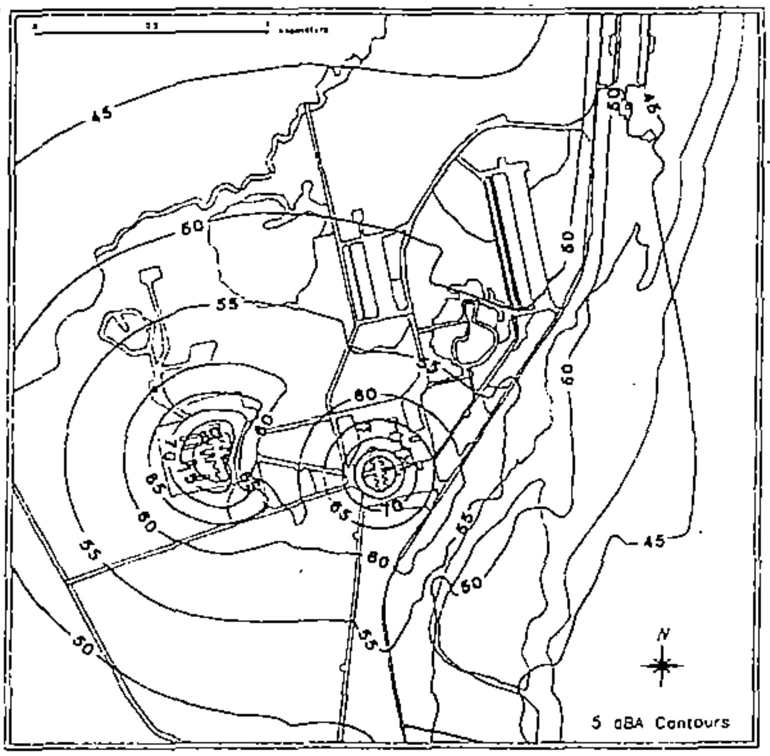
1990 ANNUAL REPORT

GHX-1 WATERBIRD AND NOISE MONITORING PROGRAM



PREPARED BY:
BETTY A. ANDERSON
STEPHEN M. MURPHY
M. TORRE JORGENSON

ALASKA BIOLOGICAL RESEARCH, INC.
P.O. BOX 81934
FAIRBANKS, ALASKA 99708

AND

JON A. CIARLETTA
B. ANDREW KUGLER

BBN SYSTEMS AND TECHNOLOGIES CORP.
21120 VANOWEN STREET
CANOGA PARK, CALIFORNIA 91303

PREPARED FOR:
ARCO ALASKA, INC.
P.O. BOX 100360
ANCHORAGE, ALASKA 99510

GHX-1 WATERBIRD AND NOISE MONITORING PROGRAM

1990 ANNUAL REPORT

Prepared for:

ARCO Alaska, Inc.
P. O. Box 100360
Anchorage, Alaska 99510

Prepared by:

Betty A. Anderson
Stephen M. Murphy
M. Torre Jorgenson

Alaska Biological Research, Inc.
P. O. Box 81934
Fairbanks, Alaska 99708

Jon A. Ciarletta
and
B. Andrew Kugler

BBN Systems and Technologies Corporation
21120 Vanowen Street
Canoga Park, California 91303

May 1991

Printed on Recycled Paper

EXECUTIVE SUMMARY

- The goal of the Gas Handling Expansion (GHX-1) monitoring program is to evaluate the effects of project-related noise on waterbird populations, particularly nesting Canada Geese and brood-rearing Brant that annually use the area near the GHX-1 site. The monitoring program was initiated in 1989 to acquire baseline information before the construction of the GHX-1 facilities. The program continued in 1990 during the construction period and will continue through the first year of operation (1991). The specific objectives of the 1990 field program were to:

  1) record the seasonal abundance, distribution, and habitat use of waterbirds during May-September in the 8.2-km^2 study area surrounding the GHX-1 site;

  2) monitor the existing noise environment in the GHX-1 area by measuring the sound pressure levels (SPL) of steady-state sources of noise (e.g., facilities) and varying or intermittent sources (e.g., flaring); and

  3) record weather information and measure noise propagation characteristics in the area to evaluate the local factors affecting noise attenuation.

- The GHX-1 study area is located along the southwestern shore of Prudhoe Bay north of the outlet of the Putuligayuk River and is bounded on the west by the abandoned peat road to the Prudhoe State No. 1 Discovery Well and on the north by an unnamed stream. The GHX-1 study area encompasses two major oilfield facilities: the Central Compressor Plant (CCP) and the Central Gas Facility (CGF). Construction of facilities for the first phase of the Gas Handling Expansion commenced during 1990 on the existing gravel pads at CCP and CGF.

OILFIELD CONDITIONS IN THE GHX-1 STUDY AREA IN 1990

- Predator populations were monitored in 1990 during road and foot surveys to assess their potential impact on nesting waterbirds. A mean of 14.1 Glaucous Gulls was seen during 27 surveys, with a maximum of 102 gulls recorded on 1 September. One pair of Glaucous Gulls nested in the study area and successfully reared two chicks to fledging. Arctic foxes were seen on approximately 25% of the 27 surveys and jaegers (Pomarine and Parasitic) and Common Ravens were seen sporadically throughout the field season.

- The influence of human disturbance was evaluated by recording vehicular traffic on West Dock Road and on the northern access road to CGF/CCP. Mean traffic rates on West Dock Road were 66.3 vehicles/h south of CCP and 21.8 vehicles/h

north of CCP. The northern access road from West Dock to CGF/CCP supported only 3.4 vehicles/h.

- Phenological conditions in the study area can affect both the onset of breeding and the level of nesting effort (i.e., number of nests established) by waterbirds. Low snow cover and rapid spring melt-off in 1990 allowed the early onset of nesting by both geese and loons in the study area. Canada Geese established nests sites approximately two weeks earlier in 1990 than in 1989, whereas Pacific Loons began breeding three weeks earlier than in 1989.

ABUNDANCE, DISTRIBUTION, AND HABITAT USE OF WATERBIRDS IN THE GHX-1 STUDY AREA

- The abundance and distribution of waterbirds in the GHX-1 study area were assessed during 25 road surveys and two foot surveys (nest searches). Road surveys were conducted during pre-nesting, nesting, brood-rearing, and fall staging. Dates for these seasonal breakdowns differed among species. Flocks of Canada and White-fronted geese were present in the study area during the first road survey on 27 May. Tundra Swans and Brant were seen first on 2 June. Several species of ducks also were present during the first road survey on 27 May, but the first loons (Pacific Loons) were not seen until 5 June.

- White-fronted and Canada geese were the most abundant geese during pre-nesting, whereas Brant occurred in moderate numbers; no Snow Geese were seen in 1990. Low numbers of Tundra Swans were seen during pre-nesting. Seven species of ducks were present during pre-nesting in the GHX-1 study area, but only four species were common (Northern Pintail, Oldsquaw, and King and Spectacled eiders).

- Eleven Canada Goose nests were located in the GHX-1 study area and ten nests (90.9%) were successful. One White-fronted Goose nest was located in the study area in 1990; this nest also was successful. No duck or swan nests were found in the GHX-1 study area. A pair of Tundra Swans nested approximately 1 km north of the study area and hatched four young. Eight Pacific Loon nests and one Red-throated Loon nest were found during nest searches. Five (62.5%) of the Pacific Loon nests were successful and the Red-throated Loon nest also was successful. The presence of a second brood of Red-throated Loons in the study area in early July was interpreted as a second nest that was missed during nest searches, yielding a total of two nests for Red-throated Loons.

- Brant were the most common brood-rearing geese in the GHX-1 study area and occupied the island at the mouth of the Putuligayuk River from approximately 29 June until 20 August. Brood-rearing flocks of Canada Geese were seen commonly along the northern edge of the study area and 1-2 broods of White-fronted Geese were seen sporadically. A pair of Tundra Swans with four young was observed regularly during brood-rearing. Most ducks seen during the brood-rearing season were adults without young; the only broods seen were of King and Spectacled eiders. Broods of Pacific and Red-throated loons occurred regularly in the study area during brood-rearing.

- More White-fronted Geese were present during fall staging than Canada Geese. By early September, few geese were using the study area; no Brant were seen after 20 August. The brood of Tundra Swans present during brood-rearing moved north out of the study area by mid-August, but a pair of adult swans with two young was seen during September. Northern Pintails were the only ducks recorded in any numbers during fall staging. Due to the early onset of breeding in 1990, loons were fall-staging by late August when fledged young had mostly moved out of the study area.

- Habitat use varied both seasonally and among species in the GHX-1 study area. Seasonal habitat use was determined by calculating the mean density (birds/km^2) of a species in each habitat for each season. Canada Geese used aquatic habitats (Water with Emergents) and Coastal Wetland Complexes during all seasons, but also occurred in relatively high densities in meadow habitats and Basin Wetland Complexes. White-fronted Geese most often used Wet Meadows, Water with Emergents, and Basin Wetland Complexes. Brant occurred almost exclusively in Coastal Wetland Complexes during all seasons. Tundra Swans were seen most often in Water with Emergents and Basin Wetland Complexes. Habitats used by ducks were characterized by the presence of water (e.g., Water with Emergents, Impoundments, Open Water), but the seasonal patterns of use varied among the different species. Pacific and Red-throated loons primarily used aquatic habitats (e.g., Open Water, Water with Emergents, Impoundments) during all seasons.

COMPARISONS OF THE 1989 AND 1990 SEASONS AT GHX-1

- The major differences in waterbird abundance and distribution noted between 1989 and 1990 can be attributed to the changes in spring melt-off and snow cover between years. Heavy snow cover, rapid melt-off, and flooding characterized the 1989 season at the GHX-1 study area and retarded the onset of breeding by most species of waterbirds. Flooding also contributed to the loss of some Canada Goose nests in 1989. Conversely, in 1990, the low snow cover, early melt-off, and absence of flooding expedited breeding for most waterbird species and probably contributed to the larger number of nests and higher nest success for all species. Another factor contributing to the higher nest success in 1990 was the relatively low impact of predators on nesting waterbirds in that year.

- Slight annual changes in abundance and distribution were observed for many species of waterbirds in the GHX-1 study area. Numbers of brood-rearing

Canada Geese and Brant increased in 1990 compared to 1989. For Canada Geese this increase was due to the increase in nesting effort and higher nest success in the study area and in adjacent areas, whereas the >50% increase in brood-rearing Brant was attributable to region-wide increases in nesting success.

- Nine species of ducks were seen in the GHX-1 study area in 1990 compared to only five species in 1989. The four new species seen were Green-winged Teal, Mallard, Northern Shoveler, and Eurasian Wigeon. These new species were neither abundant nor regularly observed, however.

- Habitat-use patterns were more similar than different between years for most waterbird species in the GHX-1 study area. Analysis of year-to-year variability in habitat use must be coupled with the analysis of differences in noise levels to assess whether changes in use were due to normal variation or to disturbance-related shifts in distribution; this analysis will be completed for the 1991 final report.

NOISE SURVEY AND MODELING OF THE GHX-1 FACILITY

- A noise survey was conducted from 9-14 August 1990 to characterize noise emanating from the CCP flare, collect normal noise data from the CCP and CGF facilities to confirm the basic acoustic model developed in 1989, and establish a sampling protocol to evaluate the effects of wind on noise propagation in the GHX-1 study area. In addition, a major goal of the 1990 noise program was to develop computer model outputs of noise contours around the CCP/CGF facilites under varying wind conditions.

- Collection of noise emission data from a flaring event at the CCP flare on 11 August provided mixed results. The flareing event consisted of a release of 830,000 standard cubic feet (SCF) of methane. The peak flow rate was 50,000,000 SCF per day (34,722 SCF/minute). Flow rates could not be controlled at the flare, which prevented measurement of noise emissions at different mass flow rates. In addition, some sample locations were not accessible due to safety considerations. Noise data collected during the flaring event were evaluated but were not acceptable for inclusion in the noise model.

- An array of 37 sampling points emanating from the CCP and CGF facilities was established to monitor the effects of wind speed and direction on noise propagation from the facilities. Initial measurements were made at these points and a sampling protocol was developed for ABR personnel to use when collecting wind data during the 1991 season.

- Equivalent noise levels (Leq; dbA) were collected in 1990 at locations originally monitored in 1989. Data collected in 1990 were consistent with the 1989 data used to construct the computer noise model.

- Noise contours (5 dbA) were modeled for the GHX-1 study area under calm wind conditions, a 10-mph northeast wind, and a 10-mph southwest wind. In general, noise contours extended away from the noise source in the direction of the wind. Some discontinuities in the contours were noted, but will be corrected with the development of smoothing algorithims for the computer model that will allow the contouring output to more closely represent actual noise levels.

ACKNOWLEDGMENTS

This project was funded by ARCO Alaska, Inc., and the Prudhoe Bay Unit Owners and administered by ARCO Alaska, Inc. The authors would like to thank Mike Joyce, Senior Environmental Consultant, ARCO Alaska, Inc., for his support and valuable input during all phases of the study. We would like to thank Tim Pinson, GHX-1 Permit Coordinator, ARCO Alaska, Inc., for his help during the planning and field phases of the study. We also are grateful to ARCO Alaska personnel Bob Elder, Rod Hoffman, and Mike Frampton for their logistical support in Prudhoe Bay. In addition, we would like to thank all the personnel at the Central Compressor Plant and the Central Gas Facility for their cooperation.

A number of ABR personnel contributed to this project. For assistance with fieldwork we thank Brian Cooper, Brian Lawhead, Todd Mabee, John Rose, Bob Burgess, and Amy Ritchie; for editing we thank Brian Lawhead; and for graphical and clerical support we thank Allison Zusi-Cobb, Ann Svensson, and Terrence Davis.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

In conjunction with the planned construction of the first phase of the Gas Handling Expansion (GHX-1) Project in the Prudhoe Bay Oilfield, ARCO Alaska, Inc., (ARCO) implemented an environmental monitoring program in 1989 to evaluate the effects of project-related noise on waterbirds. The main concern is the potential effect of gas-compressor turbine noise on waterbird populations, particularly nesting Canada Geese (*Branta canadensis*) and brood-rearing Brant (*Branta bernicla*), that annually use the area near the GHX-1 site (Murphy et al. 1986, 1987, 1988, 1989, 1990).

The monitoring program was initiated in 1989 (Anderson et al. 1990) to acquire baseline information before construction of the GHX-1 facilities. The monitoring program continued during construction in 1990, and the final year of monitoring will occur during the first year of operation (1991). The goal of the monitoring program is to assess the impact of additional noise generated by project construction and operation on the abundance and distribution of geese, swans, ducks, and loons that use the surrounding area. The specific objectives of the 1990 field program were as follows:

- record the seasonal abundance, distribution, and habitat use of waterbirds in an 8 km^2 study area surrounding the GHX-1 site during May-September. Emphasis was placed on monitoring the use of a wetland complex north of the site that supported several nesting Canada Geese and on monitoring the use of the major brood-rearing area for Brant at the mouth of the Putuligayuk River;

- monitor the existing noise environment in the GHX-1 area by measuring the sound pressure levels (SPL) of steady-state sources of noise (e.g., facilities) and varying or intermittent sources (e.g., flaring); and

- record weather information and measure noise propagation characteristics in the area to evaluate the local factors affecting noise attenuation.

Construction of the GHX-1 facilities will be completed in early 1991 on the same gravel pad as the Central Compressor Plant (CCP), near the southwest corner of Prudhoe Bay, where noise from the CCP facility, the nearby Central Gas Facility (CGF), other facilities, and road traffic is already substantial. Therefore, this study has been designed to evaluate whether the additional noise from construction activities in 1990 and operation of the GHX-1 facilities in 1991 cause a significant decline in use of the area by waterbirds.

In this annual report, information on birds and habitats collected by Alaska Biological Research, Inc., and additional information on noise collected by BBN Systems and Technologies Corporation (formerly Acentech, Inc.), are presented as separate study components with only minimal integration of results. A final product of the noise study (to be completed in 1991) will be an interactive model that can predict noise levels throughout the study area, based on prevailing weather (e.g., wind) and disturbance (e.g., number of turbines active) conditions. That model will be used in concert with the bird distribution data collected before construction (1989), during construction (1990), and during operation (1991) to evaluate whether the GHX-1 facility has affected use of the area by waterbirds.

A number of wetland and bird studies have been conducted in the vicinity of the GHX-1 study area, as a result of development of the Prudhoe Bay and Lisburne oilfields. The first year of the GHX-1 study (Anderson et al. 1990) quantified bird distribution and habitat use. Vegetation, habitats, and physical features of the area have been described and classified by Bergman et al. (1977), Walker et al. (1980), Troy (1986), Jorgenson et al. (1989) and Murphy et al. (1989). Bird use of the area northwest of the GHX-1 study area was described by the Prudhoe Bay Waterflood Environmental Monitoring Program (Troy 1986, Troy et al. 1983, Troy and Johnson 1982) and the Point McIntyre Bird Study (Johnson et al. 1990). Since 1983, Woodward-Clyde Consultants (1983, 1985) and Murphy et al. (1986, 1987, 1988, 1989, 1990) have collected seven consecutive years of data on use of the Lisburne area by waterfowl. A portion of the Lisburne study area overlapped the GHX-1 study area; therefore, the long-term monitoring provided by the Lisburne study will be useful in assessing impacts from the GHX-1 project, particularly in the Brant brood-rearing area.

STUDY AREA

The GHX-1 study area comprises 8.2 km^2 of land located along the southwestern shore of Prudhoe Bay (Figure 1). The study area is bounded on the east by Prudhoe Bay, on the west by an abandoned peat road to the Prudhoe State No. 1 Discovery Well, on the north by an unnamed stream, and on the south by the Putuligayuk River and the Lisburne access road to the Putuligayuk River. The study area also includes an island at the mouth of the Putuligayuk River.

Landforms, vegetation, and hydrology in the study area are typical of the central Arctic Coastal Plain and have been described by Bergman et al. (1977), Walker et al. (1980), and Anderson et al. (1990). Terrain features in the study area are greatly influenced by three distinct geomorphic processes: the thaw-lake cycle, eolian deposition of materials derived from the Sagavanirktok River Delta, and coastal processes (erosion, sediment deposition, and flooding). The thaw-lake cycle has created a variety of wetland types, including large, oriented lakes, small ponds, seasonally flooded lowland areas, and wetland complexes (Bergman et al. 1977). Wind transport of sand and silt from the Sagavanirktok River delta has influenced landforms, soil chemistry, and vegetation in the study area (Walker and Webber 1979). Deposition of mud along the coast near the Putuligayuk River mouth, coastal erosion of the shoreline, and flooding of low-lying coastal shoreline by storm surges have created a variety of salt-affected habitats.

As part of the Lisburne Terrestrial Monitoring Program, Jorgenson et al. (1989) developed and implemented a classification system for waterbird habitats on the Arctic Coastal Plain; this system was used to map habitats in the study area in 1989 (Appendix 1) and has been used for descriptions of habitat use (Anderson et al. 1990).

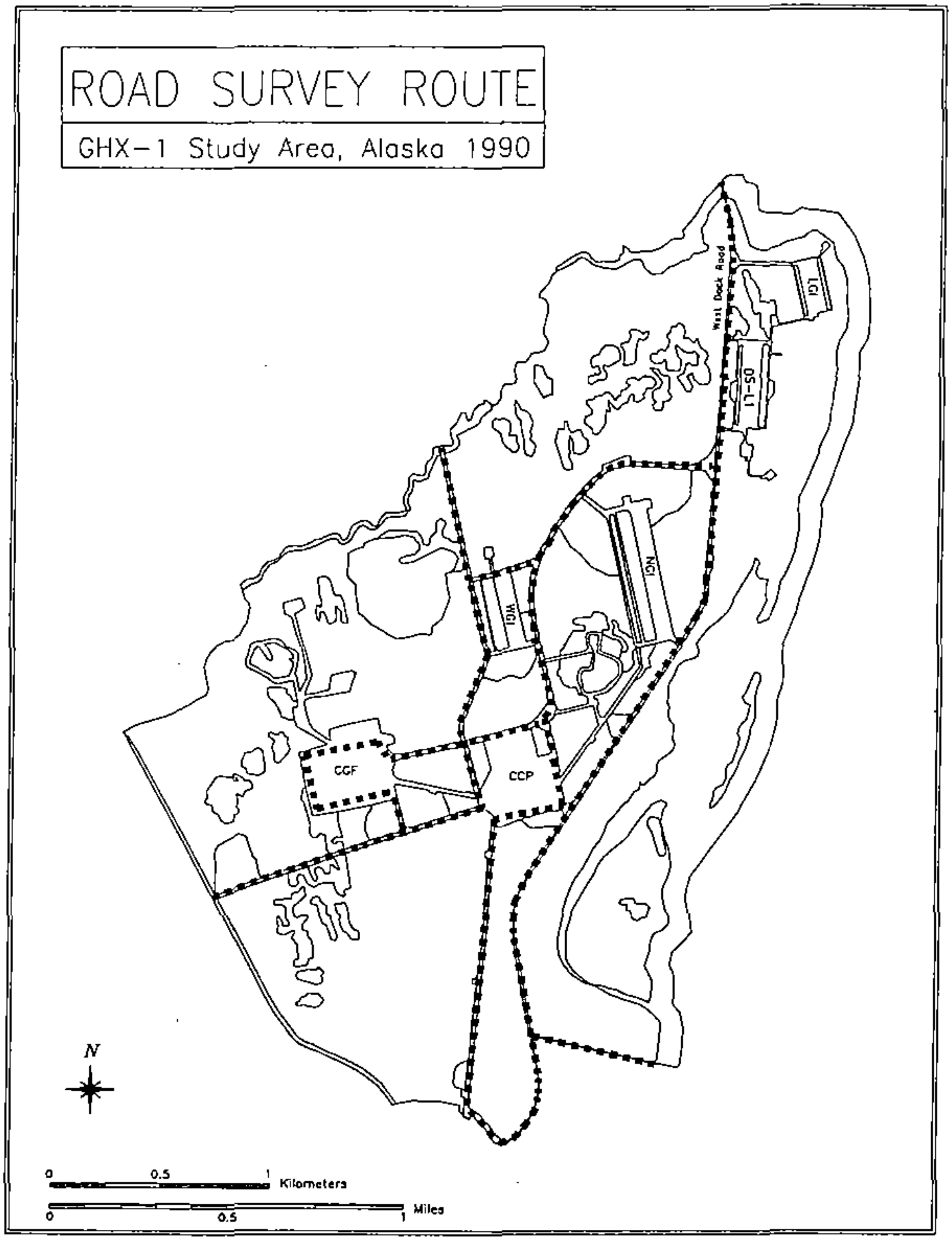


Figure 1. Study area and road survey route for the GHX-1 monitoring program, Prudhoe Bay, Alaska, 1990.

METHODS

CONDITIONS IN THE GHX-1 STUDY AREA IN 1990

Oilfield activities in the GHX-1 study area in 1990 were assessed by describing construction and drilling activities and by monitoring traffic levels on two segments of West Dock Road (south of the entrance to CCP and north of the entrance to CCP) and on the northern access road to CGF from West Dock Road (Figure 1). Traffic was counted during 15-minute periods on most survey dates. Vehicles were classified as small vehicles (e.g., pick-up trucks, "suburban"-type trucks), large vehicles (larger than "suburban"-type trucks), or "belly-dumps" (large, noisy trucks such as gravel-hauling trucks). Mean traffic rates were calculated for all vehicle types combined for each of the three road segments.

Predator activity in the study area was evaluated during road surveys by recording the abundance and distribution of arctic foxes (*Alopex lagopus*), Glaucous Gulls (*Larus hyperboreus*), Common Ravens (*Corvus corax*), and Parasitic and Pomarine jaegers (*Stercorarius parasiticus* and *S. pomarinus*, respectively). Locations of all gull and jaeger nests and of active fox dens in the study area were mapped.

Phenological conditions in the study area were assessed by monitoring snow cover, spring snow-melt, and mean monthly temperatures. The chronology of breeding activities of waterbirds was determined by monitoring the timing of major life-history events (e.g., nest initiation, incubation, brood-rearing).

The durations of nest-initiation, egg-laying, incubation, and brood-rearing periods were determined either by direct observation or by estimation ("back-dating") using known hatching dates and published records of the chronology of life-history events (Appendix 2). For geese, swans, and ducks, we delineated four seasons for this study: pre-nesting (late May to early June), nesting (early June to mid-July), brood-rearing (mid-July to mid-August), and fall staging (mid-August to mid-September). Although loons usually begin nesting later than other waterbirds and do not begin fall staging during our survey period, the early season in 1990 allowed for earlier initiation of nesting and we considered the fall-staging season for loons to have begun by the last week of our survey period.

ABUNDANCE, DISTRIBUTION, AND HABITAT USE

The abundance, distribution, and habitat use of waterbirds in the GHX-1 study area were monitored using road and foot surveys. Data recorded for each sighting included species, number of adults, and number and age-class of young (if present); the locations of all sightings were marked on maps of the study area. We also recorded weather and oilfield activity at facilities in the study area during each survey.

Birds seen flying over the study area were not included in survey counts in 1990. Twenty-five road surveys were conducted between 27 May and 5 September 1990; these surveys entailed driving 15.5 km (9.6 mi) of roads in the GHX-1 study area while counting birds and mapping their locations. The same route was covered on each survey (Figure 1), for complete coverage of the study area. In addition to the 25 road surveys, two foot surveys were conducted, on 11 and 21 June 1990, to locate waterbird nests. During these foot surveys, three observers walked the perimeters of all lakes, ponds, and wetland complexes in the study area, providing nearly complete coverage of nesting areas adjacent to aquatic habitats. Routes of travel during the initial foot survey were followed closely during the second survey. When a nest was located, observers did not approach closer than 50 m and were careful not to flush birds from the nest. Locations of all nests were recorded on maps of the study area, and species, number and sex of attendant adults, status of the nest, and habitat information were recorded on nest data forms. Sightings of all waterbirds were recorded during these nest surveys and were summarized with the road-survey information (because of relatively similar levels of coverage).

Habitat use by waterbirds was assessed by plotting observations of birds from road and nest surveys on digitized overlays of the habitat map. Observations that fell on boundaries between habitats were assigned to the correct habitat based on notes made by the observer during the surveys or were randomly assigned to one habitat.

The area (km^2) of each habitat type within the study area was measured in 1989 to determine habitat availability (Appendix 1). Mean seasonal densities ($birds/km^2$) for each species in each habitat type were calculated from road and nest survey data. We compared habitat use versus habitat availability qualitatively for each season to evaluate whether general patterns of habitat use in the study area were evident. Although observations of birds were categorized in the field according to Level IV habitats, the habitat-use data in this report are presented for Level II habitats to simplify interpretation of results and trends. When relevant, important Level IV habitats are discussed.

BREEDING BIRDS AND NEST FATE

Nest fate was evaluated for all waterbird nests located in the GHX-1 study area. Nests that ceased to be active were checked at the earliest opportunity after their change in status was noted. Nest fate was assessed based on four factors:

1) the condition of the nest (intact or disturbed);
2) the presence and condition of eggs and/or egg-shell fragments (hatched eggs were distinguished from destroyed eggs by the ease with which membranes could be separated from shell fragments, or the presence of membranes separated from the shell);
3) sign of predators or direct observation of predation; and
4) the proximity of adult birds with broods (e.g., on nearby water bodies).

The distance from each nest to the center of the CCP and CGF facilities, and to the nearest road and pad, were calculated from the digitized map. These distances were evaluated, using the Mann-Whitney test (Conover 1980), to determine whether the distances to these structures were significantly different between successful and unsuccessful nests and whether distances differed between nests located in 1989 and 1990.

RESULTS AND DISCUSSION

CONDITIONS IN THE GHX-1 STUDY AREA IN 1990

Weather, predators, and other natural factors profoundly affect the welfare of waterbirds that breed in the Arctic (Newton 1977). These factors must be assessed before cause-and-effect relationships between industrial development and bird populations can be evaluated. Similarly, human activity in the study area varies annually, and evaluating this variability in the noise environment is a major objective of this research program. Accordingly, our evaluations of the status of waterbird populations are interpreted in relation to the prevailing environmental conditions in the study area.

Oilfield Activity

Production facilities and human activities in the oilfield produce both auditory and visual stimuli that potentially can affect waterbirds. Oilfield structures within the GHX-1 study area include gravel roads, powerlines, and pads associated with either Lisburne or Prudhoe Bay facilities. Lisburne facilities include Drill Site (DS) L1 and the Lisburne Gas Injection (LGI) pad, in addition to access roads and pipelines. Prudhoe Bay facilities included CGF, CCP, the Northern Gas Injection (NGI) pad, the Western Gas Injection (WGI) pad, and access roads and pipelines.

Construction activity in the study area during 1990 included preparatory construction activities at the CCP and CGF facilities prior to the arrival of GHX-1 modules in early August and installation of these modules during August and early September. Other construction activities in the study area included pipeline maintenance south of CCP during August, gravel removal from the tundra adjacent to the eastern edge of NGI during July and August, and some road construction near WGI in July in preparation for the movement of modules to the CCP/CGF pads.

Other human activity in the study area occurred primarily as vehicular traffic, aircraft flights, and pedestrian traffic. Vehicular traffic was the most widespread and frequent source of moving stimuli. Traffic rates (vehicles/h) varied by location (i.e., segments of West Dock Road, north and south of CCP, and the northern access road to CGF/CCP). The mean traffic rate for West Dock Road south of CCP was 66.3 vehicles/h (number of counts = 19), whereas the mean traffic rate north of CCP was only 21.8 vehicles/h (n=20). The mean traffic rate on the access road to CGF/CCP was markedly lower at only 3.4 vehicles/h (n=20). Direct comparison between traffic rates in 1989 and 1990 are complicated by large differences in the total number of traffic counts (n=232 and n=59, respectively) and by the difference in the count period (i.e., 20-minute counts in 1989 versus 15-minute counts in 1990). By restricting 1989 traffic counts to only those made between 0800 and 1659 hours (the range of times for counts in 1990), the mean traffic rates were 41.0 vehicles/h (n=116) and 15.8 vehicles/h (n=64) for West Dock Road south and north of CCP, respectively; no counts were made on the access road in 1989. These mean traffic rates suggest that traffic levels on West Dock Road were higher in 1990 than in 1989, which might be expected based on the increased level of construction activity at the CCP and CGF pads.

Air traffic over the study area consisted of infrequent helicopter and small, fixed-wing, airplane flights. Most flights over the study area tended to be at relatively low altitudes (<1000 ft agl).

Pedestrians occurred almost exclusively on roads and pads and were most common near facilities. Surveyors, clean-up crews (i.e., "stick-pickers"), ABR personnel, and other contract biologists were the only people observed walking on the tundra.

Predator Activity

Predator abundance and activity in the GHX-1 study area were monitored to evaluate the effects of predators on the distribution and productivity of breeding waterbirds. Both Glaucous Gulls and arctic foxes are major predators of the eggs, young, and adults of waterbirds breeding in high latitudes (Larson 1960, Mickelson 1975, Bergman and Derksen 1977), including Prudhoe Bay (Murphy et al. 1986, 1987, 1988, 1989, 1990). Common Ravens and jaegers (primarily Parasitic) also take eggs of waterbirds (Mickelson 1975, Bergman and Derksen 1977, Murphy et al. 1988).

Glaucous Gulls were seen on 26 of 27 surveys in the study area with a mean count of 14.1 gulls per survey. The maximum number of gulls seen on any single survey was 102 on 1 September; most of those gulls were in a loosely aggregated flock of 84 birds resting on the island at the mouth of the Putuligayuk River. That group included a large number of young-of-the-year gulls. Due primarily to the presence of this single flock, significantly more gulls used the study area in 1990 than in 1989 (Mann-Whitney test, $P<0.05$). One pair of Glaucous Gulls nested in the study area in 1990 and produced two young.

Arctic foxes were seen during approximately 25% ($n=7$) of the 27 surveys with a mean count of 0.3 foxes per survey. A fox den in the coastal bluff near DS-L1 that was active in the past was not occupied in 1990. The number of foxes seen during surveys did not differ between 1989 and 1990.

Jaegers also were seen sporadically throughout the field season. Both Pomarine and Parasitic jaegers occurred during late May and early June, but only Parasitic Jaegers regularly nest in the Prudhoe Bay area. Jaegers were observed on 63% ($n=17$) of the 27 surveys with a mean count of 0.8 jaegers/survey. A maximum count of five jaegers was recorded on the 17 June survey. Common Ravens were uncommon in the study area; ravens were recorded during only four surveys (mean=0.1 ravens/survey).

Phenological Conditions and Breeding Chronology

Spring snow-melt in 1990 was relatively rapid, due to limited snow coverage and above average temperatures in April, May, and June. Because of the limited snow coverage, most of the study area was snow free during the first survey on 27 May 1990. Mean temperatures during April, May, and June were above the long-term seasonal means for those months (16°, 7°, and 4°F above normal, respectively) (NOAA; 1990 Prudhoe Bay Climatological Data).

Flocks of Canada and White-fronted geese (*Anser albifrons*) were present in the GHX-1 study area during our first survey on 27 May; therefore, the dates of their arrival in the study area are unknown. The first Canada Geese were seen in the Prudhoe Bay area on 3 May 1990 (Mike Frampton, ARCO, pers. comm.), an exceptionally early arrival date. The first Tundra Swans (*Cygnus columbianus*) were seen in the study area on 2 June. Arrival dates were not obtained for most ducks, but Northern Pintails (*Anas acuta*), Oldsquaw (*Clangula hyemalis*), and King (*Somateria spectabilis*) and Spectacled (*S. fischeri*) eiders were present in the study area on 27 May. Both Pacific (*Gavia pacifica*) and Red-throated (*G. stellata*) loons arrived in the study area in early June (5 June and 11 June, respectively).

The first waterbirds nesting in the study area were Canada Geese, which had begun nesting by the first week of June. The first Pacific and Red-throated loon nests in the study area were discovered on 20 June. We were unable to determine precise hatching dates for any of the nests, but the first brood of Canada Geese was seen in the study area on 29 June 1990, almost two weeks earlier than the first sighting of a brood in 1989. The first young Pacific Loon was seen on 13 July 1990, which was more than three weeks earlier than in 1989. First broods of other species were seen on 29 June (Brant), 3 July (White-fronted Goose), 13 July (King Eider), 18 July (Tundra Swan), 23 July (Red-throated Loon), and 31 July (Spectacled Eider).

The only waterbirds still present in the study area during the final road survey on 5 September 1990 were Canada Goose, Tundra Swan, Pacific Loon, Northern Pintail, and Green-winged Teal (*Anas crecca*); hence, departure dates for these species were not obtained.

ABUNDANCE, DISTRIBUTION, AND HABITAT USE

Seasonal Abundance, Distribution, and Density

Seasonal dates for waterbird life-history events in the GHX-1 study area were based on observations of nests, first appearance of broods in the study area, and the onset of flight for young and molting adult birds. Seasonal dates for geese, ducks, and swans were 27 May - 5 June for pre-nesting; 6-25 June for nesting; 26 June - 13 August for brood-rearing; and 14 August - 5 September for fall staging. Loons do not arrive on the North Slope until open water is present, and begin nesting later than swans, geese, and ducks. In addition, their brood-rearing period is longer and extends into September during most years. Due to the early snow-melt conditions in 1990, loons began nesting earlier than usual and were able to fledge young during our survey period, therefore, we delineated four seasons for loons: pre-nesting (27 May - 11 June), nesting (12 June - 8 July), brood-rearing (9 July - 28 August), and fall staging (29 August - 5 September).

Geese

Canada Geese were the second most abundant goose species during pre-nesting; a high count of 26 birds was recorded on 3 June (Figure 2, Appendix 3) and the mean seasonal density was 2.6 birds/km^2 (Table 1). The earlier availability of open ground throughout the Prudhoe Bay area probably contributed to the rapid dispersal of geese to their breeding areas upon arrival on the coastal plain, thus resulting in lower concentrations of geese in the "dust shadows" created by roads. Most pre-nesting Canada Geese were seen near their subsequent nest sites in the study area (Figure 3). Numbers of Canada Geese seen on surveys were relatively stable during nesting; mean density was 3.3 birds/km^2. Eleven Canada Goose nests (1.3 nests/km^2) were located in the GHX-1 study area in 1990 (Figure 4). Most nests were concentrated in the northern half of the study area, but two nests were located within 100 m of the CGF pad. The first Canada Goose brood was seen in the study area on 29 June (Figure 2). Brood-rearing flocks primarily used the northern edge of the study area along the slough (Figure 5); mean density during brood-rearing was 2.3 young/km^2 and 2.7 adults/km^2 (Table 1). Numbers of adult and young Canada Geese fluctuated during brood-rearing because of movements in and out of the study area along the northern boundary (Figure 2). The large lakes north of the study area have supported molting flocks of 50-250 Canada Geese in previous years (Johnson et al. 1990; Murphy et al. 1990) and continued to do so in 1990. Numbers of Canada Geese observed during fall staging peaked at 11 on 1 September 1990 (Figure 2), but the mean seasonal density was <1 bird/km^2 (Table 1). Canada Geese were seen primarily near DS-L1/LGI during fall staging (Figure 6). The distribution of Canada Geese in the study area in 1989 and 1990 was similar, except during pre-nesting and fall staging when the low numbers of Canada Geese seen in 1990 resulted in a more limited distribution in the study area (Anderson et al. 1990). Higher counts of Canada Geese during pre-nesting in 1989 were due to the heavy snow coverage

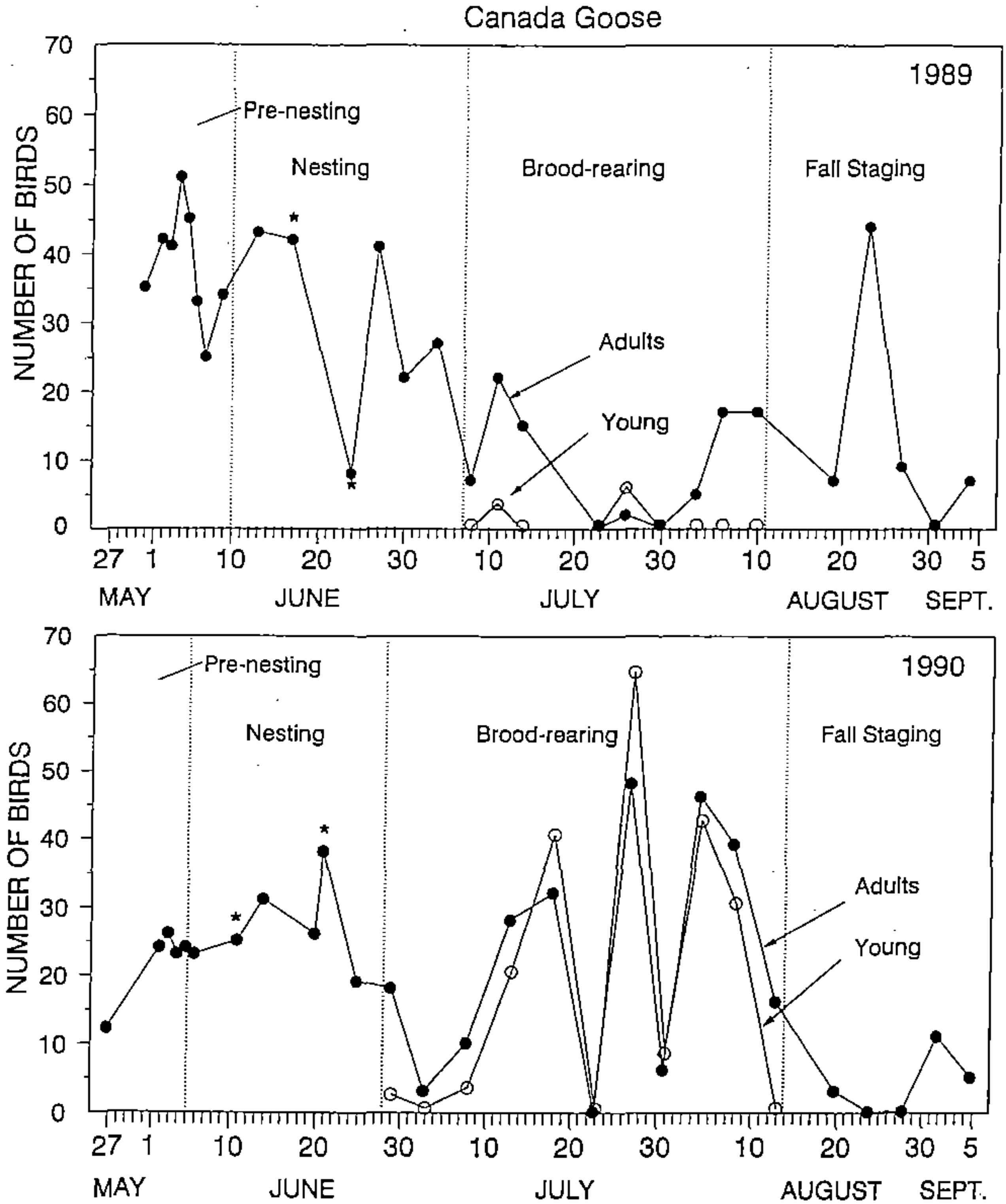


Figure 2. Counts of Canada Geese from road and foot surveys in the GHX-1 study area, Prudhoe Bay, Alaska, 1989 and 1990. Asterisks indicate foot surveys during nesting.

Table 1. Seasonal density (mean and SD, as birds/km²) of waterbirds in the GHX-1 study area, Prudhoe Bay, Alaska, 1989 and 1990. Dashes indicate that data were not collected for that season (in the case of ducks) and that fall staging was not applicable to loons in 1989.

		Pre-nesting		Nesting		Brood-rearing				Fall Staging		All Seasons	
		Total Birds		Total Birds		Adults		Young		Total Birds		Total Birds	
	Year	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD
GEESE													
Canada Goose	1989	4.6	0.9	3.7	1.7	1.1	1.0	0.1	0.2	1.6	2.1	2.8	2.0
	1990	2.6	0.7	3.3	0.8	2.7	2.1	2.3	2.7	0.5	0.6	3.3	3.4
White-fronted Goose	1989	12.4	8.0	1.1	0.8	0.3	0.6	0.3	0.8	5.1	1.6	4.8	6.6
	1990	1.3	1.2	1.1	0.9	0.2	0.2	0.2	0.3	3.7	4.2	1.4	2.1
Brant	1989	1.6	1.5	2.2	2.9	14.8	10.5	5.2	4.5	3.9	8.3	8.0	12.1
	1990	0.5	0.6	2.9	2.8	22.7	10.3	12.2	8.2	0.2	0.5	15.0	20.3
Snow Goose	1989	0.2	0.3	0.0	0.0	0.1	0.1	0.1	0.1	0.0	0.0	0.1	0.2
	1990	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SWANS													
Tundra Swan	1989	0.1	0.2	<0.1	0.1	0.1	0.2	0.0	0.0	0.3	0.3	0.1	0.2
	1990	0.1	0.1	0.1	0.2	0.2	0.1	0.3	0.2	0.3	0.3	0.3	0.3
DUCKS													
Green-winged Teal	1989	-	-	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	1990	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.2	0.2	0.1	0.1
Mallard	1989	-	-	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	1990	0.2	0.2	0.3	0.5	<0.1	<0.1	0.0	0.0	<0.1	0.1	0.1	0.2
Northern Pintail	1989	-	-	2.9	2.3	3.0	4.0	0.0	0.0	1.7	2.6	2.6	3.1
	1990	1.6	1.3	3.5	2.1	2.6	1.8	0.0	0.0	4.2	1.1	2.9	1.8
Northern Shoveler	1989	-	-	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	1990	0.0	0.0	<0.1	0.1	0.0	0.0	0.0	0.0	<0.1	0.1	0.1	0.1

Table 1. Continued.

	Year	Pre-nesting Total Birds		Nesting Total Birds		Brood-rearing Adults		Brood-rearing Young		Fall Staging Total Birds		All Seasons Total Birds	
		$\overline{X}$	SD	$\overline{X}$	SD	$\overline{X}$	SD	$\overline{X}$	SD	$\overline{X}$	SD	$\overline{X}$	SD
Eurasian Wigeon	1989	-	-	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	1990	<0.1	0.1	<0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1
American Wigeon	1989	-	-	0.0	0.0	0.4	0.7	0.0	0.0	0.2	0.4	0.2	0.5
	1990	0.1	0.3	0.0	0.0	0.2	0.4	0.0	0.0	0.0	0.0	0.1	0.3
Oldsquaw	1989	-	-	0.9	0.8	<0.1	0.1	0.0	0.0	0.0	0.0	0.3	0.6
	1990	1.4	0.7	1.0	0.9	0.2	0.4	0.0	0.0	0.3	0.4	0.6	0.8
King Eider	1989	-	-	1.3	0.8	0.1	0.1	0.1	0.2	0.2	0.3	0.5	0.7
	1990	0.6	0.4	1.6	1.0	0.2	0.3	0.2	0.3	0.1	0.2	0.7	0.8
Spectacled Eider	1989	-	-	0.4	0.5	<0.1	0.1	0.0	0.0	0.1	0.2	0.2	0.3
	1990	0.8	0.3	0.5	0.4	0.2	0.3	0.2	0.7	0.2	0.4	0.5	0.6
Unidentified eider	1989	-	-	0.1	0.1	0.2	0.6	0.0	0.0	0.0	0.0	0.1	0.4
	1990	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
LOONS													
Pacific Loon	1989	0.3	0.5	0.9	0.5	0.7	0.2	0.1	0.1	-	-	0.7	0.5
	1990	0.3	0.6	1.3	0.4	1.2	0.5	0.6	0.2	1.2	0.7	1.2	0.8
Red-throated Loon	1989	<0.1	0.1	0.2	0.1	0.1	0.1	0.0	0.0	-	-	0.1	0.1
	1990	<0.1	0.1	0.2	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.2	0.2
TOTAL DENSITY	1989	19.1	9.2	13.8	4.6	21.0	12.2	5.7	4.7	13.9	10.5	19.5	12.5
	1990	9.5	2.1	15.8	5.5	30.6	10.0	16.0	10.9	11.8	5.2	26.5	21.6

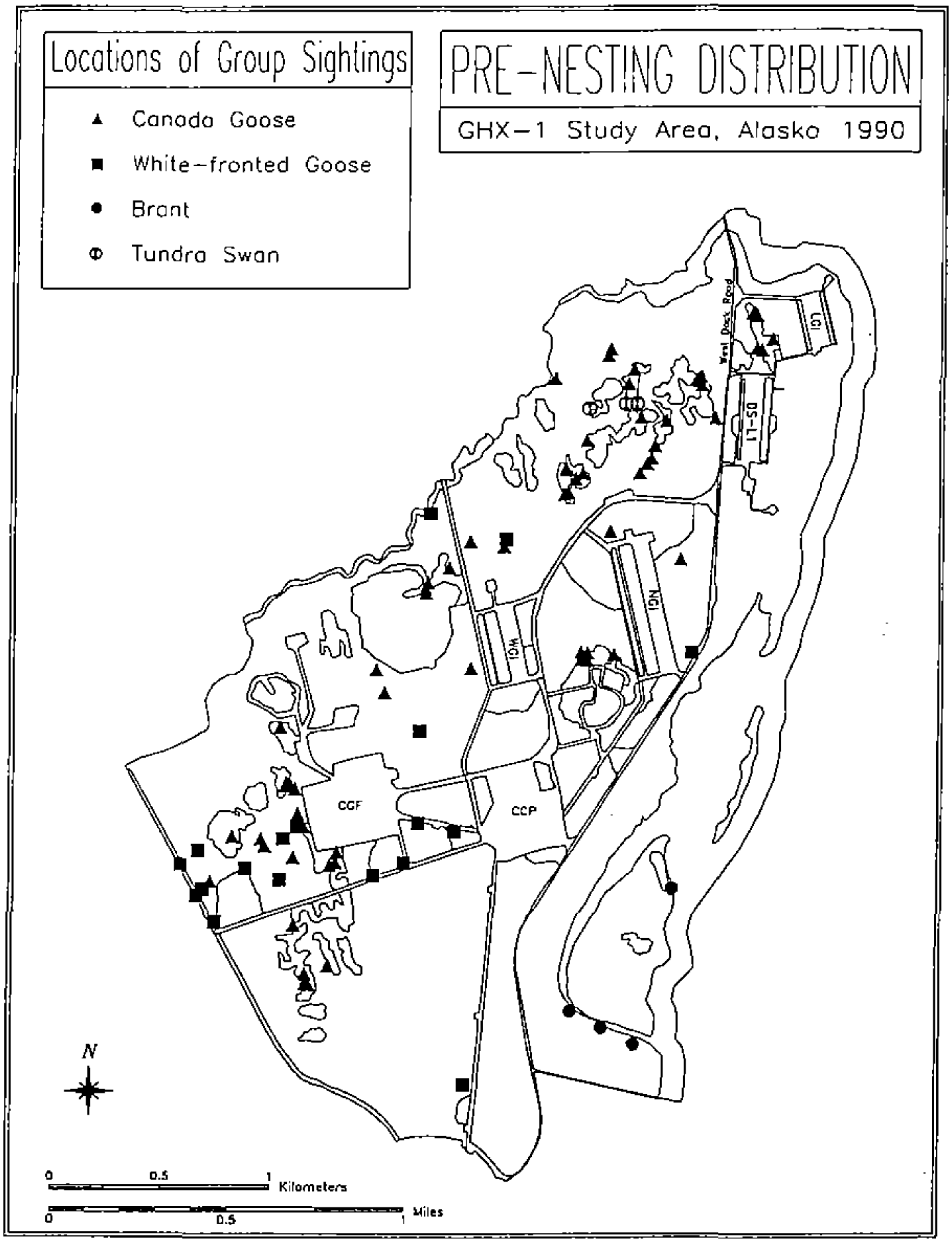


Figure 3. Distribution of Canada Geese, White-fronted Geese, Brant, and Tundra Swans during pre-nesting in the GHX-1 study area, Prudhoe Bay, Alaska, 1990. Group sightings were of one or more birds.

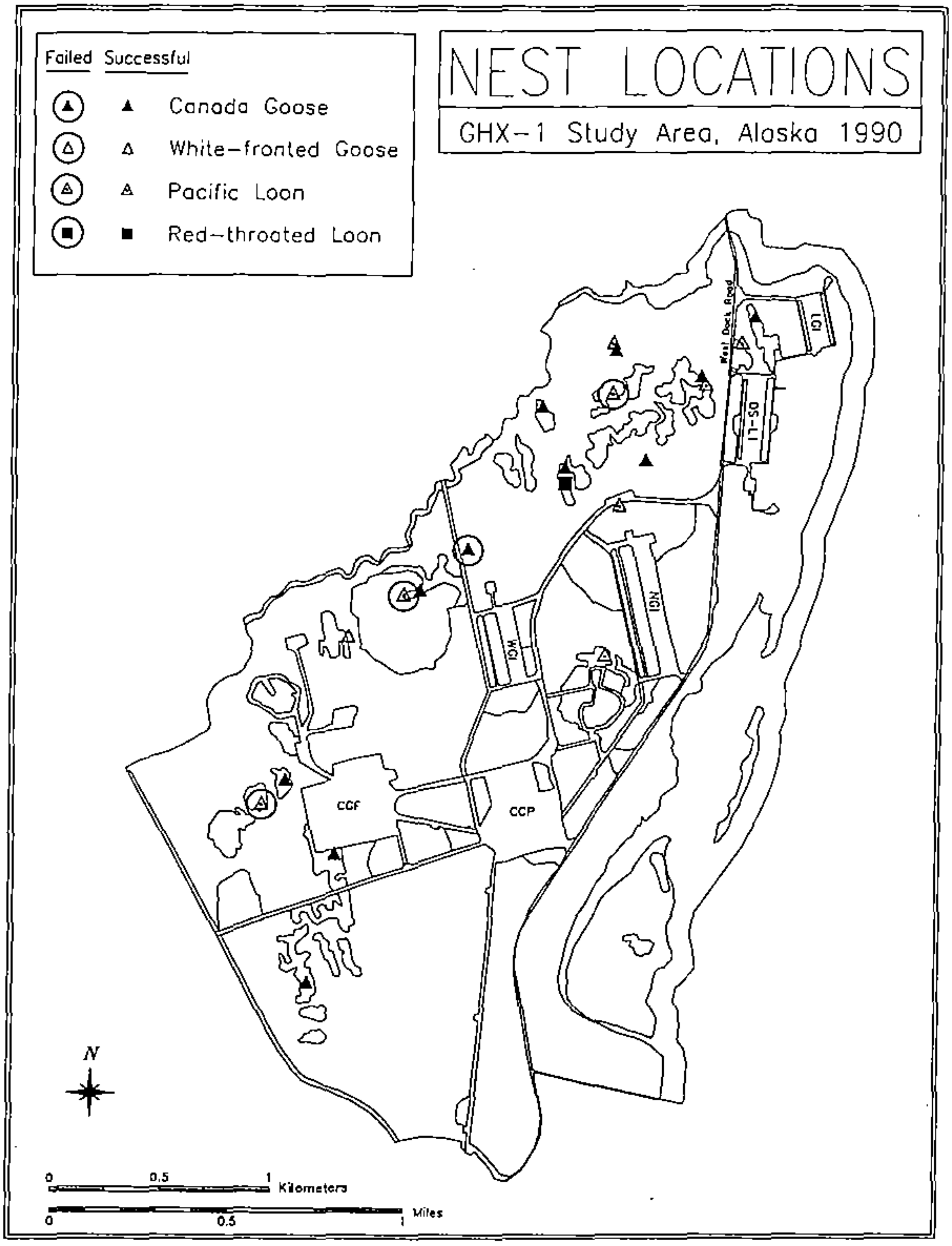


Figure 4. Locations of waterbird nests in the GHX-1 study area, Prudhoe Bay, Alaska, 1990.

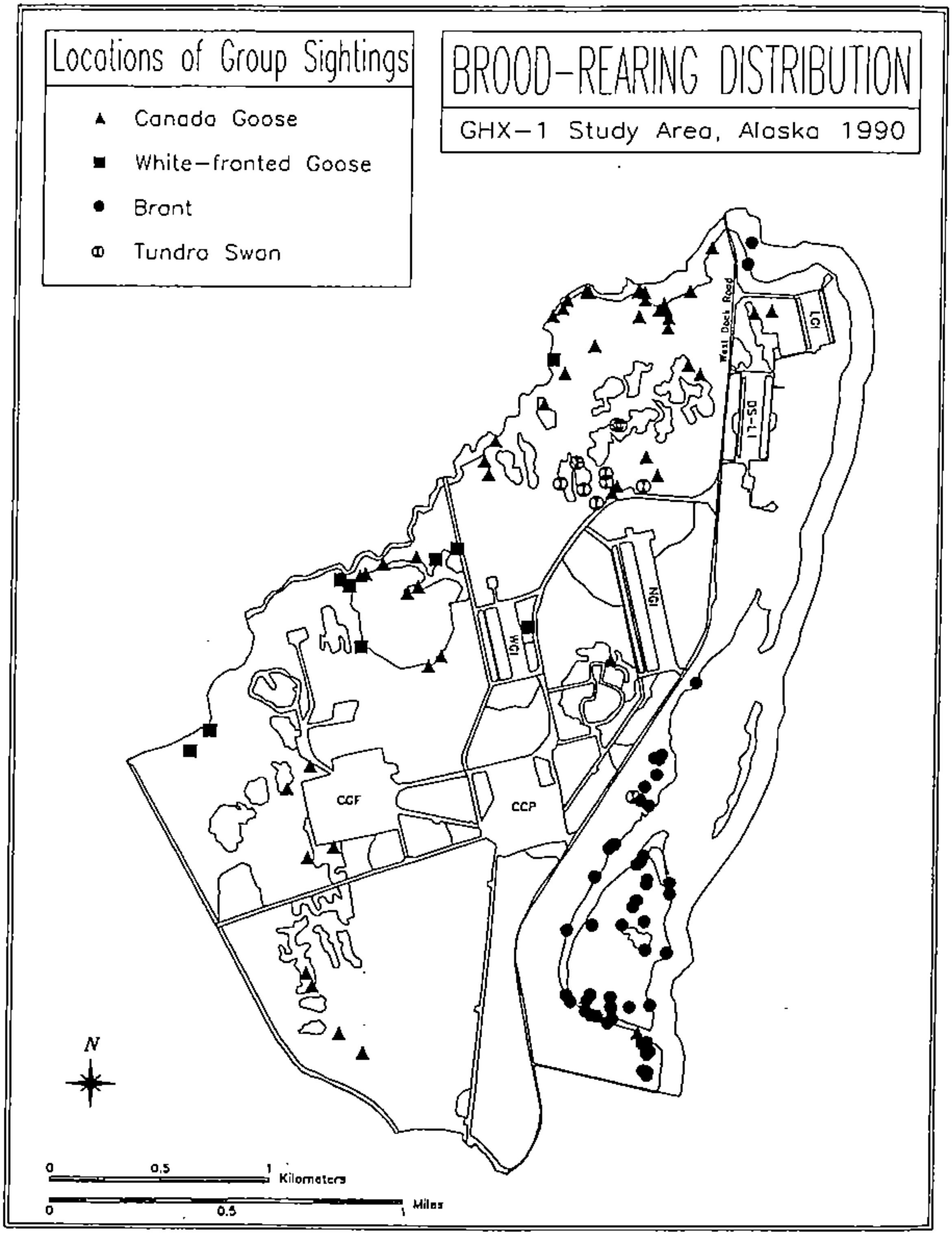


Figure 5. Distribution of Canada Geese, White-fronted Geese, Brant, and Tundra Swans during brood-rearing in the GHX-1 study area, Prudhoe Bay, Alaska, 1990. Group sightings were of one or more birds.

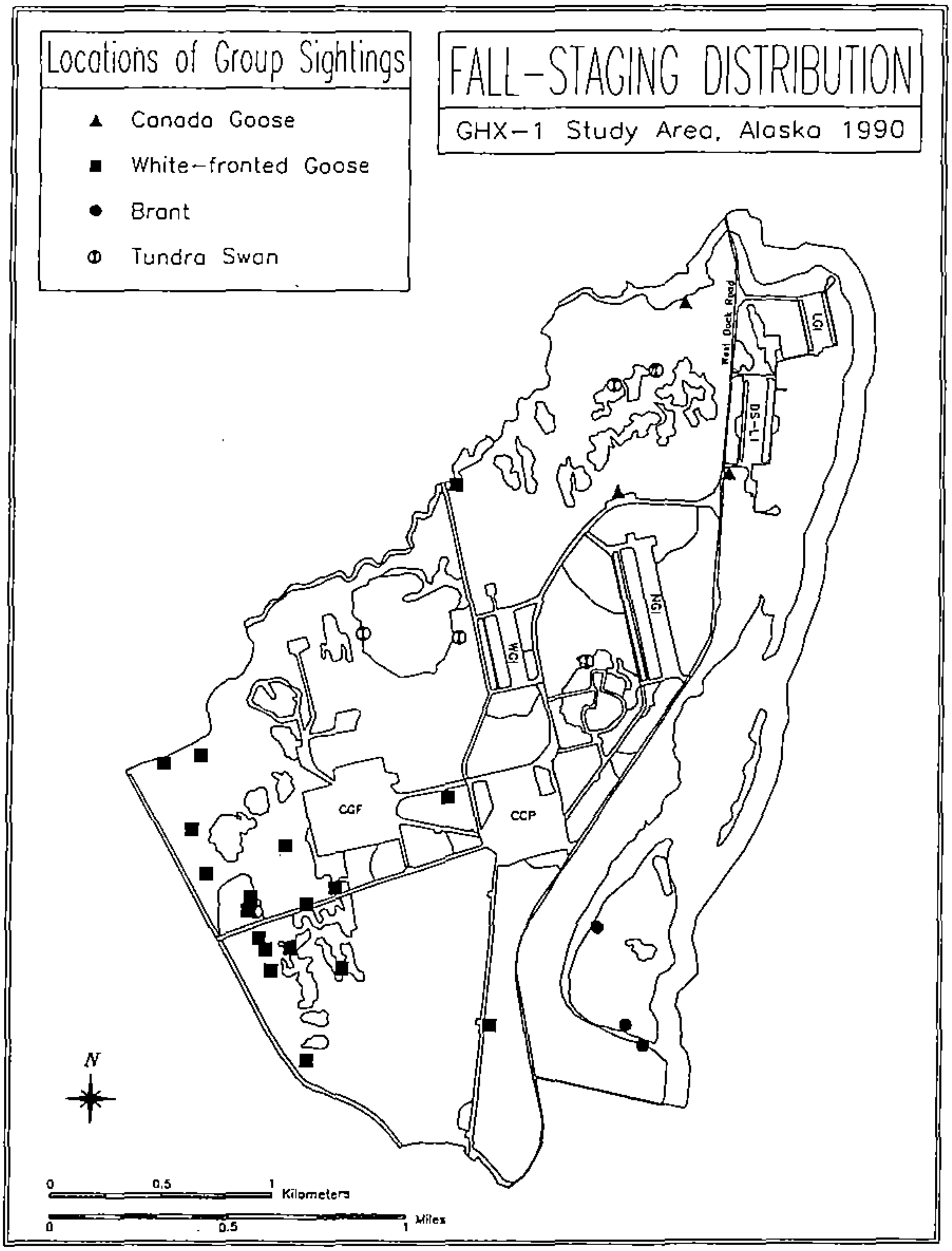


Figure 6. Distribution of Canada Geese, White-fronted Geese, Brant, and Tundra Swans during fall staging in the GHX-1 study area, Prudhoe Bay, Alaska, 1990. Group sightings were of one or more birds.

that concentrated birds near roads and facilities and prevented early dispersal to nest sites (Figure 2). The number of Canada Goose nests in the study area almost doubled in 1990, probably due to the earlier availability of nest sites in 1990 compared to 1989. This increase in nesting effort also contributed to the greater abundance of brood-rearing Canada Geese in the study area in 1990 compared to 1989. Fall-staging Canada Geese were less abundant in 1990 compared to 1989, but both years showed a decline in use of the study area as fall staging progressed.

White-fronted Geese were the most abundant geese during pre-nesting during any single survey; a high count of 28 birds was recorded on 27 May 1990 (Figure 7, Appendix 3), but the seasonal mean density (1.3 birds/km^2) was less than one-third that of Canada Geese (Table 1). Most pre-nesting White-fronted Geese were seen in the vicinity of CGF, with scattered sightings in other parts of the study area (Figure 3). Only one White-fronted Goose nest was located in the study area, north of CGF (Figure 4); mean density during nesting averaged 1.1 birds/km^2. The first brood of White-fronted Geese was observed on 3 July and several broods were seen periodically throughout the brood-rearing season (Figures 5 and 7). Mean densities of adults and young never exceeded 0.5 birds/km^2, however (Table 1). The number of White-fronted Geese using the study area during fall staging peaked at 84 birds and geese were distributed similarly to the pre-nesting season (Figure 6). The mean density of White-fronted Geese during fall staging was almost three times that recorded during pre-nesting (Table 1). Both the distribution and abundance of White-fronted Geese differed between 1989 and 1990. The major differences occurred during the pre-nesting and fall-staging seasons when White-fronted Geese were less abundant in 1990 than in 1989. The major factor affecting abundance during pre-nesting was the difference in the availability of open ground in the study area. In 1989, little open ground was available and birds concentrated in dust shadows adjacent to roads and pads and remained there for several days, whereas in 1990, open ground was readily available and geese were not concentrated in the study area (Anderson et al. 1990). Because the relative abundance and distribution of geese vary more during the fall-staging season, the differences noted between 1989 and 1990 could be simply normal yearly variation.

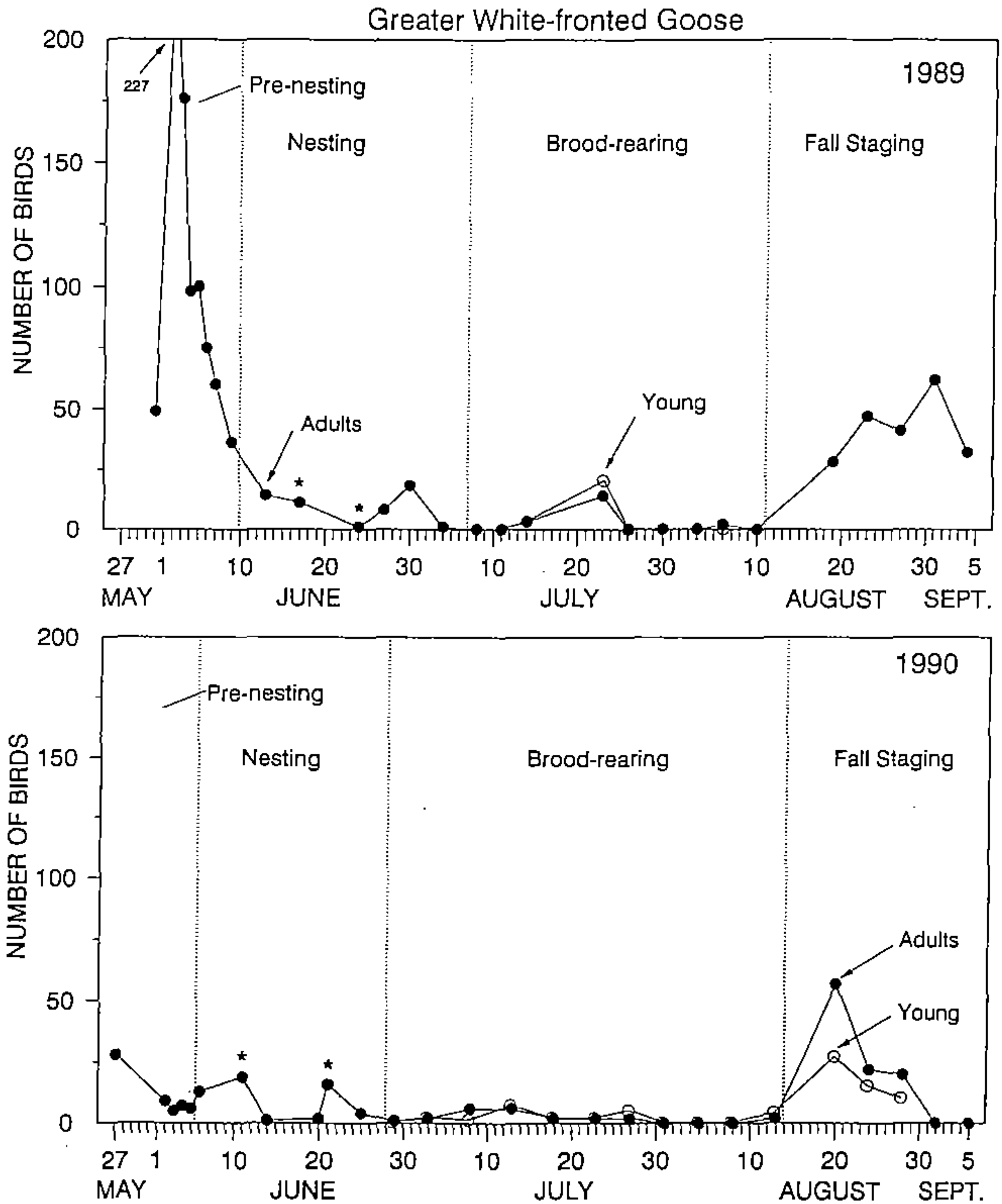


Figure 7. Counts of White-fronted Geese from road and foot surveys in the GHX-1 study area, Prudhoe Bay, Alaska, 1989 and 1990. Asterisks indicate foot surveys during nesting.

Brant were present in the study area on 2 June and moderate numbers occurred throughout pre-nesting (Figure 8, Appendix 3), but mean density was <1 bird/km^2 (Table 1). During pre-nesting, Brant were seen exclusively near the coast and on the island southeast of CCP (Figure 5). Brant did not nest in the study area, but the island at the mouth of the Putuligayuk River was used by non-breeding birds during the nesting season and was used intensively by brood-rearing flocks (Figures 5 and 8). The first Brant brood arrived at the island on 29 June and the number of brood-rearing Brant peaked on 27 July at 293 adults and 196 young (Figure 8, Appendix 3). Brant are gregarious during brood-rearing and most of the approximately 300-450 birds in the GHX-1 study area remained in several loosely associated flocks comprising pairs with young and numerous failed or non-breeding adults. Mean density during brood-rearing was the highest recorded for any species (Table 1). Brood-rearing Brant were seen almost exclusively in the coastal areas south and east of CCP and on the island; late in the season two flocks were seen along the slough north of LGI (Figure 5). Brant did not use the study area after 20 August (Figure 8); this movement out of the area has been noted in previous years and does not appear to be disturbance-related (Murphy et al. 1988, 1989). Mean density of Brant during fall staging was <1 bird/km^2 due to their movement out of the study area. Distribution of Brant in the study area was not markedly different between 1989 and 1990, but the abundance of Brant was different (Anderson et al. 1990). Fewer Brant were seen during pre-nesting in 1990 than in 1989, again due primarily to differential availability of open ground between years. The most striking difference in abundance between years was the increase in 1990 of the number of both adults and young using the brood-rearing island. This increased use was attributable to good nesting success at colonies in the Prudhoe Bay area in 1990 (Ritchie et al. 1991), as compared to the moderate success experienced in 1989 (Murphy et al. 1990, Ritchie et al. 1990). Fluctuations in abundance of brood-rearing Brant in the GHX-1 study area in 1989 (Figure 8) were due to movements of flocks south along the banks of the Putuligayuk River and out of the study area; these movements were not seen during road surveys in 1990.

Snow Geese were not seen in the GHX-1 study area in 1990 and were seen on only

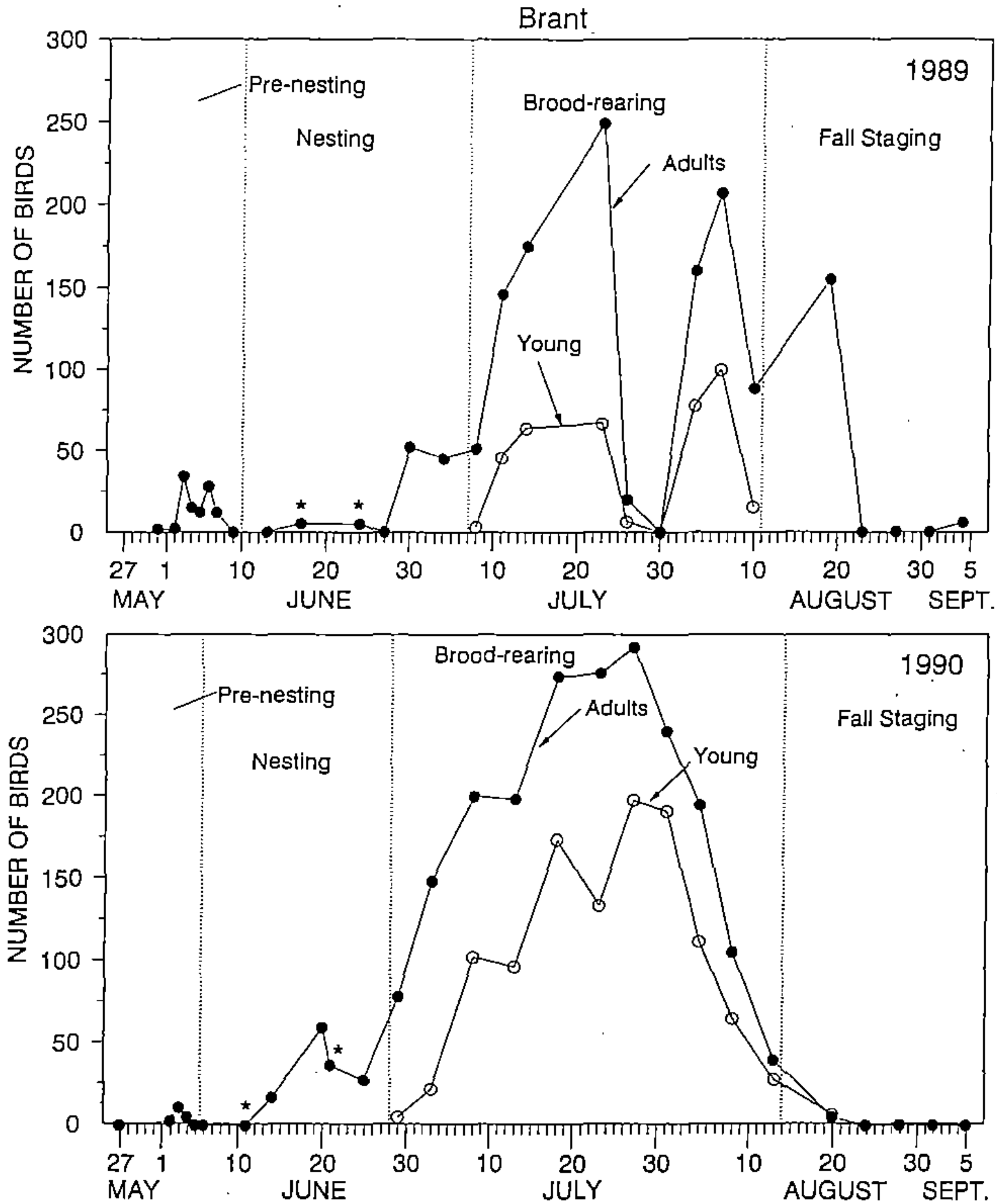


Figure 8. Counts of Brant from road and foot surveys in the GHX-1 study area, Prudhoe Bay, Alaska, 1989 and 1990. Asterisks indicate foot surveys during nesting.

six surveys (three during pre-nesting and three during brood-rearing) in 1989 (Anderson et al. 1990). Past use of the GHX-1 study area by brood-rearing Snow Geese has fluctuated between relatively low levels of use during some years (1983-1985, 1988) (WCC 1983, 1985; Murphy et al. 1986, 1989, 1990) and no use during other years (1986 and 1987) (Murphy et al. 1987, 1988). The GHX-1 study area was not used by Snow Geese during nesting or fall staging in either 1989 or 1990.

Tundra Swan

Tundra Swans were paired upon their arrival in the study area and occurred in low density during pre-nesting (Table 1); a high count of two birds was recorded on 2 June (Figure 9, Appendix 3). Sightings of Tundra Swans during pre-nesting were concentrated west of DS-L1 (Figure 3). A single swan was seen sporadically during the nesting season and was apparently one of the breeding pair that nested along the Prudhoe Bay coast approximately 1 km north of LGI. This pair produced four young and moved into the GHX-1 study area for most of the brood-rearing season (Figures 5 and 9). This family group moved north out of the study area after 13 August. A family group of two adults and two young were seen in the study area during September (Figure 6) and may have been either the original brood that had suffered 50% mortality of young or a different brood entirely. Single and pairs of swans also were seen sporadically during fall staging. Mean densities never exceeded 0.5 birds/km^2 during any season (Table 1). Differences in distribution and abundance of Tundra Swans between 1989 and 1990 were difficult to evaluate due to the relative paucity of sightings in each year. The major difference between years was the consistent use of the study area by the swan family in 1990.

Ducks

Nine species of ducks used the GHX-1 study area in 1990: Northern Pintail, American Wigeon (*Anas americana*), Eurasian Wigeon (*A. penelope*), Oldsquaw, Green-winged Teal, Mallard (*A. platyrhynchos*), Northern Shoveler (*A. clypeata*), King Eider, and Spectacled Eider (Appendix 3). Three species (American and Eurasian wigeons and

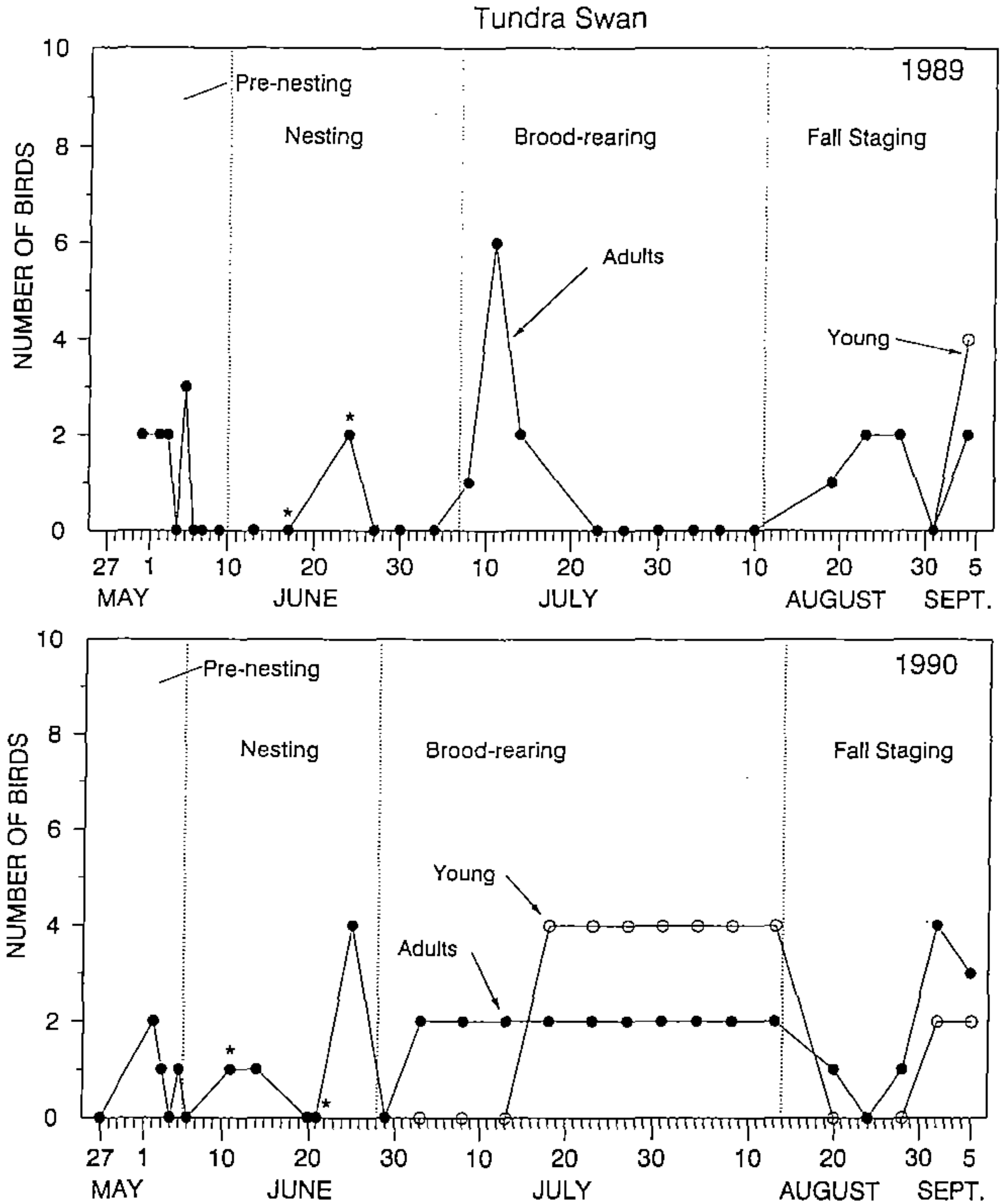


Figure 9. Counts of Tundra Swans from road and foot surveys in the GHX-1 study area, Prudhoe Bay, Alaska, 1989 and 1990. Asterisks indicate foot surveys during nesting.

Northern Shoveler) were seen on <5 surveys and two species (Green-winged Teal and Mallard) were seen on <10 surveys; all other species were relatively common. No nests of ducks or eiders were found in the GHX-1 study area in 1990.

Green-winged Teal occurred in the GHX-1 study area only during the nesting and fall-staging seasons (Appendix 3). A pair was seen twice (11 and 21 June) in the wetlands near the CCP flare during the nesting season (Figure 10). During fall staging, pairs of teal were seen adjacent to DS-L1, just east of WGI, and southwest of CGF (Figure 11); a maximum of four birds was seen on 1 September. Mean seasonal density of Green-winged Teal never exceeded 1 bird/km^2 (Table 1). No Green-winged Teal were seen in the study area in 1989 (Anderson et al. 1990).

Mallards occurred during all seasons in 1990 (Appendix 3). A maximum of ten Mallards was seen on 11 June, most other sightings were of single birds or pairs. The clustering of sightings in two locations (east of the CCP flare and near the southern boundary of the study area) suggests that some observations were repeated sightings of the same bird(s) (Figures 10, 12, and 13). The remainder of the sightings were scattered throughout the western half of the study area. Densities of Mallards never exceeded 1 bird/km^2 during any season (Table 1). Mallards were not seen in the GHX-1 study area in 1989 (Anderson et al. 1990).

Northern Pintails were the most common and abundant ducks in the GHX-1 study area in 1990. A maximum number of 52 pintails was recorded on 11 June (Appendix 3); counts exceeded 40 birds on four other surveys (Figure 14). Numbers of pintails fluctuated during pre-nesting and nesting before declining during early brood-rearing. After 20 July, pintail numbers increased until they leveled off during fall staging. During pre-nesting, Northern Pintails were seen primarily in ponds adjacent to the road system in the northern half of the study area, but were more widely distributed during nesting, brood-rearing, and fall staging (Figures 10, 11, 13, and 15). Seasonal mean densities followed a similar pattern with a peak density of 4.2 birds/km^2 during fall staging (Table 1). Except during the brood-rearing season, the densities of Northern Pintails in the study area were greater during all seasons in 1990 than in 1989 (Table 1). The year-to-year difference during brood-rearing was due to the greater use of

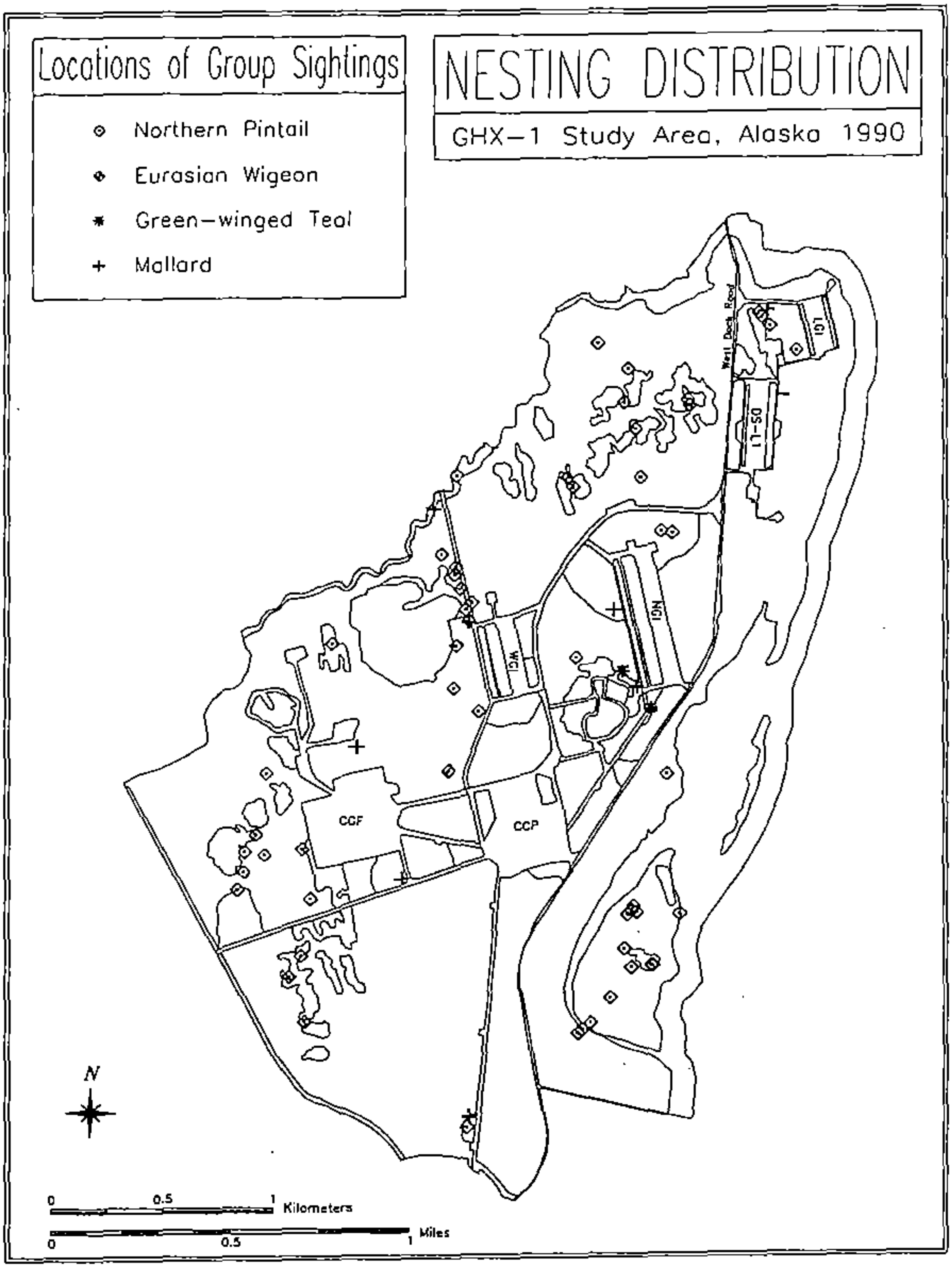


Figure 10. Distribution of Northern Pintails, Eurasian Wigeon, Green-winged Teal, and Mallards during nesting in the GHX-1 study area, Prudhoe Bay, Alaska, 1990. Group sightings were of one or more birds.

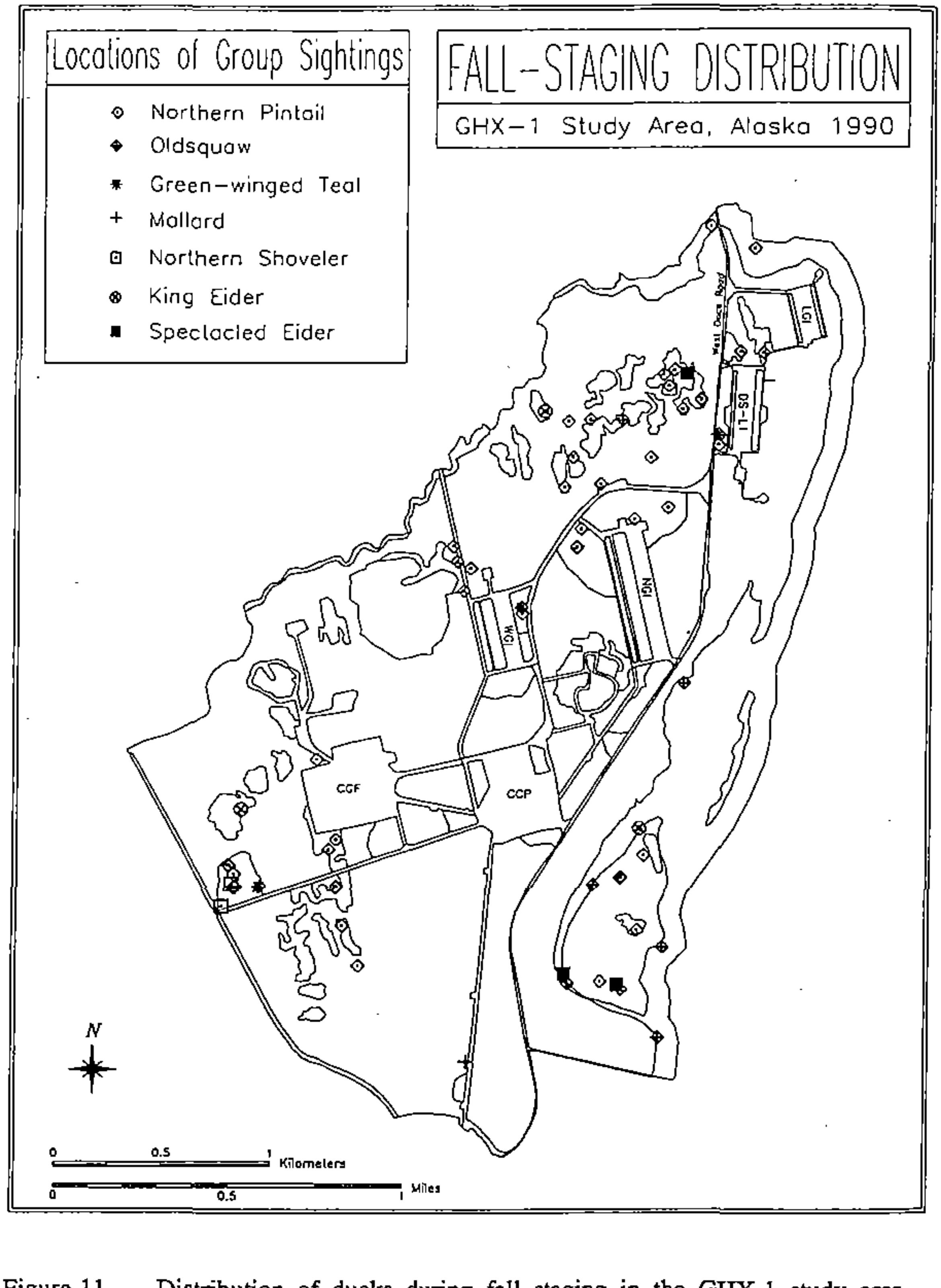


Figure 11. Distribution of ducks during fall staging in the GHX-1 study area, Prudhoe Bay, Alaska, 1990. Group sightings were of one or more birds.

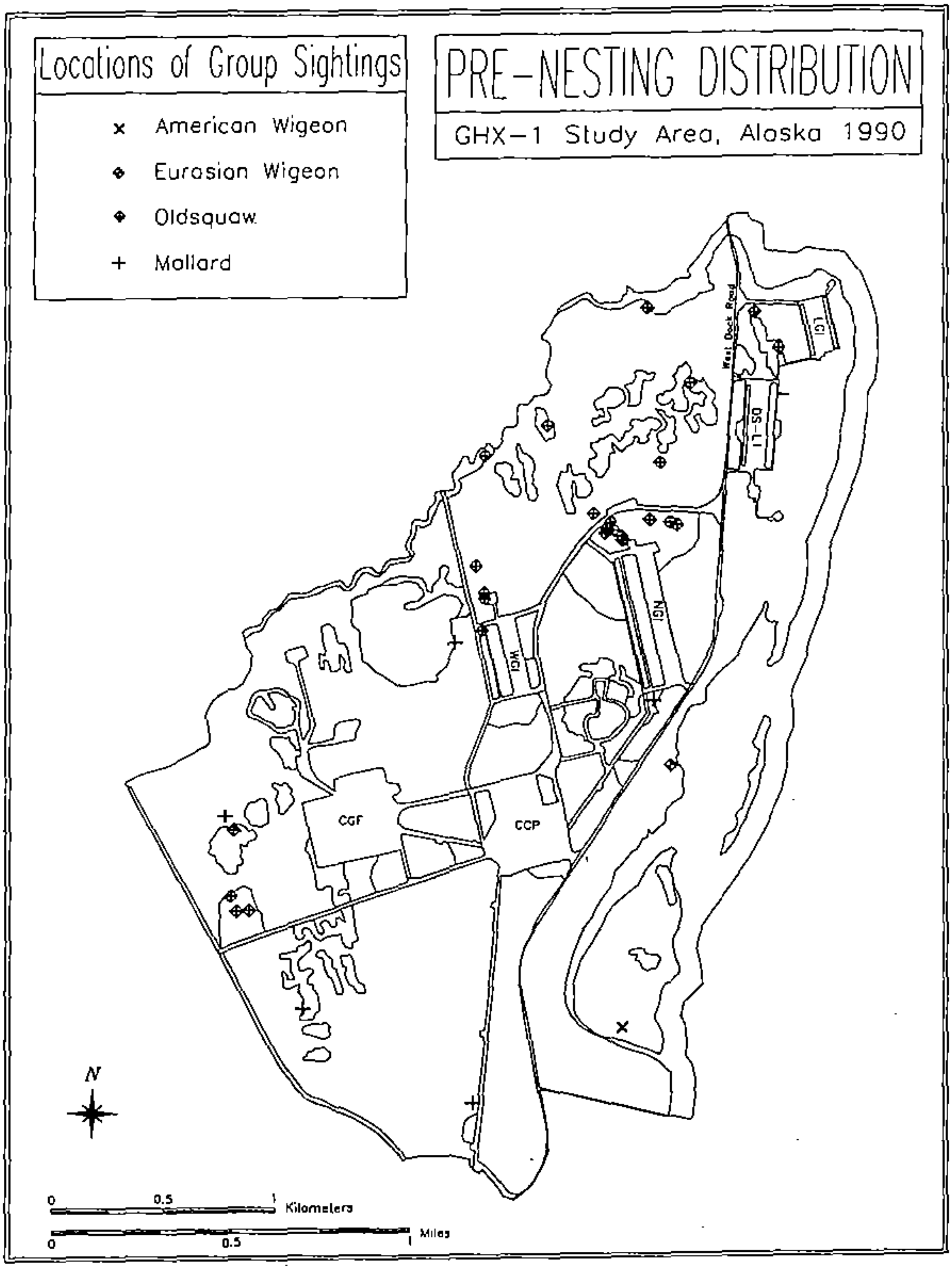


Figure 12. Distribution of American Wigeon, Eurasian Wigeon, Oldsquaw, and Mallards during pre-nesting in the GHX-1 study area, Prudhoe Bay, Alaska, 1990. Group sightings were of one or more birds.

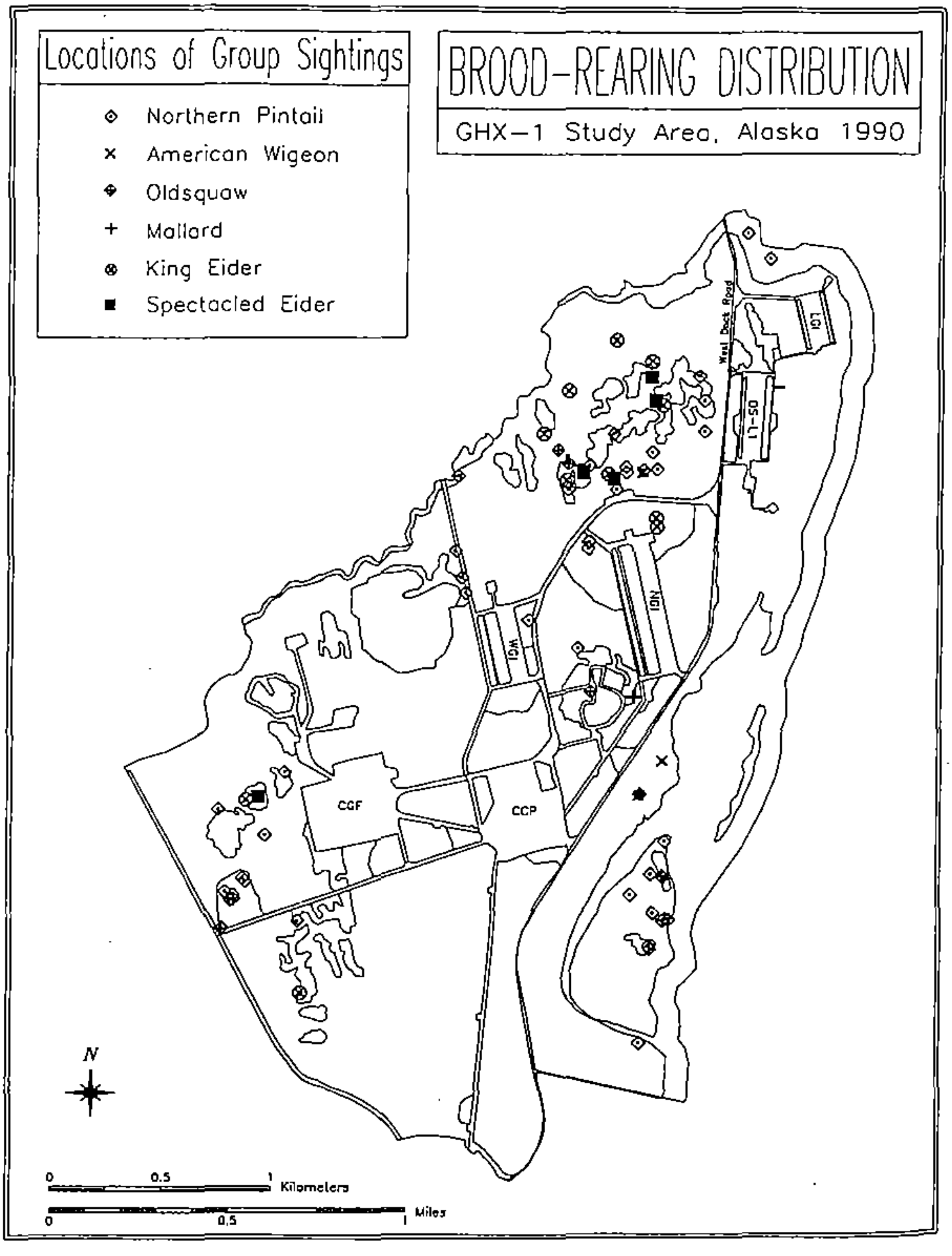


Figure 13. Distribution of Northern Pintails, American Wigeon, Oldsquaw, Mallards, King Eiders, and Spectacled Eiders during brood-rearing in the GHX-1 study area, Prudhoe Bay, Alaska, 1990. Group sightings were of one or more birds.

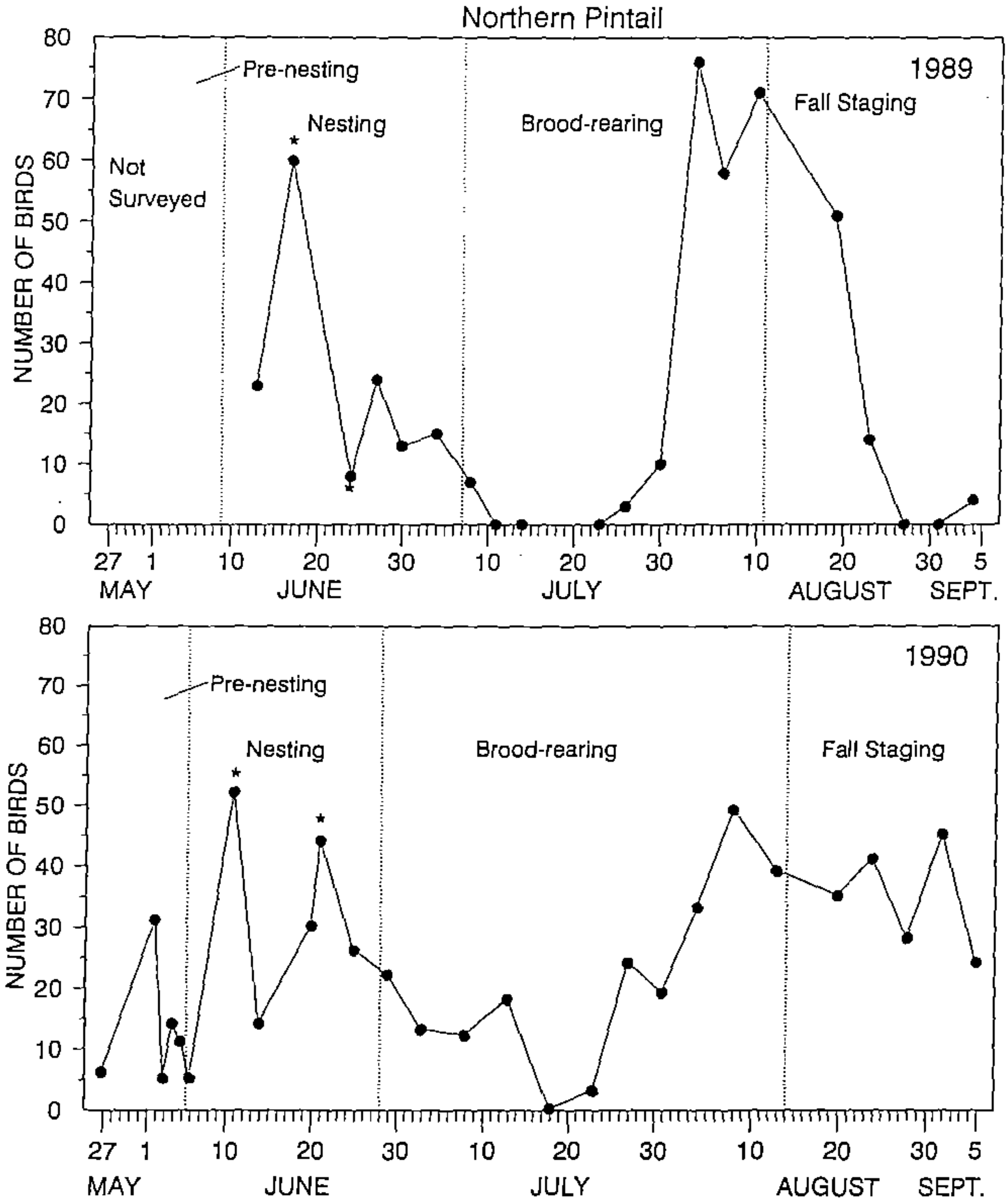


Figure 14. Counts of Northern Pintails from road and foot surveys in the GHX-1 study area, Prudhoe Bay, Alaska, 1989 and 1990. Asterisks indicate foot surveys during nesting.

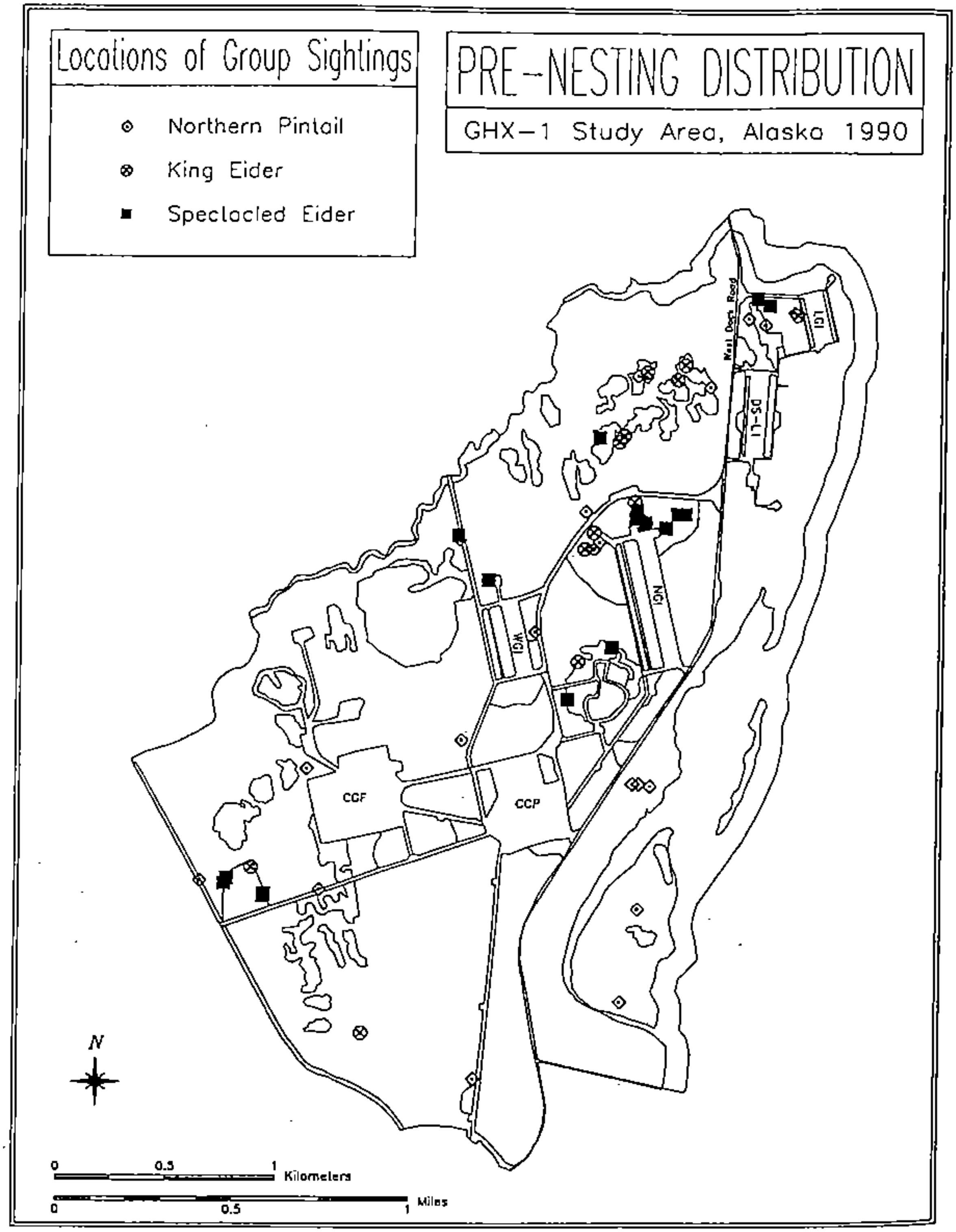


Figure 15. Distribution of Northern Pintails, King Eiders, and Spectacled Eiders during pre-nesting in the GHX-1 study area, Prudhoe Bay, Alaska, 1990. Group sightings were of one or more birds.

impoundments near NGI in 1989. These impoundments were drained partially in late August and September 1989 and did not refill during 1990, thus they did not provide the shallow, aquatic habitat preferred by dabbling ducks such as pintails (Anderson et al. 1990).

Northern Shovelers were seen during only three surveys in 1990 (Appendix 3). A pair of shovelers was seen on 21 June northwest of WGI (Figure 16) and a single bird was seen on 24 and 28 August southwest of CGF (Figure 11). Mean density was <0.1 birds/km^2 during any season (Table 1). Northern Shovelers were not seen in the GHX-1 study area in 1989 (Anderson et al. 1990).

American Wigeon occurred during only three surveys in 1990; a maximum count of 12 birds was recorded on 12 August (Appendix 3). Except for one flock seen north of NGI, most wigeon were seen along the coast southeast of CCP (Figures 12-13). American Wigeon were seen during only the pre-nesting and brood-rearing seasons and mean density never exceeded 0.5 birds/km^2 during either season (Table 1). The numbers and distribution of American Wigeon in the study area were relatively similar between 1989 and 1990 (Anderson et al. 1990).

Eurasian Wigeon (a pair) were seen during two surveys (4 and 6 June) in 1990 (Appendix 3). This species is a rare visitor to the arctic coastal plain and has been recorded several times in the Prudhoe Bay area (Johnson and Herter 1989, D.D. Gibson, Univ. Alaska Museum, pers. comm.). This pair was seen adjacent to a coastal pond east of NGI on 4 June (Figure 12) and resting near a tundra pond northwest of NGI on 6 June (Figure 10).

Oldsquaw counts in the GHX-1 study area peaked at 20 birds on 3 June before declining throughout the nesting and brood-rearing seasons (Figure 17, Appendix 3). Numbers of Oldsquaw increased again during fall staging, but not to the levels seen during pre-nesting. Seasonal mean densities of Oldsquaw exceeded 1 bird/km^2 only during the pre-nesting and nesting seasons (Table 1). Oldsquaw were distributed throughout most of the study area where aquatic habitat was available. The patterns of abundance and distribution in the study area were similar between 1989 and 1990 (Figure 17; Anderson et al. 1990).

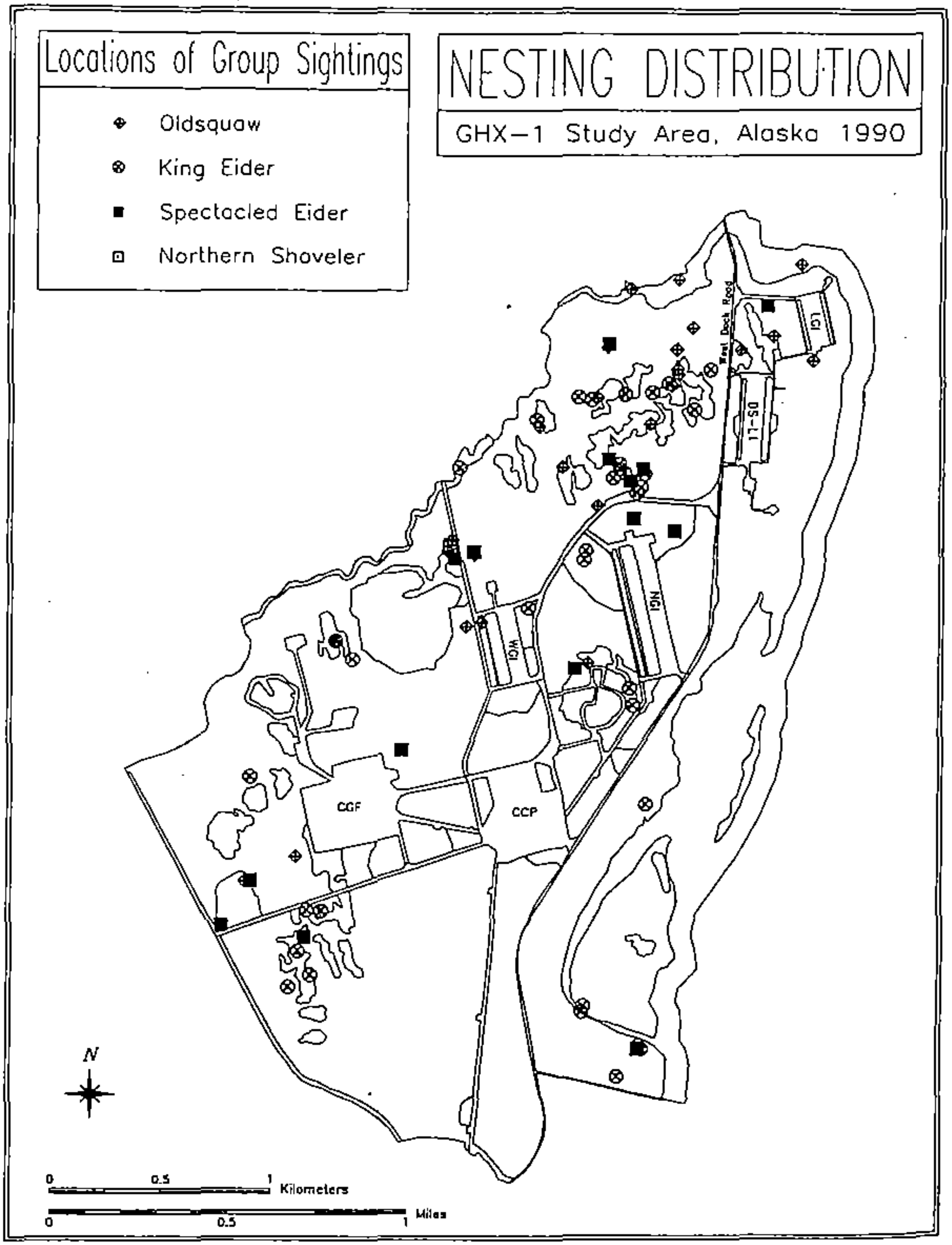


Figure 16. Distribution of Oldsquaw, King Eiders, Spectacled Eiders, and Northern Shovelers during nesting in the GHX-1 study area, Prudhoe Bay, Alaska, 1990. Group sightings were of one or more birds.

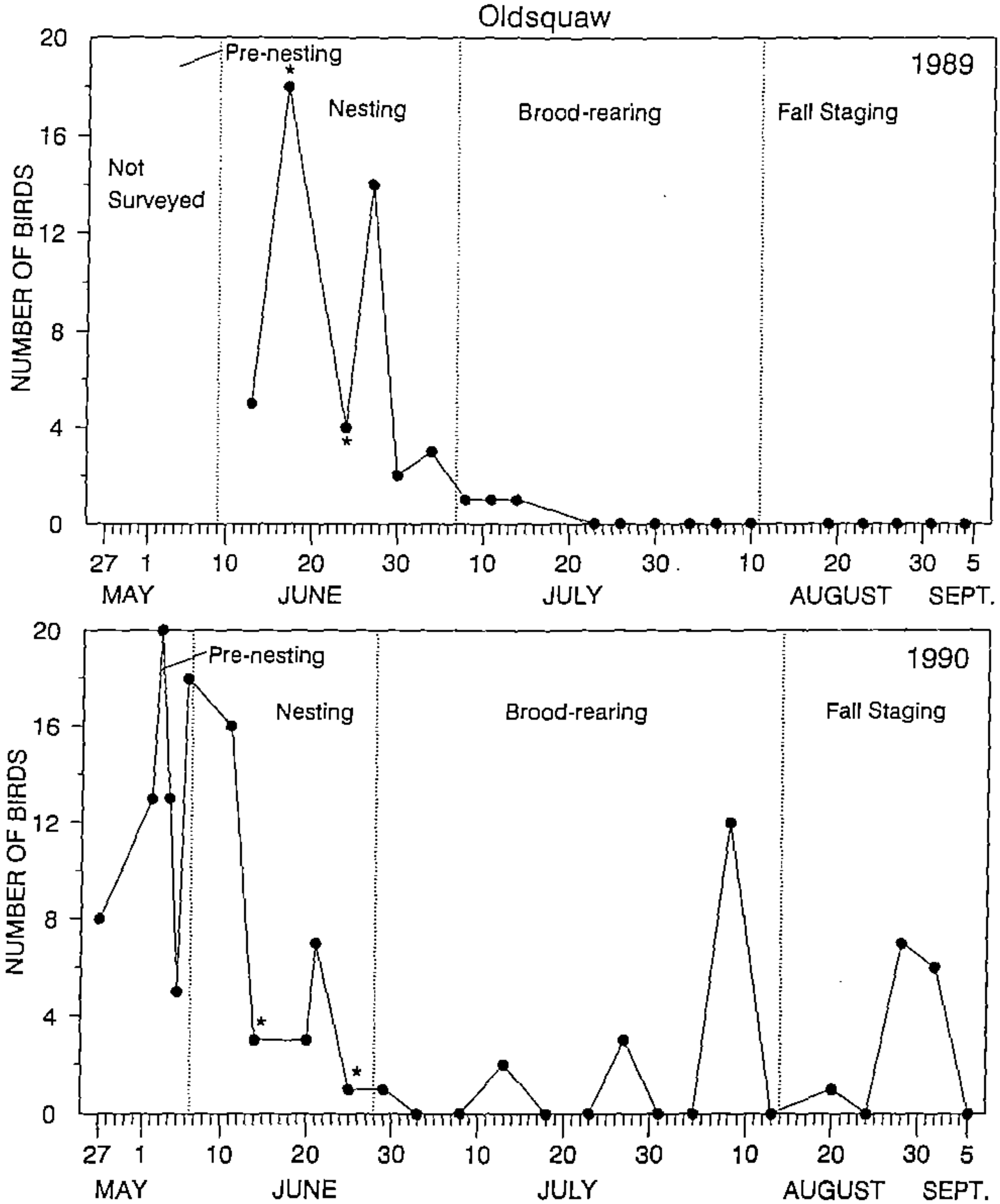


Figure 17. Counts of Oldsquaw from road and foot surveys in the GHX-1 study area, Prudhoe Bay, Alaska, 1989 and 1990. Asterisks indicate foot surveys during nesting.

King Eiders were most abundant in the GHX-1 study area during pre-nesting and nesting (Figure 18); a maximum count of 27 eiders was recorded on 11 June (Appendix 3). Although no King Eider nests were found in the GHX-1 study area, the first brood (two young) was seen on 13 July. The presence of King Eider broods in the study area may indicate that nests were missed during the nest surveys or that broods moved into the study area from outside the boundaries. Except during nesting, seasonal mean densities were <1 bird/km^2 (Table 1). King Eiders occurred in most parts of the study area, but were concentrated in the vicinity of NGI and CGF (Figures 11, 13, 15, and 16). Except during the brood-rearing season, the abundance and distribution of King Eiders was similar between 1989 and 1990 (Anderson et al. 1990). The numbers of adult and young King Eiders were greater and eiders were more widely distributed in the study area during brood-rearing in 1990 compared to 1989 (Figure 18, Anderson et al. 1990).

Spectacled Eiders were present in the study area during the first survey on 27 May; a peak count of nine eiders was recorded during two surveys (2 and 9 June) (Figure 19, Appendix 3). Numbers of Spectacled Eiders remained relatively constant until 20 June when numbers began to fluctuate between surveys. Although no Spectacled Eider nests were found in the study area, a maximum of 19 young Spectacled Eiders (one creche [several broods] of 15 young and a brood of four young) was seen on 31 July. The first appearance of these broods late in the brood-rearing season may indicate that they moved into the study area from outside, rather than being from nests that were missed during the nest searches. Seasonal mean densities of Spectacled Eiders never exceeded 0.5 birds/km^2 except pre-nesting when mean density was 0.8 birds/km^2 (Table 1). Spectacled Eiders were seen in the study area in primarily the same areas as King Eiders; most observations were concentrated in the vicinity of NGI (Figures 11, 13, 15, and 16). Spectacled Eiders were more common and more widely distributed in the study area in 1990 than in 1989 (Anderson et al. 1990).

Loons

Pacific Loons were seen first in the study area on 5 June; a maximum count of 24

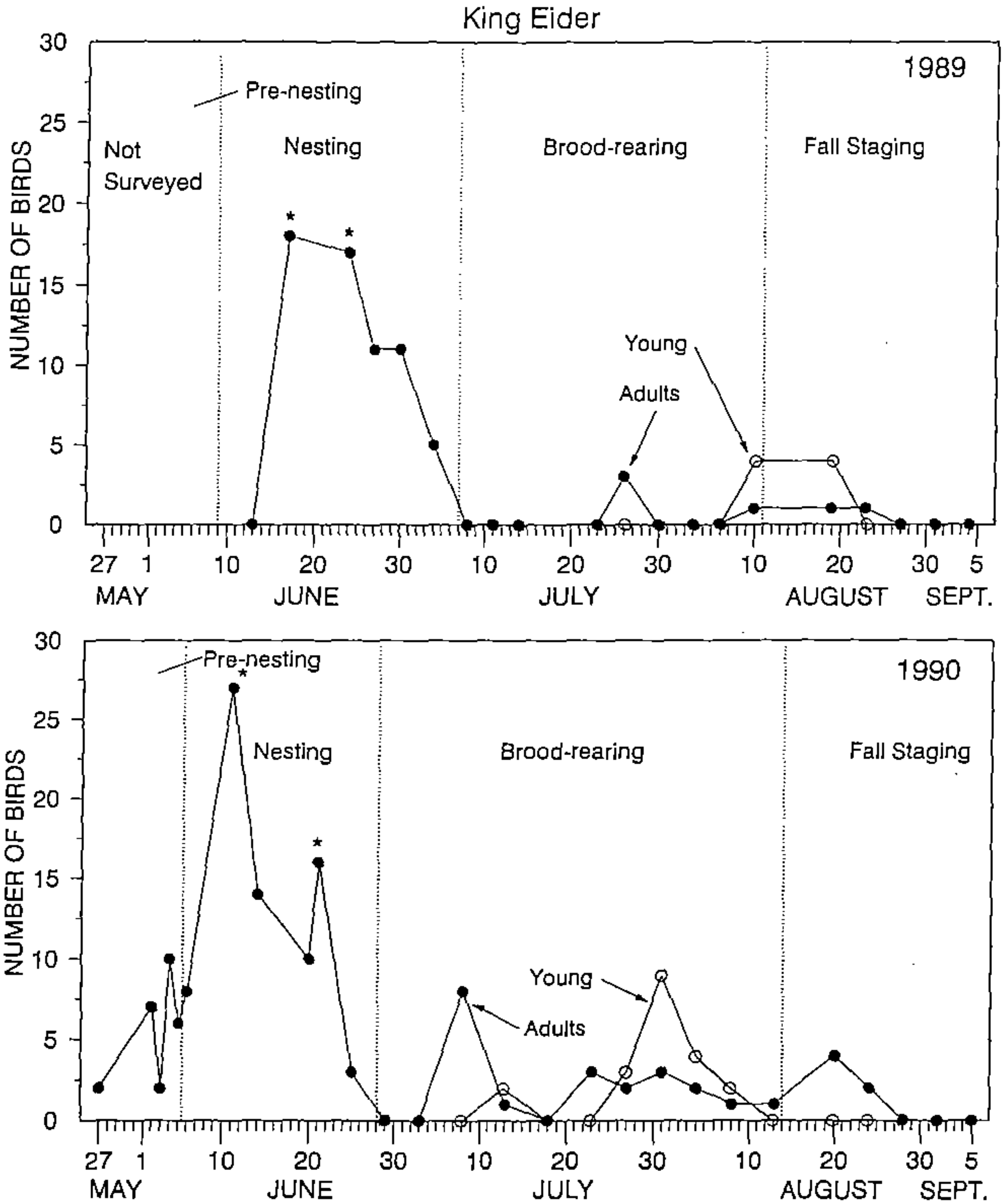


Figure 18. Counts of King Eiders from road and foot surveys in the GHX-1 study area, Prudhoe Bay, Alaska, 1989 and 1990. Asterisks indicate foot surveys during nesting.

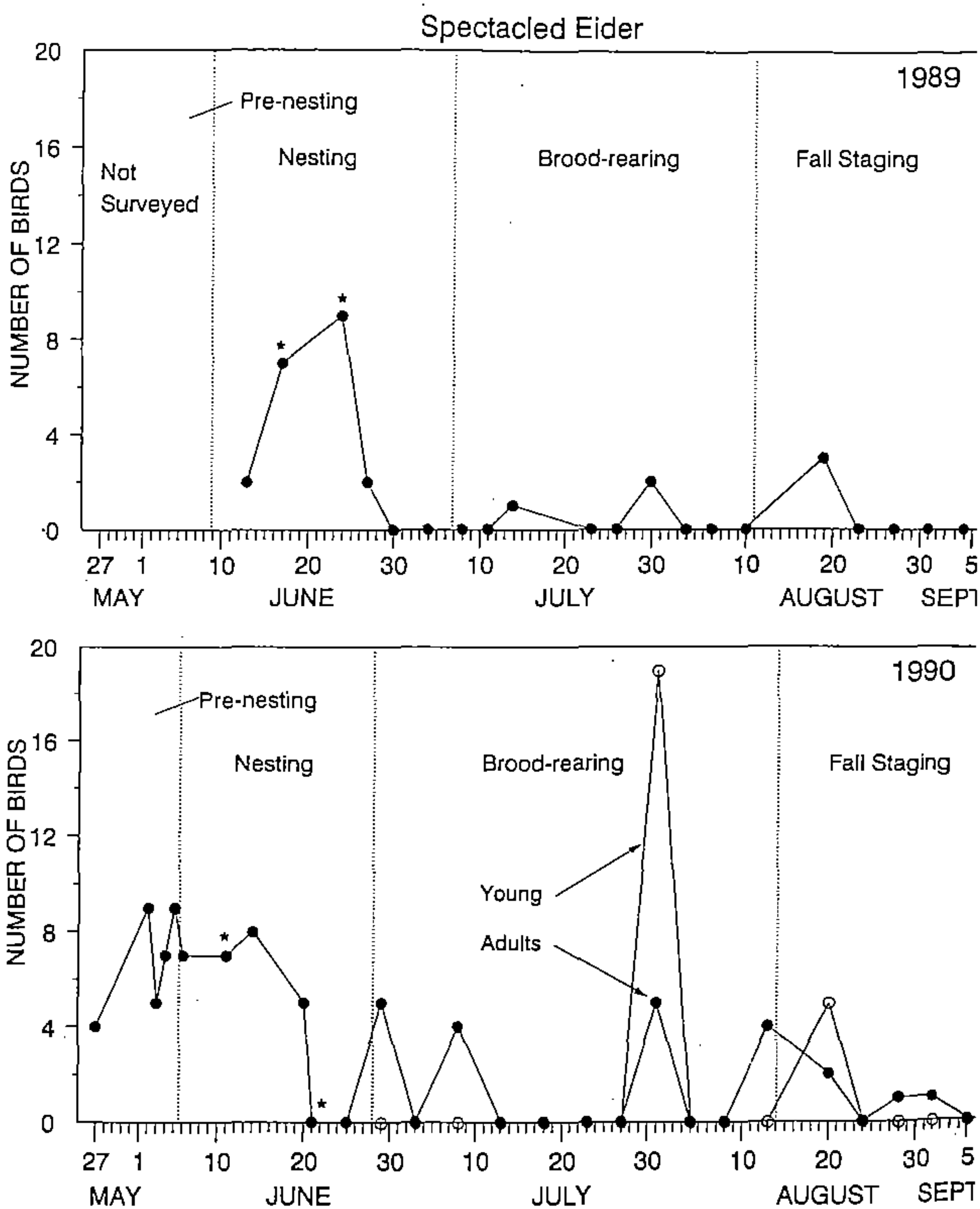


Figure 19. Counts of Spectacled Eiders from road and foot surveys in the GHX-1 study are Prudhoe Bay, Alaska, 1989 and 1990. Asterisks indicate foot surveys duri nesting.

(19 adults and 5 young) was recorded on 28 August (Figure 20, Appendix 3). Numbers of Pacific Loons were relatively constant throughout the nesting and brood-rearing seasons (except for the peak occurrence on 28 August) before declining during fall staging. Eight pairs of Pacific Loons nested in the study area in 1990; nest sites tended to be clustered in the northern half of the study area (Figure 4). A maximum of six young loons was recorded during brood-rearing and numbers of both adults and young declined during fall staging, when young became flight capable and left the immediate vicinity of the nest (Figure 20, Appendix 3). Pacific Loons were seen mainly near nest sites during the pre-nesting, nesting, and brood-rearing seasons (Figures 4, 21, and 22). During both brood-rearing and fall staging, Pacific Loons were seen regularly in the slough north of LGI and sporadically in the coastal waters near CCP (Figures 22 and 23). Seasonal mean densities were similar during all seasons except pre-nesting when loon numbers were increasing in the study area (Table 1). Two more pairs of Pacific Loons nested in the GHX-1 study area in 1990 than in 1989 and overall numbers were accordingly higher (Figure 20) (Anderson et al. 1990). In addition, more young were seen during brood-rearing in 1990 than in 1989. The distribution of Pacific Loons in the study area was similar between years and some nest sites used in 1989 were re-occupied in 1990.

Red-throated Loons were recorded first on 11 June, approximately one week later than Pacific Loons (Figure 24). Numbers and density of Red-throated Loons using the study area remained low (<5 birds; <0.3 birds/km^2) throughout all seasons (Table 1, Appendix 3). Although only one Red-throated Loon nest was located during the nest searches, the presence of two broods of young on 27 July indicated that one nest (northwest of WGI) was not located during the nest surveys or subsequent road surveys. Red-throated Loons were seen almost exclusively north and east of the WGI pad, near the nests (Figures 21-23), indicating that non-breeding loons rarely used the area. One adult loon was seen in the coastal waters near the Putuligayuk island during late brood-rearing. One nest site used in 1989 was reused in 1990 and the second nest used in 1990 was located within approximately 500 m of the 1989 nest site (Anderson et al. 1990). Red-throated Loons were distributed similarly in the study area in 1989 and 1990.

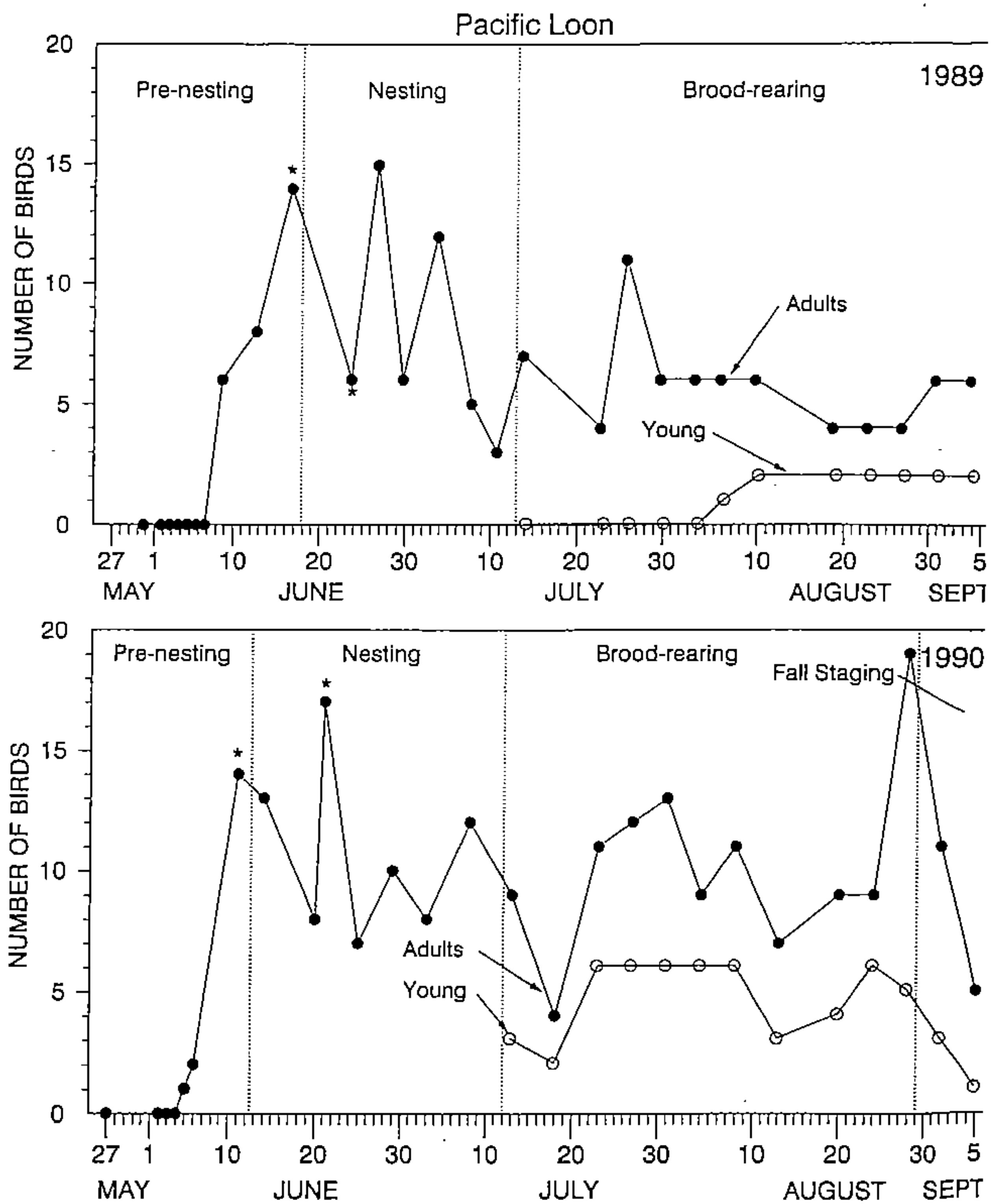


Figure 20. Counts of Pacific Loons from road and foot surveys in the GHX-1 study area Prudhoe Bay, Alaska, 1989 and 1990. Asterisks indicate foot surveys durin nesting.

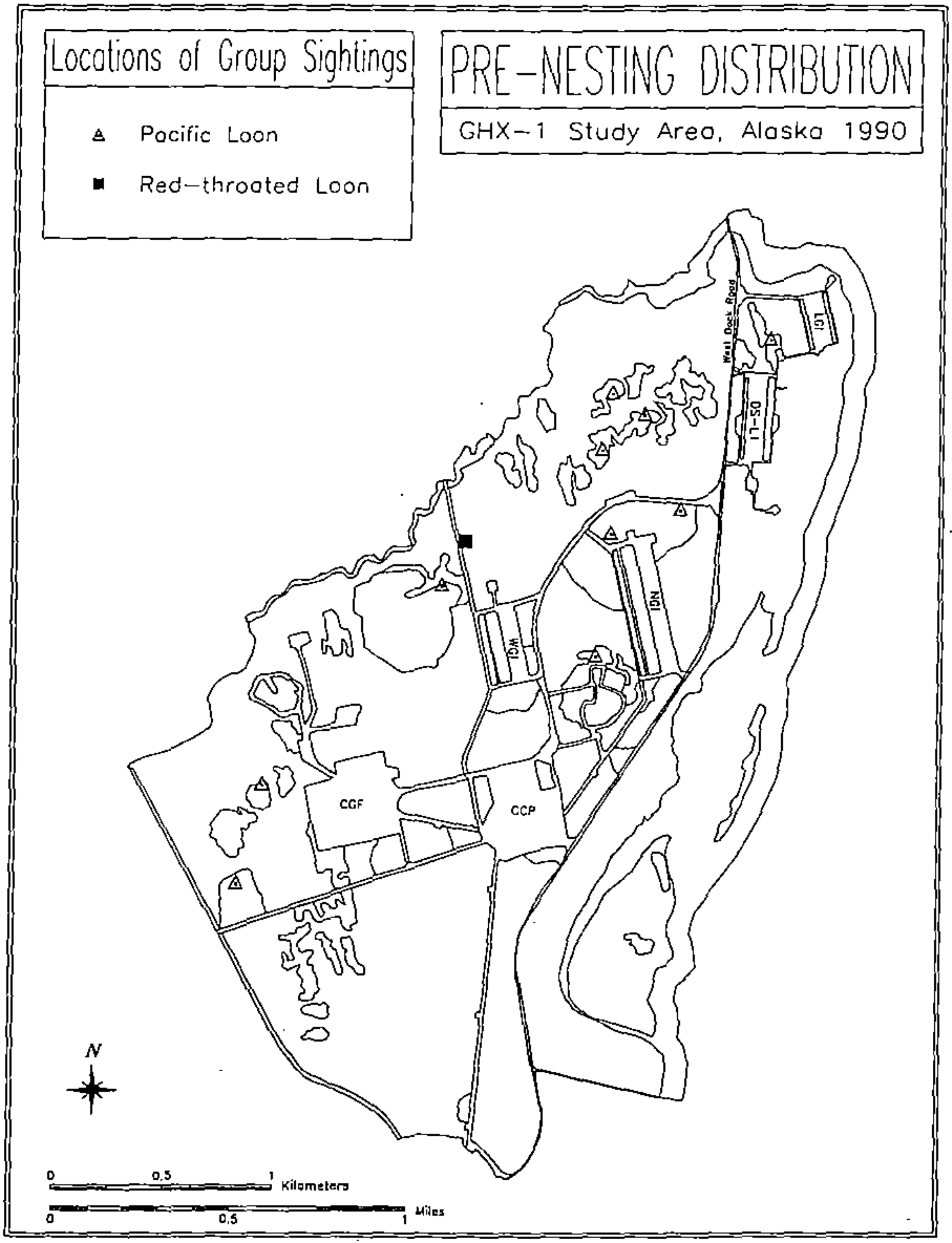


Figure 21. Distribution of Pacific and Red-throated loons during pre-nesting in the GHX-1 study area, Prudhoe Bay, Alaska, 1990. Group sightings were of one or more birds.

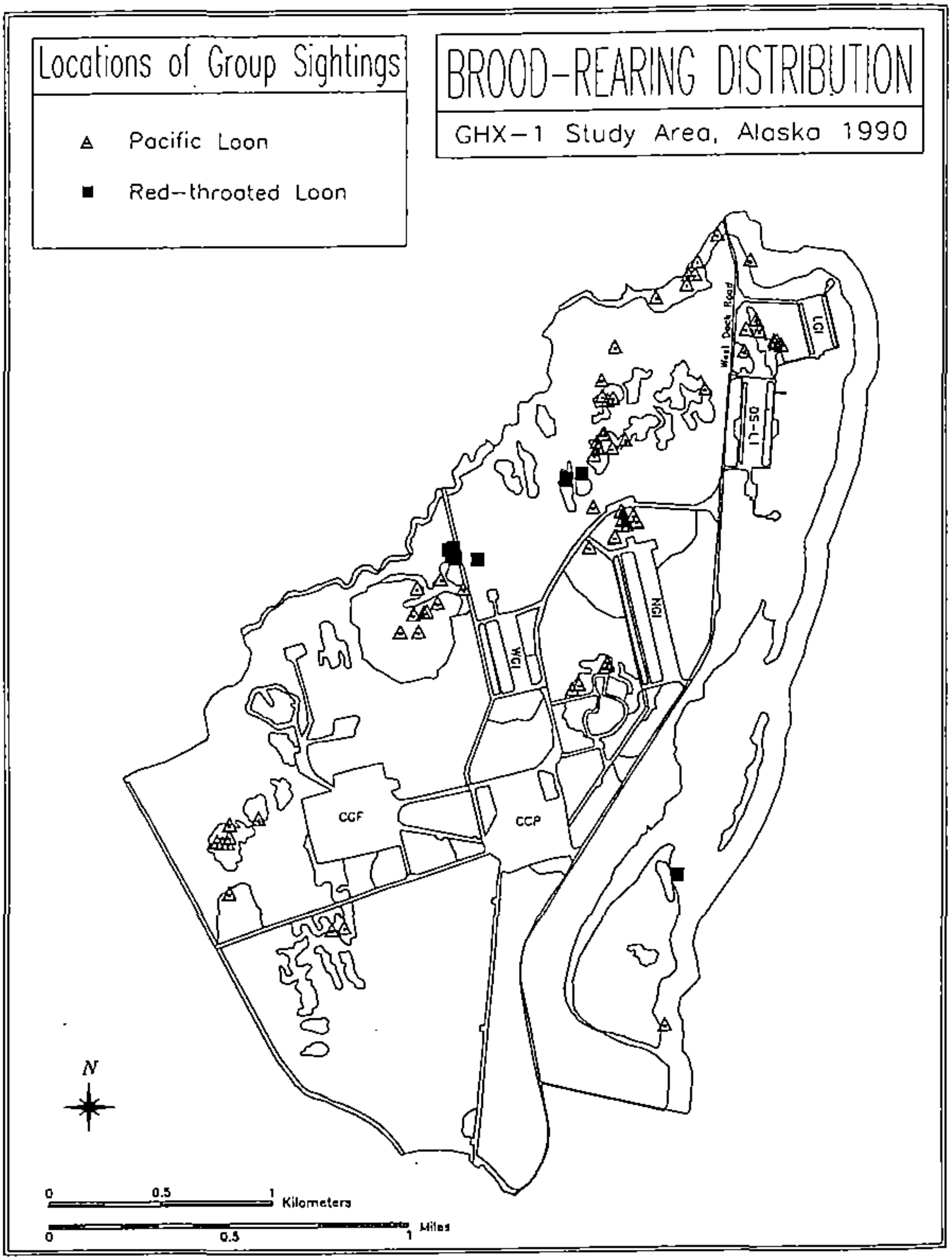


Figure 22. Distribution of Pacific and Red-throated loons during brood-rearing in the GHX-1 study area, Prudhoe Bay, Alaska, 1990. Group sightings were of one or more birds.

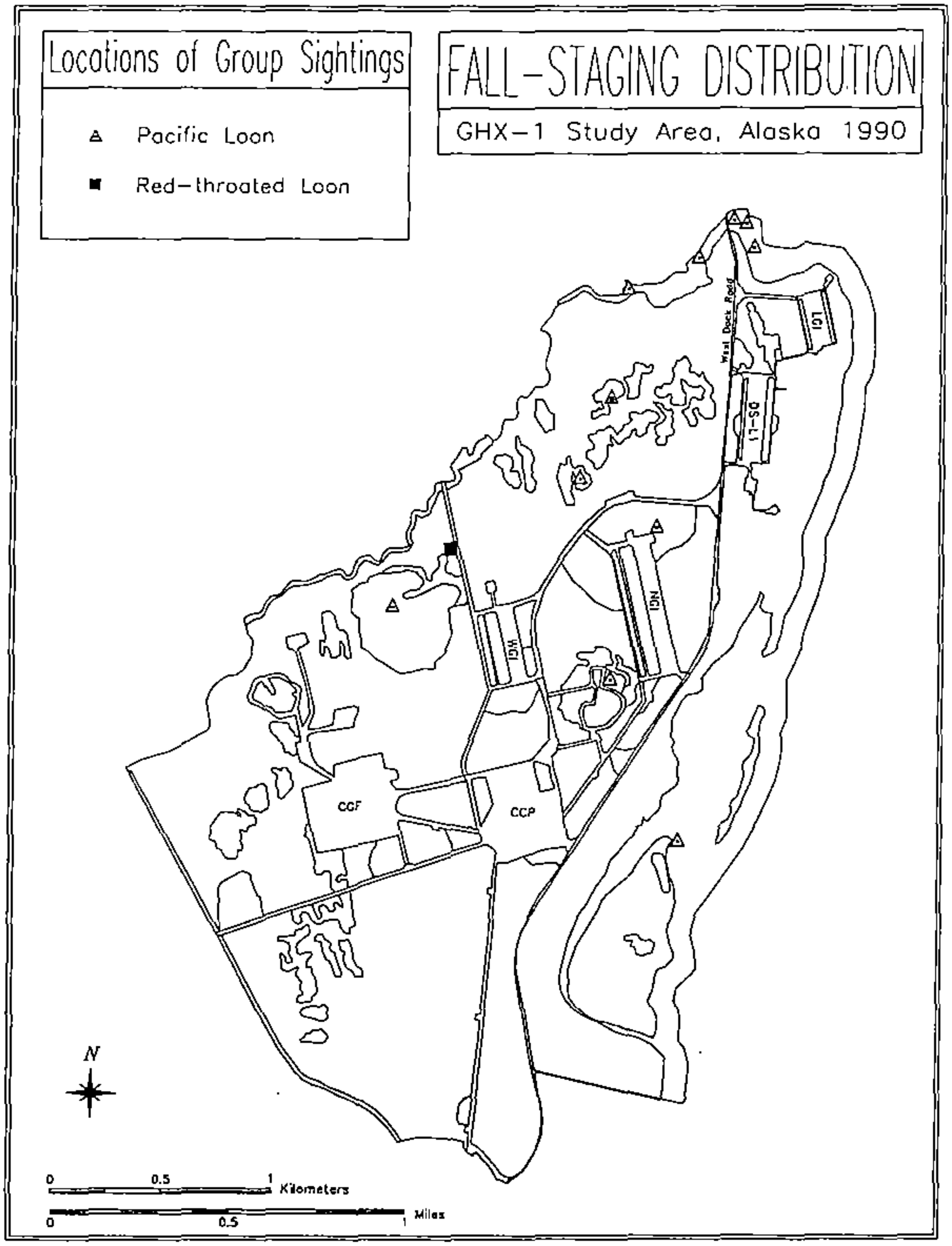


Figure 23. Distribution of Pacific and Red-throated loons during fall staging in the GHX-1 study area, Prudhoe Bay, Alaska, 1990. Group sightings were of one or more birds.

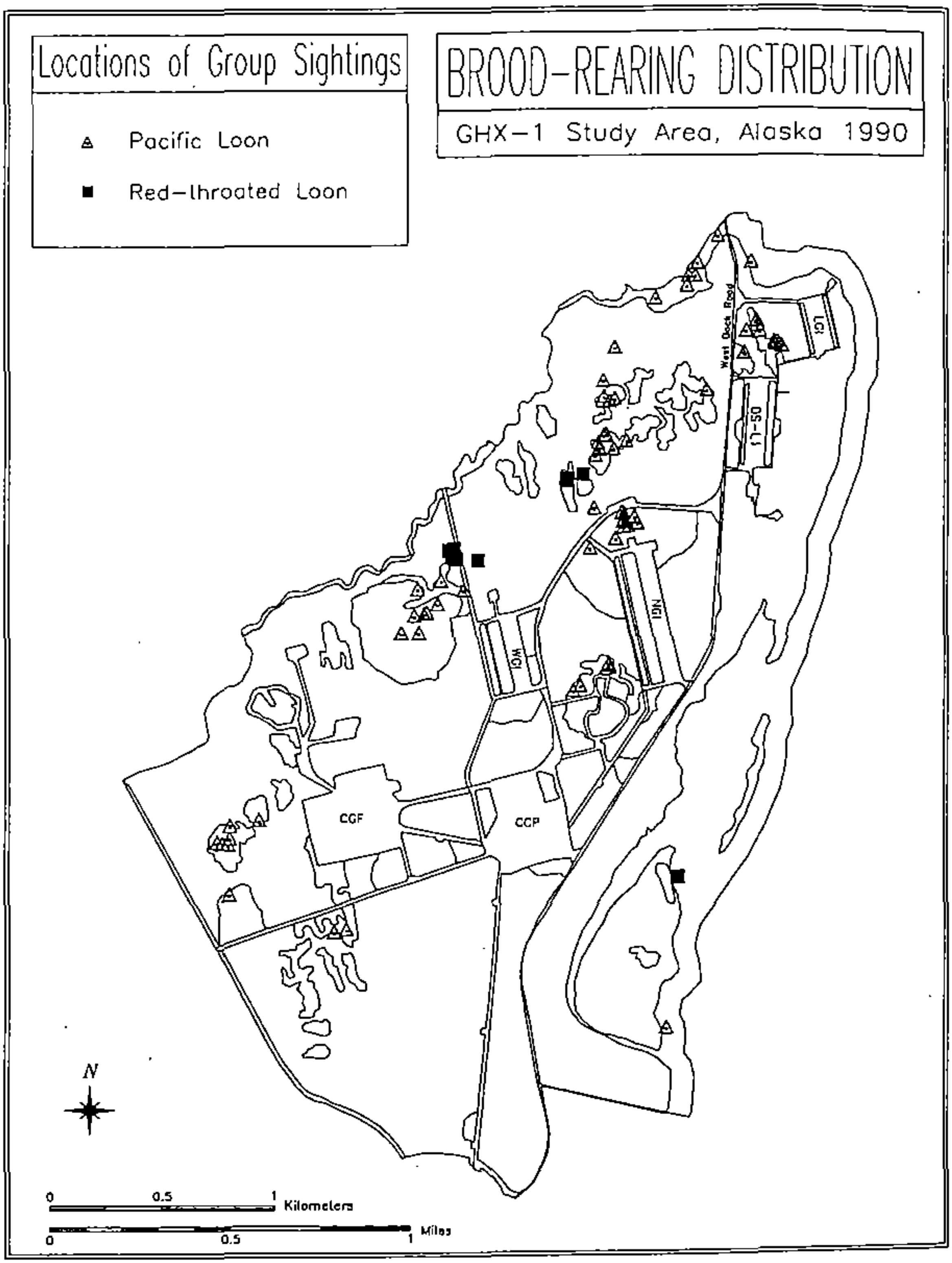


Figure 22. Distribution of Pacific and Red-throated loons during brood-rearing in the GHX-1 study area, Prudhoe Bay, Alaska, 1990. Group sightings were of one or more birds.

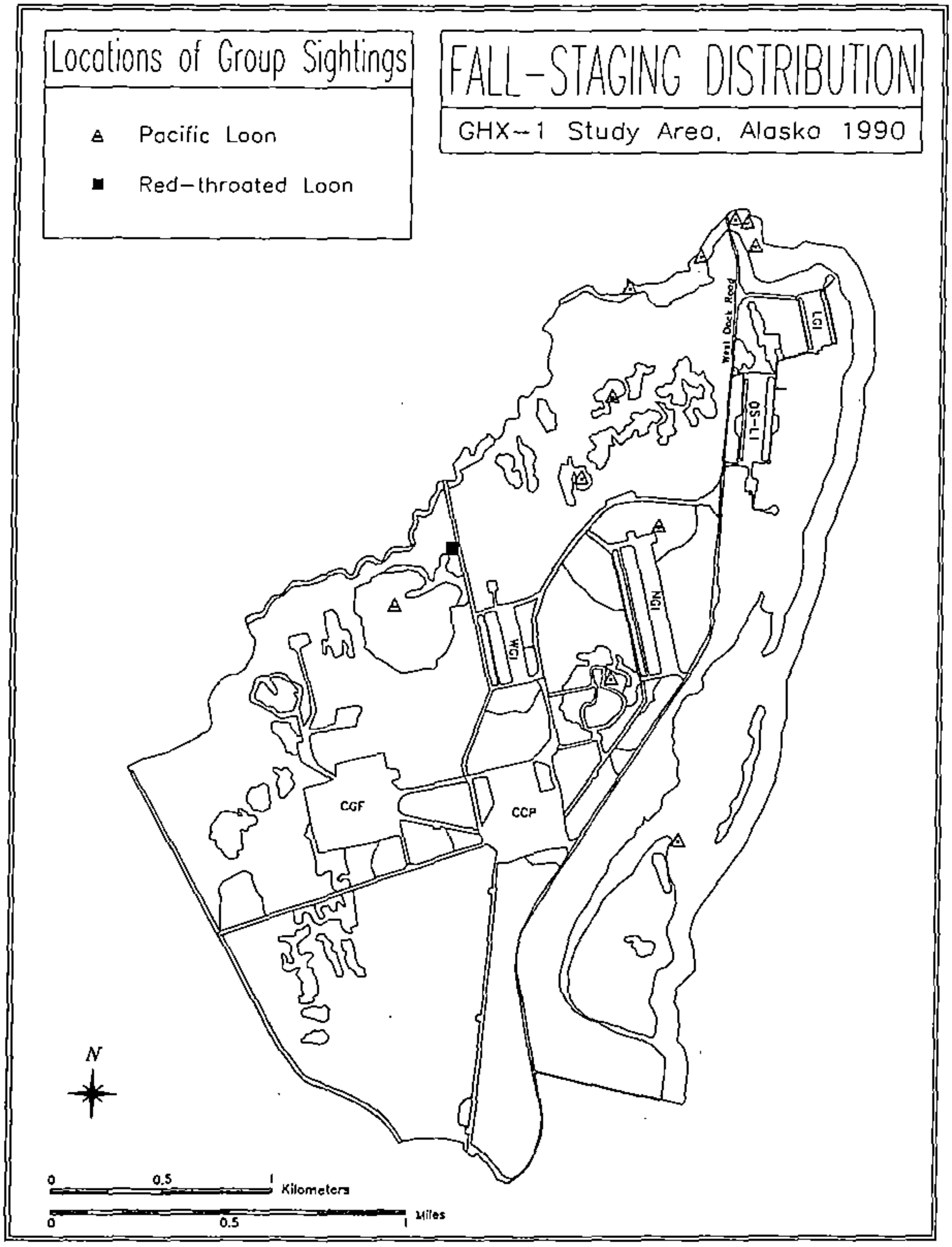


Figure 23. Distribution of Pacific and Red-throated loons during fall staging in the GHX-1 study area, Prudhoe Bay, Alaska, 1990. Group sightings were of one or more birds.

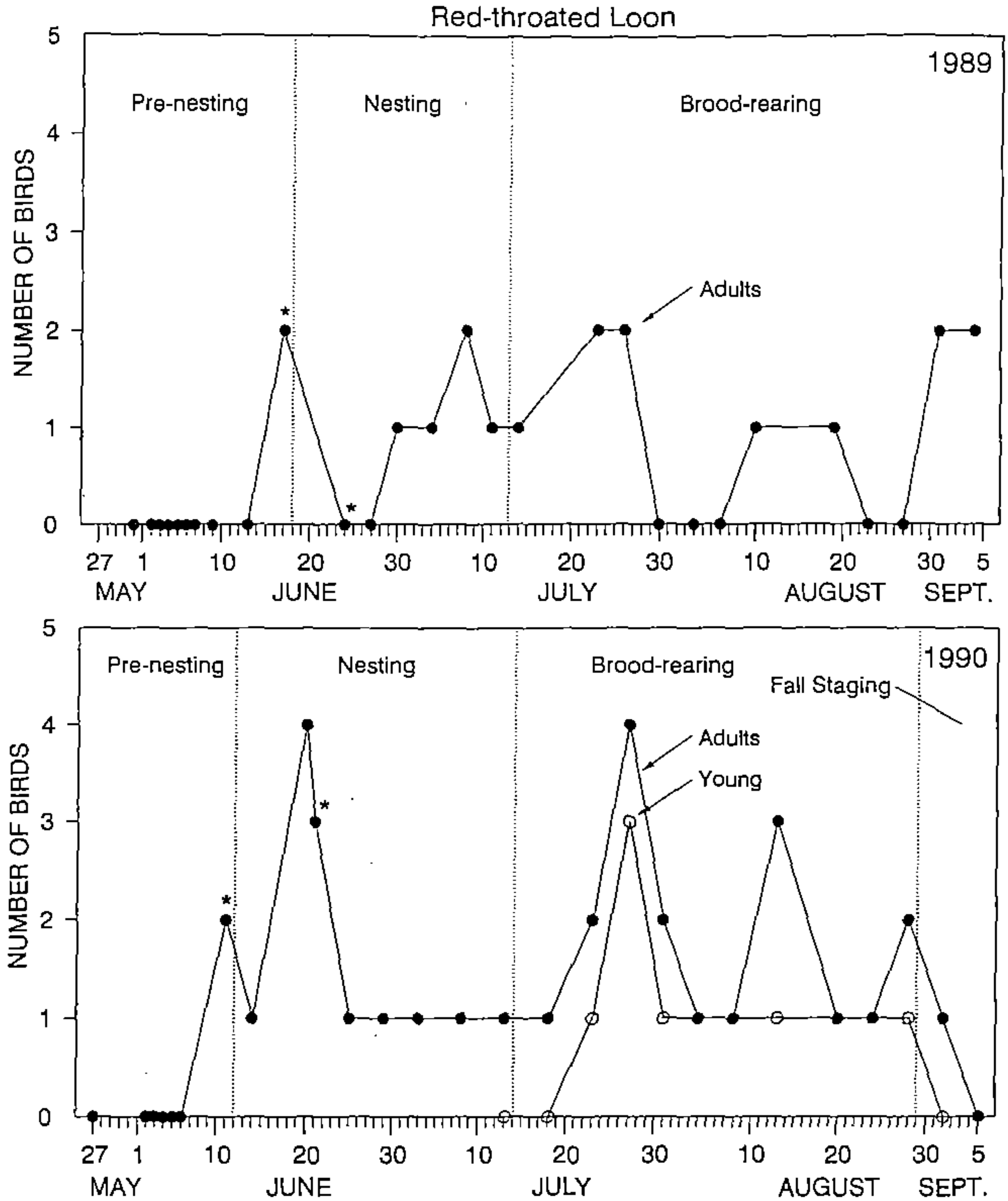


Figure 24. Counts of Red-throated Loons from road and foot surveys in the GHX-1 study area, Prudhoe Bay, Alaska, 1989 and 1990. Asterisks indicate foot surveys during nesting.

Habitat Use

Habitat use varied both among seasons and among species in the GHX-1 study area in 1990. Information on habitat use by waterbirds is presented for Level II habitats, but important Level IV habitats also are discussed when relevant. Basin Wetland Complexes, Wet Meadows, Moist Meadows, and Nearshore Waters were the four most abundant Level II habitats in the study area (Appendix 1). All other habitats contributed <1 km^2 each to the total area.

Seasonal habitat use was determined by calculating the mean density (birds/km^2) of a species in each habitat for each season. These densities are different from those overall seasonal densities presented thus far. To simplify the discussion below, we will refer to these mean densities as densities. For this report, we have characterized general patterns of habitat use during each season. We did not attempt to determine whether habitats were used in proportion to their availability; therefore, we do not discuss habitat selection by waterbirds in the study area.

Geese

Canada Geese used 8 of 11 Level II habitats, but were not seen in Nearshore Waters, Coastal Barrens, and Upland Shrublands (Figure 25). During both pre-nesting and nesting, Canada Geese occurred primarily in Water with Emergents, at densities >25 birds/km^2. The distribution of Canada Goose nests paralleled this same pattern of habitat use, with 8 of 11 (72.7%) nests located in Water with Emergents (Table 2). Six of these eight nests were in aquatic grass with islands and two were in aquatic grass without islands (Level IV habitats). The remaining three nests were located in Basin Wetland Complexes. Coastal Wetland Complexes supported the greatest density (>35 birds/km^2) of Canada Geese during brood-rearing with use divided between salt-affected meadows and halophytic wet meadows (Level IV habitats). Brood-rearing flocks of Canada Geese were seen in Coastal Wetland Complexes, Basin Wetland Complexes, Wet Meadows, Moist Meadows, and Artificial Fill. During fall staging, Canada Geese occurred again in Coastal Wetland Complexes, but at a greatly reduced density compared to brood-rearing; all observations were in salt-affected meadows (Level IV habitat).

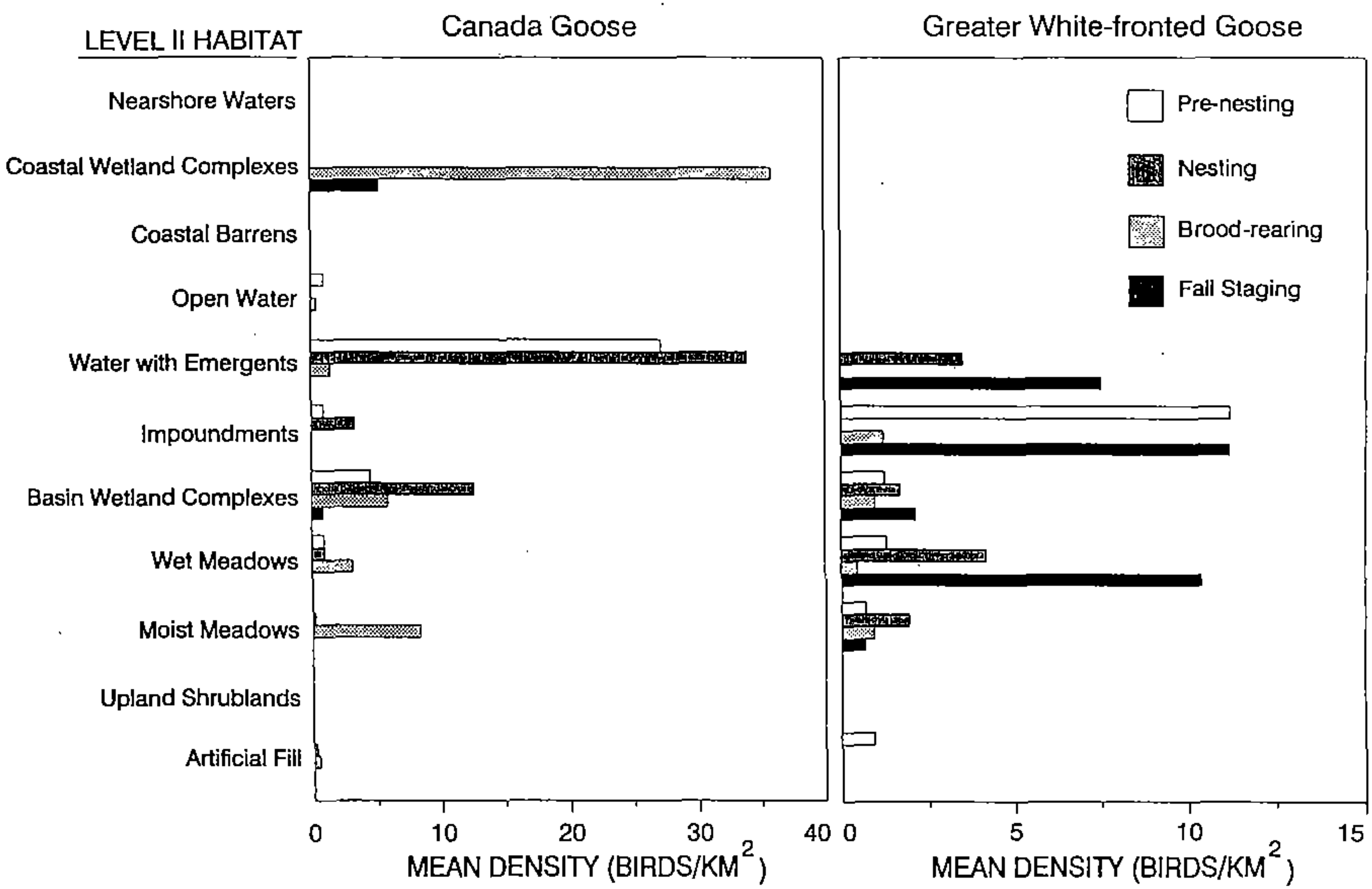

LEVEL II HABITAT
Canada Goose
Greater White-fronted Goose
Nearshore Waters
Coastal Wetland Complexes
Coastal Barrens
Open Water
Water with Emergents
Impoundments
Basin Wetland Complexes
Wet Meadows
Moist Meadows
Upland Shrublands
Artificial Fill
Pre-nesting
Nesting
Brood-rearing
Fall Staging
0
10
20
30
40
MEAN DENSITY (BIRDS/KM^2)
0
5
10
15
MEAN DENSITY (BIRDS/KM^2)

Table 2. Habitat classification of successful and failed waterbird nests in the GHX-1 study area, Prudhoe Bay, Alaska, 1989 and 1990.

Habitat (LEVEL II and Level IV)	Year	Canada Goose		White-fronted Goose		Pacific Loon		Red-throated Loon		All Species	
		Successful	Failed	Successful	Failed	Successful	Failed	Successful	Failed	Successful	Failed
OPEN WATER											
Shallow open water	1989	-	-	-	-	1	0	-	-	1	0
without islands	1990	-	-	-	-	1	0	-	-	1	0
	Total	-	-	-	-	2	0	-	-	2	0
WATER WITH EMERGENTS											
Aquatic grass	1989	-	-	-	-	0	1	-	-	0	1
without islands	1990	2	0	-	-	-	-	-	-	2	0
	Total	2	0	-	-	0	1	-	-	2	1
Aquatic grass	1989	1	3	-	-	1	2	0	1	2	6
with islands	1990	6	0	-	-	2	3	1	0	9	3
	Total	7	3	-	-	3	5	1	1	11	9
IMPOUNDMENTS											
Drainage	1989	0	2	-	-	0	1	-	-	0	3
impoundment	1990	-	-	-	-	1	0	-	-	1	0
	Total	0	2	-	-	1	1	-	-	1	3
BASIN WETLAND COMPLEXES											
Basin wetland	1989	-	-	-	-	-	-	0	1	0	1
complex	1990	2	1	-	-	1	0	-	-	3	1
	Total	2	1	-	-	1	0	0	1	3	2
MOIST MEADOWS											
Moist meadows	1989	-	-	-	-	-	-	-	-	-	-
(high-relief)	1990	-	-	1	0	-	-	-	-	1	0
	Total	-	-	1	0	-	-	-	-	1	0

Canada Geese only used two habitats, Coastal Wetland Complexes and Basin Wetland Complexes, during fall staging. Except for the primary use of Water with Emergents during nesting and Coastal Wetland Complexes during brood-rearing, the patterns of habitat use by Canada Geese were not similar between 1989 and 1990 (Anderson et al. 1990). Canada Geese used a greater variety of habitats during all seasons in 1989 compared to 1990. These differences in habitat use between years may be a function of changes in breeding phenology, flock composition (i.e., more brood-rearing groups in 1990), normal variability, or disturbance-related shifts in distribution. Analyses of distribution, habitat-use patterns, and project-related disturbance will be performed in the final report.

White-fronted Geese concentrated their use of the study area in a few habitats during each season (Figure 25). Impoundments supported the greatest density of White-fronted Geese during pre-nesting (>10 birds/km^2), whereas during nesting, White-fronted Geese occurred in greatest densities in Water with Emergents and Wet Meadows. The single White-fronted Goose nest located in the study area was in Moist Meadows (high relief) (Table 2). Relatively few White-fronted Geese used the study area during brood-rearing and occurred at densities <2.5 birds/km^2. Densities during fall staging rebounded to levels seen during pre-nesting, with Impoundments, Wet Meadows, and Water with Emergents supporting the greatest densities of staging White-fronted Geese. Patterns of habitat use displayed by White-fronted Geese were more similar between 1989 and 1990 than those shown by Canada Geese (Anderson et al. 1990). Only one habitat, Upland Shrublands, was used in 1989 but not in 1990. Seasonal densities in some habitats varied among years, however.

Brant exhibited the most specialized pattern of habitat use of any waterbird in the study area (Figure 26). The greatest density of Brant during each season occurred in Coastal Wetland Complexes, but the seasonal level of use was markedly different. This specialized pattern was even more pronounced for Level IV habitats, where Brant use of Coastal Wetland Complexes was confined to one habitat type, halophytic wet meadows. Pre-nesting Brant were observed only in Coastal Wetland Complexes in 1990, but density did not exceed 20 birds/km^2. During nesting, the failed or non-breeding Brant in the

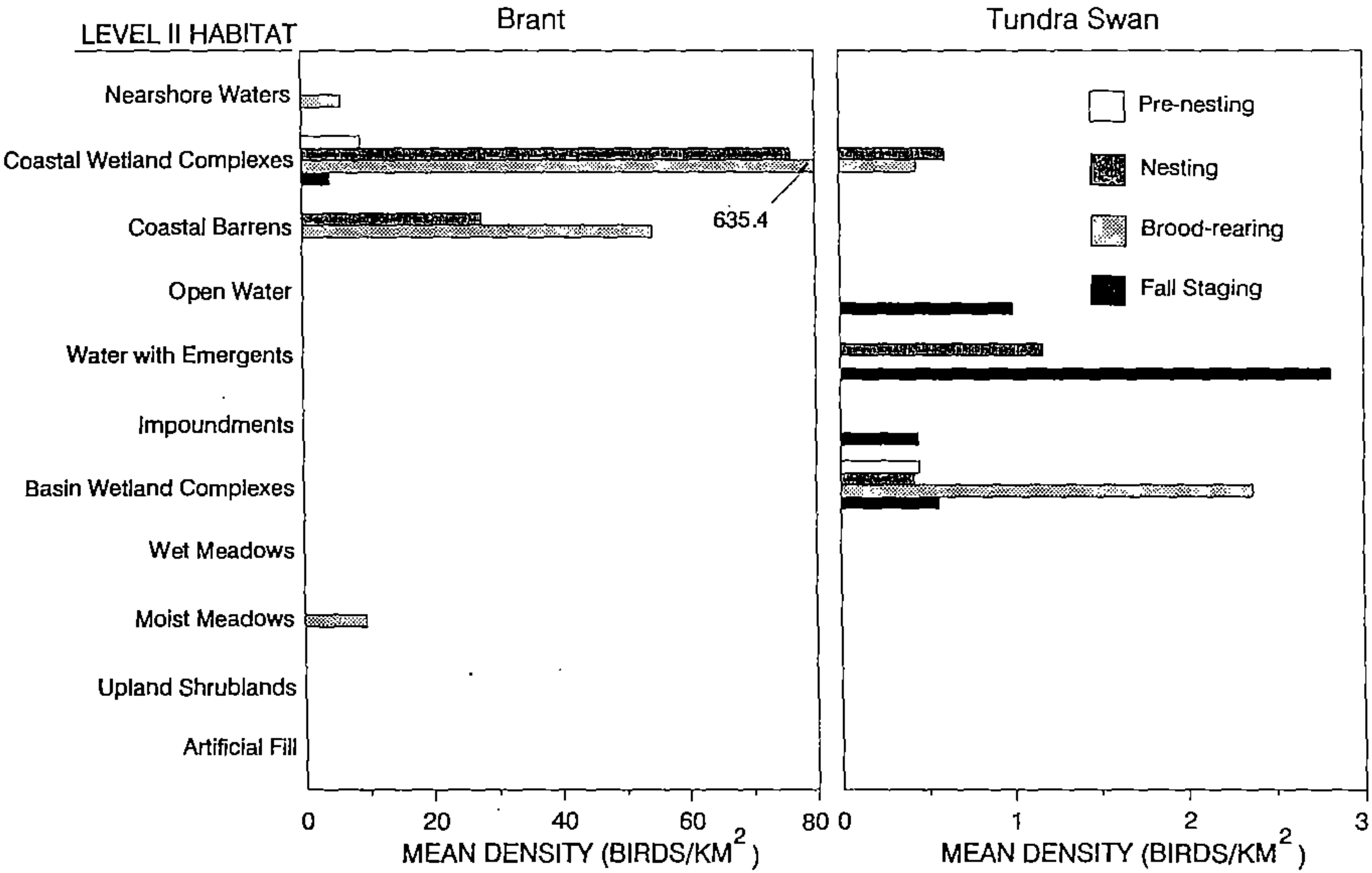


Figure 26. Mean seasonal densities (birds/km^2) of Brant and Tundra Swans in Level II habitats in the GHX-1 study area, Prudhoe Bay, Alaska, 1990.

GHX-1 study area were found almost exclusively in Coastal Wetland Complexes, although lower densities occurred in Coastal Barrens. Use of Coastal Wetland Complexes by Brant peaked during brood-rearing, when density exceeded 635 birds/km^2. Brood-rearing groups of Brant also used Coastal Barrens, Moist Meadows, and Nearshore Waters, but at markedly lower densities than recorded in Coastal Wetland Complexes. Fall-staging Brant exclusively used Coastal Wetland Complexes, but at low density (<10 birds/km^2). Of all the goose species, Brant were the most consistent in their patterns of habitat use between 1989 and 1990 (Anderson et al. 1990). The major differences between years were in the magnitude of Brant density in the Coastal Wetland Complexes during brood-rearing (approximately 2X greater in 1990 than in 1989) and in the greater variety of habitats occupied at low densities in 1989 compared to 1990.

Tundra Swan

Tundra Swans were present in 5 of 11 Level II habitats in the GHX-1 study area in 1990 (Figure 26). Pre-nesting swans were recorded only in Basin Wetland Complexes, whereas during the nesting season, swans were seen in Water with Emergents, Coastal Wetland Complexes, and Basin Wetland Complexes. The greatest density of brood-rearing Tundra Swans was recorded in Basin Wetland Complexes; swans without broods were present in low densities in Coastal Wetland Complexes. Water with Emergents supported the greatest density of Tundra Swans during fall staging and the greatest density of swans during any season. Only Open Water, Basin Wetland Complexes, and Impoundments supported other fall-staging swans. Tundra Swans were seen regularly in Wet Meadows in 1989, but this habitat was not used by swans in 1990 (Anderson et al. 1990). Except for the relatively consistent use of Basin Wetland Complexes in both years, the patterns of habitat use displayed by Tundra Swans were not similar between years. The low number of swans seen in each year suggest that these yearly variations in habitat use should be interpreted cautiously.

Ducks

Green-winged Teal used only three habitats during two seasons (nesting and fall staging) in the GHX-1 study area in 1990: Water with Emergents (Level IV = aquatic grass with islands), Impoundments (drainage impoundments), and Basin Wetland Complexes. During the nesting season, teal occurred in densities of <1.5 birds/km^2 in Water with Emergents and in Impoundments. Green-winged Teal only used Impoundments (1.8 birds/km^2) and Basin Wetland Complexes (0.4 birds/km^2) during fall staging. Green-winged Teal were not seen in 1989, so year-to-year variability in habitat use cannot be assessed.

Mallards were seen in densities of >1 bird/km^2 during only one season (nesting) in 1990. During pre-nesting, Mallards only used Impoundments (0.9 birds/km^2), Basin Wetland Complexes (0.7 birds/km^2), and Wet Meadows (0.6 birds/km^2) in the study area. Water with Emergents and Impoundments supported the greatest densities of Mallards during the nesting season (2.9 and 2.8 birds/km^2, respectively); Basin Wetland Complexes supported only 0.6 birds/km^2. Mallards used only Water with Emergents and Impoundments during brood-rearing and never exceeded 0.2 birds/km^2 in either habitat. Only Wet Meadows (0.2 birds/km^2) were used by Mallards during fall staging.

Northern Pintails used the most diverse set of habitats of any of the duck species in the GHX-1 study area (Figure 27). During pre-nesting, the greatest density of pintails occurred in Coastal Wetland Complexes. Pintails were seen in eight Level II habitats during nesting, with the greatest densities occurring in Coastal Wetland Complexes, Water with Emergents, and Basin Wetland Complexes. Impoundments, Coastal Wetland Complexes, and Water with Emergents supported the greatest densities of Northern Pintails during the brood-rearing season. A similar pattern was recorded during fall staging, with the greatest density of pintails occurring in Impoundments (22.9 birds/km^2) and lower densities in Water with Emergents and Coastal Wetland Complexes. In both 1989 and 1990, pintails heavily used Impoundments and Water with Emergents, habitats that are suitable for a dabbling duck species (Anderson et al. 1990). Some variability in density and overall habitat use among seasons was noted between years, however.

Northern Shovelers were seen only in Basin Wetland Complexes during the nesting season and in Impoundments during the brood-rearing season (density = 0.3 birds/km^2 and 0.9 birds/km^2, respectively). Northern Shovelers were not seen in the study area

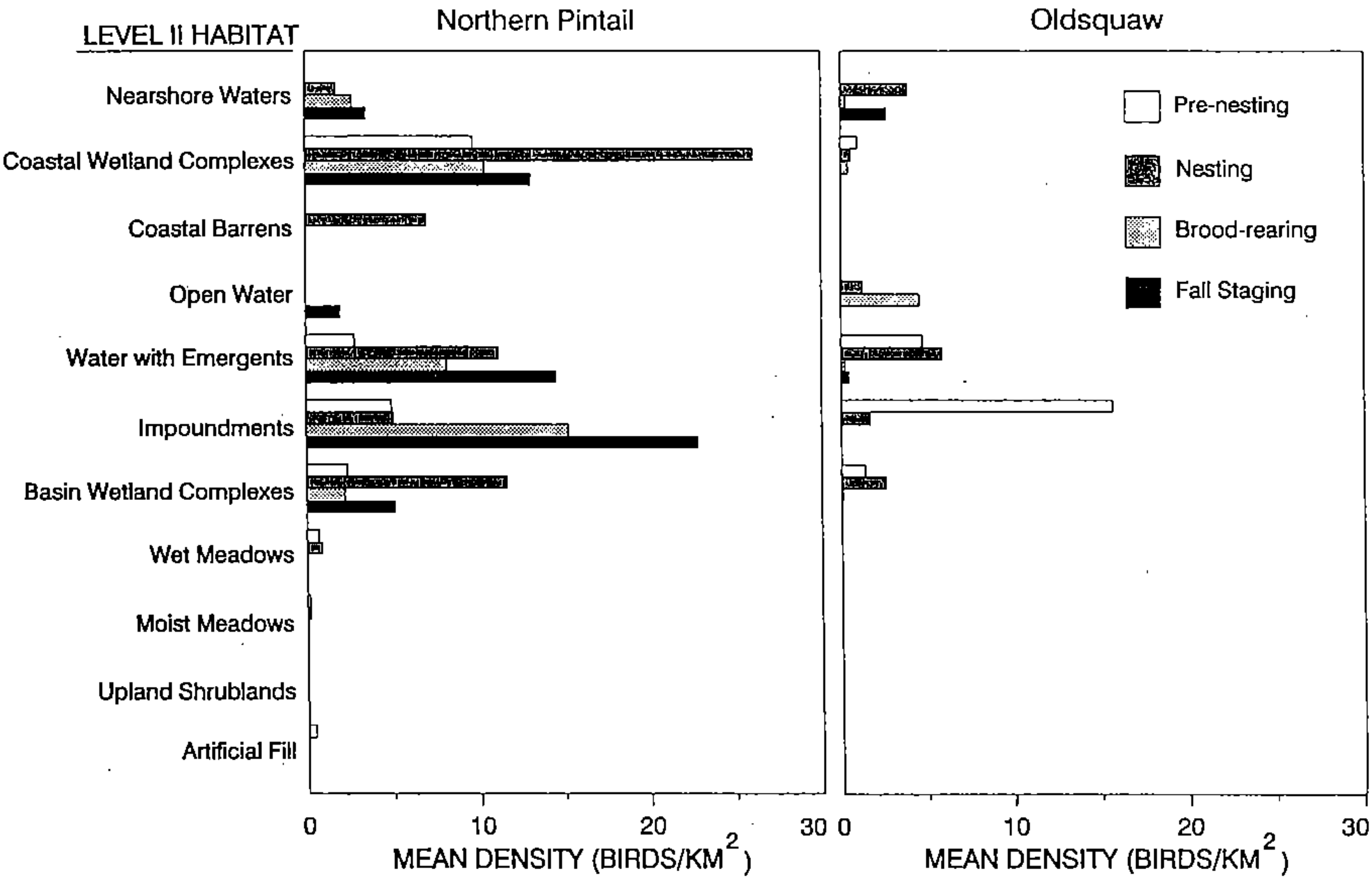


Figure 27. Mean seasonal densities (birds/km²) of Northern Pintails and Oldsquaw in Level II habitats in the GHY-1

during 1989, so no comparisons were made between years.

American Wigeon used only two Level II habitats (Coastal Wetland Complexes and Basin Wetland Complexes) in the GHX-1 study area in 1990. Pre-nesting wigeon occurred in Coastal Wetland Complexes (Level IV = halophytic wet meadows) at a density of 2.9 birds/km^2. No wigeon were recorded during nesting and during brood-rearing all wigeon were recorded either in Coastal Wetland Complexes or in Basin Wetland Complexes (densities = 1.3 and 0.4 birds/km^2, respectively). American Wigeon were not recorded during fall staging in 1990. As with other species occurring in low numbers, comparisons among years are difficult to interpret. In 1989, American Wigeon used only three habitats (Coastal Wetland Complexes, Basin Wetland Complexes, and Wet Meadows) in the study area, one habitat more than in 1990 (Anderson et al. 1990).

Eurasian Wigeon were seen only in Coastal Wetland Complexes (density = 1.0 bird/km^2) during pre-nesting and in Water with Emergents (density = 1.2 birds/km^2) during nesting. No Eurasian Wigeon were seen in 1989 (Anderson et al. 1990).

Oldsquaw used 6 of 11 Level II habitats in 1990 (Figure 27). During pre-nesting, the greatest density of Oldsquaw (18 birds/km^2) occurred in Impoundments and substantially lower densities were seen in Water with Emergents, Basin Wetland Complexes, and Coastal Wetland Complexes. Water with Emergents and Nearshore Waters supported the greatest densities of Oldsquaw during the nesting season, whereas during brood-rearing the greatest density of Oldsquaw was recorded in Open Water. Fall-staging Oldsquaw used Nearshore Waters and Water with Emergents, but at densities of <5 birds/km^2. Oldsquaw used a greater variety of habitats during most seasons in 1990 compared to 1989 and occurred in greater densities in most habitats in 1990 (Anderson et al. 1990). Only one habitat, Open Water, was used in 1990 but not in 1989.

King Eiders were seen in only three habitats during pre-nesting: Impoundments, Water with Emergents, and Basin Wetland Complexes (Figure 28). The number (n=7) of habitats occupied by King Eiders increased during nesting and densities of >5 birds/km^2 were recorded in Water with Emergents, Basin Wetland Complexes, and

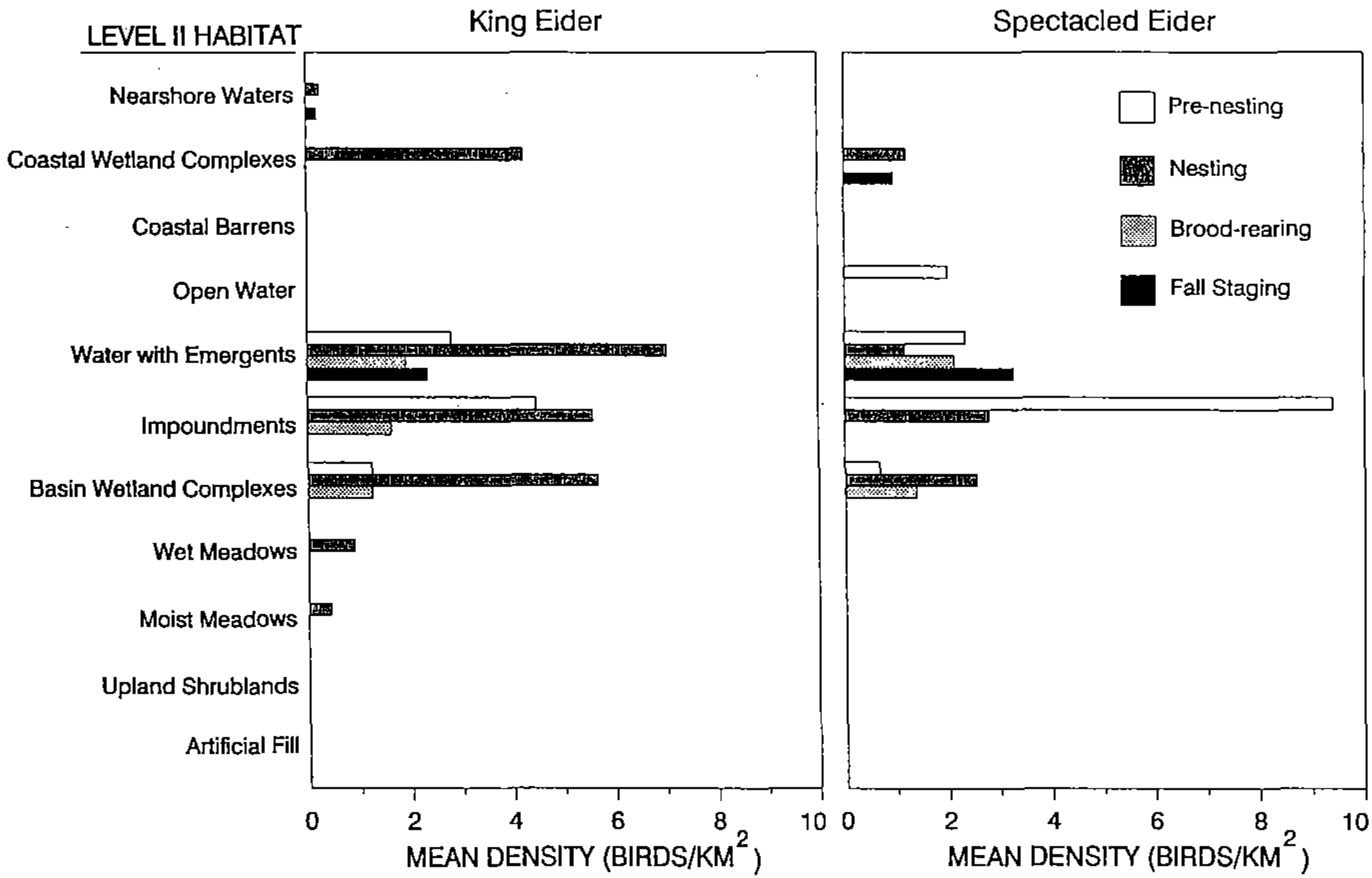


Figure 28. Mean seasonal densities (birds/km^2) of King and Spectacled eiders in Level II habitats in the GHX-1 study

Impoundments. The level of use of the study area contracted during brood-rearing and only three habitats (Water with Emergents, Impoundments, and Basin Wetland Complexes) were used, all at densities of <3 birds/km^2; eiders with broods were seen in all three habitats. Only two habitats were used by fall-staging King Eiders, Water with Emergents and Nearshore Waters. King Eiders used more habitat types, occurred in more habitats during each season, and were seen in greater densities in some habitats in 1990 compared to 1989 (Anderson et. al. 1990).

Spectacled Eiders were seen in four habitats during pre-nesting, but the greatest density occurred in Impoundments (Figure 28). Impoundments again supported the greatest density of Spectacled Eiders during nesting, but at less than half the level recorded during pre-nesting. During brood-rearing, Spectacled Eiders were seen only in Water with Emergents and Basin Wetland Complexes; females with broods used both habitat types. All Spectacled Eiders seen during fall staging were either in Water with Emergents or in Coastal Wetland Complexes. Spectacled Eiders used a greater variety of habitats in 1990 compared to 1989 and occurred in higher densities in most habitats in 1990 (Anderson et al. 1990).

Loons

Pacific Loons primarily used habitats characterized by the presence of water (Figure 29). Observations of loons in Basin Wetland Complexes were of birds using small ponds that were of insufficient size to be mapped as separate habitats. Pacific Loons occurred in the greatest densities in Water with Emergents during all seasons except fall staging. Open Water and Impoundments also were used by Pacific Loons during pre-nesting. During nesting, most loons were seen in the habitat types that contained the nests (Table 2). Five Pacific Loon nests were in Water with Emergents (Level IV = aquatic grass with islands) and one nest each was in Open Water, Impoundments, and Basin Wetland Complexes. The only additional habitat Pacific Loons used during nesting was Nearshore Waters. The five habitat types used during brood-rearing were identical to those used during nesting; loons with broods were seen in all five habitats. Open Water and Nearshore Waters supported the greatest densities of fall-staging Pacific Loons.

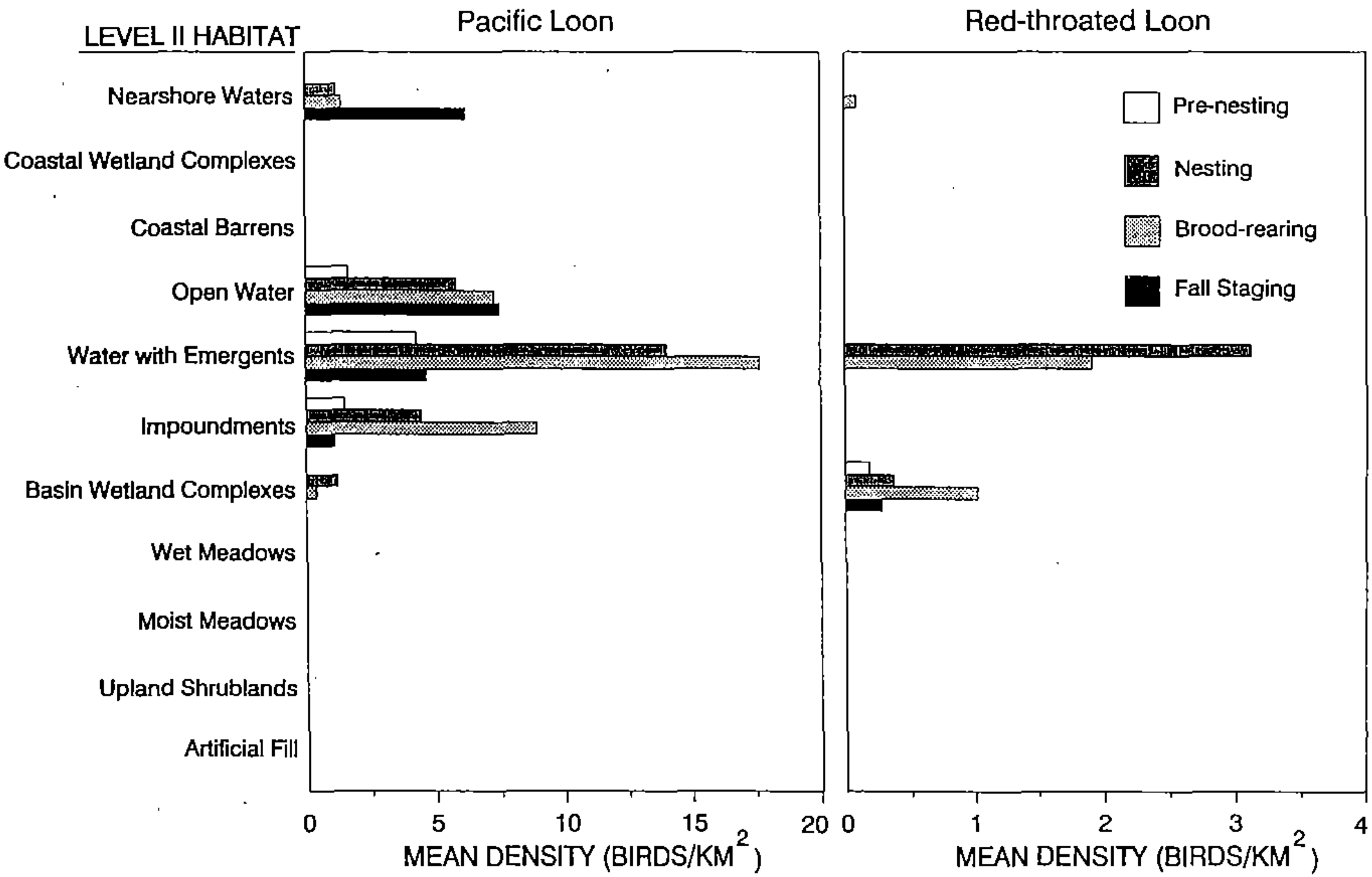


Figure 29. Mean seasonal densities (birds/km^2) of Pacific and Red-throated loons in Level II habitats in the GHX-1

Patterns of habitat use were similar between 1989 and 1990, except two habitat types (Coastal Wetland Complexes and Moist Meadows) used in 1989 were not occupied in 1990 (Anderson et al. 1990). Somewhat greater densities of Pacific Loons were recorded in some habitats in 1990, probably due to the increase in nesting effort.

Red-throated Loons were seen in three habitats in the study area and were more restricted in their habitat use than Pacific Loons (Figure 29). During pre-nesting, Red-throated Loons only used Basin Wetland Complexes. The one Red-throated Loon nest located during nest searches was in Water with Emergents (Table 2); this habitat was also the probable site of the second nest that was not located during the nest searches. As might be expected, the greatest density of Red-throated Loons was recorded in Water with Emergents during the nesting season. Red-throated Loons also were seen in Basin Wetland Complexes during nesting. Brood-rearing Red-throated Loons occurred in greatest density in Water with Emergents. Loons with young were seen in both Water with Emergents and Basin Wetland Complexes, whereas loons without young were seen in those two habitats and in Nearshore Waters. During fall staging, Red-throated Loons were seen only in Basin Wetland Complexes. In both 1989 and 1990, Red-throated Loons occupied relatively few habitats in the GHX-1 study area and occurred in greatest density during most seasons in Water with Emergents (Anderson et al. 1990).

BREEDING BIRDS AND NEST FATE

Evaluating the level of breeding effort by waterbirds in the GHX-1 study area is one of the objectives of this study. In this section, we present the results of our nest searches and evaluations of nest fate for all nests. In addition, we examine natural and development-related factors that may have influenced reproductive success.

We found nests of four species of waterbirds in the GHX-1 study area in 1990: Red-throated Loon, Pacific Loon, Canada Goose, and Greater White-fronted Goose. Of 22 nests established in the study area in 1990, 18 (81.8%) were successful (Table 3). This success rate was substantially greater than the overall 1989 success rate (21.4%) in the study area (Anderson et al. 1990). In addition, it is likely that a second Red-throated Loon nest was active in the study area and that young were successfully hatched at this

Table 3. Number of nests and nest fate (%) of waterbirds nesting in the GHX-1 study area, Prudhoe Bay, Alaska, 1989 and 1990.

	Successful		Failed		Total	
	1989	1990	1989	1990	1989	1990
Canada Goose	1 (16.7)	10 (90.9)	5 (83.3)	1 (9.1)	6	11
White-fronted Goose	0	1 (100)	0	0	0	1
Pacific Loon	2 (33.3)	5 (62.5)	4 (66.7)	3 (37.5)	6	8
Red-throated Loon	0	1 (100)	2 (100)	0	2	1
All Nests	3 (21.4)	18 (81.8)	11 (78.6)	4 (18.2)	14	22

nest. This additional nest would increase the total number of nests in the study area to 23 and the success rate to 82.6% (19 of 23 nests successful). The major contributor to the overall increase in nest success in 1990 was the 74% increase in nest success for Canada Geese (Table 3). A 29% increase in nest success from 1989 to 1990 also was recorded for Pacific Loons.

In addition to the increased success of nests established in 1990, the overall nesting effort increased by 57% compared to 1989; this increase was due primarily to an 83% increase in nesting effort by Canada Geese (Table 3). Pacific Loon nesting effort increased by a lower percentage (33%) and Red-throated Loon effort remained constant (based on two nests in 1990). Greater White-fronted Goose, which did not nest in the study area in 1989, was the only new species recorded nesting in 1990.

Unlike in 1989 when spring thaw was prolonged by heavy snow cover, the early availability of nest sites in 1990 probably contributed to both the higher success rate and the greater number of nests established in the study area. Although the number of arctic foxes seen during surveys in 1990 was not significantly lower than in 1989, the level of predatory pressure on nesting waterbirds did appear to be lower in 1990. Several Canada Goose and Pacific Loon nest sites that were accessible to arctic foxes were not preyed upon, suggesting that foxes were present in lower numbers than suggested by survey counts. Several interacting factors probably contributed to a decline in predatory pressure by arctic foxes in the GHX-1 study area and contributed to the increase in nesting success for waterbirds. First, the lemming high of 1989 and the subsequent winter crash in lemming numbers could have contributed to lower fox numbers in the study area. Second, the fox den near DS-L1 was unoccupied in 1990 and, therefore, a resident pair of foxes was not hunting in the immediate vicinity of this den site. Finally, approximately 14 foxes were live-trapped and removed from the Prudhoe Bay area during fall 1989 (M. Joyce, ARCO Alaska, pers. comm.), thus lowering the fox population in the entire Prudhoe Bay area.

Mean distances of nests to the nearest road, edge of the nearest pad, and to the center of the building complexes on the CCP and CGF pads were determined from the digitized map of nest locations (Table 4). For all waterbird nests combined, we tested

Table 4. Mean distances (m) of successful and failed waterbird nests to the nearest road and pad and to the center of the Central Compressor Plant (CCP) and Central Gas Facility (CGF) complexes, GHX-1 study area, Prudhoe Bay, Alaska, 1989 and 1990. Means were rounded to the nearest 10 m; n = number of nests.

	Road		Pad		CCP		CGF		Number of Nests	
	1989	1990	1989	1990	1989	1990	1989	1990	1989	1990
Canada Goose	170	230	260	330	1320	1630	1370	1590	6	11
Successful	260	240	330	340	1180	1660	1030	1610	1	10
Failed	150	40	250	170	1350	1300	1440	1300	5	1
White-fronted Goose	-	570	-	200	-	1140	-	800	0	1
Successful	-	570	-	200	-	1140	-	800	0	1
Pacific Loon	160	250	260	270	1670	1710	1560	1810	6	8
Successful	140	190	210	210	1800	1880	1890	2170	2	5
Failed	170	340	290	370	1610	1440	1400	1230	4	3
Red-throated Loon	130	230	290	380	1490	1640	1570	1810	2	1
Successful	-	230	-	380	-	1640	-	1810	0	1
Failed	130	-	290	-	1490	-	1570	-	2	0
All Nests	160	250	270	300	1490	1640	1480	1650	14	21
Successful	180	250	250	300	1590	1690	1600	1740	3	17
Failed	150	270	270	320	1470	1410	1450	1250	11	4

(Mann-Whitney test) whether distances to these facilities were different for successful and failed nests; species-specific distances were tested only for both years (1989 and 1990) combined, when sample sizes were adequate. Distances to each facility type for all waterbird nests were not different for successful versus failed nests ($P > 0.05$) (Table 4). In addition, nest distances were not significantly different between successful and failed nests for either Canada Geese or Pacific Loons ($P > 0.05$; both years combined).

Geese

Eleven Canada Goose nests were found in the GHX-1 study area in 1990, an increase of five nests from 1989 (Table 3). The success rate for Canada Goose nests in 1990 was 90.9% (10 of 11 nests) compared to a 16.7% (1 of 6 nests) success rate in 1989. Only one Canada Goose nest failed in the study area in 1990; this nest was lost early in the season and the exact cause of failure was unknown. Two Canada Goose nests were located within 100 m of the CGF pad where construction activities were taking place. Noise measurements at these nest sites indicated that the incubating female experienced average noise levels of 64-68 dbA during nesting. Despite this level of noise disturbance, both nests were successful.

Tundra Swan

Tundra Swans did not nest in the GHX-1 study area in 1990. The closest nest was located approximately 1 km north of LGI. Four young were hatched at this nest and this brood moved into the GHX-1 study area during brood-rearing.

Ducks

No duck nests were located in the GHX-1 study area in 1990. The presence of broods of both King and Spectacled eiders in the study area during brood-rearing suggests that either one or both species may have nested in the study area and that their nests were not located during our nest searches. Eiders are cryptic nesters and may nest well away from waterbodies which can make our search technique ineffective for locating their nests. These species also may have nested just outside the boundaries of the study area and moved into the study area with their broods after hatch.

Loons

We found eight Pacific Loon nests in the study area in 1990, an increase of two nests from 1989 (Table 3). The success rate for Pacific Loons in 1990 was 62.5% compared to only 33.3% success in 1989. The causes of failure for the three unsuccessful Pacific Loon nests were unknown. Evidence of predator disturbance at loon nests is often difficult to determine, particularly if eggs are removed whole.

One Red-throated Loon nest was located during nest searches of the GHX-1 study area in 1990 and a second nest was highly probable based on the observation of a young brood soon after hatch (Table 3). A total of two Red-throated Loon nests in 1990 matches the nesting effort recorded in 1989. Red-throated Loons had 100% nest success in 1990 compared to 0% success in 1989.

NOISE SURVEY AND MODELING OF THE GHX-1 FACILITY

ARCO Alaska, Inc. (ARCO) is actively pursuing the construction of the Gas Handling Expansion (GHX-1) Project in the Prudhoe Bay Oilfield. A major concern is the potential impact of additional noise created by the GHX-1 facility. As a consultant to ABR, BBN Systems and Technologies (a division of Bolt Beranek and Newman, Inc.) began an evaluation of the noise environment of the areas affected by the GHX-1 construction in 1989. The objective of this program is to define the pre-construction noise environment, as well as describe changes that will be expected to occur once construction of the facility is completed and operational. These objectives will be met through the development of a computerized "acoustic prediction model". Through use of this model, approximate noise levels may be obtained for locations within the study area given an assumed set of operating conditions and weather conditions, thus negating the necessity for a constant noise monitoring program.

During the first year of the study (1989) we conducted noise measurements of the surrounding areas, including plant operations, road traffic, and gravel-excavating activity. The objective of this work was to collect acoustic data needed to begin development of the computerized acoustic prediction model.

The current (1990) study had four major areas of interest:

1) to collect data in support of flare noise modeling and subsequent inclusion of that source into the acoustic model;

2) to develop a plan for the collection of acoustical data (by ABR personnel) to support refinements in predicting the effect of wind on noise propagation in the Prudhoe Bay area;

3) to collect acoustic data in support of the basic acoustic model developed in 1989; and

4) to extend the capability of the computer model outputs to provide contours around the Central Compressor Plant (CCP) and Central Gas Facility (CGF).

FIELD DATA COLLECTION

A noise survey was conducted at the CCP and CGF facilities during the period of 9-14 August 1990. Briefings were held with CCP and CGF operations personnel to become familiar with equipment, current construction activity, and flaring episodes. Temperature and humidity information, as well as wind velocity and direction, were collected with the noise data. The following sections detail the approaches used to obtain data for the three areas of interest mentioned above.

Flare Data Collection

Conversations with Mike Joyce and Tim Collins, ARCO Alaska, Inc., detailed information about flaring events that were scheduled for CCP turbine upgrades on or around 12 August 1990. Likewise, a similar maintenance flaring episode would take place for the CGF facility in October 1990, but was ruled out for possible data collection. Because the collection of flaring information was the primary objective of this project, noise measurements were scheduled around this known flaring episode.

A data collection procedure for obtaining acoustic information about the flares was developed, using two Larson-Davis Model 870 Sound Level Meters, as well as two Nagra-IV recorders. The original plan was to have CCP personnel conduct flaring events of sufficient duration and at various flow rates so that noise data could be collected to describe flare noise emissions and their variability as a function of operating conditions. This procedure would provide data to determine the power level and directionality of the flares at various flow rates for incorporation into the model. Measurements at various distances from the flares would be used to describe the propagation characteristics.

CCP personnel stated that our collection plan could not be adhered to because they did not have the ability to control flow rates as we requested. Instead, the flow rate varies throughout the event. In addition, ARCO personnel could not predict the length of the flaring event, thus making it impossible to know the number of locations where data could be collected. Furthermore, locations that were included in the original plan were inaccessible to our team due to safety requirements. A revised collection plan was developed with measurement locations selected based on accessibility constraints. Locations were chosen around the flare pit to obtain noise samples (Figure 30).

Samples of one-minute intervals were recorded at various positions along the access road bordering the east side of the flare pit and at the ends of the four flares, with distances ranging from approximately 200 to 600 ft (63 to 183 m) from the edge of the pit. Continuous measurements of the event were recorded using two Larson-Davis 870 monitors on the West Dock Road and on the access road at distances of 700 and 600 feet (214 and 183 m), respectively.

The flaring event took place on 11 August 1990 from 18:18 to 18:36. ARCO personnel reported that the total volume of methane released was 830,000 standard cubic feet (SCF) with a peak flow rate of 50,000,000 SCF per day (equivalent to 34,722 SCF/minute). Wind velocities of less than 5 mph are desirable for data collection. During the flaring event, wind velocities were approximately 15 mph, which is above the threshold considered acceptable.

Wind Data Collection

Wind of any velocity has an effect on the propagation of noise from the noise source. Although models are available that allow for changes in propagation due to wind (and are currently implemented in the computer model), refinements could produce more accurate results for the Prudhoe Bay area. Acoustic data must be collected under windy conditions so that a statistical distribution of the change in propagation can be obtained under the physical and weather conditions of Prudhoe Bay.

The current study sought to establish an effective method for obtaining these noise measurements. An array of 37 points emanating from the centers of the CCP and CGF facilities was established along the eight primary compass point axes (e.g., North, Northeast, etc.; Figure 31). Each of these points was marked identifying them for future sampling by ABR personnel and initial noise measurements were taken.

Data were collected using a Larson-Davis Model 870 and a Bruel & Kjaer Type 2231 Sound Level Meter. Noise data were collected in terms of various descriptors such as Leq, Maximum Sound Levels (Lmax), and statistical descriptors such as centile

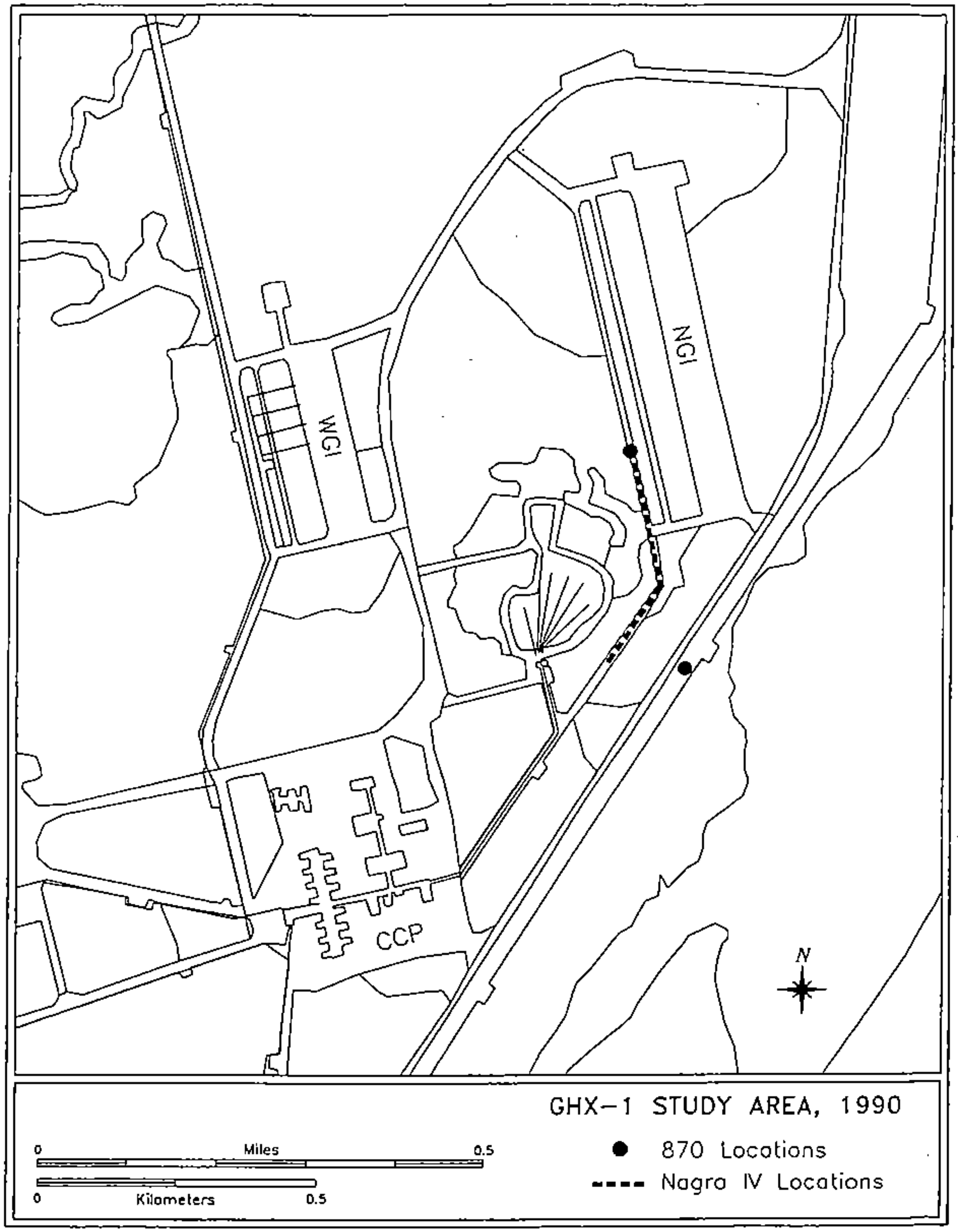


Figure 30. Monitoring locations used for collection of flaring noise data, GHX-1 study area, Prudhoe Bay, Alaska, August 1990.

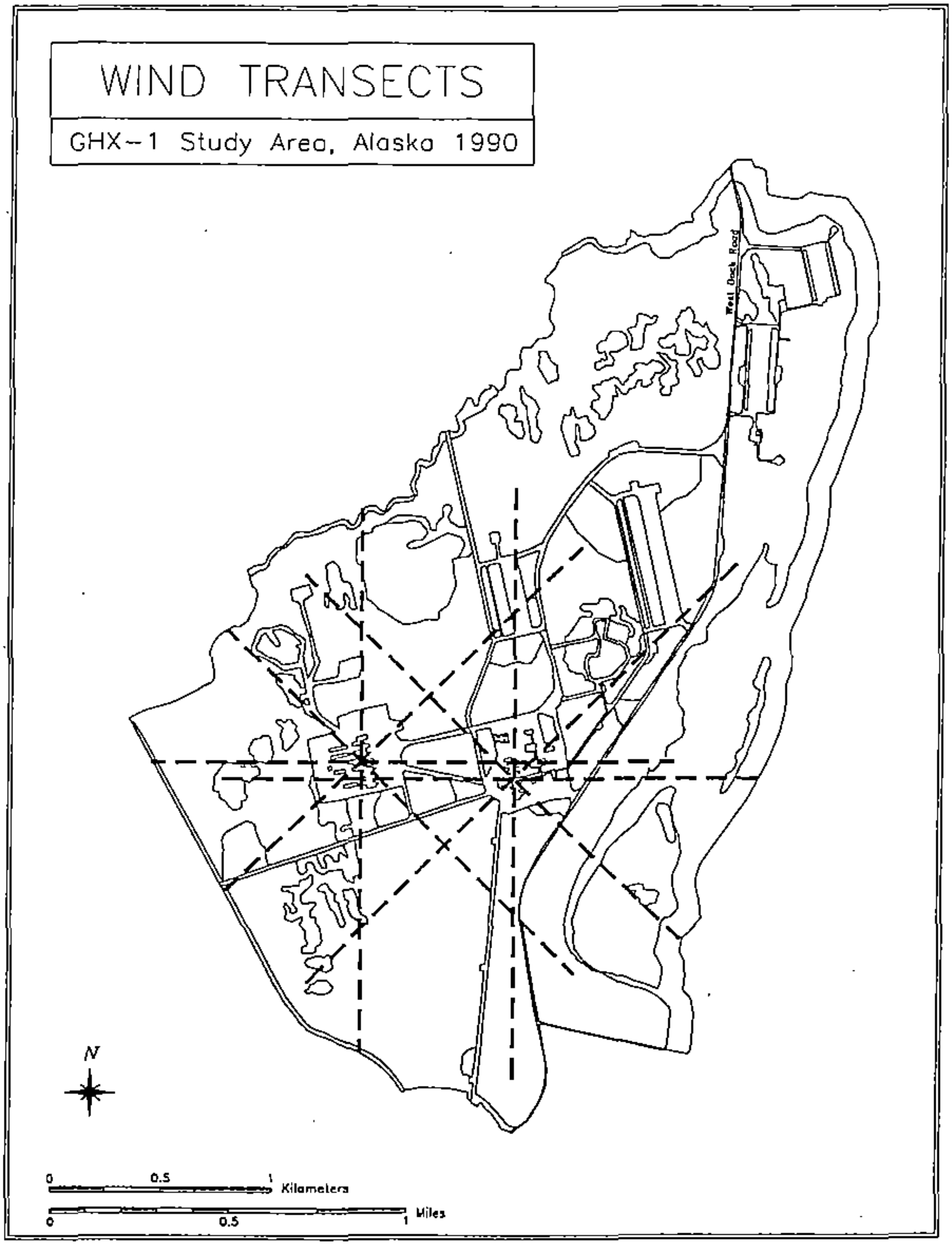


Figure 31. Transects established to monitor the effects of wind on noise propagation from the CCP and CGF facilities in the GHX-1 study area, Prudhoe Bay, Alaska.

exceedences (i.e., the decibel level a sample exceeded for *n* percent of the total sample) for the 1, 10, 25, 50, 90, and 99 centiles. These statistics may be used to understand the variability of the noise environment (i.e., did a loud noise of short duration dominate the sample or was the level relatively constant). It is important to note that these measurements were conducted under varying wind conditions ranging from calm to 15 mph.

Because a large number of measurements are necessary to describe the various wind conditions, it was agreed that ABR personnel (being on-site for much of the season) should collect the wind data. A schedule for data collection necessary for obtaining adequate modeling information was prepared and provided to ABR personnel (Table 5).

BBN conducted the initial set of measurements at the 37 locations selected. In addition, 15 data points were acquired at the same locations surveyed in 1989 and under the same wind conditions. These data were compared with data collected in the 1989 survey. Collection of wind data will continue through the 1991 season.

DATA ANALYSIS AND INTERPRETATION

Equivalent sound levels are levels of the equivalent steady-state sound level that, in a stated period of time, would contain the same acoustical energy as a time-varying sound level during the same period (i.e., the acoustical energy average of a stated sample duration). The Leq descriptor represents the primary unit of noise exposure used by federal and state agencies for environmental regulation.

Flare Data

Because of complications discussed previously with respect to the collection of flare noise data results were inconclusive for this portion of the project. Limited control of the flow rate for the flaring event made the original collection plan impossible. The data that were collected were recorded under significant wind conditions (above 15 mph). At this time, the flare noise data are insufficient for inclusion into the computer model.

Table 5. Wind data collection protocal for the GHX-1 study area, Prudhoe Bay, Alaska.

Dist.	Central Compressor Plant								Central Gas Facility							
(ft.)	N	NW	W	SW	S	SE	E	NE	N	NW	W	SW	S	SE	E	NE
0-500		500		500	500	500	500	500	500				500	500		500
501-1000		950		1000	950		1000	1000	900	750	850	800				800
1001-1500	1050					1150				1300		1500	1400	1100		
1501-2000	1600 2000				2000	2000		1600						2000		
2001-2500		2100								2600		2700				
2501-3000		2800			3000											
3001-3500																
2501-4000	4000				4000											
>4001		4800														

Primary Locations (0-1500 feet from source) should be collected 4 or 5 times per week.
Secondary Locations (1501-2500 feet from source) should be collected 3 times per week.
Tertiary Locations (greater than 2500 feet from source) should be collected 1 or 2 times per week.

Wind Data

Wind data have not been analyzed at this time. More wind data will be obtained during the next summer season (1991), at which time the data will be analyzed. Analysis will include developing propagation coefficients for each of the eight defined wind directions and incorporating that information into the computer model.

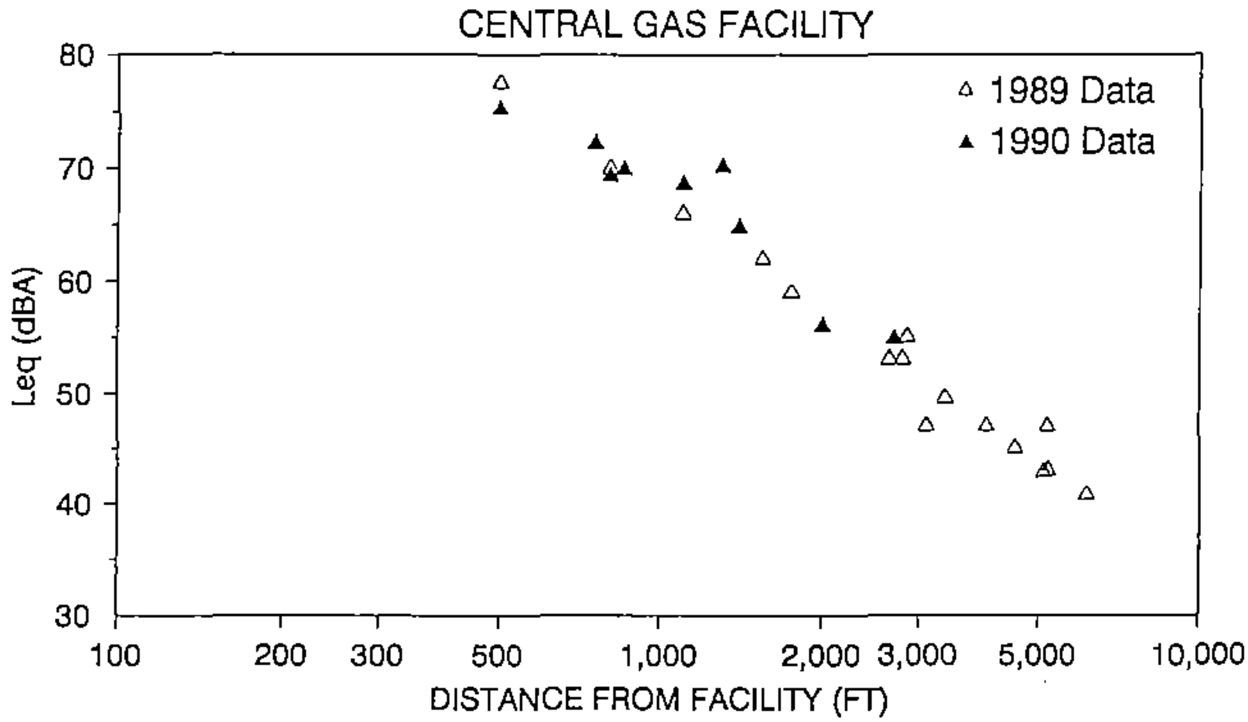
Comparison of 1989 and 1990 Noise Data

Leq data were divided into two groups depending on the facility that most influenced that location (e.g., CGF or CCP). Plots were created comparing the original first year (1989) data with the current (1990) data (Figure 32). Data collected for the current (1990) study were consistent with data entered into the model from 1989.

COMPUTER MODEL DEVELOPMENT

The computer model has undergone modifications that allow the program greater output capabilities. Of most importance is the ability to generate noise contours for the study areas. Noise contours were generated for three different scenarios, calm wind conditions, and wind from the northeast and southwest at 10 mph (Figures 33-35, respectively). The details of the new functions are provided under separate cover (see *Outdoor Noise Prediction Program for ARCO Prudhoe Bay Facilities - User's Manual*). Several features of the contour plots need to be addressed; an example is discussed below.

Note the effect that wind has on the propagation of noise from its source for a 10 mph northwest wind (Figure 34). Noise contours are extended away from the source for a greater distance in the direction the wind is blowing, and are reduced in the opposite direction. Another aspect worth noting is the discontinuity of the contours that may be seen north and south of the CGF and north of the CCP. This discontinuity is an artifact of the combination of algorithms used in the contouring routines and the directionality of the sources. Actual noise-level contours will vary more smoothly without sharp discontinuities. We expect that smoothing algorithms will be defined that should allow the contouring output of the final model to more closely represent actual noise levels.



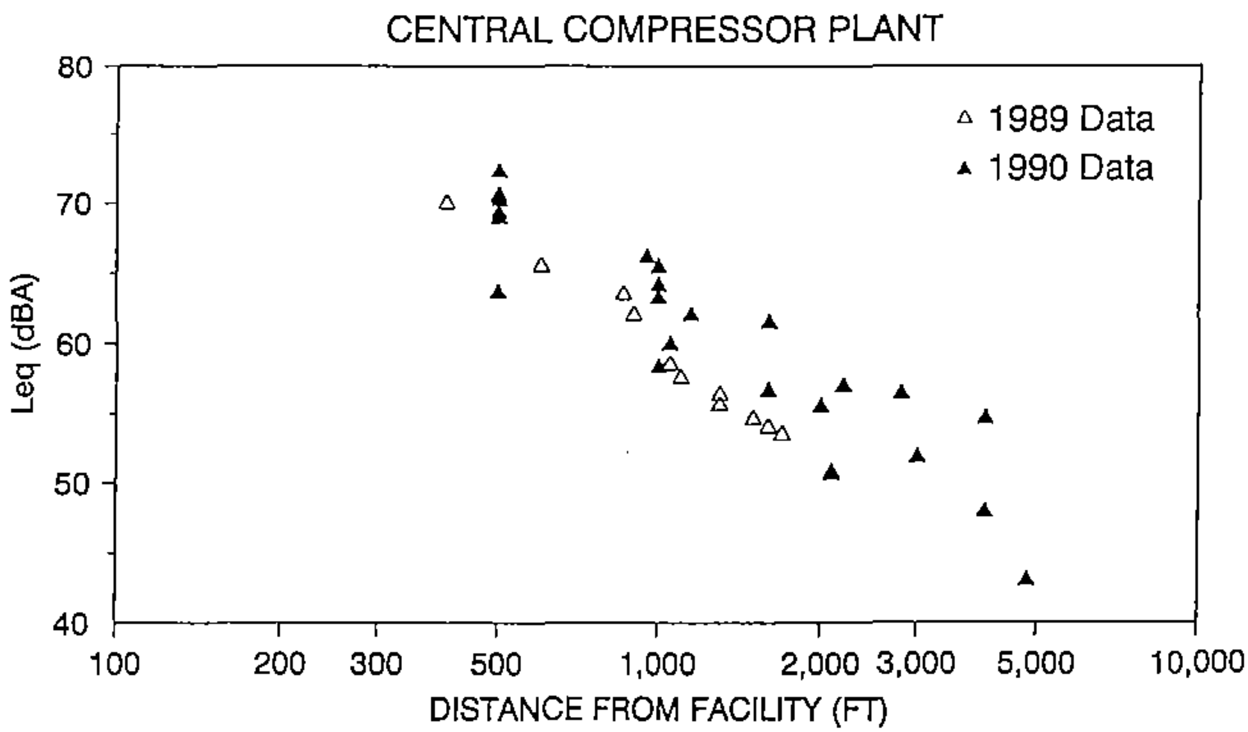


Figure 32. Comparison of 1989 and 1990 noise levels (Leq) at different distances from the CGF and CCP facilities, GHX-1 study area, Prudhoe Bay, Alaska.

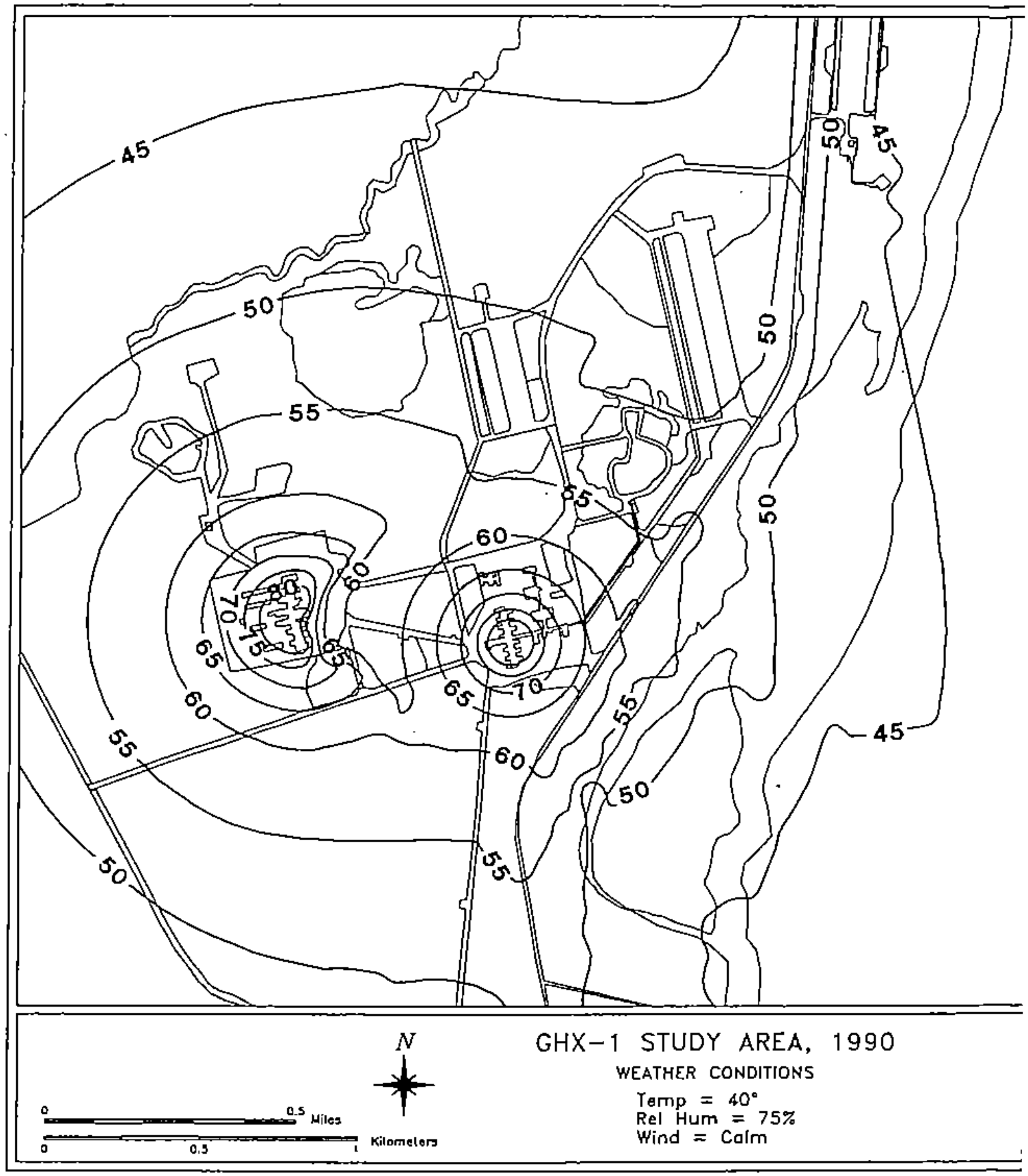


Figure 33. Computer modeling of noise contours (5 dbA) around the CCP and CGF facilities during calm wind conditions, GHX-1 study area, Prudhoe Bay, Alaska.

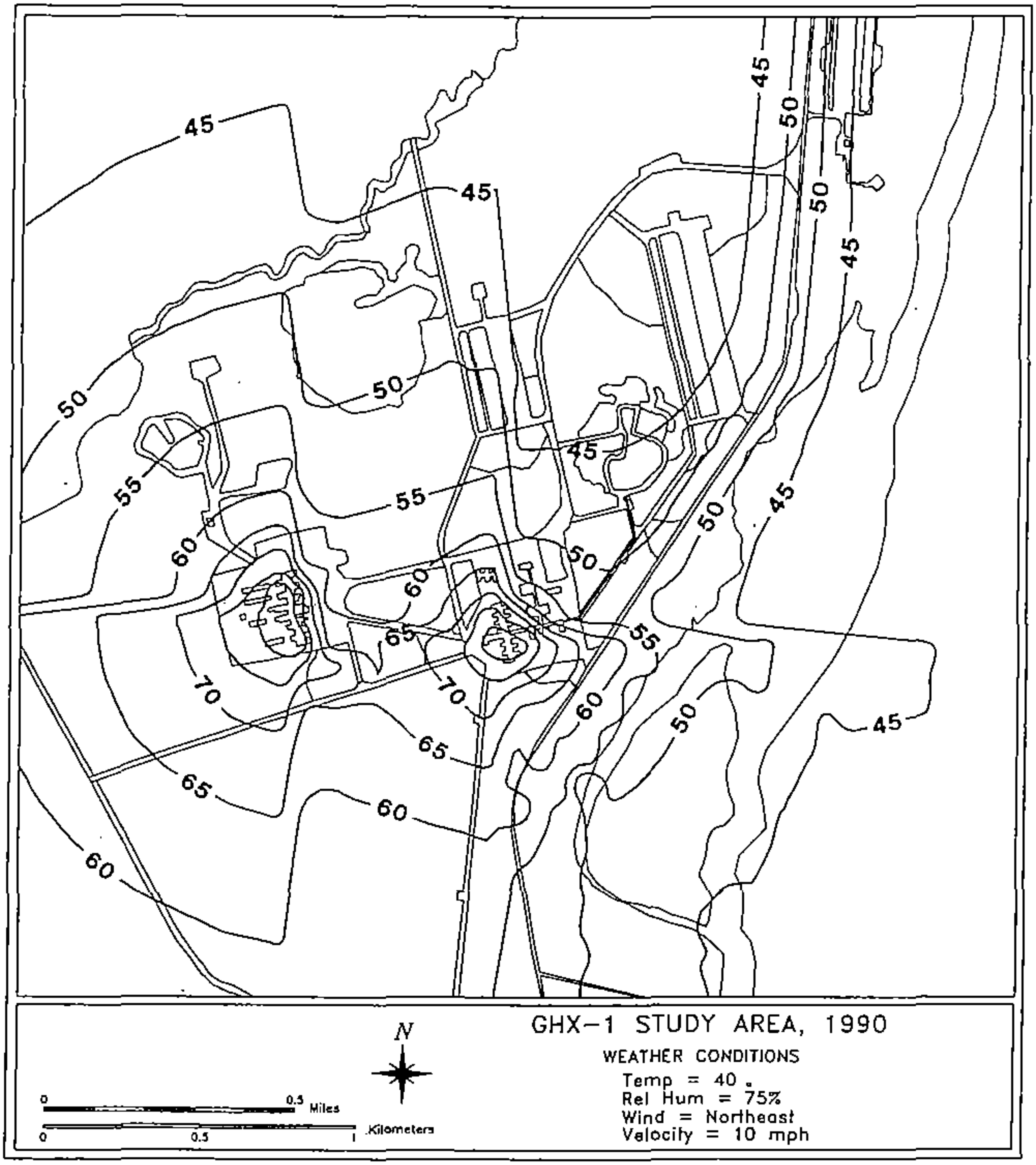


Figure 34. Computer modeling of noise contours (5 dbA) around the CCP and CGF facilities during a 10-mph northeast wind, GHX-1 study area, Prudhoe Bay, Alaska.

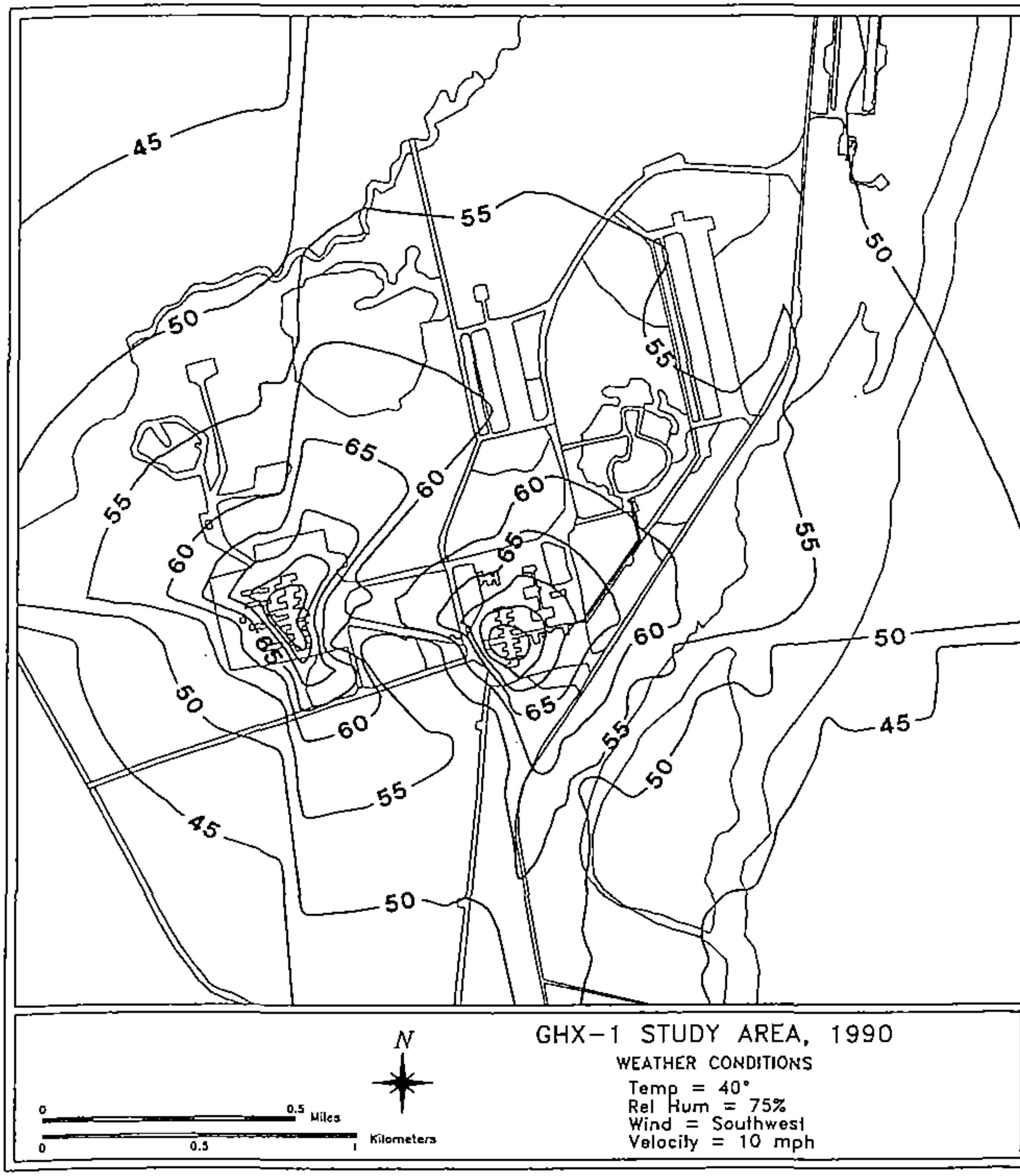


Figure 35. Computer modeling of noise contours (5 dbA) around the CCP and CGF facilities during a 10-mph southwest wind, GHX-1 study area, Prudhoe Bay, Alaska.

LITERATURE CITED

Anderson, B.A., S.M. Murphy, C.L. Cranor, M.T. Jorgenson, and B.A. Kugler. 1990. GHX waterbird and noise monitoring program. 1989 Ann. Rep., prepared for ARCO, Alaska, Inc., Anchorage, by Alaska Biological Research, Inc., Fairbanks, and Acentech, Inc., Canoga Park, CA. 109 p.

Bellrose, F.C. 1978. Ducks, Geese, and Swans of North America. 2nd Ed. Stackpole, Harrisburg, PA. 540 p.

Bergman, R.D., and D.V. Derksen. 1977. Observations of Arctic and Red-throated loons at Storkersen Point, Alaska. Arctic 30:41-51.

Bergman, R.D., R.L. Howard, K.F. Abraham, and M.W. Weller. 1977. Water birds and their wetland resources in relation to oil development at Storkersen Point, Alaska. U.S. Fish and Wildl. Serv., Resour. Publ. 129:1-38.

Conover, W.J. 1980. Practical nonparametric statistics. 2nd ed. Wiley, New York. 493 p.

Johnson, C.B., S.M. Murphy, C.L. Cranor, M.T. Jorgenson, and B.A. Kugler. 1990. Point McIntyre waterbird and noise monitoring program. Final rep., prepared for ARCO, Alaska, Inc., Anchorage, by Alaska Biological Research, Inc., Fairbanks, and Acentech, Inc., Canoga Park, CA. 132 p.

Johnson, S.R., and D.R. Herter. 1989. The birds of the Beaufort Sea. BP Exploration (Alaska) Inc., Anchorage. 372 p.

Jorgenson, M.T., S.M. Murphy, and B.A. Anderson. 1989. A hierarchical classification of avian habitats on the North Slope, Alaska. Paper presented at the Third Alaska Bird Conf. and Workshop, 20-22 March 1989, Univ. Alaska, Fairbanks. [abstract]

Larson, S. 1960. On the influence of the arctic fox *Alopex lagopus* on the distribution of arctic birds. Oikos 11:276-305.

Mickelson, P.G. 1975. Breeding biology of cackling geese and associated species on the Yukon-Kuskokwim Delta, Alaska. Wildl. Monogr. 45:1-35.

Murphy, S.M., B.A. Anderson, and C.L. Cranor. 1986. Lisburne Terrestrial Monitoring Program--1985: The effects of the Lisburne Development Project on geese and swans. First annual rep. prepared for ARCO Alaska, Inc., Anchorage, by Alaska Biological Research, Fairbanks. 151 p.

Murphy, S.M., B.A. Anderson, C.L. Cranor, and R.H. Day. 1987. Lisburne Terrestrial Monitoring Program--1986: The effects of the Lisburne Development Project on geese and swans. Second annual rep. prepared for ARCO Alaska, Inc., Anchorage, by Alaska Biological Research, Fairbanks. 246 p.

Murphy, S.M., B.A. Anderson, C.L. Cranor, and C.B. Johnson. 1988. Lisburne Terrestrial Monitoring Program--1987: The effects of the Lisburne Development Project on geese and swans. Third annual rep. prepared for ARCO Alaska, Inc., Anchorage, by Alaska Biological Research, Inc., Fairbanks. 205 p.

Murphy, S.M., B.A. Anderson, C.L. Cranor, and M.T. Jorgenson. 1989. Lisburne Terrestrial Monitoring Program--1988: The effects of the Lisburne Development Project on geese and swans. Fourth annual rep. prepared for ARCO Alaska, Inc., Anchorage, by Alaska Biological Research, Inc., Fairbanks. 255 p.

Murphy, S.M., B.A. Anderson, C.L. Cranor, M.T. Jorgenson, and B.K. Lance. 1990. Lisburne Terrestrial Monitoring Program--1989. The effects of the Lisburne Development Project on geese and swans. Fifth annual rep. prepared for ARCO Alaska, Inc., Anchorage, by Alaska Biological Research, Inc., Fairbanks. 275 p.

Newton, I. 1977. Timing and success of breeding in tundra nesting geese. Pages 113-126 *in* B. Stonehouse and C. Perrins, eds. Evolutionary ecology. Univ. Park Press, Baltimore, MD.

Palmer, R.S., ed. 1962. Handbook of North American Birds. Vol. 1: Loons through flamingos. Yale Univ. Press, New Haven, CT. 521 p.

Palmer, R.S., ed. 1976a. Handbook of North American Birds. Vol 2: Waterfowl (Part 1). Yale Univ. Press, New Haven, CT. 567 p.

Palmer, R.S., ed. 1976b. Handbook of North American Birds. Vol. 3: Waterfowl (Part 2). Yale Univ. Press, New Haven, CT. 560 p.

Ritchie, R.J., P.W. Banyas, A.A. Stickney, R.M. Burgess, and J.G. King. 1990. Tundra Swan and Brant surveys on the Arctic Coastal Plain, Colville River to Staines River, 1989. Final rep., prepared for ARCO Alaska, Inc., Kuparuk River Unit, BP Exploration (Alaska), Inc., and The Duck Island Unit Owners, Anchorage, by Alaska Biological Research, Inc., Fairbanks. 138 p.

Ritchie, R.J., A.A. Stickney, P.W. Banyas, and J.G. King. 1991. Tundra Swan and Brant surveys on the Arctic Coastal Plain, Colville River to Staines River, 1990. Final rep., prepared for ARCO Alaska, Inc., Kuparuk River Unit, BP Exploration (Alaska), Inc., and The Duck Island Unit Owners, Anchorage, by Alaska Biological Research, Inc., Fairbanks.

Troy, D.M. 1986. Prudhoe Bay Waterflood Project Environmental Monitoring Program Terrestrial Studies--1984. Unpubl. rep. prepared for Envirosphere Co., Anchorage, by LGL Alaska Research Associates, Anchorage.

Troy, D.M., and S.R. Johnson. 1982. Prudhoe Bay Waterflood Project Bird Monitoring Program. Final rep. prepared for Dep. of the Army, Alaska District, Corps of Engineers, Anchorage, by LGL Alaska Research Associates, Inc., Fairbanks.

Troy, D.M., D.R. Herter, and R.M. Burgess. 1983. Tundra Bird Monitoring Program. Chapter 7 *in* Prudhoe Bay Waterflood Project Environmental Monitoring Program, 1982, Vol. 4. Final rep. prepared for Dep. of the Army, Alaska District, Corps of Engineers, Anchorage, by LGL Alaska Research Associates, Inc., Fairbanks. 80 p.

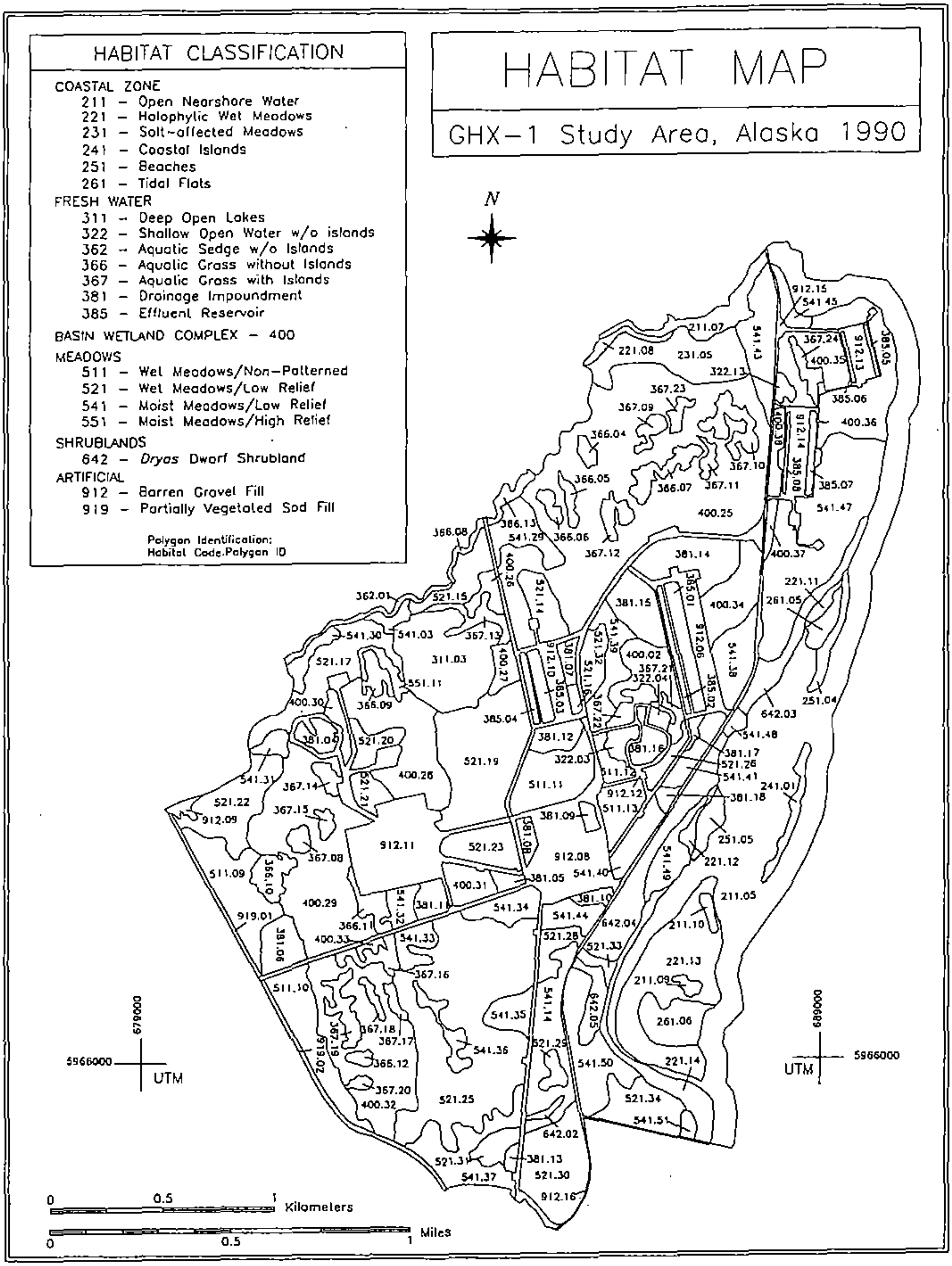
Walker, D.A., and P.J. Webber. 1979. Relationships of soil acidity and air temperature to the wind and vegetation at Prudhoe Bay, Alaska. Arctic 32:224-236.

Walker, D.A., K.R. Everett., P.J. Walker, and J. Brown. 1980. Geobotanical atlas of the Prudhoe Bay Region. U.S. Army Corps of Eng., Cold Reg. Res. and Eng. Lab. Rep. 80-14, Hanover, N.H. 69 p.

Woodward-Clyde Consultants (WCC). 1983. Lisburne Development Area: 1983 environmental studies. Final rep. prepared for ARCO Alaska, Inc., Anchorage.

Woodward-Clyde Consultants (WCC). 1985. Lisburne Development environmental studies: 1984. Vol. 2: Caribou, birds, and oceanography. Final rep. prepared for ARCO Alaska, Inc., Anchorage.

Appendix 1. Habitat map of the GHX-1 study area, hierarchical classification system, and areas of habitats in the study area.



HABITAT CLASSIFICATION
COASTAL ZONE
211 – Open Nearshore Water
221 – Halophylic Wet Meadows
231 – Salt-affected Meadows
241 – Coastal Islands
251 – Beaches
261 – Tidal Flats
FRESH WATER
311 – Deep Open Lakes
322 – Shallow Open Water w/o islands
362 – Aquatic Sedge w/o Islands
366 – Aquatic Grass without Islands
367 – Aquatic Grass with Islands
381 – Drainage Impoundment
385 – Effluent Reservoir
BASIN WETLAND COMPLEX – 400
MEADOWS
511 – Wet Meadows/Non-Patterned
521 – Wet Meadows/Low Relief
541 – Moist Meadows/Low Relief
551 – Moist Meadows/High Relief
SHRUBLANDS
642 – *Dryas* Dwarf Shrubland
ARTIFICIAL
912 – Barren Gravel Fill
919 – Partially Vegetated Sod Fill
Polygon Identification:
Habitat Code.Polygon ID
HABITAT MAP
GHX-1 Study Area, Alaska 1990
N
679000
5966000
UTM
689000
5966000
UTM
0
0.5
1
Kilometers
0
0.5
1
Miles

Appendix 1A. A provisional hierarchical classification of bird habitats for Alaska's North Slope. Each level of indentation of the table represents a level of the classification system. Classes denoted with * were found in the GHX study area.

Class	Codes	Class	Codes
MARINE WATERS	100 O	MEADOWS (Continued)	
Inshore waters	110 On	Moist Meadows	540 Mm
Offshore waters	120 Oo	Low relief *	541 Mml
Sea Ice	130 Oi	sedge-dwarf shrub tundra	542 Mmls
Ice	131 Oii	tussock tundra	546 Mmlt
Ice edge	135 Oie	herb	548 Mmlh
		High relief *	551 Mmh
COASTAL ZONE	200 C	sedge-dwarf shrub tundra	552 Mmhd
Nearshore Water (estuarine)	210 Cn	tussock tundra	556 Mmht
Open nearshore water *	211 Cno	Dry Meadows	560 Md
Brackish ponds	215 Cnp	Grass	561 Mdg
Coastal Wetland Complex	220 Cm	Herb	566 Mdh
Halophytic wet meadows *	221 Cmh		
sedge	222 Cmhs	SHRUBLANDS	600 S
grass	225 Cmhg	Riparian Shrub	610 Sr
herb	228 Cmhh	Riparian low shrub	611 Srl
Salt-affected meadows *	231 Cma	willow	612 Srlw
Barren	240 Cb	birch	615 Srlb
Coastal islands *	241 Cbi	alder	618 Srla
Coastal beaches *	251 Cbb	Riparian dwarf shrub	621 Srd
cobble-gravel	252 Cbbc	Dryas	622 Srdd
sand	256 Cbbs	Upland Shrub	630 Su
Tidal flats *	261 Cbt	Upland low shrub	631 Sul
Coastal rocky shores	271 Cbr	mixed shrub tundra	632 Sulm
low	272 Cbrl	willow	635 Sulw
cliffs	275 Cbrc	alder	638 Sula
Causeway	281 Cbc	Upland dwarf shrub	641 Sud
		Dryas *	642 Sudd
FRESH WATERS	300 W	ericaceous	645 Sude
Open Water	310 Wo	Shrubby Bogs	650 Sb
Deep open lakes *	311 Wod	Low shrub bog	651 Sbl
Shallow open water	321 Wos	mixed shrub	652 Sblm
without islands *	322 Wosw	Dwarf shrub bog	661 Sbd
with islands	323 Wosi	ericaceous	662 Sbde
Rivers and Streams	330 Wr		
Tidal	331 Wrt	PARTIALLY VEGETATED	800 P
Lower perennial	341 Wrl	Floodplains	810 Pf
Upper perennial	346 Wru	Barren	811 Pfb
Intermittent	351 Wri	Partially vegetated	815 Pfp
Water with Emergents	360 We	Eolian Deposits	820 Pe
Aquatic sedge	361 Wes	Barren	821 Peb
without islands *	362 Wesw	Partially vegetated	825 Pep
with islands	363 Wesi	Uplands (talus, ridges, etc.)	830 Pu
Aquatic grass	365 Weg	Barren	831 Pub
without islands *	366 Wegw	Partially vegetated	835 Pup
with islands *	367 Wegi	Alpine	840 Pa
Aquatic sedge-herb	371 Weh	Cliffs	850 Pc
without islands	372 Wehw	Burned Areas (barren)	860 Pb
with islands	373 Wehi		
Impoundment	380 Wi	ARTIFICIAL	900 A
Drainage impoundment *	381 Wid	Fill	910 Af
Effluent reservoir *	385 Wie	Gravel	911 Afg
		barren *	912 Afgb
BASIN WETLAND COMPLEXES *	400 B	partially vegetated	913 Afgp
		Medium-grained	914 Afm
MEADOWS	500 M	barren	915 Afmb
Wet Meadows	510 Mw	partially vegetated	916 Afmp
Nonpatterned *	511 Mwn	Sod (organic-mineral)	917 Afs
sedge (Carex, Erioph.)	512 Mwns	barren	918 Afsb
sedge-grass (Dupontia)	516 Mwng	partially vegetated *	919 Afsp
Low relief *	521 Mwl	Excavations	920 Ae
sedge	522 Mwls	Gravel	921 Aeg
sedge-grass	526 Mwlg	barren	922 Aegb
High relief	531 Mwh	partially vegetated	923 Aegp
sedge	532 Mwhs	Structures and Debris	930 As

Appendix 1B. Areas (ha) of habitats (Levels I and II) within the GHX study area, Prudhoe Bay, Alaska, 1990.

Habitat Level I	Area %	Area ha	Level II	Area %	Area ha
COASTAL ZONE	18.5	152.3	Nearshore Waters	11.7	96.7
			Coastal Wetland Complexes	5.0	41.3
			Coastal Barrens	1.7	14.3
FRESH WATERS	13.0	107.4	Open Waters	2.4	20.0
			Water with Emergents	5.2	42.7
			Impoundments	5.4	44.7
BASIN WETLAND COMPLEXES	21.4	176.3	Basin Wetland Complexes	21.4	176.3
MEADOWS	34.5	284.3	Wet Meadows	20.4	168.0
			Moist Meadows	14.1	116.3
SHRUBLANDS	2.4	19.7	Upland Shrublands	2.4	19.7
ARTIFICIAL	10.2	83.9	Artificial Fill	10.2	83.9
TOTAL	100.0	823.8		100.0	823.8

Appendix 1C. Areas of habitats (Level IV) within the GHX study area, Prudhoe Bay, Alaska, 1990.

Habitat (Level I and Level IV)	Area %	Area ha	Habitat Polygon Size (ha) Mean	Habitat Polygon Size (ha) Range	n[a]
COASTAL ZONE					
open nearshore waters	11.7	96.7	24.2	0.7 - 89.6	4
halophytic wet meadows	3.6	29.7	5.9	1.0 - 19.7	5
salt-affected meadows	0.4	11.6	11.6	11.6 - 11.6	1
coastal islands	0.3	2.4	2.4	2.4 - 2.4	1
coastal beaches	0.5	4.5	2.3	2.2 - 2.3	2
tidal flats	0.9	7.4	3.7	2.0 - 5.4	2
FRESH WATER					
deep open lakes	2.0	16.8	16.8	16.8 - 16.8	1
shallow open water w/o islands	0.4	3.2	1.1	0.7 - 1.6	3
aquatic sedge w/o islands	0.2	1.9	1.9	1.9 - 1.9	1
aquatic grass w/o islands	1.9	15.5	1.5	0.7 - 2.8	10
aquatic grass w/ islands	3.1	25.3	1.5	0.8 - 3.5	17
drainage impoundments	4.2	34.3	2.3	0.6 - 8.0	15
effluent reservoirs	1.3	10.4	1.3	0.4 - 3.7	8
BASIN WETLAND COMPLEXES	21.4	176.3	11.8	0.6 69.0	15
MEADOWS					
wet meadows/nonpatterned	4.1	33.9	6.8	2.0 - 10.2	5
wet meadows/low relief	16.2	134.1	7.4	0.6 - 43.5	18
moist meadows/low relief	13.9	114.7	5.0	0.8 - 26.9	23
moist meadows/high relief	0.2	1.6	1.6	1.6 - 1.6	1
SHRUBLANDS					
Dryas dwarf shrublands	2.4	19.7	4.9	0.5 - 10.7	4
ARTIFICIAL					
barren gravel fill	9.7	80.1	8.1	0.8 - 21.7	10
partially vegetated sod fill	0.5	3.8	1.9	1.3 - 2.5	2
TOTAL	100.0	823.8	5.5	0.4 - 89.6	150

[a] n = number of discrete habitat units (polygons).

Appendix 2. Published records, or estimates, of incubation and brood-rearing periods for waterbirds seen in the GHX study area, Prudhoe Bay, Alaska, 1989 and 1990. Data from Palmer (1962, 1976a, 1976b), Bellrose (1978), and Johnson and Herter (1989).

Species	Length of Incubation Period (days)	Length of Brood-rearing Period (days)	Estimated Duration of Breeding Activities (days)[a]
Canada Goose	25-28	45-50	70-78
White-fronted Goose	24-28	42-45	66-73
Brant	24	40-45	64-69
Snow Goose	22-23	42-49	64-72
Tundra Swan	30-32	60-70	90-102
Northern Pintail	22-23	38-45	60-68
King Eider	22-24	35-50	57-74
Spectacled Eider	24	50-53	74-77
Oldsquaw	23-26	35	58-61
Red-throated Loon	24-26	50-60	74-86
Pacific Loon	24-27	43-55	67-82

[a] Incubation and brood-rearing combined, excluding egg-laying.

Appendix 3. Counts of waterbirds from road and foot surveys in the GHX-1 study area, 27 May - 5 September 1990. Counts in parentheses are unfledged young; all other counts are of adults or adults and juveniles.

Survey Dates	Canada Goose	White-fronted Goose	Brant	Tundra Swan	Northern Pintail	Amer. Wigeon	Eura.[a] Wigeon	Old-squaw	Green-winged Teal	Mallard	Northern Shoveler	King Eider	Spectacled Eider	Pacific Loon	Red-throated Loon	Daily Total
27 May	12	28	0	0	6	0	0	8	0	0	0	2	4	0	0	60
2 June	24	9	3	2	31	6	0	13	0	0	0	7	9	0	0	104
3 June	26	5	11	1	5	0	0	20	0	2	0	2	5	0	0	77
4 June	23	7	5	0	14	0	2	13	0	4	0	10	7	0	0	85
5 June	24	6	0	1	11	0	0	5	0	3	0	6	9	1	0	66
6 June	23	13	0	0	5	0	2	18	0	0	0	8	7	2	0	78
11 June[b]	25	19	0	1	52	0	0	16	2	10	0	27	7	14	2	175
14 June	31	1	17	1	14	0	0	3	0	1	0	14	8	13	1	104
20 June	26	2	60	0	30	0	0	3	0	0	0	10	5	8	4	148
21 June[b]	38	16	37	0	44	0	0	7	2	3	2	16	0	17	3	185
25 June	19	4	28	4	26	0	0	1	0	0	0	3	0	7	1	93
29 June	18 (2)	1	79 (3)	0	22	0	0	1	0	0	0	0	5	10	1	137 (5)
3 July	3	2 (2)	149 (20)	2	13	0	0	0	0	0	0	0	0	8	1	178 (22)
8 July	10 (3)	6 (1)	201 (101)	2	12	2	0	0	0	0	0	8	4	12	1	258 (105)
13 July	28 (20)	6 (7)	199 (95)	2	18	0	0	2	0	0	0	1 (2)	0	9 (3)	1	266 (127)
18 July	32 (40)	2 (2)	275 (172)	2 (4)	0	0	0	0	0	1	0	0	0	4 (2)	1	317 (220)
23 July	0	2 (2)	277 (132)	2 (4)	3	0	0	0	0	0	0	3	0	11 (6)	2 (1)	300 (145)
27 July	48 (64)	2 (5)	293 (196)	2 (4)	24	0	0	3	0	0	0	2 (3)	0	12 (6)	4 (3)	390 (281)
31 July	6 (8)	0	241 (189)	2 (4)	19	0	0	0	0	0	0	3 (9)	5 (19)	13 (6)	2 (1)	291 (236)
4 August	46 (42)	0	195 (110)	2 (4)	33	12	0	0	0	0	0	2 (4)	0	9 (6)	1 (1)	300 (167)
8 August	39 (30)	0	106 (63)	2 (4)	49	0	0	12	0	1	0	1 (2)	0	11 (6)	1 (1)	222 (106)
13 August	16	2 (4)	40 (26)	2 (4)	39	0	0	0	0	0	0	1	4	7 (3)	3 (1)	114 (38)
20 August	3	84	5 (4)	1	35	0	0	1	0	2	0	4	7	9 (4)	1 (1)	152 (9)
24 August	0	37	0	0	41	0	0	0	2	0	1	2	0	9 (6)	1 (1)	93 (7)
28 August	0	30	0	1	28	0	0	7	0	0	1	0	1	19 (5)	2 (1)	85 (6)
1 September	11	0	0	4 (2)	45	0	0	6	4	0	0	0	1	12 (2)	1	84 (4)
5 September	5	0	0	3 (2)	24	0	0	0	2	0	0	0	0	6	0	40 (2)

[a] Eurasian Wigeon.

[b] Foot surveys (nest searches).