FINAL REPORTS

GHX-1 WATERBIRD AND NOISE MONITORING PROGRAM

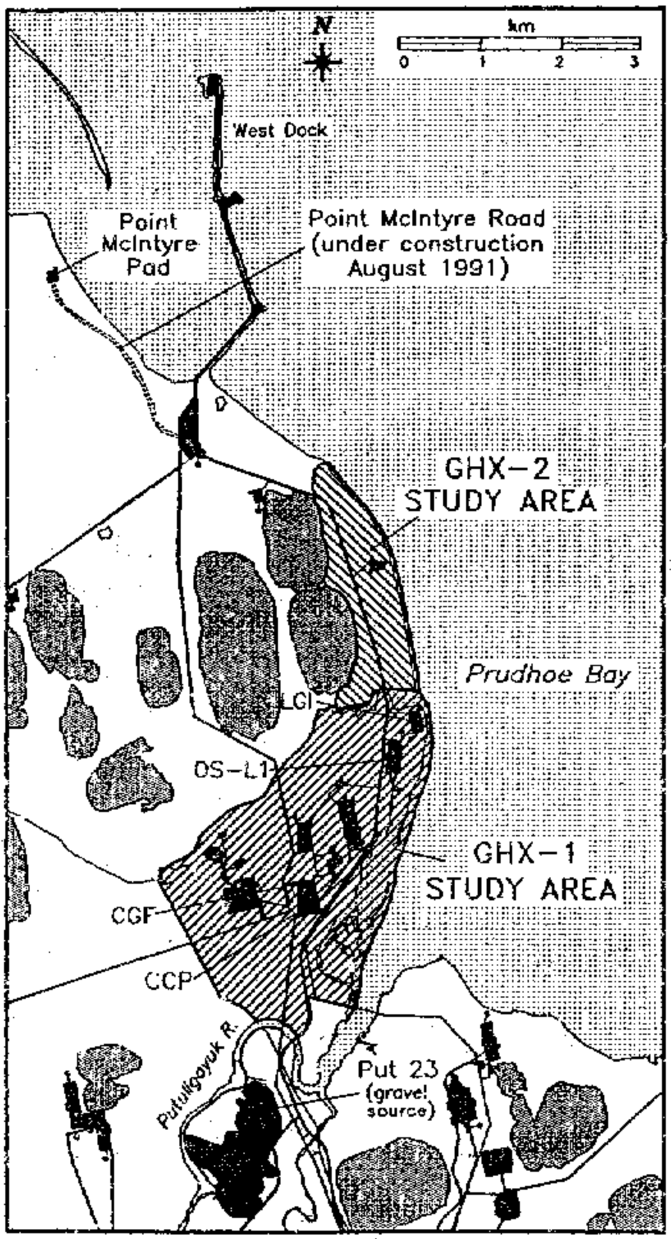
PREPARED BY:
BETTY A. ANDERSON
STEPHEN M. MURPHY
M. TORRE JORGENSON

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

AND

DAVID S. BARBER
B. ANDREW KUGLER

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



ABUNDANCE AND DISTRIBUTION OF WATERBIRDS IN THE GHX-2 STUDY AREA

PREPARED BY:
BETTY A. ANDERSON

THE EFFECTS OF POINT McINTYRE/GHX-2 GRAVEL HAULING ON BRANT

PREPARED BY:
BETTY A. ANDERSON

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

GHX-1 WATERBIRD AND NOISE MONITORING PROGRAM

FINAL 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

David S. Barber
and
B. Andrew Kugler

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

September 1992

Printed on recycled paper.

GHX-1 WATERBIRD AND NOISE MONITORING PROGRAM

FINAL 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

David S. Barber
and
B. Andrew Kugler

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

September 1992

Printed on recycled paper.

EXECUTIVE SUMMARY

- The objective of the Gas Handling Expansion (GHX) Project in the Prudhoe Bay Oilfield is to maintain efficient oil production by increasing gas processing and reinjection capability. The project will allow increased oil production and help reduce declines in field performance. The first phase (GHX-1) of the project installed two new compressors at the Central Compressor Plant. GHX-1 became operational in 1991.

- The goal of the GHX-1 monitoring program was 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 facility. The second and third years of the study were 1990 (construction) and 1991 (the first operational year). The specific objectives of the 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);

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

  4) evaluate the effects of noise from GHX-1 on the seasonal abundance, distribution, habitat use, and nesting success of waterbirds.

NOISE SURVEY AND MODELING OF THE GHX-1 FACILITY

- Noise surveys in 1989 and 1990 characterized noise emanating from the CCP and CGF facilities prior to the construction of GHX-1. Data collected in 1991 determined the contribution of GHX-1 to the noise environment, and evaluated the propagation of noise under different wind conditions.

- GHX-1 compressors and turbines contributed mostly at lower frequency ranges (31.5 Hz and 63 Hz) and, due to the specific location of the turbines, noise generated by the facility was highly directional (over a range of 30° -- 15° on each side of the northwest direction).

- Noise levels (hourly L_{eq}) at the permanent noise monitor located on the shore of Prudhoe Bay southeast of CCP were significantly higher in 1991 than in 1989.

The mean L_{eq} in 1989 was 52.2 dBA and the mean L_{eq} in 1991 was 54.9 dBA, 2.7 dBA higher than in 1989. In addition to the GHX-1 facility, gravel-hauling traffic on West Dock Road, located approximately 250 m west of the microphone, contributed to the higher noise levels recorded in 1991.

- Estimated noise levels in 1-km^2 and 4-km^2 plots centered on CCP indicated that noise levels increased significantly only to the northwest and northeast of the GHX-1 facility, and only under north winds (wind speed = 13 mph). In other directions, mean noise levels rarely increased more than 1 dBA.

- Comparisons of estimated noise levels in different habitat types during pre-operational and GHX-1 operating conditions indicated that only one habitat type, Open Waters, had significantly higher noise levels in 1991 than in pre-operational years, but only when winds were from the north and northeast.

ABUNDANCE, DISTRIBUTION, HABITAT USE, AND THE EFFECTS OF NOISE

- Seventeen species of waterbirds occurred in the study area during the three years of this study: four species of geese (Canada Goose, White-fronted Goose, Brant, and Snow Goose), Tundra Swan, ten species of ducks (Red-breasted Merganser, Northern Pintail, American Wigeon, Eurasian Wigeon, Oldsquaw, Green-winged Teal, Mallard, Northern Shoveler, King Eider, and Spectacled Eider), and two species of loons (Pacific Loon and Red-throated Loon). Shorebirds were not monitored. We saw six duck species (Red-breasted Merganser, Mallard, Green-winged Teal, American and Eurasian wigeons and Northern Shoveler) on <25% of all surveys for the three years.

- Canada Goose numbers did not differ among years except during pre-nesting when they were significantly lower in 1990 than both 1989 and 1991. Lower numbers in 1990 were due to warmer spring conditions that allowed early dispersal to nesting grounds. The number of nests increased from six in 1989 to 11 in both 1990 and 1991. Shifts in distribution attributable to avoidance of increased noise in 1991 were apparent only during pre-nesting, when flocks were located significantly farther from CCP (the site of GHX-1) in 1991 than in 1989. Mean estimated noise levels at the locations of pre-nesting flocks also were significantly lower in 1991 than in 1989.

- White-fronted Geese occurred in large numbers only during pre-nesting and fall staging, but no changes in distribution among years were apparent during those seasons. The number of nests in the study area increased annually from zero in 1989 to two in 1991. Only during pre-nesting and brood-rearing (adults only) did the abundance of White-fronted Geese differ significantly among years. Neither of those differences could be attributed to the effects of noise, because higher numbers occurred in 1991, the operational year for GHX-1.

- Brant were the most common brood-rearing goose and occupied the coastal island at the mouth of the Putuligayuk River from late June through August each year. Significant annual changes in the abundance of Brant adults and young during brood-rearing were due to higher productivity in 1990 compared to 1989 and 1991, and not to any noise effects. Estimated noise levels at the locations of Brant flocks were significantly higher in 1991 than in the two previous years, however.

- Tundra Swans were present during all seasons and years of this study but were never abundant, and no significant annual changes in abundance were found for any season. During brood-rearing, Tundra Swans occurred significantly farther from CCP 1990 and 1991 than in 1989, but estimated noise levels at flock locations did not differ significantly among years.

- Northern Pintails and Oldsquaw were the most common ducks each year. Pintails showed two peaks in abundance in May-June and in August, whereas Oldsquaw were abundant only in May and June. No changes in distribution or abundance due to noise emanating from CCP and GHX-1 were observed for either species.

- King and Spectacled eiders occurred in low numbers during most seasons. Spectacled Eiders were less abundant than King Eiders during most seasons and years. Annual changes in abundance occurred only during pre-nesting when we saw significantly fewer eiders in 1991 than in 1990 (no counts in 1989), probably because of colder spring conditions in 1991. Although we never found evidence of nesting, broods of both species were seen each year. King Eiders displayed no changes in distribution, abundance, or habitat use that were attributable to disturbance by noise from the GHX-1 facility. During nesting, Spectacled Eider flocks were significantly farther from CCP in 1991 than in 1989 (mean distances of 1845 m and 1246 m, respectively), suggesting that they were exhibiting some avoidance of increased noise from the GHX-1 facility in 1991.

- Pacific Loons were the most abundant loon during all seasons and years. The number of nesting pairs was relatively constant at six to eight each year. Only during brood-rearing did loon numbers differ significantly among years; more loons were seen in 1990 and 1991 than in 1989. Pacific Loons did not change in abundance, distribution, or habitat use in ways that could be attributed to the effects of noise from GHX-1.

- Red-throated Loons were uncommon during all seasons and years. Two pairs attempted to nest each year, although the number of nests found varied between one and three (includes one re-nesting attempt). We saw significantly more loons during brood-rearing in 1990 and 1991 than in 1989. During brood-rearing, Red-throated Loon flocks also were significantly farther from CCP (GHX-1) in 1991 than in 1990; distances in 1989 and 1991 were similar. This shift in distribution was not directly attributable to disturbance from noise associated with the GHX-1 facility.

BREEDING BIRDS, NEST FATE, AND THE EFFECTS OF NOISE ON NESTING SUCCESS

- We found nests of four species of waterbirds: Canada Goose, White-fronted Goose, Pacific Loon, and Red-throated Loon. The total number of nests increased annually from 14 in 1989 to 25 in 1991. Overall nesting success was highest (82%) in 1990, lowest (21%) in 1989, and intermediate (52%) in 1991. The major factor influencing nesting success was spring weather conditions, in particular the warm spring in 1990.

- Canada Geese experienced their highest nesting success in 1990 when 10 of 11 (91%) nests were successful. Nesting success was low (17%, 1 of 6 nests) in 1989 and intermediate (46%, 5 of 11 nests) in 1991. Noise from GHX-1 and the other facilities (CCP and CGF) did not affect nesting success among years or within a year. Logistic regression analysis indicated that spring weather conditions most strongly determined nesting success of Canada Geese.

- White-fronted Geese did not nest in the study area in 1989 and nested in low numbers in 1990 (1 nest) and 1991 (2 nests). All nesting attempts were successful. Noise from GHX-1 and CCP did not affect the distribution of nests or nesting success of White-fronted Geese.

- Pacific Loons had variable nesting success among years. Nesting success was highest (62%, 5 of 8 nests) in 1990, lowest (33%, 2 of 6 nests) in 1989, and intermediate (44%, 4 of 9 nests) in 1991. Nesting success of Pacific Loons did not appear to be affected by noise from GHX-1 or other facilities.

- Red-throated Loons nested in low numbers each year. The number of nests found during nest searches varied from one (1990) to three (1991), but the number of nesting pairs was constant at two pairs; one nest was missed during nest searches in 1990, and one pair re-nested in 1991. Nesting success varied annually; all nests were successful in 1990, all failed in 1989, and 2 of 3 were successful in 1991 (this could be considered 100% success for the two pairs, however). Noise from GHX-1 did not significantly affect nesting success, but successful nests were farther from all types of facilities than failed nests.

CONCLUSIONS

- We found few detrimental effects of noise on waterbirds in the area. For only two species during two seasons, Canada Goose (pre-nesting) and Spectacled Eider (nesting), did we find strong indications that birds responded to noise from GHX-1. All other changes in abundance, distribution, and habitat use were attributable more to annual variations in spring weather conditions and species-specific shifts that were not due directly to noise from GHX-1.

- A specific objective of this study was to evaluate the effects of GHX-1 noise on nesting Canada Geese in the wetlands north of NGI and on brood-rearing Brant on the coastal island southeast of CCP. Nesting Canada Geese were not affected by noise generated by GHX-1. Although brood-rearing Brant using the coastal island southeast of CCP experienced significantly higher noise levels in 1991 than in previous years, they did not shift their use of the island to the quieter southeastern end of the island or increase their use of the mainland to the south, the quietest habitats available. Thus, increased noise apparently did not affect use of the area by brood-rearing Brant.

- It appears that most waterbirds have become habituated to the steady noise emanating from both the CCP and CGF pads and that any adjustments that they may have made in reaction to noise occurred well prior to the onset of this study. In conclusion, noise from the GHX-1 facility made only a small contribution to the total noise environment around the CCP and CGF facilities and had little effect on use of the study area by most waterbirds.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

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. We thank Michelle Gilders of BP Exploration (Alaska) Inc. for her comments and suggestions for improvements on this report.

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, Suzann Speckman, Paul Banyas, Alice Stickney, and Amy Ritchie; for editing we thank Bob Day; and for graphical and clerical support we thank Allison Zusi-Cobb and Terrence Davis.

INTRODUCTION

The objective of the Gas Handling Expansion Project in the Prudhoe Bay Oilfield is to maintain oil production by increasing gas production and reinjection capability. The project will improve high pressure oil production capability and delay the declines in oil production in the field. The increased gas handling capacity allows for the reinjection of greater quantities of gas to the reservoir that will enhance oil production as well as increase the production of natural gas liquids for shipment through the Trans-Alaska Pipeline. The project was divided into two phases. Phase I (GHX-1), which was completed in 1991, was designed to increase gas handling capacity by adding compressors to the Central Compressor Plant (CCP). Phase II (GHX-2) will involve additional increases in gas handling capacity at several facilities, the construction of a new reinjection site, and additional pipelines. The first phases of construction of GHX-2 commenced in 1991 and will continue through final start-up in 1995.

In conjunction with the planned construction of GHX-1 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 was 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 (Anderson et al. 1991) and during the first year of operation in 1991. The goal of the monitoring program was 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 field program were to:

- 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;

- 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 of noise (e.g., flaring); and

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

In this report, the final product of the noise study, an interactive model was used to predict noise levels throughout the study area, based on prevailing weather (e.g., wind velocity and direction) and disturbance (e.g., number of turbines active) conditions during each year of the study. Data from the model then were 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.

Several 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. 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 area used by brood-rearing Brant.

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 (Figure 2). 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 influenced greatly 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 by birds in the GHX-1 study area (Anderson et al. 1990, 1991).

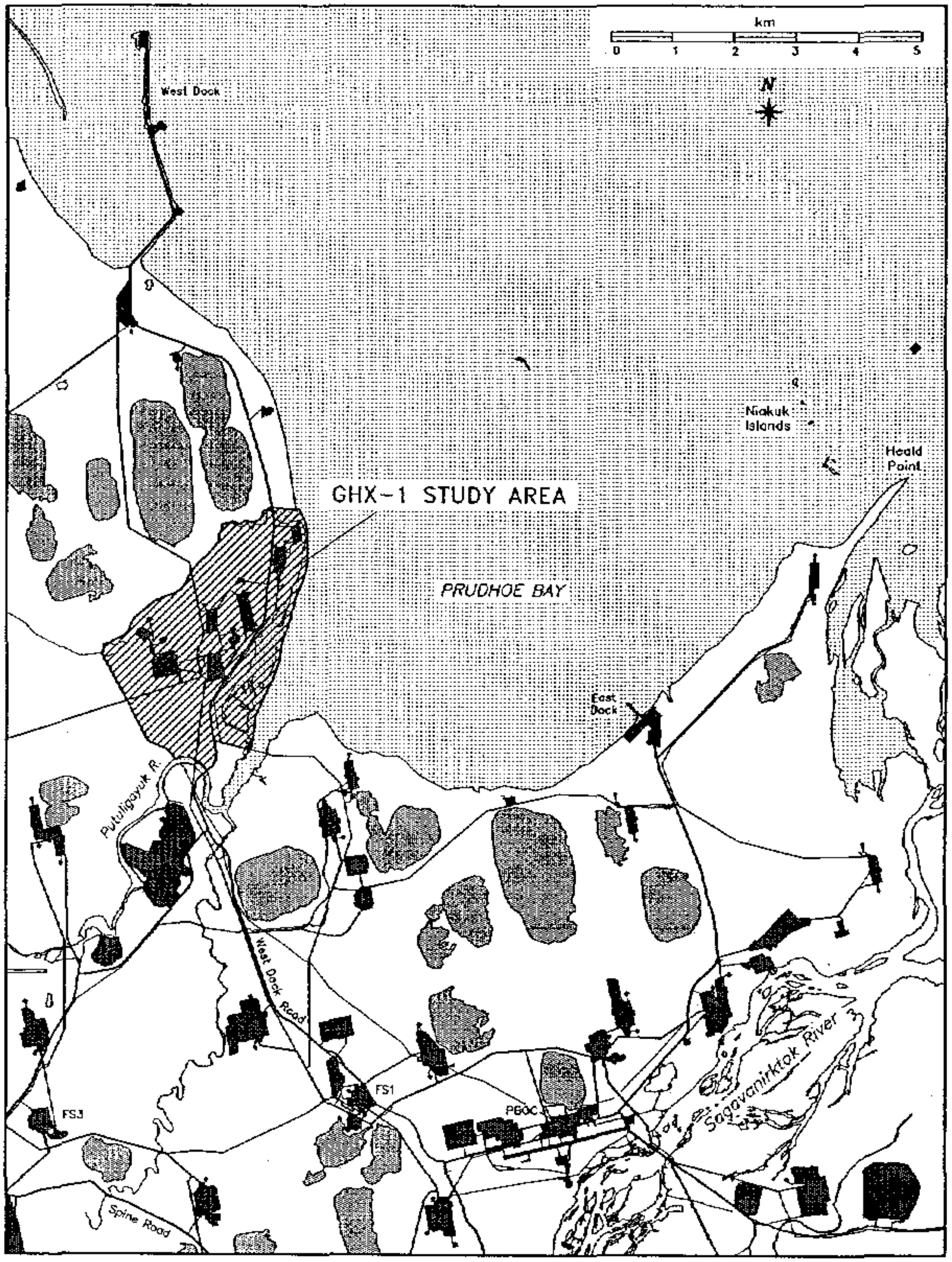


Figure 1. Location of the GHX-1 study area in the Prudhoe Bay region, Alaska.

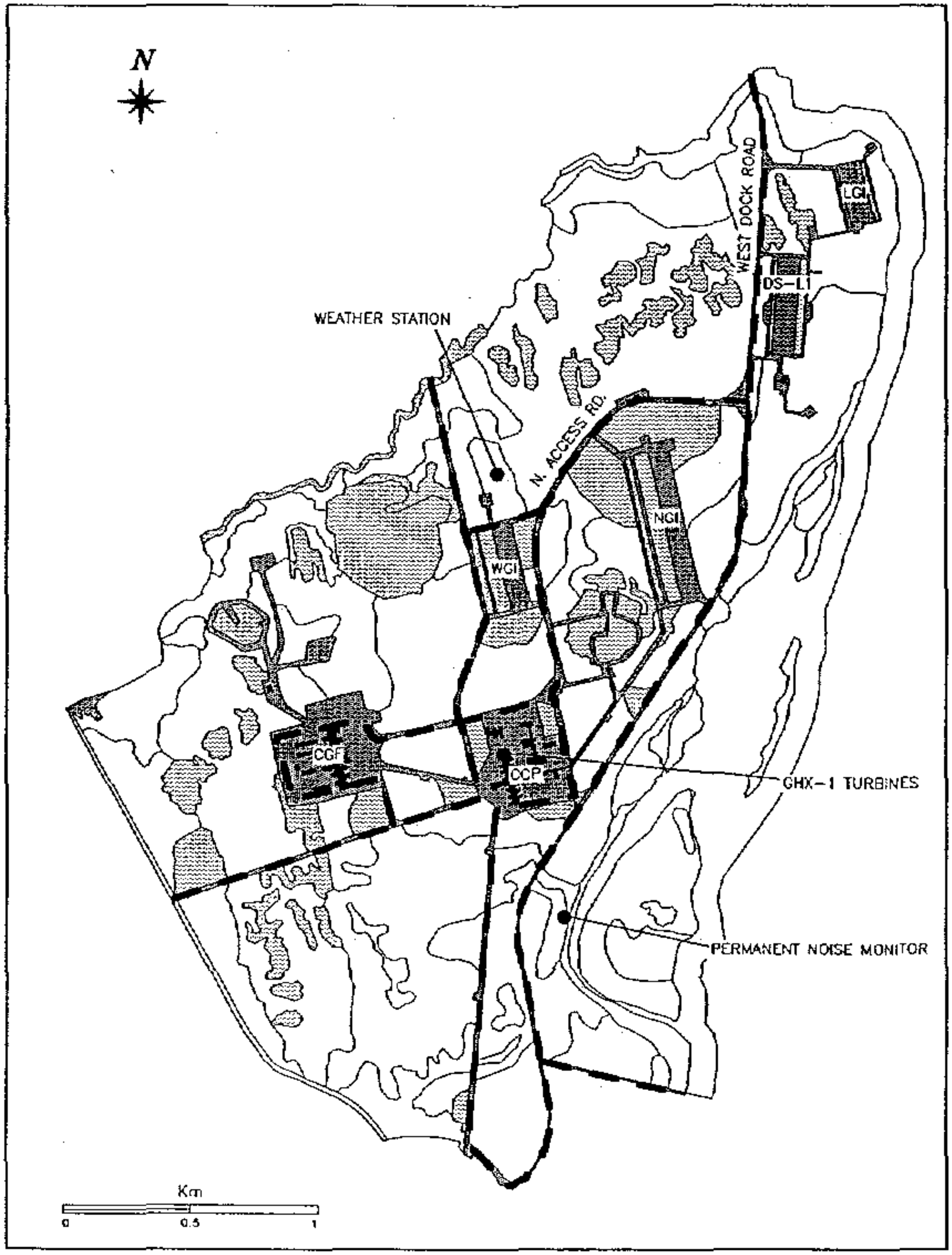


Figure 2. Study area and road survey route for the GHX-1 monitoring program, Prudhoe Bay, Alaska, 1989-1991.

METHODS

DATA COLLECTION

CONDITIONS IN THE GHX-1 STUDY AREA

Phenological conditions in the study area were assessed by monitoring snow cover, spring snow-melt, and mean monthly temperatures. A relative measure of the "earliness" of each spring was calculated based on the cumulative degree days between May 15 and June 15. The number of degree days in a day were equal to the number of degrees that the daily mean temperature exceeded freezing, 0°C (e.g., a day with mean temperature of 3°C had 3 degree-days). Weather conditions (temperature, relative humidity, wind speed and direction) were monitored using a weather station located north of the West Gas Injection (WGI) pad. This station was operated continuously and summarized weather information every 20 min (every 30 min in 1991), except for brief periods when equipment malfunctioned.

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) during each year. The durations of nest-initiation, egg-laying, incubation, and brood-rearing periods were determined either by direct observation or by estimation ("back-dating") from 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). Loons usually began nesting later than other waterbirds and did not begin fall staging prior to the end (early September) of our survey period. Only during 1990 did the early spring melt allow earlier initiation of nesting by loons, and we considered the fall-staging season for loons to have begun by the last week of our survey period.

Predator activity in the study area was evaluated during road surveys by recording the abundance and distribution of birds and mammals that prey on waterbird eggs, young, and adults: arctic fox (*Alopex lagopus*), Glaucous Gull (*Larus hyperboreus*), Common Raven (*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 each year.

Oilfield activities in the GHX-1 study area were assessed each year by describing all 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 2). Traffic was counted during 15-min periods on most survey dates in 1990 and 1991 (total time for counts was approximately 9.8 h and 15.2 h, respectively). Traffic counts in 1989 were collected in conjunction with the Lisburne Terrestrial Monitoring Program (Murphy et al. 1990) and were 20 min long (total time for counts was approximately 64.7 h). Vehicles were classified as small vehicles (e.g., pick-up trucks, "suburban"-type trucks), large vehicles (larger than "suburban"-type trucks), or very large, noisy trucks (e.g., gravel-hauling trucks). Mean traffic rates (vehicles/h) were calculated for each vehicle type and for all vehicle types combined for each of the three road segments.

NOISE SURVEY AND MODELING OF THE GHX-1 FACILITY

BBN Systems and Technologies Corporation was responsible for data collection and modeling of the noise environment in the GHX-1 study area. An "acoustic prediction model" was developed from these field data to predict the noise environment at any point near the CCP, CGF, and GHX-1 facilities. In support of this model, the focus of the first year field study (1989) was to describe the existing noise environment prior to construction of GHX-1. Source and propagation acoustic data were collected in the area surrounding the CCP and CGF facilities. Both major continuous sources (plant equipment) and time-varying sources (e.g., flare noise, road traffic, and gravel excavating activities) were surveyed. The second year of study (1990) focused on collecting data in support of flare noise modeling, developing a plan for the collection of acoustic data to refine predictions of the effect of wind on noise propagation, and to extend the capability of the computer model's output to provide noise contours that could be plotted around the CCP/CGF facilities. The main objectives of the third year of study (1991) were to collect acoustic field data with the GHX-1 facility in operation, collect a final set of noise propagation data in the area surrounding the facilities, repair and reinstall the automated stationary noise monitor located southeast of CCP, and incorporate the results of the GHX-1 measurements into the computer model.

Field collection methods were similar during the three years of the study. Sound measurements were made with a Larson-Davis Model 870 sound meter and a Nagra SJ-IV tape recorder. Specifics on field measurements for 1989 and 1990 are discussed in Anderson et al. (1990, 1991). In 1991, all measurements were made at locations around the CCP complex, with an emphasis on the noise contribution from the GHX-1 units, which were attached to the north end of the building containing the CCP turbines and compressors. BBN personnel collected acoustic data in the GHX-1 study area on 24-27 June 1991. The stationary noise monitor was repaired and installed immediately upon arrival and began collecting data on 27 June 1991. For acoustic measurements around CCP, accurate measurements could not be collected until 26 June, because wind conditions exceeded 30 mph at times. After briefings with CCP facility operations personnel, noise measurements of the GHX-1 unit were conducted on 26-27 June 1991. Temperature, humidity, and wind velocity information were collected in addition to the noise data. The noise survey was hampered by continuous wind that, although not as intense as during the first two days, made collection of the acoustic data difficult. On-site data were collected in terms of the same metrics as in previous surveys (Anderson et al. 1990, 1991), such as Equivalent Sound Level (L_{eq}) and Maximum Sound Level (L_{max}). L_{eq} is the primary unit of noise exposure used by federal and state agencies for environmental regulation and is defined as the equivalent steady-state sound level over a period of time that contains the same acoustic energy as a time-varying sound level during the same period (i.e., the acoustic energy average of a given sample duration). L_{eq} is used as the noise predictor in the acoustic prediction model.

ABUNDANCE, DISTRIBUTION, HABITAT USE, AND THE EFFECTS OF NOISE

The abundance, distribution, and habitat use of waterbirds in the GHX-1 study area were monitored by 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. The total number of road surveys conducted each year varied slightly, but all surveys were conducted between 27 May and 5 September (Table 1). Road surveys were conducted approximately every four days, except during pre-nesting when surveys were conducted approximately daily. Each road survey 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 2), for consistent and complete coverage of the study area. In addition to road surveys, two foot surveys were conducted each year during the early nesting season 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 between the two survey types). If dates of nesting surveys and road surveys coincided, only road survey data were used.

Habitat use by waterbirds was assessed by plotting observations of birds from road and nest surveys on a digitized overlay of the habitat map. The habitats mapped were based on the avian habitat classification developed for the Lisburne Monitoring Program (Jorgenson et al. 1989, Murphy et al. 1989; Appendix 1). All observations were assigned to Level IV habitats, the most specific of the four levels of habitat classification provided in the habitat mapping system (Appendix 1A). Any 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 the levels of habitat use among years to look for shifts in habitat use

Table 1. Number of road surveys during each season and year of the GHX-1 study, Prudhoe Bay, Alaska, 1989-1991. Number of surveys differ among species groups because of differences in breeding phenology (i.e., seasonal dates).

		Season				
Species Group	Year	Pre-nesting	Nesting	Brood-rearing	Fall Staging	Total
Geese/Ducks/ Swans	1989	8/0[a]	6	9	5	28
	1990	5	6	11	5	27
	1991	6	8	9	7	30
Loons	1989	10	6	12	-	28
	1990	7	7	11	2	27
	1991	10	8	12	-	30

[a] Ducks were not counted during pre-nesting surveys in 1989.

attributable to noise generated by the operation of GHX-1. Although observations of birds were categorized according to Level IV habitats, the habitat-use data in this report are presented for Level II habitats (a more general classification of habitat type) to simplify interpretation of results and trends. When relevant, important Level IV habitats are discussed.

BREEDING BIRDS, NEST FATE, AND THE EFFECTS OF NOISE ON NESTING SUCCESS

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 distances of each nest to the center of the CCP and CGF facilities and to the nearest road and pad were calculated from the digitized map.

DATA ANALYSIS

All statistical tests were performed using a significance level of $\alpha = 0.05$ ($P \leq 0.05$), unless otherwise indicated. Nonparametric statistical tests are described in Conover (1980) and were conducted using SPSS/PC+ statistical software (SPSS Inc. 1989).

CONDITIONS IN THE GHX-1 STUDY AREA

Among year differences in predator counts and traffic counts were evaluated with Kruskal-Wallis nonparametric tests (the nonparametric equivalent of an analysis of variance test). Any significant tests were then subjected to a Kruskal-Wallis pairwise comparison procedure to determine which years were significantly different from each other.

NOISE SURVEY AND MODELING OF THE GHX-1 FACILITY

The tape-recorded data collected in 1991 were analyzed in the laboratory in terms of one-third octave band frequency, using a real-time analyzer and computer program. From this analysis, other acoustic descriptors, such as "statistical noise levels," were computed. The statistical noise levels describe the percentage of time a given time-varying noise level is exceeded, in this case, the 1, 10, 25, 50, 90, and 99 centiles. These statistics can 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?). Noise data collected at the permanent noise monitor in 1989 and 1991 were summarized as hourly noise levels (L_{eq}). A Mann-Whitney test was used to test whether noise levels differed between years. The relative contribution of the GHX-1 turbines to the total noise emanating from CCP were evaluated by a qualitative comparison of the one-third band octave frequencies of each facility operating alone.

Results of these data analyses then were used to complete the "acoustic prediction model" that can predict the noise environment at any point near the CCP, CGF, and GHX-1 facilities. The final model, the Outdoor Noise Prediction Model (ONPP), was provided to ABR as a set of computer diskettes and a user's manual (McCraw 1992). The ONPP permits the user to estimate noise levels at any point in the study area for a variety of operational (the number of equipment items operational at any time) and propagation conditions (distance to operational equipment, weather conditions) without the need for a continuous noise monitoring program (Table 2). In this manner, bird observations could be matched with the corresponding noise levels obtained with the computerized acoustic prediction model.

To test whether noise levels increased within habitat types in the study area, we compared estimated noise levels in Level II habitats for conditions present in the study area during 1989 and 1990 (pre-operational) to estimated noise levels in 1991 with GHX-1 operating. These changes were tested by using the "area" output (which develops a

Table 2. Disturbance and weather parameters in the Outdoor Noise Prediction Program (McCraw 1992), for the GHX-1 study.

DISTURBANCE PARAMETERS (options)		
Turbines	CCP	(0-13 turbines)
	CGF	(0-6 turbines)
	GHX-1	(0-2 turbines)
Vehicles	Main road	(Day [25.5 vehicles/h] / Night [14.5 vehicles/h])
	Gravel trucks	(number vehicles/h)
	Center Pit Activity	(number of pieces of equipment operating at the Putuligayuk gravel pit)
Other Sources	Drill site[a]	(On/Off)
	Weighting scale	(A/C)
WEATHER PARAMETERS (options)		
Humidity	(enter % humidity)	
Temperature	(enter temperature °F, if default temperature below is not used)	
Wind direction	(Calm, N, NE, E, SE, S, SW, W, NW)	
Wind speed	(select 1 of 5 Conditions - based on a default temperature and wind speed)	
	Condition 1 - 68.0°F, 0.0 m/s [0.0 mph]	
	Condition 2 - 31.1°F, 5.9 m/s [13.2 mph]	
	Condition 3 - 21.0°F, 4.4 m/s [9.8 mph]	
	Condition 4 - 44.4°F, 4.4 m/s [9.8 mph]	
	Condition 5 - 35.4°F, 6.5 m/s [14.5 mph]	

[a] Drill site is DS-L1.

grid of 1764 points across most of the study area) available in the noise model with a standardized set of conditions (Day traffic; no gravel trucks or pit activity; Drill Site on; and weather conditions set to 39°F, 80% humidity) and then modeling noise levels for all wind directions (wind speed set to Condition 2 [13 mph]) and for calm conditions. For each wind direction, two runs of the model were conducted, one with the number of GHX turbines set to zero (the "pre-operational" data set) and a second with the number of GHX turbines set to two (the "operational" data set). The habitats into which the 1764 points fell were determined using a GIS program (AtlasGIS, version 1.2; Strategic Mapping, San Jose, CA). Because the locations of the points did not change between runs, the model produced a pre-operational and operational noise level at each point. Mean estimated noise levels were then calculated for each Level II habitat type for the pre-operational and operational conditions. For each habitat, we then tested for significant difference between these two estimated noise levels with a Mann-Whitney nonparametric test.

Because the GHX facility was located on the north side of CCP, we evaluated the directional effect of noise from the facility on the nearby area by calculating mean noise levels in two plots (1 km^2 and 4 km^2) centered on the CCP facility. The center point selected was that used in the ONPP computer model, and we used the same area outputs (pre-operational and operational conditions) developed above for evaluating changes in noise within habitat types under different wind conditions. For each wind direction and calm condition, we tested (Mann-Whitney tests; $\alpha = 0.05$) for significant increases in dBA between pre-operation and operation of GHX-1 in the entire plot and in the four quadrats (northwest, northeast, southeast, and southwest) of the plot.

ABUNDANCE, DISTRIBUTION, HABITAT USE, AND THE EFFECTS OF NOISE

The effects on waterbirds of noise from the GHX-1 facility were evaluated by looking for differences in abundance, distribution, and habitat use that could be attributed to avoidance of noise. Changes in abundance were assessed by testing for differences in seasonal mean densities among years with Kruskal-Wallis tests. A Mann-Whitney nonparametric test (the nonparametric equivalent of a t-test) was used to test for annual differences in densities of duck species during pre-nesting, because only two years of data were available. Changes in distribution were evaluated by testing for annual differences in mean distances of waterbird flocks to CCP during each season (Kruskal-Wallis procedure) and by visually inspecting maps of distributions for obvious shifts in use of the study area, which would not result necessarily in any changes in distance to CCP. Flock locations, rather than locations of individual birds, were used for analyses because of lack of independence among individuals in the same flock. In addition, for those waterbird species that nested in the study area, distance to CCP was not tested because of the lack of independence between repeated observations of incubating birds. Changes in distribution of nesting birds were evaluated by testing distances of nests to facilities (see below). Changes in habitat use were evaluated qualitatively by comparing densities within habitats among years.

The Outdoor Noise Prediction Program (ONPP) was used to estimate the noise level in decibels (dB, A scale; hereafter, abbreviated as dBA) at the location of each bird sighting during each year of the study. The computer model used the (x,y) coordinates of each sighting from the digitized map of the study area and calculated an estimated noise level at that location, based on a set of environmental and disturbance parameters that the user can change to simulate most closely the actual conditions present at the time of the road survey. Actual weather conditions at the time of each survey were used in the model, and disturbance parameters were set based on known operating conditions at the facilities and our observations of traffic on West Dock Road (Table 3).

Using the noise model, we estimated the noise level at each bird location during each road and foot survey during the three years of the study. These noise levels then were used in all subsequent analyses for changes in waterbird distribution that could be attributed to increase noise from the GHX-1 facility. Because the decibel scale is logarithmic, we transformed decibel values to sound power for any statistical analyses that would be affected by the logarithmic scale. The equation used to transform decibel levels to sound power was $dBA = 20 \log P/P_r$, with P = sound power level and P_r = 0.00002 microPascals (Peterson 1980).

To evaluate whether observed changes in abundance, distribution, or habitat use were due only to increased noise from the GHX-1 facility, we looked primarily for changes in distribution, in particular increased distance to CCP in 1991 as compared to

Table 3. Disturbance and weather parameters used for input into the Outdoor Noise Prediction Program (McCraw 1992) for the GHX-1 study, 1989-1991. Parameters were determined for each survey date.

		Year of Study		
		1989	1990	1991
DISTURBANCE PARAMETERS				
Turbines	CCP	13	13	13
	CGF	6	6	6
	GHX-1	0	0	2
Vehicles	Main road	Day	Day	Day
	Gravel trucks [no./h if present; count from traffic counts]			
	Center pit activity [0; unless gravel pit operating, then set at 2]			
Other sources	Drill site	On	On	On
	Weighting scale	A	A	A
WEATHER PARAMETERS				
Humidity	a) average % humidity from weather station[a], or b) if no weather station data available, then set at: 1) 85% (temperature $<65^{o}F$; no fog or precipitation), 2) 80% (temperature $>65^{o}F$; no fog or precipitation), or 3) 100% (fog or precipitation)			
Temperature	^{o}F at start of survey [do not use default temperature]			
Wind direction	wind direction at start of survey			
Wind speed	Condition 1, 2, 4, or 5 -- based on wind speed at start of survey[b]			

[a] Weather station (datalogger) was located north of the Western Gas Injection pad.
[b] Condition 3 was not used because wind speed was identical to Condition 4.

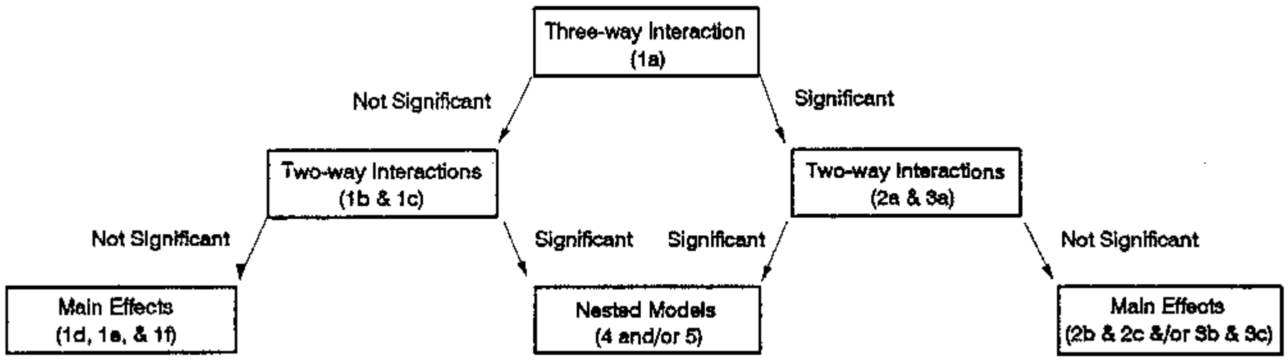
1989 or 1990. If those changes were present, we subjected data for that species and season to an analysis of covariance procedure (SuperANOVA; Abacus Concepts, Inc., Berkeley, CA) that evaluated the effects of distance to CCP, distance to CGF (a secondary noise source), and year on noise levels (dBA). This analysis of covariance (ANCOVA) procedure is a hierarchical model that evaluates interaction terms first before testing for main effects (Figure 3). We used noise level as the dependent variable to determine if the observed shifts in distance to CCP simply were changes in distribution that did not affect the noise level experienced by the birds (for example an east-west shift). Decibel levels, rather than sound power, were used because the plot of residuals using sound power as the dependent variable suggested that a logarithmic transformation was appropriate; therefore, we used the dBA values.

BREEDING BIRDS, NEST FATE, AND THE EFFECTS OF NOISE ON NESTING SUCCESS

The distances of waterbird nests to the center of the CCP and CGF facilities and to the nearest road and pad were evaluated with Mann-Whitney tests (within a year) or a Kruskal-Wallis test (multiple years only) to determine whether the distances differed significantly between successful and unsuccessful nests in each year, among years for successful nests, among years for failed nests, and among years for all fates combined. Pairwise comparisons were used for all significant Kruskal-Wallis tests to determine which years were different.

For nest sites, we used the ONPP model to estimate a noise level for each survey during the nesting season, and we then calculated a mean sound level that accounted for the variability in noise experienced by nesting birds during the course of the nesting season. Because weather conditions, particularly prevailing wind direction and wind speed, affected the estimated sound level at nest sites, we also calculated a mean sound level for each nest site with a standardized set of weather conditions. This standardized mean value allowed for an analysis of changes in noise levels at nest sites that removed the effect of weather differences among years, and thus, tested only for changes that could be attributed to differences in noise emanating from the GHX-1 facilities. Ten weather conditions were used to calculate this standardized mean; these conditions were

ANCOVA ANALYTICAL HIERARCHY



Model 1: Three-Way Model
a. Distance to CCP * Distance to CGF * Year
b. Distance to CCP * Year
c. Distance to CGF * Year
d. Year
e. Distance to CCP
f. Distance to CGF

Model 2: Two-Way CCP Model
a. Distance to CCP * Year
b. Year
c. Distance to CCP

Model 3: Two-Way CGF Model
a. Distance to CGF * Year
b. Year
c. Distance to CGF

Model 4: Nested Pad Model
a. Distance to CCP (Year)

Model 5: Nested Road Model
a. Distance to CGF (Year)

Figure 3. Analysis of covariance (ANCOVA) models used and the hierarchy for interpreting significant interactions and main-effects for testing the effects of noise on waterbird distribution in the GHX-1 study area, Prudhoe Bay, 1989-1991.

based on the frequency of actual conditions experienced during the three nesting seasons of study.

We used a logistic regression procedure to assess the relative contributions of noise, spring weather conditions, predator abundance, and habitat on the probability of nesting success. Logistic regression is a multivariate statistical technique that evaluates a set of factors to determine those that best predict the probability of a dichotomous dependent variable, in this case, nest fate (the model predicts the probability of nesting success). One of the useful attributes of logistic regression is the ability of the model to accommodate both continuous and nominal variables in the same model. We used SPSSPC+ (SPSS Inc. 1989) statistical software to run logistic regression models for Canada Goose nests (the only species with an adequate sample size of nests among years). A slightly higher significance level ($\alpha = 0.10$) was used for this logistic regression analysis to all entry of more variables into the model that could explain differences in nesting success.

RESULTS AND DISCUSSION

CONDITIONS IN THE GHX-1 STUDY AREA

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 varied annually, and evaluating this variability, particularly with respect to the noise environment, was a major objective of this research program. Accordingly, our evaluations of the status of waterbird populations are interpreted in relation to both the prevailing environmental and disturbance conditions in the study area.

PHENOLOGICAL CONDITIONS AND BREEDING CHRONOLOGY

Spring snow-melt and temperatures in the study area varied among years (Figure 4). A yearly comparison of the cumulative degree-days between 15 May and 15 June revealed that the spring of 1990 was the warmest of the three years of study. The other two years were colder but showed different temperature patterns. Temperatures from 15-30 May 1989 were colder than for the same period in 1991, but colder temperatures in early June retarded snow melt in 1991. The influence of spring temperatures on nest-site availability and breeding chronology of waterbirds was due to both the effects of winter snow accumulation and the pace of spring snow melt. For example, the combination of heavy winter snow accumulation and rapid snow melt during early June in 1989 contributed to flooding of the major Canada Goose nesting area west of DS-L1, thus limiting access to nest sites for arriving Canada Geese and probably contributing to nest loss at several sites. Conversely, low snow accumulation during winter and the gradual and prolonged snow melt in 1990 resulted in earlier availability of nest sites to all waterbird species.

Canada and Greater White-fronted geese (*Anser albifrons*; hereafter referred to as White-fronted Geese) usually arrived in the Prudhoe Bay area by the middle of May and were present in the study area during the first survey in each year of this study (Table 4). First sightings of Tundra Swans (*Cygnus columbianus*) and Brant in the study area

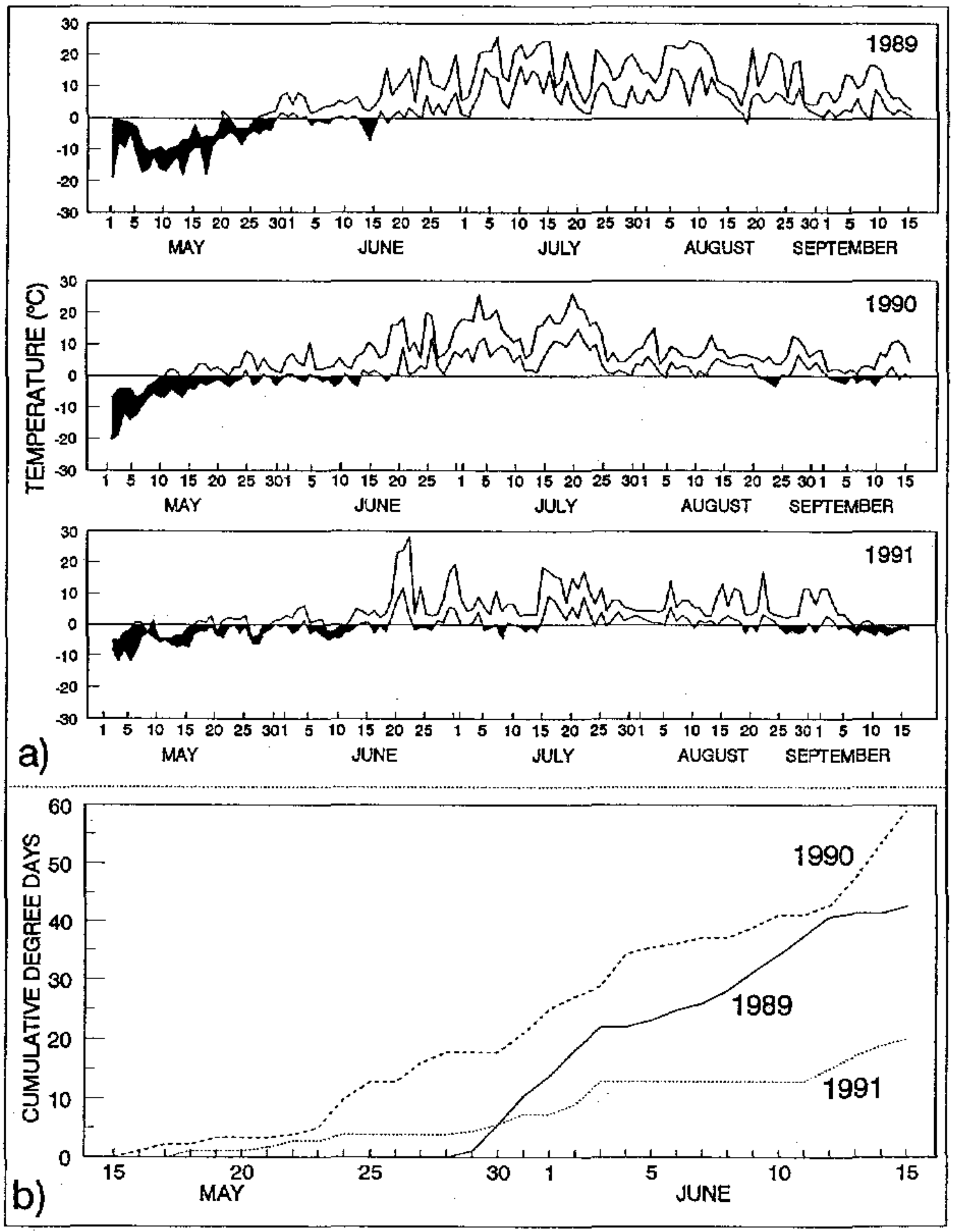


Figure 4. Weather conditions in the GHX-1 study area, Prudhoe Bay, Alaska, 1989-1991; a) maximum and minumum daily temperatures between 1 May and 15 September; and b) cumulative degree days between 15 May and 15 June, 1989-1991.

Table 4. Phenological dates for those species that nested or raised broods in the GHX-1 study area, Prudhoe Bay, Alaska, 1989-1991.

Species	First Observation			First Nest[a]			First Brood Sighting			Last Observation		
	1989	1990	1991	1989	1990	1991	1989	1990	1991	1989	1990	1991
Canada Goose	31 MY[b]	27 MY[b]	26 MY[b]	9 JN	2 JN	4 JN	11 JL	29 JN	6 JL	4 SE[c]	5 SE[c]	1 SE
White-fronted Goose	31 MY	27 MY	26 MY	9 JN	21 JN	17 JN	14 JL	3 JL	15 JL	4 SE	28 AU	4 SE[c]
Brant	31 MY	2 JN	27 MY	-	-	-	8 JL	29 JN	6 JL	4 SE	20 AU	4 SE
Tundra Swan	31 MY	2 JN	26 MY	-	-	-	4 SE	18 JL	-	4 SE	5 SE	28 AU
King Eider	5 JN	27 MY	30 MY	-	-	-	10 AU	13 JL	5 AU	23 AU	24 AU	1 SE
Spectacled Eider	2 JN	27 MY	8 JN	-	-	-	-	31 JL	5 AU	19 AU	1 SE	14 AU
Pacific Loon	9 JN	5 JN	4 JN	24 JN	20 JN	21 JN	6 AU	13 JL	23 JL	4 SE	5 SE	4 SE
Red-throated Loon	17 JN	11 JN	13 JN	4 JL	20 JN	21 JN	-	23 JL	27 JL	4 SE	1 SE	4 SE

[a] Date of confirmed incubation, although most nests probably were initiated earlier than this date.
[b] First road survey date.
[c] Last road survey date.

were more variable, but they usually were present by late May or early June. Like geese, most ducks arrived on the North Slope by mid-late May, although King (*Somateria spectabilis*) and Spectacled (*S. fischeri*) eiders usually did not arrive until late May or early June. Pacific (*Gavia pacifica*) and Red-throated (*G. stellata*) loons tended to arrive 1-2 weeks after the geese, probably because they need extensive open water on ponds for takeoff and landings. Red-throated Loons appeared in the study area later each year than Pacific Loons (Table 4).

Both Canada and White-fronted geese began nesting as soon as nest sites were snow free, usually by the first week of June (Table 4). Because of their later arrival Pacific and Red-throated loons initiated nesting later and often did not begin incubation until mid-late June. The first brood sighting varied among years, with broods appearing earliest in 1990, the year with the earliest onset of nesting for most species. The first broods of Brant, which nest outside the study area, arrived at the brood-rearing island southeast of CCP during the first ten days of July in 1989 and 1991, but the first brood had moved onto the island by 29 June in 1990; this earlier arrival apparently was attributable to a region-wide effect of favorable spring conditions on breeding waterbirds that year. The first young Pacific Loons usually were seen by late July or early August, although the first brood in 1990 was seen on 13 July, 24 days earlier than in 1989 and 10 days earlier than in 1991. Sightings of the first broods of other species varied among years, and we saw no broods for some species in some years (Table 4). Departure dates for most waterbird species occurred each year after our final survey date of 4-5 September.

PREDATOR ACTIVITY

Predator abundance and activity were monitored to evaluate the potential detrimental 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).

Predator numbers varied annually in the GHX-1 study area, but only the numbers of Glaucous Gulls changed significantly among years (Table 5). Glaucous Gulls were less abundant in the study area during 1989 than in either 1990 or 1991. One pair of Glaucous Gulls nested at the same site (the deep, open lake northwest of the WGI pad) in the study area in each of the three years; this pair successfully hatched young in 2 of 3 years (2 young in 1989 and 1 young in 1990).

Arctic foxes occurred annually in low numbers and slightly fewer foxes were seen in 1990 than in the other years, but the mean number per survey did not differ among years (Table 5). One den site was active in the study area in both 1989 and 1991. In 1989, the fox den was located in the coastal bluff near Drill Site (DS) L1, but this site was abandoned and unoccupied in 1990. A new site, on the coastal bluff overlooking the Putuligayuk River island southeast of CCP, was occupied in 1991, and adults were observed bringing prey (including a gosling) to pups at this den.

Jaegers and Common Ravens also were seen sporadically throughout the summer in all years. Both Pomarine and Parasitic jaegers are present during late May and early June, but only Parasitic Jaegers regularly nest in the Prudhoe Bay area, whereas Pomarine Jaegers apparently pass through on the way to their breeding grounds farther north. Approximately 1-2 jaegers were seen per survey in each of the three years, but mean counts did not differ among years (Table 5). Common Ravens, like arctic foxes, were not seen on every survey, although they were slightly more common in 1991 (Table 5). On two occasions in 1991, we observed Common Ravens near CCP carrying either goose or loon eggs, thus demonstrating the detrimental affect these avian predators can have on nesting waterbirds 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 study area include gravel roads, powerlines, and pads associated with either Lisburne or Prudhoe Bay facilities. Lisburne facilities include DS-L1 and the Lisburne Gas Injection (LGI) pad, in addition to access roads and pipelines. Prudhoe Bay facilities include

Table 5. Mean (SD) numbers of various predators seen during road surveys of the GHX-1 study area, Prudhoe Bay, Alaska, 1989-1991.

Predator	1989		1990		1991	
	$\overline{X}$	(SD)	$\overline{X}$	(SD)	$\overline{X}$	(SD)
Arctic fox	0.3	(0.6)	0.2	(0.4)	0.3	(0.6)
Glaucous Gull*	7.0[a]	(6.2)	14.1[b]	(20.5)	14.3[b]	(14.8)
Jaegers	1.5	(1.7)	2.0	(3.2)	1.0	(1.2)
Common Raven	0.2	(0.4)	0.2	(0.6)	0.5	(0.7)
All Predators	11.6	(6.3)	16.6	(20.2)	16.2	(15.2)
No. of surveys	28		27		30	

* Survey counts significantly different among years (Kruskal-Wallis test, $P < 0.05$).

ab Years with identical superscripts were not significantly different (Kruskal-Wallis pairwise comparisons).

CGF, CCP, the Northern Gas Injection (NGI) pad, the WGI pad, and access roads and pipelines.

The three years of the GHX-1 study included a pre-construction year (1989), a construction year (1990), and an operational year (1991). Oilfield activity differed in intensity among these years according to the types of activities taking place in the study area. In 1989, construction activities related to the gas-handling expansion project were minimal. Major construction activities took place on both CCP and CGF throughout the summer in 1990 and the new GHX-1 modules were delivered on the sealift in August 1990. In 1991, oilfield activities were again at normal levels except for some gravel hauling and construction in August associated with GHX-2 (the second phase of the gas-handling project) and gravel hauling on West Dock Road for the Point McIntyre road construction.

Other human activity in the study area during the three years of study 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 both among locations (i.e., segments of West Dock Road north and south of CCP, and the northern access road to CCP/CGF) and among years (Table 6). Traffic rates differed among years, because of increased vehicular traffic in 1990, which was the main construction year for the GHX-1 project (Table 6). Another major difference among years was in the increased gravel-hauling traffic on West Dock Road in 1991; this increase was associated with pad expansion at CGF for GHX-2 and road construction in the Point McIntyre area (Table 6). Gravel-hauling traffic for the northern access road to CCP/CGF also increased in 1991.

Air traffic and pedestrians, the other two common sources of human disturbance in the study area, were uncommon. Air traffic included infrequent helicopter and small, fixed-wing, airplane flights that usually were at 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.

Table 6. Mean (SD) traffic rates of different vehicle types on roads in the GHX-1 study area, Prudhoe Bay, Alaska, 1989-1991. Differences among years within vehicle type and road were tested with Kruskal-Wallis or Mann-Whitney nonparametric tests ($P < 0.05$). Years that were not significantly different (within vehicle type) are indicated by identical superscripts (Kruskal-Wallis pairwise comparisons). Number of traffic counts = n (20-min counts in 1989, 15-min counts in 1990 and 1991).

Road	Year	Heavy Truck		Light Truck		Road Maintenance Vehicles		Very Large Trucks		All Vehicles		n
		$\bar{X}$	(SD)	$\bar{X}$	(SD)	$\bar{X}$	(SD)	$\bar{X}$	(SD)	$\bar{X}$	(SD)	
West Dock - S. of CCP	1989	9.1	(7.4)	28.0[a]	(14.1)	0.1	(0.6)	3.3[a]	(5.7)	40.5[a]	(19.0)	126
	1990	11.2	(8.4)	52.8[b]	(21.1)	0.4	(1.3)	1.9[a]	(4.5)	66.3[b]	(25.1)	19
	1991	7.9	(7.0)	34.5[c]	(15.0)	0.1	(0.7)	8.1[b]	(12.4)	50.6[a]	(27.8)	29
West Dock - N. of CCP	1989	5.5	(6.0)	9.3[a]	(6.2)	0 [a]		0.6[a]	(1.7)	15.4[a]	(9.4)	70
	1990	5.4	(5.5)	15.0[b]	(9.9)	0.4[b]	(1.2)	1.0[a]	(3.6)	21.8[b]	(12.3)	20
	1991	4.4	(5.3)	16.2[b]	(7.5)	0 [a]		8.6[b]	(13.2)	29.2[b]	(17.4)	32
N. Access Road to CCP/CGF	1989	-		-		-		-		-		-
	1990	0.8	(2.1)	2.4	(3.8)	0.2	(0.9)	0 [a]		3.4	(5.4)	20
	1991	1.1	(3.1)	2.7	(4.1)	0		2.5[b]	(7.9)	6.3	(10.8)	21

NOISE SURVEY AND MODELING OF THE GHX-1 FACILITY

Noise data from the permanent noise monitor, located on the mainland shore southeast of CCP (Figure 2), varied over a range of 20 dBA for a number of reasons, including operational conditions and weather (Figure 5). Some of the high-end noise samples resulted from wind and rain and did not reflect the acoustic environment at the site. When wind speeds exceeded 15 mph, noise generated by the wind across the microphone gave false readings of the actual noise level, as did rain dropping on the microphone screen. Most readings above an L_{eq} of 60 dBA probably occurred because of weather conditions (heavy rain, hail, or wind) or were due to noise from gravel-hauling trucks on West Dock Road (during the period from approximately 20 August - 4 September 1991).

The mean L_{eq} in 1989, for periods when the monitor was operational, was 52.2 dBA. The mean L_{eq} in 1991 was 54.9 dBA, 2.7 dBA higher than in 1989. Noise levels differed significantly between years. In addition to increased noise from the GHX-1 facility, part of the increase in noise could be attributed to greater levels of traffic noise on West Dock Road, located approximately 250 m west of the microphone. Gravel-hauling trucks were transporting gravel to CGF and north to Point McIntyre from approximately 20 August to 4 September 1991 and passed by the location of the monitor, thus, most of the readings in excess of 60 dBA during those periods were probably due to this noise source.

A major analytical task was to determine the contribution of the GHX-1 facility to the total noise environment, over and above that noise generated by the CCP complex. Because noise data were collected with all facilities in operation, the contribution of the GHX-1 unit alone was calculated by comparing the weather-adjusted values collected in 1991 to the previously measured CCP-only condition, collected during the noise surveys in 1989 and 1990. The octave-band frequency results indicated that GHX-1 turbines contributed mostly at lower frequency ranges (31.5 Hz and 63 Hz; Figure 6). The values for the GHX-1 unit are valid only for a range of 30° (15° on each side of the northwest direction); the contribution of GHX-1 at other angular directions used in the acoustic prediction model varied because of the directionality of the source and the shielding provided by the CCP facility structures. Comparison of noise contours (5 dBA) in the

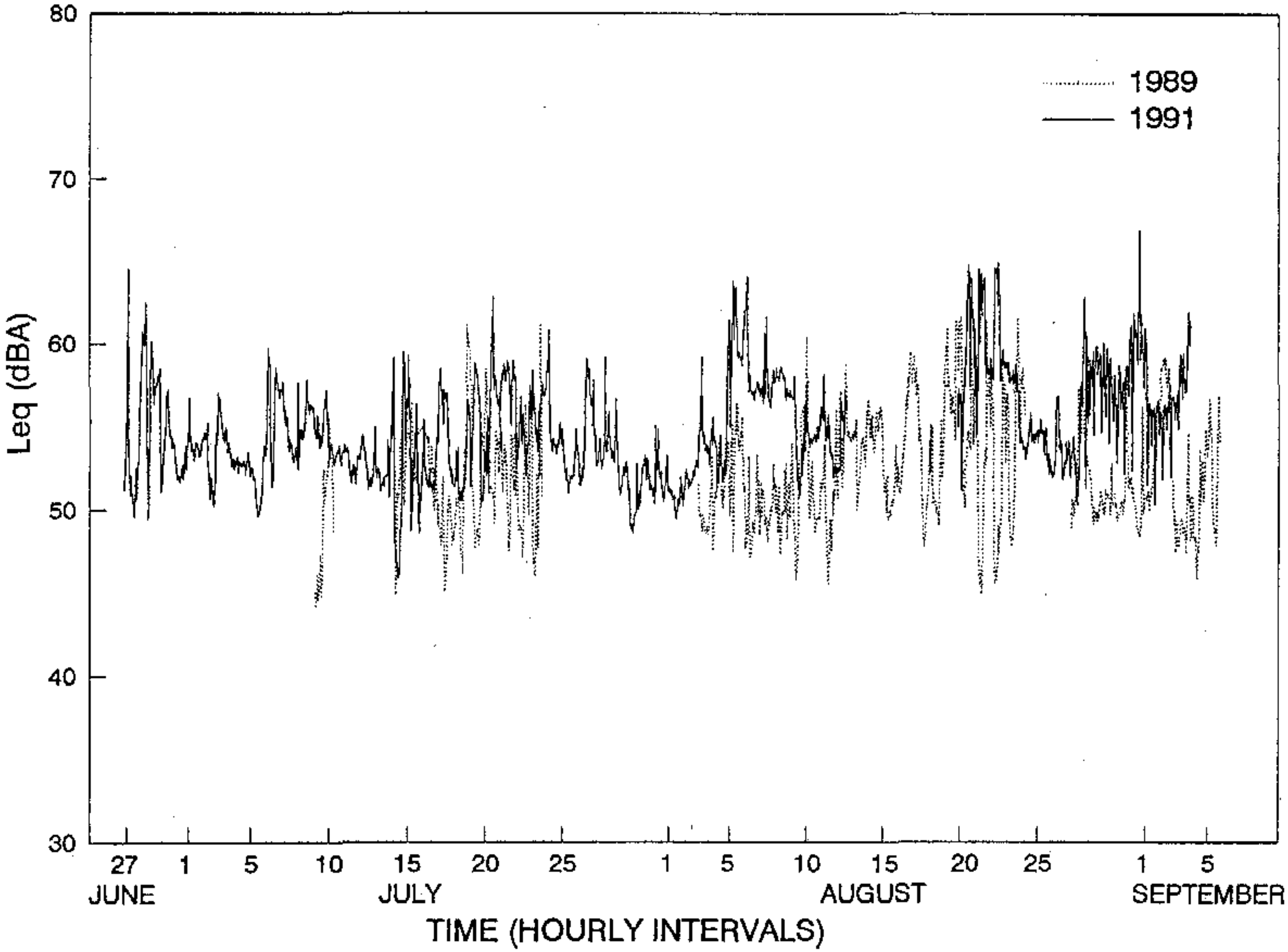


Figure 5. Noise levels (L_{eq}, dBA) recorded at the permanent noise monitor located southeast of CCP during 1989 (pre-construction) and 1991 (operation) of the GHX-1 facility at CCP, Prudhoe Bay, Alaska.

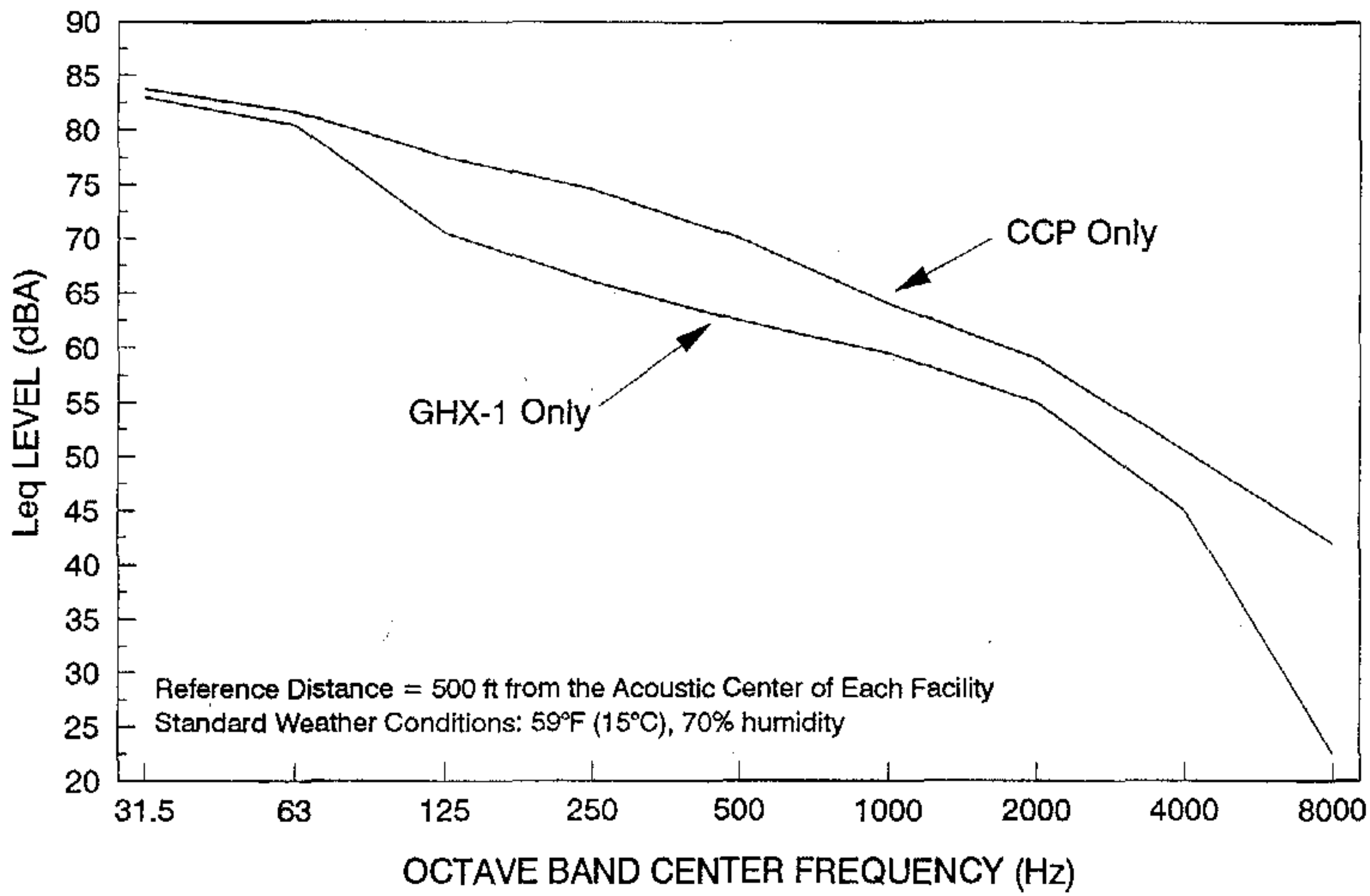


Figure 6. One-third octave-band frequencies for the CCP facility and GHX-1 facility, GHX-1 study area, Prudhoe Bay, Alaska, 1991.

study area for the pre-construction and operational phases of the GHX-1 facility illustrate the directional nature of noise from the GHX-1 facility (Figures 7 and 8). The differences in noise during 1990, the construction year for GHX-1, were not significantly different from 1989 (Anderson et al. 1990), thus, we considered the noise environment for pre-construction and construction to be similar and we did not plot noise contours for 1990.

The directional nature of noise generated by the GHX-1 facility suggests that not all habitats in the study area were subjected to increased noise in 1991. Before we can examine whether increased noise affected the abundance, distribution, and habitat use of waterbirds in the study area, we must determine which habitats have been affected by noise generated by the GHX-1 facility. To test for changes in waterbird distribution in 1991 that are the result of avoidance of noise, we must assume that birds moved to habitats in 1991 that had noise levels comparable to those they experienced in the study area prior to the operation of GHX-1 (i.e., that the shift in distribution was from habitats with more noise to habitats with less noise). This assumption is important because we would not expect to see noise-related shifts in the distribution of waterbirds within the study area if quieter habitats were not available; shifts outside the study area would be possible and would be apparent from decreased abundance. To test whether habitats were available in 1991 at noise levels comparable to those experienced in previous years, we compared the mean estimated noise levels in Level II habitat types for pre-operational and operational data modeled for various wind directions. Only one Level II habitat type, Open Waters, had significantly higher noise levels in 1991 than in previous (pre-operational) years and only when winds were from the north and northeast. An examination of noise levels in the two Level IV habitats (deep open lakes and shallow open water) that compose the Open Waters type revealed that this difference in noise levels occurred only in the deep open lake habitat. Only one deep open lake occurred in the study area and was located west of the waterflood pipeline northwest of WGI. Overall, however, the results of this analysis suggest that habitats were available in 1991 at noise levels comparable to those present before the operation of the GHX-1 facility. Thus, birds that did not change their distribution within the study area and still

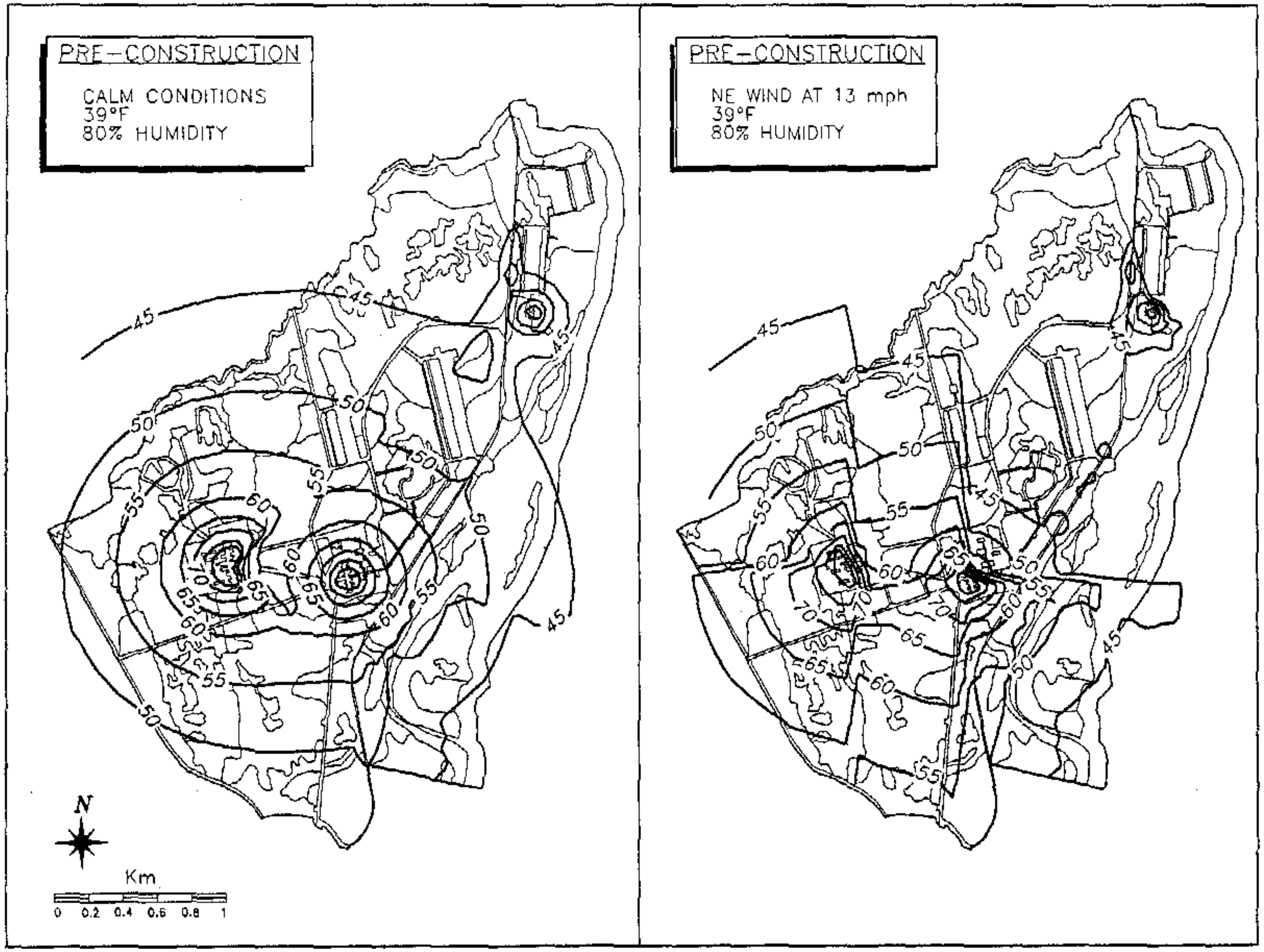


Figure 7. Predicted noise contours (5 dBA) around the CCP and CGF facilities during pre-construction (1989 and 1990) under calm and windy conditions in the GHX-1 study area, Prudhoe Bay, Alaska. Contours were modeled with the Outdoor Noise Prediction Program (McCraw 1992).

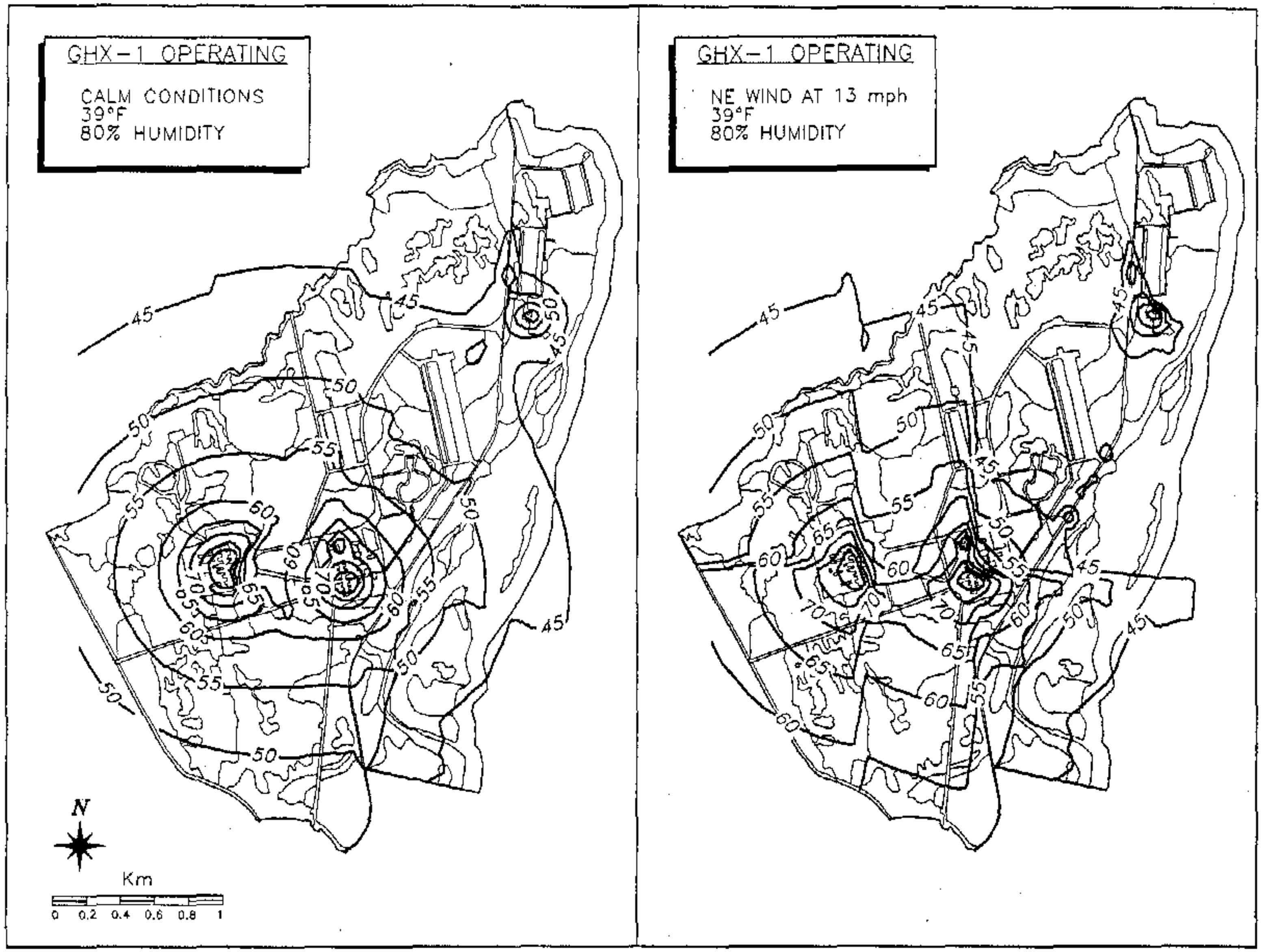


Figure 8. Predicted noise contours (5 dBA) around the CCP and CGF facilities during the first operational year for GHX-1 (1991) under calm and windy conditions in the GHX-1 study area, Prudhoe Bay, Alaska. Contours were modeled with the Outdoor Noise Prediction Program (McCraw 1992).

experienced higher noise levels were not constrained in their response simply because quieter habitats were unavailable.

Both the habitat analysis and the directional nature of the noise from GHX-1 suggested that not areas around CCP experienced the same amount of increase in noise when the GHX-1 facility became operational. Our analysis of noise levels in two plots (1 km^2 and 4 km^2) around CCP revealed that significant increases in noise occurred only under certain wind conditions and were confined to the areas northwest and northeast of CCP and the GHX facility (Table 7). In the area closest to CCP (the 1-km^2 plot in Figure 9), noise levels increased significantly in the northwest quadrat of the plot when winds were from the north. This 2.9 dBA increase in noise represented approximately a doubling in sound intensity in the quadrat (an increase of about 3 dBA occurs if a single noise source is replaced by two identical noise sources [Peterson 1980]). In the larger area (the 4-km^2 plot) around CCP, significant increases in noise levels occurred in the entire plot and in the northwest and northeast quadrats when winds were from the north (Table 7). The greater number of significant results in this larger plot probably are due to the increasing influence of noise from CGF on the estimated noise levels (see Figure 9). A comparison of the relative changes in noise levels in the four quadrats of each plot indicated that most increases in noise due to GHX-1 operation occurred north of CCP. Differences in noise levels south of CCP ranged from 0.0 to 0.6 dBA, with no change in noise between pre-operational and operational conditions under most wind conditions (Table 7). It also was apparent that the effect of different wind directions on noise levels in these areas close to CCP was more pronounced than any increases in noise from the GHX-1 operation. Increases in noise between pre-operational and operational conditions ranged from 0.0 to +2.9 dBA, whereas absolute differences in noise under different wind directions within a plot or a quadrat ranged from 0.1 to 17.3 dBA. Thus, changes in wind direction probably had more effect on the noise level experienced by birds close to CCP than did increased noise from the addition of the GHX-1 turbines to the facility.

Table 7. Mean estimated noise levels (dBA), before and after construction of GHX-1 within 1-km^2 and 4-km^2 plots centered on the Central Compressor Plant, Prudhoe Bay, Alaska. Noise was modeled for calm conditions and under different wind directions[a]. Mean noise levels were calculated for each of the four quadrats in the plots and for all quadrats combined (the entire plot). Increase (Δ) in noise is measured as the difference between the two means.

	Wind Direction									
	N	NE	E	SE	S	SW	W	NW	Calm	n[b]
1-km^2 PLOT										
All Quadrats										182
Before	59.5	59.1	58.9	58.5	59.6	60.7	61.6	61.4	60.2	
After	60.7	59.7	59.2	58.9	59.9	61.1	62.1	61.9	60.8	
Δ	+1.2	+0.6	+0.3	+0.4	+0.3	+0.4	+0.5	+0.5	+0.6	
NW Quadrat										42
Before	55.0	59.8	63.7	67.0	65.1	62.8	59.8	53.7	60.8	
After	57.9[c]	61.5	64.7	67.9	66.0	64.3	61.1	55.4	62.5	
Δ	+2.9	+1.7	+1.0	+0.9	+0.9	+1.5	+1.3	+1.7	+1.7	
NE Quadrat										42
Before	54.0	49.3	54.5	59.4	62.8	66.6	63.2	59.4	59.4	
After	55.6	49.8	54.9	59.9	63.1	66.8	63.9	60.0	59.9	
Δ	+1.6	+0.5	+0.4	+0.5	+0.3	+0.2	+0.7	+0.6	+0.5	
SE Quadrat										49
Before	61.2	58.5	52.9	48.7	54.4	58.5	62.4	65.2	58.5	
After	61.5	58.5	52.9	48.7	54.4	58.5	62.4	65.2	58.5	
Δ	+0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
SW Quadrat										49
Before	66.3	67.6	64.6	60.3	57.5	56.1	61.2	65.9	62.2	
After	66.6	67.6	64.6	60.3	57.5	56.1	61.2	65.9	62.2	
Δ	+0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
4-km^2 PLOT										
All Quadrats										702
Before	54.4	54.0	54.3	53.5	54.8	56.1	56.6	56.6	54.8	
After	55.4[c]	54.4	54.5	53.8	55.0	56.3	56.9	56.9	55.2	
Δ	+1.0	+0.6	+0.2	+0.3	+0.2	+0.2	+0.3	+0.3	+0.4	
NW Quadrat										169
Before	51.2	56.9	63.7	64.9	65.9	62.3	58.0	53.4	59.0	
After	52.8[c]	58.0	64.3	65.6	66.4	62.9	58.7	54.0	59.8	
Δ	+1.6	+1.1	+0.6	+0.7	+0.5	+0.6	+0.7	+0.6	+0.8	

Table 7. Continued.

	Wind Direction									
	N	NE	E	SE	S	SW	W	NW	Calm	n[b]
NE Quadrat										169
Before	47.4	43.8	48.3	52.1	56.4	60.2	56.2	52.1	52.1	
After	48.5[c]	44.2	48.7	52.6	56.7	60.5	56.7	52.6	52.6	
Δ	+1.1	+0.4	+0.4	+0.5	+0.3	+0.3	+0.5	+0.5	+0.5	
SE Quadrat										182
Before	53.7	50.4	45.8	41.8	46.8	50.4	55.1	58.4	50.4	
After	54.3	50.5	45.8	41.8	46.8	50.4	55.1	58.4	50.4	
Δ	+0.6	+0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
SW Quadrat										182
Before	64.6	64.3	59.6	55.8	51.1	52.3	57.1	62.0	57.9	
After	65.2	64.3	59.6	55.8	51.1	52.3	57.1	62.0	57.9	
Δ	+0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	

[a] Other model parameters: wind speed = 13.2 mph, temperature = 39°F, humidity = 80%.
[b] n = number of locations for which noise was estimated (250 ft x 250 ft grid).
[c] Noise levels were significantly higher during operation (Mann-Whitney test, $P \leq 0.05$).

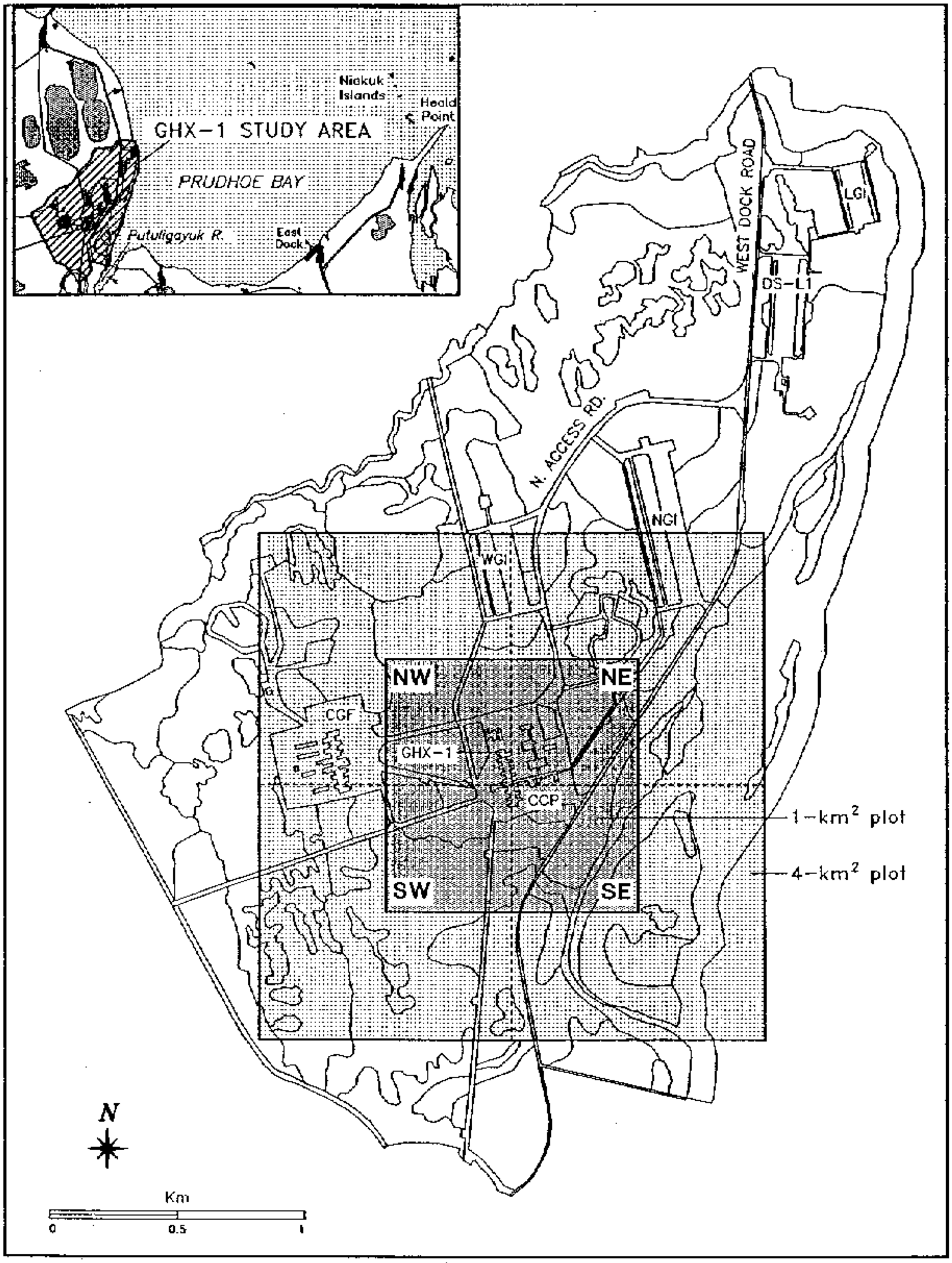


Figure 9. Locations of 1-km^2 and 4-km^2 plots used in modeling noise levels at the GHX-1 facility, Prudhoe Bay, Alaska. Each plot was divided into four quadrats (NW, NE, SE, SW) to assess the relative effects of wind direction on noise propagation from the facility.

ABUNDANCE, DISTRIBUTION, HABITAT USE, AND THE EFFECTS OF NOISE

Seventeen species of waterbirds occurred in the study area during the three years of this study: four species of geese (Canada Goose, White-fronted Goose, Brant, and Snow Goose [*Chen caerulescens*]; Tundra Swan; ten species of ducks (Red-breasted Merganser [*Mergus serrator*], Northern Pintail [*Anas acuta*], American Wigeon [*A. americana*], Eurasian Wigeon [*A. penelope*], Oldsquaw [*Clangula hyemalis*], Green-winged Teal [*A. crecca*], Mallard [*A. platyrhynchos*], Northern Shoveler [*A. clypeata*], King Eider, and Spectacled Eider); and two species of loons (Pacific Loon and Red-throated Loon). Six duck species (Red-breasted Merganser, Mallard, Green-winged Teal, American and Eurasian wigeons and Northern Shoveler) were seen on <25% of all surveys for the three years (Appendix 3); therefore, to simplify the discussion, we have focused only on the more common duck species. We have calculated seasonal densities for all species for comparative purposes, however.

Seasonal dates for waterbird life-history events in the study area were based on observations of breeding events (e.g., onset of incubation, first appearance of broods). Thus, seasonal dates varied both among years and between the two major species groups (waterfowl and loons) because of annual differences in spring conditions and species-specific differences in breeding biology (Figure 10). The abundance, distribution, and habitat use of waterbirds in the study area are discussed on a seasonal basis for most waterbird species. Because analyses of habitat selection were outside the scope of this report we discussed habitat use patterns and looked for any shifts in habitats that could be attributed to noise from the GHX-1 facility.

The effects of noise on waterbirds were assessed by looking for changes in abundance, distribution, or habitat use that could be attributed to disturbance from increased noise generated by the GHX-1 facility. Because the GHX-1 facility is located on the north side of CCP, one test for changes in distribution was to look for changes in the distances of flocks to CCP. The ONPP model bases its estimate of noise at flock locations on the distance of each location from the center of the CCP facility, therefore, we also could use the estimated noise levels at bird locations to assess whether they actually experienced more noise in 1991. The possible responses of waterbirds to noise

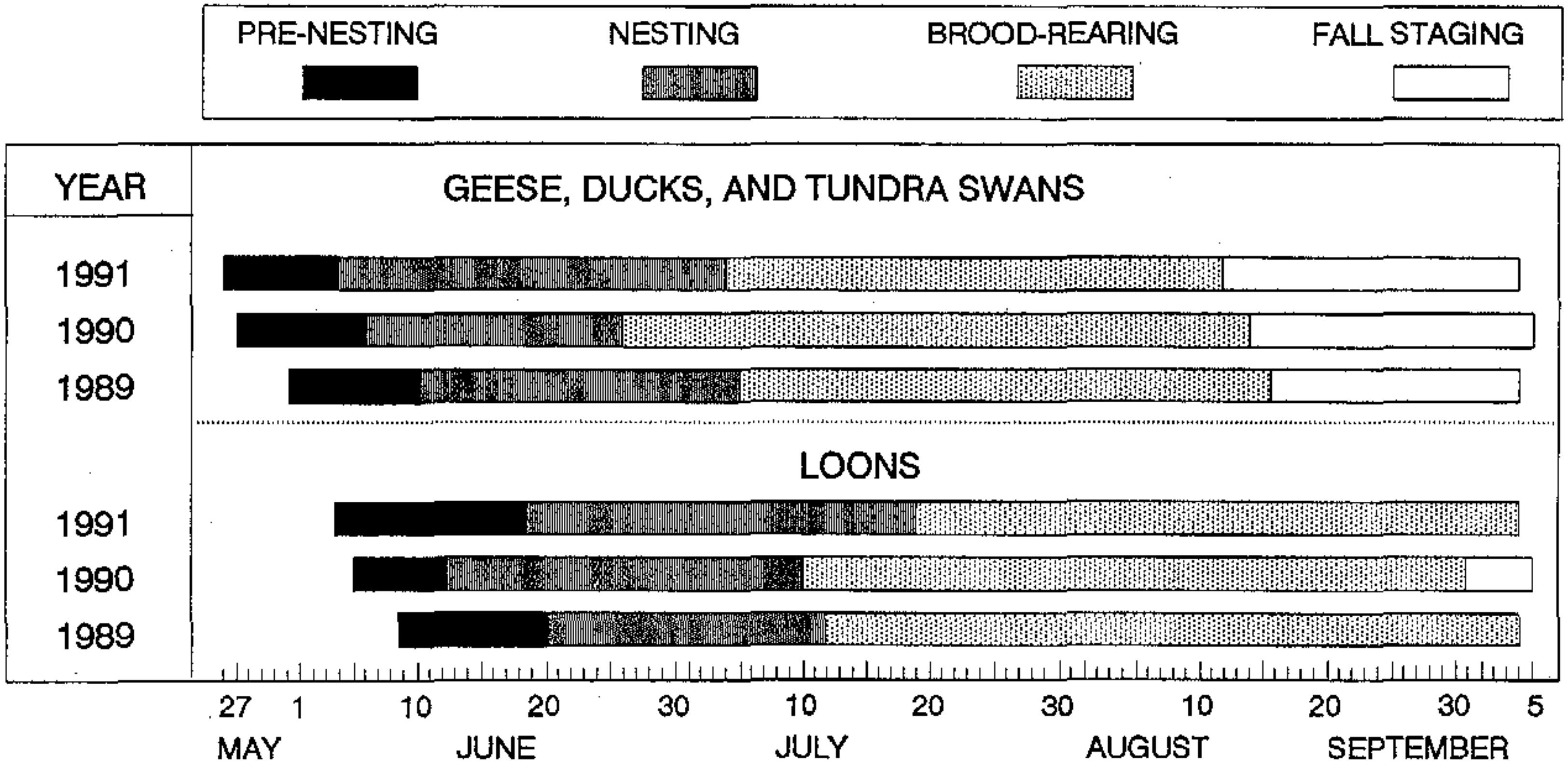


Figure 10. Seasonal dates for waterbirds in the GHX-1 study area, Prudhoe Bay, Alaska, 1989-1991.

could include either no response or some change in abundance, distribution, or habitat use:

1) no response because noise levels had remained the same or declined in 1991 compared with previous years and no changes in distribution occurred;

2) no response although noise increased in 1991 compared with previous years (noise levels at waterbird locations were significantly higher, but no significant change in distribution occurs);

3) decreased abundance in 1991 from that in previous years, as measured by seasonal density;

4) changes in distribution in 1991 from that in previous years, as measured by distance of flocks to CCP; and

5) changes in habitat use in 1991 from that in previous years, as measured by changes in seasonal density within habitat types, or obvious shifts between habitats.

CANADA GOOSE

Seasonal Abundance, Distribution, and Habitat Use

Canada Geese were more abundant in the study area during pre-nesting in 1989 and 1991 than in 1990 (Figure 11, Table 8). The primary reason for this significant difference among years was the early spring conditions in 1990, when the earlier availability of open ground throughout the Prudhoe Bay region contributed to the rapid dispersal of geese to their breeding areas upon arrival on the coastal plain. In years of later snow melt, such as 1989 and 1991, pre-nesting geese concentrate in the "dust shadows" created by roads, such as West Dock Road in the GHX-1 study area. These annual differences in spring conditions are reflected in the relative abundance and distribution of geese in the study area during pre-nesting (Table 8, Figure 12). Canada Geese occurred adjacent to roads and pads in 1989 and 1991 but not in 1990, and were more abundant in 1989 and 1991 than in 1990. Because spring conditions in 1989 and 1991 were more similar to each other than to 1990, any disturbance-related shifts in distribution would be more apparent when comparing those two years; changes in distribution in 1990 were obviously due to spring weather conditions and not to any

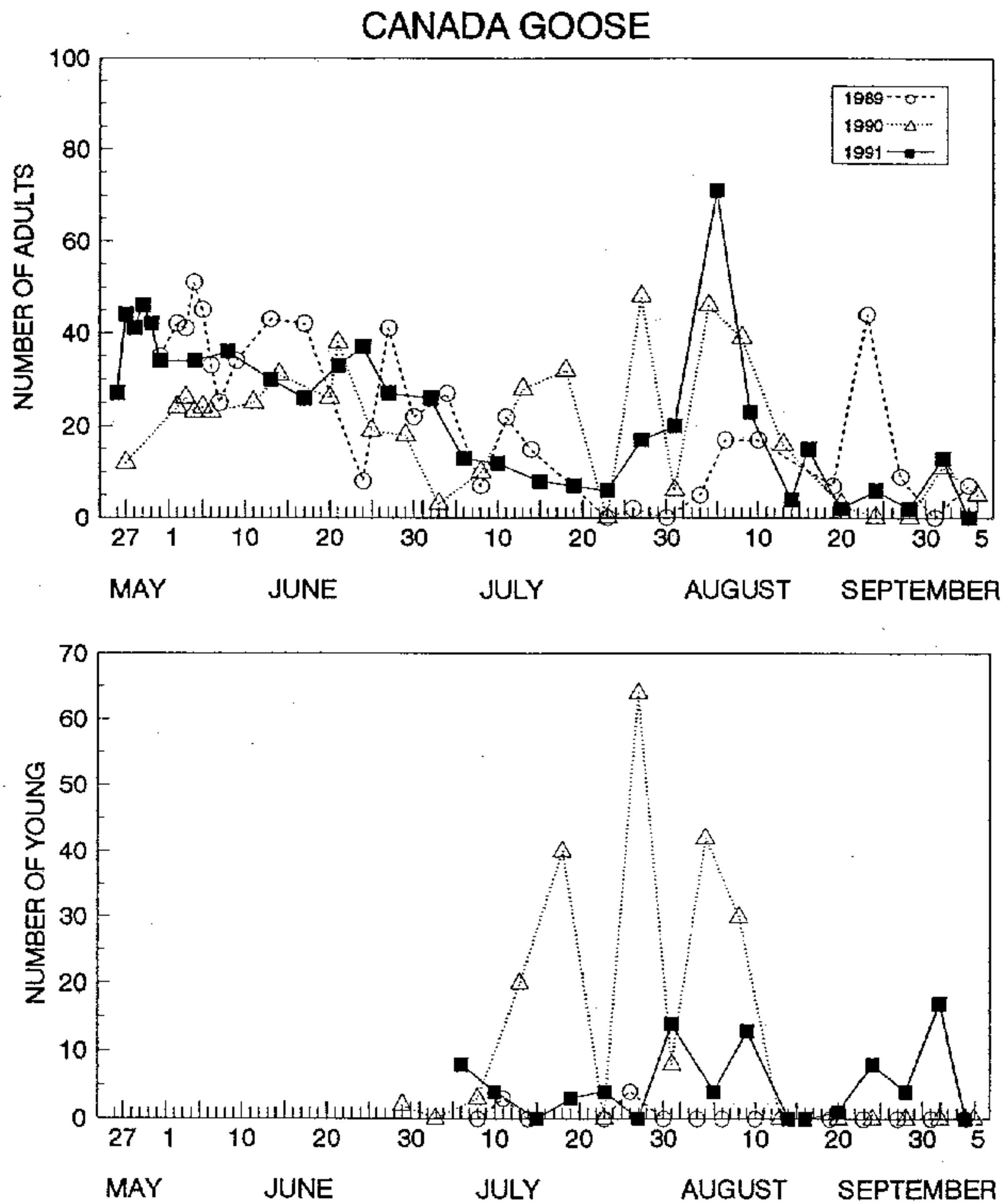


Figure 11. Counts of adult and young Canada Geese from road and foot surveys in the GHX-1 study area, Prudhoe Bay, Alaska, 1989-1991.

Table 8. Seasonal density (mean and SD, as birds/km²) of waterbirds in the GHX-1 study area, Prudhoe Bay, Alaska, 1989-1991. 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 and 1991. An asterisk (*) indicates species for which statistical tests (Kruskal-Wallis or Mann Whitney tests $P<0.05$) of density among years were performed. Identical superscript letters within a species and season indicate years that were not significantly different (pairwise comparisons).

		Pre-nesting		Nesting		Brood-rearing				Fall Staging		All Seasons	
		Total Birds		Total Birds		Adults		Young		Total Birds		Total Birds	
	Year	$\overline{X}$	SD	$\overline{X}$	SD	$\overline{X}$	SD	$\overline{X}$	SD	$\overline{X}$	SD	$\overline{X}$	SD
GEESE													
Canada Goose*	1989	4.6^{a}	0.9	3.7	1.7	1.1	1.0	0.1^{a}	0.2	1.6	2.1	2.8	2.0
	1990	2.6^{b}	0.7	3.3	0.8	2.7	2.1	2.3^{b}	2.7	0.5	0.6	3.3	3.4
	1991	4.7^{a}	0.8	3.8	0.5	2.4	2.4	0.7^{b}	0.6	1.2	1.2	3.2	2.0
White-fronted Goose*	1989	12.4^{a}	8.0	1.1	0.8	0.3^{a}	0.6	0.3	0.8	5.1	1.6	4.8	6.6
	1990	1.3^{b}	1.2	1.1	0.9	0.2^{a}	0.2	0.2	0.3	3.7	4.2	1.4	2.1
	1991	13.5^{a}	4.6	1.9	1.2	1.2^{b}	1.0	0.6	0.8	3.3	2.2	4.5	5.2
Brant*	1989	1.6	1.5	2.2	2.9	14.8	10.5	5.2^{a}	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^{b}	8.2	0.2	0.5	15.0	20.3
	1991	0.6	0.5	8.9	6.8	21.3	9.4	3.4^{a}	2.5	4.3	4.9	10.9	12.0
Snow Goose*	1989	0.2	0.3	0	0	0.1	0.1	0.1	0.1	0	0	0.1	0.2
	1990	0	0	0	0	0	0	0	0	0	0	0	0
	1991	0.1	0.1	0	0	0	0	0	0	0	0	<0.1	0.1
SWANS													
Tundra Swan*	1989	0.1	0.2	<0.1	0.1	0.1^{a}	0.2	0^{a}	0	0.3	0.3	0.1	0.2
	1990	0.1	0.1	0.1	0.2	0.2^{b}	0.1	0.3^{b}	0.2	0.3	0.3	0.3	0.3
	1991	0.2	0.2	0.2	0.4	0.1^{ab}	0.1	0^{a}	0	0.1	0.1	0.2	0.2
DUCKS													
Red-breasted Merganser	1989	-	-	0	0	0	0	0	0	0	0	0	0
	1990	0	0	0	0	0	0	0	0	0	0	0	0
	1991	0	0	0	0	0	0	0	0	<0.1	0.1	<0.1	<0.1

Table 8. Continued.

	Year	Pre-nesting Total Birds $\bar{X}$	SD	Nesting Total Birds $\bar{X}$	SD	Brood-rearing Adults $\bar{X}$	SD	Brood-rearing Young $\bar{X}$	SD	Fall Staging Total Birds $\bar{X}$	SD	All Seasons Total Birds $\bar{X}$	SD
Green-winged Teal	1989	-	-	0	0	0	0	0	0	0	0	0	0
	1990	0	0	0.1	0.1	0	0	0	0	0.2	0.2	0.1	0.1
	1991	0.1	0.2	0	0	<0.1	<0.1	0	0	<0.1	<0.1	<0.1	0.1
Mallard	1989	-	-	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	<0.1	0.1	0.1	0.2
	1991	0	0	<0.1	0.1	0.1	0.2	0	0	0.1	0.1	<0.1	0.1
Northern Pintail*	1989	-	-	2.9	2.3	3.0	4.0	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	4.2	1.1	2.9	1.8
	1991	2.5	0.8	2.9	1.4	3.0	2.9	0	0	5.0	4.2	3.3	2.7
Northern Shoveler	1989	-	-	0	0	0	0	0	0	0	0	0	0
	1990	0	0	<0.1	0.1	0	0	0	0	<0.1	0.1	0.1	0.1
	1991	0	0	0.1	0.3	<0.1	<0.4	0	0	0	0	<0.1	0.2
Eurasian Wigeon	1989	-	-	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	0.1	0.1
	1991	0	0	0	0	0	0	0	0	0	0	0	0
American Wigeon	1989	-	-	0	0	0.4	0.7	0	0	0.2	0.4	0.2	0.5
	1990	0.1	0.3	0	0	0.2	0.4	0	0	0	0	0.1	0.3
	1991	0.4	0.4	0.1	0.2	0	0	0	0	<0.1	<0.1	0.1	0.2
Oldsquaw*	1989	-	-	0.9	0.8	<0.1	0.1	0	0	0 [a]	0	0.3	0.6
	1990	1.4[a]	0.7	1.0	0.9	0.2	0.4	0	0	0.3[b]	0.4	0.6	0.8
	1991	0.5[b]	0.6	0.7	0.4	0.4	0.5	0	0	0 [a]	0	0.4	0.5
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[a]	0.4	1.6	1.0	0.2	0.3	0.2	0.3	0.1	0.2	0.7	0.8
	1991	0.1[b]	0.3	1.2	0.7	0.1	0.3	0.2	0.7	0.7	0.5	0.6	0.7

Table 8. Continued.

Year		Pre-nesting Total Birds		Nesting Total Birds		Brood-rearing Adults		Brood-rearing Young		Fall Staging Total Birds		All Seasons Total Birds	
		$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD
Spectacled Eider*	1989	-	-	0.4	0.5	<0.1	0.1	0	0	0.1	0.2	0.2	0.3
	1990	0.8[a]	0.3	0.5	0.4	0.2	0.3	0.2	0.7	0.2	0.4	0.5	0.6
	1991	0[b]	0	0.2	0.2	0.2	0.2	0.8	1.6	0.4	1.2	0.5	1.1
Unidentified eider	1989	-	-	0.1	0.1	0.2	0.6	0	0	0	0	0.1	0.4
	1990	0	0	0	0	0	0	0	0	0	0	0	0
	1991	0	0	0	0	0.1	0.2	0	0	0	0	<0.1	0.1
LOONS													
Pacific Loon*	1989	0.3	0.5	0.9	0.5	0.7[a]	0.2	0.1[a]	0.1	-	-	0.7	0.5
	1990	0.3	0.6	1.3	0.4	1.2[b]	0.5	0.6[b]	0.2	1.2	0.7	1.2	0.8
	1991	0.4	0.7	1.0	0.3	1.0[b]	0.4	0.5[b]	0.2	-	-	1.0	0.7
Red-throated Loon*	1989	<0.1	0.1	0.2	0.1	0.1[a]	0.1	0[a]	0	-	-	0.1	0.1
	1990	<0.1	0.1	0.2	0.2	0.2[b]	0.1	0.1[b]	0.1	0.1	0.1	0.2	0.2
	1991	<0.1	0.1	0.2	0.1	0.3[b]	0.2	0.3[b]	0.1	-	-	0.3	0.3
TOTAL DENSITY*	1989	19.1[a]	9.2	13.8	4.6	21.0	12.2	5.7[a]	4.7	13.9	10.5	19.5	12.5
	1990	9.5[b]	2.1	15.8	5.5	30.6	10.0	16.0[b]	10.9	11.8	5.2	26.5	21.6
	1991	22.7[c]	5.4	21.2	6.8	30.4	10.3	6.0[a]	4.2	17.3	10.0	25.2	12.1

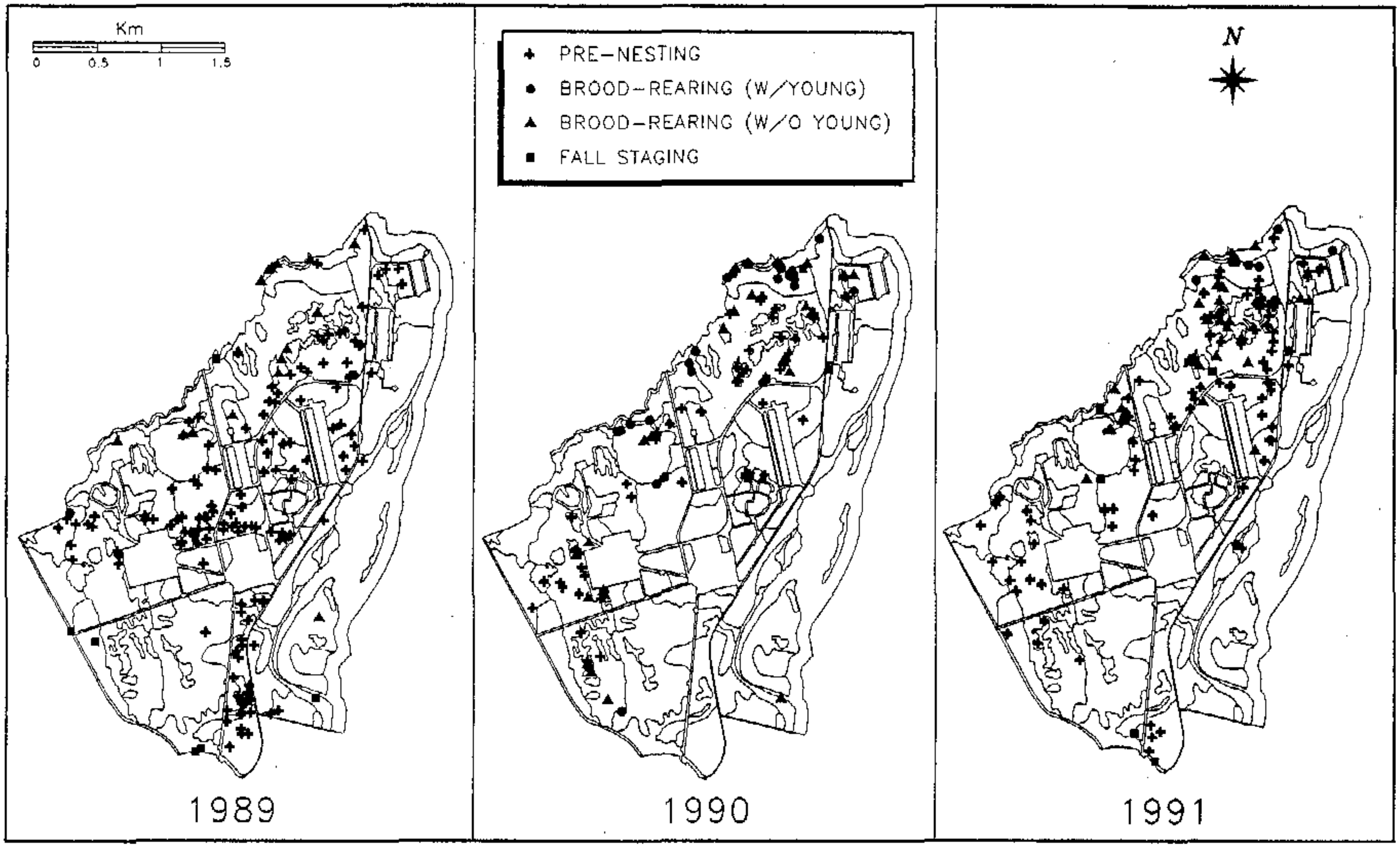


Figure 12. Distribution of Canada Geese during pre-nesting, brood-rearing, and fall staging in the GHX-1 study area, Prudhoe Bay, Alaska, 1989-1991. Each flock sighting was of one or more birds.

noise-related disturbance. In both 1989 and 1991, pre-nesting Canada Geese were present in the area north of NGI, where many of the nest sites eventually were located (Figure 12). Two obvious differences in distribution were apparent between 1989 and 1991, however. First, the clusters of pre-nesting geese immediately north of CCP and northeast of CGF in 1989 were absent in 1991. Second, use of the area directly south of CCP (between the pipeline and West Dock Road) decreased markedly from 1989 to 1991. The occurrence of White-fronted Geese in those areas (see below) suggests that this shift in distribution was not due to habitats being unavailable, but could be related to increased noise levels from the GHX-1 turbines at CCP. Another factor simply could be the lower number of flocks in 1991 than in 1989 (98 and 145, respectively). The habitat type of the area immediately north of CCP and northeast of CGF where shifts of distribution of pre-nesting geese were apparent was Wet Meadows, and this shift in distribution between 1989 and 1991 was reflected in a slight decrease in density in that habitat type (Figure 13). The major habitats used by pre-nesting Canada Geese were Water with Emergents and Basin Wetland Complexes. but they used all of the available habitats during at least one year of the study.

Although numbers of Canada Geese fluctuated somewhat during the nesting season (Figure 11), densities did not differ significantly among years (Table 8). The number of nests each year was greatest in the area west of DS-L1 (Figure 14); the number of active nests each year ranged between 6 in 1989 and 11 in both 1990 and 1991. A comparison of nest locations showed that there was little reuse of nest sites among years: out of a total of 28 nests found in the three years of study, 22 were unique nest sites. Four (18%) of those 22 sites were used in two of three years, and only one (4%) site was used in all three years. During nesting, Canada Geese were present in greatest density in Water with Emergents and Basin Wetland Complexes (Figure 13). The distribution of nests among habitats paralleled this pattern, with 17 of 28 (61%) nests located in Water with Emergents (Table 9). The remaining nests were located in Basin Wetland Complexes (n = 7; 25%), Impoundments (n = 3; 11%), and Wet Meadows (n = 1; 3%). All of the nest sites that were reused between years were located in Water with Emergents. The influence of habitat on nest fate was not entirely clear, but only in Water with Emergents were more than 50% of nests successful.

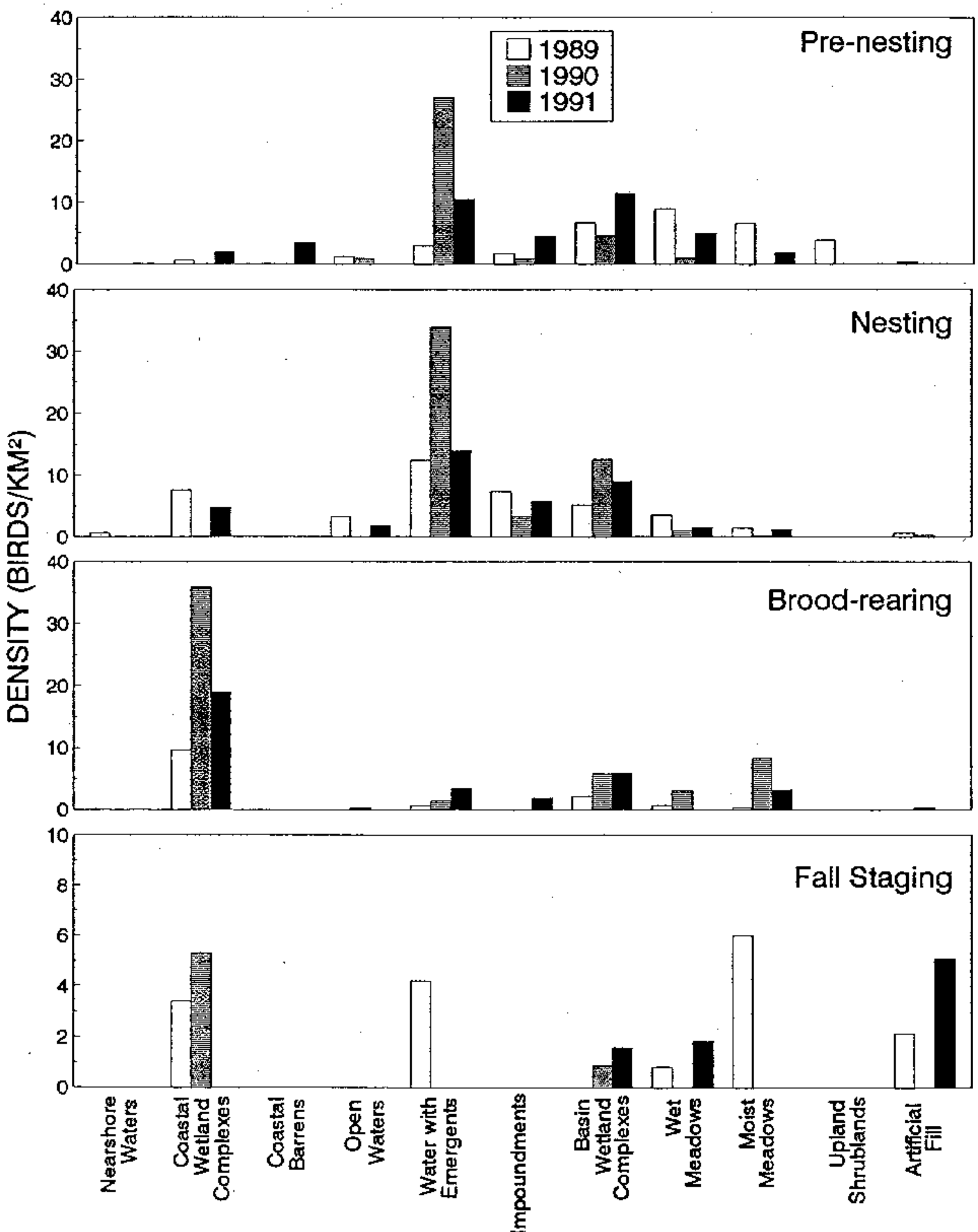


Figure 13. Mean seasonal densities (birds/km²) of Canada Geese in Level II habitats in the GHX-1 study area, Prudhoe Bay, Alaska, 1989-1991.

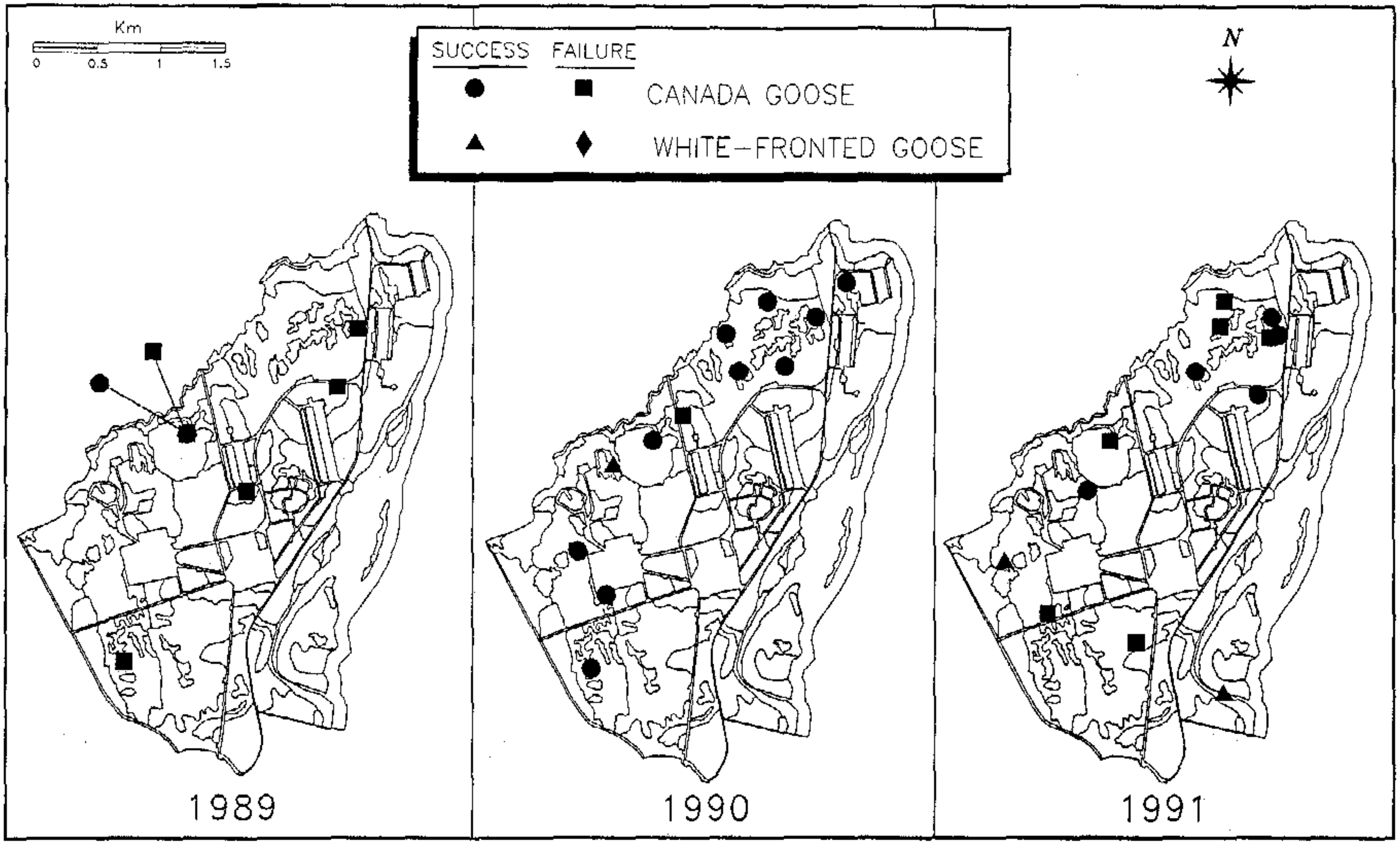


Figure 14. Location and nest fate of Canada and White-fronted goose nests in the GHX-1 study area, Prudhoe Bay, Alaska, 1989-1991.

Table 9. Habitat classification of successful and failed waterbird nests in the GHX-1 study area, Prudhoe Bay, Alaska, 1989-1991.

Habitat (LEVEL II and Level IV)[a]	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 without islands	1989	-	-	-	-	1	0	-	-	1	0
	1990	-	-	-	-	1	0	-	-	1	0
	1991	-	-	-	-	0	1	-	-	0	1
	Total	-	-	-	-	2	1	-	-	2	1
COASTAL ZONE											
Halophytic wet meadows	1991	-	-	1	0	-	-	-	-	1	0
	Total	-	-	1	0	-	-	-	-	1	0
WATER WITH EMERGENTS											
Aquatic grass without islands	1989	-	-	-	-	0	1	-	-	0	1
	1990	2	0	-	-	-	-	-	-	2	0
	Total	2	0	-	-	0	1	-	-	2	1
Aquatic grass with islands	1989	1	3	-	-	1	2	0	1	2	6
	1990	6	0	-	-	2	3	1	0	9	3
	1991	3	2	-	-	3	1	1	0	7	3
	Total	10	5	-	-	6	6	2	1	18	12
IMPOUNDMENTS											
Drainage impoundment	1989	0	2	-	-	0	1	-	-	0	3
	1990	-	-	-	-	1	0	-	-	1	0
	1991	1	0	-	-	1	1	-	-	2	1
	Total	1	2	-	-	2	2	-	-	3	4
BASIN WETLAND COMPLEXES											
Basin wetland complex	1989	-	-	-	-	-	-	0	1	0	1
	1990	2	1	-	-	1	0	-	-	3	1
	1991	1	3	1	0	0	2	1	1	3	6
	Total	3	4	1	0	1	2	1	2	6	8

Table 9. Continued.

Habitat (LEVEL II and Level IV)[a]	Year	Canada Goose		White-fronted Goose		Pacific Loon		Red-throated Loon		All Species	
		Successful	Failed	Successful	Failed	Successful	Failed	Successful	Failed	Successful	Failed
WET MEADOWS											
Wet Meadows	1991	0	1	-	-	-	-	-	-	0	1
(low-relief)	Total	0	1	-	-	-	-	-	-	0	1
MOIST MEADOWS											
Moist meadows	1990	-	-	1	0	-	-	-	-	1	0
(high-relief)	Total	-	-	1	0	-	-	-	-	1	0

[a] Habitat levels refer to the hierarchical classification system (Appendix 1).

Although densities of Canada Goose adults during brood-rearing did not differ significantly among years, densities of young were significantly lower in 1989 than in both 1990 and 1991 (Table 8). The peak number of young for all years was 64, recorded on 27 July 1990 (Figure 11, Appendix 3). Within years, some of the fluctuations in the abundance of young were due to brood-rearing flocks moving in and out of the study area, usually along the northern boundary (Figure 12). In 1990 and 1991, most of the brood-rearing groups were seen along the edge of the unnamed stream that formed the northern boundary of the study area. Of the two broods seen in 1989, one was seen just north of the intersection of West Dock Road and the northern access road to CCP and CGF, and the second was seen west of the CGF flarepit. In 1990 and 1991, it also was evident from the large numbers of young that not all Canada Goose broods seen were produced from nests in the study area. Coastal Wetland Complexes supported the greatest density of Canada Geese during brood-rearing in each year of the study; densities were greatest in 1990, primarily because more pairs raised broods in that year (Figure 13). Most of the use of this habitat type occurred along the edge of the unnamed slough on the northern boundary of the study area where a narrow fringe of Coastal Wetland Complexes (specifically, halophytic wet meadow) was present. Other habitats used during brood-rearing included Nearshore Waters, Open Waters, Water with Emergents, Impoundments, Basin Wetland Complexes, Wet Meadows, Moist Meadows, and Artificial Fill.

Densities of fall-staging Canada Geese did not differ significantly among years (Table 8). In general, few Canada Geese remained in the area after young had fledged; further, the study area was not a major fall-staging site for other geese in the Prudhoe Bay vicinity (Figure 11). During fall staging, Canada Geese occurred again in Coastal Wetland Complexes, but at densities much lower than those during brood-rearing (Figure 13). Other habitats used during fall staging included Water with Emergents, Basin Wetland Complexes, Wet Meadows, Moist Meadows, and Artificial Fill.

Effects of Noise

Shifts in the distribution of Canada Goose flocks that could be attributed to an avoidance of increased noise in 1991 were apparent only during pre-nesting. Pre-nesting

Canada Geese were located significantly farther from CCP in 1991 than in 1989, but not in 1990 (Table 10). Mean noise levels at the locations of pre-nesting flocks also were significantly lower in 1991 than in 1989 (Table 11). These results suggest that Canada Geese shifted their distribution during pre-nesting in 1991 to quieter parts of the study area, particularly because they avoided the area immediately north and northwest of CCP where increases in noise due to GHX-1 were most apparent. The decrease in use by pre-nesting Canada Geese of areas south of CCP could not be attributed completely to noise from GHX, because this area experienced little increase in noise in 1991.

To evaluate differences in distribution among years and to determine the influence of CGF, the main secondary noise source in the study area, we conducted an analysis of covariance procedure on the pre-nesting data. The results of this analysis indicated that most of the variation in noise levels at the locations of pre-nesting flocks of Canada Geese was due to shifts in distribution relative to the CCP and CGF facilities and not simply to movements away from the CCP facility (Appendix 4). Apparently some pre-nesting geese shifted west of CGF in 1991 to an area that, although much farther from CCP, still experienced relatively high levels of noise, which was emanating from CGF.

Distances of flocks to CCP were not tested for differences among years during nesting, because of the lack of independence among repeated sighting of nesting pairs at their nest. A better assessment of the effects of noise on nesting birds can be made by looking at distances of nests to CCP, rather than flocks (see Breeding Biology below). During brood-rearing and fall staging, no shifts in distribution or changes in distance to CCP that could be attributed to noise were apparent among years (Table 10). Noise levels at flock locations during those seasons also did not differ significantly among years (Table 11).

GREATER WHITE-FRONTED GOOSE

Seasonal Abundance, Distribution, and Habitat Use

White-fronted Geese were most abundant during pre-nesting during 1989 and 1991 (Figure 15, Appendix 3); densities during 1990 were significantly less than those during both 1989 and 1991 (Table 8). As mentioned above for Canada Geese, this decline in use during pre-nesting in 1990 was attributable to the early spring conditions in that year

Table 10. Mean (SD) distances (m) of waterbird flocks to the center of the Central Compressor Plant (CCP) during each season, GHX-1 study area, Prudhoe Bay, Alaska, 1989-1991. Dashes indicate no data collected. Among year differences in distances were tested with a Kruskal-Wallis test ($P < 0.05$). Significant tests were then evaluated with a Kruskal-Wallis pairwise procedure. Identical superscript letters within a species and season indicate years that were not significantly different.

		Pre-nesting			Nesting			Brood-rearing			Fall-staging		
Species	Year	$\bar{X}$	SD	n	$\bar{X}$	SD	n	$\bar{X}$	SD	n	$\bar{X}$	SD	n
Canada Goose													
	1989	1070[a]	593	145	1446	511	72	1826	572	18	1396	196	6
	1990	1530[b]	596	71	1626	563	117	1817	641	51	2025	467	3
	1991	1622[b]	567	98	1705	504	163	1854	562	48	1442	366	6
White-fronted Goose													
	1989	978	636	188	1148	493	18	1777	871	3	1420	512	18
	1990	1068	404	18	1248	525	25	1380	346	9	1187	314	18
	1991	992	553	155	1088	396	51	1297	405	19	1186	515	20
Brant													
	1989	1005	305	14	924	531	8	818	231	25	870	311	3
	1990	947	152	4	950	433	7	928	453	52	904	292	3
	1990	1066	357	7	775	233	26	943	455	41	1151	717	14
Tundra Swan													
	1989	1900	1282	5	1307	0	1	1094[a]	412	3	1799	273	4
	1990	2011	38	3	1572	538	5	1588[ab]	357	11	1416	594	6
	1991	1872	980	7	1778	750	5	1817[b]	360	6	1560	203	4
Northern Pintail													
	1989	-	-	-	1201	500	27	1447	449	19	1338	436	17
	1990	1384	687	23	1268	545	55	1348	541	46	1430	596	50
	1991	1229	764	39	1052	497	60	1228	560	46	1196	506	77

Table 10. Continued.

Species	Year	Pre-nesting			Nesting			Brood-rearing			Fall-staging		
		$\bar{\bar{X}}$	SD	n	$\bar{\bar{X}}$	SD	n	$\bar{\bar{X}}$	SD	n	$\bar{\bar{X}}$	SD	n
Oldsquaw													
	1989	-	-	-	1573 [ab]	570	24	1849	974	3	0	0	0
	1990	1609	437	26	1868 [a]	628	26	1101	578	5	1137	511	5
	1991	1374	786	11	1464 [b]	423	28	1531	351	11	0	0	0
King Eider													
	1989	-	-	-	1398	318	23	1485	581	2	1803	290	2
	1990	1650	528	14	1436	463	36	1758	375	11	1249	638	3
	1991	1564	935	2	1534	343	40	1772	101	5	1399	496	8
Spectacled Eider													
	1989	-	-	-	1246 [a]	288	7	1424	479	2	2124	0	1
	1990	1506	519	17	1471 [ab]	529	15	1753	401	5	1325	779	3
	1991	0	0	0	1845 [b]	383	6	2075	413	7	2620	0	1
Pacific Loon													
	1989	1536	697	17	1708	566	34	1676	634	53	-	-	-
	1990	1595	503	10	1744	583	54	1682	628	77	2006	864	11
	1991	1918	686	19	1833	505	58	1754	610	78	-	-	-
Red-throated Loon													
	1989	1128	0	1	1422	275	8	1673 [a]	165	9	-	-	-
	1990	1349	0	1	1556	184	10	1405 [b]	233	16	1330	0	1
	1991	1663	37	2	1543	170	14	1606 [a]	262	28	-	-	-

Table 11. Mean (SD) estimated noise levels (dBA) at waterbird flock locations during each season in the GHX-1 study area, Prudhoe Bay, Alaska, 1989-1991. Dashes indicate no data collected. Noise levels for each flock location were modeled with the Outdoor Noise Propagation Program (McCraw 1992). Statistical tests for seasonal differences in noise among years were performed with a Kruskal-Wallis nonparametric test ($P<0.05$). Significant tests then were evaluated with a Kruskal-Wallis pairwise procedure. Identical superscript letters within a species and season indicate years that were not significantly different.

		Pre-nesting			Nesting			Brood-rearing			Fall-staging		
Species	Year	$\bar{X}$	SD	n	$\bar{X}$	SD	n	$\bar{X}$	SD	n	$\bar{X}$	SD	n
Canada Goose													
	1989	52 [a]	7	145	47	6	72	44	7	18	53	8	6
	1990	50 [b]	9	71	49	11	117	45	12	51	46	6	3
	1991	48 [b]	7	98	43	7	163	42	7	48	48	2	6
White-fronted Goose													
	1989	52	8	188	52	7	18	43	7	3	51	9	18
	1990	55	10	18	50	5	25	47	6	9	56	9	18
	1991	54	8	155	53	8	51	49	6	19	52	8	20
Brant													
	1989	48	4	14	51 [a]	6	8	46 [a]	4	25	49	4	3
	1990	48	3	4	45 [b]	4	7	49 [b]	4	52	47	3	3
	1991	48	6	7	50 [a]	5	26	50 [c]	4	41	49	4	14
Tundra Swan													
	1989	46	10	5	48	0	1	54	11	3	48	10	4
	1990	44	7	3	46	12	5	42	6	11	52	9	6
	1991	45	11	7	41	8	5	42	6	6	47	7	4
Northern Pintail													
	1989	-	-	-	49	7	27	44 [a]	6	19	51	6	17
	1990	49	9	23	49	7	55	48 [a]	10	46	49	8	50
	1991	53	10	39	48	9	60	50 [b]	8	46	52	8	77

Table 11. Continued.

Species	Year	Pre-nesting			Nesting			Brood-rearing			Fall-staging		
		$\bar{X}$	SD	n	$\bar{X}$	SD	n	$\bar{X}$	SD	n	$\bar{X}$	SD	n
Oldsquaw													
	1989	-	-	-	47	7	24	44	7	3	0	0	0
	1990	45	6	26	47	6	26	42	5	5	47	7	5
	1991	49	8	11	46	9	28	40	3	11	0	0	0
King Eider													
	1989	-	-	-	47	5	23	42	9	2	46	1	2
	1990	44	6	14	48	8	36	42	9	11	49	11	3
	1991	46	5	2	43	7	40	42	3	5	55	5	8
Spectacled Eider													
	1989	-	-	-	47 [a]	2	7	38	2	2	51	0	1
	1990	49	8	17	48 [a]	8	15	41	9	5	44	5	3
	1991	0	0	0	42 [b]	3	6	46	7	7	38	0	1
Pacific Loon													
	1989	49 [a]	11	17	47	8	34	46 [ab]	8	53	-	-	-
	1990	48 [a]	6	10	45	10	54	44 [a]	9	77	47	9	11
	1991	42 [b]	9	19	42	7	58	48 [b]	7	78	-	-	-
Red-throated Loon													
	1989	48	0	1	48	3	8	41 [a]	5	9	-	-	-
	1990	48	0	1	42	8	10	46 [b]	6	16	56	0	1
	1991	42	6	2	42	5	14	48 [b]	6	28	-	-	-

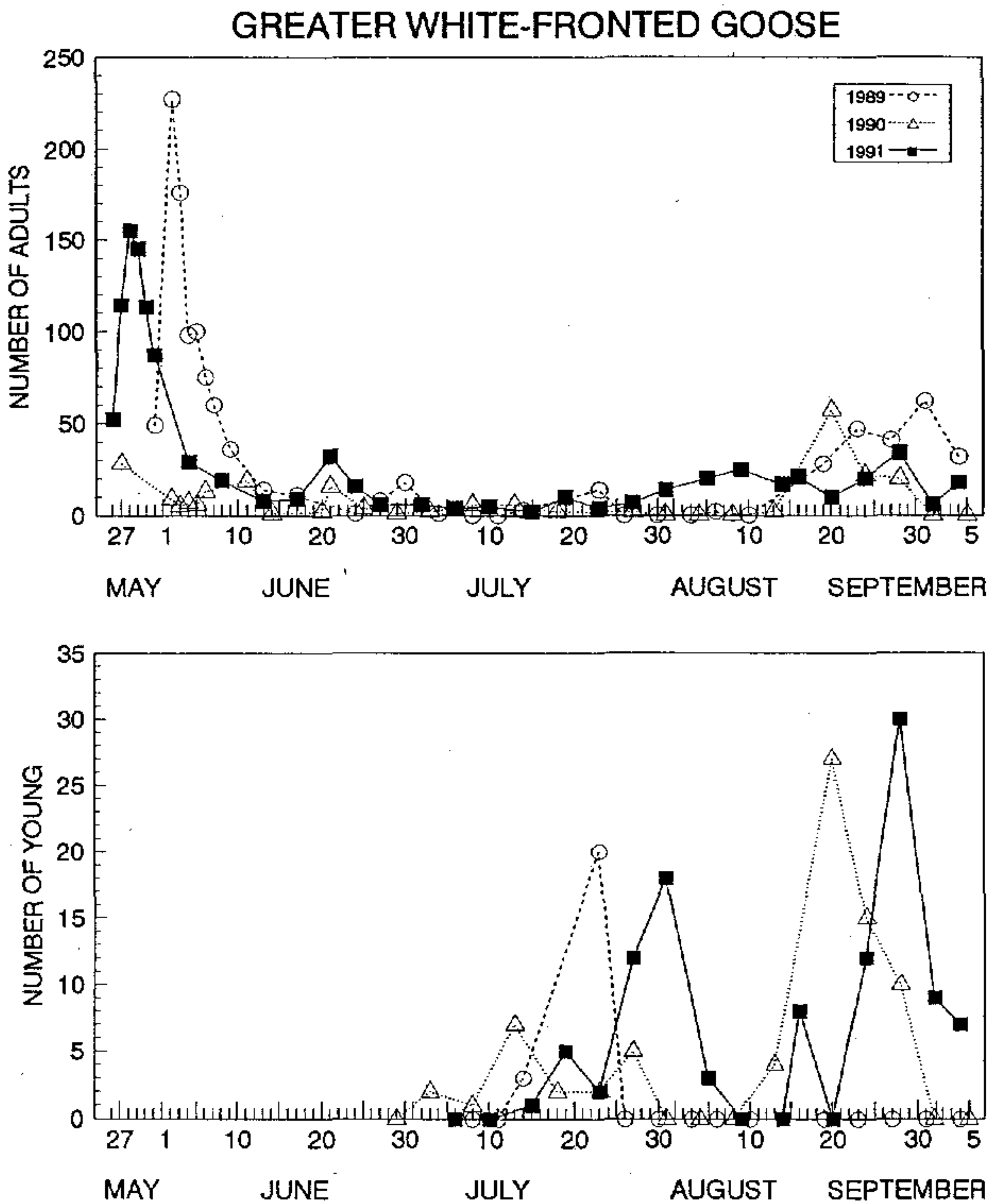


Figure 15. Counts of adult and young White-fronted Geese from road and foot surveys in the GHX-1 study area, Prudhoe Bay, Alaska, 1989-1991.

and, thus, the dispersal of nesting geese to other parts of the North Slope earlier than in other years. As was the case for Canada Geese, the best years to compare for any shifts in the distribution of pre-nesting White-fronted Geese were 1989 and 1991. In both years, the distribution of White-fronted Geese in the study area was similar to that of pre-nesting Canada Geese, except that White-fronted Geese did not show major shifts in flock locations between years (Figure 16). Only a small area of Wet Meadow habitat directly east of CCP was used heavily in 1989, but not at all in 1991. Wet Meadows, Moist Meadows, and Impoundments supported the greatest densities of White-fronted Geese during pre-nesting, although the levels of use differed among years (usually much lower densities in 1990) (Figure 17). Only in Impoundments were annual increases in density apparent.

The study area did not support large numbers of nesting White-fronted Geese in any year of this study (Figure 14). The number of nests located in the study area increased steadily from zero in 1989 to two in 1991. Unlike Canada Geese, White-fronted Geese did not reuse the same nest site in subsequent years. Nests were scattered around the study area, with the two nests used in 1991 being located in somewhat atypical sites for White-fronted Geese. For example, one nest was located west of CGF on a small island in a pond, which is a site more typical of a Canada Goose than of a White-fronted Goose. Usually, White-fronted Geese nest on open tundra away from waterbodies. The second nest site in 1991 was located on a grassy mound in halophytic wet meadow habitat on the mainland south of the brood-rearing island used by Brant; this site, although more drier than the other nest site, was in a coastal habitat type rarely used by nesting White-fronted Geese. Although the number of nests established increased each year, densities of White-fronted Geese during nesting did not differ significantly among years (Table 8). Densities of White-fronted Geese in habitats within the study area were much lower during nesting than during pre-nesting (Figure 17). Wet Meadows supported the highest densities in both 1989 and 1990, whereas Coastal Wetland Complexes supported the highest density in 1991. Some of these differences in habitats among years are explained by the location of each nest in a different habitat (Table 9).

The number of young White-fronted Geese seen during road surveys fluctuated both among survey dates and among years (Figure 15). Comparison of numbers of young in

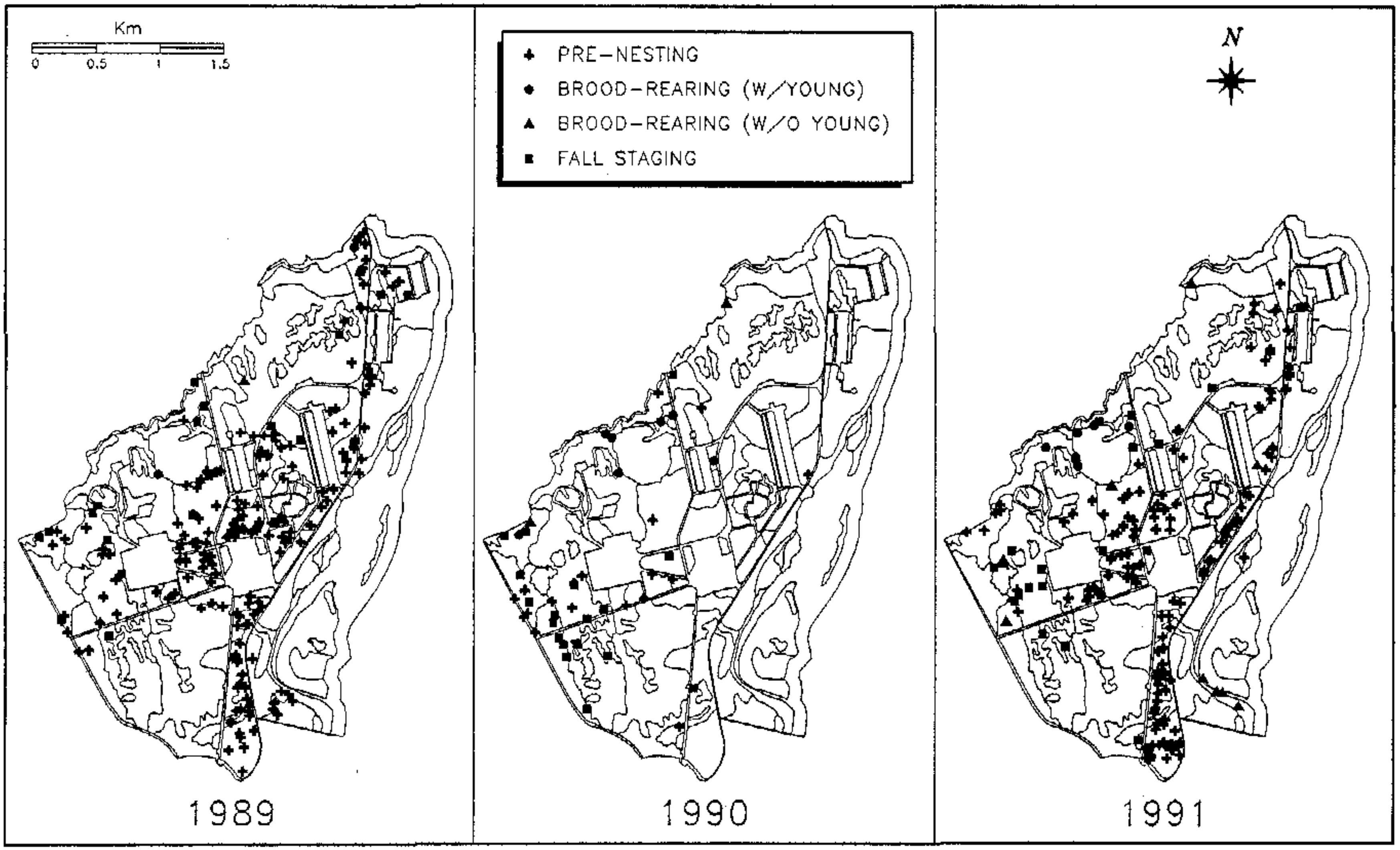


Figure 16. Distribution of White-fronted Geese during pre-nesting, brood-rearing, and fall staging in the GHX-1 study area, Prudhoe Bay, Alaska, 1989-1991. Each flock sighting was of one or more birds.

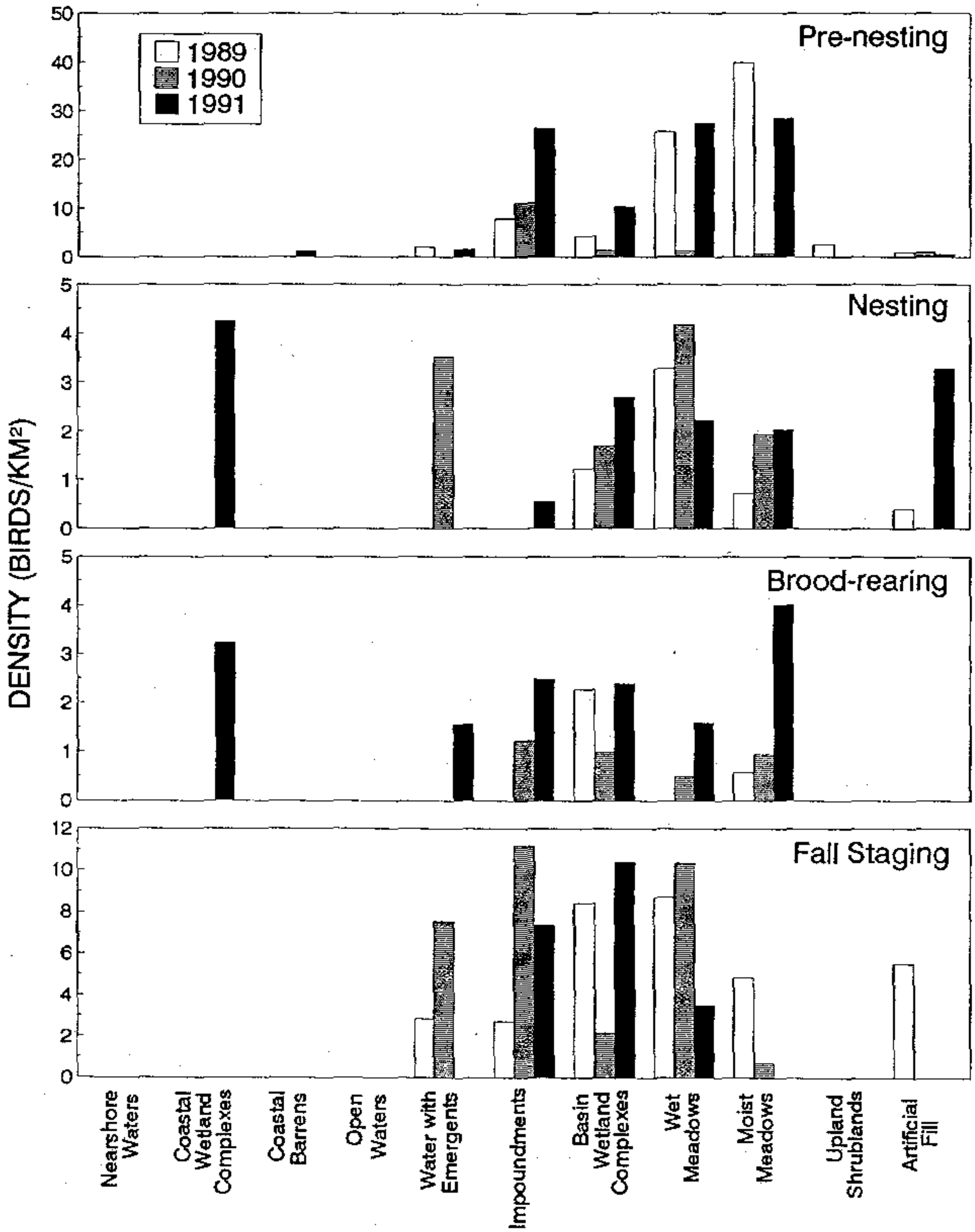


Figure 17. Mean seasonal densities (birds/km^2) of Greater White-fronted Geese in Level II habitats in the GHX-1 study area, Prudhoe Bay, Alaska, 1989-1991.

1990 and 1991 and numbers of nesting pairs in the study area indicated that there was an influx of broods into the study area in late July. Density of adults during brood-rearing was significantly greater in 1991 than in both 1989 and 1990, but densities of young did not differ significantly among years (Table 8). In each year, most brood sightings clustered around the deep open lake located northwest of WGI (Figure 16). This tendency for broods to occur annually in the same location partially explains why only two habitats (Basin Wetland Complexes and Moist Meadows) were used by brood-rearing White-fronted Geese in all years (Figure 17). Densities of White-fronted Geese in Basin Wetland Complexes were similar in 1989 and 1991 but much lower in 1990, whereas densities in Moist Meadows increased markedly in 1991. In addition, more habitat types were used in 1991 than in either previous year.

Densities of fall-staging White-fronted Geese in the study area, although somewhat greater in 1991, did not differ significantly among years (Table 8). Fall-staging flocks occurred primarily west and southwest of CGF in all years, although scattered sightings occurred in other parts of the study area (Figure 16). During fall staging, White-fronted Geese consistently occurred in Impoundments, Basin Wetland Complexes, and Wet Meadows, but trends in annual densities were different in each habitat (Figure 17).

Effects of Noise

White-fronted Geese occurred in the study area in numbers only during pre-nesting and fall staging, but no changes in distribution among years were apparent during those seasons (Table 10). Distances of flocks to CCP varied annually during each season, but the pattern was not consistent among seasons and the trend was not towards greater distances in 1991, which would have implied shifts away from noise generated by the GHX-1 facility. Only during pre-nesting and brood-rearing (adults only) did the abundance of White-fronted Geese differ significantly among years. Neither of those differences could be attributed to the effects of noise, however, because the differences were due to higher numbers in 1991, which was the operational year for GHX-1. In addition, the estimated noise levels at the locations of White-fronted Goose flocks also did not differ significantly among years for any of the seasons and the highest estimated noise level did not always occur in 1991 (Table 11). These results suggest that for

White-fronted Geese the GHX-1 facility and any increased noise associated with its operation did not substantially affect their use of the study area.

BRANT

Seasonal Abundance, Distribution, and Habitat Use

Brant were present in the study area in low numbers during pre-nesting in all three years (Figure 18 and Appendix 3). Although, densities of pre-nesting Brant were greater in 1991 than in the previous two years, they did not differ significantly among years (Table 8). Pre-nesting Brant were seen primarily along the mainland southeast of CCP in 1989 and 1990 (Anderson et al. 1990, 1991), but also in a temporary impoundment south of CCP along the Putuligayuk River in 1991. This affinity for coastal locations in the study area was supported by the annual use of Coastal Wetland Complexes, although a downward trend in density occurred from 1989 to 1991 (Figure 19). That trend probably resulted from low overall abundance in both 1990 and 1991 and from use of other habitats in the study area in 1991.

Brant did not nest in the study area in any of the three years of study, but the coastal island at the mouth of the Putuligayuk River was used by non-breeding birds during the nesting season, particularly in 1991, when a large group of non- or failed-breeders moved onto the island by 24 June (Figure 18, Appendix 3). This early movement in 1991 onto the island probably was due to the breeding failure of the major nesting colony at Howe Island, which is located approximately 10 km to the east. Although Brant were observed in the vicinity of Howe Island in early June, they never attempted to breed, because of the presence on the island of arctic foxes, which already had destroyed most of the Snow Goose nests (Stickney et al. 1992). Again an affinity for coastal habitats was apparent because Brant occurred almost exclusively in Coastal Wetland Complexes during the nesting season; low densities also occurred in Coastal Barrens and Nearshore Waters. Unlike during pre-nesting, the densities of Brant in Coastal Wetland Complexes increased annually between 1989 and 1991, rather than decreased. Most of the increased density seen in 1991 could be accounted for by the early arrival of the non-breeding component of the local population on this traditional brood-rearing area.

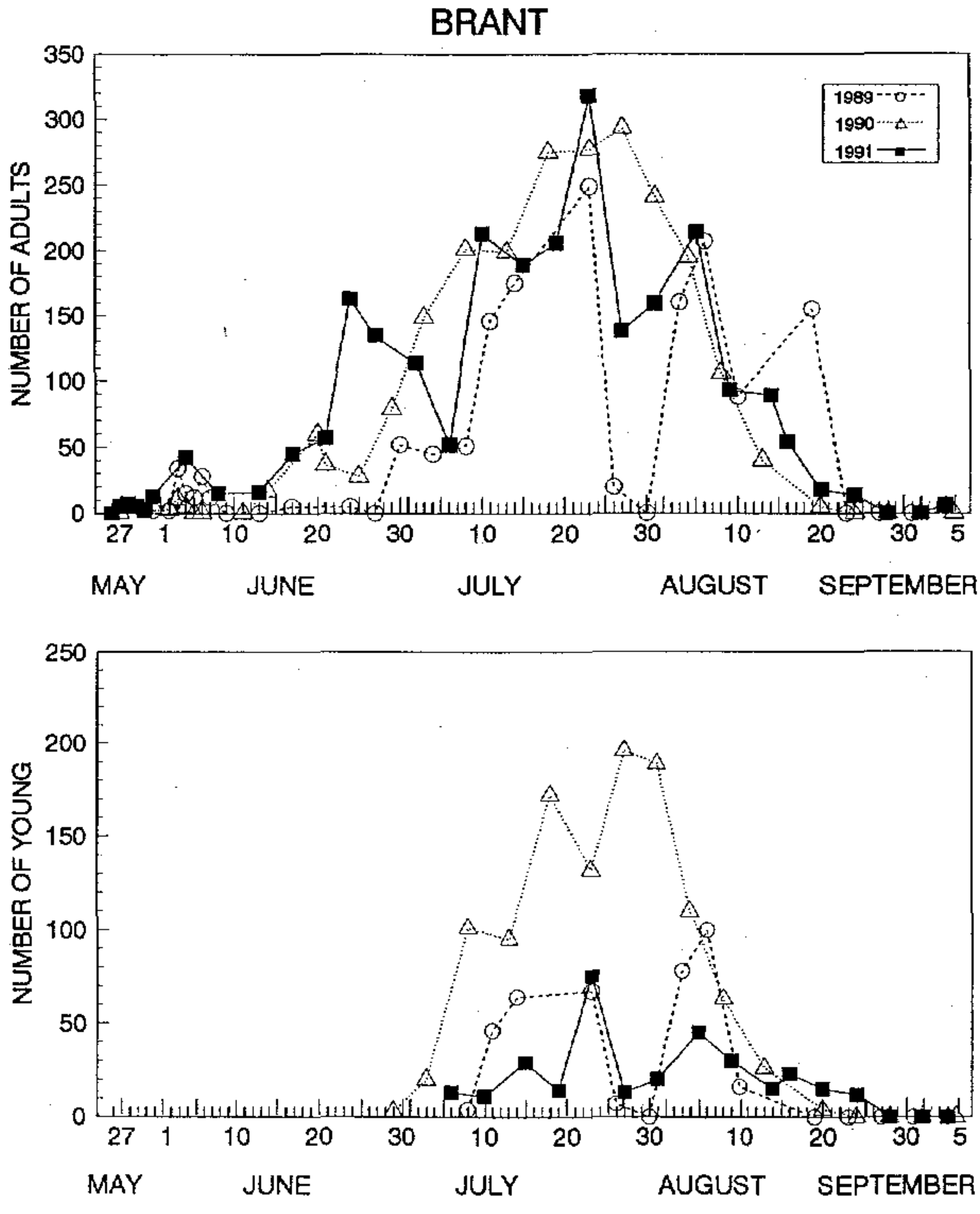


Figure 18. Counts of Brant from road and foot surveys in the GHX-1 study area, Prudhoe Bay, Alaska, 1989-1991.

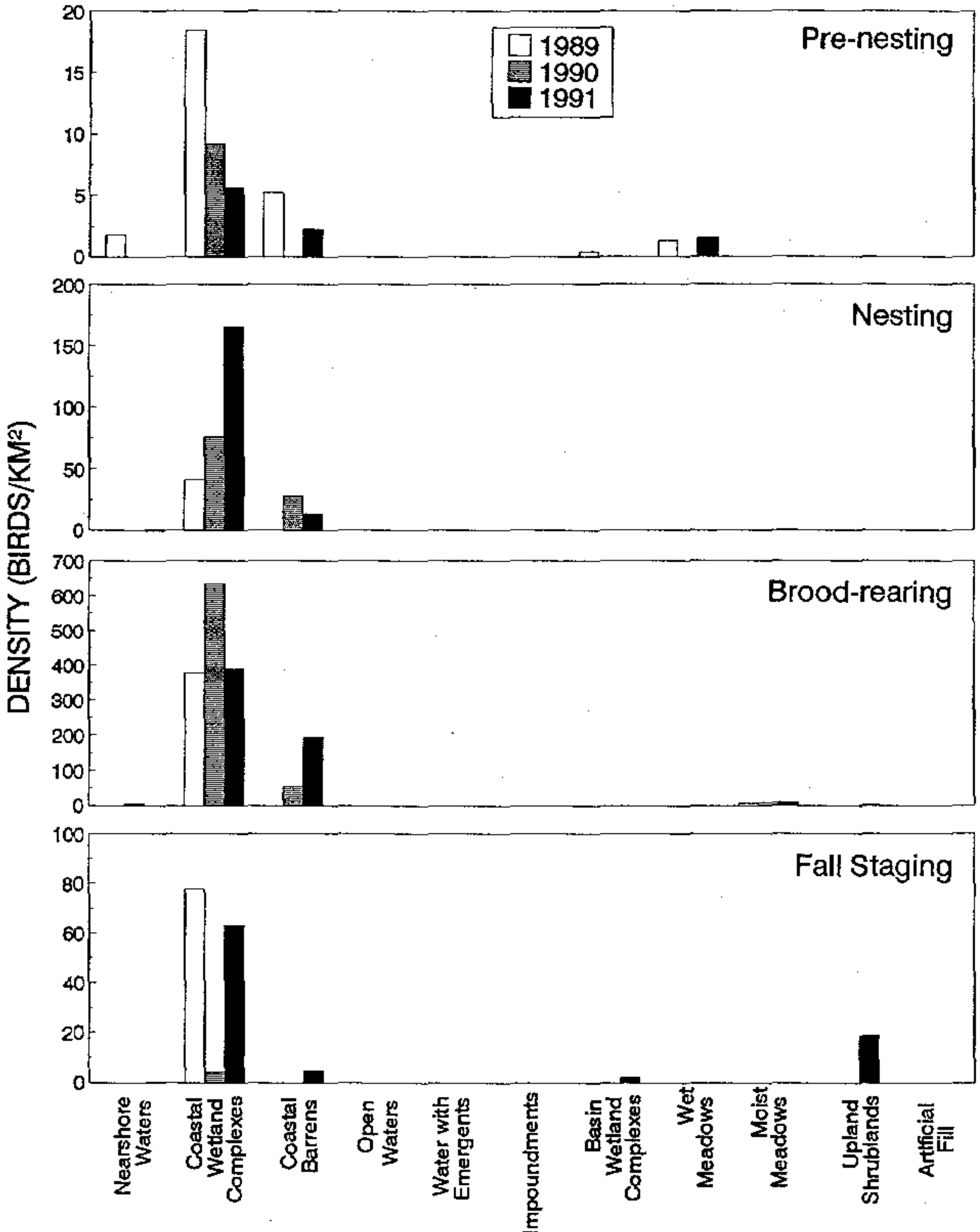


Figure 19. Mean seasonal densities (birds/km^2) of Brant in Level II habitats in the GHX-1 study area, Prudhoe Bay, Alaska, 1989-1991.

Brant primarily used the study area during the brood-rearing season, when large numbers of adults and young occupied the coastal island southeast of CCP (Figure 20). Although numbers of adults varied among years, densities did not differ significantly among years (Table 8). The number of young observed during brood-rearing was greater in 1990 than in either 1989 or 1991, and this difference was reflected in a significantly greater density of young recorded in 1990 than in the other two years (Figure 18, Table 8). Other than the coastal areas east of CCP and the coastal island, the only other part of the study area used by brood-rearing Brant was the banks of the unnamed stream north of LGI (Figure 20). This affinity for coastal habitats again was reflected in the densities of Brant in Coastal Wetland Complexes; densities peaked during brood-rearing in each year. Annual differences in density in this habitat were due primarily to changes in annual production at nesting colonies in the Prudhoe Bay vicinity. The highest density occurred in 1990, when Brant production in the Prudhoe Bay area was high and large numbers of adults and young used the brood-rearing island (Anderson et al. 1991, Ritchie et al. 1991). Brood-rearing groups also used Coastal Barrens, Moist Meadows, and Nearshore Waters, but at markedly lower densities than recorded in Coastal Wetland Complexes; only Moist Meadows was used in all three years.

After adults finished molting and the young were able to fly, most Brant moved out of the study area, and few birds were seen after late August (Figure 18). Fall-staging Brant occurred in greatest densities in Coastal Wetland Complexes each year, but annual fluctuations in density were attributable to movements out of the study area in 1989, but not in the other two years. The use of Upland Shrublands in 1991 represented a single flock resting in this dry habitat on the mainland bluff west of the coastal island.

Effects of Noise

Brant did not display any changes in abundance, distribution, or habitat use that could be attributed to the effects of increased noise from the GHX-1 facility in 1991. Although the abundance of young Brant during brood-rearing was lowest in 1991, this change resulted from lower productivity in the entire region that year and not from avoidance of the area because of noise emanating from GHX-1. Given the strong affinity of Brant for the coastal island and the adjacent mainland shoreline, it was not surprising

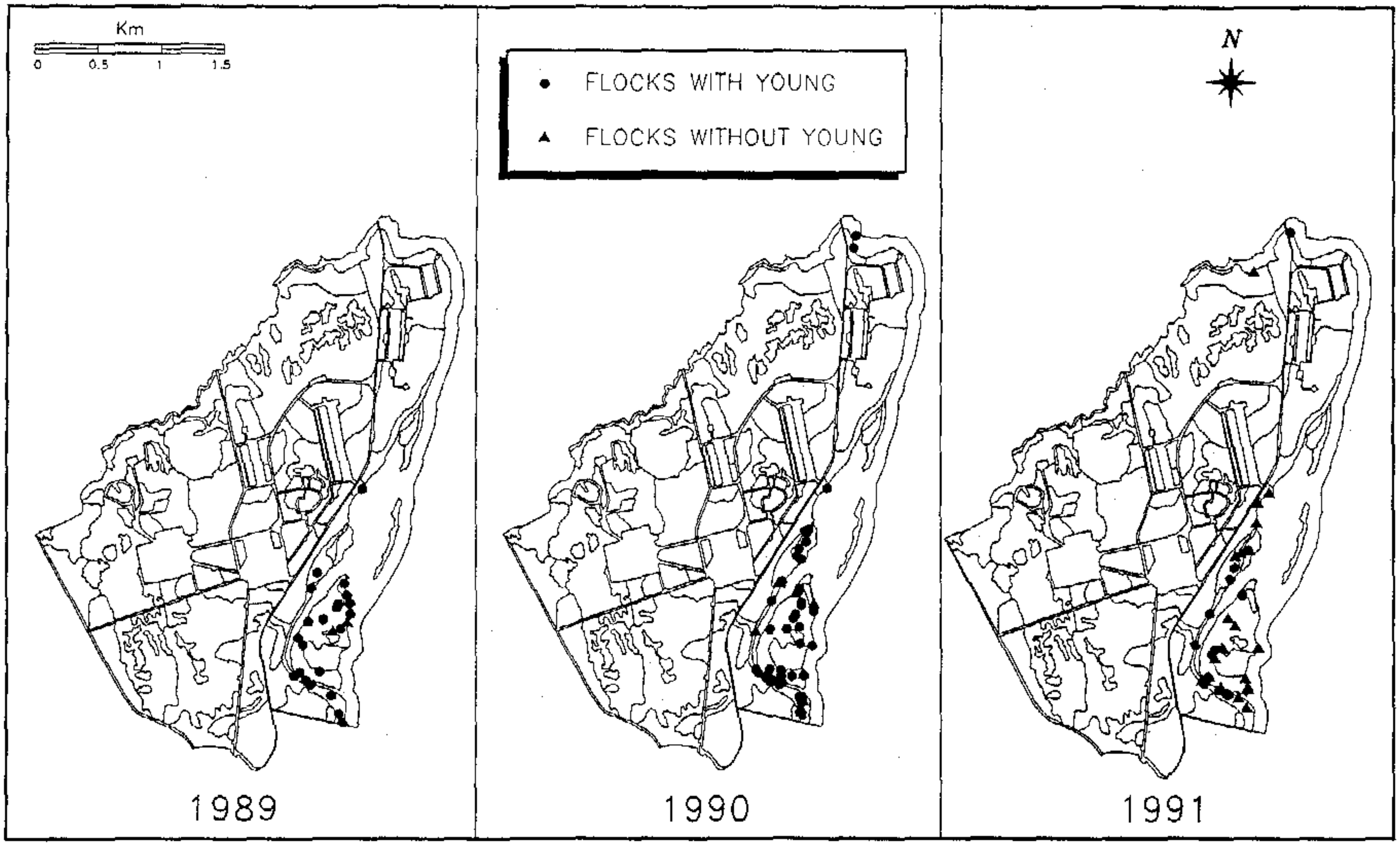


Figure 20. Distribution of Brant during brood-rearing in the GHX-1 study area, Prudhoe Bay, Alaska, 1989-1991. Each flock sighting was of one or more birds.

that the mean distances of flocks to CCP did not differ among years for any season (Table 10). Although the mean distances of flocks to CCP did not differ among years, mean estimated noise levels at those flock locations increased significantly from 1989 to 1991 (Table 11). The ability of Brant to shift brood-rearing habitats in response to increased noise was constrained somewhat by the limited extent of suitable coastal habitats in the study area, thus, it was not surprising that brood-rearing flocks experienced higher noise levels in 1991. However, Brant did not appear to avoid the mainland shore east of CCP in 1991, where noise levels were higher than on the coastal island (Figure 17). In general, it appeared that Brant were able to adjust to those increased noise levels and still use their brood-rearing habitats on the island and mainland near CCP.

SNOW GOOSE

Seasonal Abundance, Distribution, and Habitat Use

Snow Geese, unlike the other species of geese, did not use the study area consistently. During the three years of study, Snow Geese were observed on only eight surveys in two years (two in 1991, six in 1989; Appendix 3). Densities never exceeded 0.5 birds/km^2 at any time (Table 8). Snow Geese were seen in the study area during pre-nesting in both 1989 and 1991 (Anderson et al. 1990). In 1989, a pair with four young used the study area for several weeks in July and was seen along the unnamed stream north of LGI and in the Brant brood-rearing area southeast of CCP (Anderson et al. 1990). The tendency for limited use of the study area was not a new phenomenon; past use by brood-rearing Snow Geese has fluctuated between relatively low levels of use during some years (e.g., 1983-1985, 1988; WCC 1983, 1985; Murphy et al. 1986, 1989, 1990) and no use during other years (e.g., 1986 and 1987; Murphy et al. 1987, 1988). Pre-nesting Snow Geese were seen in low densities in Basin Wetland Complexes in 1989 (0.4 birds/km^2), in Wet Meadows in 1991 (0.3 birds/km^2), and in Moist Meadows in both years (0.9 and 0.1 birds/km^2 in 1989 and 1991, respectively). The brood-rearing flock of Snow Geese in 1989 was seen only in Coastal Wetland Complexes, although in higher density in salt-affected meadows than in halophytic wet meadows (4.8 birds/km^2

and 3.0 birds/km^2, respectively), the two Level IV habitats that make up the Coastal Wetland Complex habitat.

Effects of Noise

The limited use of the study area by Snow Geese during each year precluded any analyses for changes in abundance, distribution, or habitat use that could be attributed to the operation of the GHX-1 facility.

TUNDRA SWAN

Seasonal Abundance, Distribution, and Habitat Use

Tundra Swans, which were paired upon their arrival in the study area, occurred in low numbers during pre-nesting in all years (Figure 21, Appendix 3). Mean densities during pre-nesting exceeded 0.1 birds/km^2 only in 1991 and did not differ significantly among years (Table 8). Pre-nesting swans used primarily the northern half of the study area, in particular the unnamed slough and its banks northwest of LGI and the wetlands west of DS-L1 (Figure 22). No habitat type was used every year by pre-nesting swans (Figure 23). The greatest densities were recorded in Impoundments in 1991; other habitats used were Nearshore Waters, Basin Wetland Complexes, Wet Meadows, and Moist Meadows.

Tundra Swans never nested in the study area, and densities during nesting were similar to those recorded during pre-nesting (Table 8). Swans were seen throughout most of the study area, but most occurred in the northern half (Figure 22). During nesting, swans primarily used Basin Wetland Complexes and except for Water with Emergents all other habitats were used in only one year (Figure 23).

Brood-rearing Tundra Swans also were uncommon in the study area. Only in 1990 was a pair with young (four) consistently seen in the area north of NGI (Figure 22). This brood was produced at a nest on the Prudhoe Bay coast approximately 1 km north of LGI. Although a pair of swans was observed near this nest site in 1991, they apparently did not attempt to nest. The significant differences among years in densities of brood-rearing adults and young were due entirely to the presence of this pair in 1990 (Table 8). Basin Wetland Complexes and Coastal Wetland Complexes were used

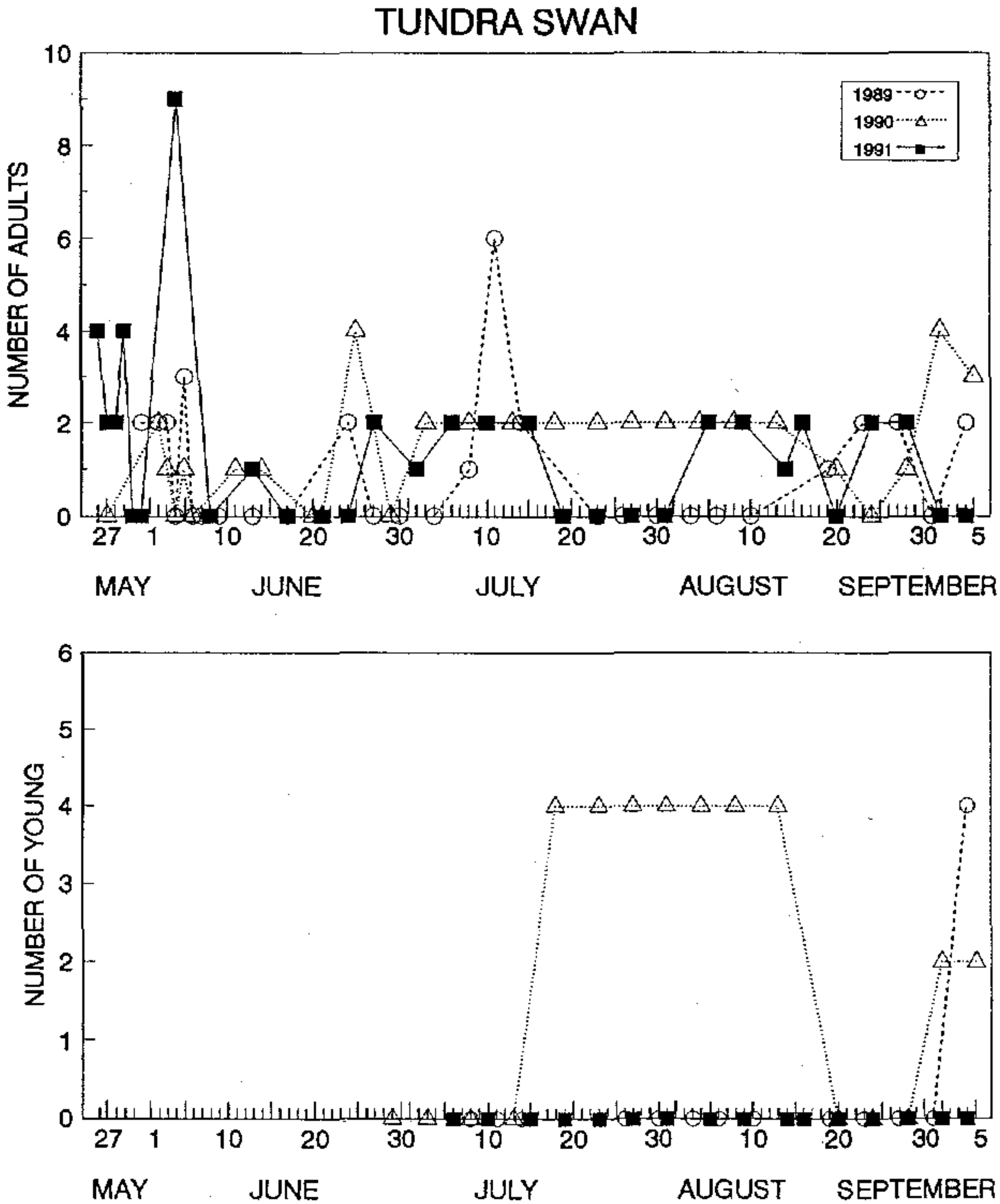


Figure 21. Counts of Tundra Swans from road and foot surveys in the GHX-1 study area, Prudhoe Bay, Alaska, 1989-1991.

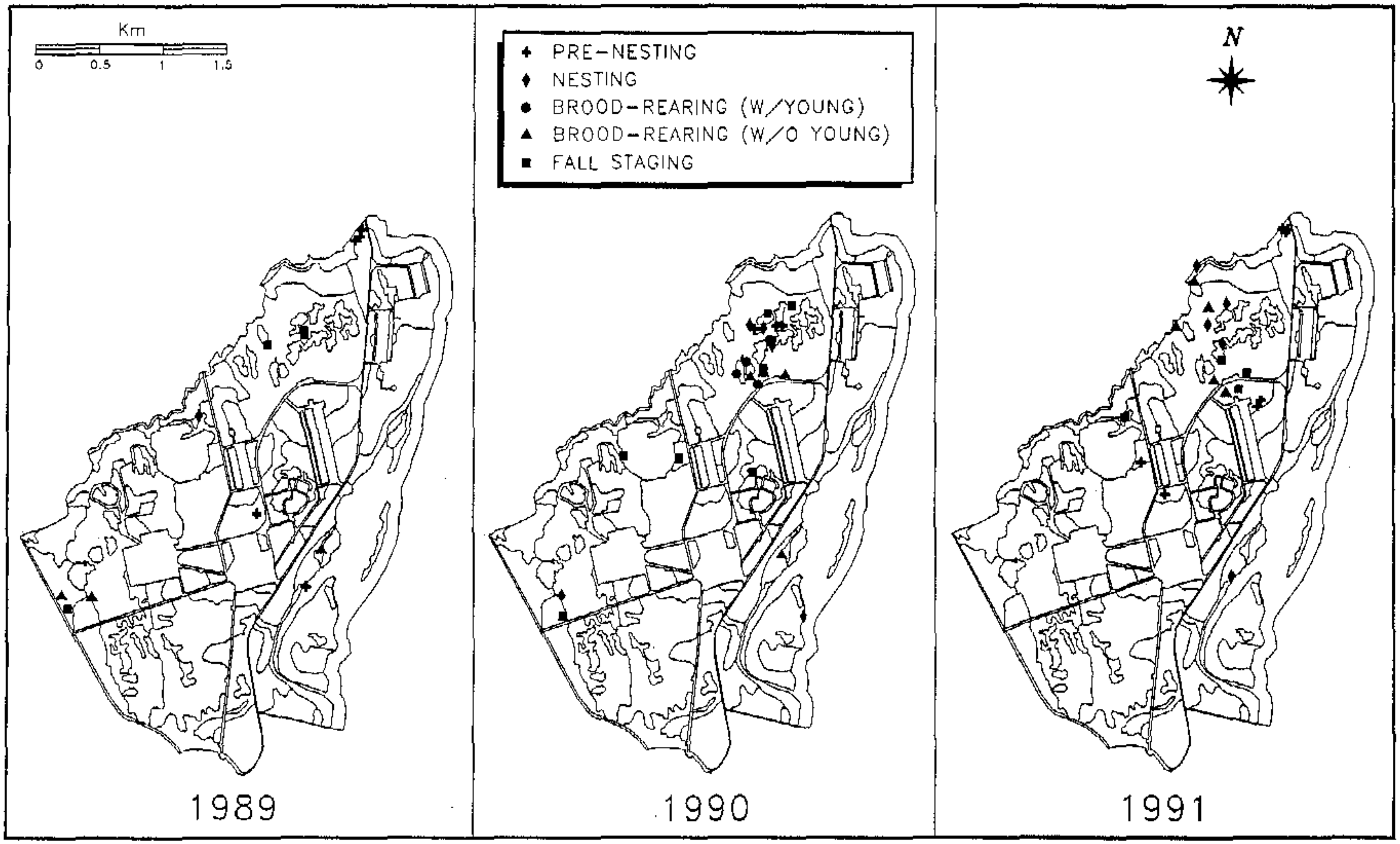


Figure 22. Distribution of Tundra Swans during all seasons in the GHX-1 study area, Prudhoe Bay, Alaska, 1989-1991. Each flock sighting was of one or more birds.

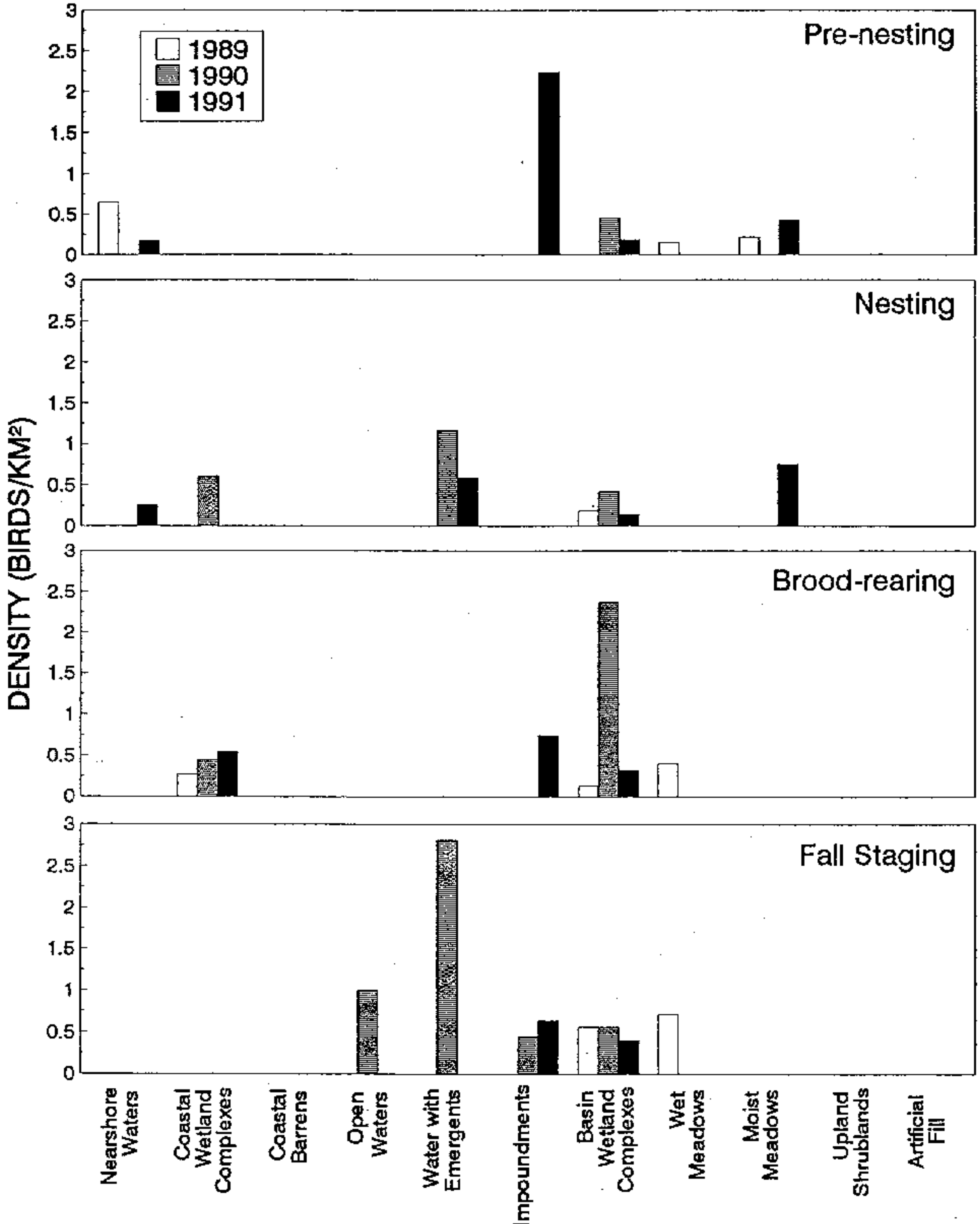


Figure 23. Mean seasonal densities (birds/km^2) of Tundra Swans in Level II habitats in the GHX-1 study area, Prudhoe Bay, Alaska, 1989-1991.

annually during brood-rearing, but the magnitude of use varied markedly for Basin Wetland Complexes (Figure 23); this annual difference was due to the presence of the pair with a brood in 1990. Only two other habitats, Impoundments and Wet Meadows, were used by swans during brood-rearing.

Single swans and pairs were seen sporadically during fall staging in all years, and family groups of adults with fledged or nearly fledged young occasionally were seen in early September in 1989 and 1990 (Figure 21, Appendix 3). Densities during fall staging were lowest in 1991 but did not differ significantly among years (Table 8). Fall-staging swans occurred mostly in the wetlands north of NGI, near the deep open lake west of WGI, and near the junction of the peat road and the pipeline road southwest of CGF (Figure 22). Only Basin Wetland Complexes were used annually by fall-staging swans; impoundments were used in both 1990 and 1991, and three other habitats were used in only one year (Figure 23).

Effects of Noise

Although distances of Tundra Swans to CCP during brood-rearing were greater in 1990 and 1991 than in 1989, estimated noise levels were not significantly different among years (Tables 10 and 11). Low samples sizes for all years hampered a conclusive explanation of this trend, however. Some of the differences in locations could be due to a differences in flock composition among years, in that most observations of swans during brood-rearing in 1990 were of a family group, whereas all observations in 1989 and 1991 were of adults. Not unexpectedly, family groups were more likely to seek areas of lower noise.

NORTHERN PINTAIL

Seasonal Abundance, Distribution, and Habitat Use

Northern Pintails were the most abundant ducks in the study area all three years (Figure 24, Appendix 3). The occurrence of pintails on the North Slope of Alaska is due to primarily the displacement of birds from prairie regions that are suffering drought conditions (Hanson and McKnight 1964, Derksen and Eldridge 1980). Few of these displaced birds attempt to nest in the Prudhoe Bay region, probably due to low energy

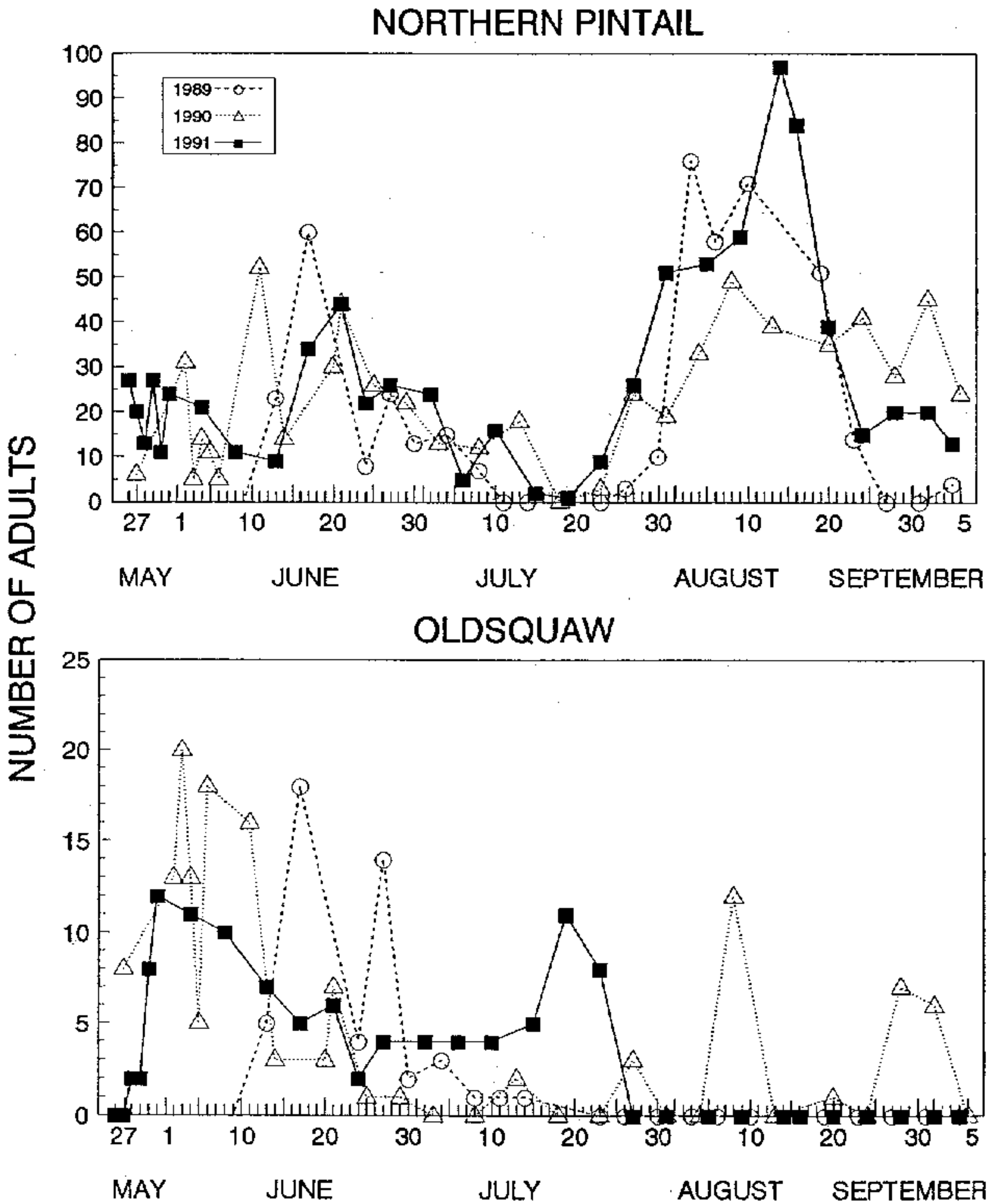


Figure 24. Counts of Northern Pintails and Oldsquaws from road and foot surveys in the GHX-1 study area, Prudhoe Bay, Alaska, 1989-1991.

reserves upon arrival (Derksen and Eldridge 1980). Because these ducks are not attempting to breed, the seasonal breakdowns (particularly for nesting and brood-rearing) are not helpful in identifying changes in distribution and habitat use in the study area. Therefore, the following discussion focuses more on general trends rather than on seasonal differences, although we have provided seasonal summaries. In each year, numbers of pintails fluctuated between late May and early July before declining during the middle of July (Figure 24). During late July and early August, numbers increased, and the greatest use of the study area occurred in August (usually between 1-15 August). Numbers decreased throughout fall staging, although a consistent pattern of decline was not apparent among years. Among-year comparisons of seasonal densities revealed no significant differences among years for any season (Table 8). Pintails were distributed throughout most of the study area, with concentrations in wetlands north of NGI, northwest of WGI, and southwest of CGF. The most substantial annual shift in distribution among the three years was a cluster of observations in a small, triangular patch of habitat immediately west of CCP in 1991 (Figure 25). This area, which was not used heavily in 1989 or 1990, is a combination of an Impoundment and a Basin Wetland Complex that is temporarily flooded in the spring and provides ideal habitat for dabbling ducks such as pintails. Use of the coastal island southeast of CCP also increased annually (Figure 25). This low-lying island is inundated periodically by tidal water and storm tides during the summer, thus providing temporary, shallow ponds that are ideal pintail habitat.

Northern Pintails occupied all of the available habitats in the study area during one or more seasons, except for Upland Shrublands (Figure 26). As might be expected of dabbling ducks, pintails occurred in highest densities in habitats dominated by water, although they also were seen in low densities in both Wet and Moist meadows. Early in the summer (pre-nesting and nesting seasons), pintails occurred in greatest densities in Coastal Wetland Complexes and Impoundments. Impoundments continued to support high densities in the latter half of the summer (brood-rearing and fall staging seasons). Water with Emergents, Basin Wetland Complexes, and Coastal Wetlands also were important habitats, although they supported low densities of pintails. Annual changes in density varied among habitat types. For example, use of Impoundments declined

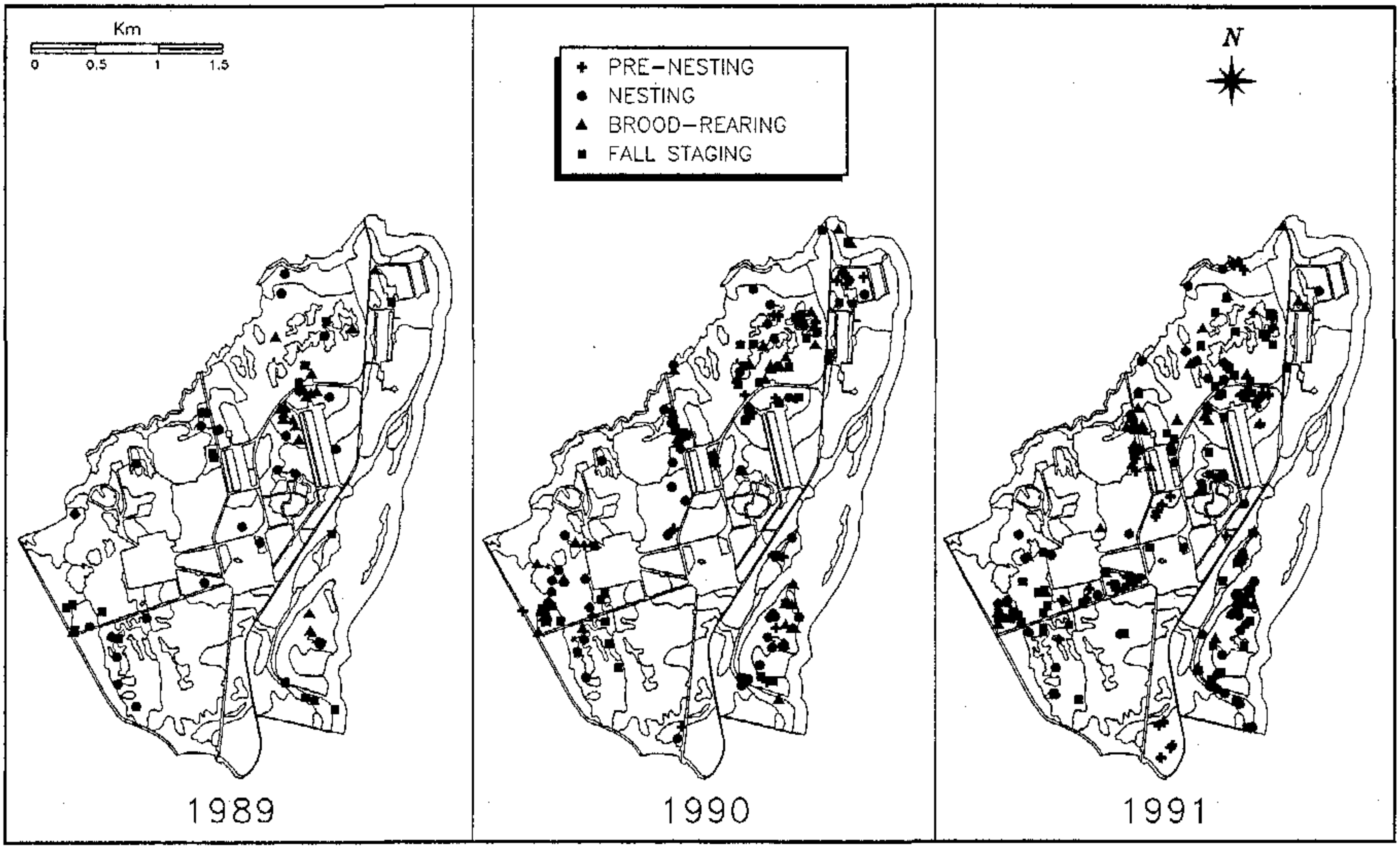


Figure 25. Distribution of Northern Pintails during all seasons in the GHX-1 study area, Prudhoe Bay, Alaska, 1989-1991. Each flock sighting was of one or more birds.

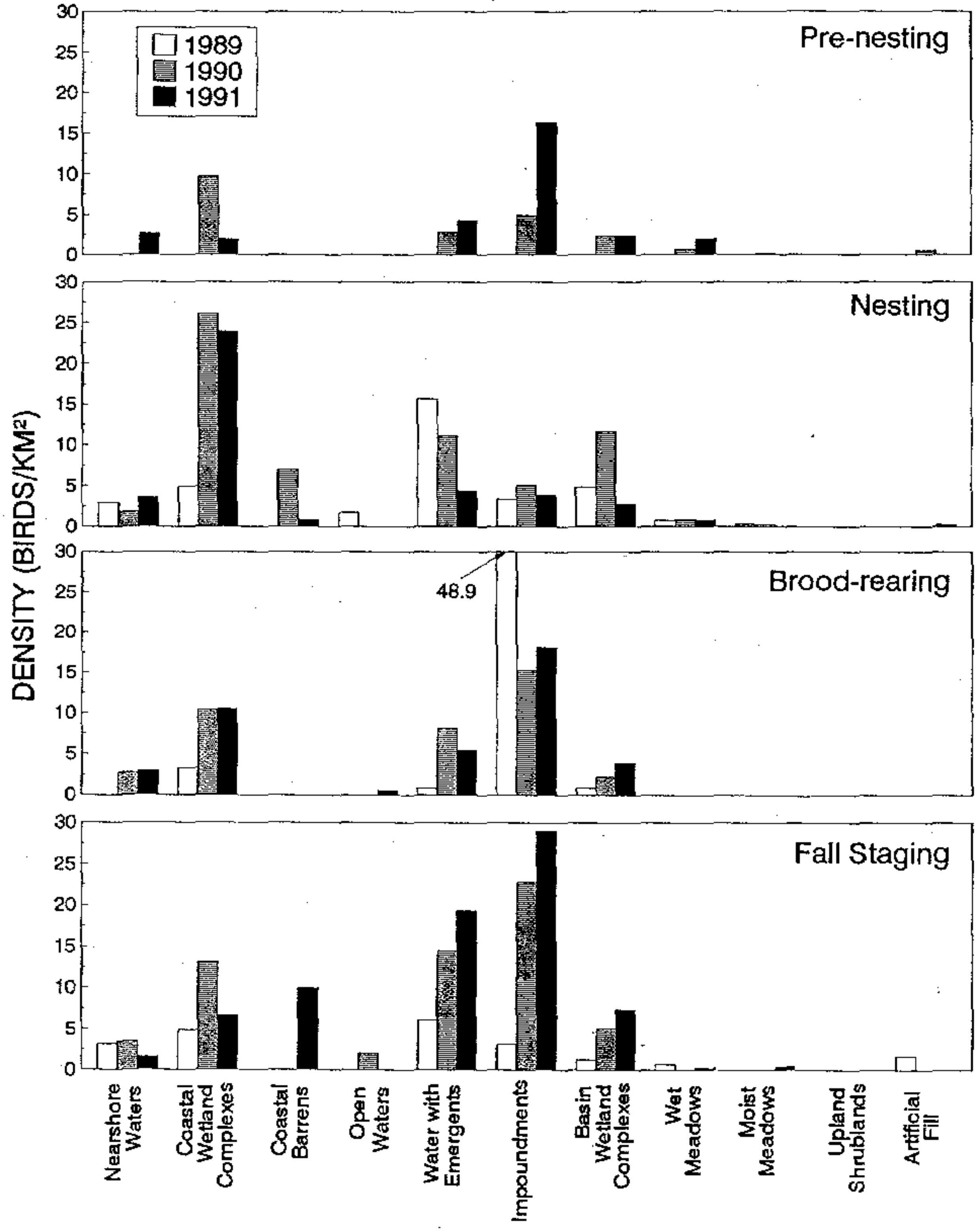


Figure 26. Mean seasonal densities (birds/km^2) of Northern Pintails in Level II habitats in the GHX-1 study area, Prudhoe Bay, Alaska, 1989-1991.