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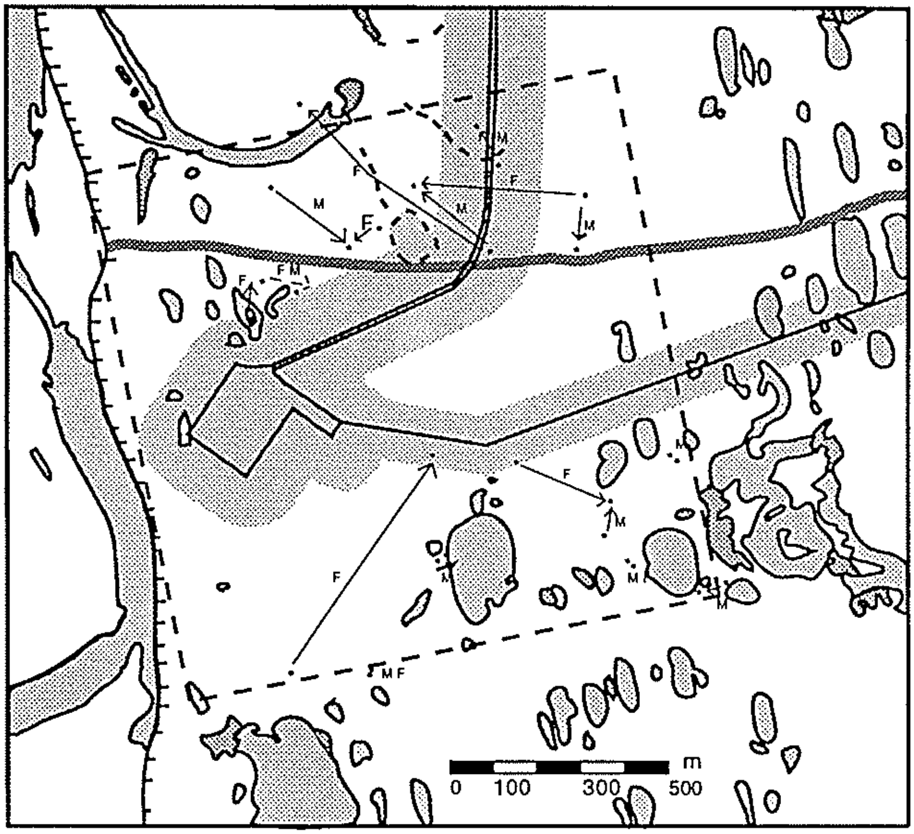
The Fate of Birds Displaced by the Prudhoe Bay Oil Field:

The Distribution of Nesting Birds Before and After P–Pad Construction



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THE FATE OF BIRDS DISPLACED BY THE PRUDHOE BAY OIL FIELD:

THE DISTRIBUTION OF NESTING BIRDS BEFORE AND AFTER P-PAD CONSTRUCTION

by

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EXECUTIVE SUMMARY

The inability to directly link habitat modification with effects on organisms frequently hampers assessment of environmental impacts. At Prudhoe Bay it is possible to document the spatial extent of tundra covered by gravel, and to estimate the amount of tundra altered by drainage modification, dusting, and other factors. It is also possible to describe local changes in abundance or distribution of the birds, mammals, and fish. While we have become better at describing the changed local abundance of species, the link between habitat modification and abundance at the population level has been elusive.

Tundra birds provide an opportunity to assess directly the relationship between habitat change and population level effects. Many species of birds exhibit site-tenacity; the tendency for individuals to return to the previous year's breeding location. Thus, we know with some degree of confidence where individuals of site-tenacious species of tundra birds should occur in successive years. We can take advantage of this trait by marking these birds and tracking them in subsequent years to monitor their response to development-induced habitat changes.

An opportunity to conduct such an experiment occurred during construction of P–Pad, in the southern part of the Prudhoe Bay oil field. In 1988, during the summer prior to construction, we located nest sites of birds breeding in the vicinity of the proposed facilities and marked the birds with colored leg bands. Based on previous studies on Alaska's North Slope and from the literature, Semipalmated Sandpiper, Dunlin, and Lapland Longspur were expected to be site-tenacious; whereas, Pectoral Sandpipers and Buff-breasted Sandpipers were not. If habitat availability restricted their abundance, the individuals most affected (i.e., displaced) by the development would not be expected to nest following pad and road construction. If habitat availability was not limiting, these birds would be expected to resettle in nearby, unaffected areas. The first breeding season following construction of the road and pad (1989), we returned to determine the nesting distribution of birds, and attempted to relocate the birds marked the preceding year.

Key findings were as follows:

- Some marked birds displaced by habitat alteration returned and nested in adjacent areas. These included Semipalmated Sandpiper, Dunlin, and Lapland Longspur.

- Nest success of displaced individuals was not reduced indicating that the new nest sites were in suitable habitats.

- The number of nests in the study area decreased from 1988 to 1989. Most of this was attributable to decreases in Pectoral Sandpiper and Lapland Longspur density. These decreases also occurred away from the oil field (in the Pt. McIntyre Reference Area); therefore they were unrelated to the presence of P-Pad.

- Several shorebirds, including Semipalmated Sandpiper and Dunlin, experienced natural increases in density. Thus, in addition to absorbing the displaced birds, there was sufficient habitat for density increases resulting from recruitment by these species.

- Four species not found nesting in 1988, nested on the study plot in 1989. Two of these species, Baird's Sandpiper and Snow Bunting, nested in altered habitats, and their colonization was probably attributable to the presence of the pad and road.

- Nesting attempts declined in areas adjacent to the road and pad. Nest densities of Semipalmated Sandpipers and Dunlin declined in this zone. Lapland Longspurs and especially Pectoral Sandpipers may also be avoiding this area, but their areawide decrease in density complicated detection of this effect. Some avoidance of facilities had been previously documented for all of these species except Pectoral Sandpipers (e.g., Troy 1988).

As reported in past studies, the distribution of birds adjacent to the facilities differed from that predicted in the absence of gravel placement. Some species increased in density while some decreased. This study has documented that displaced individuals are not necessarily lost from the breeding population, but rather, that many resettle in suitable areas nearby.

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ACKNOWLEDGMENTS

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Special thanks are due to the field crews. Terry Schick assumed a major role in coordinating the sampling of the P-Pad plot and in developing the color marking scheme. Craig Hohenberger contributed his considerable expertise in capturing birds. Ken Kertell, Robert Rodrigues, Jeff Wickliffe, and Jo Young were the other members of the field teams.

Danny Bystrak of the Bird Banding Laboratory processed our color-marking authorization to include species on the P-Pad plot on short notice. We thank Kate Moitoret (USFWS) for cooperating in working out a marking system to enable us both to color band shorebirds without duplicative marking schemes. She also shared some of her preliminary results with us. Jennifer Brown (Bodega Marine Laboratory), Cheri Gratto (North Dakota State University), and Nellie Tsipoura (Western Hemisphere Shorebird Reserve Network) kindly loaned us Darvic bands at the onset of this study. This study was initiated under a contract to LGL Alaska Research Associates, Inc.; we thank the individuals in LGL who have assisted us.

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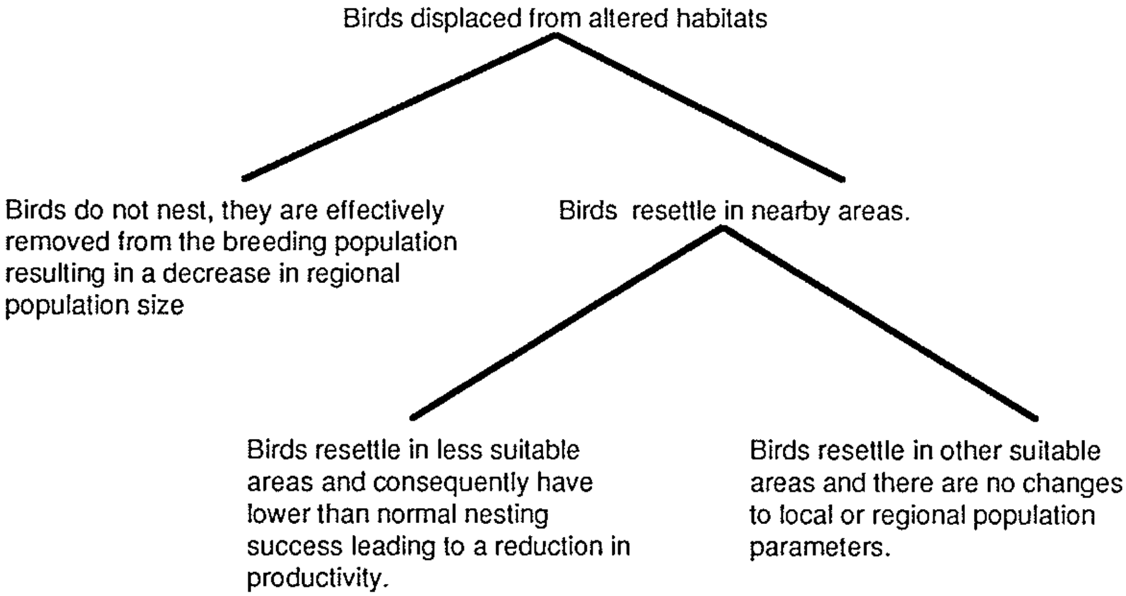
INTRODUCTION

Are North Slope bird populations limited by habitat availability? Disagreement as to the answer to this question is pervasive in environmental assessments pertaining to oil development in northern Alaska (e.g., Senner 1989, Post 1990). The answer has important implications for the interpretation of oil field environmental assessment studies. Changes in bird nesting distribution at Prudhoe Bay, on the Arctic Coastal Plain, have resulted from man-made structures required for petroleum development. Effects of oil field development on birds include elimination of tundra habitat within the facility "footprint," and reduction in densities in adjacent areas (Connors and Risebrough 1979, Meehan 1986, Troy 1986, 1988). Considerable effort has been expended in describing and quantifying the extent and magnitude of the impacts of oil field development on nesting birds. The results are varied (Meehan 1986; Troy 1986, 1988), but in many cases bird and nest densities appear to be lower than expected near oil field facilities. The question remains: What happens to the affected birds? If habitat is limiting to bird populations on the North Slope, then bird populations are affected by changes in habitat availability. Meehan (1986) concluded that at Prudhoe Bay there was a reduction by 18 percent in populations of six common shorebirds, about 19,000 individuals, due to the presence of the oil field. If habitat is not limiting, these birds are presumably still present, but in new locations.

Ultimately, the concern for birds is not that fewer individuals will be present near oil field facilities, but that this equates to reduced population sizes. The underlying assumption of most impact concerns is that habitat availability limits population size; therefore, bird populations are adversely affected by any habitat loss or change. If habitat is limiting then prevention of further loss by minimizing construction will maintain bird populations at predevelopment levels. If displaced birds can resettle and breed without a reduction in nest success, then it follows that population size is not being affected by small amounts of habitat loss.

Objectives and Rationale

The objective of this study is to determine whether birds displaced by a North Slope oil field expansion are lost from the local breeding population, or do they resettle in adjacent areas. After facilities are built, some birds (individuals) can no longer nest in areas they would otherwise have used because these areas are covered by the new facility. Additional birds may avoid areas adjacent to the facility due to disturbance effects. The fate of displaced birds may follow one of the following alternatives:



For a bird to resettle successfully, suitable habitat must be available. The location where birds resettle is a topic of important consideration. Behavioral attributes of each species influence how far displaced birds can be expected to move in search of new nesting areas. Site-tenacity or fidelity is the tendency for birds to return to the same location in successive years. Detection of site-tenacity requires a multi-year study of marked birds. Consequently, the occurrence of site-tenacity is unknown for many species. This trait appears to be widespread and has been documented for many species and during all times of the year. Site-tenacity has been documented frequently at breeding areas (e.g., Schamel and Tracy 1977, Hildén 1979, Redmond and Jenni 1982) and at migration and wintering locations (e.g., Stewart and Connor 1980, Arnold 1981, Johnson et al. 1981, Yunik 1983). In an exceptional case, an individual Black Turnstone was tracked to demonstrate fidelity to both breeding and winter sites (Gill et al. 1983). Site-tenacious species are the most useful for assessing the impacts of development by quantifying changes in bird or nest abundance. For these species we know with some confidence where individuals should occur in successive years. In the case of breeding birds, we also have a single unambiguous location, the nest site, that can be used to measure presence and changes in locations of birds.

The presence of site-tenacity as a trait and the magnitude of changes in nest locations vary considerably among species and are further influenced by age, sex, and prior nesting success. Some common species in the Prudhoe Bay area are known, or suspected, to be site-tenacious. The most numerous nesting species in the P–Pad area prior to development in 1988 were, in decreasing order: Lapland Longspur, Semipalmated Sandpiper, Pectoral Sandpiper, Dunlin, and Buff-breasted Sandpiper. These five species are our key study species and are emphasized in the analyses and ensuing discussion. Evidence for site-tenacity in these species is discussed below.

Lapland Longspur—Longspurs are known to exhibit site-tenacity, but the return rates have been poorly quantified. Hanson and Eberhardt (1979) found longspurs returning to their North Slope study areas, but did not report return rates or distances between successive nest sites. Recovery data provided by the U.S. Fish and Wildlife Service Bird Banding Laboratory shows most recoveries of longspurs occur at the banding location (defined as 10 minute blocks of latitude and longitude). We expected this species to be site tenacious at P-Pad.

Semipalmated Sandpiper—Several studies (Norton 1973; Norton et al. 1975; Gratto et al. 1983, 1985) have documented site-tenacity in Semipalmated Sandpipers. Gratto et al. (1983, 1985) also found some first-time breeders were philopatric (returned to nest near their own hatching location). In five years of study, Hanson and Eberhardt (1981), consistently found the nest of one marked bird within a 1-ha (0.01 km^2) area. Norton et al. (1975) observed that if both members of a pair survived, the nest was frequently within 100 m of their previous year's site. When birds had new mates, the distance from previous nest sites increased but remained in the same vicinity.

Pectoral Sandpiper—In complete contrast to Semipalmated Sandpipers, Pectoral Sandpipers show little evidence of site-tenacity or philopatry. Norton (1973) found no evidence of site-tenacity in Pectoral Sandpipers and, at Prudhoe Bay, had no returns of banded birds (Norton et al. 1975). The only returns for breeding Pectoral Sandpipers are of two individuals found a year after banding south of Prudhoe Bay at Mile 12 Trans Alaska Pipeline (TAPS) (Hohenberger pers. comm.). The absence of site-tenacity and large among-year variations in breeding density (Pitelka 1959, Troy and Wickliffe 1990) suggest this species is prone to changing breeding areas.

Dunlin—Dunlin appear similar to Semipalmated Sandpipers in their fidelity to breeding areas. Norton (1973) found Dunlin to be site-tenacious at Barrow. The most intensive study of marked Dunlin took place in Finland (Soikkeli 1967, 1970) and found Dunlin were both site-tenacious and philopatric. Males usually returned to their former territories. Females also returned, but if they had a new mate and hence a new territory, the distance moved between successive nest sites was greater than for males. For both sexes, new nests were rarely more than 500 m (and usually much less) from previously used locations.

Buff-breasted Sandpiper—Little detailed information is available on the breeding biology of this species. Therefore, predictions of the expected site-tenacity are speculative. Based on our experience in the Prudhoe Bay area, Buff-breasted Sandpipers are not expected to be site-tenacious. The low incidence of nests found annually in the same area and the considerable of among-year variability in densities support this conclusion.

Factors Affecting Shorebird Population Size

The effect of environmental changes on tundra birds has proved difficult to assess because the basics of the population dynamics of the affected species are so poorly known. Implicit in most assessments that predict population changes, is that we are dealing with stable populations whose carrying capacities are defined in local areas, and that loss of habitat will result in decreased populations. This reasoning requires three important assumptions:

1. The affected birds have populations at maximum levels (i.e., they are resource limited and a loss of a resource translates directly into a population change).

2. Habitat is the resource limiting population size.

3. Population limitation occurs in the area of concern.

Specific to the case of North Slope shorebirds, the common underlying assumption is that these species are limited by habitat availability during the breeding season. The validities of these general assumptions are discussed in the following sections.

Habitat availability is but one of many factors that could limit population size of shorebirds. Predation, food availability, and weather are alternative factors. There is also the variable of location where regulation occurs. In the case of long-distance migrants, the bottleneck may occur in breeding, migration, or wintering areas. Loss or alteration of habitat in all three regions has reduced use of areas previously used by shorebirds. Displacement of birds has occurred without doubt, but whether populations have been reduced is largely a matter of speculation (Senner and Howe 1984).

Are Shorebird Populations at Their Maxima?

Many shorebird populations underwent a major decline early in this century, during the years of market hunting. Some species have not recovered from over-harvest (see Myers et al. 1987, Senner and Howe 1984); e.g., the present abundance of Buff-breasted Sandpiper does not compare to the descriptions prior to market hunting declines. Species that were the most heavily hunted were the large, densely flocking shorebirds, but even small species were intensively harvested.

The second argument against maximum population sizes is that shorebird populations may be regulated by density-independent factors such as weather. Populations can be periodically reduced by catastrophic conditions, followed by periods of population rebuilding. Adverse conditions may occur at a frequency such that the population never reaches levels where density-dependant factors would inhibit population size. Regulation can occur during any time of the year but with shorebirds most cases appear to be on the wintering grounds (Evans 1981).

Where Could Density-Dependent Regulation Occur?

Breeding Areas

In areas where habitat modification has been extensive, effects on breeding shorebirds have been quite marked. For example, habitat loss and disturbance on the Piping Plover's breeding grounds resulting in poor reproductive success is believed to be the cause of its precipitous population decline (e.g., Flemming et al. 1988). Piping Plovers nest on sandy beaches along the Atlantic coast, the Great Lakes, and in central North America. Overlap of their nesting areas with human recreation areas has lead to frequent disturbance of breeding birds.

Habitat limitation is also indicated by the presence of birds unable to find suitable breeding habitat (more birds than space). At Barrow, Alaska, Holmes (1966) found that removal of a territorial Dunlin was followed by another taking over the territory. In Finland, Soikkeli (1967) also concluded that territoriality limited the number of Dunlin and that ultimately the size of the population was limited by habitat. Removal experiments have also suggested the presence of surplus individuals in Lapland Longspurs (Seastedt and MacLean 1979), Temminck's Stint (Hildén 1979), and Oystercatchers (Harris 1970).

Examples also exist in which habitat alteration has resulted in the increase in some shorebird populations. The entire Dutch shorebird community, dominated by Oystercatcher, Northern Lapwing, Black-tailed Godwit, Redshank, Ruff, and Common Snipe, breeds on artificial grasslands reclaimed from marine areas (Beintema 1986).

Wintering Areas and Migration Stopovers

For some species of shorebirds, there is a great disparity between expansive breeding grounds and restricted sites used during migration and winter. This results in enormous shorebird concentrations outside the breeding season (Myers et al. 1987). As a first approximation, the place one would look for habitat limitations would be where the available acreage is most restricted and birds are most concentrated.

Many shorebirds maintain feeding territories during the winter. These territories are reduced in size compared to those maintained during the breeding season. During winter, territories are to defend food resources, whereas spacing to minimize predation appears to be a more important function during the summer. Competition for restricted resources should result in specialization among species. The greatest segregation of shorebirds, either in diet or habitat, would be expected when food is relatively scarce (Holmes and Pitelka 1968). Baker and Baker (1973) compared the foraging of tundra nesting shorebirds on the breeding grounds (Churchill, Manitoba) and at a wintering site (Florida). In the summer, shorebirds were found to have high behavioral and microhabitat use diversity and higher overlap among species than during the winter. They found that resource partitioning among species was greatest during the winter and concluded that was the time of year when density-dependent mortality could act to limit population size. Changes in prey availability on the wintering grounds have been implicated in changes in shorebird populations. Dunlin, Redshank, and Northern Lapwing numbers on the Clyde Estuary in Britain declined markedly between 1977 and 1979 (Furness et al. 1986). The most likely cause of the decline was reduced availability of their main prey, the amphipod *Corophium volutator*.

Availability of winter habitat can limit shorebird numbers. Dunlin numbers decreased by half in the British Isles, France, and the Netherlands between the mid 1970s and 1980s (Goss-Custard and Moser 1988). This decrease was related to the spread of cord grass, *Spartina anglica*, over the mudflats previously used by Dunlin. A corresponding increase in Dunlin could not be found in other wintering areas. In the British Isles, the Black-bellied Plover has increased in abundance over the past half-century. Monitoring of wintering sites suggests now that almost 50 percent of the estuaries in Britain are at or near their carrying capacity (Moser 1988).

In determining where populations of shorebirds encounter limiting factors, it is evident that there has been too little research directed at this topic. Fragmentary information from many species and areas must be examined. The best evidence for wintering ground limitations comes from Great Britain, but this northern area does not typify the types of environments in which most North Slope species winter. Nearctic tundra nesting shorebirds tend to winter in tropical or subtropical areas. Attempts to document evidences of population limiting factors in these regions have been unsuccessful. Duffy et al. (1981) found no support for competition or population limitation on tropical wintering grounds (Peru). Their results were questioned by Myers and McCaffery (1984) who found that most of the wintering shorebird species were territorial and witnessed a few instances of interspecific territoriality. They interpreted this behavior as evidence of competition.

In conclusion, there are many potential resources that could be limiting shorebird populations. Alternatively, population size many not be limited by any resource; density independent factors may keep numbers depressed below levels that resource availability permits. Some examples of potential resource limitation were described; these included cases from both breeding and non-breeding areas. The lack of concerted effort at determining where and if population regulation occurs, precludes any definitive conclusion. Given the diversity of shorebird species with such varied distributions and life history patterns, it is likely that no single generality should be expected. This study addresses the narrow question, "Is breeding habitat a resource limiting population size of shorebirds at Prudhoe Bay?"

METHODS

Study Area

The study area was located along the southern portion of the Prudhoe Bay oil field, near the Kuparuk River (Fig. 1). A square plot measuring 1.25 km on each side (1.56 km^2) was marked on the tundra surrounding the proposed site of P–Pad (Fig. 2). The plot bordered on a high bank of the Kuparuk River and included a portion of an old oxbow at a low elevation next to the river. Two small gullies ran part-way through the plot and into the oxbow area. These gullies

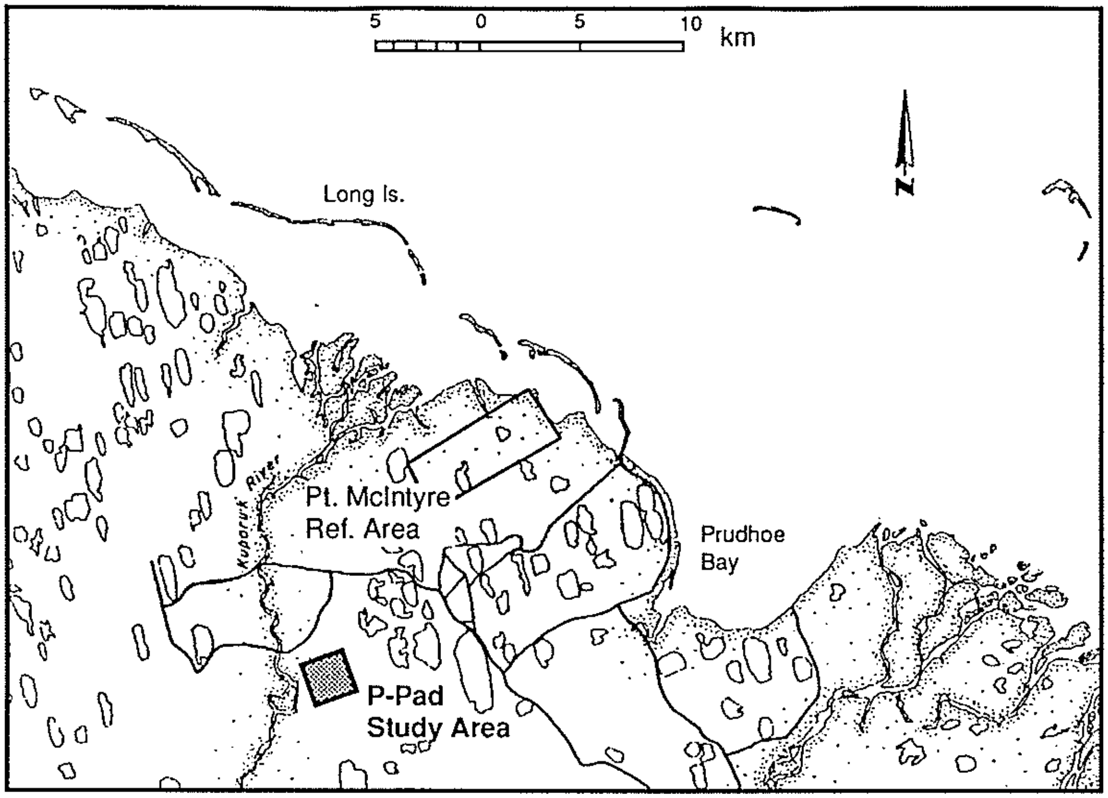


Figure 1. Locations of the P-Pad study area and Pt. McIntyre Reference Area.

were full of water during melt, but contained little or no water by late June. Several small ponds were within the plot area, principally the northwest and southeast corners. A section of peat road (abandoned trail) traversed the full width of the plot. Standing water remained in most of the peat road ditches throughout both nesting seasons.

During the winter of 1988-89, a 1829 m (6000 ft) gravel road and a 4.25 ha (10.5 acre) gravel pad were constructed in the study area. A total of 5.7 ha, or 3.7 percent of the plot, were covered by gravel.

Field Methods

Plot Set-up

Corners of the plot, as well as several lines of stakes, were surveyed and marked using an electronic distance meter. The plot was marked with stakes at 50 m intervals to form a reference grid. There were 26 stakes (A-Z) in each of 26 rows (1-26), for a total of 676 reference markers. Each stake was labeled with the line letter and number and served to identify the grid (50 x 50 m unit of the plot) to its southeast (Fig. 2).

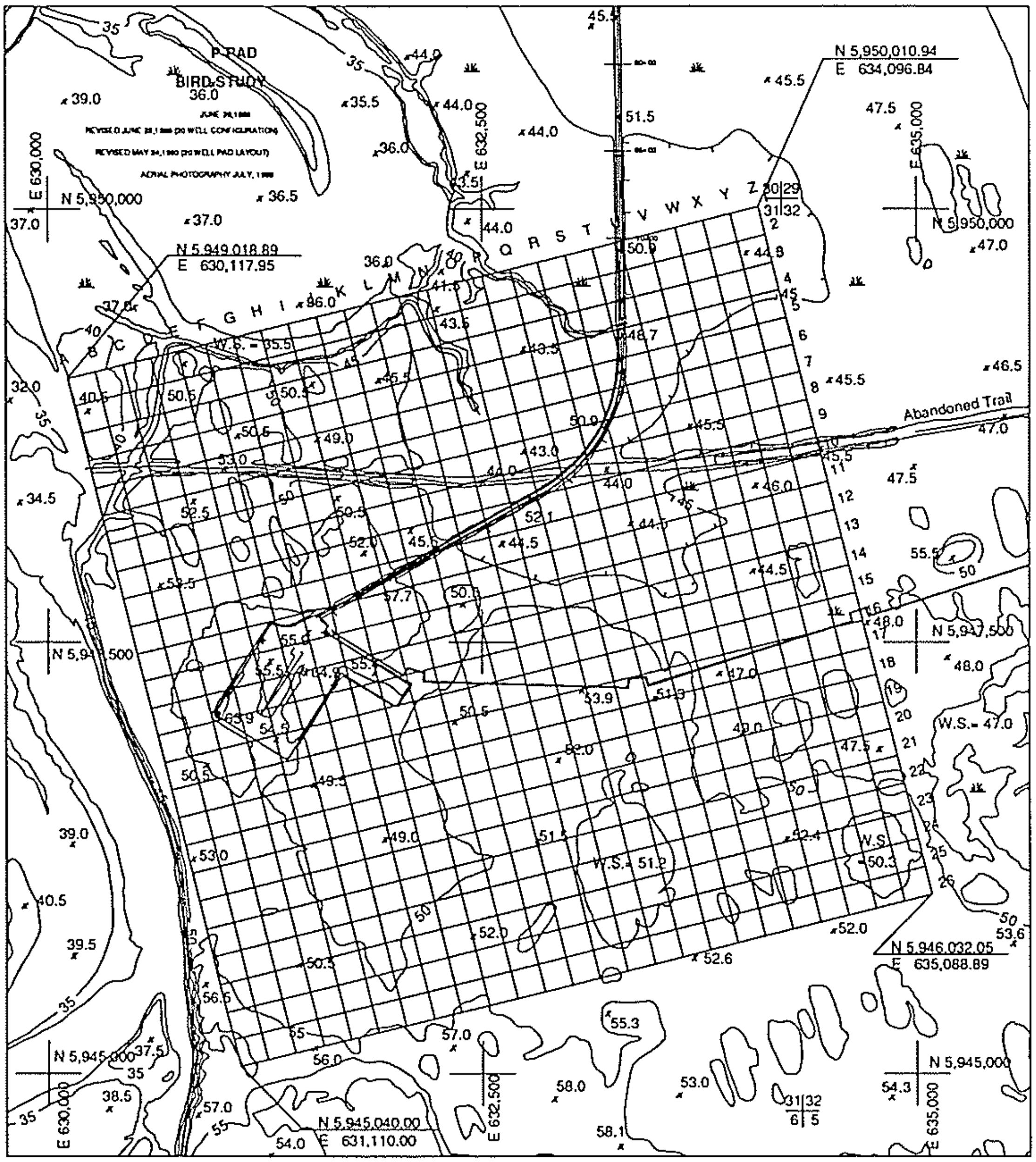


Figure 2. Grid pattern used to mark the study area into 50 m x 50 m units. A wooden stake was placed at the intersection of each letter and number line. The road, pad, and pipeline were not present during the 1988 sampling.

Nest Search Methods

Each year, field work commenced at the start of June. After plot set-up or maintenance, one to three biologists worked in different sections of the plot most days between 8 June and 15 July. The entire plot was rope dragged once during the peak of the nesting season, the second half of June. In 1988, the tundra on both sides of the proposed access road was surveyed as biologists walked the alignment when moving to and from the study plot.

In an attempt to locate birds that might have moved off the study plot, in 1989 the area was searched for marked birds was expanded. A band 200 m outside the marked study plot and 200 m on either side of the access road was rope dragged during late June.

Nest Monitoring

Information on the species, number of eggs or young, location, vegetation and surface-form, was recorded for each nest located. A unique number was assigned to each nest. The nest was marked with a plain tongue depressor placed approximately one meter from the nest. An orange tongue depressor was placed on the line to the west, perpendicular to the nest. Markers were also placed at intermediate locations to guide the observer to nests difficult to locate. Nests located around the periphery of the plot were marked from the nearest point of the perimeter or along the road edge. Nests were checked at 2-5 day intervals until hatching (fledging in the case of passerines) or until failure.

Banding Methods

Adult birds were captured for banding after the full clutch was laid and incubation was underway. The method used for capturing most of the shorebirds and female Lapland Longspurs was a simple box trap. The trap was propped over the nest and dropped by pulling a line after the bird had resumed incubation. Adult male Lapland Longspurs were captured with the box trap upon returning to the nest to feed chicks. Male Longspurs from unsuccessful nests could not be captured.

Captured birds were fitted with a metal Fish and Wildlife Service band on the left leg. Lapland Longspurs, Semipalmated Sandpipers, Dunlin, Pectoral Sandpipers, and Red-necked Phalaropes were also banded with unique combinations of color bands (red, green, white, yellow, and orange) in 1988. The color-banding system was expanded in 1989 to include most other species.

To designate the shorebirds from this study, a white band was placed on the left leg above the "knee".

Bill length (exposed culmen), tarsus length, flattened wing length, mass, and stage of feather molt, were recorded for each bird. These measures aided in sexing and aging the birds.

Analyses

The objectives of this study were addressed by comparing the nest site relocations and return rates of birds displaced by P–Pad and associated facilities relative to birds from peripheral areas. By necessity, this study is largely qualitative; birds displaced are either present or absent. Further, given the area covered by pads and the average bird densities on the North Slope, the number of birds actually displaced by incremental oil field expansions is small. In most cases small sample sizes preclude detailed statistical analysis. Tests of proportions are used to assess the significance of differences in return rates being compared. Note that throughout this report, we speak of nest locations in relation to facilities even though there were no facilities present in 1988. References to 1988 distances from facilities are based on where the facilities would be in 1989; changes from 1988 to 1989 are analyzed to assess the impact of these facilities.

Three degrees of habitat alteration were used to designate affected birds:

lost — 1988 nest site was covered by gravel or impounded water

disrupted — 1988 nest site was located in an area that became physically altered, usually abraded during snow removal operations during construction

close to facilities — 1988 nest site not obviously altered but located close to facilities and potentially affected by drainage alteration, timing of snow melt, or activities on the facility. Prior studies of birds in the oil field have shown that most distribution changes occur within 100 m of roads (Troy 1986, 1988). Since the pipeline was constructed from an ice road, effects should be less than for a road. For assessment purposes we considered birds whose 1988 nest sites were within 100 m of gravel facilities or within 50 m of the pipeline, to have been potentially affected by the P–Pad development.

For most analyses, all types of affected birds were pooled to compare their fates with (unaffected) birds that originally nested distant from the facilities.

Return Rates

Return rates are the proportion of birds banded on the plot in 1988 that returned in 1989. To be considered to have returned the bird had to be found nesting on or adjacent to the plot. Birds may have nested too far off the plot for the nest to have been found, or may have been present but not nesting in 1989. These birds would not have been considered returned by our criterion even if the individual had been seen. As defined here, return rates are at best minimal estimates of survival rates. Return rates are calculated for all individuals within a species to assess site-tenacity, and by distance to facilities (close versus distant) for impact assessment purposes.

Distance to Facilities

Return rates were compared for affected birds (close to facilities) and those more distant. Under the hypothesis that habitat is limiting, one would expect lower return rates for those individuals affected by the development. In addition, the number of nests in successive distance increments from the facilities were compiled for each year to evaluate the assumption that nest densities are reduced close to facilities. The increments used were: 0–100 m, 100–200 m, 200–300 m, 300–400 m, and 400–500 m.

Changes in Nest Location

Distances between nest sites were compared for affected and nonaffected birds. Two distances were considered. The first is the actual distance between the nest sites. Birds unaffected by the development have the option of reusing their 1988 nest sites in 1989, but affected birds that lost their 1988 nest sites could not. Therefore, affected birds are expected to have the larger relocation distances between nest sites. To evaluate the relative importance of relocation attributable to the presence of facilities, we also summarized the net displacement from facilities; i.e., (1989 distance to facility) – (1988 distance to facility site).

Allowances for Natural Population Variation

Biological systems are not static. Changes in bird distribution and abundance occur due to natural causes independent of events such as construction of P-Pad. Two methods are used to control for natural changes in bird populations. For trends between years we rely on comparison of results from P-Pad and the Pt. McIntyre Reference Area (PMRA) (Troy and Wickliffe 1990). Bird use of the PMRA, an area within the Prudhoe Bay Unit but remote from oil field facilities, some 12 km north of P–Pad (Fig. 1), has been monitored most years since 1981. Subtlety in differences in habitat composition eliminates the expectation that nest densities would be identical in the two study areas. However, population trends as manifested in local nest densities would be expected to occur in parallel fashions in the two areas. Thus, the major changes in densities observed in the PMRA between 1988 and 1989 provide the expected changes in the P-Pad study area. Any major differences in trends between the two areas become suspected effects of oil field expansion at P-Pad. Note that the experimental design at P-Pad focuses on individual birds (many marked individuals but one plot for density estimation). In contrast, in the PMRA the focus is on density estimation (several plots but no tracking of individuals). Therefore, comparisons between the two studies are qualitative.

The internal control for factoring out natural and developmental induced changes in bird use of the P-Pad study area, is the comparison of close versus distant portions of the P-Pad study plot. Prior studies indicate that most effects of development occur close to the facilities. Changes in distribution, return rates, or nest successes that occur disproportionately between birds close to the facilities versus those in the periphery of the plot are presumably due to the new facilities.

RESULTS

Nest Densities and Distribution

Between-Year Changes in Density

Total density in the P-Pad study area was lower in 1989 than in 1988 (Table 1). Almost all of the decrease ($\approx$ 8 nests/km^2) was attributable to a lower density of Lapland Longspur nests. Two other key species, Buff-breasted and Pectoral sandpipers, had lower densities; with the former being absent as a nesting species in 1989. The remaining key species had higher nest densities in 1989 as compared to 1988. Semipalmated Sandpiper nest density increased by $\approx$ 4

Table 1. Nest densities (# /km^2) in the P–Pad study area. The five key study species are emphasized in boldface.

SPECIES	1988	1989
Greater White-fronted Goose	2.6	1.3
Oldsquaw	0	0.6
Rock Ptarmigan	1.9	1.9
Black-bellied Plover	0	0.6
Lesser Golden-Plover	3.2	4.5
Semipalmated Sandpiper	**9.6**	**13.4**
Baird's Sandpiper	0	1.3
Pectoral Sandpiper	**8.3**	**4.5**
Dunlin	**4.5**	**5.1**
Stilt Sandpiper	1.9	3.2
Buff-breasted Sandpiper	**4.5**	**0**
Red-necked Phalarope	0.6	0.6
Red Phalarope	1.9	0.6
Lapland Longspur	**23.0**	**15.4**
Snow Bunting	0	0.6
All Species	62.1	53.8

nests/km^2, whereas Dunlin nest density was only slightly higher in 1989 as compared to 1988.

Distribution of Nests In Relation to Facilities

Nest Locations

The locations of all nests found in both years reveal that the attempt to place the pad so as to avoid bird nesting areas was successful (Fig. 3). Only one 1988 nest site was actually under the site of P-Pad and few 1988 nest sites were directly affected by the pad or road. We have previously shown that nest distribution on the plot was influenced by habitat distribution and individual species habitat preferences (Troy and Carpenter 1989). A large area to the southeast of P–Pad, corresponding to an old drained lake basin, was largely devoid of nests during both years. Locations of nests by species are provided in the Appendix. Distributions of key species are described below.

Semipalmated Sandpiper nests (Fig. A-1) were not evenly distributed through the plot; they were largely absent from the southwest quadrant and the central portion of the plot. Although there were more nests on the plot in 1989, fewer were found close to the pad and along the road than in 1988. Pectoral Sandpipers (Fig. A-2) were concentrated in the northeast quadrant and south-central portions of the plot. No 1988 nest sites were affected by the pad but some birds nested along the road corridor, and one along the pipeline corridor in 1988; areas not used in 1989.

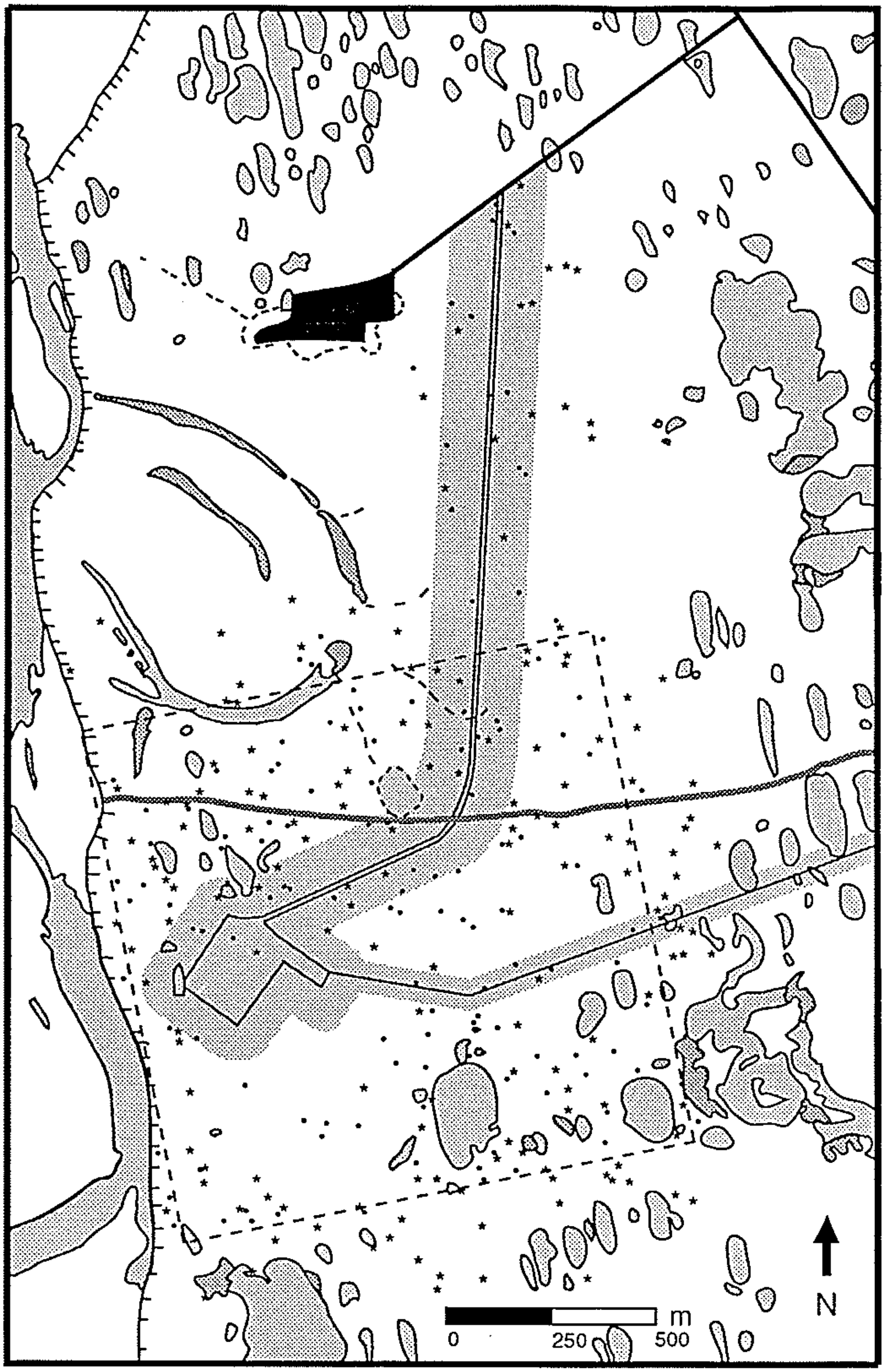


Figure 3. Locations of all nests (• = 1988, * = 1989) found near the P–Pad study area. Shaded areas adjacent to the facilities (≤ 100 m from gravel structures or ≤ 50 m from the pipeline) delimit the area considered close to the facilities for assessment purposes.

Dunlin (Fig. A-3) were sparsely distributed in the plot. None was affected by the pad, but nests were found along the road and pipeline corridors during both years of study. Buff-breasted Sandpiper nests (Fig. A-4) were widely scattered in the plot in 1988 but none was found in 1989. No nests were in close proximity to the future pad or road location and only one was close to the pipeline corridor. Lapland Longspur (Fig. A-5) was the most widely distributed species in the study area, being found in most portions of the plot. The highest concentration of nests was in the northwest portion of the plot. Nests were found close to the facilities during both years.

Distance From Facilities

To assess the response of tundra birds to new facilities, we compiled the distance-from-facility profiles for the key species, and compared the distributions in 1988 and 1989 (Fig. 4). Buff-breasted Sandpipers are not included in this analysis because none nested in the area in 1989. Fewer nests of all four species were found near (<100 m) the facilities in 1989 than in 1988. This trend extended to all distance increments for Pectoral Sandpiper and Lapland Longspur, consistent with overall lower densities of these species in 1989. The number of nests of Semipalmated Sandpipers and Dunlin at distances greater than 100 m from the facilities in 1989 usually exceeded the numbers found in 1988.

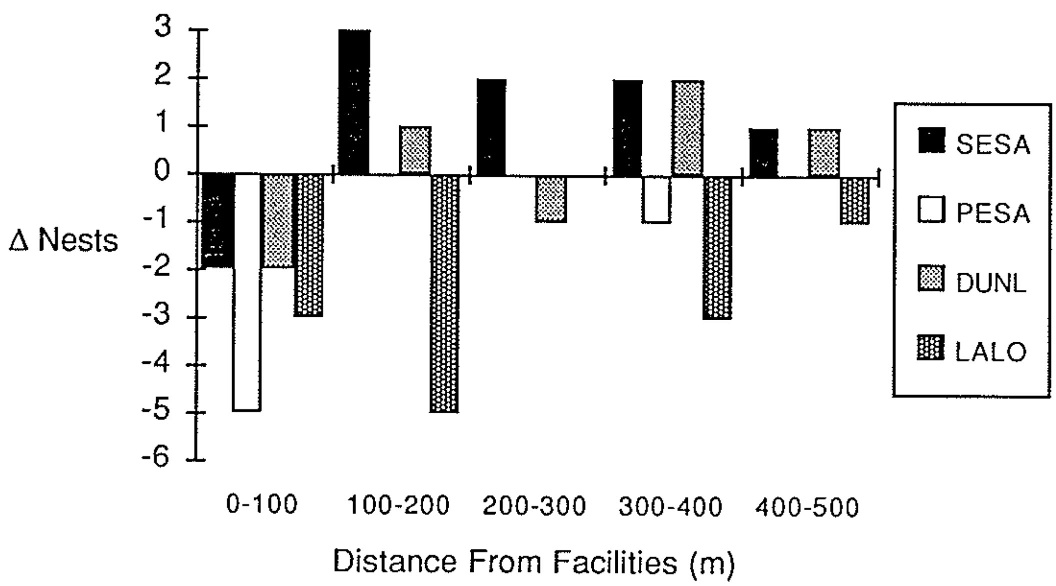


Figure 4. Change between 1988 and 1989 nest abundances in successive distance increments from facilities. Species codes are Semipalmated Sandpiper (SESA), Dunlin (DUNL), Pectoral Sandpiper (PESA), and Lapland Longspur (LALO).

Banding Studies

Banding of Nesting Birds on the P–Pad Plot

Attempts to band the breeding shorebirds and longspurs on the study plot were quite successful (Table 2). Most (80-90 percent) key shorebirds nesting on the plot were banded, as well as many of those nesting adjacent to it. In the case of Lapland Longspurs, we were able to mark most (≈70 percent) of the females but were less successful (≈20 percent) in trapping males as they do not incubate. The primary opportunity to trap males arises when they are feeding young just prior to fledging. Low nest success reduced the opportunities for capturing and banding male longspurs.

Table 2. Numbers of nesting birds banded on the P–Pad study plot.

SPECIES	1988 On Plot	1988 Band	1988 Marking Success	1989 On Plot	1989 Return	1989 Band	1989 Marking Success
Semipalmated Sandpiper	30	27	0.90	44	15	24	0.89
Dunlin	14	12	0.86	14	6	6	0.86
Pectoral Sandpiper	13	12	0.92	07	00	05	0.71
Buff-breasted Sandpiper	07	06	0.86	00	00	00	
Lapland Longspur	78	37	0.47	62	9	19	0.45

Changes in Nest Sites in Relation to Facilities

Relocation Distances

For marked birds with known nest locations before (1988) and after (1989) construction of P–Pad, we determined the distances from the nests to the structures to compare this distance between sites occupied each year. The difference between these values gives the net movement, or component of relocation, in relation to the new oil field structures (Table 3). Specifically, did birds located close (≤ 100 m) to the P–Pad site in 1988 (structures as yet not built) relocate farther to 1989 nest sites than birds that were more distant? For the two shorebirds, Semipalmated Sandpiper and Dunlin, individuals close to the facilities did relocate farther between years than did those more distant. This is what would have been predicted given that birds directly affected by the development had to change nest sites, whereas unaffected birds could either move, or remain at their former sites. The lone returning longspur that had nested close to the future facility locations in 1988 moved somewhat less than the average of the more distant longspurs.

Table 3. Comparison of distances (m) between 1988 and 1989 nest sites of birds whose 1988 nests were close to (≤ 100 m) versus distant from the site of P-Pad, its road, or pipeline.

	Mean Relocation Distance		Δ Displacement From Facilities	
1988 Proximity to Facilities	close (n)	distant (n)	close	distant
Semipalmated Sandpiper	263 (4)	126 (14)	158	-26
Dunlin	460 (3)	124 (3)	113	48
Lapland Longspur	215 (1)	233 (11)	85	76

A large component of relocations between years was independent of the facilities. The net displacement (Δ) from facilities (Table 3) gives a measure of the relative importance of facility presence as it influences bird relocations. The average net displacement of birds away from facilities is expected to be zero. Table 3 shows that actual values range from -26 to 76 m, depending on the species. This range tells us two things. Since the estimates bracket zero, with larger samples they probably would approach it. However, there is considerable variability in the distances between nest sites and a single large relocation can have a large effect on the mean values. Consequently these values should not be interpreted too literally. Large differences in net displacements of close and distant birds are probably of importance.

Returning Semipalmated Sandpipers and Dunlin that had been close to the facility site in 1988, exhibited substantial net displacements away from the facilities (110-160 m), considerably more so than birds that had been distant. Approximately half of the movements of close Semipalmated Sandpipers and Lapland Longspurs were directed away from facilities, but only one quarter of Dunlin movements was so directed. In fact, Semipalmated Sandpipers originally distant from the facilities had a slight net movement towards the new structures. The net movement of Lapland Longspurs with respect to facilities was similar for birds originally close and distant, approximately 80 m away from the structures. For longspurs these data probably should not be interpreted as indicating a directional displacement in response to the facilities.

Male Semipalmated Sandpipers tended to be more site-tenacious than females, both close to the facilities and away from them (mean distances of 84 m for males compared to 248 m for females) (Fig. 5). The longest movement was for a female who in 1988 nested near the southern periphery of the plot but relocated near the facilities in 1989. Both members of four pairs banded in 1988 returned to nest in 1989. Two of these, all distant from facilities, remained mated and nested at or near their 1988 sites. The remaining two pairs divorced (one member of each pair formed a new pair). One of these affected pairs was probably displaced due to the presence of the P–Pad road.

The movement data for Dunlin nests suggest they moved away from the new structures. However, most of the increased distance was due to an 800 m move by one female Dunlin whose old nest site was essentially covered by the road (Fig. 6). The distance relocated exaggerates the actual displacement because much of the relocation, especially in the 800 m example, was parallel to the facilities, not necessarily away from them. Still, the net displacement of all returning Dunlin was away from facilities; approximately 110 m in the case of birds originally close to facilities. Only one pair banded in 1988 was known to have both members return in 1989; these birds remained mated.

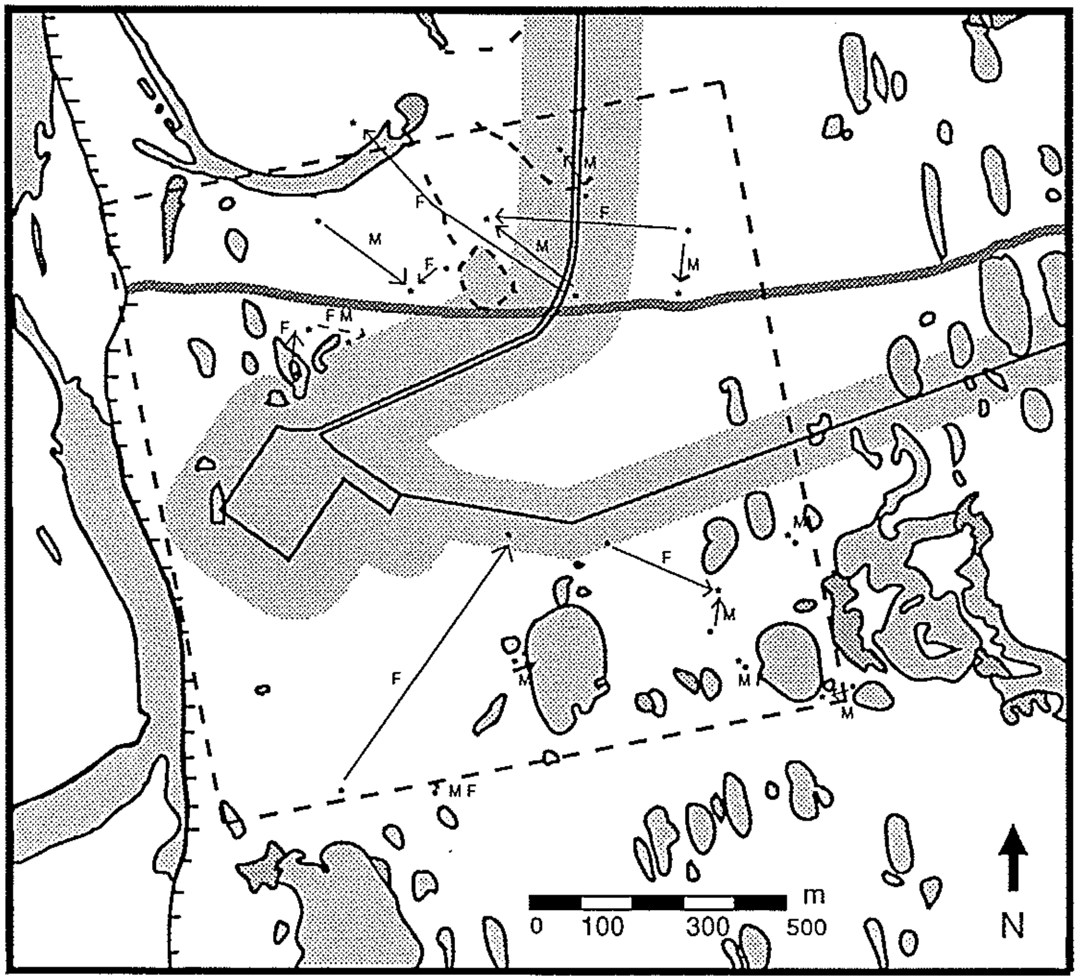


Figure 5. Relocations of color-marked Semipalmated Sandpipers between 1988 and 1989 nest sites. Dashed lines indicate within-year renesting; • show 1988 nest locations, * show 1989 nest locations.

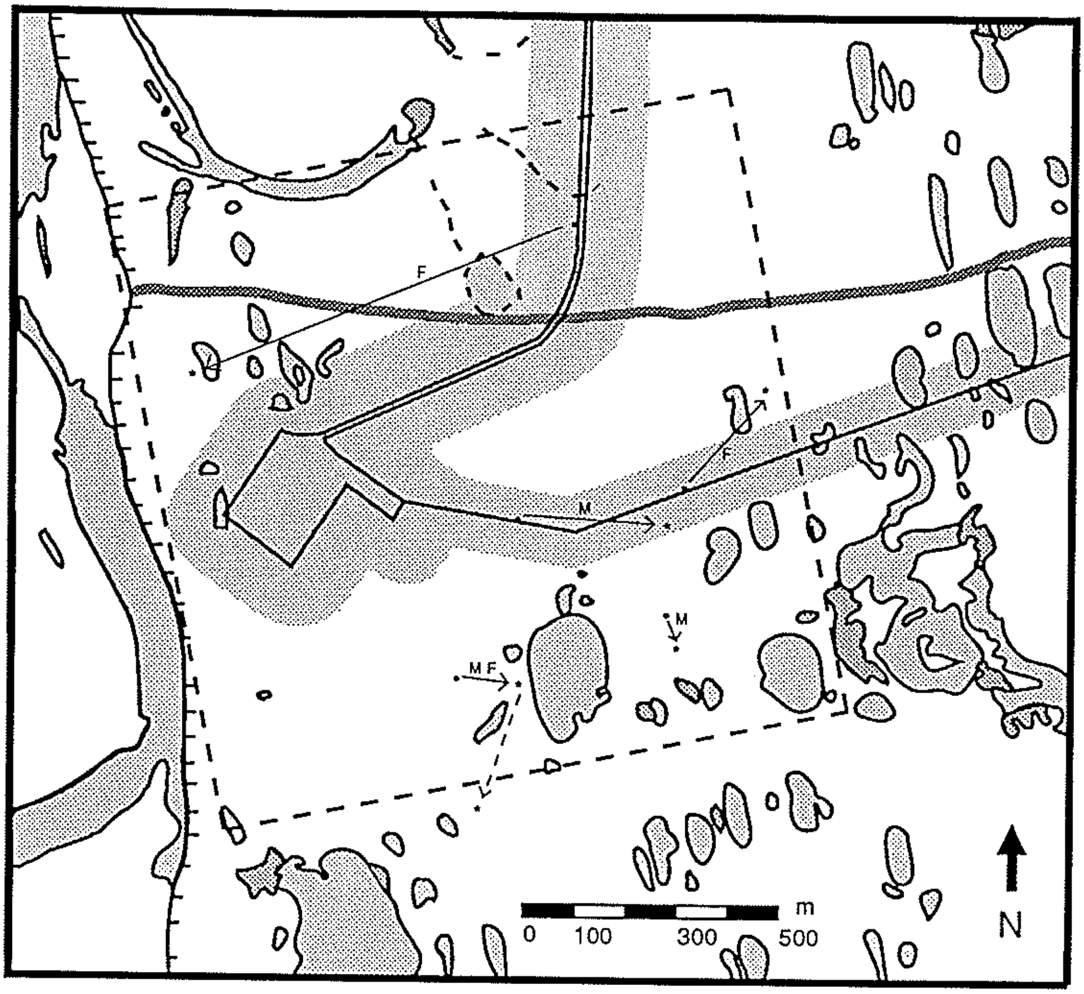


Figure 6. Relocations of color-marked Dunlins between 1988 and 1989 nest sites. Dashed lines indicate within-year renesting; • show 1988 nest locations, * show 1989 nest locations.

The longspur relocation data set (Fig. 7) has several interesting features. Only one bird marked in 1988 within the zone close to the future facilities returned, and this bird relocated slightly away from the facilities. The longest movement was of a bird remote from the development, at the southern edge of the plot, that relocated most of the width of the plot. In the case of both birds described above (both were females), there was a longspur nest in 1989 close to the 1988 site of each moved bird, one even using the old nest cup. Perhaps, the same male longspurs were at these sites in both years, but we are unable to verify this. In both cases, the site was still suitable for longspur nests but, perhaps due to failure in 1988, both females selected new nesting areas in 1989. Longspurs had a high degree of nest failure in both years and much of the data represents the distance these birds move between successive nest attempts within a year.

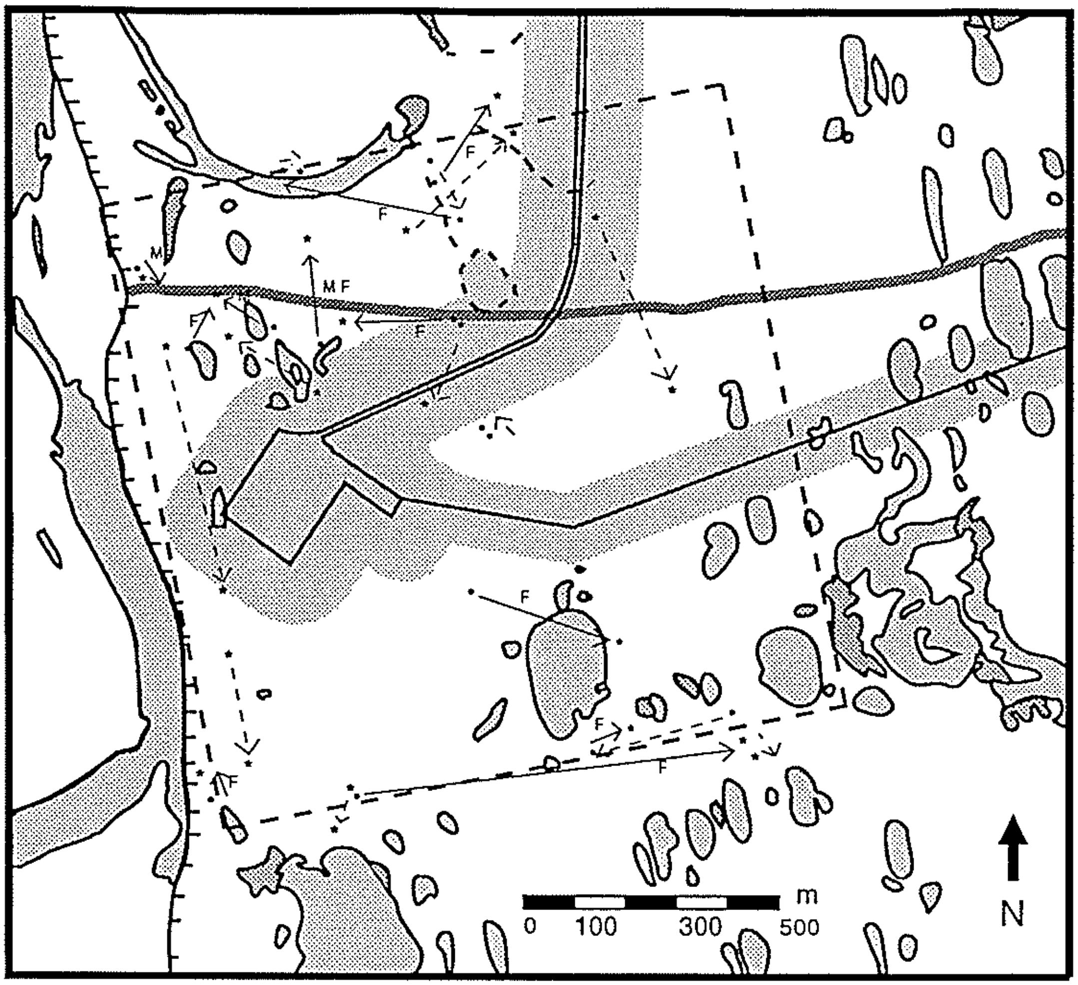


Figure 7. Relocations of color-marked Lapland Longspurs between 1988 and 1989 nest sites. Dashed lines indicate within-year renesting; • show 1988 nest locations, * show 1989 nest locations.

Renests were often 200 meters or more from prior attempts, indicating little confinement due to territoriality (Fig. 7).

Return Rates of Birds Banded in 1988

Approximately 50 percent of the site-tenacious shorebirds—Semipalmated Sandpiper and Dunlin—banded in 1988 were present and nesting on or adjacent to the plot in 1989 (Table 4). Pectoral and Buff-breasted sandpipers were not expected to be site-tenacious and no returns were recorded for either of these species. Return rates of longspurs (30 percent) were approximately half that of the site-tenacious shorebirds (≥ 50 percent).

The return rates in Table 4 include only the banded birds that had known nest sites. In addition to these, two female Semipalmated Sandpipers, two male

Table 4. Summary of return rates, 1988 to 1989, of species banded on the P-Pad plot. Returned birds include only those actually found nesting in 1989.

Species	Banded 1988	Returned 1989	Return Rate
Semipalmated Sandpiper	28	16	0.57
Pectoral Sandpiper	12	0	0.00
Dunlin	12	6	0.50
Buff-breasted Sandpiper	6	0	0.00
Lapland Longspur	37	11	0.30

Lapland Longspurs, and one female Dunlin were seen in the study area, but were not associated with known nests.

The strongest evidence for a negative impact on populations caused by development would be a reduced return rate for birds directly affected (displaced) by the new facilities. This possibility is evaluated for the three site-tenacious species—Semipalmated Sandpiper, Dunlin, and Lapland Longspur. Birds banded outside the bounds of our plot (around the periphery or along the road) are excluded from the following analyses because the average distance between 1988 and 1989 nest sites frequently exceeded 200 m. The excluded birds had a reduced probability that they would have been found even if they had returned.

Return rates of Semipalmated Sandpiper and Dunlin close to the facilities were the same as those more distant (Fig. 8). The biggest difference in return rate based on proximity to facilities was for Lapland Longspur; birds close to the facilities returned at a rate two-thirds that of those farther away. This difference was not statistically significant ($z = -1.154$, $p > 0.05$).

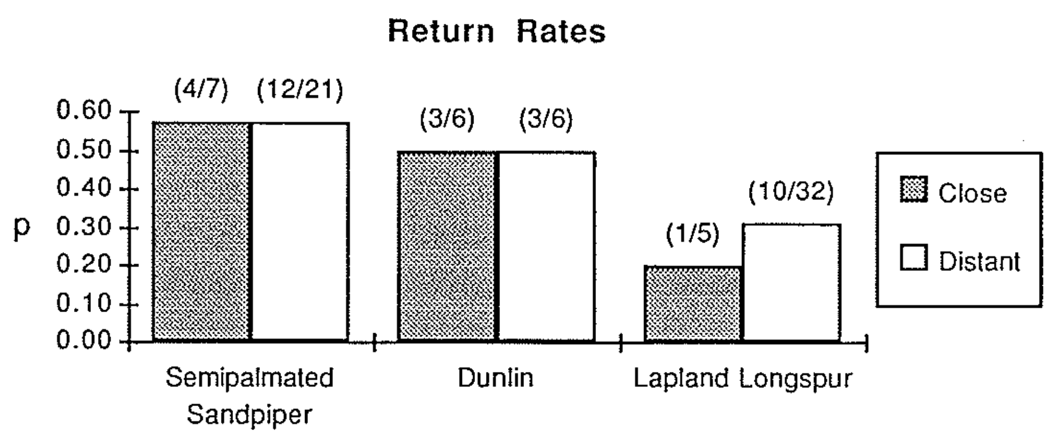


Figure 8. Return rates at the P-Pad study area. Numbers in ( ) represent sample sizes of birds returned/birds banded.

Four 1988 nest sites were directly covered by gravel placement or water impoundment. These four were one each of Lesser Golden-Plover (this nest failed in 1988 and the birds renested at a location distant from the future facility location), Stilt Sandpiper, Semipalmated Sandpiper, and Red Phalarope. Eight others—3 Pectoral Sandpipers, 2 Semipalmated Sandpipers, 2 Dunlin, and 1 Lapland Longspur—were disrupted by vegetation damage immediately adjacent to the new structures. There were 14 more nests from 1988 that fell within the zone considered as close to facilities—2 Greater White-fronted Geese, 1 Lesser Golden-Plover, 1 Semipalmated Sandpiper, 2 Dunlin, 1 Pectoral Sandpiper, 1 Buff-breasted Sandpiper, and 6 Lapland Longspur.

The fates of marked individuals of key species from affected nests are of particular interest and are summarized in Table 5. Only one nest was directly covered by gravel or water. The lone bird marked at this nest, a Semipalmated Sandpiper, was not found nesting the following year. Most of the birds from the disrupted area returned. In the covered or disrupted areas, 62 percent (5 of 8 birds) were found nesting in 1989 (Table 5). Birds nesting close to the gravel structures but outside the areas of direct effects had a lower return rate, approximately 30 percent (3 of 10). A reason for birds (the major difference appears to be Dunlin) close to facilities having lower return rates than those directly affected, is counter-intuitive and may be an artifact of small sample sizes.

Hatching Success

Overall nest success declined at both the P-Pad and in the Pt. McIntyre Reference Area in 1989 as compared to 1988 (Table 6). Pectoral Sandpipers did the poorest; no eggs hatched in the P–Pad study area in 1989. The low success probably resulted from increased predation by Arctic foxes on bird nests. In comparison to the PMRA, nest success at P–Pad was about 10 percent lower in both 1988 and 1989, perhaps because fox predation increased as a result of banding activities.

Table 5. Returns of birds at the most affected nests. Only site-tenacious species banded on the plot are summarized. Only one site-tenacious bird (a Semipalmated Sandpiper) was color-banded at the nest site actually covered, so this category has been pooled with the disrupted class.

	Covered or Disrupted		Close to Facilities	
	Marked	Returned	Marked	Returned
Semipalmated Sandpiper	5	3	2	1
Dunlin	2	2	4	1
Lapland Longspur	1	0	4	1

Table 6. Nest success rates at P-Pad and the Pt. McIntyre Reference Area (PMRA). Blanks indicate that no nests of that species were found. Success rates were calculated from all nests located and monitored, both off and on the study plots.

	1988		1989	
	PMRA	P-Pad	PMRA	P-Pad
Semipalmated Sandpiper	0.89	0.80	0.43	0.53
Pectoral Sandpiper	0.78	0.47	0.50	0.00
Dunlin	0.70	0.63	0.43	0.29
Buff-breasted Sandpiper		0.43		
Lapland Longspur	0.63	0.38	0.31	0.47
All Species	**0.63**	**0.54**	**0.44**	**0.36**

One of the alternative fates of displaced birds was that they would resettle but that nest success would be reduced because the areas newly occupied would be of inferior habitat. Nest success of the affected birds—3 Dunlin, 4 Semipalmated Sandpipers, 1 Lapland Longspur—present in both years of study was 71 percent (5 of 7 nests) in 1988 and 50 percent (4 of 8 nests) in 1989. (The number of nests increased in 1989 because two Semipalmated Sandpipers were paired in 1988 but divorced and had separate nests in 1989.) Thus, the nest success of displaced birds decreased in 1989; however, these birds had higher nest success than was found for the overall study area. If consideration is limited to those birds whose 1988 nest sites were physically disrupted (2 Dunlin and 3 Semipalmated Sandpipers), nest success increased from 50 percent (2 of 4 nests) in 1988 to 60 percent (3 of 5 nests) in 1989.

DISCUSSION

Nest Densities and Distribution

Between-Year Changes in Density

Based on trends at the Pt. McIntyre Reference Area, we expected lower nest densities of Pectoral Sandpipers and Lapland Longspur at P–Pad in 1989 than in 1988 (Troy and Wickliffe 1990). These trends were confirmed at P–Pad. Other changes, although not detected in a statistically significant way at Pt. McIntyre, occurred in a parallel fashion in the two study areas. For example, Buff-breasted Sandpiper disappeared as a nesting bird at P–Pad in 1989. Although none was found nesting on Pt. McIntyre plots in 1988 or 1989, Buff-breasted Sandpiper breeding-season density (birds/km^2) was significantly lower in 1989. In contrast, parallel increases in Semipalmated Sandpiper and Dunlin nest densities occurred in both areas from 1988 to 1989.

Four species—Oldsquaw, Black-bellied Plover, Baird's Sandpiper, and Snow Bunting—first nested on the P–Pad plot in 1989. No particular importance can be attributed to finding a single Oldsquaw nest in 1989 compared to none in 1988. One Black-bellied Plover nest was present along the road alignment in 1988, but five nests were found in the area in 1989; only one within the plot boundaries.

The occurrence of Baird's Sandpipers and Snow Buntings was probably related to the presence of the facilities. These species nested directly on (Snow Bunting) or adjacent to (Baird's Sandpiper) the facilities. Snow Buntings nest in cavities among debris, pipes, or other anthropogenic materials, especially along the coastal plain where natural cavities are rare. Colonization of altered habitats by Snow Buntings was demonstrated in the PBU Waterflood Monitoring Study where their nesting coincided with installation of the West Road pipeline (e.g., Troy 1986). Documentation of increased use of disturbed habitat by Baird's Sandpipers is not as rigorous as is the case for Snow Buntings. This study may be the first that describes changes in Baird's Sandpiper (Fig. 9) use of an area as a result of development. Circumstantial evidence has been available, such as results from the PBU Waterflood studies, where nests were found in disturbed areas along roads or adjacent to pads. At P–Pad, the three nests were in abraded tundra with scattered gravel, adjacent to facilities (two

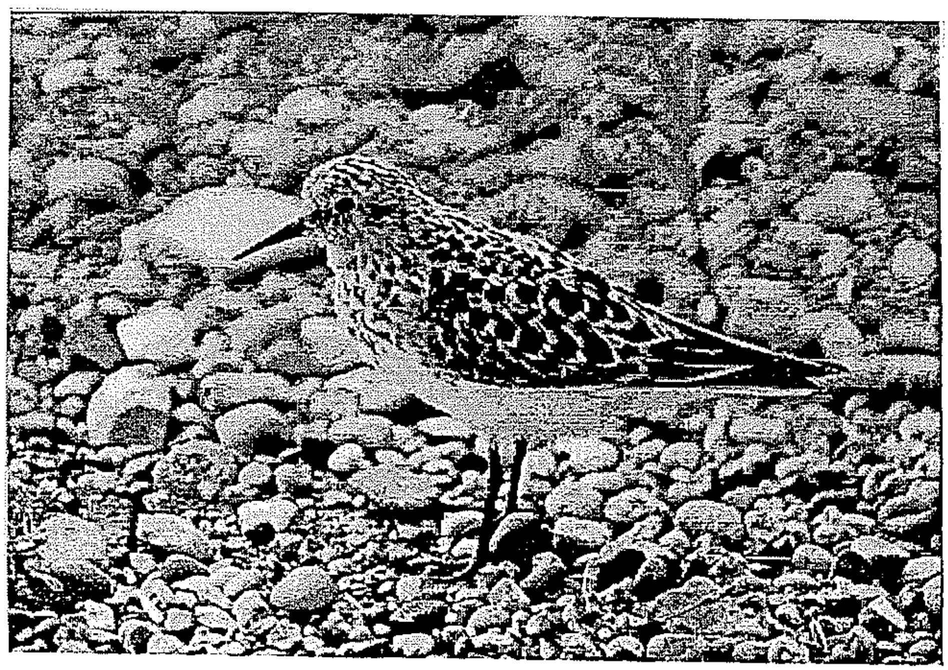


Figure 9. Baird's Sandpiper distribution coincided with disturbed tundra. This individual was photographed along the peat road east of the P–Pad study plot. From a photograph by J.K. Wickliffe.

along the road, one near the pad). No Baird's Sandpipers were found in these areas prior to the disturbance (Fig. A-3).

Distribution of Nests in Relation to Facilities

Nest abundance of all five key species decreased within 100 m of the facilities. The site-tenacious species were all present near facilities but in reduced numbers. For both species lacking site tenacity—Pectoral and Buff-breasted sandpipers—no 1989 nests were found in this zone. The lack of Buff-breasted Sandpiper nests near facilities is trivial because this species was absent as a breeding species in 1989 and thus could not be evaluated for a response to facilities. The number of Semipalmated Sandpiper nests increased in all zones greater than 100 m away from facilities in 1989. This pattern is most consistent with an avoidance of facilities. Dunlin also appeared to avoid the facilities as their overall density in the study area increased in 1989 but there were fewer nests near the facilities, and correspondingly, more away from them. In 1989 there were no Pectoral Sandpiper nests within 100 m of facilities, whereas about one-third of nests were found within this zone in 1988. Reduced use of areas close to facilities by Pectoral Sandpipers was not expected, since this species has not been identified as being sensitive to oil field facilities in prior studies (Meehan 1986, Troy 1988). However, the trends noted here are complicated by a natural decrease of Pectoral Sandpiper densities; decreased numbers of nests were found in most distance increments. Similarly, Lapland Longspur nest abundance was low in most distance increments. This species also had an area wide decline in density (Troy and Wickliffe 1990).

Banding Studies

Changes of Nest Sites in Relation to Development

Many of the marked birds at P–Pad changed their nest sites considerable distances between years; somewhat more than expected. Two factors were found to influence the degree of relocation. Qualitative evidence indicates that sex of the bird influences relocation distances. In general, females were likely to move greater distances than were males. Gratto et al. (1985) also found that female Semipalmated Sandpipers moved more between years than did males. They found males moved, on average, about 40 m each year regardless of whether or not they retained their former mates. Females, in contrast, were much more variable in their movements. Those that changed mates between years moved over four times as far (average 174 m). Second, and of greater interest for impact assessment, was proximity to development. In most cases, those individuals classified as being potentially affected by the facilities relocated greater distances than unaffected birds. The distance from facility locations of these birds increased from 1988 to 1989, more so than for birds originally more distant from facilities. This indicates that the increased distance between nest sites was, in part, an avoidance of the new facilities.

Return Rates of Marked Birds

We verified our expectation that Semipalmated Sandpipers, Dunlin, and Lapland Longspurs are site-tenacious. However, on a local scale these birds exhibited a considerable amount of mobility; distances between successive nests averaging more than 100 m (> 200 m in the case of longspurs). Some changes in nest sites were more than 500 m, even between nest sites within a year.

Lapland Longspur return rates were lower than for the site-tenacious shorebirds. This suggests lower annual survival rates of longspurs than the shorebirds. Future years of marking and measuring return rates will assess if this low return rate is typical or indicative of unusually high mortality during the winter of 1988-89. Even with the low return rate, the absolute number of returning longspurs was exceeded only by Semipalmated Sandpiper. Pectoral and Buff-breasted sandpipers, as expected, were not site-tenacious.

Some comparative data on return rates are available from other studies. The most comprehensive results for Semipalmated Sandpipers are from a five year study at Churchill, Manitoba (Gratto et al. 1985). Return rates varied among years, in the range of 35-56 percent and averaged 46 percent. Our return rate of 57 percent slightly exceeded their results. A study similar to ours conducted concurrently in the Kuparuk oil field had 63 percent of marked Semipalmated Sandpipers return to nest in 1989 (27 of 43, Moitoret pers. comm.). This was slightly greater than our return rate; however, the difference is not statistically significant ($z = -0.53$, $p = 0.596$).

The Kuparuk study also provides return rates for Dunlin during the same years as our study. Moitoret reported (pers. comm.) that 43 percent of Dunlin banded in 1988 nested in 1989 (3 of 7); slightly less than the 50 percent at P-Pad (6 of 12, $z = 0.295$, $p > 0.5$). Perhaps the most intensive study of Dunlins involves a Finnish population (Soikkeli 1967). Again, considerable among-year variability in returns of marked birds were noted, but Soikkeli reported return rates of 62-73 percent. Soikkeli (1967) also briefly studied shorebirds at Barrow and had returns of 50-70 percent of the Dunlin he marked there. These values exceed the return rates at P-Pad and the Kuparuk study. The slightly lower return rates in Kuparuk and P-Pad, compared to these other studies, could be due to several factors. Alternative hypotheses include the following:

- Return rates are actually the same but the small samples exaggerate the differences in the proportions. A single additional returning bird increases the return rate to 50-60 percent at P-Pad and Kuparuk, closer to the estimates at Barrow.

- Mortality during 1988-89 was higher than the years of the other studies.

- Dunlin at Prudhoe Bay are at the edge of their distribution (they are rare east of the Sagavanirktok River). Survival, and thus return rate, of birds at the periphery may be lower than in other portions of their distribution.

As the studies continue we will be able to evaluate the generality of these early estimates of return rates.

Our return rates provide minimum estimates of survival rates since birds could be alive but not found nesting. However, comparing our return rates with other estimates of survival rates (or mortality rates = 1 – survival rate) reveals a reasonable correspondence. For example, Boyd (1962) estimated mortality rates for several European shorebirds based on recoveries of banded birds. His methods differed considerably from ours, but his results are remarkably similar to our return rates. The estimated mortality for most adult shorebirds was in the range of 30-45 percent (e.g., Dunlin were 37.7 percent). Thus, survival should be on the order of 55-70 percent, similar to our return rates.

Hatching Success

One of the alternative fates of displaced birds was that they would be forced into inferior habitats. According to this hypothesis the number of birds or nests would not change but the population would be reduced because these birds would experience low productivity. The nest success data we collected does not support this hypothesis. The birds most affected by the P-Pad facilities (1988 sites covered or abraded) actually had higher hatching success after they were displaced than at their 1988 sites. When all potentially affected birds are considered (1988 sites close to facility locations) they experienced a decrease in nest success in 1989 but they did better than the average for the study area.

Overall nest success in 1989 was low with only about a third of the nests hatching.

Oil fields may indirectly affect birds by reducing nest success due to increased predator populations. Arctic foxes are an important predator of shorebird nests throughout the Arctic. Fox population sizes vary widely among years, often following fluctuations in microtine numbers. It has been hypothesized, but not documented, that fox numbers in the oil fields are artificially high due to supplemental food sources that maintain them during periods of reduced prey availability. If this is the case, then tundra birds may not get the natural reprieve between highs in fox abundance that would permit their populations to rebound following years of intense predation.

The effect of oil field development on fox abundance can not be determined by local studies such as at P–Pad. This is because Arctic foxes often travel great distances, not only between areas used during winter and summer, but also within their home range while breeding. Our results do not indicate a local effect attributable to P-Pad construction. The high predation at P–Pad during 1989 occurred without much oil field related activity. Nest success at P-Pad was lower than in the PMRA both before and after development. Therefore, increased predation due to the P–Pad expansion itself cannot be concluded.

Habitat Disturbance and Limitation at the P–Pad Study Site

Changes in Habitat Availability

The extent of habitat alteration due to gravel placement in the P–Pad study plot approximates that found throughout the Prudhoe Bay oil field. Gravel placement for the pad and road covered 5.7 ha (3.7 percent) of the study plot. This amount of fill slightly exceeds 2.3 percent, the average gravel placement in the Prudhoe Bay Unit as a whole (22.7 km^2 fill in 976 km^2, BP Exploration 1989). Thus, the habitat changes experienced by birds at P–Pad, and their responses should be representative of the oil field in general. In addition to area covered by gravel, additional habitat alteration was accrued because of impounded water adjacent to the road and pad, physical disturbance of tundra adjacent to construction sites, and an increase in vehicle and human traffic in the area.

Several lines of evidence indicate the direct effects of P–Pad placement on nesting bird populations have been small. Few nest sites from 1988 were covered by gravel or were in those areas disturbed during construction. This was partially because of attempts to locate the pad so that it avoided habitats expected to support high densities of birds. Ironically, one of the major concerns was to avoid a drained lake basin which was subsequently found to have low nesting use relative to other portions of the P-Pad study area. The densities of some key species—Semipalmated Sandpiper and Dunlin—increased on the study plot. This trend was evident throughout the Prudhoe Bay area, not just at P–Pad. This indicates these species were not present at their maximum levels region-wide; therefore, habitat loss would not result in population decreases. Key species that decreased in density at P-Pad, Lapland Longspur, Pectoral and Buff-breasted sandpipers, also decreased in the PMRA; thus, this was not a response to the new facilities. Finally, the observation that several of the most affected birds returned and relocated on the plot demonstrated that individuals displaced by oil field facilities can assimilate into adjacent areas.

Some types of impacts expected based on previous studies were documented to have occurred at P-Pad. There appeared to be a displacement of birds from a zone surrounding the new facilities. This was indicated by reduction in density rather than absolute absence in the area. The extent of this area of reduced use was less than 100 m adjacent to the gravel structures. This was evident both in the comparisons of bird distributions without (1988) and with (1989) actual gravel present, and in the net nest displacement analyses. Disturbance resulting from traffic was minimal during the 1989 breeding season, particularly during nest initiation because little activity besides road compaction was undertaken. Additional changes in the birds' use of the area may occur when activity levels increase during production drilling operations.

There are some potential or presumed impacts that could not be resolved with the existing data. Several species decreased in density, most notably Lapland Longspur and Pectoral and Buff-breasted sandpipers. We have attributed these changes to natural population fluctuations, since similar trends were noted in other areas, especially the Pt. McIntyre Reference Area. However, in the case of Pectoral Sandpipers, none of the birds present in 1989 nested within 100 m of the new facilities. This apparent avoidance was unexpected based on prior studies in the oil field (e.g., Troy 1986). Future investigations, when these species are regionally more numerous, should help to determine whether these changes in density are related to construction of the pad. Although there were no statistical differences of return rates between longspurs close to and distant from the facilities, the absolute difference in return rates was reasonably large. The power of the tests is not great because of the small sample sizes: therefore, the lower return rates may actually be of biological importance. It is unlikely that habitat availability was involved in the low return rate of displaced longspurs. Longspur densities decreased substantially on the P-Pad plot (and elsewhere in the Prudhoe Bay area, Troy and Wickliffe 1990) between 1988 and 1989 such that there must have been more habitat unoccupied in 1989 than in 1988. Therefore the low return rate of displaced birds must have been due to some other factor.

Interruption of natural drainage resulting in temporary and permanent water impoundments during breakup has been a frequent impact of coastal plain construction. Culverts through the P-Pad road were successful in draining impounded meltwater by 12 June 1989, within 5 days of the earliest nest initiation. A small, residual impoundment remained, on the west side of the pad, throughout the breeding season. It covered the 1988 nest sites of one Semipalmated Sandpiper and one Lesser Golden-Plover nest. This plover renested in 1988 near the Peat Road and returned to the second nest site in 1989. Some of the movement away from the facilities may have been due to the greater availability of dry sites more distant from facilities prior to the drainage of the impoundments. Early nesting species such as Dunlin and Lapland Longspur would be the most affected if this were true.

Factors Affecting Shorebird Population Sizes

Our study provides some useful information pertaining to the question of where and how tundra bird populations are regulated. The ability of both displaced birds and an influx of recruits to be assimilated into adjacent areas is inconsistent with limited habitat availability. It could be argued that perhaps densities were low and at higher densities absorption of additional birds would not be possible. However, we have little evidence to support the hypothesis of unusually low population levels because in the Pt. McIntyre Reference Area, nest densities of the key shorebird species were near (Dunlin) or above (Semipalmated Sandpiper) their highest prior densities.

Habitat availability may be important for some species. New habitats were immediately colonized by species previously absent from the area; i.e., Baird's Sandpiper and Snow Bunting. Therefore, habitat availability may be restricting local abundance of some species. The significance of these habitats to Baird's Sandpiper and Snow Bunting populations is unknown and evaluation requires information on site tenacity of these species. The limited information available suggests that Baird's Sandpiper is not site-tenacious (Norton 1973).

The shorebirds provide indirect evidence for population regulation occurring on the breeding grounds. In general, site-tenacious shorebirds increased in density. These were Lesser Golden-Plover, Black-bellied Plover, Semipalmated Sandpiper, Dunlin, and Stilt Sandpiper. These species increased in density despite wintering in very disjunct areas (e.g., Dunlin in Asia, Semipalmated Sandpipers in South America). The only common link for these species is where they nest. Qualitative examination of the nest success summaries indicates that 1987 was a relatively good year for nest success (Troy and Wickliffe 1990). Recruitment of these birds into the breeding population was expected in 1989 because most shorebirds first nest during their second summer. Nest success may be the factor regulating these populations. Nest success, in turn, appears to be determined by levels of Arctic fox predation, the suspected major cause of nest failure for most tundra nesting birds.

Trends in shorebird numbers on the wintering grounds have previously been linked to cycles in fox abundance in breeding areas. In South Africa, shorebird abundance (Sanderling, Curlew Sandpiper, and Ruddy Turnstone) follows an approximate 3 year cycle. Most of the variability in numbers is due to the proportion of first-year birds (i.e., nest success) (Summers et al. 1987, Summers and Underhill 1987). Researchers there have correlated this cycle to fox and lemming abundance on the Taimyr Peninsula in the Soviet Union where many of the shorebirds breed (Summers et al. 1987, Summers and Underhill 1987). Predation in the breeding areas has been implicated in limiting shorebird populations in other areas. A Swedish Dunlin population with low hatching success (23 percent hatching) due to egg-predation was believed not to be self sustaining and headed for local extinction (Jönsson 1985). Page et al. (1983) reported that predation of clutches and broods, mostly by California Gulls, was the major limiting factor for Snowy Plovers in California. They concluded that low nesting density was an antipredator adaptation. In England, the southern limit of the breeding distribution of the Ringed Plover is thought to be determined by predation, which is more intense at southern latitudes (Pienkowski 1984). We do not have a sufficient data base to link definitively fox predation with changes in shorebird populations, but preliminary indications are that it is a reasonable hypothesis. Additional fluctuations in high and low predation years will be required to assess the relationship.

If Arctic fox predation, rather than habitat availability, regulates shorebird population levels, we have a situation similar to the catastrophic weather hypothesis for density independent regulation (Evans and Pienkowski 1984). The major difference being that a biotic factor (foxes) rather than a physical factor (weather) is keeping the shorebird populations depressed relative to the levels sustainable by their available habitats. Note that a dichotomy between species regulated during the winter and those regulated on the breeding grounds would not occur. The occurrence of catastrophic mortality during the non-breeding season may temporarily be more important in depressing population levels relative to reduced breeding output. In the 1988-89 studies, we documented a large decrease in Lapland Longspur density. The cause of this is uncertain; mortality during the severe winter of 1988-89 seems plausible, yet can't be verified. Similarly, catastrophic events could affect any or all of the site-tenacious shorebirds. Droughts in the midwestern United States may result in the loss of the migration staging areas and affect some of the North Slope shorebird populations. A major shorebird staging area, at Cheyenne Bottoms dried up in 1989 due to these droughts (Castro et al. 1990).

CONCLUSIONS

Several changes in the density and distribution of birds on the P–Pad plot were noted subsequent to construction of the oil production facilities. Three of the five key species, Lapland Longspurs, Pectoral and Buff-breasted sandpipers, had substantially lower nest densities in 1989 compared to 1988. Buff-breasted Sandpipers did not nest in the study plot in 1989. Nest densities of the remaining key species, Semipalmated Sandpiper and Dunlin, increased. These changes at P–Pad were paralleled by changes at the Pt. McIntyre Reference Area and did not appear to be related to the construction of new facilities. Colonization of the study area by two species, Snow Bunting and Baird's Sandpiper, was likely in response to habitat modification resulting from construction activities in the area.

The greater distances between yearly nest sites of affected individuals, including a large component directed away from facilities, suggests that there is a degree of facility avoidance by some species. The finding of reduced nesting density in a band adjacent to facilities reinforces this conclusion. All key species show some evidence of this effect, but the evidence is most compelling for Semipalmated Sandpiper and Dunlin.

The expected site-tenacity of Semipalmated Sandpipers, Dunlin, and Lapland Longspurs, was verified, as was the lack of tenacity of Pectoral Sandpipers and Buff-breasted Sandpipers.

The objective of the study was to evaluate the effect of habitat loss on tundra nesting birds. Two nested dichotomies of alternatives were identified. The first alternative is whether or not displaced birds returned to breed; i.e., :

- The loss of tundra habitat and activities associated with construction of P-Pad resulted in displaced birds failing to breed in 1989, or

- The displaced birds were breeding in adjacent areas in 1989.

Habitat was available in the P-Pad area for birds whose nest sites were covered or altered by the new facilities. Some Semipalmated Sandpipers, Dunlin, and Lapland Longspurs displaced by the new construction were found nesting in adjacent areas, generally at a site more distant from the disturbance than in 1988. Return rates of the affected birds were comparable to those of unaffected birds. The overall densities of most site-tenacious shorebirds increased indicating that space was available for increases due to recruitment, in addition to absorbing displaced birds.

Since displaced birds resettled remained on the plot, we needed to evaluate if they resettled in lower quality habitat than they had originally nested in, i.e., to evaluate the following dichotomy:

- Birds displaced from altered habitats resettle in other less suitable areas and consequently have less than normal nesting success, or

- Birds displaced from altered habitats resettle in other suitable areas.

The data available to evaluate this alternative are limited by the small number of individuals directly affected and the overall reduction in nest success in 1989. However, the data do not lead to rejection of the hypothesis that the displaced birds fared equally in their new sites as in their previous locations. The birds whose 1988 nest sites were physically altered by construction of the P–Pad facilities had higher nest success in 1989 than in 1988, even though overall nest success decreased on the study plot.

Availability of nesting habitat suggests that population size is being regulated by factors other than space on the breeding grounds. Many factors both on the breeding and wintering grounds affect shorebird populations. Results of this study, supplemented with a literature review, leads us to hypothesize that the species nesting at Prudhoe Bay occur at levels less than the carrying capacity of the area. Density-independent factors, both on the wintering grounds and breeding grounds, keep shorebird population levels depressed. In particular, predation by Arctic foxes appears to play a major role in limiting the increase in shorebird populations.

In summary, our study shows that the introduction of the P-Pad development affected the local distribution of nesting birds. Most species were precluded from nesting in areas covered by gravel and at least some individuals moved away from areas close (≤ 100 m) to the new facilities. These changes did not translate into changed numbers of birds in the area as the displaced birds were found nesting in nearby areas having returned at rates similar to unaffected birds. There is no indication that displaced birds settled in habitat inferior to that they were displaced from because they did not incur disproportionately lower nest success at their new nest sites. We conclude that habitat availability is not the resource limiting most bird populations at Prudhoe Bay. Nest predation by Arctic foxes, a density-independent agent, is proposed as the factor most likely limiting population levels.

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APPENDIX—NEST DISTRIBUTION MAPS

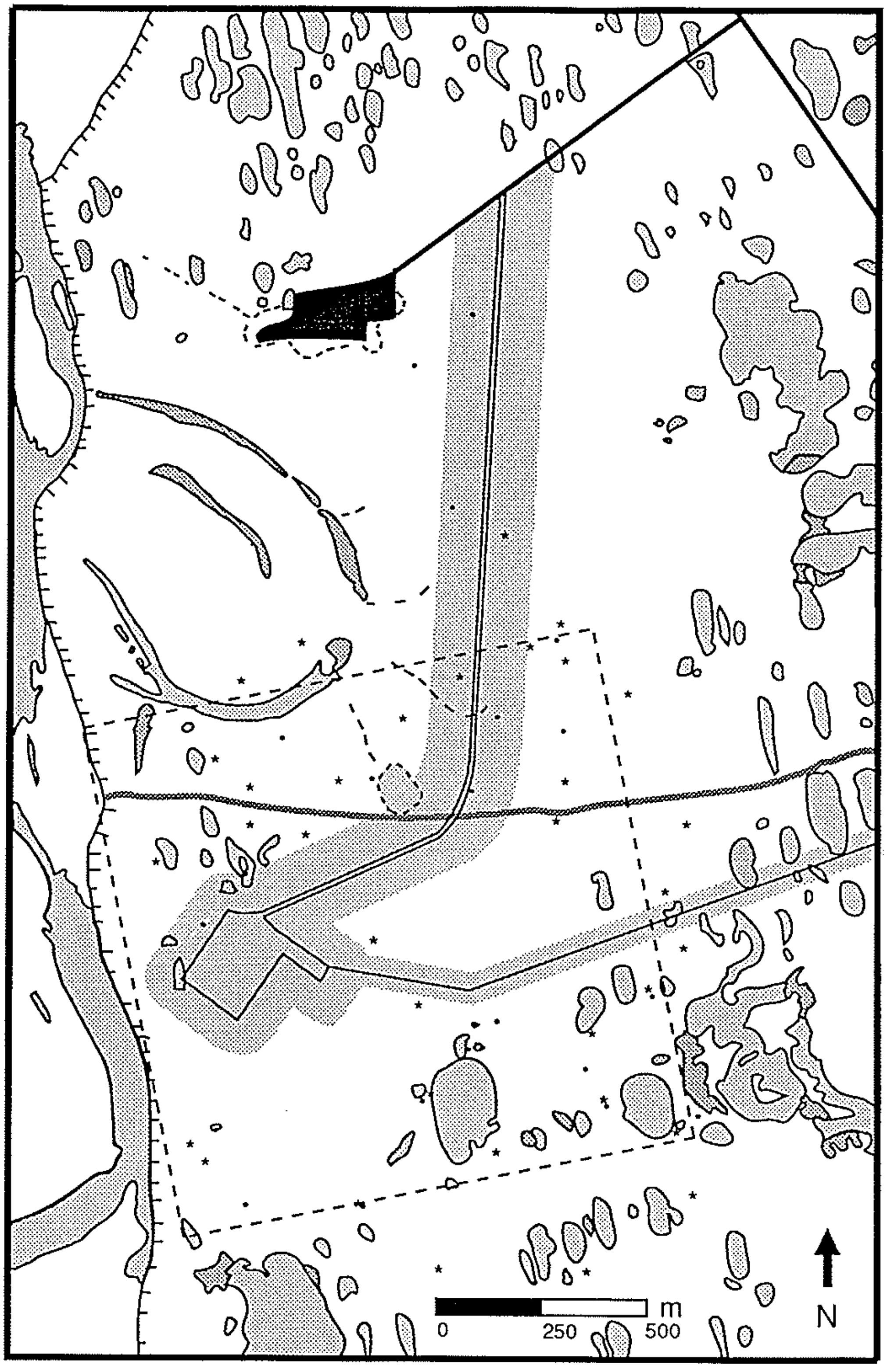

Figure A-1. Locations of Semipalmated Sandpiper nests (• = 1988, * = 1989) found near the P-Pad study area. Shaded areas adjacent to the facilities delimit the area considered close to the facilities for assessment purposes.

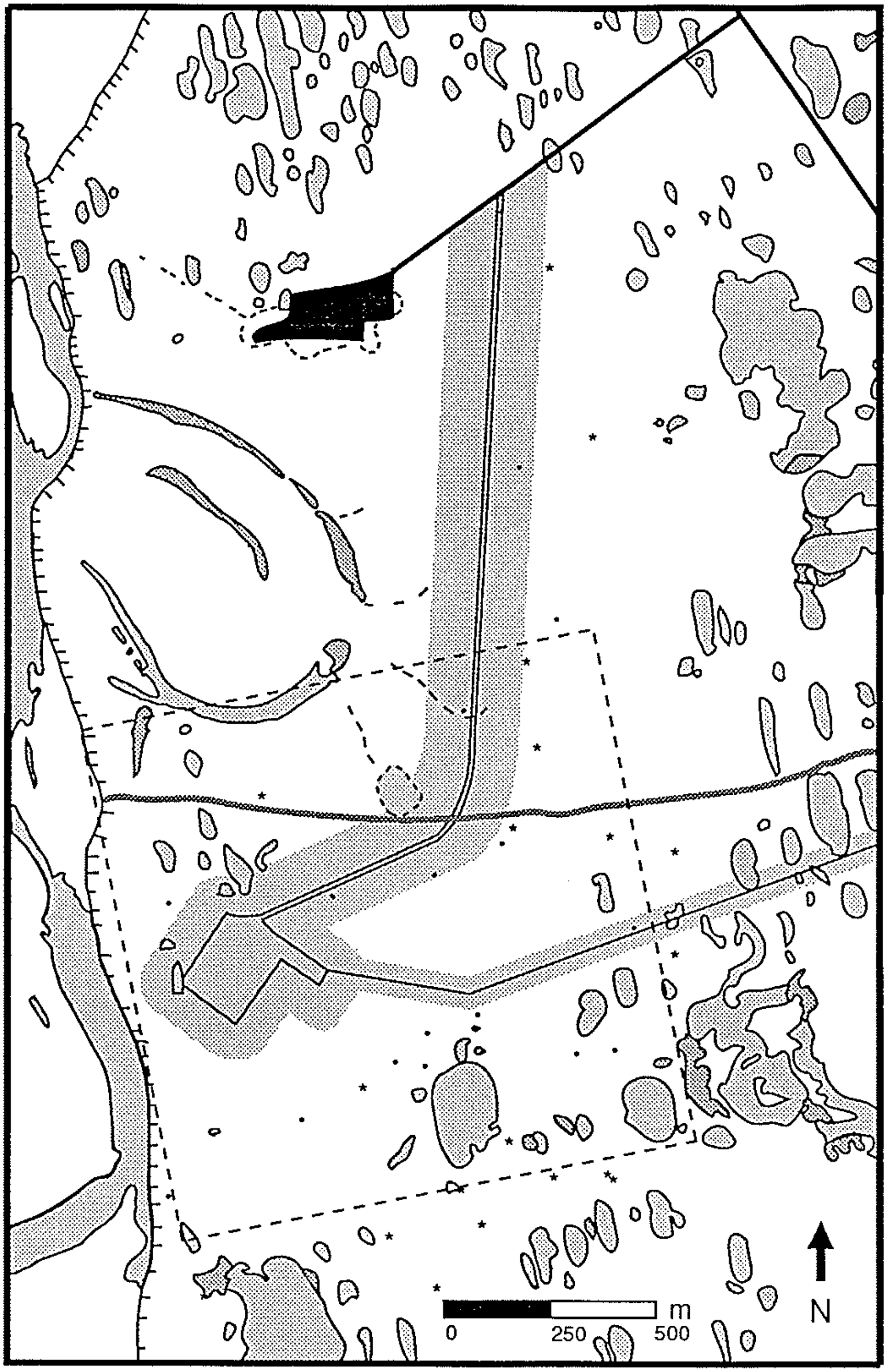

Figure A-2. Locations of Pectoral Sandpiper nests (• = 1988, * = 1989) found near the P–Pad study area. Shaded areas adjacent to the facilities delimit the area considered close to the facilities for assessment purposes.

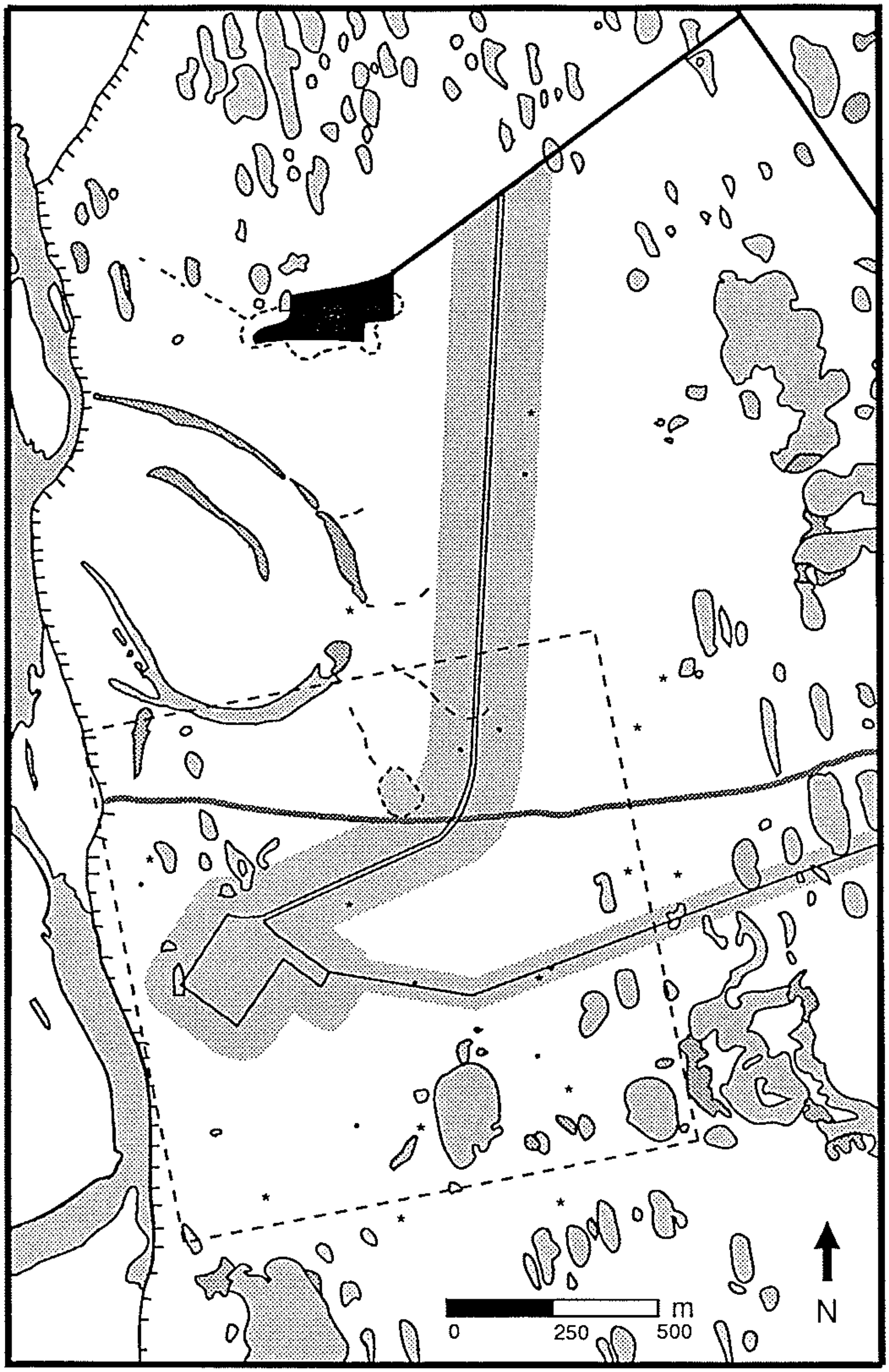

Figure A-3. Locations of Dunlin nests (• = 1988, * = 1989) found near the P–Pad study area. Shaded areas adjacent to the facilities delimit the area considered close to the facilities for assessment purposes.

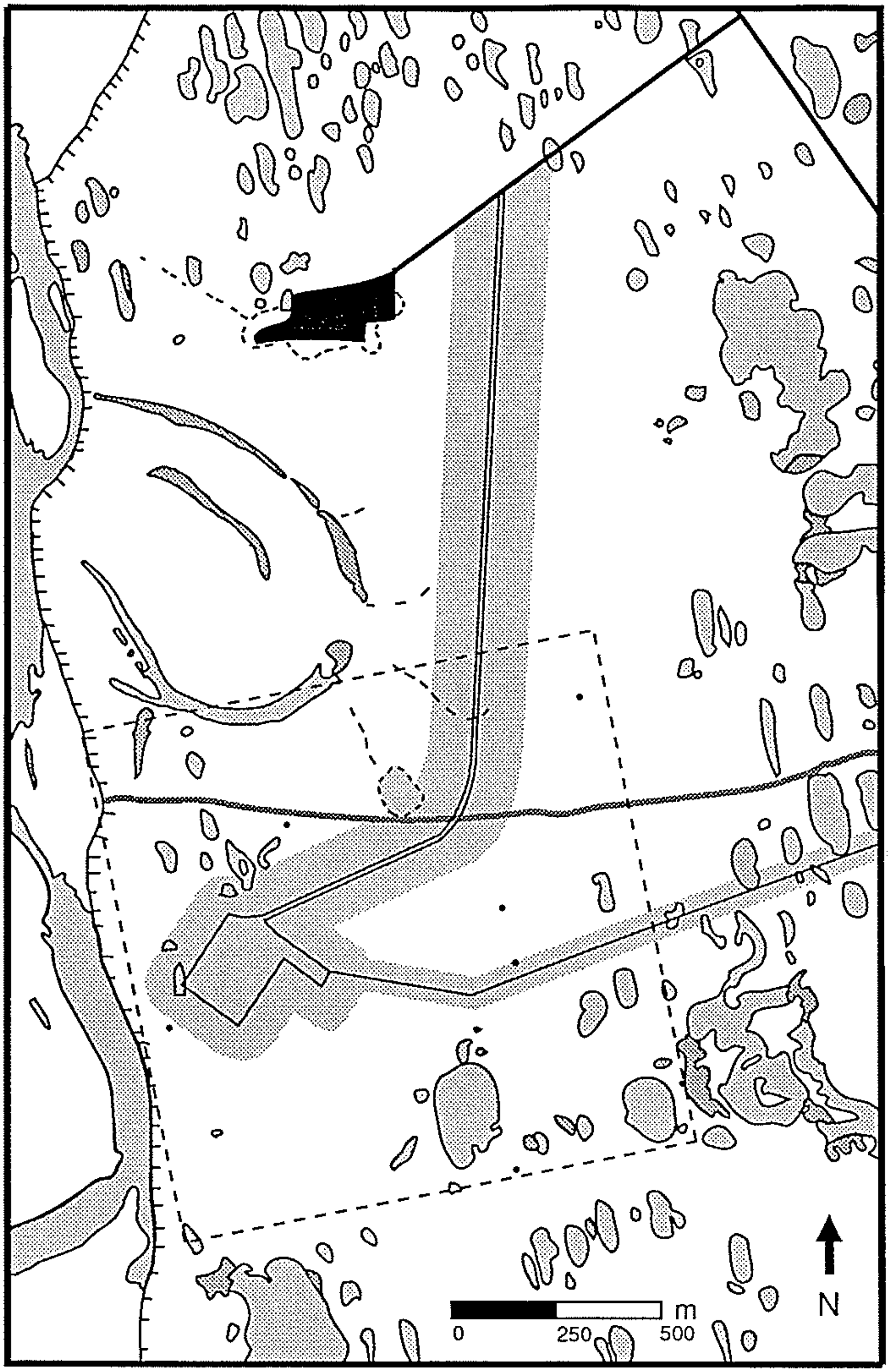

Figure A-4. Locations of Buff-breasted Sandpiper nests found near the P–Pad study area in 1988 (none was found in 1989). Shaded areas adjacent to the facilities delimit the area considered close to the facilities for assessment purposes.

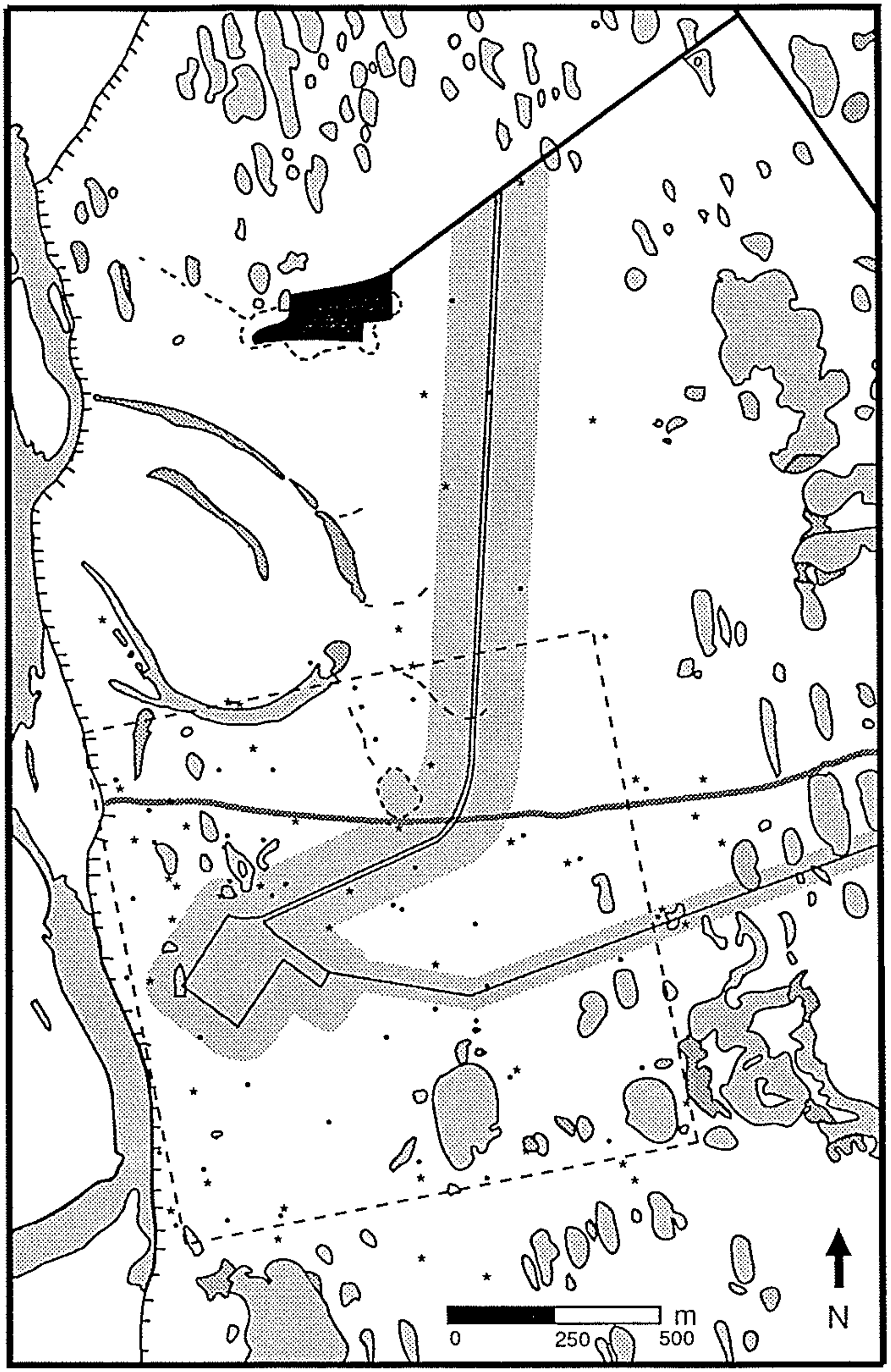

Figure A-5. Locations of Lapland Longspur nests (• = 1988, * = 1989) found near the P–Pad study area. Shaded areas adjacent to the facilities delimit the area considered close to the facilities for assessment purposes.

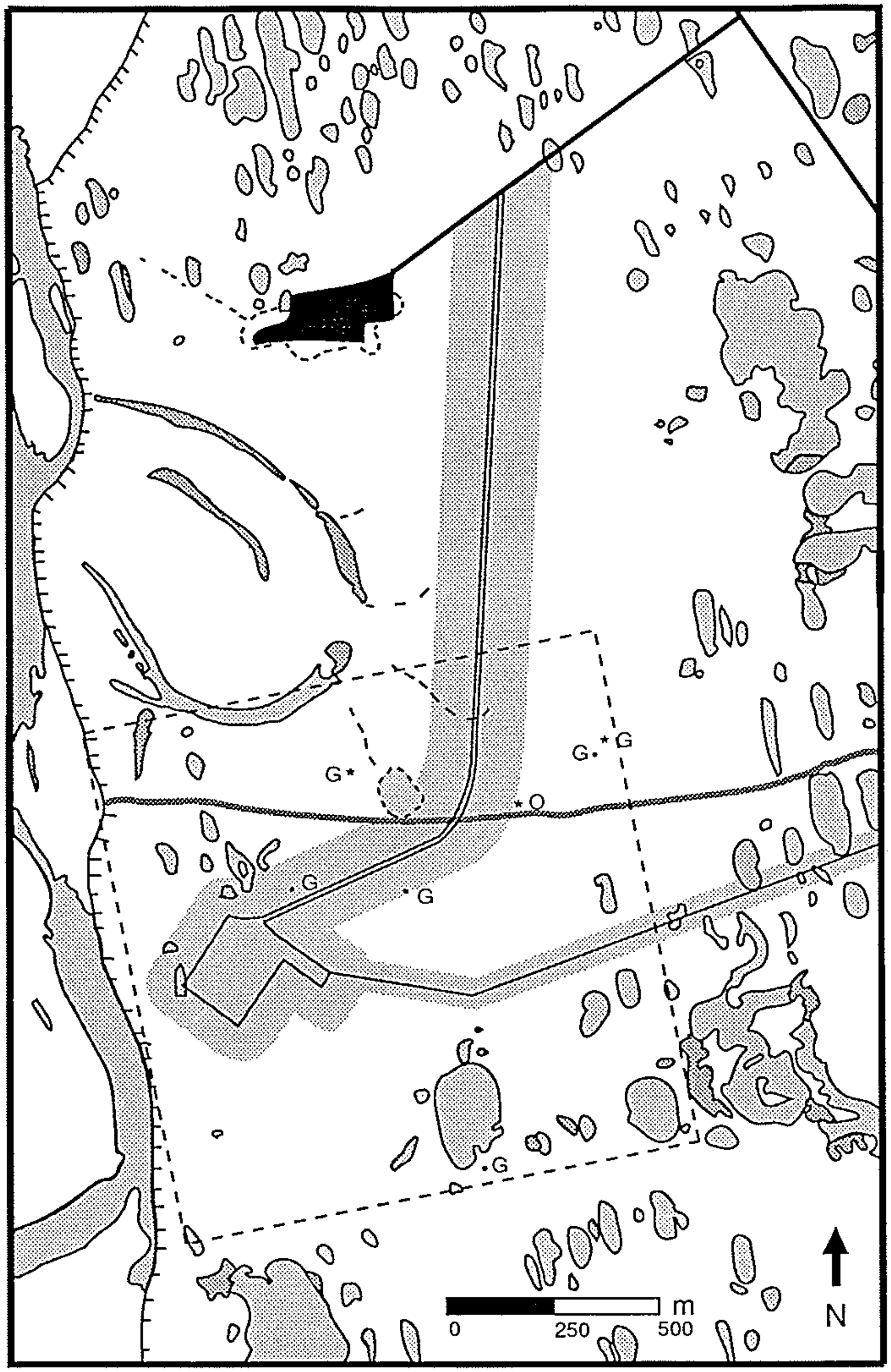

Figure A-6. Locations of Greater White-fronted Goose (G) and Oldsquaw (O) nests (• = 1988, * = 1989) found near the P–Pad study area. Shaded areas adjacent to the facilities delimit the area considered close to the facilities for assessment purposes.

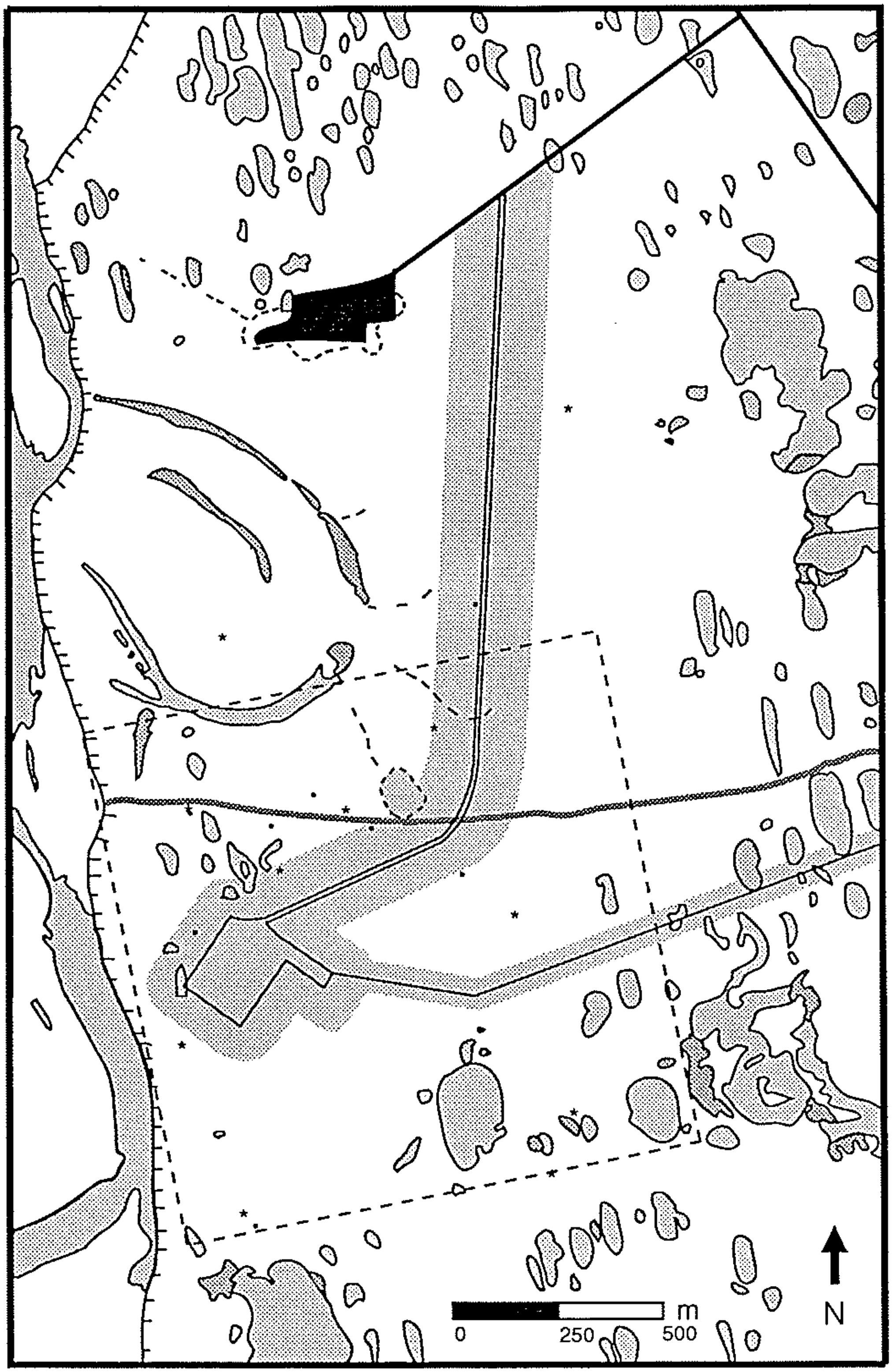

Figure A-7. Locations of Lesser Golden-Plover nests (• = 1988, * = 1989) found near the P-Pad study area. Shaded areas adjacent to the facilities delimit the area considered close to the facilities for assessment purposes.

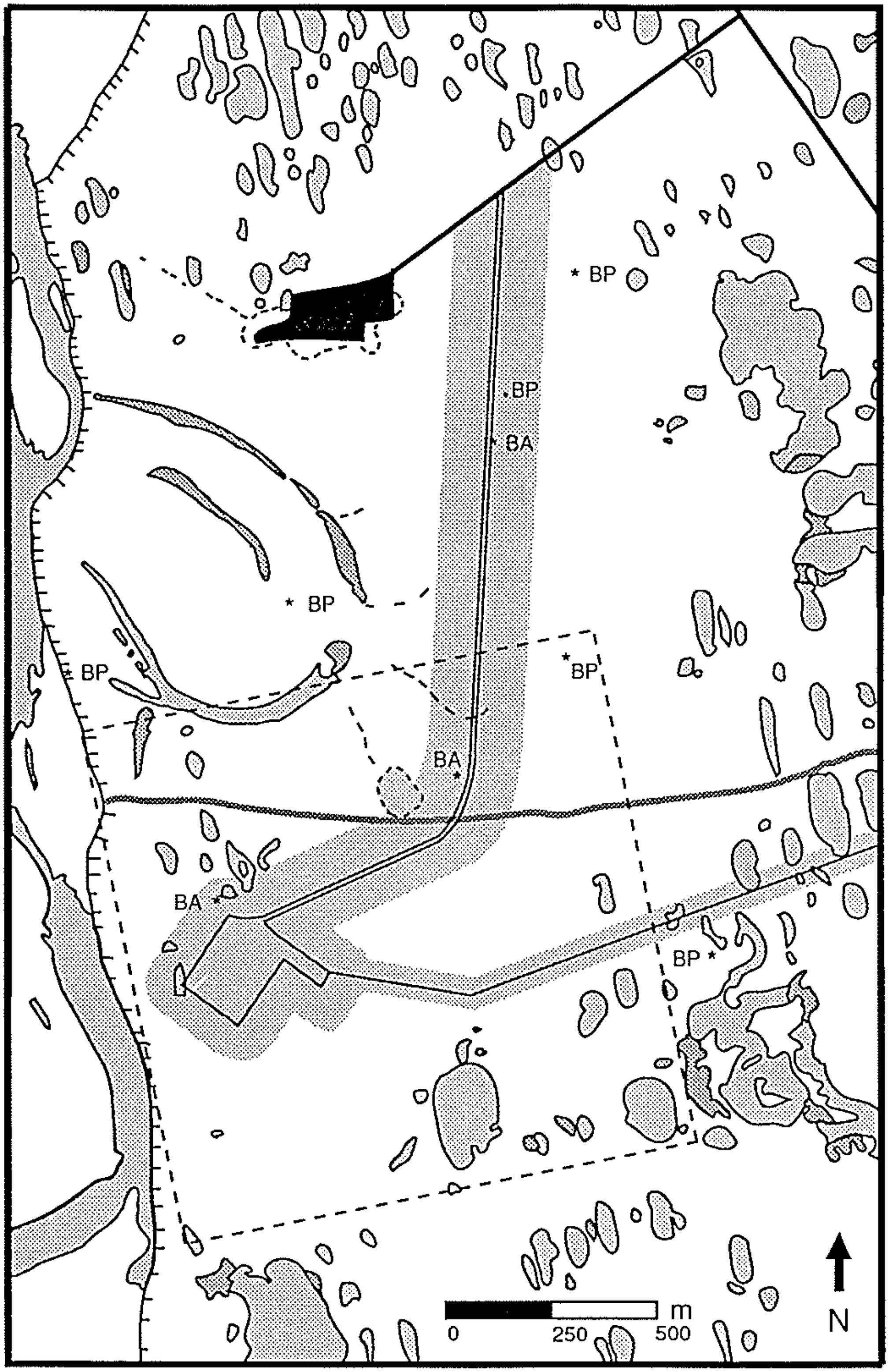

Figure A-8. Locations of Black-bellied Plover (BP) and Baird's Sandpiper (BA) nests (• = 1988, * = 1989) found near the P–Pad study area. Shaded areas adjacent to the facilities delimit the area considered close to the facilities for assessment purposes.

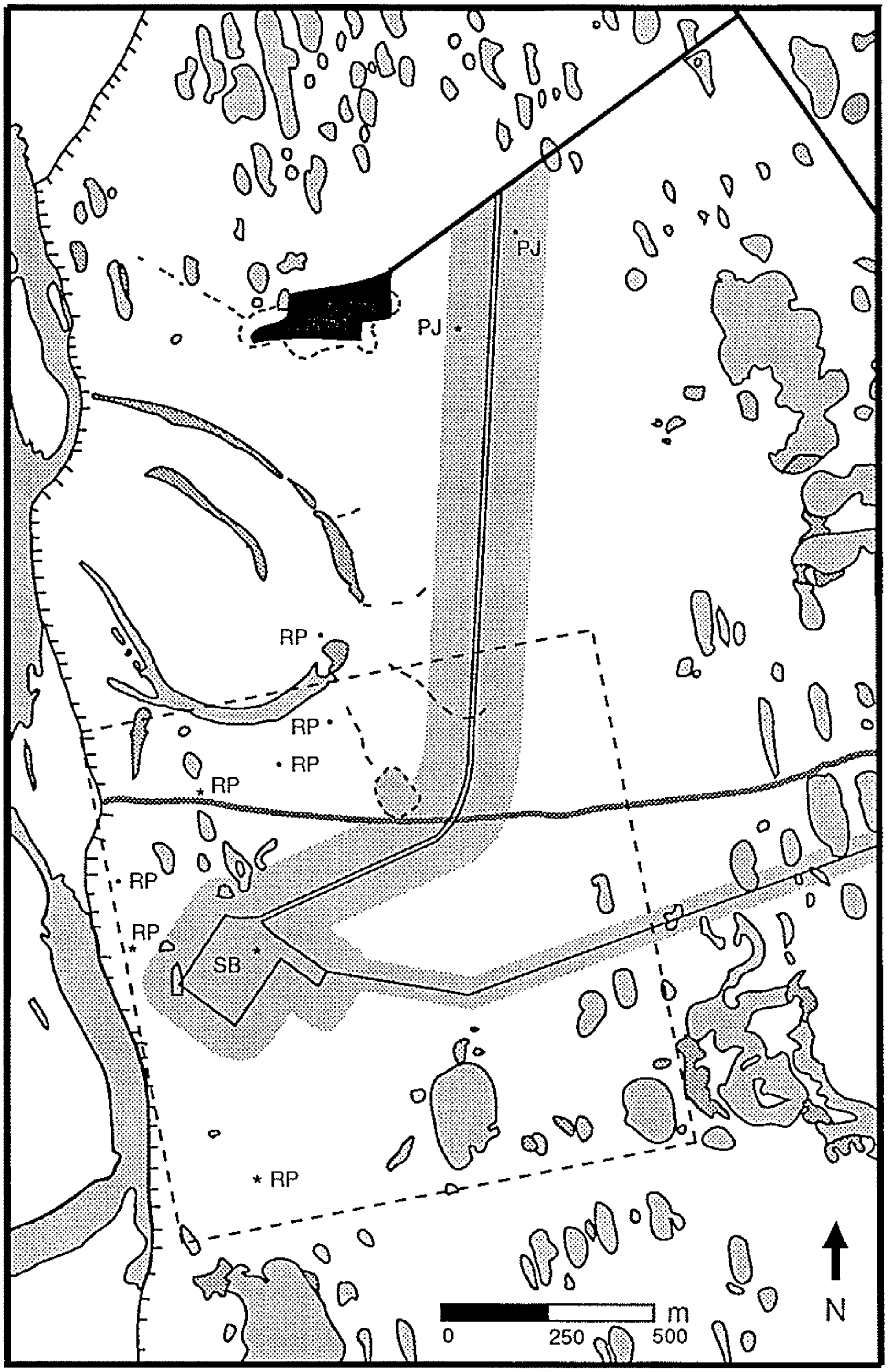

Figure A-9. Locations of Parasitic Jaeger (PJ), Rock Ptarmigan (RP), and Snow Bunting (SB) nests (• = 1988, * = 1989) found near the P–Pad study area. Shaded areas adjacent to the facilities delimit the area considered close to the facilities for assessment purposes.

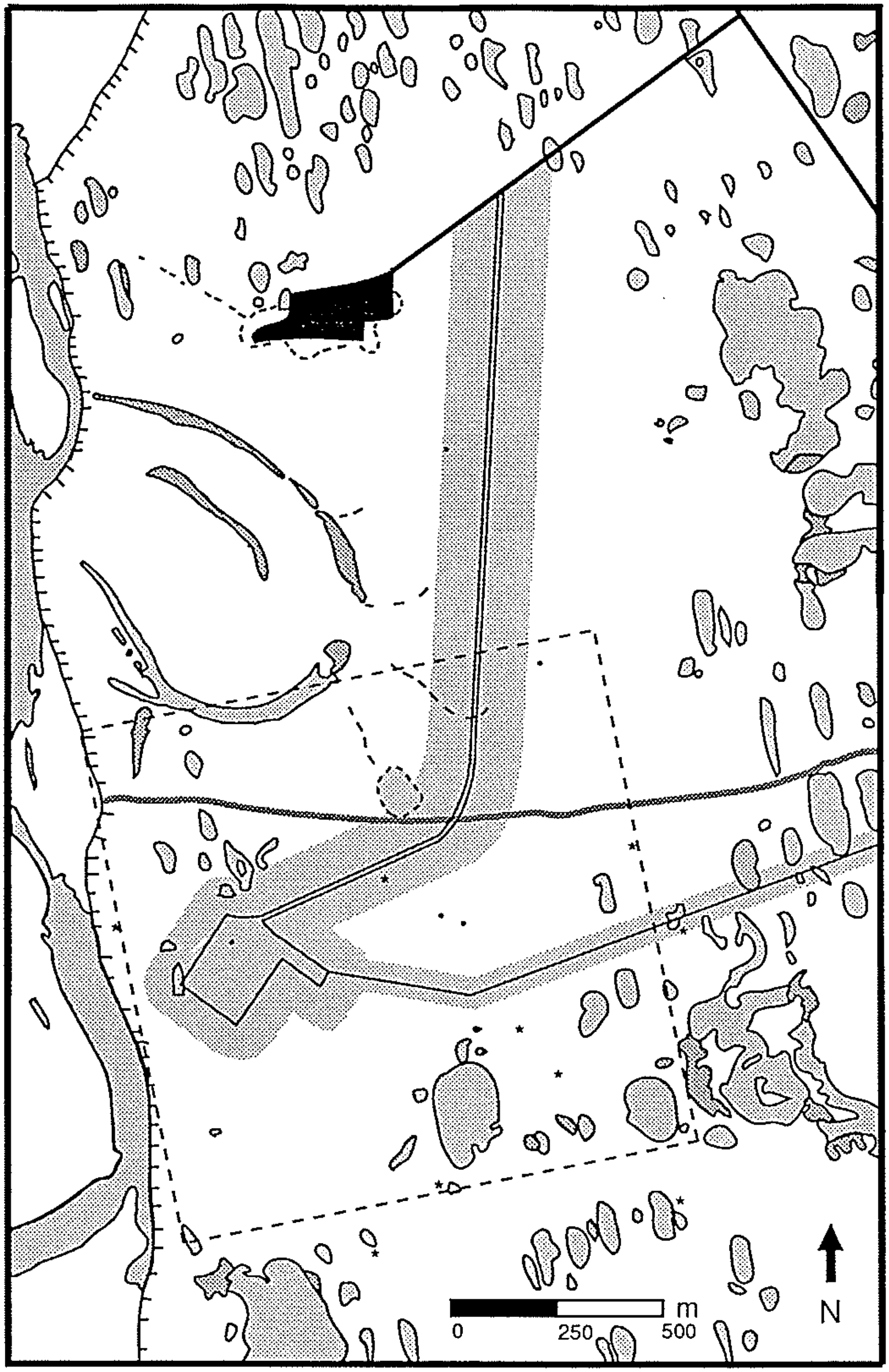

Figure A-10. Locations of Stilt Sandpiper nests (• = 1988, * = 1989) found near the P–Pad study area. Shaded areas adjacent to the facilities delimit the area considered close to the facilities for assessment purposes.

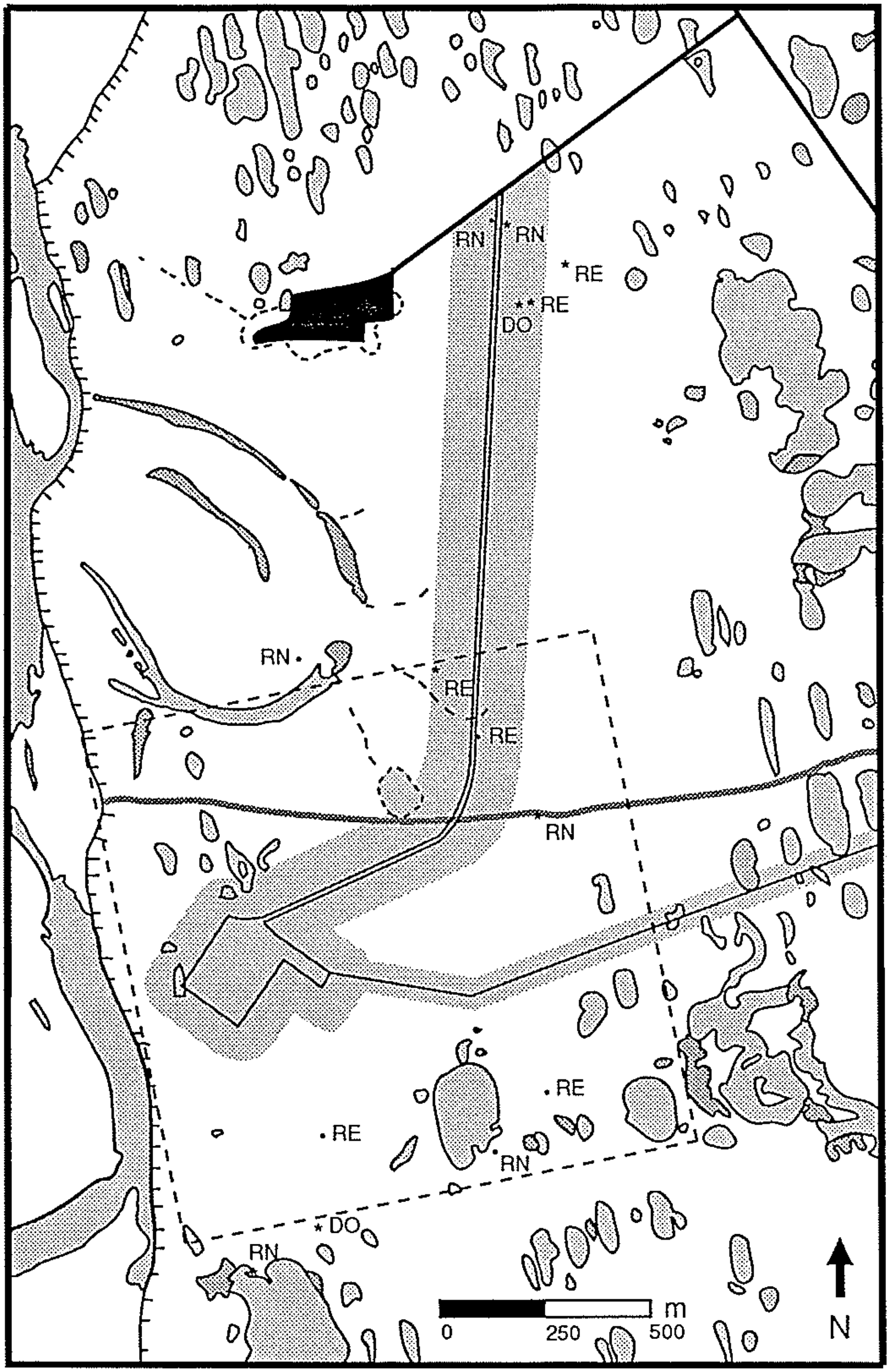

Figure A-11. Locations of Red-necked Phalarope (RN), Red Phalarope (RE), Long-billed Dowitcher (DO) nests (• = 1988, * = 1989) found near the P–Pad study area. Shaded areas adjacent to the facilities delimit the area considered close to the facilities for assessment purposes.