generalized from 1" = 500' mapping from Aeromap U.S.
Nesting Sites
SCALE 1" = 2.5 MILES
MILES
KILOMETERS

List of Figures



DATUM: NAD27
PROJECTION: UTM ZONE 6
SPHEROID: CLARKE 1866

Figure 1
General location of study area in relation to oil production units on the Arctic Coastal Plain, Alaska. Figures 1A-1D depict specific locations of all study sites. Names and descriptions of all study sites can be found in Appendices (A and B).

List of Tables

Acknowledgments

This study was funded by BP Exploration (Alaska) Inc. (BPX). Thanks go to Debra Beaubien and Dr. Chris Herlugson (Supervisors of Special Studies for BPX's Environmental Department) for their promotion and support of this project. I would also like to thank Steve Lombard and Michelle Gilders of BPX. Steve provided us with numerous aerial photographs and maps of the study areas. Michelle provided many useful comments on various drafts of this report. Staff from BPX's North Slope Operations division also provided support in the form of lodging, transportation, storage, and workspace. Dan Waters and Jody Werner helped in the production of the study area base maps and the overlays for the aerial photographs in the appendix. Many conversations with Dr. Jay McKendrick and Pete Scorup (University of Alaska, Agricultural and Forestry Experimental Station) regarding plant identification, plant colonization of disturbed sites, and oil field history were very informative and helpful. Pete also had many suggestions which were helpful during the study of microhabitats associated with bird nests. Gwen Turner, also of the University of Alaska, had many helpful comments and suggestions during and after the field season. Additional thanks go to John Luginbuhl, Ken Kertell, David Wimpfheimer, and Eric Ruhlen, Diane Roche, Chris Knapp, and Midge Miller for their assistance in the field. Over the years, other field biologists, especially Craig Hohenberger, Jo Young, Terry Carpenter, Terry Schick, Dave Rudholm, Nils Warnock, and Mark Colwell, provided suggestions and moral support during the field season. Many comments and suggestions by Bob Pollard, Randall Howard, Matt Cronin, and Peter Lent of LGL were extremely helpful. Phillip Martin of the U.S. Fish and Wildlife Service had constructive comments on the 1991 report which helped improve this report. Cathy Taylor computerized our field data; Curt Wilkinson and Vijay Chhipa assisted with computer analysis of the data. Mark Miller and Sally Bibb helped with statistical analyses of the data. Vijay Chhipa, Rob Dillinger, and Benny Gallaway helped with the principal components analysis of the data for the study of microhabitat characteristics associated with nest sites. Jim Lukin had many helpful editorial comments. Finally, special thanks go to Dr. Joe Truett for his help during the first two years of this study. Joe's guidance and assistance during the initial formulation of the study design, his help in the field, and his editing skills have been invaluable.

Appendix C
Cartographic Notes

The regional map (Figure 1) is a base map generalized from various sources, and projected to Universal Transverse Mercator, Zone 6, NAD27.

The specific area maps (Figures 1A–1D) were produced from 1:63360 USGS quad maps. The coastline, rivers, and all facilities were taken from unit operator 1:6000 maps. The U.S. Public Land System (USPLS) grid was generated from a Bureau of Land Management (BLM) based protraction software package. All townships and sections are protracted. All features have been projected to Universal Transverse Mercator, Zone 6, NAD27.

Aerial photography was obtained at a scale of 1"=500' with a cartographic camera using Kodak 2443 false-color infrared film. The date of each photograph and the original photograph label are given below in Table C-1.

Table C-1. Dates and original labels of color infrared aerial photographs used to produce site maps in Appendix A. The original scale of all photographs was 1"=500'. The photographs were enlarged, and the scale is indicated on each map.

Figure	Date	Original Photo Label
A-1	8/22/89	EPB DS-16 #3
A-2	8/22/89	WPB Put River 22-33-11-13 #1
A-3	8/22/89	WPB Term Well C #2
A-4	8/22/89	EPB 17 #6
A-5	8/22/89	EPB DS-7 #2
A-6	8/22/89	WPB MP 13-15-11-12 #2
A-7	8/22/89	WPB 16 #16
A-8	8/22/89	ENDCT 25 #10

Appendix B
List of Birds and Mammals

Table B-1. Wildlife species observed during nesting and observational studies, Prudhoe Bay, Alaska, 1990 and 1991.

Birds		Birds (cont'd)	
Scientific Name	**Common Name**	**Scientific Name**	**Common Name**
Anser albifrons	Greater White-fronted Goose	*Calidris bairdii*	Baird's Sandpiper
Branta canadensis	Canada Goose	*Calidris melanotos*	Pectoral Sandpiper
Branta bernicla	Brant	*Tryngites subruficollis*	Buff-breasted Sandpiper
Anas acuta	Northern Pintail	*Stercorarius parasiticus*	Parasitic Jaeger
Anas clypeata	Northern Shoveler	*Larus hyperboreus*	Glaucous Gull
Somateria spectabilis	King Eider	*Xema sabini*	Sabine's Gull
Clangula hyemalis	Oldsquaw	*Lagopus mutus*	Rock Ptarmigan
Charadrius semipalmatus	Semipalmated Plover	*Lagopus lagopus*	Willow Ptarmigan
Pluvialis squatarola	Black-bellied Plover	*Corvus corax*	Common Raven
Pluvialis dominica	Lesser Golden-Plover	*Motacilla flava*	Yellow Wagtail
Phalaropus lobatus	Red-necked Phalarope	*Calcarius lapponicus*	Lapland Longspur
Phalaropus fulicaria	Red Phalarope	*Plectrophenax nivalis*	Snow Bunting
Limnodromus scolopaceus	Long-billed Dowitcher	*Carduelis flammea*	Common Redpoll
Calidris himantopus	Stilt Sandpiper		
Arenaria interpres	Ruddy Turnstone		
Calidris alpina	Dunlin	**Mammals**	
Calidris pusilla	Semipalmated Sandpiper		
Calidris fuscicollis	White-rumped Sandpiper	*Alopex lagopus*	Arctic Fox

Bird Use of Abandoned Gravel Pads in Arctic Alaska 1990 and 1991

INTRODUCTION

In Arctic Alaska, activities related to petroleum development can result in disturbances to wildlife habitats. One of the principal kinds of disturbance is the placement of gravel fill (Walker et al. 1986; 1987a, b, c). Gravel fill is used to support facilities and transportation associated with the production phase of development and is required to prevent thawing of the underlying permafrost. In past years, gravel fill was also used in the construction of exploratory well pads which have since been abandoned. This practice was discontinued in 1986 when technological advances led to the use of temporary ice pads for exploratory drilling in winter.

The oil industry and regulatory agencies are interested in learning how the placement of gravel fill affects wildlife habitat and wildlife populations. Information concerning impacts of gravel fill upon wildlife will be useful in establishing guidelines for the eventual rehabilitation of abandoned gravel pads and in minimizing potential future impacts should additional petroleum development occur in the Arctic.

Studies have been conducted to gain insight into the effects of various aspects of oil-related development on wildlife and habitats in the Prudhoe Bay oil field. Troy and Burgess (1983), Troy et al. (1983), Meehan (1986), and Troy (1985, 1988, 1991a) investigated the effects of roads, road dust, habitat fragmentation, and abandoned peat roads on bird nest densities and bird use of tundra habitats. Troy and Carpenter (1990) studied nesting birds before and after construction of oil field facilities. Jorgenson (1988, 1989) and Jorgenson et al. (1990) studied revegetation of disturbed sites.

With support from BP Exploration (Alaska) Inc. (BPX), LGL Alaska Research Associates, Inc. initiated a pilot study in 1989 (Pollard et al. 1990) to investigate further the effects of development-related habitat disturbance on wildlife. During this pilot study, observations were made of wildlife uses of abandoned gravel pads and impoundments and of "natural" habitats that resembled disturbed habitats (e.g., floodplain alluvium and ponds). These observations set the stage for the development of hypotheses about the relationship between disturbed habitats and wildlife populations which could be more rigorously tested in future years.

The results of the 1989 studies showed that many species of birds and mammals used disturbed habitats and that the extent of use differed among different species. During these studies, observations of nesting birds in the vicinities of abandoned gravel pads suggested that the pads did not exclude birds from nesting on nearby tundra. Other observations indicated that certain microhabitat features on and near pads may have attracted some species of nesting birds. Similarly, certain microhabitat features may have attracted birds to feed or rest on the pads.

The study was continued in 1990 (Rodrigues and Miller 1991) and consisted of two parts. Part 1 examined the effects of abandoned gravel pads on nest density and success of tundra-nesting birds (nesting study); and Part 2 compared levels of post-breeding use among several microhabitat types on disturbed and undisturbed terrain at and near some of these abandoned sites (post-breeding observational study). When data were pooled for all gravel sites, results of the nesting study showed no statistically significant differences in nest density, nest success, or species diversity

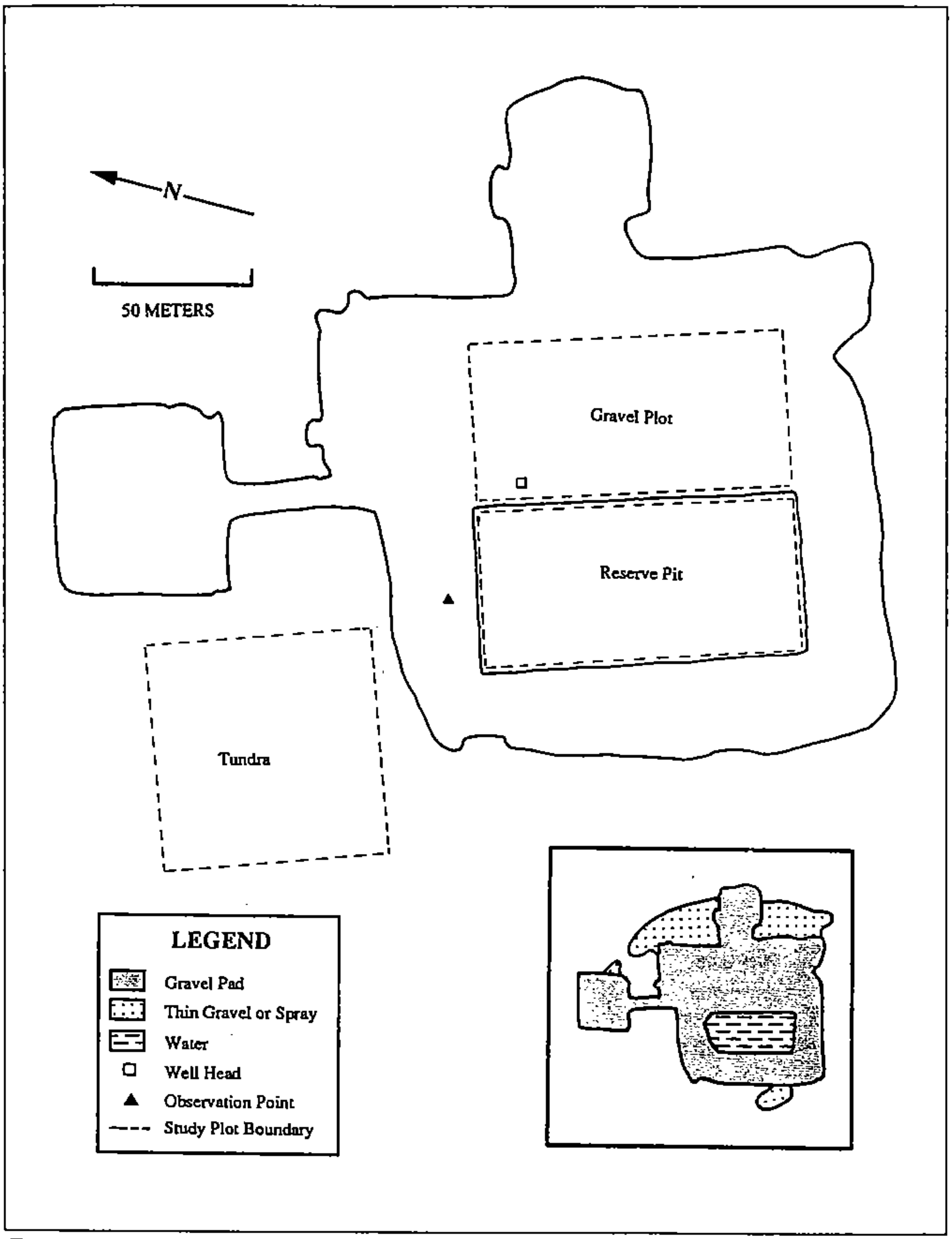


Figure A-8. Location of disturbed and undisturbed study plots for post-breeding observational study at Delta State 2, Prudhoe Bay, Alaska, 1990. Inset shows extent of gravel and related disturbances.

ing study showed no statistically significant differences in nest density, nest success, or species diversity between disturbed and undisturbed plots. The association of some nests with natural vegetation and thermokarst on and near abandoned gravel fill suggested that habitat manipulation may improve the value of abandoned sites as nesting habitat for some bird species. During the post-breeding observational study, Lapland Longspurs seemed to be attracted to areas of abandoned gravel fill, where their most frequently observed behavior was feeding. Levels and types of post-breeding uses of abandoned gravel pads depended on the character of the microhabitats available on the pads, especially the vegetational characteristics and water regime.

This report describes the continuation of this study in 1991 and is divided into three parts. For the nesting study (Part 1), the sites used were the same as in 1990; and nest density, nest success, and species diversity are compared between years. For the post-breeding observational study (Part 2), new sites were selected in an effort to look at different sets of microhabitat variables. A study was initiated (Part 3) to determine what types of microhabitat characteristics attract birds to nest at particular sites by comparing microhabitat characteristics associated with small (2 m x 2 m) plots centered on bird nests with characteristics of similar plots centered on random points.

STUDY AREA

Study sites (Table 1) were located on the Arctic Coastal Plain of Alaska in or near the Kuparuk and Prudhoe Bay oil fields (Figs. 1A–1D). Physiography of the landscape in the region is typical of that of the coastal plain in general. Soils are moist to wet and the vegetation is dominated by graminoids. The topography is generally flat but has a high degree of microrelief caused primarily by the formation of frost polygons, by the formation and drainage of thaw lakes, and by thermokarst. Many lakes and ponds of various sizes and depths are present. Two major rivers, the Kuparuk and the Sagavanirktok, pass through the study area.

PART ONE: BIRD NESTING AND ABANDONED GRAVEL PADS

Objectives

The 1991 nesting study had two main objectives:

- To test the null hypothesis that there is no difference in bird nest density, nest success, or species composition between plots containing abandoned gravel pads and undisturbed plots.
- To test the null hypothesis that there is no difference in the number of birds observed on plots containing abandoned gravel pads and on undisturbed plots.

Table 1. Name, number, and location of sites used for observation of nesting and post-breeding birds at Prudhoe Bay, Alaska, 1990 and 1991. Sites are located on Figures 1A-1D.

Site No.	Site Name	Location (Figure)
1	West Sak 17	1A
2	Ugnu 1	1A
3	West Sak 9	1A
4	West Sak 3	1A
5	Mobil Kuparuk 3-15-11-12	1B
6	Term Well C	1B
7	Hurl State	1B
8	Put River 22-33-11-13	1B
9	Getty State	1C
10	Put State 1	1C
11	Storage Pad	1C
12	Prudhoe Bay State 1	1C
13	Lake State 1	1C and 1D
14	Delta State 2	1D

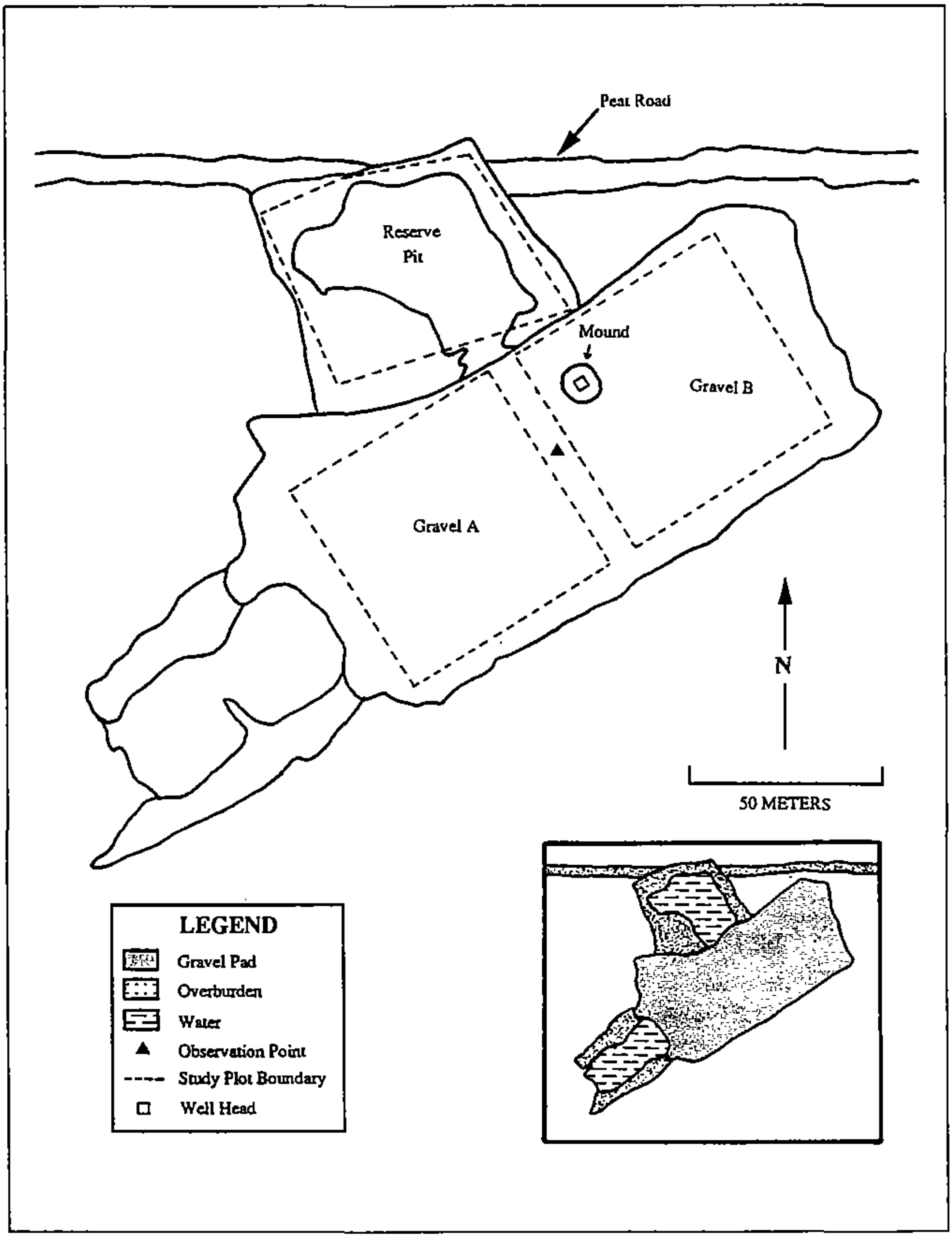


Figure A-7. Location of disturbed and undisturbed study plots for post-breeding observational study at Put State 1, Prudhoe Bay, Alaska, 1991. Inset shows extent of gravel and related disturbances.

Methods

Site Selection and Plot Setup

The 14 sites selected for the nesting study (Figs. 1A–1D) were the same as those used during the previous year (Rodrigues and Miller 1991). Thirteen sites contained an abandoned gravel pad from an exploratory well. One site, Put River 22-33-11-13 ("BP Pad"), originally contained an abandoned pad, but most of the gravel had been removed prior to the start of our 1990 observations.

At each site, a pair of study plots (disturbed and undisturbed) of 10 hectares (ha) each was established. One of the pair, designated as the "disturbed" plot, contained an abandoned gravel pad and surrounding tundra. Some disturbed plots also contained other disturbed areas such as reserve and/or flare pits, old vehicle tracks and other areas of barren ground. On average, gravel disturbances composed approximately 25 percent of the disturbed plots. One site, Put State 1, contained an old peat road. An "undisturbed" tundra plot was established near (usually 1 m from but as far as 300 m from) the disturbed plot at each site. Three undisturbed plots (Ugnu 1, West Sak 3, and Put State 1) contained minor disturbances (surface disruptions) which were vegetated and usually difficult to observe on the ground, but which could be seen on aerial photographs. At Put State 1, the peat road in the disturbed plot also passed through the undisturbed plot.

Plot boundaries at each site were set such that the two plots contained similar habitat types, excluding the affected portions of the disturbed plot. To obtain the best possible habitat match, color infrared (CIR) aerial photographs (scale 1"=500') taken in 1989 by Aeromap U.S. were examined, and the boundaries were sketched on the photographs prior to entering the field. The 10-ha plots were either square (316.2 m x 316.2 m) or rectangular (200 m x 500 m or 250 m x 400 m).

The CIR photographs, a hand-held compass, and a surveyor's chain were used to establish the plots. A grid system marked at intersections with 3-ft-tall stakes was established in each plot. Grid cells were 52.7 m x 52.7 m in square plots and 50 m x 50 m in rectangular plots. Each stake was marked with a letter and number so that nests could be relocated at a later date.

To facilitate the display of nest distributions, study sites were mapped from 1"=500' CIR aerial photographs (Rodrigues and Miller 1991, Appendix A). Gravel pads, gravel spray, reserve and flare pits, other obvious disturbances, and geobotanical types on both disturbed and undisturbed plots were delineated on maps. Geobotanical types were based on Walker et al. (1983). In some cases, geobotanical types were lumped when more than one type of vegetation or landform was present. A planimeter was used to measure areas of gravel and gravel-related disturbances on maps. Spatially limited disturbances (such as thermokarsting and vegetation changes around the perimeters of pads) that were too small to map were not depicted on maps but can be seen on aerial photos (Rodrigues and Miller 1991, Appendix A).

Data Collection

Nest Searching. Methods for nest searches were adapted from those described by LGL (1983), Martin (1983), and Troy and Wickliffe (1990), and were similar to those used in the 1990 study (Rodrigues and Miller 1991). Two techniques, "searches" and "rope drags", were used at each study plot. During the searches, a biologist slowly walked a zig-zag pattern to make four passes through each grid of each plot in an attempt to locate bird nests either by flushing individuals from the nest or by waiting for birds suspected of having a nest in the area to return. The rope drags involved two biologists walking abreast along the grid lines dragging a nylon rope between them in an attempt to flush tight-sitting birds from their nests. Birds that had not been flushed during this procedure, but that exhibited behavior indicating that they might be nesting in the area, were also observed to determine if they returned to the nest. Two searches and two rope drags were used at each site in 1990; in 1991, a third search period was also employed (Table 2).

Table 2. Schedule of activities for nesting study at disturbed and undisturbed plots, Prudhoe Bay, Alaska, 1991.

Activity	Dates
Plot maintenance	June 2-6
First search/First plot-use survey	June 7-12
Second search	June 12-22
First rope-drag	June 13-26
Third search/Second plot-use survey	June 23-July 4
Second rope-drag	June 28-July 10
Third plot-use survey	July 19-24
Nest monitoring	July 1-24

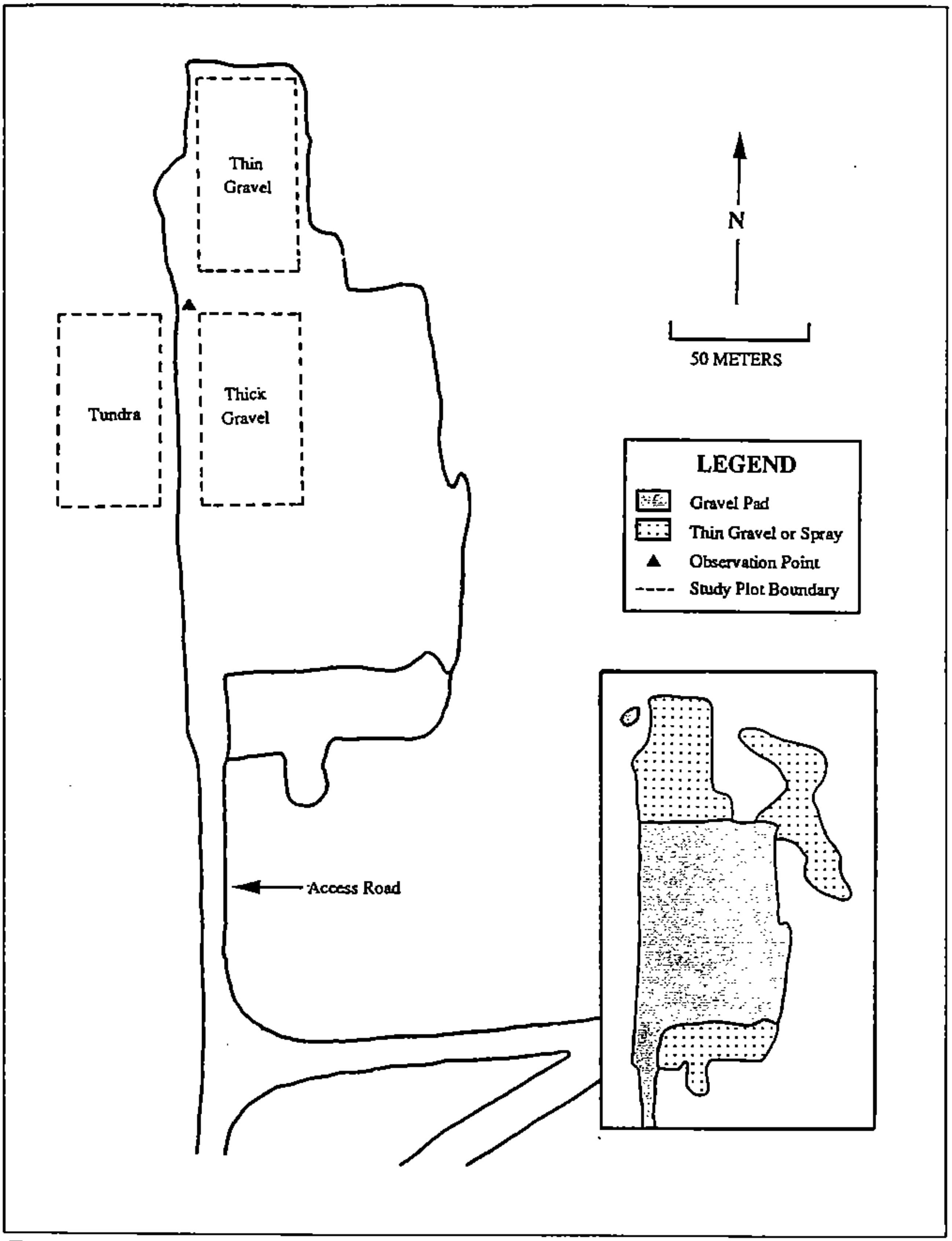


Figure A-6. Location of disturbed and undisturbed study plots for post-breeding observational study at Mobil Kuparuk 3-15-11-12, Prudhoe Bay, Alaska, 1991. Inset shows extent of gravel and related disturbances.

When a nest was located, it was marked using a plain wooden tongue depressor on which was written a unique number and the species name. The tongue depressor was placed approximately 1 m from the nest toward the gridline having the lower letter of the alphabet. A fluorescent orange tongue depressor with a direction arrow indicating the number of paces to the nest was then placed on that gridline. Information, including species name, nest number, date, habitat type, number of eggs or young, and number of paces to the nearest grid markers, was recorded in a field notebook.

Nest Monitoring. In 1991, eggs began to hatch by approximately July 1, at which time the monitoring of nests to determine hatching success commenced. Nests were checked every three to five days by a biologist who walked through the plots looking for eggs, chicks, or signs of hatching or predation. New nests found during monitoring were marked similarly to those discovered during plot setup and nest searches.

Plot-Use Surveys. In 1991, all plots were surveyed for bird use three times. During the first and third nest searches (Table 2), all birds using each plot type at each site were recorded. These two surveys corresponded in time to the periods of nest initiation and nest incubation, respectively. A third plot-use survey was conducted after most nesting was completed and birds were beginning to stage for fall migration. Birds flying over the plots, but not actively using the plots, were not counted during plot-use surveys.

Snow Cover. During the first plot-use survey, the percent of snow cover was estimated for each grid cell on both disturbed and undisturbed plots. This was done to determine the effect of abandoned gravel pads on snow cover. It was not done in 1990, however, because snow had disappeared prior to the beginning of the study.

Data Analysis

Density of nests, nest success, and species diversity of nesting birds were calculated and compared on disturbed and undisturbed plots. Values of $P \leq 0.05$ were considered statistically significant. Data gathered at the rehabilitation site, Put River 22-33-11-13, were not included in the analysis because gravel had been removed from this site. All other sites were included in statistical comparisons.

Nest density data (total nests per 10-ha plot) were analyzed for each pair of disturbed and undisturbed plots. The null hypothesis of no difference in mean nest densities between disturbed and undisturbed plots was tested by using a Wilcoxon signed-ranks test in the computer package SYSTAT® (Wilkinson 1990).

Nest density on non-graveled portions of disturbed plots was calculated and compared with nest density on undisturbed plots. The null hypothesis of no difference in nest density was tested using a Wilcoxon signed-ranks test.

All known nests on both plot types were classified as successful or unsuccessful. The null hypothesis of no difference in nest success between disturbed and undisturbed plots was tested by using a Wilcoxon signed-ranks test. Success or failure of a nest was determined using the criteria of Troy and Wickliffe (1990). That is, a nest was considered to have failed if the initiation date was known and the nest was found empty before the normal incubation period was complete, or signs of predation, such as broken eggs, fox scat or fox scent, or a destroyed nest were present. A nest was considered successful if chicks were found near the nest, or if tiny shell fragments ("egg bits" originating from egg shell pipping) were present in the nest cup. In the case of longspur nests, the presence of feather sheaths (powdery material shed from developing feathers) and adults alarming around an empty nest were also used as indicators of nest success.

Species diversity of nesting birds was compared between disturbed and undisturbed plots in two ways. Species richness (the total number of species present) was used because of its simplicity. Shannon's diversity index (Begon et al. 1986:595), which takes into account the relative abundance of species in addition to the total number of species present, also was used because it is a commonly applied diversity measure that gives managers a wildlife-oriented option for establishing mitigation goals. The value of the index increases with the presence of more species and decreases if the relative abundance (nests, in this case) among species is uneven.

Index data were paired for co-located plots, and the null hypothesis of no difference in mean diversity indices between disturbed and undisturbed plots was tested by a paired-sample t test in the computer package SYSTAT® (Wilkinson 1990). Green (1979) and Zar (1984) have noted the tendency of Shannon's index to underestimate the diversity of a sampled population, but the relative comparison of mean indices between disturbed and undisturbed plots should be valid if underestimation of true diversity is proportional in both habitat types. Green (1979) further advised that a high diversity index does not necessarily

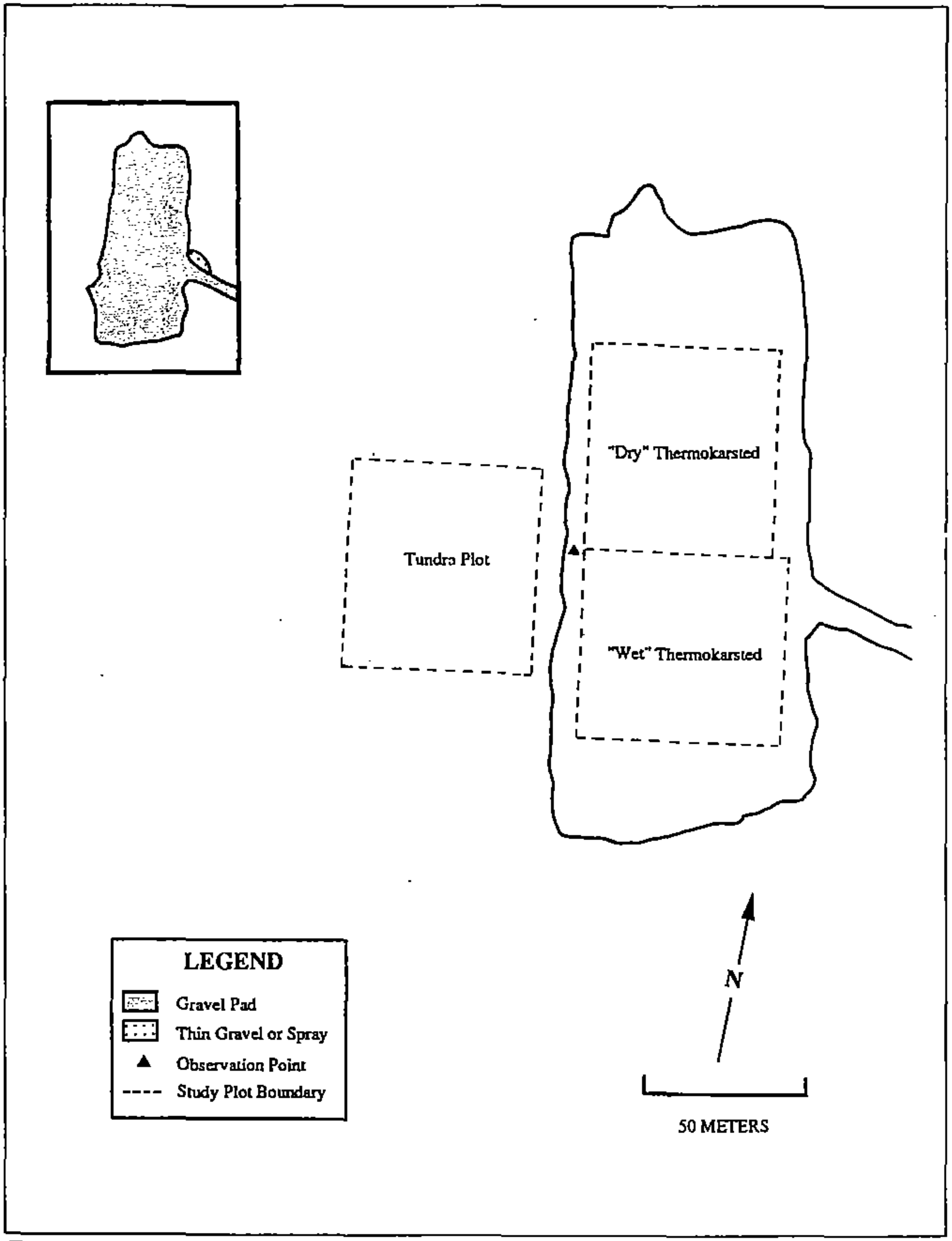


Figure A-5. Location of disturbed and undisturbed study plots for post-breeding observational study at Storage Pad, Prudhoe Bay, Alaska, 1990. Inset shows extent of gravel and related disturbances.

mean high environmental quality.

Plot-use survey data from disturbed and undisturbed plots were analyzed and compared on the basis of number of birds per unit area (10-ha plot) for each of three surveys. The null hypothesis of no difference in bird use between disturbed and undisturbed plots was tested by using a Wilcoxon signed-ranks test.

The snow cover data from disturbed and undisturbed plots were analyzed and compared on the basis of percent cover per unit area (mean percent cover per 10-ha plot). The null hypothesis of no difference in percent snow cover between disturbed and undisturbed plots was tested by using a Wilcoxon signed-ranks test.

Results

The following results are based on comparisons of bird nest density, nest success, and species composition between disturbed and undisturbed plots for 1990 and 1991. Bird use and snow cover data are from 1991 only. Physical characteristics (thin gravel and a high degree of plant colonization) at one site, Ugnu 1 (Site 2), are outside the range of those of other sites, and this site may be an ecological outlier. For this reason, the analysis of nest density is presented both with and without data from Ugnu 1. Snow cover data for three sites (Term Well C, Lake State 1, and Delta State 2) were eliminated from the analysis because a brief snow storm lightly covered these sites on the day they were surveyed. Much of this snow had melted by the next day.

Nest Density

The total number of nests located in 1990 was higher than in 1991 (Table 3). This difference is attributed principally to the decline in the number of nests of Pectoral Sandpipers in 1991 compared with 1990 (Table 4).

For both years, more nests were located in undisturbed plots than in disturbed plots (Table 3). In 1990, there were 153 nests in undisturbed plots and 128 nests in disturbed plots. In 1991, there were 121 nests in undisturbed plots and 111 nests in disturbed plots. The difference in the total number of nests between disturbed and undisturbed plots declined from 25 in 1990 to 10 in 1991. Pooling data from all sites, the null hypothesis of no difference in mean nest densities between plot types for either year was not rejected (P=0.17 and P=0.56). If Ugnu 1 is considered to be an outlier and data from that site are dropped, disturbed plots had significantly lower nest densities than undisturbed plots in 1990 (P=0.05); in 1991, there was no statistically significant difference between the two plot types (P=0.84).

In 1990, higher nest densities generally occurred on the undisturbed plot of each pair. Eight undisturbed plots had higher nest densities than did the corresponding disturbed plot, while four disturbed plots exceeded their undisturbed counterpart. One site (Delta State 2), had the same number of nests in both plot types. In 1991, six undisturbed plots had higher nest densities than their disturbed counterparts, while five disturbed plots had more nests than undisturbed plots. At two sites (West Sak 17 and Delta State 2), nest densities were the same in both plot types. If data from Ugnu 1 are dropped, undisturbed plots with higher nest densities outnumber their disturbed counterparts by eight to three in 1990; in 1991, plot types with higher nest densities were equal (five each).

Each disturbed plot is composed of gravel, related disturbances, and adjacent tundra. On average, gravel disturbances cover approximately 25 percent of the disturbed plots (Rodrigues and Miller 1991). Nest density was calculated for the non-graveled portion of each disturbed plot (Table 5). The density of nests on the non-graveled portion of disturbed plots was not significantly different from the nest density on the undisturbed plots for either year (P=0.70 and P=0.35), indicating that the value of tundra adjacent to abandoned gravel pads as nesting habitat was not diminished.

Nest Success

Nest success in 1990 was higher in the disturbed plots (82 percent) than in the undisturbed plots (73 percent); in 1991, nest success was virtually the same in the two plot types (65 vs. 64 percent) (Table 3). Undisturbed plots had six more successful nests than disturbed plots for each year. Nest success was not significantly different between disturbed and undisturbed plots for either year (P=0.31 and P=0.84). Nest success was also not significantly different between the two plot types when data from Ugnu 1 were excluded (P=0.25 and P=0.96).

Species Composition

The number of species (richness) nesting in undisturbed plots remained the same (13), but declined from 16 to 12 in disturbed plots from 1990 to 1991 (Table 3). Shannon's diversity indices for all plots combined were slightly higher in undisturbed plots each year

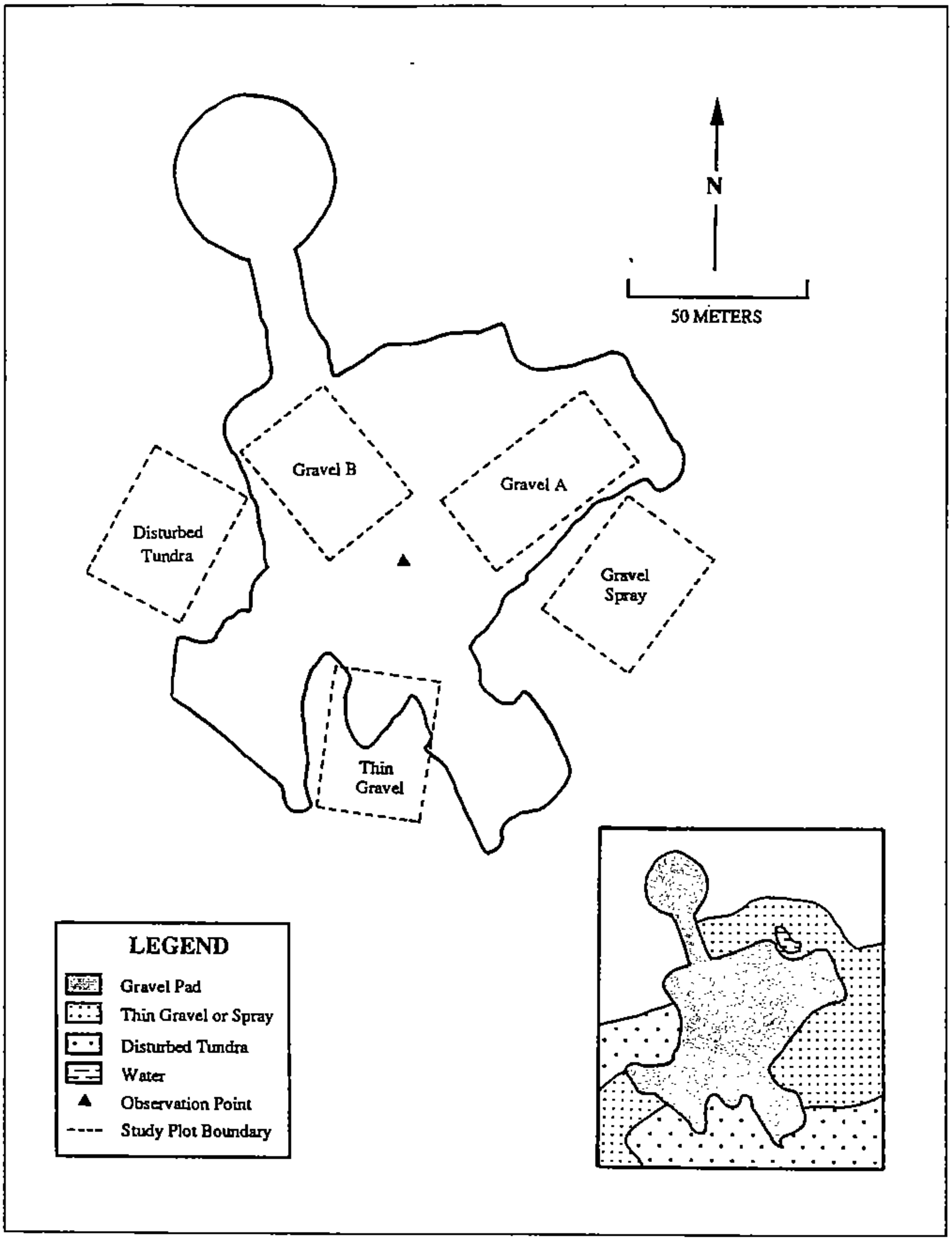


Figure A-4. Location of disturbed and undisturbed study plots for post-breeding observational study at Prudhoe Bay State 1, Prudhoe Bay, Alaska, 1991. Inset shows extent of gravel and related disturbances.

Table 3. Comparison of bird nesting attempts and success by site on disturbed and undisturbed study plots during the 1990 and 1991 field seasons, Prudhoe Bay, Alaska. Sites are listed by the total number of nests found on both plot types during both years. "D" and "U" designate disturbed and undisturbed plots, respectively.

		Number of Species				Total Nests				Number of Successful Nests and (Percent Success)			
Site No.	Site	1990		1991		1990		1991		1990		1991	
		D	U	D	U	D	U	D	U	D	U	D	U
2	Ugnu 1	6	3	4	5	21	11	15	21	17 (81)	9 (82)	13 (87)	16 (76)
13	Lake State	5	5	3	5	12	18	15	11	6 (75)	14 (78)	11 (73)	9 (82)
1	West Sak 17	5	7	4	5	11	13	13	13	9 (82)	9 (69)	7 (54)	8 (62)
3	West Sak 9	5	5	3	3	12	15	8	7	9 (75)	12 (80)	3 (38)	4 (57)
7	Hurl State	5	7	3	7	6	18	4	11	6 (100)	7 (39)	2 (50)	3 (27)
9	Getty State	5	7	4	3	10	16	7	6	8 (80)	14 (88)	6 (86)	4 (67)
12	Prudhoe Bay State 1	5	5	3	2	12	11	7	9	10 (83)	10 (91)	4 (57)	8 (89)
4	West Sak 3	5	3	4	2	8	13	13	4	8 (100)	10 (77)	8 (62)	4 (100)
6	Term Well C	4	6	4	5	12	7	10	8	10 (83)	2 (29)	6 (60)	2 (25)
11	Storage Pad	4	4	3	5	8	7	4	12	6 (75)	5 (71)	3 (75)	9 (75)
10	Put State 1	3	7	3	2	7	11	5	6	6 (86)	11 (100)	2 (40)	1 (17)
5	Mobil Kuparuk 13-15-11-12	5	5	2	5	5	9	4	7	3 (60)	4 (44)	4 (100)	6 (86)
14	Delta State 2	2	2	4	5	4	4	6	6	4 (100)	4 (100)	3 (50)	4 (67)
	Overall	16	13	12	13	128	153	111	121	105 (82)	111 (73)	72 (65)	78 (64)

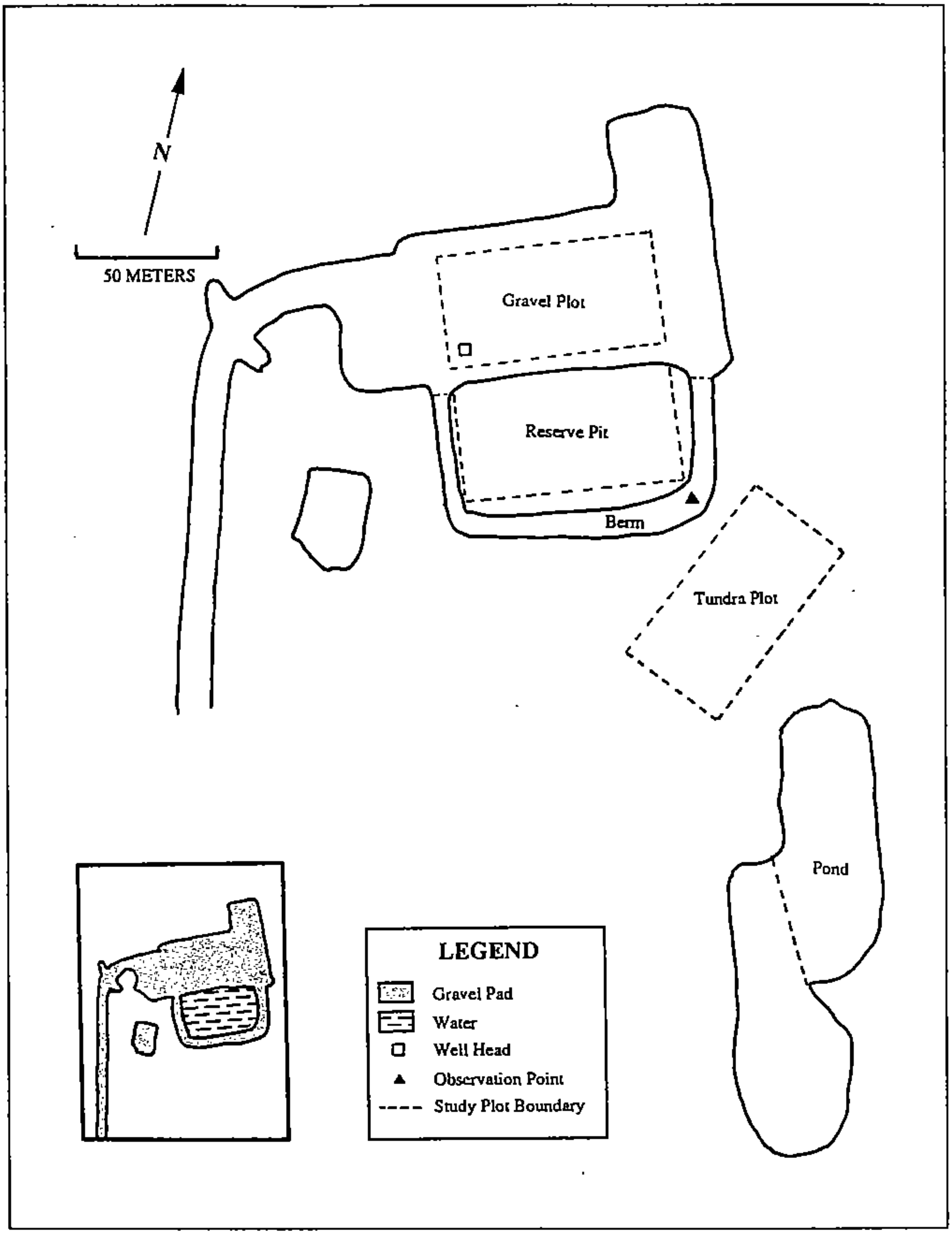


Figure A-3. Location of disturbed and undisturbed study plots for post-breeding observational study at Term Well C, Prudhoe Bay, Alaska, 1990. Inset shows extent of gravel and related disturbances.

Table 4. Nest density and success of bird species on disturbed and undisturbed study plots, Prudhoe Bay, Alaska, 1990 and 1991. "D" and "U" indicate disturbed and undisturbed plots, respectively.

	Density in nests/square km (total number of nests)								Percent Success (number of successful nests)							
	1990				1991				1990				1991			
Species	D		U		D		U		D		U		D		U	
Lapland Longspur	27.7	(36)	30.8	(40)	30.0	(39)	35.4	(46)	75	(27)	78	(31)	49	(19)	61	(28)
Semipalmated Sandpiper	28.5	(37)	26.2	(34)	26.9	(35)	30.0	(39)	95	(35)	76	(26)	80	(28)	74	(29)
Pectoral Sandpiper	17.7	(23)	29.2	(38)	6.2	(8)	7.7	(10)	87	(20)	71	(27)	75	(6)	60	(6)
Red-necked Phalarope	12.3	(16)	5.4	(7)	13.8	(18)	5.4	(7)	81	(13)	86	(6)	72	(13)	100	(7)
Dunlin	.8	(1)	5.4	(7)	2.3	(3)	2.3	(3)	100	(1)	71	(5)	33	(1)	67	(2)
Buff-breasted Sandpiper	.8	(1)	5.4	(7)	.8	(1)	.8	(1)	100	(1)	86	(6)	100	(1)		
Red Phalarope	2.3	(3)	3.8	(5)			1.5	(2)	100	(3)	60	(3)				
Lesser Golden Plover	1.5	(2)	3.8	(5)	.8	(1)	3.8	(5)	0		60	(3)	0	(0)	40	(2)
Stilt Sandpiper	.8	(1)	4.6	(6)	.8	(1)	3.1	(4)	100	(1)	50	(3)	0	(0)	75	(3)
Oldsquaw	.8	(1)	.8	(1)					0		0					
Ruddy Turnstone	1.5	(2)			1.5	(2)	.8	(1)	50	(1)			100	(2)	100	(1)
Gr. White-fronted Goose	.8	(1)			.8	(1)			100	(1)			100	(1)		
Canada Goose			.8	(1)							100	(1)				
Northern Shoveler	.8	(1)							0							
King Eider			.8	(1)			.8	(1)			0					
Willow Ptarmigan	.8	(1)					.8	(1)	100	(1)						
Rock Ptarmigan			.8	(1)							0					
Baird's Sandpiper	.8	(1)							0							
Snow Bunting	.8	(1)							100	(1)						
Black-bellied Plover							.8	(1)								
Northern Pintail					.8	(1)							0	(0)		
Redpoll					.8	(1)							100	(1)		
Total or Mean	98.5	(128)	117.7	(153)	85.4	(111)	93.2	(121)	82	(105)	73	(111)	65	(72)	64	(78)

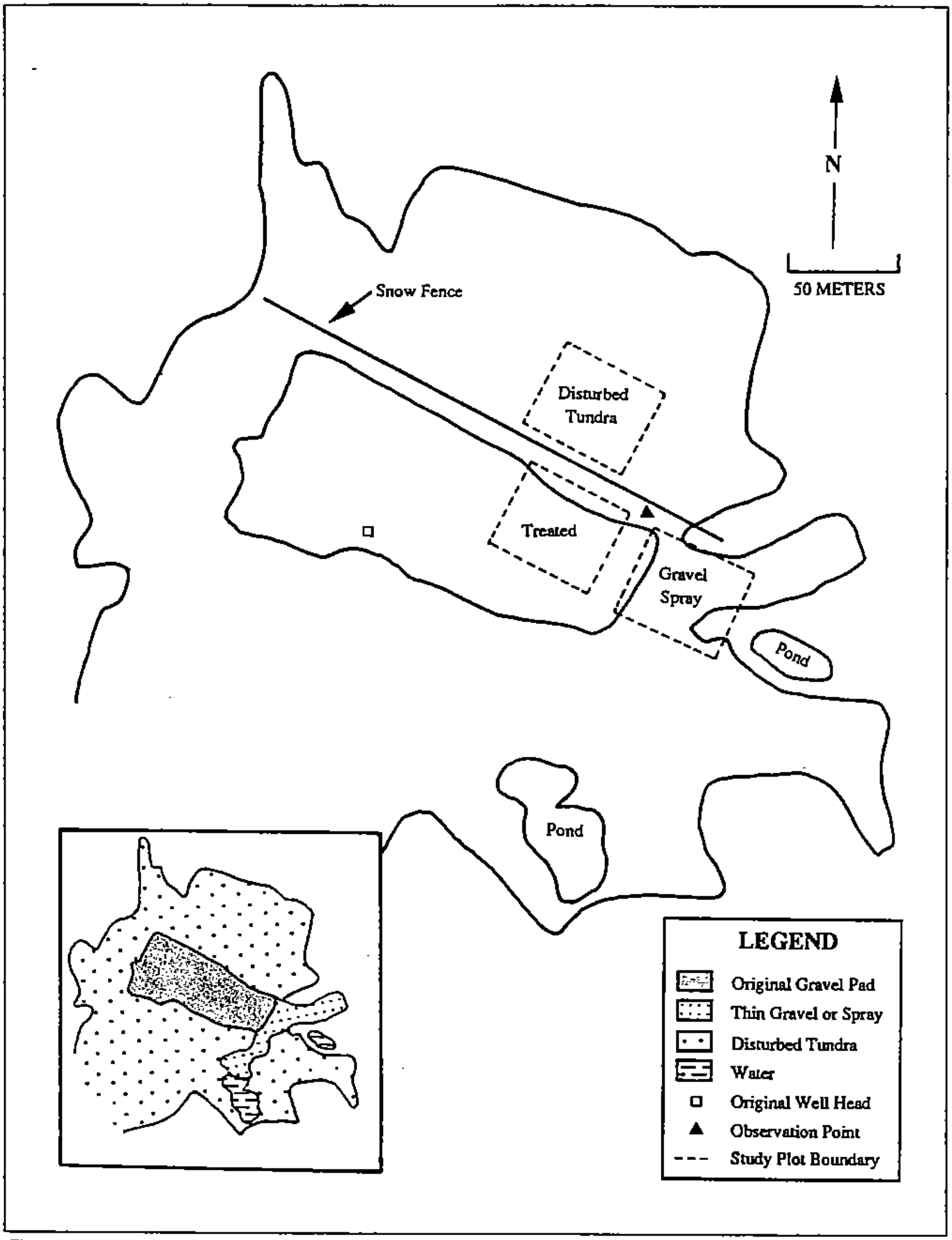


Figure A-2. Location of disturbed and undisturbed study plots for post-breeding observational study at Put River 22-33-11-13, Prudhoe Bay, Alaska, 1991. Inset shows extent of gravel and related disturbances.

Table 5. Percent gravel disturbance on disturbed plots, nest density (nests/km²) on undisturbed plots, and nest density of non-graveled portion of disturbed plots for each study site, Prudhoe Bay, Alaska, 1990 and 1991.

Site	Percent gravel disturbance	Nest Density (1990) Undist. Plot	Nest Density (1990) Dist. Plot (tundra only)	Nest Density (1991) Undist. Plot	Nest Density (1991) Dist. Plot (tundra only)
Ugnu 1	20	110	213	210	163
Lake State	13	180	138	110	172
West Sak 17	26	130	149	130	176
West Sak 9	39	150	197	70	131
Hurl State	28	180	83	110	56
Getty State	17	160	121	60	84
Prudhoe Bay State 1	33	110	164	90	105
West Sak 3	28	130	97	40	153
Term Well C	21	70	152	80	127
Storage Pad	17	70	84	120	48
Put State 1	18	110	85	60	61
Mobil Kuparuk 13-15-11-12	25	90	67	70	53
Delta State 2	39	40	66	60	98
Mean	25	118	124	93	110

Table 6. Number of species that initiated nests and Shannon's diversity indices for disturbed and undisturbed plots, Prudhoe Bay, Alaska, 1990 and 1991.

Site No.	Site	Number of Species Undisturbed 90	Number of Species Undisturbed 91	Number of Species Disturbed 90	Number of Species Disturbed 91	Shannon Diversity Index Undisturbed 90	Shannon Diversity Index Undisturbed 91	Shannon Diversity Index Disturbed 90	Shannon Diversity Index Disturbed 91
1	West Sak 17	7	5	5	4	1.80	1.26	1.50	1.16
2	Ugnu 1	3	5	6	4	1.04	1.28	1.50	0.99
3	West Sak 9	5	3	5	3	1.40	1.00	1.36	1.08
4	West Sak 3	3	2	5	4	0.91	0.56	1.49	1.22
5	Mobil Kuparuk 13-15-11-12	5	5	5	2	1.52	1.55	1.61	0.56
6	Term Well C	6	5	4	4	1.75	1.56	1.33	1.28
7	Hurl State	7	7	5	3	1.85	1.77	1.56	1.04
9	Getty State	7	3	5	4	1.72	1.01	1.50	1.35
10	Put State 1	7	2	3	3	1.85	0.69	1.00	1.05
11	Storage Pad	4	5	4	3	1.28	1.35	1.26	1.04
12	Prudhoe Bay State 1	5	2	5	3	1.59	0.64	1.47	0.78
13	Lake State 1	5	5	5	3	1.49	1.55	1.55	1.05
14	Delta State 2	2	5	2	4	0.56	1.56	0.56	1.24
	Mean	5.1	4.2	4.5	3.4	1.44	1.21	1.36	1.06
	Overall (all sites combined)	13	13	16	12	1.94	1.71	1.84	1.64

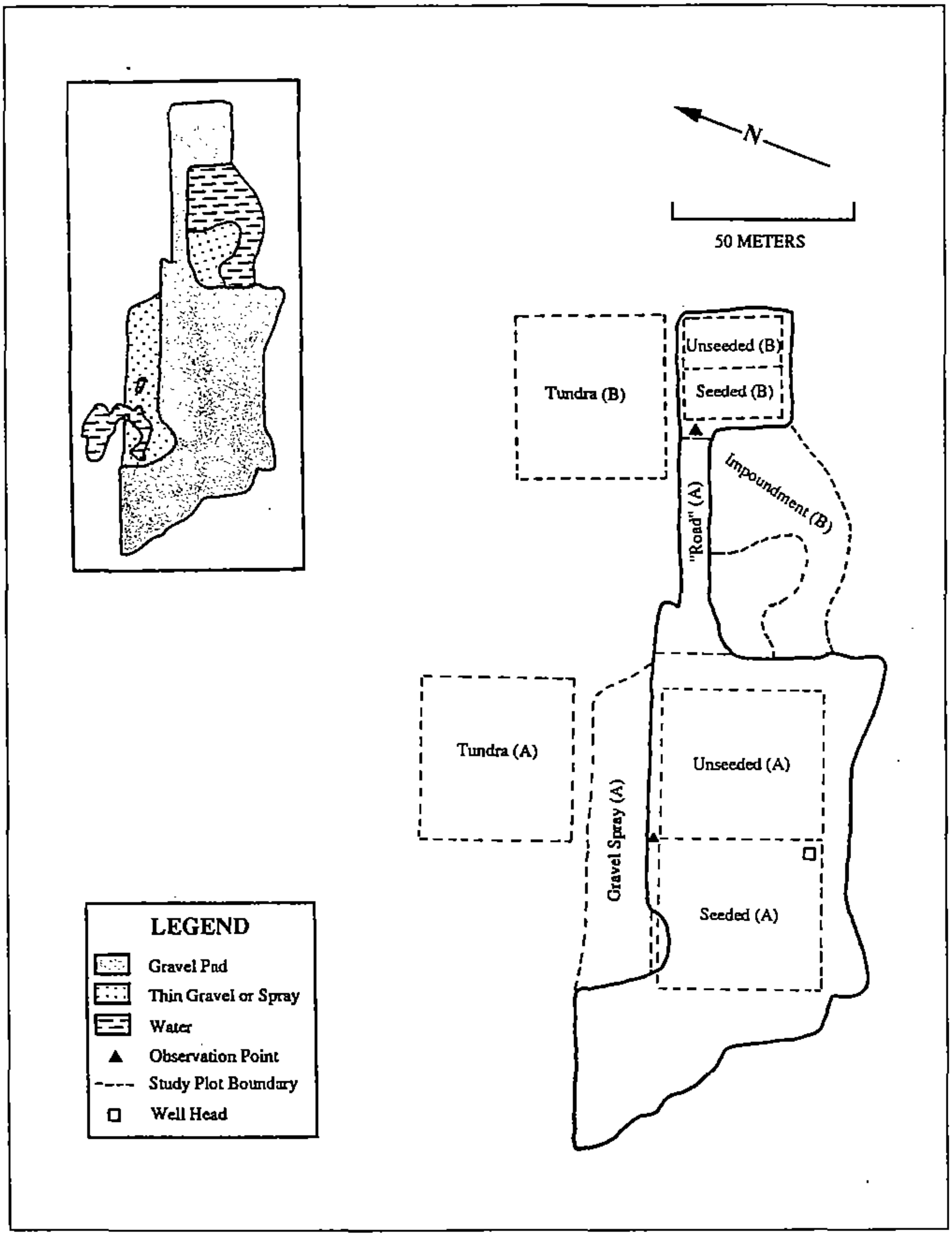


Figure A-1. Location of disturbed and undisturbed study plots for post-breeding observational study at Lake State 1 (A and B), Prudhoe Bay, Alaska, 1990 and 1991. Inset shows extent of gravel and related disturbances.

(Table 6). However, there was no significant difference in mean Shannon's diversity indices between disturbed and undisturbed plots for either year (P=0.43 and P=0.27).

In 1991, nest densities of three of the four most common species (Lapland Longspur, Semipalmated Sandpiper, and Red-necked Phalarope) were similar to those in 1990 (Table 4). However, the number of Pectoral Sandpiper nests in both disturbed and undisturbed plots declined by approximately 70 percent in 1991.

There was no significant difference in the mean numbers of nests of Lapland Longspur or Semipalmated Sandpiper between disturbed and undisturbed plots in 1990 or 1991. There were significantly more Pectoral Sandpiper nests in undisturbed plots than in disturbed plots in 1990 (P=0.01). In 1991, the number of nests in undisturbed plots (10) was not significantly different from the number of nests in disturbed plots (8); however, the sample size was low. The number of nests of Red-necked Phalarope in disturbed plots was over twice the number of nests in undisturbed plots in both years. The difference was significant only in 1991 (P=0.05). This species seemed to select thermokarst sites on tundra near gravel pads in 1990 and continued to do so in 1991.

Less common species (<15 total nests for both years combined) generally nested more frequently on undisturbed plots than on disturbed plots. The differences were less in 1991. The sample size was small and observations were too few to determine whether or not any avoidance of gravel was significant.

Bird Use

The total number of birds occurring in each plot for each survey in 1991 is shown in Figure 2. The mean number of birds that used disturbed plots during each of the three plot-use surveys was higher than the number that used undisturbed plots (Table 7). The greatest difference in bird use between disturbed and undisturbed plots occurred during the post-breeding survey. When comparing the total numbers of birds on disturbed and undisturbed plots for each survey, there was no significant difference in bird use between the two plot types (P=0.75, P=0.29, and P=0.06).

The four most common nesting species (Lapland Longspur, Semipalmated and Pectoral sandpipers, and Red-necked Phalarope) were also the species most frequently observed during plot-use surveys. For all surveys combined, density of each of these species was higher on disturbed plots than on undisturbed plots (Table 8).

Lapland Longspur was by far the most abundant species. The density of Lapland Longspurs peaked on both disturbed and undisturbed plots during the second survey and was lowest during the third survey (Fig. 3).

Semipalmated Sandpipers followed a trend similar to that of Lapland Longspurs, although numbers were lower (Table 8). Density of Semipalmated Sandpipers was slightly higher in undisturbed plots during the first survey, but was higher in disturbed plots during the second and third surveys (Fig. 3).

Density of Pectoral Sandpipers increased on disturbed plots on subsequent surveys but decreased on undisturbed plots (Fig. 3). For Red-necked Phalaropes, density increased on both plot types on subsequent surveys, and was highest on disturbed plots each survey.

For all other shorebird species combined, there was a general trend of lower density on subsequent surveys, although numbers were relatively stable. This is the only group which consistently had higher densities on undisturbed plots each survey (Fig. 3).

For waterfowl, the highest density occurred on disturbed plots during the first survey (Fig. 3). For all other surveys, densities were much lower on disturbed

Table 7. Means and standard deviations of numbers of birds surveyed on disturbed and undisturbed study plots during three plot-use surveys, Prudhoe Bay, Alaska, 1991. See Table 2 for dates of surveys.

Survey	Mean (dist.)	SD (dist.)	Mean (undist.)	SD (undist.)
First	24.5	11.1	21.2	7.5
Second	26.5	13.0	23.4	10.9
Third	21.3	14.6	12.5	6.8
Overall	24.1	12.8	19.0	9.6

four-fifths the size of the gravel plots. The plot included the water in the reserve pit and most of the berm (overburden) which surrounded the pit. The reserve pit was being colonized by *Eriophorum vaginatum*, *Carex aquatilis*, and *Arctophila fulva*. Other plant species were associated with the berm (Table A-1).

Observer's Station

The blind was located on the central portion of the gravel pad between the gravel A and B plots.

DELTA STATE 2 OBSERVATIONAL PLOTS

Gravel Plot

A gravel plot, 50 m x 100 m, was established east of the reserve pit (Fig. A-8). The well head, consisting of a "christmas tree", was located on the plot near the northwest corner. Gravel thickness was approximately 0.5 m. No thermokarsting had occurred on the pad, but some vehicle tracks were present. Virtually no vegetation was present on the plot.

Reserve Pit Plot

The reserve pit plot had the same dimensions as the gravel plot. The plot included the water in the pit, the mud around the water's edge, and the gravel bank extending down from the pad. Much of the mud in the pit was composed of cuttings from the drilling operation.

Tundra Plot

The tundra plot was located northeast of the reserve pit. The surface area was the same as that of the gravel and reserve pit plots, but the dimensions were 71 m x 71 m. The vegetation was moist and wet graminoid tundra, and the landform was non-patterned ground.

Observer Station

The blind was located on the gravel pad north of the reserve pit. The entire area of the gravel and reserve pit plots could be seen well, and probably no birds were missed. Observations on the tundra plot were obscured by the vegetation; however, few birds were seen during routine walks through the plot, and few birds were probably missed.

LITERATURE CITED

BP Exploration (Alaska), Inc. 1991. 1990 BP pad progress report.

Jorgenson, M.T. 1988. Revegetation of the Lake State 1 exploratory well site, Prudhoe Bay Oilfield, Alaska, 1987. Report prepared for ARCO Alaska, Inc. and Kuparuk River Unit by Alaska Biological Research, Inc., Fairbanks, Alaska. 67pp.

Walker, D.A., K.R. Everett, P.J. Webber. 1983. Chapter 2. Geobotany. In: D.M. Troy (ed.) Prudhoe Bay Unit-Eileen West End environmental studies program, summer 1982. Report to Sohio Alaska Petroleum Co., Anchorage, by LGL Alaska Research Associates, Inc., Fairbanks. 77pp.

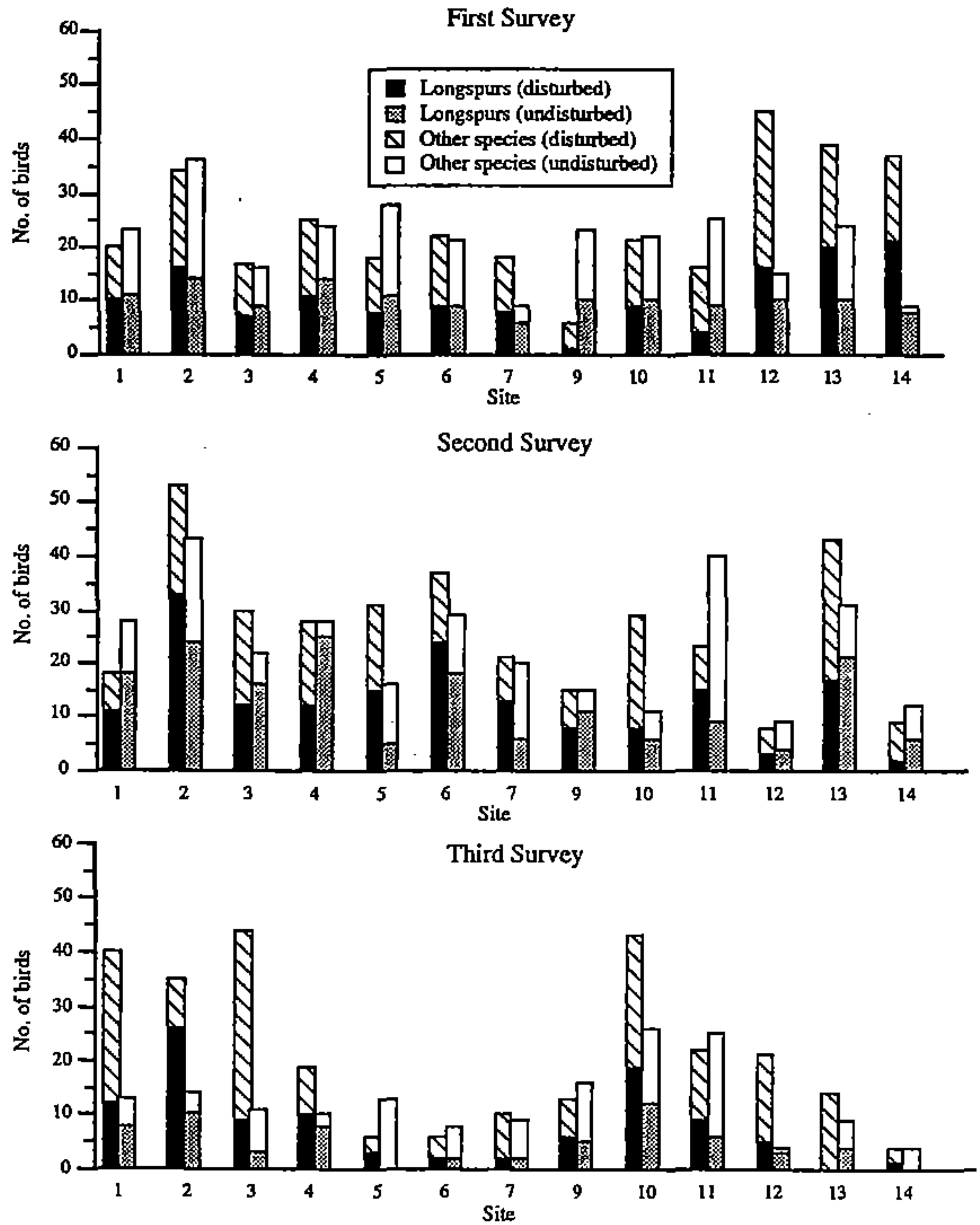


Figure 2. Number of Lapland Longspurs and all other species of birds combined on disturbed and undisturbed study plots at all sites during three survey periods, Prudhoe Bay, Alaska, 1991.

"Dry" Thermokarsted Plot

A gravel plot designated as "dry" thermokarsted was established on the northern portion of the pad. Plot measurements and gravel thickness were the same as the "wet" thermokarsted plot. This plot was also composed of high-centered polygons formed by deep troughs; however, the troughs contained little water. Vegetation appeared to be more sparsely distributed than on the "wet" thermokarsted plot; however, most of the plant species in the two plots were the same (Table A-1).

Tundra Plot

A tundra plot the same size as the gravel plots was established adjacent to the west edge of the pad. The landform was primarily low and high-relief high-centered polygons, although a small area of low-centered polygons was present on the southern portion of the plot. The vegetation was primarily moist graminoid tundra, although the tops of some high-centered polygons had plant species characteristic of dry prostrate shrub tundra. Most of the troughs did not contain water; a wet thermokarsted area was located in the northwestern portion of the plot.

Observer Station

The blind was located on the western edge of the pad at the margin of the two gravel plots. Most of the area of the study plots could be seen well, except for the thermokarst troughs in all plots, which were sometimes obscured from view.

MOBIL KUPARUK 3-15-11-12 OBSERVATIONAL PLOTS

Two wells were drilled on this pad. The first was spudded on April 21, 1975, and the second on December 1, 1980. These wells were plugged and abandoned on May 22, 1977 and March 23, 1981, respectively.

Thick-Gravel Plot

A gravel plot, measuring 37 m x 70 m, was established on the thick portion of the gravel pad near the northwestern corner (Fig. A-6). Gravel thickness was approximately 1.3 m. No thermokarsting or structures, and only traces vegetation were present on the plot. Some vehicle tracks were present in the loose gravel at the surface.

Thin-Gravel Plot

The thin-gravel plot, also 37 m x 70 m, was established on the northern portion of the gravel pad. Gravel thickness was approximately 0.3 m and tapered to tundra level on the northern portion. Plant species (Table A-1) were sparsely distributed on the plot and provided little cover. There was no thermokarsting, but some old vehicle tracks were present. Water had collected in a few low areas on the northern portion of the plot.

Tundra Plot

The tundra plot, also 37 m x 70 m, was located west of the gravel pad plot. The plot was composed of very wet, graminoid tundra, and contained a shallow pond (the margins of which are not well defined) with emergent vegetation.

Observer's Station

The blind was located on the thick portion of the gravel pad near the northwest corner of the thick-gravel pad plot.

PUT STATE 1 OBSERVATIONAL PLOTS

The well was spudded on May 12, 1969, and suspended on July 1, 1979. The status is now "plugged and abandoned."

Gravel A Plot

The gravel A plot measured 60 m x 59 m and covered most of the western portion of the pad (Fig. A-7). Gravel thickness was approximately 1 m at the thickest portions and tapered to approximately 0.3 m at the western edge of the plot. A group of wooden pilings, which rise above the gravel surface to about 0.3 m, were located on the central portion of the plot. No thermokarsting was evident. A wide variety of plant species was sparsely scattered over the plot surface (Table A-1).

Gravel B Plot

The gravel B plot, also 60 m x 59 m, was located on the eastern portion of the pad. Gravel thickness averaged approximately 1.3 m. A large mound of gravel on the northwestern portion of the plot covered the plugged and abandoned well. A pipe was embedded in this mound. Some mild thermokarsting was evident on the eastern portion of the plot. Water had not collected in the troughs. A wide variety of plant species was also sparsely scattered over this plot; plant species were similar to those on the gravel A plot (Table A-1).

Reserve Pit

The reserve pit plot, located north of the gravel pad, was irregular in shape and was approximately plots but remained rather stable on undisturbed plots.

Snow Cover

Mean percent snow cover was higher on disturbed plots than on undisturbed plots (Table 9, Fig. 4), but the difference was not statistically significant (P=0.21).

Discussion

In this section, nest density, nest success, and bird use are discussed and compared with findings of other researchers. On this basis, some ideas are presented about how gravel placement may affect the quality of adjacent nesting habitats.

Nest Density

For each year, the average nest densities for both disturbed plots (98.5 and 85.4 nests/km²) and undisturbed plots (117.7 and 93.2 nests/km²) (Table 4) were relatively high compared to most nest densities previ-

Table 8. Density (birds/km²) of bird species on each of three surveys and the mean density for all three surveys combined on disturbed and undisturbed study plots, Prudhoe Bay, Alaska, 1991. Species are listed in order of overall abundance.

	Survey 1		Survey 2		Survey 3		Mean Density	
Species	Dist.	Undist.	Dist.	Undist.	Dist.	Undist.	Dist.	Undist.
Lapland Longspur	107.8	100.8	133.1	130.0	80.0	48.5	106.9	93.1
Semipalmated Sandpiper	24.6	28.5	48.5	30.8	39.2	12.3	37.4	23.9
Red-necked Phalarope	8.5	3.8	21.5	8.5	27.7	19.2	19.2	10.5
Pectoral Sandpiper	12.3	18.5	13.8	12.3	23.1	7.8	16.4	12.9
Greater White-fronted Goose	23.1	11.5	2.3	1.5		8.5	8.5	7.2
King Eider	1.5	[illegible]	6.2	5.4	13.8		7.2	2.3
Oldsquaw	5.4	2.3	5.4	5.4	7.8	2.3	6.2	3.3
Dunlin	7.8	6.9	5.4		2.3	.8	5.2	2.6
Lesser Golden Plover	1.5	6.9	.8	3.8	.8	7.8	1.0	6.2
Canada Goose	8.5	3.1	3.1	5.4		1.5	3.8	3.3
Stilt Sandpiper	2.3	4.6	2.3	4.6	2.3	4.6	2.3	4.6
Parasitic Jaeger	4.6	3.1	2.3	5.4	3.1	.8	3.3	3.1
Glaucous Gull	6.9	.8		6.2	.8	2.3	2.6	3.1
Red Phalarope	4.6	3.1	.8	1.5	2.3	.8	2.6	1.8
Northern Pintail	8.5	.8	1.5	1.5	.8		3.6	.8
Long-tailed Jaeger	2.3	3.8	.8	3.1	.8		1.3	2.3
Rock Ptarmigan	5.4	1.5	.8	1.5			2.1	1.0
Black-bellied Plover		2.3	.8	2.3	1.5	2.3	.8	2.3
Long-billed Dowitcher	2.3	2.3			3.1	1.5	1.8	1.2
Snow Bunting	1.5	1.5	.8	.8	3.8		2.0	.8
Willow Ptarmigan		1.5	4.6	1.5		2.3	1.5	1.3
Ruddy Turnstone	1.5	.8	2.3	1.5			1.3	.8
Buff-breasted Sandpiper	.8	3.1	.8	.8		.8	.5	1.5
Savannah Sparrow			2.3				.8	
Tundra Swan			2.3				.8	
Redpoll	1.5						.5	
Ptarmigan spp.			1.5				.5	
Brant			1.5				.5	
Mallard	1.5						.5	
Arctic Tern						.8		.3
Total	244.7	211.5	265.5	233.8	213.2	124.9	241.1	190.2

serve pit. The vegetation type was moist and wet graminoid tundra, and the landform was primarily strangmoor. The tundra plot and the pond (see below) were scanned during the same three-min periods.

Pond Plot

The pond plot consisted of a portion of a natural pond lying southeast of the tundra plot. It was similar in size to the gravel, reserve pit, and tundra plots. Water had receded, and a mud bank on the eastern pond edge was exposed. The entire pond could be seen well from the blind except for the water's edge in the northwest portion which was blocked by tundra vegetation.

Observer's Station

The blind was located on the berm above the southeast corner of the reserve pit.

PRUDHOE BAY STATE 1 OBSERVATIONAL PLOTS

The well was spudded on April 22, 1967, and plugged and abandoned on April 14, 1985.

Gravel A Plot

The gravel A plot, measuring 24 m x 50 m, was established on the eastern portion of the pad (Fig. A-4). Gravel thickness was approximately 0.6 m. There was no evidence of thermokarsting, and only traces of vegetation were present (Table A-1). Short, wooden pilings, cut just above the gravel surface, were present on the northeastern portion of the plot.

Gravel B Plot

The gravel B plot, measuring 30 m x 40 m, was established on the northwestern portion of the pad. Gravel thickness approached 1 m. Some thermokarsting was present, creating a low area which contained shallow water. Several short, wooden pilings were also present. Plant species identified (Table A-1) were sparsely scattered over portions of the plot.

Gravel Spray Plot

The gravel spray plot, measuring 30 m x 40 m, was established on disturbed tundra southeast of the pad. Traces of gravel were scattered over the surface of the plot. Thermokarsting produced several troughs which contained water. Plant species identified (Table A-1) were primarily graminoids, which were distributed in dense patches in thermokarst troughs, and diffuse bunches in drier areas between troughs. Few forb species were present.

Thin Gravel Plot

The thin gravel plot, measuring 30 m x 40 m, was established south of the main portion of the pad. Gravel thickness was approximately 0.3 m on portions of this plot and tapered to tundra level on the south side. Moderate thermokarsting was evident on the plot with water present in thermokarst troughs. Plant species identified (Table A-1) were sparsely distributed on the plot, although areas where gravel was thinnest were well vegetated with graminoid species.

Disturbed Tundra Plot

The disturbed tundra plot, measuring 30 m x 40 m, was established on tundra west of the main portion of the pad. Very little gravel was present on the plot. This area appeared to be the terminus of an old road over the tundra which was probably used as a supply route during drilling operations. Disturbance from equipment appeared to have caused heavy thermokarsting which created high-centered polygons with deep troughs, some of which contained shallow water. Plant species identified (Table A-1) formed moderate to high cover throughout the plot, especially in the low areas around troughs where vegetation was lush.

Observer's Station

The blind was located on the central portion of the pad near the gravel A and B plots.

STORAGE PAD OBSERVATIONAL PLOTS

Two study plots were established on the gravel pad at this site (Fig. A-5). Gravel thickness over most of the pad was about 0.5 m. The pad exhibited a high degree of thermokarsting and was composed primarily of high-centered polygons. The primary differences between the two plots were the amount of standing water in thermokarst troughs and the extent of the vegetation.

"Wet" Thermokarsted Plot

A gravel plot designated as "wet" thermokarsted was established on the southern portion of the pad. Gravel thickness averaged less than 1 m. Plot measurements were 60 m x 65 m. The plot was characterized by the presence of high-centered polygons formed by deep thermokarst troughs, many of which were water-filled. Plant species colonizing the pad were varied (Table A-1) and were similar to species on the "dry" thermokarsted plot (see below); however, vegetation was more robust on the "wet" plot, particularly near wet troughs where dense clumps of graminoid species were present.

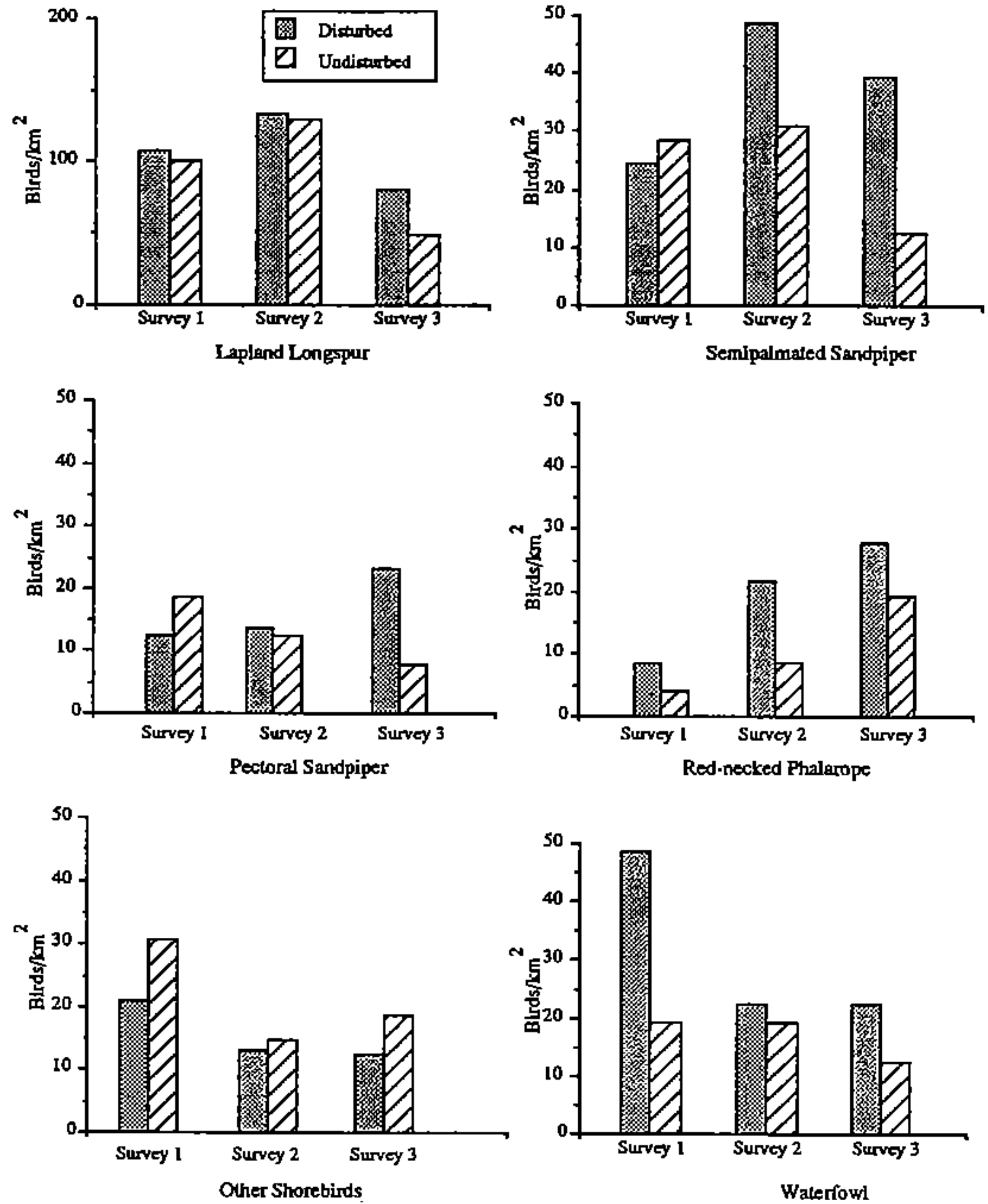


Figure 3. Density (birds/km²) of Lapland Longspur, the three most common shorebird species, all other shorebirds, and waterfowl during three surveys on disturbed and undisturbed study plots, Prudhoe Bay, Alaska, 1991.

A wooden snow fence was installed north of the gravel site just prior to gravel removal. The purpose of this fence was to attempt to accumulate drifting snow as a source of water for the cultivars. The cultivars were doing well during the 1990 and 1991 field seasons. During the course of the 1991 observations, the snow fence was removed by helicopter on 3-4 August.

Treated Plot

The treated plot, measuring 40 m x 50 m, was located south of the snow fence on the eastern portion of the area formerly occupied by the gravel pad. The "treatment" consisted of gravel removal, placement of topsoil, fertilization, and seeding. Gravel was removed to within six inches of the original tundra. This area was then covered with topsoil, which was seeded and fertilized. Virtually no gravel was present at the surface. Mild thermokarsting produced several shallow troughs, some of which were partially filled with water. Most of the lush vegetation on the plot was composed of cultivars, although several other graminoid species were present (Table A-1). In addition, one forb and one shrub species were identified on the plot.

Gravel Spray Plot

The gravel spray plot, also measuring 40 m x 50 m, was established south of the southeast end of the snow fence on disturbed tundra east of the former gravel pad. Traces of gravel spray were present over most of the surface of the plot. Mild thermokarsting produced troughs similar to those of the adjacent treated plot above. No topsoil was applied to this plot, although it was seeded and fertilized. Vegetation was not as lush on this plot as on the treated plot, and cultivars were sparsely distributed. In addition to most of the graminoid species identified on the treated plot (above), several other graminoid species, and a wide variety of forb and shrub species (Table A-1), were colonizing this plot.

Disturbed Tundra

The disturbed tundra plot, also measuring 40 m x 50 m, was established on heavily disturbed tundra north of the snow fence. Virtually no gravel was present on the plot. Thermokarsting produced shallow troughs, some of which were partially filled with water. This area was also fertilized and seeded. However, cultivars and other vegetation were more sparsely distributed on this plot than on the treated or gravel spray plots. Most of the same graminoid species present on the other plots were distributed in patches on the disturbed tundra plot. The number of forb and shrub species identified were lower than that found on the gravel spray plot, but higher than on the treated plot (Table A-1). *Cochlearia officinalis* was particularly abundant.

Observer's Station

The blind was centrally located among the three plots on a disturbed area near the snow fence.

TERM WELL C OBSERVATIONAL PLOTS

Gravel Plot

The gravel pad at Term Well C was approximately 150 m x 65 m (Fig. A-3). This was a thick pad, and gravel depth was over 2 m in most places. Virtually no vegetation was growing on the pad, and no thermokarsting had occurred. A plot measuring 75 m x 40 m was established on the main portion of the pad immediately north of the reserve pit. This plot included the well head, which consisted of a "christmas tree" surrounded by steel railing.

Reserve Pit Plot

The dimensions of the reserve pit plot were the same as the gravel plot. The reserve pit was water-filled, and the plot included the mud bank below the base of the berm surrounding the pit. The reserve pit and the berm (see below) were scanned during the same three-min periods.

Berm

The berm was composed of a mixture of gravel and overburden, and surrounded the reserve pit on the east, west, and south sides. The plot was approximately half the size of the other plots at this site. Portions of the berm were well vegetated, particularly the outside banks, which had less gravel; vegetation was also scattered on the top where gravel was mixed with overburden. The vegetation was composed primarily of graminoids (Table A-1).

Most of the berm (the top surface, the inside bank, and most of the outside bank) could be seen well from the blind. None of the outside bank on the west side could be observed, and observations were sometimes obscured by the vegetation on the southern bank.

Tundra Plot

The tundra plot was the same size as the gravel and reserve pit plots, and was located southeast of the re-

Table 9. Percent snow cover on disturbed and undisturbed study plots, Prudhoe Bay, Alaska, 1991. SD=Standard deviation.

	Disturbed		Undisturbed	
Site	Percent Snow Cover	SD	Percent Snow Cover	SD
1	22.6	22.8	14.7	11.3
2	6.9	10.0	8.3	8.4
3	29.7	30.5	7.2	8.8
4	25.1	28.6	24.4	20.1
5	40.7	18.1	40.3	17.3
7	23.8	29.3	26.1	36.6
9	11.0	15.0	2.4	2.5
10	4.3	6.2	1.7	2.8
11	0.0	0.0	0.0	0.0
12	7.0	11.1	8.9	14.6
Overall	17.1	13.1	13.4	13.0

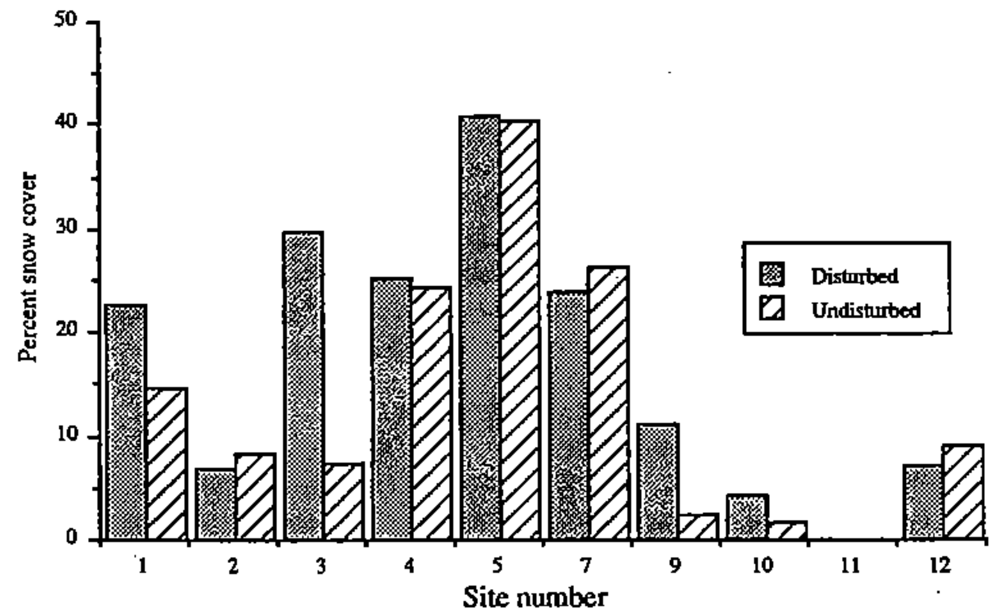


Figure 4. Percent of snow cover on disturbed and undisturbed study plots during first plot-use survey, Prudhoe Bay, Alaska, 1991.

Gravel thickness was approximately 0.5 m. The plot was approximately one-third the size of the seeded and unseeded plots. A variety of graminoid, forb, and shrub vegetation had colonized the site (Table A-1).

Gravel Spray Plot

The gravel spray plot was located north of the main pad and was approximately three-quarters the size of the seeded and unseeded plots. Gravel was thinner than on the main pad, and the plot was well vegetated with graminoid, forb, and shrub species (Table A-1). Plant cover was higher on this plot than on other unseeded plots. Several thermokarst troughs contained water and had exposed mud banks. Observations of bird use on the gravel spray plot and the tundra plot north of the main pad (see below) were made during the same three-min periods.

Tundra Plot

The tundra plot, located north of the gravel spray plot, had the same dimensions as the seeded and unseeded plots. The vegetation type was moist and wet graminoid tundra, and the landform was non-patterned ground. The high level of use on the gravel spray plot (which was observed during the same 3-min scanning period) may have distracted from observations of the tundra plot, and some birds may have been missed. However, this number was probably low as few birds were seen on the tundra during routine walks after observation periods.

Observer's Station

The blind was located on the main pad between the gravel spray plot and the seeded and unseeded plots.

Lake State 1(B)

Seeded Plot

The dimensions of this fertilized plot, located on the flare pad, were 14 m x 28 m. Gravel thickness was approximately 0.5 m, and no thermokarsting was evident. This plot was approximately one-fifth the size of the tundra plot (see below). Cultivars were well established, and the vegetation was green and robust on the southeastern portion of this plot and brown and stunted on the northwestern portion. Small wire exclosures were also present. The seeded plot and the adjacent unseeded plot (see below) were scanned during the same three-min period.

Unseeded Plot

This fertilized plot was adjacent to the seeded plot and had the same dimensions. Gravel thickness was similar to that of the seeded plot. Small wire exclosures were also present. The plot was abundantly colonized by naturally occurring graminoid, shrub, and forb species (Table A-1). Plant cover was greater on this plot than on the unseeded plot at Lake State 1(A). *Sagina intermedia* was particularly abundant.

Impoundment Plot

The impoundment plot, located between the flare pad and the main pad, was approximately four-fifths the size of the tundra plot. Much of the water had receded, exposing areas of mud. A channel on the south side was water-filled. Graminoids were distributed in dense clumps over portions of the plot, particularly in drier areas. A peninsula of vegetated gravel spray which extended into the impoundment from the main gravel pad was not part of the plot.

Tundra Plot

The dimensions of the tundra plot were 45 m x 40 m. The vegetation was moist and wet graminoid tundra and the landform was primarily non-patterned ground.

Observer's Station

The blind was located near the western edge of the flare pad on the end of the gravel berm connecting it to the main pad. All plots could be seen well, and very few birds were probably missed.

PUT RIVER 22-33-11-15 OBSERVATIONAL PLOTS

The well was spudded on January 24, 1969, and suspended on May 5, 1969. The well head was removed from the site.

This site is the object of an experimental rehabilitation project being undertaken by BPX. Most of the gravel was removed from this site to within six inches of the original grade in May, 1989 (BP Exploration 1991). Some additional gravel was removed in April 1990. Topsoil (overburden) was placed over the area of gravel removal. The entire area, including the area formerly occupied by the pad and most of the adjacent disturbed area (Fig. A-2), was fertilized and seeded with *Poa glauca*, *Festuca rubra*, and *Arctagrostis latifolia* by May 1989. The area of the former pad was fertilized again after the first growing season in September 1989.

ously reported for the Prudhoe Bay area (Troy 1982; Troy and Burgess 1983; Troy et al. 1983; Troy 1985, 1988; Troy and Carpenter 1990; Troy and Wickliffe 1990). Nest densities were within the range of those reported from Barrow (Myers and Pitelka 1975a, b; Myers et al. 1977a, b; 1978a, b; 1979a, b, c; 1980a, b, c; 1981a, b, c).

Of the three most common species, two (Semipalmated Sandpiper and Lapland Longspur) displayed relatively stable nest density between years, while the third (Pectoral Sandpiper) declined by about 70 percent. Nest density of Pectoral Sandpipers displayed large year-to-year fluctuations at Barrow (Pitelka 1959). Troy (1991b) found that nest densities of Pectoral Sandpipers (1 to 33 nests/km^2) and Lapland Longspurs (6 to 22 nests/km^2) varied significantly over eight years of study in an undisturbed area near Pt. McIntyre in the Prudhoe Bay oil field. Pitelka et al. (1974) and Custer and Pitelka (1977) reported similar results based on studies at Barrow.

For both years, nest density of Red-necked Phalaropes on disturbed plots was over twice that observed on undisturbed plots. In undisturbed habitats in the Arctic National Wildlife Refuge (ANWR), Red-necked Phalaropes were considered to be lowland breeders, nesting in wet areas with poor drainage (Martin 1983). Many of the experimental sites in the current study (i.e., Ugnu 1, West Sak 9, Term Well C, Getty State, and Prudhoe Bay State 1) contain wet, thermokarsted tundra adjacent to the gravel pads which seem to be attractive to Red-necked Phalaropes as nest sites. Troy (1988) found that Red-necked Phalarope nest densities were higher along roads in the Prudhoe Bay oil field than in away-from-road portions of the field. Troy (1991a) also found higher nest densities of Red-necked Phalaropes on study plots containing abandoned peat roads than on undisturbed plots.

High nest densities (all species combined) during 1990 and a decline in 1991 were also reported from other studies. In 1990, C. Moitoret, U.S. Fish and Wildl. Serv. (pers. comm.), reported densities of 89.9 and 94.2 nests/km^2 on two undisturbed plots in the Kuparuk oil field. Densities on these plots declined to 73.8 and 80.6 nests/km^2 in 1991. During the previous two seasons (1988 and 1989), densities on these plots had ranged from 49 to 67 nests/km^2. Ongoing studies by D. Troy, Troy Ecol. Res. Assoc. (pers. comm.) showed similar results.

Nest Success

When compared with results reported by Troy and Carpenter 1990, Troy et al. 1983, and Troy 1985, nest success in 1990 was high both on disturbed plots (82 percent) and on undisturbed plots (73 percent) (Table 4). Norton et al. (1975) reported nest success of 38 percent and 86 percent in 1971 and 1972 on study plots at Prudhoe Bay, although his method of measuring success differed slightly from the above studies. On an inland plot south of Deadhorse, the nest success doubled over a two-year period (1979 to 1980) from 35 percent to 70 percent (Hohenberger et al. 1980, 1981). During five years at Barrow, nest success averaged approximately 66 percent (Myers and Pitelka 1975a, b; Myers et al. 1977a, b; 1978a, b; 1979a, b, c; 1980a, b, c; 1981a, b, c).

In 1991, the overall decline in nest success (as with nest density) in the two plot types (65 and 64 percent, respectively) may be related to the more severe weather conditions. Nine nests were abandoned, many with incomplete clutches; no nests were known to have been abandoned in 1990. Clutch size was also reduced in 1991; many shorebirds incubated only two or three eggs rather than the normal clutch size of four eggs. This apparently reflected the inability of some individuals to expend the energy necessary to complete the nesting cycle under severe environmental conditions.

Predation by Arctic foxes probably was responsible for most of the nest losses during this study. Troy and Carpenter (1990) reported heavy nest losses due to Arctic foxes at P Pad in the Prudhoe Bay oil field, and Norton et al. (1975) felt that removal of Arctic foxes may have increased the nest success on his study plots in Prudhoe Bay. Wiggins and Johnson (1991) hypothesized that the increased abundance of nesting Common Eiders (*Somateria mollissima*) along the Endicott causeway may be related to the absence of Arctic foxes there after break-up.

Bird Use

Bird densities (all species combined) on disturbed plots (241.1 birds/km^2) and on undisturbed plots (190.2 birds/km^2) were similar to densities in other Arctic Coastal Plain studies (Troy 1885, 1988). Martin (1983) also reported densities of approximately 200 birds/km^2 on two study plots in ANWR, although density on a third plot was lower. Spindler (1978) reported densities from 111.9 to 245.2 birds/km^2 on tundra plots in ANWR.

Although undisturbed plots tended to have higher bird densities, this difference was not statistically significant. Troy (1991a) reported significant differences in bird density between undisturbed plots and dis-

Table A-1 (cont'd). Checklist of vascular plant taxa found on study plots with vegetation at disturbed gravel sites, Prudhoe, Bay, Alaska, 1990 and 1991.

	Lake State 1 A			Lake State 1 B	Put River 22-33-11-13			Term Well C	Prudhoe Bay State 1					Storage Pad		Mob. Kup.	Put State 1		
	Unseed	Road	GrSp	Unseed	Treated	GrSp	Dis.Tund.	Berm	GrA	GrB	SpA	SpB	Dis.Tund.	Wet	Dry	GrSp	GrA	GrB	Res.Pit
Chrysanthemum integrifolium										x			x		x			x	x
Cochlearia officinalis					x	x	x		x	x	x	x	x					x	x
Draba alpina																	x	x	
Draba cinerea	x		x							x		x	x				x	x	x
Draba lanceolata	x	x																	
Draba macrocarpa																x	x	x	
Draba spp.	x			x	x	x			x	x	x	x	x	x	x	x	x		x
Epilobium latifolium	x	x		x								x		x	x		x	x	x
Melandrium apelatum					x	x				x		x	x	x	x			x	
Minuartia rossii										x		x					x		
Minuartia rubella				x						x				x	x		x	x	
Oxytropis nigrescens																	x	x	
Papaver lapponicum				x						x				x	x		x	x	
Polemonium boreale																	x		
Polygonum viviparum						x						x							
Potentilla Hookeriana										x		x	x						
Sagina intermedia	x	x	x	x												x			
Saxifraga cernua													x						x
Saxifraga hirculus		x				x				x	x	x	x	x	x	x			x
Saxifraga oppositifolia														x	x	x			
Stellaria Edwardsii																			x
Stellaria longipes										x			x						
Shrubs																			
Dryas integrifolia						x				x				x	x	x		x	
Salix arctica		x	x											x	x				
Salix spp.		x	x	x	x	x	x			x	x	x	x			x	x	x	

turbed plots on old peat roads; the disturbed plots had very high breeding-season densities (469.3 birds/km^2) compared to the studies mentioned above.

In the current study, the decline in bird density during the third survey (19–24 July) was due primarily to the lower densities of Lapland Longspurs and Semipalmated Sandpipers. Pectoral Sandpipers on disturbed plots and Red-necked Phalarope on both plot types had higher densities during the third survey; densities of all other shorebird species combined remained relatively stable from the second to the third survey. Connors et al. (1979) also reported shorebird density peaking on tundra plots at Barrow in late July before birds moved to littoral habitats in August.

Effects of Gravel Placement

According to Connors (1983), tundra covered with gravel is lost as bird nesting habitat. This is probably true immediately after gravel placement has occurred and while pads are being used during oil field operations. The abandoned gravel pads that were part of this study did not serve as nesting habitat for most species. However, some species (Greater White-fronted Goose, Red-necked Phalarope, Baird's Sandpiper, Lapland Longspur, Snow Bunting, and Redpoll) did have nests on gravel pads. Nests occurred on pads at Ugnu 1 (six nests), Storage Pad (one nest), and Prudhoe Bay State 1 (one nest). These sites had been abandoned for ten years or more, and varying amounts of plant colonization and thermokarsting had altered the gravel substrate.

Nests on pads usually were associated with clumps of vegetation, although a Baird's Sandpiper nested on barren gravel at Storage Pad. Nests of two species were associated with debris on pads. A Snow Bunting nested in a 55-gallon drum and Redpoll nested on the jagged edge of a wooden piling at Ugnu 1.

At Ugnu 1 nest density was high in both 1990 and 1991 on disturbed plots (21 and 15 nests) and also on undisturbed plots (11 and 21 nests). In addition, eight nests were found here in 1989, although systematic searches were not conducted (Pollard et al. 1990). Four of these nests were on the pad. Robus et al. (1986) also found high levels of use at this site, although fewer nests were reported.

Ugnu 1 is an old site with thin gravel (<0.5 m) and a high degree of natural plant colonization and thermokarsting; it is very different from thick, unvegetated pads (Pollard et al. 1990, Rodrigues and Miller 1991). That nest density and bird use are high on and near this pad suggests the possibility that, if managed properly, abandoned gravel sites may become valuable as nesting habitat.

Troy (1988) found that nest densities for most common shorebirds and Lapland Longspur were higher in portions of the oil field away from roads than near roads. Red-necked Phalarope, which had higher nest densities near roads, was an exception. In this study, such avoidance did not occur in response to abandoned gravel pads; nest density of the most common species on tundra adjacent to abandoned gravel pads was not significantly different from that on undisturbed plots. The lower nest densities on tundra near roads found by Troy may have resulted from activities on the roads, such as traffic, and from the effects of dust, rather than proximity of gravel.

The data also point out the possibility that abandoned gravel pads may enhance the suitability of adjacent tundra as nesting habitat. Thermokarsting of tundra near the edges of some gravel pads produces water-filled pits and other areas of varied microrelief. Red-necked Phalaropes seem to be attracted to these areas, which may be the reason for the higher number of nests and bird sightings of this species on disturbed plots (Tables 4 and 8). Troy (1991a) indicated that thermokarsting and enhanced microrelief may increase bird use of an area for nesting. He suggested that in reclaiming abandoned sites, one should strive for heterogeneity of habitat, and that a combination of ridges and ditches might increase bird use of an area. Other studies also have suggested that greater variability of microrelief may benefit tundra nesting birds (e.g., Norton et al. 1975, Martin and Moitoret 1981). Further studies on the effects to nesting habitats of thermokarsting and variability of microrelief may prove beneficial in developing plans for future rehabilitation of gravel facilities. Part 3 of this report investigates some of these questions.

Conclusions

Although there was a tendency for more nests to be found on undisturbed tundra plots than on disturbed tundra plots containing abandoned gravel pads, when data from all sites are pooled, the difference in mean nest densities between plot types was not statistically significant for either year of the study. However, disturbed plots did have significantly fewer nests in 1990 when data from one site, Ugnu 1, which may have been an outlier, were discarded. This was not the case in 1991.

Of the common species, only Pectoral Sandpiper in 1990 showed a statistically significant difference in

Table A-1. Checklist of vascular plant taxa found on study plots with vegetation at disturbed gravel sites, Prudhoe, Bay, Alaska, 1990 and 1991.

	Lake State 1				Put River			Term Well	Prudhoe Bay State 1					Storage Pad		Mob. Kup.	Put State 1		
	A			B	22-33-11-13			C											
Species	Unseed	Road	GrSp	Unseed	Treated	GrSp	Dis.Tund.	Berm	GrA	GrB	SpA	SpB	Dis.Tund.	Wet	Dry	GrSp	GrA	GrB	Res.Pit
Graminoids																			
Agropyron spp.								x											
Alopecurus alpinus			x		x		x	x		x	x	x	x	x					
Arctogrostis latifolia		x	x	x	x	x	x	x		x				x	x		x	x	x
Arctophila fulva													x						x
Carex aquatilis		x	x		x	x	x			x	x	x	x	x	x	x			x
Carex Biglowii														x					
Carex capitata		x																	
Carex spp.					x	x					x	x	x				x	•	
Deschampsia caespitosa		x	x		x	x	x	x				x		x	x				x
Dupontia fischeri			x		x					x	x	x	x						
Eriophorum angustifolium		x	x		x	x	x	x		x	x	x	x	x	x	x			x
Eriophorum russeolum			x																
Eriophorum Scheuchzeri					x	x	x			x	x	x	x			x			x
Festuca baffinensis		x	x	x		x	x	x		x				x	x		x	x	x
Festuca brachyphylla						x				x		x	x				x	x	x
Festuca rubra						x	x												
Festuca vivipara		x	x											x	x				
Juncus arcticus		x	x											x	x				
Juncus castaneus		x	x																
Juncus spp.																			x
Poa glauca					x	x	x	x											
Poa paucispicula																			x
Poa spp.					x	x	x			x	x	x	x						
Puccinellia Andersonii					x	x			x	x	x	x	x						
Puccinellia borealis								x											
Tricetum spicatum		x	x			x	x	x		x							x		
Forbs																			
Androsaace chamaejasme																	x		
Armeria meritima																	x		
Artemisia alaskana														x					
Artemisia arctica						x				x							x		
Artemisia glomerata														x	x		x	x	
Astragalus alpinus																	x		
Braya humilis																	x	x	
Cerastrium Beeringianum		x	x	x		x		x		x		x	x	x	x		x	x	x

nest density between disturbed and undisturbed plots. It nested more commonly in undisturbed plots. In some cases, disturbed study plots actually had higher nest densities than did nearby undisturbed plots, even though gravel covered an average of approximately 25 percent of the area of disturbed plots. When only non-graveled portions of the disturbed plots were considered, nest density on the two plot types was not significantly different, indicating that tundra adjacent to abandoned gravel pads was not affected.

Similarly, the presence of abandoned gravel pads did not seem to affect nest success or species diversity of nesting birds. There were almost as many successful nests on disturbed plots as on undisturbed plots. There also was a tendency for undisturbed plots to have a higher Shannon's diversity index value than disturbed plots, but the difference was not statistically significant.

Although gravel fill generally does not serve as nesting habitat for tundra-nesting bird species, some birds did nest on abandoned gravel pads. These nests were located on older pads that had some naturally occurring plant colonization and thermokarsting. The fact that nesting densities were high at the Ugnu 1 site, and that some birds have consistently nested on this pad, is an indication of the possibility that nesting habitat can be restored at abandoned gravel pads. In some cases, abandoned gravel pads may have enhanced the suitability of adjacent tundra as nesting habitat by causing greater microrelief as the result of thermokarsting near the pad.

These findings suggest that the nesting-habitat value of undisturbed tundra surrounding abandoned gravel pads is similar to that of undisturbed tundra elsewhere. Nest density, nest success, and species diversity of nesting birds all were similar on both disturbed and undisturbed plots. The association of some nests with natural vegetation and thermokarst on and near abandoned gravel fill indicates that some level of manipulation may improve the value of abandoned sites as nesting habitat for some bird species.

PART TWO: POST-BREEDING USE OF ABANDONED GRAVEL PADS

Introduction

Abandoned gravel pads generally do not serve as nesting habitat for birds; however, our study in 1990 (Rodrigues and Miller 1991) indicated that some birds were attracted to gravel pads during the post-breeding season. When vegetation was present, particularly natural plant colonization as opposed to seeded cultivars, levels of use were higher than on pads that lacked vegetation. By far the most frequently observed species on pads was Lapland Longspur, which often comprised more than 90 percent of the observations; the primary behavior observed was feeding. Shorebirds often were attracted to plots that had water (i.e., reserve pits, impoundments, or water-filled thermokarst troughs).

Results from 1990 also indicated that gravel plots generally had higher levels of use than tundra plots (Rodrigues and Miller 1991). This is not to say that the value of gravel as post-breeding habitat is greater than that of tundra. Because abandoned gravel sites are surrounded by extensive tundra habitat, and because birds are dispersed in low densities over the tundra, few birds were expected on any given tundra plot. The comparison of study plots on tundra with those on gravel was made only to provide an indicator of what might be expected on undisturbed plots of similar size.

The focus of this study is not to compare bird use of gravel sites with that of undisturbed tundra sites, but rather to compare bird use at gravel plots with different physical characteristics in an effort to determine how these characteristics influence use by birds. Knowledge of these characteristics will be useful to managers considering wildlife-oriented goals for rehabilitation of abandoned gravel sites. This report describes and discusses the results of observations from both the 1990 and 1991 field seasons.

Objectives

- To compare levels and kinds of post-breeding bird use of several microhabitat types on disturbed and undisturbed terrain at and near abandoned gravel pads.
- To describe microhabitats preferred by post-breeding tundra bird species at abandoned gravel pads.

Methods

Site Selection and Plot Setup

Of the 14 sites used for the nesting study (Figs. 1A–1D), we selected four in 1990 and five in 1991 to conduct the post-breeding observational study (Table 10). At one site, Lake State 1, two sets of plots (designated as A and B) were established in 1990. In 1991, observations were continued at set B to provide a be-

Appendix A
Post-Breeding-Use Site Descriptions

INTRODUCTION

This section contains descriptions of all sites which were part of the post-breeding observational study. Each site is made up of a combination of disturbed and, in some cases, undisturbed plots.

The disturbed plots include portions of gravel pads, areas of thin gravel or gravel spray, reserve pits, and an impoundment. For these plots, descriptions include plot size, gravel thickness, extent of thermokarsting, and presence or absence of vegetation and water. Where more than one gravel plot is present at a particular site, the extent and type of plant cover is compared among plots. Plant species were identified on disturbed plots with vegetation (Table A-1). For undisturbed plots, the vegetation and landform are described (after Walker et al. 1983).

Maps of the study sites (Figs. A1–A8) are included at the end of Appendix A. These maps are provided to show the spatial relationships among plots.

LAKE STATE 1 OBSERVATIONAL PLOTS

This site is the object of an ARCO Alaska, Inc., revegetation study which was initiated in 1986 (Jorgenson 1988). The gravel pads were fertilized, and portions were seeded with Tundra bluegrass (*Poa glauca*) and Arctared fescue (*Festuca rubra*). No seed or fertilizer were distributed over gravel spray around the edges of pads or on the "road" connecting them. Observations were made at the main drilling pad and a flare pad to the northeast, but not at a thick pad southwest of the main pad.

Two sets of plots were established at this site (Fig. A-1). Initially, four gravel plots (seeded, unseeded, "road", and gravel spray) and one tundra plot were established at the main gravel pad to compare bird use among different types of gravel habitats. These plots are designated as Lake State 1(A). By August 3, 1990, a second set of plots was established at the flare pad. The second set consists of seeded and unseeded gravel plots, an impoundment, and a tundra plot, and is designated as Lake State 1(B).

Lake State 1(A)

Seeded Plot

The dimensions of this fertilized plot were 40 m x 45 m. Gravel thickness was approximately 0.7 m and no thermokarsting was evident. Cultivars were well established over the entire plot; they were green and robust on the southeastern portion, and brown and stunted on the northwestern portion. The well head (a pipe embedded into the gravel) was located on the southeast portion of the plot. Several small wire exclosures (associated with the revegetation study) were present on the plot.

Unseeded Plot

The unseeded plot was adjacent to the seeded plot and had the same dimensions. Gravel thickness was also approximately 0.7 m, and no thermokarsting was evident. Naturally colonizing forb species (Table A-1) were sparsely distributed on this fertilized plot. The unseeded plot and the "road" plot were scanned during the same three-min periods.

"Road" Plot

A plot designated as the "road" was located on the gravel berm joining the main pad to the flare pad.

Table 10. General physical characteristics of disturbed and undisturbed study plots, Prudhoe Bay, Alaska, 1990 and 1991. All plots other than tundra and pond are disturbed habitats. See Appendix A for more detailed description of study plots.

Site	Plot	Characteristics
Lake State 1(B)	Impoundment	Water and mud filled, vegetated at edges
(1990/1991)	Unseeded	Thin gravel, dense natural plant colonization, fertilized
	Seeded	Thin gravel, dense cultivars, fertilized
	Tundra	Moist and wet graminoid, non-patterned ground
Lake State 1(A)	"Road"	Thin gravel, natural plant colonization, moderate cover
(1990)	Gravel spray	Thin gravel, wet troughs, natural colonization, dense cover
	Unseeded gravel	Moderately thick gravel, sparse natural colonization, fertilized
	Seeded gravel	Moderately thick gravel, dense cultivars, fertilized
	Tundra	Moist and wet graminoids, non-patterned ground
Put River	Disturbed tundra	No gravel, sparse natural plant colonization, fertilized
22-33-11-13	Gravel spray	Trace gravel, sparse cultivars and natural colonization, fertilized
(1991)	Treated	Gravel removed, topsoil added, dense cultivars, fertilized
Term Well C	Berm	Mixed gravel and overburden, moderately vegetated (graminoids)
(1990)	Reserve pit	Water-filled, mud edge
	Pond	Water-filled, partial mud edge
	Gravel pad	Thick gravel, no vegetation
	Tundra	Moist graminoids, strangmoor
Prudhoe Bay	Gravel A	Thin gravel, trace vegetation
State 1	Gravel B	Thin gravel, sparce vegetation
(1991)	Spray A	Sparse gravel spray, sparse vegetation
	Spray B	Sparse gravel spray, sparse vegetation
	Dist. tundra	No gravel, heavily thermokarsted, moderately vegetated
Storage Pad	Tundra	Moist graminoids, mixed high and low-centered polygons
(1990)	"Wet" thermokarsted	Moderately thick gravel, wet troughs, natural colonization
	"Dry" thermokarsted	Moderately thick gravel, dry troughs, natural colonization
Mobil Kuparuk	Thick gravel	Thick gravel, no vegetation
3-15-11-12	Thin gravel	Thin gravel, sparse natural plant colonization
(1991)	Tundra	Wet graminoid tundra with pond
Put State 1	Gravel A	Thick gravel, moderate natural plant colonization
(1991)	Gravel B	Thick gravel, moderate natural plant colonization
	Reserve pit	Overburden dike with vegetation, water filled
Delta State 2	Reserve pit	Water filled, mud edge
(1990)	Tundra	Moist and wet graminoids, non-patterned ground
	Gravel pad	Moderately thick gravel, no vegetation

Service, Fairbanks. 86 pp.

Spindler, M.A., and P.A. Miller. 1983. Terrestrial bird populations and habitat use on coastal plain tundra of the Arctic National Wildlife Refuge. pp 107–200 In: G. W. Garner and P. E. Reynolds (eds.). 1982 update report baseline study of the fish, wildlife, and their habitats. USDI Fish and Wildl. Serv., Anchorage, AK. 379 pp.

Troy, D.M. 1982. Avifaunal investigations. Chapter 6 In: Biological and archeological investigations in the vicinity of the proposed Duck Island Unit pipeline through the Sagavanirktok River Delta, Alaska. Report prepared by LGL Alaska Research Associates, Inc., for Exxon Company, U.S.A. 27 pp

Troy, D.M. 1985. Prudhoe Bay waterflood environmental monitoring project terrestrial studies. Report by LGL Alaska Research Associates, Inc., for Envirosphere Company, Anchorage, Alaska. 152 pp.

Troy, D.M. 1988. Bird use of the Prudhoe Bay Oilfield during the 1986 nesting season. Report prepared by LGL Alaska Research Associates, Inc., Anchorage, for Alaska Oil and Gas Association, Anchorage. 96 pp.

Troy, D.M. 1991a. Bird use of disturbed tundra at Prudhoe Bay, Alaska: bird and nest abundance along the abandoned peat roads, 1988–1989. Report to BP Exploration (Alaska) Inc. by Troy Ecological Research Associated, Inc., Anchorage. 48 pp.+ appendices.

Troy, D.M. 1991b. Trends in bird use of the Pt. McIntyre reference area: 1990 update. Report prepared by Troy Ecological Research Associates for BP Exploration (Alaska) Inc. 47 pp.

Troy, D.M., and R.M. Burgess. 1983. Chapter 3. Avifauna. In: D.M. Troy (ed.). Prudhoe Bay Unit–Eileen West End environmental studies program, summer 1982. Report by LGL Alaska Research Associates, Inc., Fairbanks, for Sohio Alaska Petroleum Company, Anchorage.

Troy, D.M., and T.A. Carpenter. 1990. The fate of birds displaced by the Prudhoe Bay Oilfield: the distribution of nesting birds before and after the P-Pad construction. Report prepared by Troy Ecological Research Associates for BP Exploration (Alaska) Inc. 39 pp + appendices

Troy, D.M., and J.K. Wickliffe. 1990. Trends in bird use of the Pt. McIntyre reference area, 1981–1989. Final report by Troy Ecological Research Associates, Inc., Anchorage, to BP Exploration (Alaska) Inc., Anchorage. 45 pp. + appendix.

Troy, D.M., D.R. Herter, and R.M. Burgess. 1983. Prudhoe Bay waterflood environmental monitoring project: tundra bird monitoring program. Chap. 7. In: Vol. 4, Prudhoe Bay waterflood project environmental monitoring program 1982. U.S. Army Corps of Engineers, Alaska District, Anchorage.

Walker, D.A., K.R. Everett, P.J. Webber. 1983. Chapter 2. Geobotany. In: D. M. Troy (ed.) Prudhoe Bay Unit-Eileen West End environmental studies program, summer 1982. Report to Sohio Alaska Petroleum Co., Anchorage, by LGL Alaska Research Associates, Inc., Fairbanks. 77 pp.

Walker, D.A., E.F. Binnian, N.D. Lederer, E.A. Nordstrand, M.D. Walker, and P.J. Webber. 1986. Cumulative landscape impacts in the Prudhoe Bay oil field, 1949–1983. Final report to USDI Fish & Wildl. Serv., Habitat Resources Section, Anchorage, Alaska, by Inst. of Arctic and Alpine Res., Univ. Colorado, Boulder.

Walker, D.A., P.J. Webber, E.F. Binnian, K.R. Everett, N.D. Lederer, E.A. Nordstrand, and M.D. Walker. 1987a. Cumulative impacts of oil fields on northern Alaskan landscapes. Science 238:757–761.

Walker, D.A., D. Cate, J. Brown, and C. Racine (eds.). 1987b. Disturbance and recovery of arctic Alaskan tundra terrain. CRREL Report No. 87-11. U.S. Army Cold Regions Research and Engineering Laboratory, Hanover, NH. 70 pp.

Walker, D.A., P.J. Webber, N.D. Lederer, and M.D. Walker. 1987c. Terrain and vegetation of the Department of Energy R4D research site, Imnavait Creek, Alaska. Classification and Mapping. Report by Plant Ecology Lab., Inst. of Arctic and Alpine Res., Univ. of Colorado, Boulder.

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

Wiggins, D.A., and S.R. Johnson. 1991. Use of gravel causeways by nesting common eiders, Beaufort Sea, Alaska, 1990. Report by LGL Alaska Research Associates, Inc., Anchorage, to BP Exploration (Alaska) Inc., Anchorage. 26 pp. + appendix.

Wilkinson, L. 1990. SYSTAT: the system for statistics. Evanston, IL. 638 pp.

Zar, J.H. 1984. Biostatistical analysis. Second ed. Prentice Hall, Englewood Cliffs, N.J. 718 pp.

tween year comparison. Other sites were chosen because of the availability of differing microhabitat types at each one. Table 10 briefly describes the physical characteristics of each study plot. See Appendix A for more detailed descriptions.

Each site had patches of distinct microhabitat types which could be compared on the basis of bird use. Plots were established on gravel at most sites; at one site, Put River 22-33-11-13, most of the gravel had been removed and only traces remained. Some of these plots included various types (e.g., seeded or naturally colonized) or degrees (e.g., sparse to dense) of vegetation. Other plots were established in disturbed areas such as reserve pits, impoundments, or disturbed tundra adjacent to gravel pads. At most sites, undisturbed tundra plots adjacent to the gravel pads were also established. Plot size was usually standardized within each site, but size sometimes varied due to the limited availability of a particular microhabitat type. Each plot was established such that the microhabitat within the plot was as homogeneous as possible. An elevated observation blind was erected at each site to provide a clear view of all study plots at that site.

Maps of the observational sites were made using 1"=150' CIR aerial photographs (see Appendix A). The purpose of these maps is to illustrate the spatial relationships among the various plots and microhabitats at each site.

Data Collection

Observations were made from 17 July to 13 August in 1990, and from 19 July to 14 August in 1991 to coincide with the period when most nesting had been completed and fall staging was beginning. Observation periods were 2.5 hours (hr) each in the morning and afternoon. During each 2.5-hr period, the observer slowly scanned a study plot for three minutes (min) with binoculars and with the naked eye. Data from the scan were recorded during a two-min period following each scan. The observer then shifted to the next plot for three min, recorded data during the following two min, and so on. Because each site had at least three plots, it took 15 min (five min per plot) to complete one cycle of the plots. For sites that had more than three plots, it was possible to scan two adjacent plots at the same time such that the 15-min cycle was maintained. Thus, each plot at each site was scanned ten times during each 2.5-hr observation period (20 times per day).

During each scan of a plot, observers recorded the number of individuals of each species and the behavior of each individual (i.e., feeding, resting/preening, hunting, interacting, unknown). For birds landing on the plot during a three-min scanning period, the behavior recorded was the behavior first observed after about ten seconds. Birds flying over the plot but not landing on it were not recorded.

Data Analysis

Given the limited number of available abandoned gravel pads and the unique character of each of them, it was not possible to observe replicates of each plot. In most cases, observations of bird use of plots within a given site constituted repeated measures of the same experimental units (the plots); thus, data (such as use levels) were not appropriate for statistical analyses (see Hurlbert 1984).

Observational data were compared among all plots at all sites. Several criteria were used to compare bird use among plots. Mean numbers of observations of birds per 2.5-hr period were calculated to measure levels of bird use. Because plot size varied among sites, levels of use were adjusted to a standard plot size (one hectare). Thus, the values for level of use represent the number of observations per 2.5-hr period per hectare. Species richness (total number of species observed) was compared among plots. In addition, species were divided into two groups, Lapland Longspurs (by far the most common species) and all other species combined. The percent of occurrence of the two groups was compared among plots. Plots were also compared with respect to the percentage of feeding behavior observed on them by Lapland Longspurs and for all other species combined.

Results and Discussion

In this section, levels of use, species richness and composition, and bird behavior are compared among plots at all of the study sites (Table 11, Fig. 5). Physical characteristics of plots, such as gravel thickness, extent of thermokarsting, amount and type of vegetation, presence of water/mud, and type of tundra, are also discussed. For detailed descriptions of study plots, see Appendix A.

At most of the study sites, birds were less visible on tundra plots than on other plots because of concealing vegetation. However, searches of the tundra plots made routinely after each observational period suggested that, despite the plant cover, few birds escaped detection. Thus, relative comparisons of levels of bird use among plots are valid irrespective of differences in

LGL Alaska Research Associates, Inc. 1983. Prudhoe Bay waterflood project bird studies procedures. In: Vol. 5, Prudhoe Bay waterflood project environmental monitoring program 1982. Procedures manuals. U.S. Army Corps of Engineers, Alaska District, Anchorage.

MacArthur, R.H., and E.R. Pianka. 1966. On optimal use of a patchy environment. Am. Nat. 100:603–609.

Martin, P.D. 1983. Bird use of arctic tundra habitats at Canning River Delta, Alaska. Masters thesis. University of Alaska, Fairbanks. 117 pp.

Martin, P.D., and C.S. Moitoret. 1981. Bird populations and habitat use, Canning River Delta, Alaska. Unpubl. report. USDI Fish and Wildl. Serv., Arctic National Wildlife Refuge, Fairbanks, Alaska. 188 pp.

Meehan, R.H. 1986. Impact of oilfield development on shorebirds, Prudhoe Bay, Alaska. Ph. D. dissertation. Univ. Colorado, Boulder. 92 pp.

Myers, J.P., and F.A. Pitelka. 1975a. Wet coastal plain tundra I. Am. Birds 29:1135–1136.

Myers, J.P., and F.A. Pitelka. 1975b. Wet coastal plain tundra II. Am. Birds 29:1136.

Myers, J.P., and F.A. Pitelka. 1980. Effects of habitat conditions on spatial parameters of shorebird populations. Unpublished report to the Department of Energy for 1975–1979. 82 pp.

Myers, J.P., R.S. Greenberg, and F.A. Pitelka. 1977a. Wet coastal plain tundra I. Am. Birds 31:82.

Myers, J.P., R.S. Greenberg, and F.A. Pitelka. 1977b. Wet coastal plain tundra II. Am. Birds 31:82–83.

Myers, J.P., R.A. Erickson, and F.A. Pitelka. 1978a. Wet coastal plain tundra I. Am. Birds 32:116–117.

Myers, J.P., R.A. Erickson, and F.A. Pitelka. 1978b. Wet coastal plain tundra II. Am. Birds 32:117–118.

Myers, J.P., B.J. McCaffery, and F.A. Pitelka. 1979a. Wet coastal plain tundra I. Am. Birds 33:101–102.

Myers, J.P., B.J. McCaffery, and F.A. Pitelka. 1979b. Wet coastal plain tundra III. Am. Birds 33:102.

Myers, J.P., W.D. Shuford, and F.A. Pitelka. 1979c. Wet coastal plain tundra II. Am. Birds 33:102.

Myers, J.P., S.T. Gellman, and F.A. Pitelka. 1980a. Wet coastal plain tundra III. Am. Birds 34:83.

Myers, J.P., B.J. McCaffery, and F.A. Pitelka. 1980b. Wet coastal plain tundra II. Am. Birds 34:83.

Myers, J.P., C.W. Swarth, and F.A. Pitelka. 1980c. Wet coastal plain tundra I. Am. Birds 34:82–83.

Myers, J.P., B.J. McCaffery, T.A. Sordahl, and F. A. Pitelka. 1981a. Wet coastal plain tundra III. Am. Birds 35:96.

Myers, J.P., T.A. Sordahl, B.J. McCaffery, and F.A. Pitelka. 1981b. Wet coastal plain tundra I. Am. Birds 35:95–96.

Myers, J.P., T.A. Sordahl, B.J. McCaffery, and F.A. Pitelka. 1981c. Wet coastal plain tundra II. Am. Birds 35:96.

Norton, D.C., I.W. Ailes and J.A. Curatolo. 1975. Ecological relationships of the inland tundra avifauna near Prudhoe Bay, Alaska. Pages 125–133 In: J. Brown (ed.). Ecological investigations of the tundra biome in the Prudhoe Bay region, Alaska. Biol. Pap. Univ. of Alaska, Spec. Rep. No. 2.

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

Pitelka, F.A., R.T. Holmes, and S.F. MacLean, Jr. 1974. Ecology and evolution of social organization in arctic sandpipers. Am. Zool. 14:185–204.

Pollard, R.H., R. Rodrigues, and R.C. Wilkinson. 1990. Wildlife use of disturbed habitats in arctic Alaska: 1989 final report. Report by LGL Alaska Research Associates, Inc., Anchorage, to BP Exploration (Alaska) Inc., Anchorage. 111 pp. + appendices.

Pyke, G.H. 1984. Optimal foraging theory: a critical review. Ann. Rev. Ecol. Syst. 15:523–575.

Robus, M.A., S.M. Murphy, R.M. Burgess, and B.A. Anderson. 1986. Natural revegetation and bird use of three disturbed sites in the Kuparuk Oilfield, Alaska, 1985. Report prepared for ARCO Alaska, Inc. by Alaska Biological Research, Fairbanks Alaska. 75 pp.

Rodrigues, R., and M.E. Miller. 1991. Bird use of abandoned gravel pads in arctic Alaska. Report prepared for BP Exploration (Alaska), Inc. 62 pp + appendices.

Rosenzweig, M.L. 1985. Some theoretical aspects of habitat selection. pp 517–540 In: M.L. Cody (ed.). Habitat selection in birds. Academic Press, San Diego.

Seastedt, T.R., and S.F. MacLean. 1979. Territory size and composition in relation to resource abundance in Lapland longspurs breeding in arctic Alaska. Auk 96:131–142.

Spindler, M.A. 1978. Bird populations and habitat use in the Okpilak River delta area, Arctic National Wildlife Refuge, Alaska. U. S. Fish and Wildlife

Table 11. Means and standard deviations of numbers of observations of birds/2.5-hr period/hectare, percent occurrence of Lapland Longspurs and all other species combined, and species richness on disturbed and undisturbed study plots, Prudhoe Bay, Alaska, 1990 and 1991.

Site	Plot	Plot Size(ha)	Periods	Observations per Period per ha Mean	SD	Percent Occurrence Longspurs	Other	Number of Species
Delta State 2	Gravel pad*	0.500	14	2	2	91	9	2
	Tundra	0.500	14	3	4	65	35	3
	Reserve pit*	0.500	14	14	15	22	78	6
Put State 1	Gravel A*	0.354	16	2	4	91	9	2
	Gravel B*	0.354	16	4	4	86	14	3
	Reserve pit*	0.287	16	13	12	26	74	6
Mobil Kuparuk 3-15-11-12	Thin gravel*	0.259	10	1	2	0	100	3
	Thick gravel*	0.259	10	4	11	90	10	2
	Tundra	0.259	10	5	7	43	57	6
Storage Pad	"Dry" thermokarsted*	0.390	18	14	16	95	5	4
	"Wet" thermokarsted*	0.390	18	14	15	89	11	7
	Tundra	0.390	18	15	11	93	7	5
Prudhoe Bay State 1	Gravel A*	0.120	18	11	21	83	17	4
	Spray A*	0.120	18	13	18	82	18	3
	Gravel B*	0.120	18	23	42	94	6	3
	Spray B*	0.120	18	24	25	76	24	5
	Disturbed tundra*	0.120	18	25	42	89	11	4
Term Well C	Tundra	0.300	18	3	4	64	36	4
	Gravel pad*	0.300	18	15	31	97	3	2
	Pond	0.300	18	21	25	0	100	7
	Reserve pit*	0.300	18	28	51	15	85	6
	Berm*	0.144	18	74	69	93	7	4
Put River 22-33-11-13 (overall)	Treated*	0.200	28	14	23	40	60	6
	Gravel spray*	0.200	28	35	40	34	66	6
	Disturbed tundra*	0.200	28	97	101	18	82	8
Lake State 1(A)	Tundra	0.180	32	5	9	90	10	3
	Seeded gravel*	0.180	32	27	22	94	6	4
	Unseeded gravel*	0.180	32	62	47	79	21	4
	Gravel spray*	0.133	32	169	94	75	25	11
	"Road"*	0.063	32	197	238	93	7	5
Lake State 1(B) (1990)	Tundra	0.180	18	6	13	79	21	6
	Impoundment*	0.148	18	90	97	36	64	8
	Seeded gravel*	0.039	18	88	101	99	1	2
	Unseeded gravel*	0.039	18	486	524	99	1	3
Lake State 1(B) (1991)	Tundra	0.180	18	16	14	89	11	3
	Impoundment*	0.148	18	81	99	54	46	12
	Seeded gravel*	0.039	18	116	102	87	13	2
	Unseeded gravel*	0.039	18	329	257	78	22	3

* indicates disturbed habitats

Literature Cited

BP Exploration (Alaska), Inc. 1991. 1990 BP pad progress report.

Begon, M., J.L. Harper, and C.R. Townsend. 1986. Ecology: individuals, populations, and communities. Sinauer Associates, Inc., Sunderland, Massachusetts. 876 pp.

Connors, P.G., J.P. Myers, and F.A. Pitelka. 1979. Seasonal habitat use by arctic Alaskan shorebirds. Published by Cooper Ornithological Society. Studies in Avian Biology No. 2:101–111.

Connors, P.G. 1983. Effects of food resource levels on tundra bird populations. Chap. 7, Appendix. In: Vol. 4, Prudhoe Bay waterflood project environmental monitoring program 1982. U.S. Army Corps of Engineers, Alaska District, Anchorage.

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

Custer, T.W., and F.A. Pitelka. 1978. Demographic features of a Lapland longspur population near Barrow, Alaska. Auk 94:505–525.

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

Emlen, J.M. 1966. The role of time and energy in food preference. Am. Nat. 100:611–617.

Green, R.H. 1979. Sampling design and statistical methods for environmental biologists. John Wiley and Sons, New York. 257 pp.

Hohenberger, C.J., A. Hendrick, and W.C. Hanson. 1980. Wet coastal plain tundra. Am. Birds 34:82–83.

Hohenberger, C.J., D.P. Rudholm, and W.C. Hanson. 1981. Wet coastal plain tundra. Am. Birds 35:95.

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

Holmes, R.T. 1970. Differences in population density, territoriality, and food supply of dunlin on arctic and subarctic tundra. Symp. of the British Ecol. Soc. 10:303–319.

Hurlbert, S.H. 1984. Pseudoreplication and the design of ecological field experiments. Ecol. Monog. 54(2):187–211.

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

Jorgenson, M.T. 1988. Revegetation of the Lake State 1 exploratory well site, Prudhoe Bay Oilfield, Alaska, 1987. Report prepared for ARCO Alaska, Inc. and Kuparuk River Unit by Alaska Biological Research, Inc., Fairbanks, Alaska. 67 pp.

Jorgenson, M.T. 1989. Rehabilitation studies in the Kuparuk Oilfield, Alaska, 1988. Report prepared for ARCO Alaska, Inc. by Alaska Biological Research, Inc., Fairbanks, Alaska. 66 pp.

Jorgenson, M.T., T.T. Heffernan, and B.K. Lance. 1990. Land rehabilitation studies in the Kuparuk Oilfield, Alaska, 1989. Annual report prepared for ARCO Alaska, Inc. by Alaska Biological Research, Inc., Fairbanks, Alaska. 132 pp.

Larson, D.L., and C.E. Bock. 1986. Determining avian habitat preference by bird-centered vegetation sampling. pp. 37–43. In: J. Verner, M. Morrison, and C. Ralph (eds.). Wildlife 2000. University of Wisconsin Press.

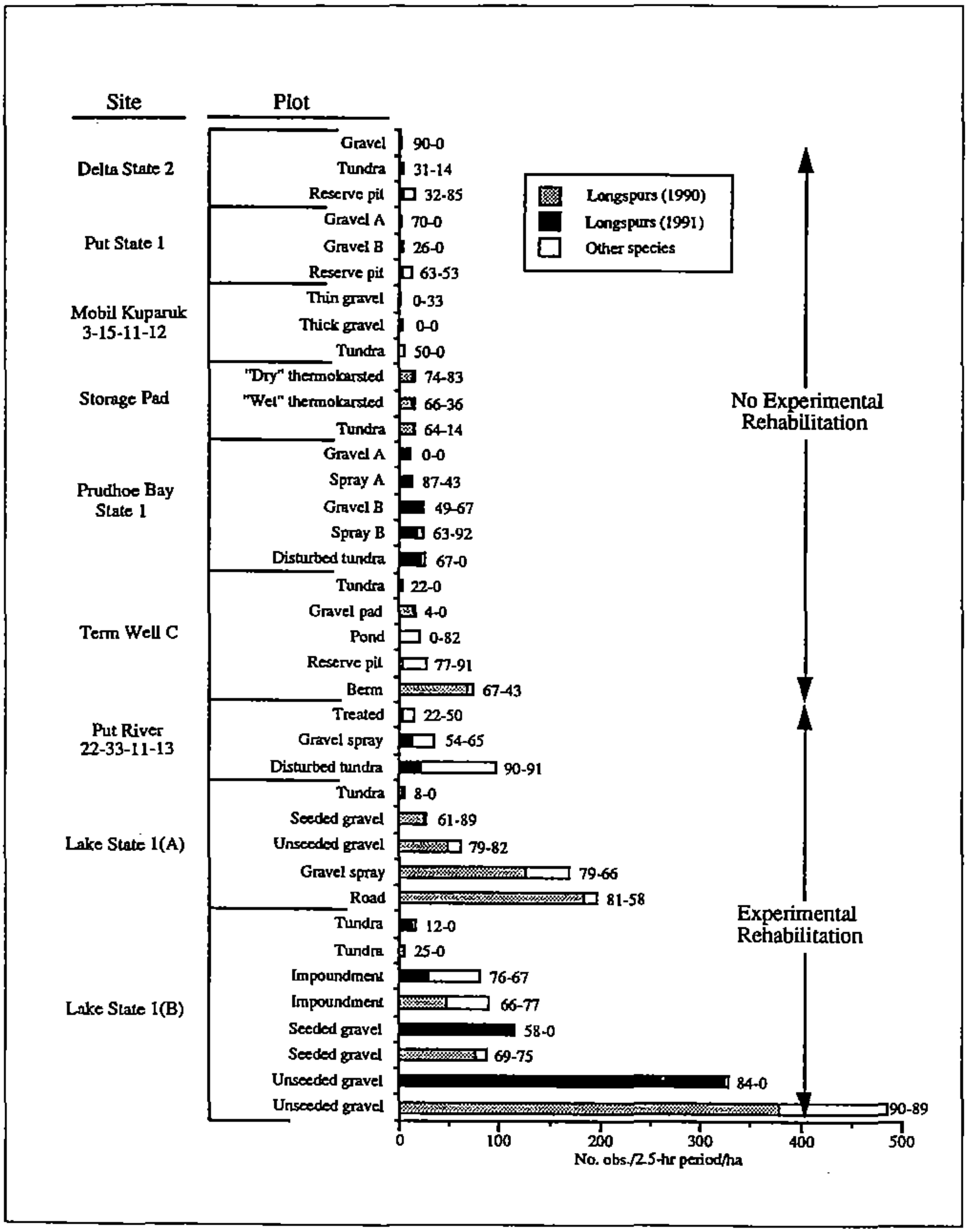


Figure 5. Number of observations of Lapland Longspurs and of all other species combined per 2.5-hr observation period per hectare on disturbed and undisturbed study plots, Prudhoe Bay, Alaska, 1990 and 1991. Numbers to the right of bars indicate percentage of observations in which the behavior was feeding for longspurs and for all other species combined.

sloping areas. Lapland Longspur, which nests predominantly on the south and southwest sides of ridges or polygon rims, would probably benefit from ridges oriented in a northwest to southeast direction.

Although water was generally not present on nest plots of most species, moisture is important because of its effect of the plant community, and is considered to be a limiting factor in determining plant growth on disturbed gravel sites. The amount of water available to plants may be increased by reducing gravel thickness, constructing "snow fences", and creating troughs and low areas on gravel sites to collect precipitation.

visibility. However, behavior of birds was more difficult to discern on tundra plots than was the presence of birds, and comparisons of behavior among plots should be qualified accordingly.

Level of Use

Of the eight sites selected for the observational study [note: Lake State 1(A) and 1(B) compose two sets of plots at one site], individual plots at two sites received relatively high levels of use. These include some gravel plots and the impoundment at Lake State 1, and the disturbed tundra plot at Put River 22-33-11-13. The berm at Term Well C was the only other plot with similarly high levels of use.

Lake State 1 and Put River 22-33-11-13 have been the focus of rehabilitation experiments. Lake State 1 is the object of an ARCO Alaska, Inc. revegetation study which was initiated in 1986 (Jorgenson 1988). The gravel pads were fertilized and plots were seeded with Tundra bluegrass (*Poa glauca*) and Arctared fescue (*Festuca rubra*). Other plots were established and left unseeded. Put River 22-33-11-13 is the object of an experimental rehabilitation project being undertaken by BPX. Most of the gravel was removed to within six inches of the original tundra grade in May 1989 (BP Exploration 1991). Topsoil (overburden) was then placed over the area of the former pad. The entire area, including the area formerly occupied by the pad and most of the adjacent disturbed area, was fertilized and seeded with *Poa glauca*, *Festuca rubra*, and *Arctagrostis latifolia*.

Although some plots at both of these sites received high levels of bird use, the level of use was lower on plots with seeded cultivars. This was true at Lake State 1, where the results in 1991 supported the results of 1990, although the difference between seeded and unseeded plots was less. At Put River 22-33-11-13, the "treated" plot, where cultivars were well established, had the lowest level of use. The low level of use on seeded plots indicated that seeded grass species, which can stabilize disturbed sites and enhance their esthetic value, may not enhance the value of such sites as habitat for post-breeding bird species.

Plots which did have high levels of use were in disturbed habitats which had been fertilized and where natural plant colonization was occurring. At Lake State 1(B), a wide variety of plant species was colonizing the unseeded plot on the gravel pad (see Appendix A for list of plant species). Longspurs and Snow Buntings were observed eating the seeds of some forb species, particularly *Sagina intermedia*, which was very common. Reasons for the high level of use on the disturbed tundra plot at the Put River site may be related to the presence of *Cochlearia officinalis*, which is known to be a food source for longspurs (Pollard et al. 1990).

Since birds did not seem to prefer plots with seeded grass species, the reasons for the higher levels of use at sites undergoing rehabilitation is unclear, but may be related to the effect of fertilizer on naturally colonizing plant species. Further studies using fertilizers to encourage natural plant colonization may prove beneficial in determining methods for rehabilitating abandoned gravel sites.

The presence of a snow fence may have influenced the level of use at Put River 22-33-11-13. The snow fence was removed from the site on 3 and 4 August, 1991. There were 12 observation periods before and 16 observation periods after removal of the fence. The level of use on the disturbed tundra plot was about six times higher before removal of the snow fence (Fig. 6). In the other plots, which had much lower levels of use, the differences were not as great, although very few birds were observed on the treated plot after removal of the snow fence. Birds may initially have been attracted to this site because the snow fence provided perching sites, and then they remained to take advantage of the local food source. It is also likely that the birds did not leave the site because the snow fence was gone, but because of the disturbance caused by two days of helicopter activity during its removal.

The differences in levels of use among various plots may be partly related to the relative sizes of the microhabitat "patches" on which the plots were located. That is, birds might be expected to be more concentrated on plots (or patches) that offered a unique resource but were relatively small in size. Several of the smaller plots (i.e., seeded and unseeded plots at Lake State 1(B), road plot at Lake State 1(A), and the berm at Term Well C) had the highest levels of use. This concept is discussed further in the section on behavior.

Species Composition

Lapland Longspur was the most frequently observed species on most plots which did not have water, and sometimes accounted for more than 90 percent of the observations (Table 11). However, at Put River 22-33-11-13, Snow Bunting was the most frequently observed species. Where water was present (i.e., plots with reserve pits and impoundments), species richness

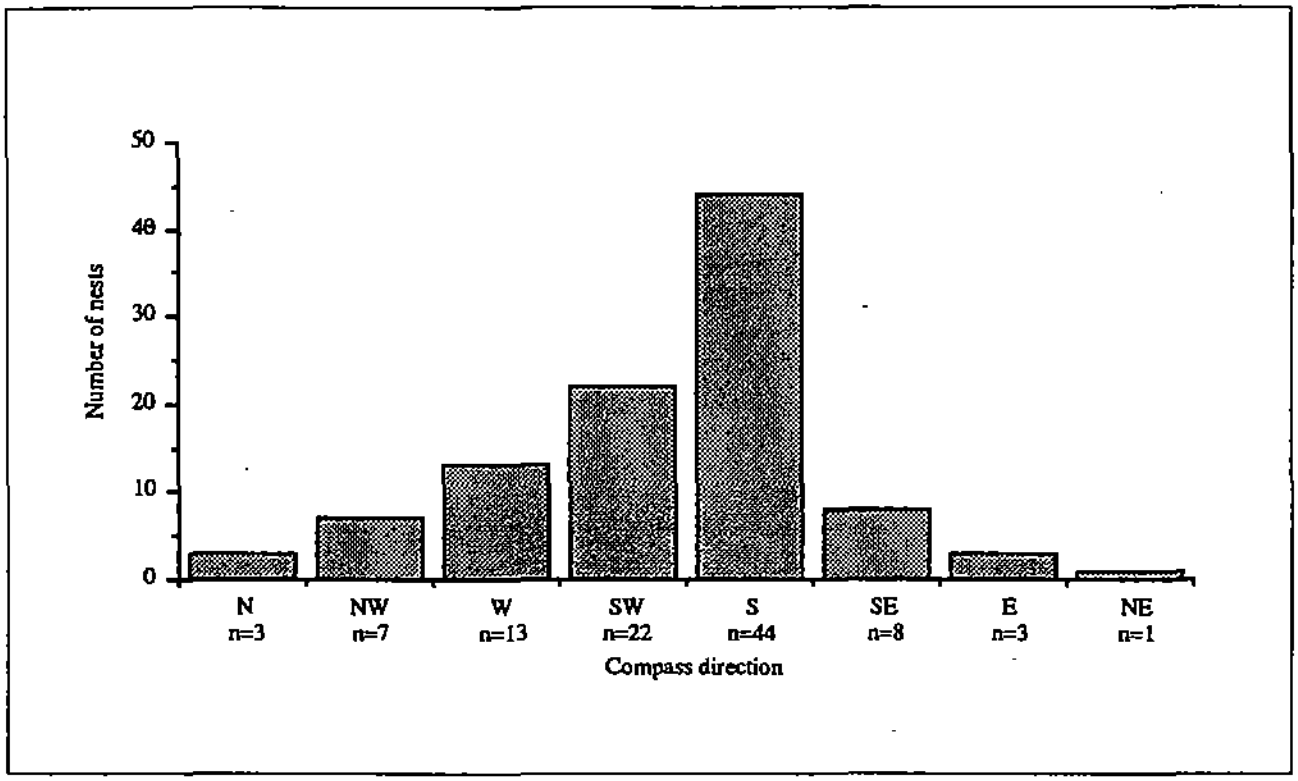


Figure 11. Orientation with respect to compass direction of Lapland Longspur nests on sides of ridges, troughs, or tussocks in the Prudhoe Bay oil field, Prudhoe Bay, Alaska, 1991. (n is number of nests.)

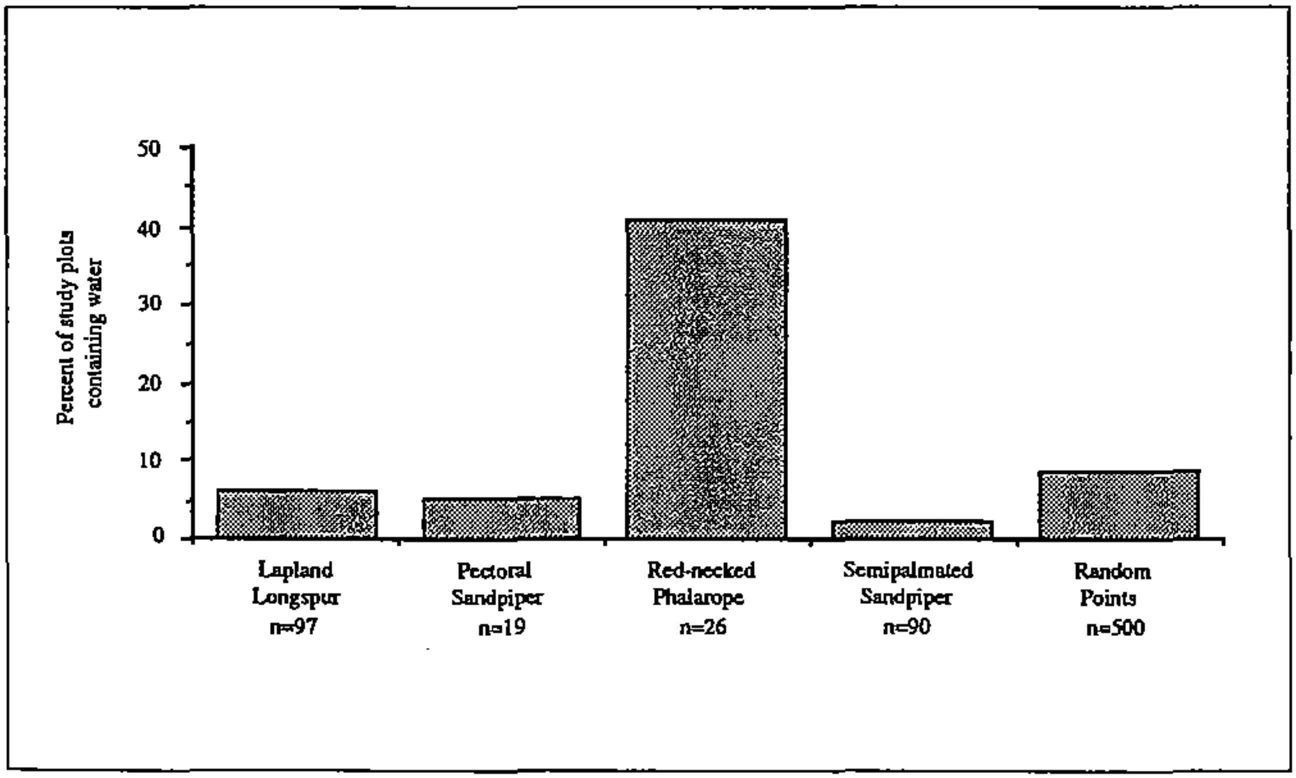


Figure 12. Percent of study plots centered on bird nests and on random points on which water was present in the Prudhoe Bay oil field, Prudhoe Bay, Alaska, 1991. (n is the total number of nests or random plots.)

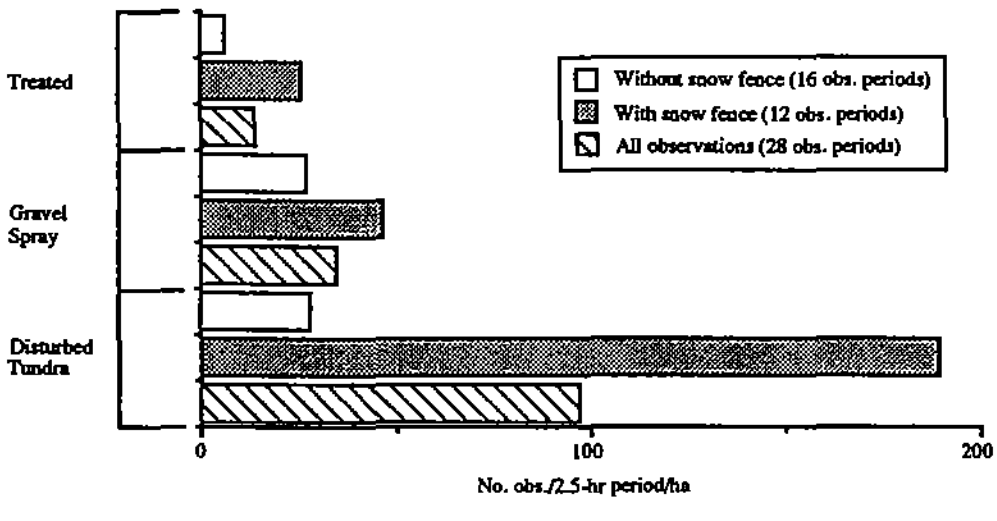


Figure 6. Number of observations of birds per 2.5-hr period per hectare on disturbed study plots at Put River 22-33-11-13, Prudhoe Bay, Alaska, 1991.

was high (6 to 12 species) because plots were used by shorebirds, waterfowl, and gulls. At Lake State 1(A), water was present in thermokarsted areas of the gravel spray plot, and species richness was also high (11 species).

Behavior

Because the observational study did not begin until after most nesting had been completed, breeding-related behaviors, such as displaying or incubating, were not expected. Of the few nests that were still active, none were located on the observational plots. Most young birds had fledged by this time, and activities of adults and young were oriented toward preparation for migration. For longspurs on 63 percent of the study plots and for all other species on 55 percent of the plots, feeding was the behavior observed at least 50 percent of the time (Fig. 5).

Most plots where feeding was not the most frequently observed behavior were those on which visibility was hampered by vegetation (i.e., tundra plots, "treated" plot at Put River 22-33-11-13), and the behavior was unknown. However, feeding was probably the primary behavior on these plots also. Some gravel plots also had few observations of birds feeding. These were usually plots which lacked appreciable vegetation. For many plots, the numbers of observations were low, and observed behaviors may not have been representative.

If the predominant behavior observed was feeding, the question arises: what were they eating? Custer and Pitelka (1978) analyzed longspur stomach samples and found that although diets at Barrow consisted primarily of insects, seeds composed up to 70 percent of their diet early in the season (late May) and 24 to 30 percent late in the season (August). These birds were collected within 10 km of the Naval Arctic Research Laboratory at Barrow and, presumably, were feeding on tundra habitats, although this is not clear.

Although insects formed the bulk of the diet of longspurs in the studies by Custer and Pitelka (1978), it seems unlikely that longspurs were feeding on insects at gravel sites in our study. Densities of insects generally are much higher on tundra habitats than on gravel pads (personal observation), and it is more likely that longspurs were attracted by the many forb species, which are prolific seed producers and common colonizers of gravel sites (Robus et al. 1986; Jorgenson ten located under or on the sides of tussocks.

Red-necked Phalaropes had the highest percentage of plots classified as having low roughness, and no plots were classified as having high roughness. Phalaropes generally selected relatively flat areas, often with a small mound present, for nest sites. These areas were typically associated with water (see below). Roughness of plots centered on the nests of Semipalmated and Pectoral sandpipers, although slightly higher than that of phalaropes, still tended to be low.

When rehabilitating abandoned gravel sites, constructing areas with high variability of microrelief would be most beneficial to longspurs. Other species would probably benefit to a lesser extent.

Orientation of Longspur Nests

Of 165 nests of Lapland Longspurs, 101 were clearly placed on the side a ridge, a polygon rim, or a tussock. The remaining 64 longspurs nests were located in open areas, and no orientation could be determined. There was a tendency for longspurs to select nest sites on the south and southwest sides of these ridges (Fig. 11). Few nests were located on the north and northeast sides. The null hypothesis that nests have an equal probability of falling in any compass direction was rejected ($P<0.001$). The sheltering of nests behind these elevated areas may be a response to the prevailing northeasterly winds of the Prudhoe Bay area. When rehabilitating gravel sites, creating ridges with a northwest to southeast orientation may be beneficial to longspurs.

Water Regime

At the 0.05 confidence level, the occurrence of water was significantly different on nest plots of Red-necked Phalarope and Semipalmated Sandpiper compared random plots (Table 15). At the 0.01 confidence level, only nest plots of Red-necked Phalarope differed from random plots. The occurrence of water on nest plots of Red-necked Phalarope was much greater than for nest plots of other species or random plots (Fig. 12).

Water is important because of its effect on the plant community. Soil moisture may be a critical component of gravel ecosystems and is considered to be a limiting factor in determining plant growth on disturbed gravel sites (Jorgenson 1988). The addition of water to abandoned gravel sites would be beneficial to plant species trying to colonize these sites, thus increasing the probability that birds may use these sites for nesting.

Moisture content at abandoned gravel sites could be increased in several ways. Reduction of gravel thickness would bring the surface of the gravel closer to the water table, thus allowing for more efficient transfer of water by capillary action. "Snow fences", constructed to concentrate drifting snow and thereby provide increased water during the growing season, have been successfully used on gravel pad enhancement projects on the North Slope (BP Exploration 1991). Additionally, the construction of ditches, troughs, or other low areas which could trap precipitation would probably encourage plant colonization.

Conclusions

Results from one site examined during the nesting study (Part 1) indicate that it may be possible to rehabilitate abandoned gravel sites as nesting habitat for birds. This site, Ugnu 1, is over 20 years old, and a high degree of thermokarsting and plant colonization has occurred. The gravel layer is approximately 0.5 m thick, and is relatively thin compared to most other abandoned gravel sites. Birds have nested on this pad for at least the past three years.

Comparisons of microhabitat variables of plots centered on bird nests with plots centered on random points has yielded information which will be useful during assessment of rehabilitation options. A high percentage of graminoid and shrub/forb cover is not necessary to attract some species to nest. Mean percent graminoid cover was less than 35 percent on nest plots of most species. Of the species studied, graminoid cover is probably most important for Pectoral Sandpiper and Red-necked Phalarope, and Lapland Longspur to a lesser extent. For Semipalmated Sandpiper, graminoid cover on nest plots was usually closer to that of random plots, which averaged approximately 25 percent. Mean percent shrub/forb cover was always less than graminoid cover on nest plots of all species and on random plots.

The amount of microrelief and the variability of relief, or surface roughness, appear to be important factors influencing nest site selection, particularly for Lapland Longspurs. Differences in comparisons of mean amounts and variability of microrelief on nest plots of other species and random plots were less than that of longspurs. However, the presence of some relief, similar to that which occurs on the tundra, may also be important for these species. When rehabilitating abandoned gravel sites, it will be important to construct a series of ridges and troughs, and also flat, 1988, 1989; Pollard et al. 1990; Rodrigues and Miller 1991).

In the current study, it was usually impossible to determine what the birds were eating or how successful they were at obtaining food. However, on occasion longspurs were observed eating seeds of various plant species including *Eriophorum* spp., *Sagina intermedia, Minuartia rubella, Saxifraga hirculus*, and *Dryas integrifolia*. Pollard et al. (1990) also reported longspurs feeding on seeds of plant species growing on gravel pads, notably *Draba* spp., *Braya purpurascens*, and *Cochlearia officinalis*.

Arctic tundra is composed of patches of different habitat types (Holmes 1970, Pitelka et al. 1974). Bird populations, including longspurs, are widely dispersed over these patches, which provide them with their normal food and cover requirements. In this context, the gravel pads in this study can be considered to be patches of disturbed habitat surrounded by a mosaic of tundra habitat patches.

According to optimal foraging theory (Rosenzweig 1985), natural selection should favor a forager which behaves "optimally" by making dietary or patch choices that lead to the highest rate of energy intake (Emlen 1966, MacArthur and Pianka 1966, Pyke 1984). Some abandoned gravel pads may provide longspurs with habitat patches which are optimal for feeding, at least after the breeding season when seeds become more important in longspur diet. Seastedt and MacLean (1979), who studied longspurs on breeding territories at Barrow, believed that food density, rather than total quantity of food, was more important to the birds. Thus, longspurs may be attracted to those abandoned gravel pads where concentrations of seed-producing forbs enable them to obtain food at the least cost. Preferred forage also may be more visible on gravel than on tundra, and thus more accessible.

Conclusions

Data from the post-breeding observational study have increased our understanding of how and why birds use abandoned gravel fill. Some bird species (especially Lapland Longspur) are attracted to abandoned gravel pads during the post-breeding season. At this time, these birds are often concentrated at abandoned gravel sites in higher densities than on nearby undisturbed tundra habitats.

The highest levels of bird use occurred at two sites which were the objects of experimental rehabilitation. Most of the birds attracted to these two sites were Lapland Longspurs and Snow Buntings. This high level of use is probably related to the vegetation found there. Plots with natural plant colonization by native forb species had higher levels of use than adjacent plots with seeded cultivars. The use of fertilizers probably enhanced plant colonization and may prove beneficial in the rehabilitation of abandoned gravel sites. Levels of use on seeded plots may have been artificially high because of their proximity to plots with natural plant colonization which had higher levels of use. Levels of use at sites not undergoing experimental rehabilitation were low.

The most frequently observed bird behavior on most plots was feeding. On gravel plots, birds were probably feeding on the seeds of colonizing forb species, many of which are prolific seed producers.

Levels and types of bird use of abandoned gravel pads were also related to the presence or absence of standing water on pads. Where impounded water such as reserve pits or thermokarst pools was present at gravel sites, shorebirds (and sometimes waterfowl) were attracted, and their behavior primarily was feeding. Consequently, microhabitats with water had relatively high levels of use and higher species richness and species diversity than did dry gravel microhabitats.

These findings will be useful to managers beginning to consider wildlife-oriented goals for abandoned-site rehabilitation. Vegetating abandoned gravel pads (or portions of them) with native forb species would probably encourage high levels of use by bird species such as Lapland Longspur and Snow Bunting that use seeds as part of their diet. Creating ponds and pools with mud shorelines on or near abandoned gravel pads would probably increase the utility of rehabilitated sites to shorebirds and waterfowl and would result in greater species diversity than would occur in the absence of water.

PART THREE: MICROHABITAT VARIABLES INFLUENCING NEST-SITE SELECTION

Introduction

In the future, oil companies and regulatory agencies may attempt to rehabilitate abandoned gravel sites by restoring their value as nesting habitat for birds. Part 1 of this study indicated that this may be possible. Although birds generally did not nest on abandoned gravel pads, they did consistently nest on the pad at one site, Ugnu 1. In order to restore abandoned sites, it is microrelief on the tundra (random plots) and on plots centered on bird nests is relatively high, the manipulation of the pad surface should mimic this variation. Some areas could remain relatively flat or with little slope, while other areas could be manipulated to create greater microrelief. If the management plan favors Lapland Longspurs, the microrelief of the pad surface could be made even higher.

Manipulation of the pad surface could be accomplished by forming a series of ridges and troughs interspersed with flat, slightly sloping areas. Troy (1991a) also believed that heterogeneity of terrain should be a consideration when rehabilitating disturbed sites. The height of ridges should vary such that trough depths reach approximately 40 cm for the highest ridges. This is slightly higher than the mean amount of microrelief plus one standard deviation for plots centered on nests of Lapland Longspurs. If longspurs were not a species of concern, the height of the ridges could probably be reduced.

Nest Height

At the 0.05 confidence level, nest height (mean distance from the high point in the plot to the nest cup) was significantly different between species for all combinations tested (Table 15). Mean nest height of Lapland Longspurs was lower than that of any other species (Fig. 9). The lower nest height of Lapland Longspur seemed particularly significant, especially from a biological standpoint, because longspurs often place their nests in concealed areas on the sides of ridges or polygon rims. The shorebird species generally nest in open areas, often on the tops of ridges or polygon rims.

Variability of Relief (Roughness)

At the 0.05 confidence level, variability of microrelief (or plot roughness) was significantly different between random plots and nest plots of all species except Pectoral Sandpiper (Table 15). At the 0.01 confidence level, only nest plots of Lapland Longspur and Semipalmated Sandpiper differ from random plots. Because of the high degree of overlap in plot roughness (Fig. 10), these differences may be biologically meaningful only for Lapland Longspur. The greater roughness of nest plots of longspurs is consistent with the higher amount of microrelief (Fig. 9) for plots centered on longspur nests. The higher amount of relief results from the presence of more ridges, troughs, and polygon rims. Additionally, longspur nests are of-

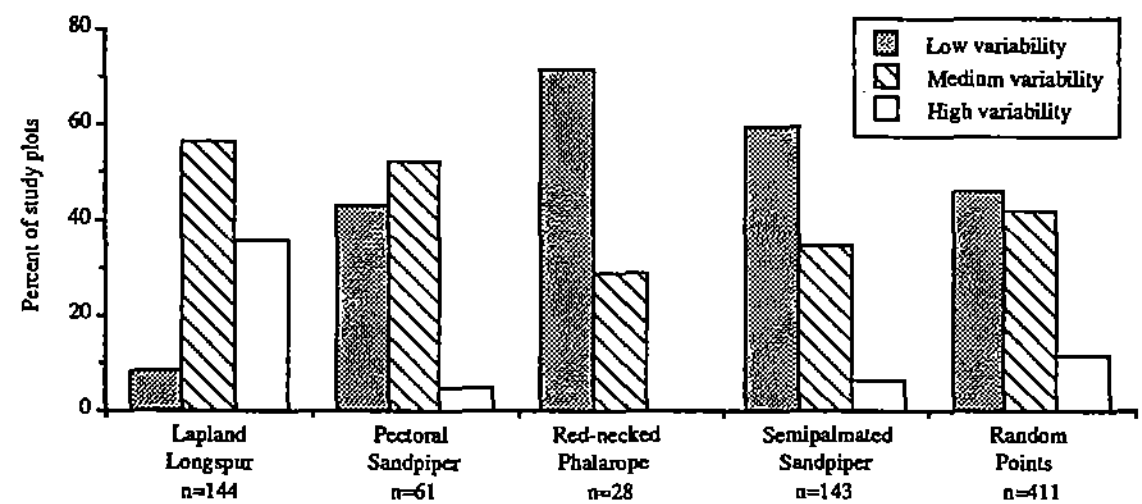


Figure 10. Percent of study plots with low, medium, and high variability of microrelief for the four most common nesting species and for random plots in the Prudhoe Bay oil field, Prudhoe Bay, Alaska, 1991. (n is the total number of nests or random points.)

necessary to know what habitat characteristics influence birds to nest at particular sites.

A common method for determining habitat preference is to estimate the numbers of birds occupying various habitat types and to correlate those numbers with the average characteristics of the habitats. This has been done for bird species in a number of locations on the Arctic Coastal Plain (Holmes 1966, Myers and Pitelka 1980, Martin and Moitoret 1981, Spindler and Miller 1983, Troy 1985). Another method, which may better enable managers to determine specific habitat characteristics preferred by bird species, is to measure habitat characteristics on small plots centered on individual birds. James (1971) and Whitmore (1975) used plots centered on the perches of singing males and compared habitat characteristics among species. Larson and Bock (1986) compared traditional sampling methods with bird-centered habitat analysis, and found that bird-centered analysis was a more powerful tool for examining habitat relationships than traditional methods.

In this study, microhabitat characteristics of plots centered on nests of the four most common bird species (Lapland Longspur, Semipalmated and Pectoral sandpipers, and Red-necked Phalarope) were measured and compared with the characteristics of plots centered on random points. The microhabitat variables which were measured were percent graminoid cover, percent shrub/forb cover, presence or absence of water, and overall amount and variability of microrelief. It was felt that these might be features which could be influenced or controlled when rehabilitating abandoned gravel sites.

The size of plots established at nest sites and random points was 2 m x 2 m square. This small plot size was used to determine the habitat characteristics in the immediate area of the nest. A disadvantage of the small plot size is that, compared to larger plots, it may reduce the means of measurements of habitat characteristics, thus masking differences in habitat preferences among species. This problem may be particularly relevant for mean microtopographic relief, but is probably less critical in measurements of plant cover. However, Larson and Bock (1986) found that small plots (5 m radii) were at least as powerful in determining habitat preferences as larger ones (11 and 25 m radii) in scrubsteppe communities. The small plot size is advantageous because of the short time required for establishing plots and recording data, thus allowing increased sample size.

Objective

- To describe microhabitat features associated with nest sites selected by the four most common bird species by testing the null hypothesis that there is no difference between measurements of habitat variables associated with bird nests and random points.

Methods

Plot Selection and Setup

Virtually all nests from the 1991 nesting study (see Part 1) and nests from the 1990 nesting study which could be relocated were used as experimental units for this study. In addition, a few nests which were located just outside the boundaries of the study plots of the nesting study were also used. Data were collected from late July to mid-August, 1991, after completion of the nesting season to insure that birds would not be disturbed at nest sites.

Two-meter square plots (4 m^2), centered on each nest, were established using 1/4-inch nylon rope to outline the plot. A 12-inch steel spike, which could be pushed into the tundra, was tied to each corner of the rope forming the 2-m square. A piece of rope which formed one diagonal of the square was marked in the center. The center point of the diagonal was placed directly over the nest, the diagonal was stretched, and the two spikes attached to the diagonal were pushed into the tundra. The corners opposite the diagonal automatically fell into place when the rope forming the plot perimeter was stretched.

One random point was established in each grid cell of each undisturbed plot from the nesting study in Part 1. Points which fell in a lake or pond were discarded. Random points were selected only from undisturbed plots; thus, measurements of variables centered on these points represent characteristics of undisturbed tundra habitat.

The points were randomized within each cell using a computerized random-number generator which yielded the location by giving the number of meters in two directions from one corner of the grid cell. The location of the random point was then determined by pacing off the distance in one direction along one of the gridlines, then turning 90 degrees and pacing off the second distance. This is, in effect, a stratified random sampling system. Two-meter square plots were established around the random points in the same manner as described above.

Wildlife Refuge (ANWR), Martin (1983) found higher densities of Pectoral Sandpiper nests on lowland and mesic plots which had higher moisture content than an upland plot. Troy (1985) reported higher nest densities in wet tundra habitats than in moist ones in the Prudhoe Bay oil field.

Graminoid cover near nests of Semipalmated Sandpiper was lower than that of other species, and is the only species for which graminoid cover did not differ between nest plots and random plots (P=0.471 in 1990). This low graminoid cover is consistent with the findings of Martin (1983), who classified this species as an upland breeder. Upland habitats generally have a wider variety of dry sites, and graminoid vegetation is more restricted.

Vegetating gravel pads with grass and sedge species would probably benefit the majority of tundra-nesting bird species. Greater graminoid cover would most benefit Red-necked Phalarope and Pectoral Sandpiper, and Lapland Longspur to a lesser extent. Semipalmated Sandpiper seemed to select areas with less graminoid cover.

Shrub/Forb Cover

Shrub/forb cover was lower than graminoid cover on nest plots of all four species studied and on random plots (Fig. 9). This is consistent with the general landscape of the tundra of the Arctic Coastal Plain, which is dominated by graminoid vegetation. Shrub/forb cover was significantly higher on nest plots of Semipalmated Sandpiper than random plots for both years (P<0.001). Nests of Semipalmated Sandpipers often were surrounded by low, prostrate willows (*Salix* spp). It is possible that Semipalmated Sandpipers are not selecting nest sites with higher shrub and forb cover as much as they are selecting nest sites in drier habitats where this vegetation occurs.

Shrub/forb cover was significantly lower on nest plots of Red-necked Phalaropes than on random plots for both years (P<0.001). Phalaropes are lowland breeders, where the higher moisture regime is less conducive to shrub and forb vegetation.

At the 0.05 confidence level, mean shrub/forb cover on nest plots of Lapland Longspur was significantly higher than that of random plots (Table 15), but this difference may not have been biologically meaningful (Fig. 9). There was no significant difference in mean shrub/forb cover between plots centered on Pectoral Sandpiper nests and random plots.

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

Microrelief

The tundra of the Arctic Coastal Plain is generally flat, and changes in relief are often subtle. Microrelief appears to be an important element influencing tundra bird nesting (Troy 1985, 1991a). The average microrelief of plots centered on random points in this study was only 17.2 cm (Table 14). Microrelief values of tundra plots in ANWR (Martin 1983) were generally higher than those of random plots in the current study, but that may be due in part to the larger plot size.

Mean amount of microrelief of plots centered on the nests of Pectoral and Semipalmated sandpipers and Red-necked Phalarope did not differ from that of plots centered on random points (Table 15), indicating that there may not have been any particular selection of nest sites based on microrelief for these species. For these species, variation in selection for microrelief demonstrated that many individuals selected flat areas with little microrelief, while others selected plots with higher than average microrelief (Fig. 9). For the species studied, only nest plots of Lapland Longspur had significantly higher microrelief than random plots (P<0.001).

Although some gravel pads, particularly older pads with thinner gravel, have some thermokarsting which has produced troughs and polygons, the surface of most gravel pads is flat with little or no relief. The results of this study indicate that, to restore or enhance nesting habitat on these gravel sites for three of the four most common species (Pectoral and Semipalmated sandpipers, and Red-necked Phalarope), the surface of the pads should have as much microrelief as occurs randomly on the tundra. Since the variation of

Data Collection

Graminoid and Shrub/Forb Cover. Graminoid (grass and sedge) and shrub/forb cover were measured using the Daubenmire cover class system (Daubenmire 1959). The cover classes (Table 12) were modified to match those used by Pete Scorup (University of Alaska, Agricultural and Forestry Experimental Station, pers. comm.) to study the vegetation of caribou range on the Seward Peninsula, Alaska. Four estimates for both graminoid and shrub/forb cover were made for each 2-m square plot. Two Daubenmire boxes, 20 cm x 50 cm, were simultaneously tossed into the plot on one side of the diagonal. After cover classes were recorded, boxes were tossed into the plot on the other side of the diagonal, and recording of cover classes was completed.

Water. Using the modified Daubenmire cover class system, water cover also was recorded for each plot. Because of the high percentage of zero values, water was designated either as present on a plot if it occurred on any of the cover class records, or absent if it did not.

Amount of Microrelief. The vertical distance from the high point to the low point was measured to determine the amount of relief for each plot. Initially, a Wilde laser level was used, but use of this instrument was discontinued after a few days when it was found that the range of the laser beam emitted by the unit diminished in heavy fog. Ultimately, a 6-foot level was used to measure differences in relief by placing one end on the high point and measuring down to the low point with a tape measure to the nearest 0.5 cm. The location of the high and low points could usually be determined visually, but sometimes several measurements were taken.

Table 12. Range of cover and class midpoint for modified Daubenmire cover classes used to estimate percent graminoid and shrub/forb cover on bird-nest centered and random plots, Prudhoe Bay, Alaska, 1991.

Cover Class	Range of Cover (Percent)	Class Midpoint (Percent)
1	0 to 6.3	3.1
2	6.3 to 12.5	9.4
3	12.5 to 25.0	18.8
4	25.0 to 50.0	37.5
5	50.0 to 75.0	62.5
6	75.0 to 93.8	84.4
7	93.8 to 100.0	96.9

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

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

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

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

Data Analysis

The means of the habitat variables from nest and random plots were combined using a principal components analysis to characterize nesting habitat. Two separate principal components analyses of the data using SYSTAT® Version 5.1 for DOS were used to characterize the nesting habitat of each species. Variables included in the initial analysis were relief, percent graminoid and shrub/forb cover, and presence or absence of water. Because the measure of plot roughness

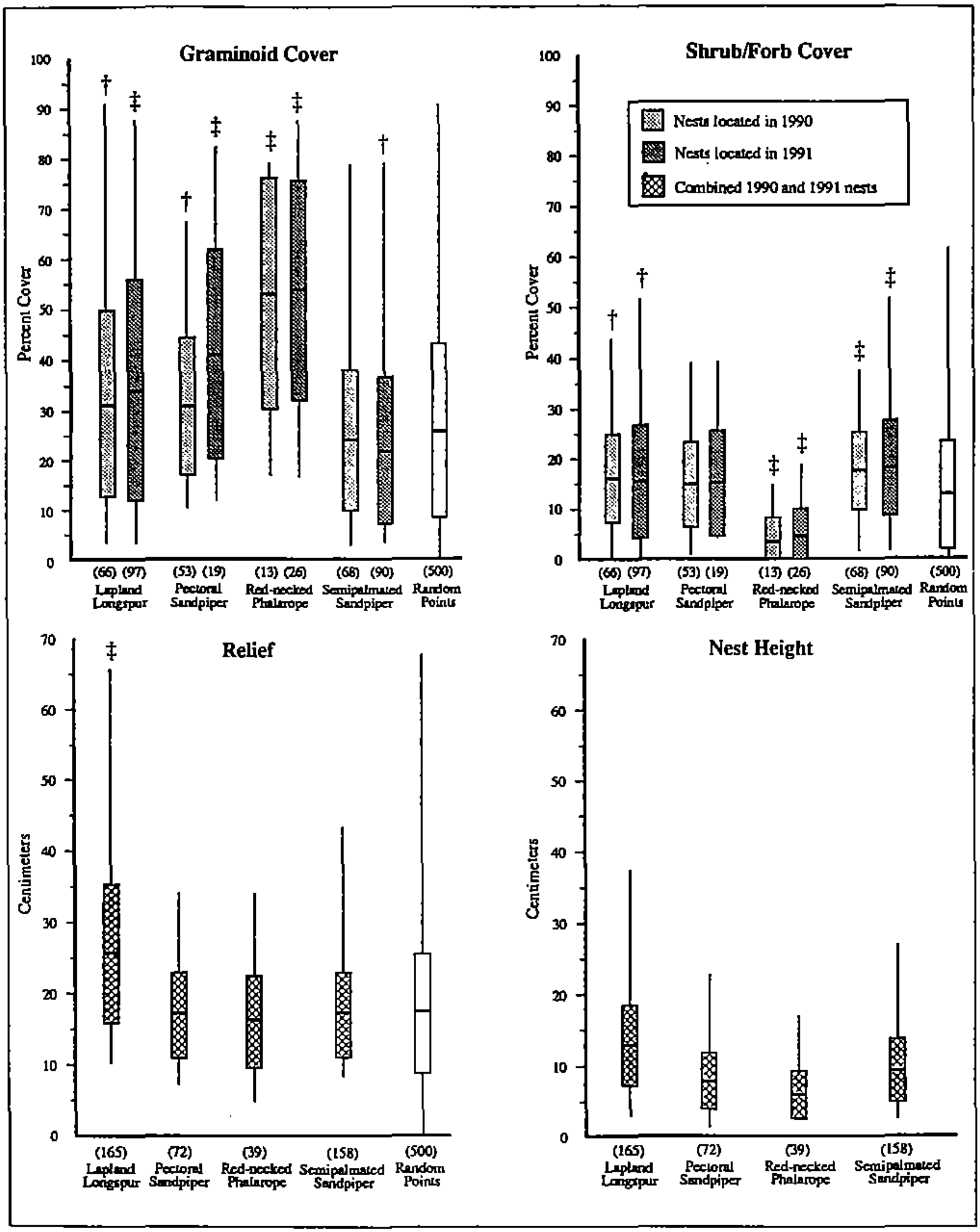


Figure 9. Values of variables selected to characterize plots centered on nests of bird species and on random points. The horizontal line is the mean, the vertical line is the range, and the rectangle encloses ±1 standard deviation. Significant differences between the means of bird-centered plots and random plots at the 0.05 confidence level are indicated by †, and at the 0.01 confidence level by ‡.

was not developed until the study was underway, this variable was not present in the data set for all nests and random plots. A second analysis which incorporated roughness was performed on data which did include this variable. Two data sets were excluded from the analyses: nest height was not included because this variable was not present for plots centered on random points, and orientation of nests was not included because these data pertained only to Lapland Longspurs.

In addition, the individual microhabitat variables associated with bird nests were compared for each year between each species and random plots. Table 13 lists the type of statistical test used for each variable. The results of statistical tests are discussed at the 0.05 and 0.01 confidence levels.

Results and Discussion

The tundra of the Arctic Coastal Plain exists as a mosaic of habitats ranging from upland areas, which usually have a relatively high degree of microtopographic relief and a wide availability of dry sites, to poorly drained lowland areas, which are usually associated with less microtopographic relief and a higher moisture regime (Holmes 1966, Myers and Pitelka 1980). Tundra bird species show preferences for certain habitats when choosing nest sites. Of the common species in this study, Martin (1983) classified Lapland Longspur and Semipalmated Sandpiper as upland breeders, while Pectoral Sandpiper and Red-necked Phalarope were classified as lowland breeders.

Troy (1985) reported that most species select drier habitats for nesting than for other activities and stated that Pectoral Sandpiper was extreme in this regard. He also reported that Red-necked Phalaropes were associated with ponds with emergent vegetation at all times of the year. If dry sites do represent preferred nesting habitat for most species, then abandoned gravel sites may be prime candidates for manipulation in an effort to restore or enhance nesting habitat.

The initial principal components analysis (Fig. 7) extracted two factors which accounted for approximately 42 (factor 1) and 25 (factor 2) percent of the variance. The first factor described a positive association for water and graminoid cover and was negatively associated with shrub/forb cover. The second factor described a positive association for relief. Species were consistent in their loadings between years. Red-necked Phalarope was strongly positive for factor 1, indicating a strong preference for water and graminoid cover, and a negative association for shrub/forb cover. Strong preferences for particular habitat characteristics were not shown for other species or random points, although longspurs, and to a lesser extent Red-necked Phalaropes, were moderately associated with high relief.

The second principal components analysis (Fig. 8) also extracted two factors, which accounted for approximately 36 (factor 1) and 24 (factor 2) percent of the variance. The first factor described a positive association for roughness and relief and a negative association for water. The second factor described a positive association for graminoid cover and a negative association for shrub/forb cover. Lapland Longspurs were positive for factor 1, indicating a preference for high relief and roughness. Red-necked Phalaropes were strongly negative for factor 1, indicating a positive association with water and a negative association with roughness and relief. Phalaropes were also strongly positive for factor 2, indicating a positive association for graminoid cover and a negative association for

Table 13. Statistical tests used to compare microhabitat variables associated with plots centered on bird nest with those of plots centered on random points, Prudhoe Bay, Alaska.

Variable	Statistical Test
Percent Graminoid Cover	two-sample t test
Percent Shrub/forb Cover	two-sample t test
Amount of Relief	two-sample t test
Nest Height	two-sample t test
Roughness	chi-square goodness of fit
Nest Orientation (longspurs)	chi-square goodness of fit
Water (presence/absence)	chi-square goodness of fit

Table 15. Type of test and test scores of statistical analyses for comparisons of means of individual habitat variables. In most cases, comparisons are between plots centered on nests of bird species in 1990 and 1991 and random plots. Abbreviations are: LALO=Lapland Longspur, PESA=Pectoral Sandpiper, RNPH=Red-necked Phalarope, SESA=Semipalmated Sandpiper, RAND=Random Plots.

Variable	Comparison	Test Type	Test Score		
Graminoid Cover	LALO(90) vs. RAND	two-sample t test	t=2.46,	P=0.014	
	LALO(91) vs. RAND	two-sample t test	t=4.31,	P<0.001	
	PESA(90) vs. RAND	two-sample t test	t=2.06,	P=0.040	
	PESA(91) vs. RAND	two-sample t test	t=4.16,	P<0.001	
	RNPH(90) vs. RAND	two-sample t test	t=4.91,	P<0.001	
	RNPH(91) vs. RAND	two-sample t test	t=7.93,	P<0.001	
	SESA(90) vs. RAND	two-sample t test	t=0.72,	P=0.471	
	SESA(91) vs. RAND	two-sample t test	t=2.02,	p=0.044	
Shrub/forb Cover	LALO(90) vs. RAND	two-sample t test	t=2.28,	P=0.023	
	LALO(91) vs. RAND	two-sample t test	t=2.25,	P=0.025	
	PESA(90) vs. RAND	two-sample t test	t=1.23,	P=0.220	
	PESA(91) vs. RAND	two-sample t test	t=0.71,	P=0.476	
	RNPH(90) vs. RAND	two-sample t test	t=3.01,	P=0.003	
	RNPH(91) vs. RAND	two-sample t test	t=3.91,	P<0.001	
	SESA(90) vs. RAND	two-sample t test	t=3.58,	P<0.001	
	SESA(91) vs. RAND	two-sample t test	t=4.31,	P<0.001	
Relief	LALO vs. RAND	two-sample t test	t=0.00,	P<0.001	
	PESA vs. RAND	two-sample t test	t=0.49,	P=0.627	
	RNPH vs. RAND	two-sample t test	t=0.89,	P=0.376	
	SESA vs. RAND	two-sample t test	t=0.91,	P=0.363	
Nest Height	PESA vs. SESA	two-sample t test	t=2.31,	P=0.023	
	LALO vs. SESA	two-sample t test	t=6.67,	P<0.001	
	RNPH vs. SESA	two-sample t test	t=4.55,	P<0.001	
	PESA vs. RNPH	two-sample t test	t=2.70,	P=0.008	
Roughness	LALO vs. RAND	chi-square	χ^2=121.04,	d.f.=2,	P<0.001
	PESA vs. RAND	chi-square	χ^2=4.07,	d.f.=2,	0.10<P<0.25
	RNPH vs. RAND	chi-square	χ^2=8.34	d.f.=2,	0.01<P<0.025
	SESA vs. RAND	chi-square	χ^2=11.03	d.f.=2,	0.001<P<0.005
Water Presence/ absence	LALO vs. RAND	chi-square	χ^2=0.72	d.f.=1,	0.25<P<0.50
	PESA vs. RAND	chi-square	χ^2=0.27	d.f.=1,	0.50<P<0.75
	RNPH vs. RAND	chi-square	χ^2=37.58	d.f.=1,	P<0.001
	SESA vs. RAND	chi-square	χ^2=4.66	d.f.=1,	0.025<P<0.05
Nest Orientation	Compass direction (observed vs. expected)	chi-square	χ^2=114.75	d.f.=7,	P<0.001

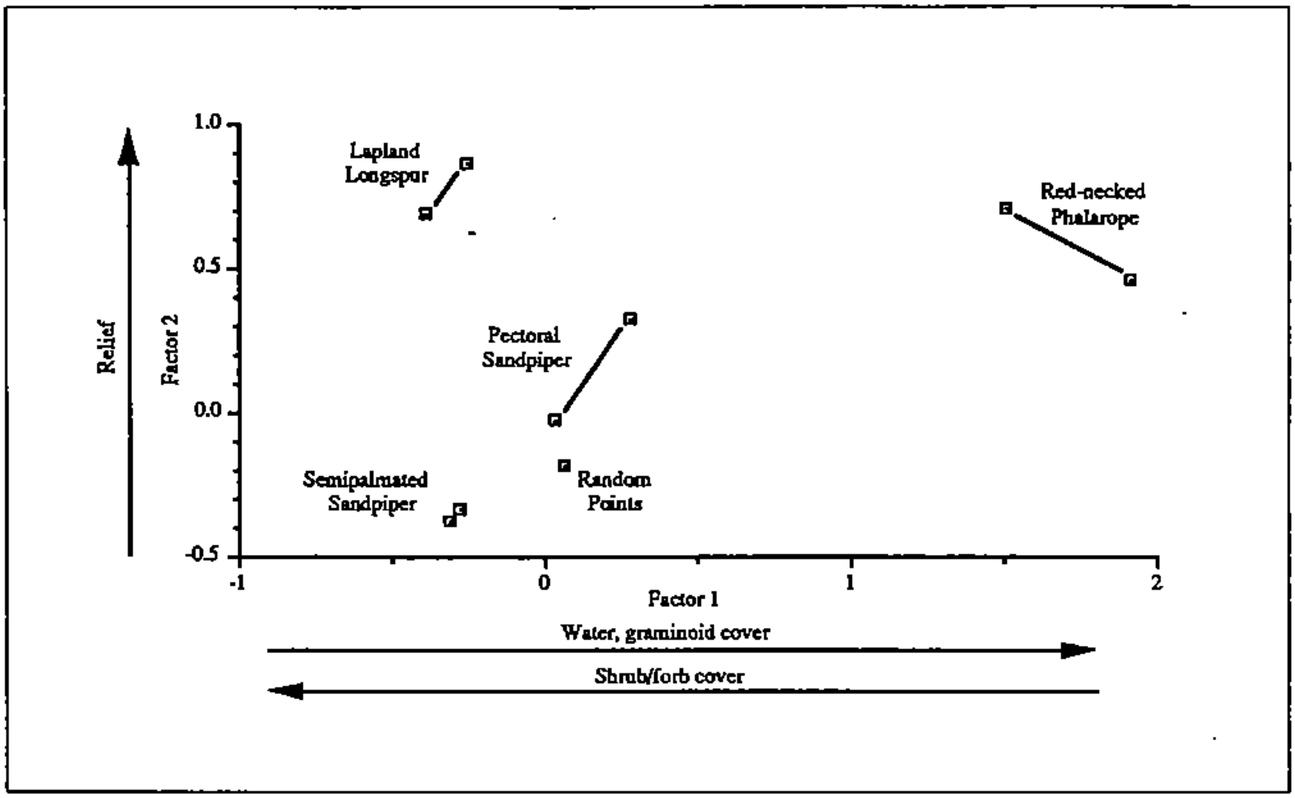


Figure 7. Principal components analysis of microhabitat variables (not including roughness) of plots centered on nests of bird species and random points, Prudhoe Bay, Alaska, 1991.

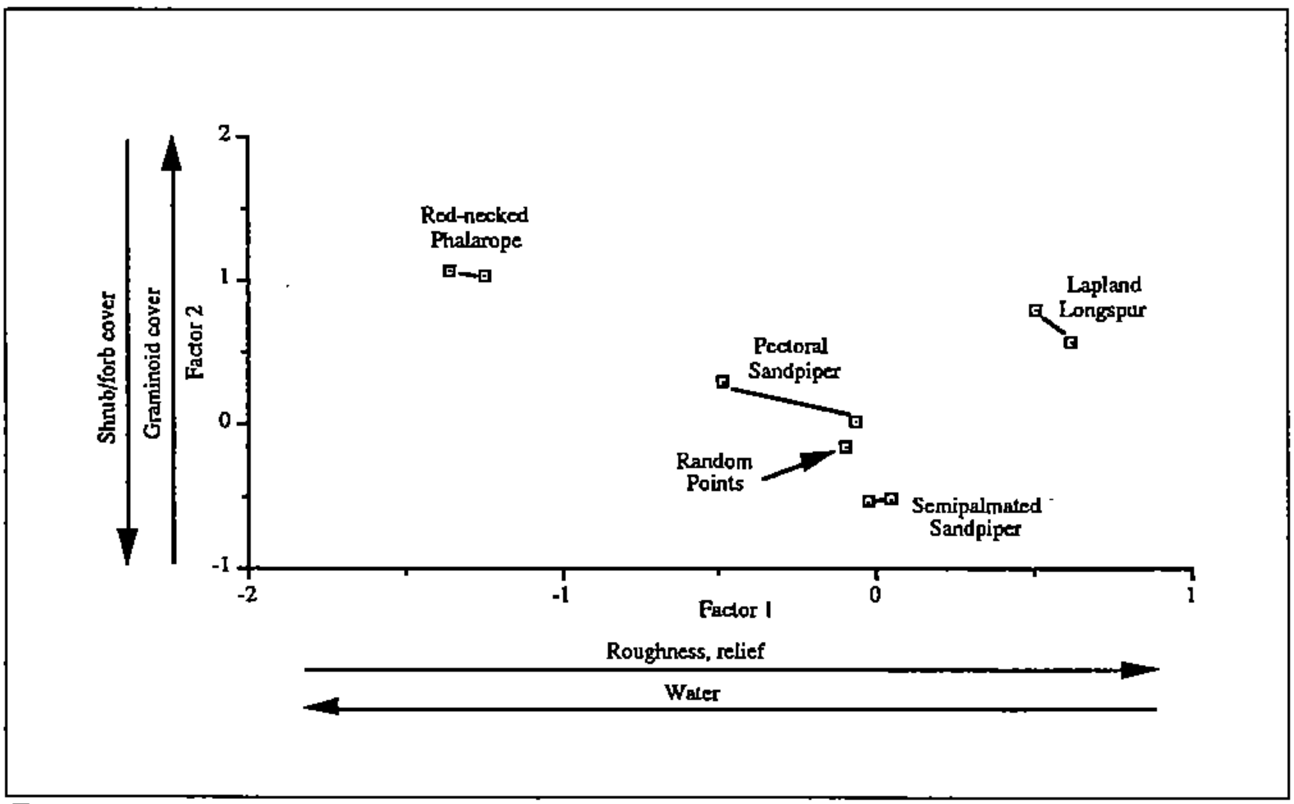


Figure 8. Principal components analysis of microhabitat variables (including roughness) of plots centered on nests of bird species and random points, Prudhoe Bay, Alaska, 1991.

shrub/forb cover.

The principal components analyses were consistent with analyses of the individual variables. The data (Table 14) suggest that several habitat variables are important in the selection of nest sites by some species. These variables should be considered if abandoned gravel sites are to be restored or enhanced as nesting habitat.

Graminoid Cover

Mean percent graminoid cover was significantly higher on nest-centered plots than on random plots for all species except Semipalmated Sandpipers in 1990 (Table 15). However, some of these differences may not be biologically meaningful due to the large standard deviations and ranges (Fig. 9). At the 0.01 confidence level, mean percent graminoid cover was significantly higher on nest plots of Red-necked Phalarope in both years and on plots centered on Lapland Longspur and Pectoral Sandpiper nests in 1991 ($P<0.001$) than on random plots. Red-necked Phalaropes selected nest sites with a high degree of graminoid cover; this cover value (53.9 percent) was approximately twice that of random plots (25.4 percent) (Table 14).

Pectoral Sandpipers, like Red-necked Phalaropes, also seemed to select nest sites with relatively high graminoid cover, although mean values of percent cover were slightly lower. This tendency may be related to the moisture regime, because nest sites were often located on flat, wet areas with poor drainage where graminoid cover was well developed. Although the general area may be wet, the nest site itself was frequently located on a small, well-drained mound or ridge. Pitelka (1959) reported that nest sites of Pectoral Sandpipers at Barrow occurred in all variants of tundra vegetation, as long as there was a continuous cover of grass or sedge. On study plots in the Arctic National

Table 14. Means and standard deviations (SD) of variables measured on 2-m square plots centered on nests of the four most common nesting species and on random points in the Prudhoe Bay oil field, Prudhoe Bay, Alaska. Plots centered on random points contain no nests, and measurement of nest elevation is not applicable. All data were collected in 1991 and are presented for nests initiated both in 1990 and in 1991, and also are pooled for both years.

Species	Number of plots	Microrelief (cm)		Nest elevation (cm)		Percent graminoid cover		Percent shrub/forb cover	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD
Lapland Longspur*	67	25.0	9.7	14.6	4.9	31.1	18.6	16.1	8.8
Lapland Longspur**	98	26.1	9.9	12.0	5.8	34.2	22.1	15.6	11.3
Lapland Longspur***	165	25.6	9.7	13.0	5.6	32.9	20.7	15.8	10.3
Pectoral Sandpiper*	53	17.0	5.7	8.4	4.2	30.6	13.6	14.8	8.5
Pectoral Sandpiper**	19	16.1	5.0	6.9	2.8	42.6	21.4	14.7	10.3
Pectoral Sandpiper***	72	16.8	5.5	8.0	3.9	33.7	16.7	14.8	8.9
Red-necked Phalarope*	13	15.3	6.9	5.7	3.0	52.8	23.0	3.3	5.0
Red-necked Phalarope**	27	16.4	6.3	6.2	3.5	54.4	21.6	4.5	5.4
Red-necked Phalarope***	40	16.1	6.4	6.0	3.3	53.9	21.8	4.1	5.2
Semipalmated Sandpiper*	68	16.2	6.5	9.4	3.8	24.0	14.0	17.7	7.7
Semipalmated Sandpiper**	91	16.8	6.4	9.3	4.7	21.5	14.7	18.1	9.3
Semipalmated Sandpiper***	159	16.5	6.4	9.3	4.3	22.6	14.4	17.9	8.6
Random Points	500	17.2	8.4	N/A	N/A	25.4	17.5	12.9	10.8

* Nests initiated during 1990 season.

** Nests initiated during 1991 season.

*** Combined 1990 and 1991.