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TECHNICAL REPORT

**PREDEVELOPMENT SURVEYS OF NESTING BIRDS AT TWO SITES
IN THE KUPARUK OILFIELD, ALASKA, 1988-1992**

by

Cathryn S. Moitoret
Timothy R. Walker
Philip D. Martin

U.S. Fish and Wildlife Service
Northern Alaska Ecological Services
101 12th Ave., Box 19, Room 232
Fairbanks, AK 99701

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SUMMARY

Baseline data on nesting birds were collected during five breeding seasons (1988-92) on two 1 sq km study plots in the Kuparuk Oilfield, on the North Slope of Alaska. The study was initiated to provide information that could be used to make recommendations for minimizing impacts of oilfield development on migratory birds and their habitats.

All nests were located and marked each year during three breeding season censuses. Adult shorebirds and Lapland longspurs¹ were trapped at their nests using drop-box traps, and banded with colored plastic leg bands to identify individual birds. Data were collected on nest and bird sighting densities, nesting phenology, and nest success. Returns, nest locations, and mates of banded birds were noted in subsequent years. Observations of shorebird brood movements and brood attendance were added to the study in 1991-1992. Habitat relationships of nest sites and bird sightings are still being analyzed and will appear in a subsequent report.

Thirty-four species were sighted on the two plots, of which 23 species nested. Nest densities were highest for Lapland longspurs, semipalmated sandpipers, and pectoral sandpipers. Total nest densities were similar to other sites on the North Slope of Alaska, but species with higher than average nest densities at Kuparuk included greater white-fronted geese, black-bellied plovers, long-billed dowitchers, semipalmated and pectoral sandpipers, and willow ptarmigan. Kuparuk was similar to other North Slope sites in annual variability of bird nest densities. Overall nest densities were highest in 1990, the year with warmest temperatures and earliest snowmelt.

Timing and patterns of nest initiation varied among species and years. Median date of nest initiation for most species was earliest in 1990. Lapland longspurs and stilt sandpipers consistently had the earliest median nest initiation date (June 3-8), while buff-breasted sandpipers and long-billed dowitchers initiated latest among the shorebirds (June 12-17 and June 17-July 3, respectively). Among waterfowl, greater white-fronted geese and tundra swans had the earliest nest initiation dates, whereas initiation dates for loons, eiders, and oldsquaw were generally later in the season. Estimated (Mayfield) nest success rates for 1989-1992 showed a wide range of values. Pacific loons had overall estimated nest success of 60%, tundra swans and king eiders had nest success around 50%, but other waterfowl species had overall nest success of 16% or less. Most shorebird species had overall estimated nest success ranging from 64% (black-bellied plover) to 81% (semipalmated sandpiper), although American golden-plover nest success was only 47%. Lapland longspur overall estimated nest success was 79%. Shorebird and longspur nest success was consistently higher than at other oilfield locations. Fledging success rates were not determined by this study, but were likely much lower than nest success.

¹ Scientific names of all birds found on the plots are given in Appendix A.

Among the ten shorebird species that nested regularly on the plots, monogamous and territorial species, in which both sexes incubate (semipalmated and stilt sandpipers, dunlin, black-bellied and American golden-plovers), showed high site fidelity, with return rates of 40-69% from one year to the next. Species which are promiscuous and opportunistic, and in which a single sex incubates (pectoral sandpipers, red and red-necked phalaropes), showed low site fidelity (return rates 4-17%). Lapland longspur return rates were intermediate between these two shorebird groups (35%). We had no returns of buff-breasted sandpipers or long-billed dowitchers. Mate fidelity was 68% for semipalmated sandpipers; sample size was insufficient for a meaningful estimate of mate fidelity for other species.

Among the site-faithful species, males generally had greater site tenacity than females, but intact pairs had greater site tenacity than either males or females that returned with a new mate. Mean distance moved between nest sites from one year to the next was less than our estimate of territory radius for the territorial species, indicating that most birds returned to the same territories. All shorebirds except the plovers and red-necked phalaropes were observed to re-use nest cups from previous years, but the highest rates of re-use were found for semipalmated sandpipers (17%), stilt sandpipers (15%), and dunlin (10%). Much higher rates of nest cup re-use were found among Pacific loons (71%), tundra swans (67%), and red-throated loons (25%).

On average, semipalmated and pectoral sandpiper broods moved a gradually increasing distance from their nest site during each day after hatch, but there was considerable variability. Some broods remained in the vicinity of the nest site throughout the brood-rearing period, while others moved as far as 800 m in seven days from hatch. Stilt sandpiper and dunlin broods tended to move farther and faster than semipalmated and pectoral sandpiper broods, and never remained in the vicinity of the nest site more than one day. In 1992, most semipalmated sandpiper broods hatched between 25 June - 2 July, while pectoral sandpiper hatching was less synchronous, with hatching dates from 28 June - 19 July. Male semipalmated sandpipers generally stayed with the brood longer than females. Maximum brood attendance observed was 18 days for male semipalmated sandpipers, 10 days for female semipalmated sandpipers, and 21 days for female pectoral sandpipers.

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PREDEVELOPMENT SURVEYS OF NESTING BIRDS AT TWO SITES IN THE KUPARUK OILFIELD, ALASKA, 1988-1992

BACKGROUND AND OBJECTIVES

Wetland habitats on Alaska's North Slope provide nesting, feeding, and staging habitat for hundreds of thousands of migratory birds, including loons, geese, swans, ducks, shorebirds, gulls, terns, and passerines. In the past 25 years, nearly 45 sq km (USFWS unpublished data) have been excavated or filled with gravel for roads and pads in the oilfields surrounding Prudhoe Bay, and an additional unquantified area has been subject to indirect impacts of development (e.g., noise, dust, non-point source pollution). As North Slope development proceeds, the U.S. Fish and Wildlife Service and other resource agencies must consider mitigation for projects which represent relatively small increments to the larger cumulative impact. The Service has been seeking methods to address the problem of cumulative impacts on the North Slope of Alaska for several years (Meehan et al. 1986).

When this study was initiated in 1988, ARCO Alaska, Inc. was proposing construction of at least 17 new drilling pads and associated roads in the Kuparuk Oilfield. Test drilling pads for the West Sak and Ugnu formations were being constructed within the same area. All of these projects would occur in wetlands, and would require review by the Service under Section 404 of the Clean Water Act (40 CFR 230). Although considerable information on bird populations and development impacts had been collected through monitoring studies in the Prudhoe Bay Oilfield (Troy et al. 1983; Troy 1984, 1986, 1988; Meehan 1986; Murphy et al. 1986, 1987, 1988), these studies were not directly applicable to the Kuparuk region because of habitat differences between the two areas. In 1988 the only published bird studies in the Kuparuk area were for Eileen West End (Troy 1983) and for the CPF-3 development (Hampton 1988, 1989).

Some biologists have suggested that habitat is not limiting to North Slope wildlife species, and that birds or other wildlife displaced from a particular area by development are not lost to the population, but may simply move to adjacent unoccupied habitat. This argument is used to justify the lack of compensatory mitigation for North Slope development impacts. Evidence of habitat limitations for some North Slope birds has been provided by a number of removal studies, where individual birds were removed to see if their territories would be subsequently occupied by other individuals. A pool of non-breeding dunlin was available to occupy territories vacated by removal of breeding birds near Barrow (Holmes 1970). Seastedt and MacLean (1979) noted that when territorial male Lapland longspurs near Barrow were trapped for banding, their temporarily vacated territories were almost immediately occupied by neighboring or intruding males. The existence of non-breeding adults who become breeders as soon as territories are vacated provides a strong indication that the breeding populations of these species are limited by availability of suitable nesting habitat.

If North Slope birds were not limited by habitat availability, and were merely displaced from their territories into adjacent areas by development, one might expect to find more birds concentrated in a smaller area as development proceeds, resulting in higher bird densities in the areas surrounding roads and pads than were there prior to development. However, the available evidence does not support this conclusion. Troy (1988) has shown lower bird and nest densities for several species adjacent to roads in the oilfield. Meehan (1986) has shown lower densities of birds in the Prudhoe Bay Oilfield compared to a control area outside the oilfield. Hanson (in prep.) found that densities of tundra nesting birds did not change significantly as development proceeded in a study plot in Prudhoe Bay, but nesting numbers decreased as habitat was lost to development.

In 1988 it was anticipated that proposed construction in the Kuparuk Oilfield would provide a unique opportunity to pursue a more complete answer to the question of habitat limitation. This study was originally designed to assess the fate of birds whose habitat was eliminated by development, by comparing bird species, densities, and distributions in the project areas before and after development, and also by monitoring the fate of individually marked birds subsequent to development. The original objectives of the study were: (1) to obtain baseline survey information of bird species, densities, and distribution at two proposed drilling pad sites in the Kuparuk Oilfield prior to development, for use in Section 404 permit review; (2) to monitor any changes in bird species, densities, and distribution subsequent to development at these sites; and (3) to determine whether birds displaced from a development site move to adjacent unoccupied habitats, or are lost from the breeding population.

By 1990, after collection of three years of baseline data on the two study plots, it became apparent that neither site would likely be developed in the near future. The permit application for drillsite 1-M was withdrawn, and the permit for drillsite 3-L was issued for a different location, outside our study plot boundaries, which was determined to be a less damaging alternative to the environment. The study was continued for two additional years, with revised objectives reflecting the need for additional baseline data on various aspects of bird biology in the Kuparuk Oilfield. The following data were obtained: bird and nesting densities, habitat relationships, nesting phenology, and nest success for all bird species; and return rates, site fidelity, mate fidelity, site tenacity, and brood movements for the shorebird and passerine species. The resulting baseline data set will be useful in assessing potential impacts of future development projects in the Kuparuk Oilfield area, and for recommending appropriate mitigation. This report includes methods, results, and discussion for all aspects of the study with the exception of habitat relationships, which will be reported separately. We also offer, with 20:20 hindsight based on the knowledge and experience gained from conducting this baseline study, and from reviewing other similar studies, our conclusions as to whether the original objectives of the study, including the question of habitat limitation, could actually be addressed by a study of this type and design.

STUDY AREA

The study area is located on the North Slope of Alaska, between the Colville and Kuparuk Rivers (Figure 1). The Kuparuk Oilfield encompasses an area of approximately 12,000 sq km, of which approximately 14.4 sq km has currently been covered with gravel or excavated for material sites in the construction of oilfield facilities, pads, and roads. At the initiation of this project, 17 new pads and roads encompassing approximately 2.3 sq km were proposed for additional development. Currently, new technology for directional drilling has allowed reduction of the number of proposed new pads to seven.

The study area is located in Arctic Coastal Plain tundra, which includes moist, wet, and aquatic wetland types. Climate is severe, with a snow-free season lasting approximately four months beginning in early June. A more complete description of habitat types and weather conditions is given in the RESULTS section of this report.

METHODS

Study Site Selection and Marking

Two proposed drilling pad sites, 1-M and 3-L, were selected for detailed study in 1988. It was anticipated that additional sites might be added to the study design in future years if time, funding, and personnel were available. The initial two study sites were selected because of their anticipated early development, and because of our perception that they contained habitat likely to support high densities of nesting birds, based on previous North Slope studies (Bergman et al. 1977; Martin 1983; Troy 1984; Moitoret et al. 1985). Site 3-L is located approximately 8 km from the Beaufort Sea coast, and approximately 2.5 km south of the Mine Site E access road. Site 1-M is located approximately 20 km from the Beaufort Sea coast, and is adjacent to and north of the Spine Road, just west of the Milne Point Road intersection (Figure 2).

Square plots, 1 km x 1 km (100 ha), surrounding each of the two proposed pad sites, were marked on 1:18,000 aerial photos. The large size of the plots relative to the area of future impact (an average drill pad is about 10 ha) would allow the perimeter of each plot to provide control data for assessing species site fidelity, return rates, and annual variability within similar habitat types as the impacted area, as well as providing a large enough area for assessing movements of marked birds.

Corners of each 100-ha plot were surveyed using aerial photos and permanently marked on the ground with an orange plastic tent stake, metal rebar, and aluminum tag. A grid of 50-m x 50-m blocks within each plot was marked with numbered plastic tent stakes and wire flagging. Because portions of each plot could not be surveyed due to overlap with roads (in plot 1-M) and a large lake (in plot 3-L), additional rows were added subsequent to the original survey. This resulted in a surface area of 1.03 sq km for plot 1-M; plot 3-L

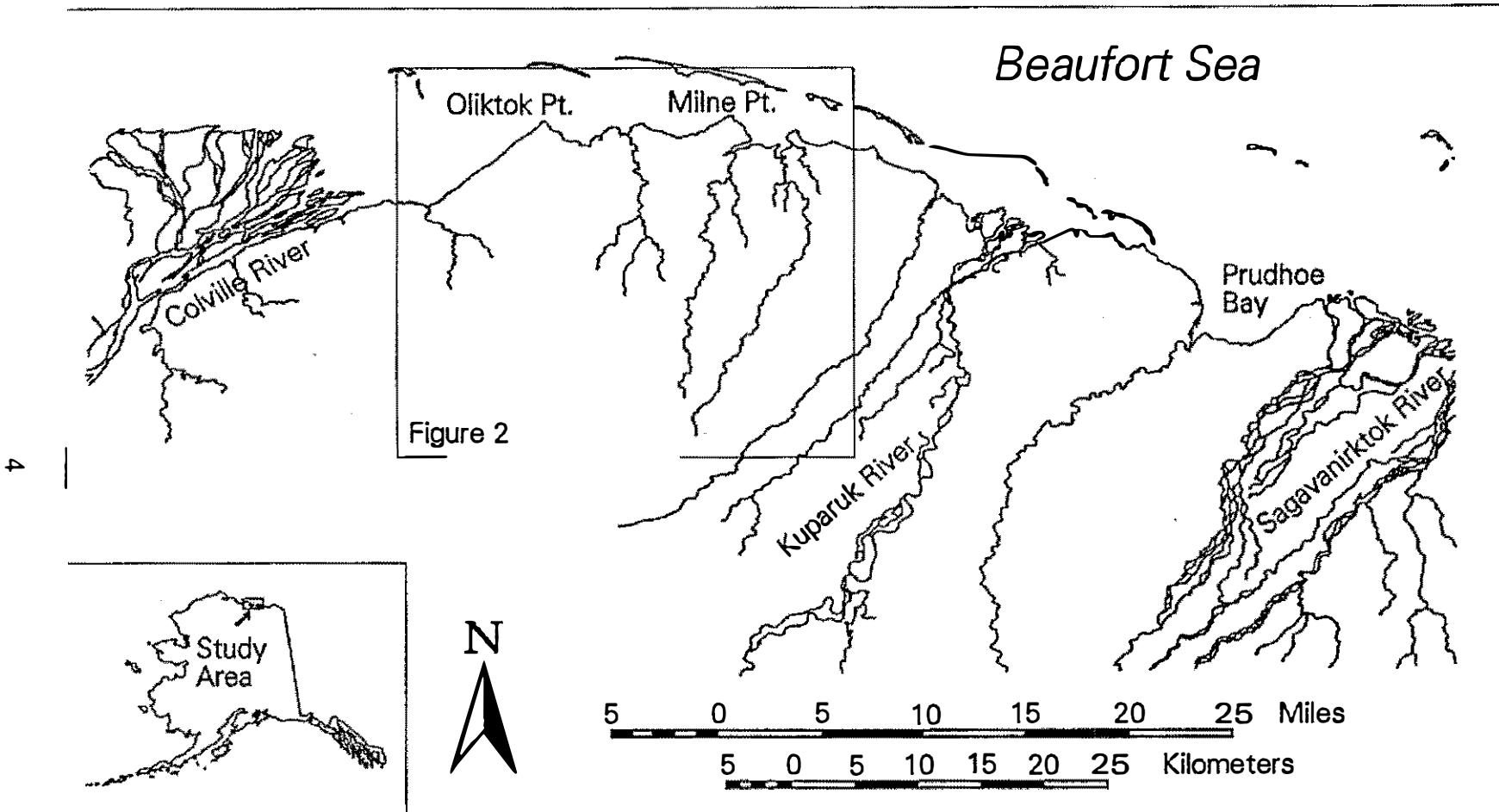


Figure 1. Location of the Kuparuk Oilfield on the North Slope of Alaska.

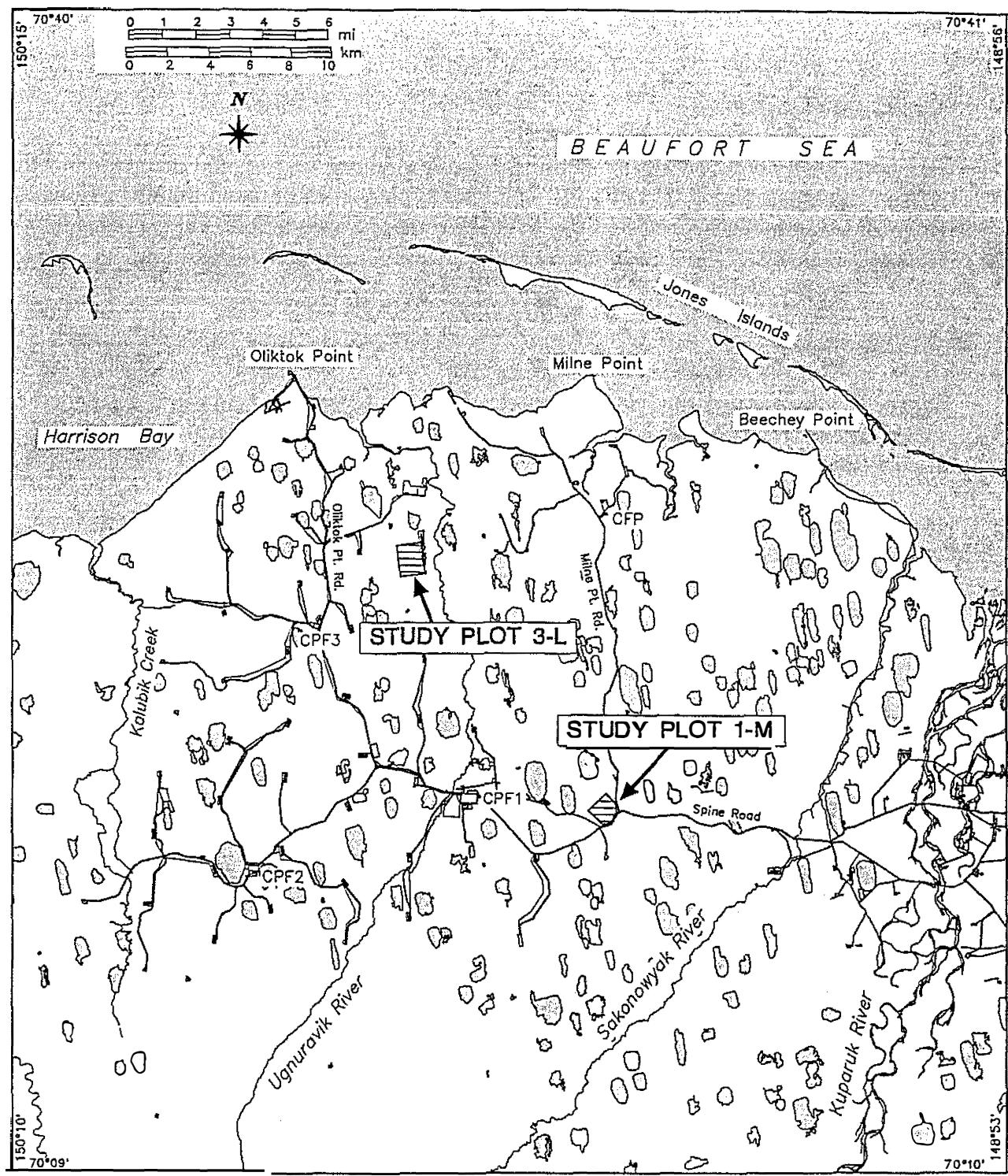


Figure 2. Location of two bird study plots in the Kuparuk Oilfield on the North Slope of Alaska.

encompassed 0.92 sq km in 1988 and was enlarged to 1.49 sq km in 1989 and subsequent years.

Habitat Mapping

Habitat mapping was accomplished using a combination of aerial photo interpretation from 1:6,000 enlargements of 1:18,000 true-color aerial photos, and ground truthing. Habitat was recorded using parameters of dominant landform types (Walker et al. 1980), vegetation types (Viereck et al. 1992), soil moisture, and relief, within 50-m grid squares.

Weather Data

Weather data were recorded daily at approximately 8 AM at the field camp location at Oliktok Point. Current temperature, 24-hr maximum and minimum temperatures, wind speed and direction, cloud cover, ceiling, precipitation, and incidental comments were recorded.

National Weather Service data for daily temperatures at Prudhoe Bay were used in our analyses, because of some questions about accuracy of our own temperature data. Daily mean temperatures for May, June, and July 1988-1992 were obtained by averaging the daily maximum and minimum. The difference between each daily mean and a 22-year daily mean (1968-1989 data from Thoman 1990) was plotted cumulatively for each month (May-July) and each year of the study (1988-1992).

Census Methods

Each study plot was censused for total birds and nests three times during the peak of the nesting season, from mid- to late June, except in 1988 when plot 1-M was censused twice and plot 3-L only once. Dates for each census on each plot are shown in Table 1. Individual observers travelled in a zigzag pattern along each 50-m row, making passes approximately 10 m apart. All bird observations were recorded by grid number on data sheets. Data recorded for each observation included species, sex, number, behavior, and band combinations of previously banded birds.

Nests were marked on the ground with a numbered tongue depressor placed 1 m north of the nest. Nest locations were identified by a compass bearing and number of paces from the nearest grid stake. Each observer determined the length of his/her pace, so that the angle and distance from the nearest grid stake could be used to calculate approximate x-y coordinates for each nest site. These coordinates were used to plot nest locations on grid maps and aerial photos. Nest site habitat characteristics (vegetation, landform, aspect, distance to water) were recorded when the nest was found, and nest status (number of eggs and/or chicks, presence and behavior of adults, evidence of predation) was recorded during each visit.

Table 1. Census dates for breeding bird surveys on two study plots in the Kuparuk Oilfield on the North Slope of Alaska 1988-1992.

	Census 1	Census 2	Census 3
PLOT 1-M			
1988	---	6/18-6/21	6/27-6/30
1989	6/12-6/14	6/20-6/22	6/29-7/1
1990	6/9-6/11	6/15-6/19	6/27-6/30
1991	6/8-6/11	6/16-6/18	6/23-6/26
1992	6/7-6/9	6/14-6/16	6/23-6/25
PLOT 3-L			
1988	---	6/23-6/25	---
1989	6/16-6/19	6/24-6/26	7/2-7/3
1990	6/12-6/15	6/20-6/24	7/2-7/5
1991	6/12-6/14	6/19-6/22	6/27-7/1
1992	6/11-6/13	6/18-6/21	6/26-6/30

Tabulation of Bird Sighting Data

Observers were instructed to concentrate on recording birds in the row they were censusing, but because birds tend to move in response to the observer's presence (in some cases toward, and in others away from, the observer), birds in adjacent rows were also recorded, especially in the case of larger birds (loons, ducks, geese) which were unlikely to allow close approach in the row being censused. Observers recorded birds in the grid square where they were first observed, and attempted to keep track of bird movements to avoid double-counting.

All observations were entered in a computer data base, and sorted by species and grid square. Obvious duplicate sightings (same species, number, sex, and grid square on the same date) were eliminated before tabulating the census data, but clearly some instances of double-counting still occurred (e.g., the same bird may have been seen in different grid squares by different observers censusing different rows, or on different days). Very visible and mobile birds (e.g., dunlin, male Lapland longspurs) were most likely to be over-counted, while less mobile and more cryptic birds (e.g., female Lapland longspurs and female ptarmigan) were likely to be under-counted. Because of the high probability of either under- or over-counting, bird sighting data were considered inappropriate for estimating absolute abundance. However, a "bird sighting index" (derived by averaging sightings per square kilometer for all censuses) provided useful qualitative comparisons between plots, and provided information on species use that is not apparent from the nesting data alone.

The "bird sighting index" was derived only from sightings of birds seen on the ground, and did not include sightings of birds seen flying over the plots; thus it does not adequately represent use of the plots by aerial hunters (jaegers, gulls, raptors) which were seldom recorded on the ground. A separate "frequency of occurrence" tabulation was made for birds seen flying over the plots, defined as the number of days on which a particular species was sighted, divided by the total number of census days on the plot.

Nesting Density

Nesting densities were calculated for each species on each plot, by dividing the total number of nests found (excluding known renests) by the plot area censused. Nests found adjacent to the plot, but outside the plot boundaries, were not included in density calculations. A nesting attempt was considered a renest if at least one member of the pair was color-marked and had been associated with an earlier nest, or if the nest was found near a recently failed nest of a conspecific. Renests were omitted when calculating nesting densities, but were not treated separately when considering phenology of nest initiation dates.

Nest density calculations assume that all nests were found, which was likely not the case, especially in the first year of the study when the census effort was less intensive, and birds were not yet color-banded. In subsequent years, returns of previously banded birds and banding of unbanded adults soon after their nests were found, allowed us to more easily

assess whether there were any breeding birds on the plot for which nests had not yet been found, and adjust our search efforts accordingly. Our nesting density estimates are more likely to reflect actual densities in 1989-1992 than in 1988.

Trapping and Banding

Adults of ten shorebird species, as well as Lapland longspurs, were captured on their nests using a wire mesh drop-box trap, and marked with colored leg bands to allow future identification of individuals. Semipalmated sandpipers and dunlin were initially selected for color marking in 1988 because they were expected to show high nest site fidelity (Hanson, in prep.; Soikkeli 1970), to be abundant in the study area (Troy 1983), and to be relatively easy to capture (Hanson, pers. comm). Additional species selected for color banding in 1989, due to their relative abundance, were pectoral sandpipers, red phalaropes, and Lapland longspurs. In 1990 and subsequent years the banding effort was expanded to include color banding of black-bellied and American golden-plovers, stilt and buff-breasted sandpipers, long-billed dowitchers, and red-necked phalaropes.

Individual birds were banded with standard USFWS numbered metal tarsus bands, and with heat-sealed ultra-violet resistant color bands appropriate to identify individuals and location of capture. Beginning in 1989, young birds were opportunistically captured and banded at the nest. Young birds were banded with only a single color band indicating plot location, in addition to standard numbered metal tarsus bands.

- * All personnel were trained by staff experienced in bird handling and banding techniques. The color banding scheme was coordinated with the Pan American Shorebird Program. We attempted to capture and band at least one adult from each nest. On nests of species with both sexes attending the nest (dunlin, semipalmated and stilt sandpipers, black-bellied and American golden-plovers, long-billed dowitchers, Lapland longspurs) both adults were captured and banded when possible. Wing length, bill length, and mass were recorded for each banded bird.

Sex Determination

Sex was determined by plumage for Lapland longspurs, phalaropes, and plovers. Bill length (culmen length for dunlin) was used as a guide for sexing other shorebird species. When both members of a pair were banded, the bird with the longer bill was assumed to be the female (from data given in Prater et al. 1977), unless behavioral observations (courtship, copulation) indicated otherwise. Any bird for which the mate was not banded, and whose bill length was in the overlap zone for male and female bill lengths, was recorded as sex unknown. Mass and wing length data were occasionally used to support sex determinations (female shorebirds tended to be slightly heavier and to have greater wing length than the males), but there was considerable overlap between the sexes for these measurements (see Appendix B).

Return Rate, Site Fidelity, Mate Fidelity, and Site Tenacity

Color band combinations, and locations and behaviors of color-marked birds, were recorded by observers during plot censuses, nest visits, brood censuses, and during other occasional visits to the plots. No systematic attempt was made to locate color-marked birds outside the plots. Only those birds found on a nest or associating with an incubating bird in a pair bond were considered to have nested.

Return rate, or the percentage of color-marked birds returning to the plots at some subsequent time period, was calculated in three ways. The first method, "Percent Return in Any Year," used the percentage of total birds banded on the plots that were ever seen again in any subsequent year, and yielded a minimum estimate of annual survival. The second method, "Percent Return in Subsequent Year," used the percentage of banded birds nesting on the plots in one year that returned to the plots in the year immediately following. This method yielded the best estimate of nesting site fidelity, which is the tendency of a bird to return to the general area of a previous nesting attempt. The third method, in which return rates were calculated by considering the percentage of banded birds returning to the plots in the first year, second year, and each succeeding year after the year in which they were banded, allowed estimation of average lifespan. This was applicable only for site-faithful species, with the assumption that loss was due primarily to mortality (and not emigration), and that the survival rate was constant between ages and between years.

All return rates were calculated for both "nesting" returns (returning birds for which a nest was found) and "sighting" returns (birds which were sighted, but no nest was found). "Nesting" return rates were generally considered the best estimates of nest site fidelity ("sighted" birds may have nested elsewhere), but for species with difficult nests to find (such as dunlin) the "sighting" return rates may actually give a more accurate estimate of nest site fidelity. "Sighting" return rates were used in estimates of survival and longevity. The denominators of all return rate calculations included only banded birds found on nests within the plot boundaries, but the numerators included all sightings and nests of banded birds regardless of whether they were within plot boundaries.

For species with adequate sample size of known-gender individuals (Lapland longspur, semipalmated sandpiper, black-bellied and American golden-plovers), return rates were calculated separately for males and females. For dunlins, stilt sandpipers, and long-billed dowitchers, return rates were calculated for both sexes combined. For pectoral and buff-breasted sandpipers, and red and red-necked phalaropes, return rates were calculated only for the incubating sex.

Estimates of mate fidelity were derived from nesting pairs for which both members of the pair were banded, and both members returned. Site tenacity (the degree to which a bird chooses the same site or territory for nesting from one year to the next) was measured by the distance between nest locations in subsequent years for an individual bird, and was calculated to the

nearest meter using nest site coordinates for birds color-marked at a nest in one year and found at a nest in a subsequent year.

We used a chi square contingency table (Conover 1980) to test whether the probability of a bird returning (and being sighted) in any year subsequent to banding is dependent on gender, for semipalmated sandpipers and Lapland longspurs (the only species that provided adequate sample size). We used a chi square multiway contingency table (Conover 1980) to test whether the probability of a bird returning to the same territory in the following year was influenced by gender, and/or by species (shorebirds² vs. Lapland longspurs). We tested the hypothesis that distance moved was similar for males and females (semipalmated sandpipers, dunlin, Lapland longspurs) with a Mann-Whitney test (SAS NPAR1WAY procedure: SAS Institute 1988). We tested the hypothesis that mean distance moved was similar for intact pairs, males with a new mate, and females with a new mate (semipalmated sandpipers and Lapland longspurs) with a Kruskal-Wallis test, by using one-way ANOVA on the ranked data (SAS GLM procedure) with multiple comparisons obtained by Fisher's least significant difference test (Conover 1980; SAS Institute 1988).

Nesting Phenology

Nesting phenology was determined from observations made during censuses and nest visits. We used nest initiation dates (the date the first egg was laid) to compare nesting phenology among years. Nest initiation dates were normally determined in one of two ways: (1) discovery of a nest with an incomplete clutch during egg laying permitted calculation of the initiation date using the egg laying interval. A review of the literature indicated that for all species except for red-throated and Pacific loons the assumption that one egg is laid each day is reasonable. (2) discovery of a nest with one or more eggs hatched permitted calculation of the initiation date by adding the incubation period and the egg laying period (based on the egg laying interval and clutch size). Incubation was defined as the period between the laying of the last egg and its subsequent hatching (Ricklefs 1979). Appendix C contains a listing of incubation periods used in this study. When the exact date of initiation could not be calculated, we used an estimated initiation date if it could be estimated to within two days.

We did not use nest initiation data obtained in 1988 in our analysis because there were too few known, calculable, or estimable nest initiation dates. Surveys in 1988 did not continue through the entire nesting season, so of the known nest initiation dates most would tend to be early and therefore not representative of the actual distribution for that year.

For the six species with at least three known nest initiation dates in each year from 1989-1992 (semipalmated sandpiper, pectoral sandpiper, stilt sandpiper, dunlin, red phalarope, and

² ("Shorebirds". in this analysis includes pooled data for semipalmated sandpipers, stilt sandpipers, dunlin, black-bellied plovers, and American golden-plovers.)

Lapland longspur), we tested the hypothesis that mean nest initiation dates did not vary among years with a Kruskal-Wallis test, using one-way ANOVA on the ranked data (SAS GLM procedure) with multiple comparisons obtained by Fisher's least significant difference test (Conover 1980, SAS Institute 1988). For the same six species, we ranked years from earliest to latest median nest initiation dates for each species, and tested the hypothesis that the rank order of years was the same among species (i.e., that early or late nesting years were the same for all species) using a Friedman test (Conover 1980).

Nest Success

Nests were checked during censuses until we noted the first hatching shorebird nest; then we initiated a schedule of checking all nests on a plot every two days (except in 1988, when we departed the study area before hatching of most shorebird nests). Since hatching and departure from the nest usually spanned at least a 24-hour period, this nest checking schedule increased our likelihood of being able to determine nest fate. We considered a nest successful if we saw: (1) at least one chick; (2) at least one defensive adult known to be associated with that nest, subsequent to the nest being found empty; or (3) pipped eggs on the visit prior to the nest being empty, if there was no indication of failure. A nest was considered depredated if it was empty prior to a reasonable hatching date, if punctured or broken eggs were found in or near the nest, or if there was fox sign in or near the empty nest. We considered a nest abandoned if several visits were made to the nest without seeing adults, and the eggs remained cold. The remaining nests were recorded as having an unknown outcome. Nest success was calculated using a simple Mayfield (1975) estimate, with 95% confidence interval calculated according to Johnson (1979).

Brood Movements

Shorebird brood locations were determined by recording locations and color band combinations of defensive adults, subsequent to hatching of their eggs. These observations were made incidental to censusing, banding, and nest-checking activities in 1989 and 1990. Three systematic brood searches were conducted each year in 1991 and 1992, during the first two weeks of July (brood-rearing continued beyond this time period, but our field presence did not). During the brood searches, observers walked each grid-row of the plot and recorded all observations of defensive birds (whether banded or not) and all observations of banded birds (whether defensive or not).

For banded defensive birds, distance moved from the nest site was estimated by calculating the distance from the center of the grid square where the nest was located to the center of the grid square where the defensive adult was seen. Average distance moved for each day subsequent to hatching date was calculated by pooling data (to increase sample size) from all years (1989-1992) for each species.

Brood Attendance Period

Brood attendance period (the number of days adults spent with broods) was determined for all banded shorebirds with successful clutches, by noting the last date on which each defensive adult was seen subsequent to hatch. The adult was assumed to have been attending its brood throughout this time period. Number of birds known to be attending broods was calculated and plotted for each day of the brood-rearing season. Although brood censuses were conducted in both 1991 and 1992, the later hatching dates in 1991 resulted in our study being terminated prior to completion of brood-rearing, so meaningful brood attendance data could only be derived from the 1992 season.

RESULTS

Weather and Phenology

Weather in the study area during the five years of this study reflected the variability typical of Alaska's North Slope. Overall, daily mean temperatures recorded at the Deadhorse Flight Service Station in May, June, and July 1988 were fairly close to the 22-year (1968-1989) daily means (Figures 3-5). In 1989 temperatures were fairly close to the mean through mid-June but were well above the mean from mid-June through July. Overall, 1990 was the warmest year during our study, with cumulative daily mean temperatures in May, June, and July all well above average. May temperatures were especially high. May temperatures were also very high in 1991. In contrast to 1990, 1991 temperatures were often below the mean in June and much colder than average in July. July was colder in 1991 than any other year during the study. In 1992 there were temperature fluctuations above and below the mean, but cumulative temperatures were close to the mean in all three months.

Snowmelt phenology was slightly later in 1988 than in 1989. In 1988 we recorded 85% snow cover on the plots on June 8; 80% on June 11; 30% on June 12; and 10% on June 15. In 1989 we recorded 80% snow cover on June 7; 50% on June 9; 25% on June 12; 5% on June 16; and 1% on June 19. In 1990, snowmelt was much earlier than the other years, as there was no snow cover on the plots upon our arrival, June 6. Snowmelt also occurred early in 1991 and 1992. In 1991 there was 20-25% snow cover remaining on June 5, and in 1992 there was only 5-10% snow cover when we arrived on June 3.

The number of days on which we recorded some form of precipitation varied from 20-45% in June and 14-31% in July. The percentage of days on which we recorded at least 50% cloud cover was around 70% all years.

Northeast winds predominated in all five years. In most years we recorded wind blowing out of the northeast for well over 50% of the days in June and July. In 1989 wind direction was more variable, and there were more days without wind in 1989 than in other years. In all years, windy conditions prevailed on 75-100% of the days. The percentage of days when the wind speed reached 10 mph was highest in 1992, about 50%. In other years wind speed reached 10 mph 13-25% of the time, except in July 1991 when we recorded no days with winds exceeding 10 mph.

Habitats

Although detailed habitat mapping is not yet complete, some general observations can be made about the habitats included in each plot (see Appendix E for plot maps). In general, plot 3-L included more wet and aquatic areas than 1-M. Both plots contained numerous lakes and ponds, but their configuration was somewhat different. A large, deep lake, approximately

Cumulative deviation (degrees C) from daily mean temperatures

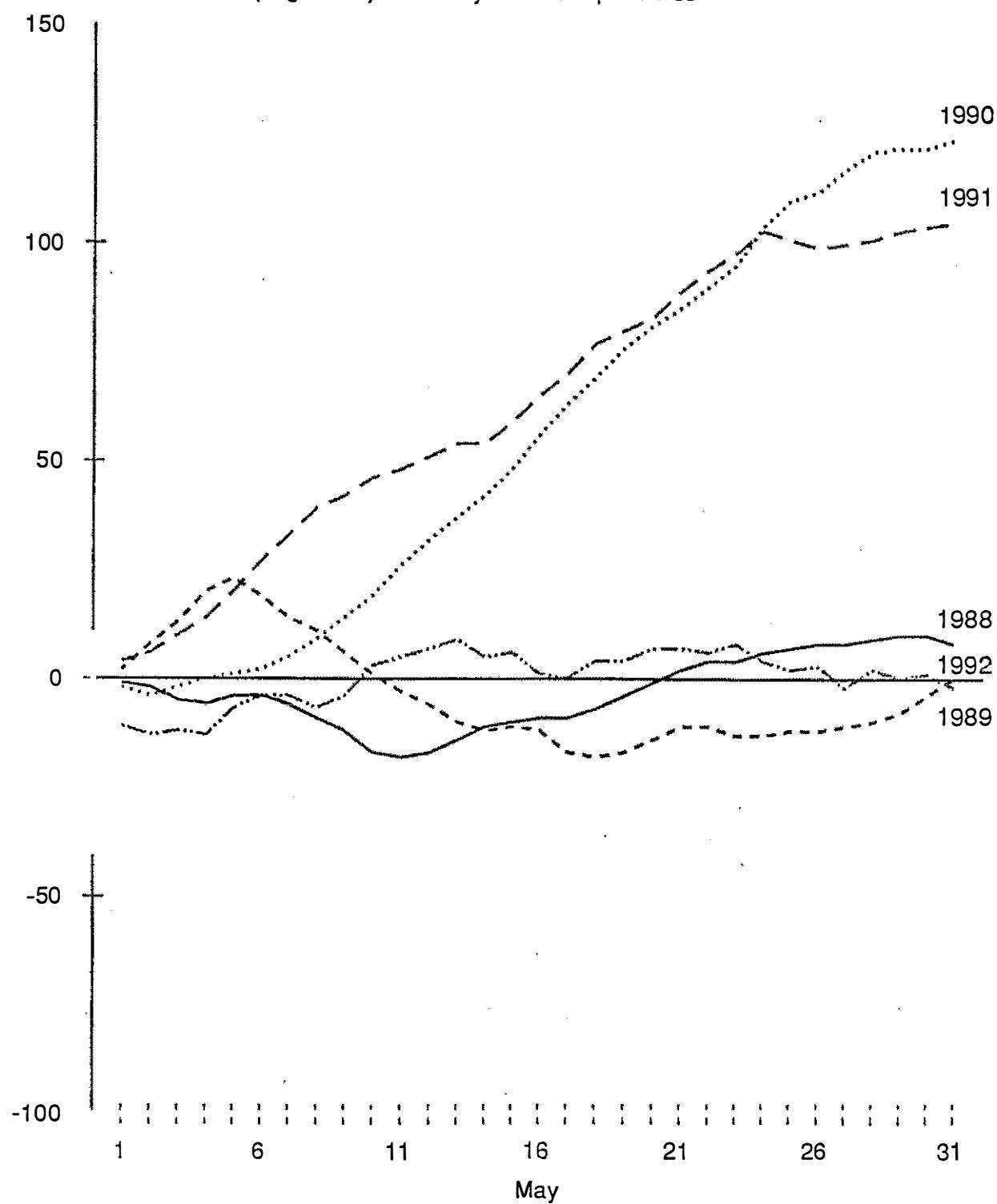


Figure 3. Cumulative deviation from the 20-year mean daily temperatures at Prudhoe Bay, Alaska, during the month of May, 1988-1992.

Cumulative deviation (degrees C) from daily mean temperatures
150

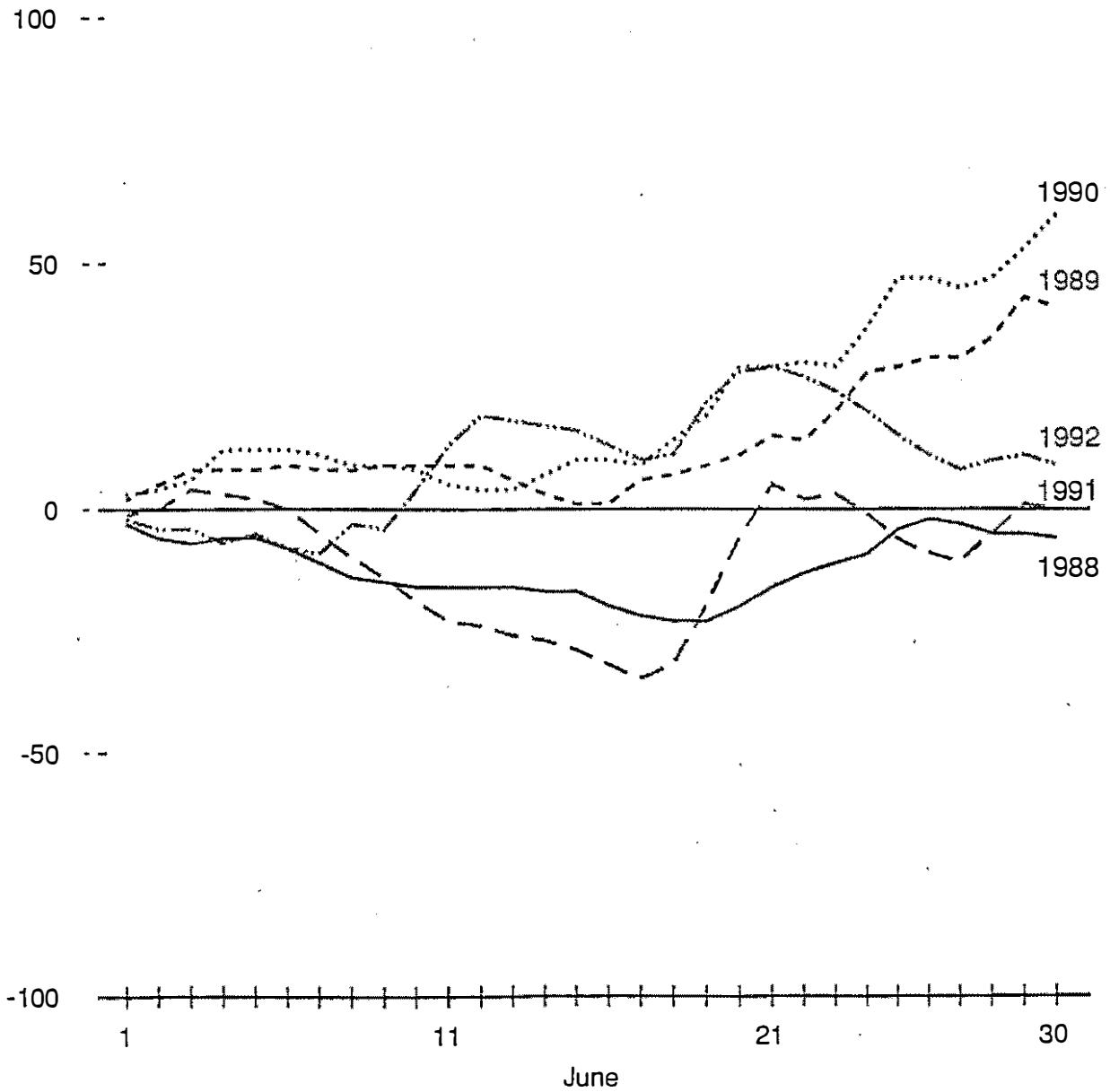


Figure 4. Cumulative deviation from the 20-year mean daily temperatures at Prudhoe Bay, Alaska, during the month of June, 1988-1992.

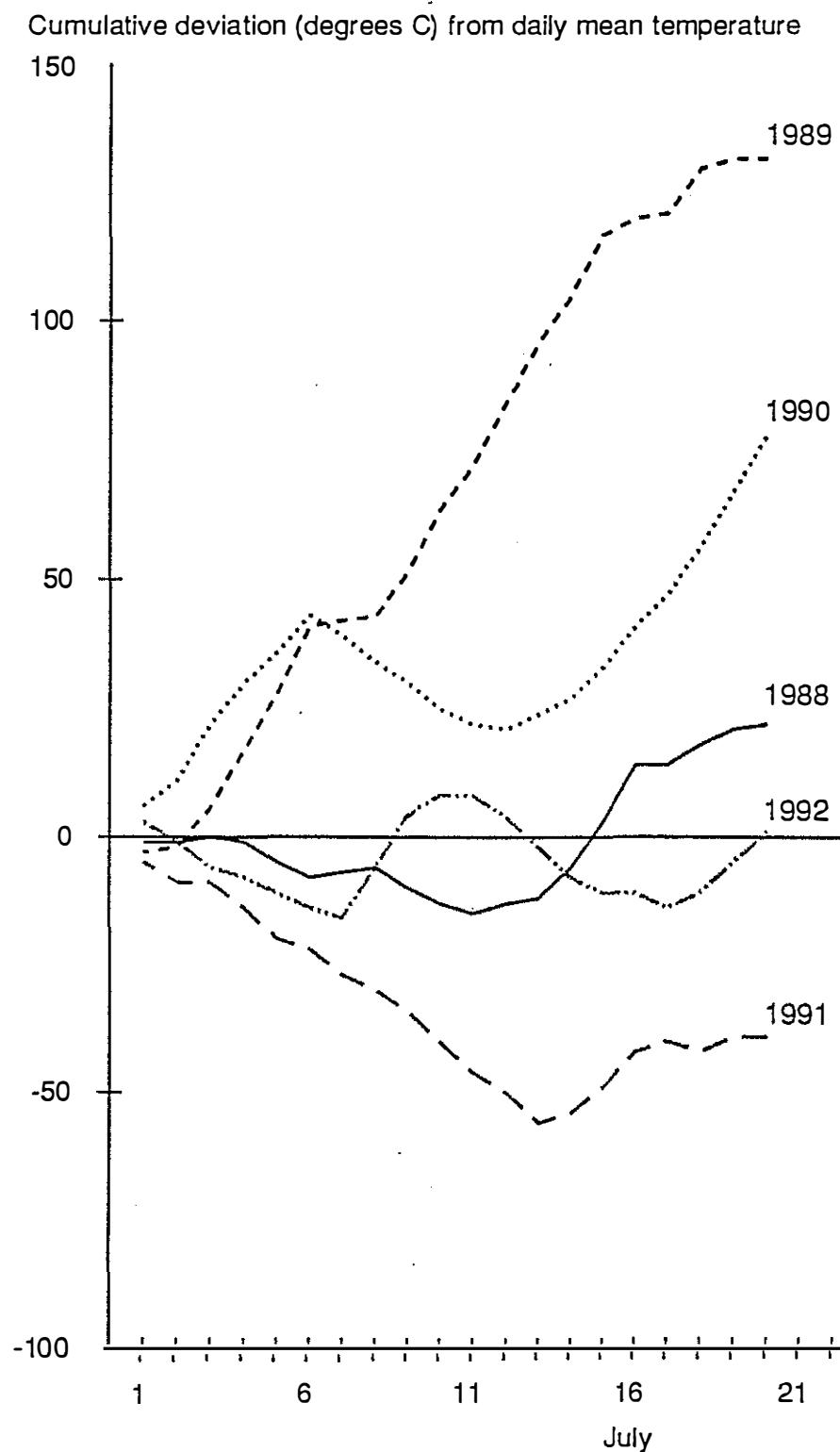


Figure 5. Cumulative deviation from the 20-year mean daily temperatures at Prudhoe Bay, Alaska, during the month of July, 1988-1992.

22 ha in area, covered the northeast corner of plot 3-L. Plot 3-L was also bisected by a series of long, parallel, shallow lakes, totalling approximately 10.5 ha, oriented north-south, with numerous peninsulas and islands. Additional smaller lakes and ponds covered approximately 15 ha on plot 3-L. The lakes on plot 1-M were generally smaller and shallower than those on plot 3-L, rectangular or oval in shape, oriented north-south, and associated with drained-lake basin-complex wetlands. The largest lake was approximately 2.8 ha, and the total area covered by lakes and ponds on plot 1-M was approximately 17 ha.

The most abundant habitat type on both plots was unpatterned, low-relief, mesic tundra characterized by small hummocks of sedge/dwarf shrub vegetation interspersed with small areas of wet sedge and frost boils. Both plots contained areas of sedge tussock vegetation; on plot 1-M these areas were unpatterned, and included a low ridge that ran east-west through the center of the plot (location of the proposed road and pad site); the smaller areas of tussock tundra on plot 3-L were more polygonized, with some wet troughs.

Plot 1-M contained significant areas of drained-lake basin-complex wetlands (Bergman et al. 1977), characterized by a mosaic of shallow ponds, wet sedge, and mesic sedge/shrub ridges or mounds. Plot 1-M also contained a small proportion of high-relief low-centered polygon tundra, where wet sedge polygon centers and troughs were interspersed with mesic sedge/shrub polygon rims.

Plot 3-L contained a significant area of high-relief high-centered polygon tundra, interspersed with wet sedge areas and polygon troughs. Plot 3-L also included significant areas of low-relief low-centered polygons, and of unpatterned wet sedge (mainly adjacent to large lakes).

Nest Densities

A total of 19 species nested on plot 1-M and 20 species nested on plot 3-L during 1988-1992 (Tables 2 and 3). Four waterfowl species, ten shorebird species, Lapland longspurs, and willow ptarmigan nested on both plots. Nests of red-throated loons, tundra swans, parasitic jaegers, and western sandpipers were found only on plot 3-L. Nests of northern pintails, rock ptarmigan, and Baird's sandpipers were found only on plot 1-M.

The five-year means for total waterfowl nest density and total shorebird nest density were almost identical on the two plots, but the two plots differed in mean nest densities of individual species. Lapland longspurs had the highest overall average nest density on both plots. Semipalmated sandpipers had by far the highest average nest density among shorebirds on plot 1-M, and semipalmated sandpiper nest densities were higher than Lapland longspur nest densities on plot 1-M in three of the five years of study (1988-1990). Among shorebird species on plot 3-L, pectoral sandpipers had the highest average nest density, and they outranked Lapland longspurs in 1990. Among waterfowl species, greater white-fronted geese had the highest nest densities on plot 1-M in all years. On plot 3-L, greater white-fronted geese had the highest nest densities among waterfowl species during the first two years of the

Table 2. Bird nest densities (nests/sq km) for 1988-1992 on 1-M study plot in the Kuparuk Oilfield on the North Slope of Alaska. 1988 densities are derived from two breeding season searches on a 1.03 sq km plot; 1989-1992 densities are derived from three breeding season searches on the same plot. \bar{x} = five year mean; s = standard deviation; cv = coefficient of variation (s/\bar{x}).

SPECIES	1988	1989	1990	1991	1992	\bar{x}	s	cv
Pacific loon	1.9	1.0	1.9	1.9	1.9	1.7	0.4	0.2
Greater white-fronted goose	4.9	1.9	3.9	3.9	2.9	3.5	1.1	0.3
Northern pintail	0	0	1.0	0	0	0.2	0.4	2.2
King eider	0	0	1.0	1.9	2.9	1.2	1.3	1.1
Oldsquaw	0	1.0	0	1.9	0	0.6	0.9	1.5
Black-bellied plover	2.9	1.0	2.9	1.0	1.9	1.9	1.0	0.5
American golden-plover	1.9	1.0	1.9	1.9	2.9	1.9	0.7	0.4
Semipalmated sandpiper	22.3	24.3	22.3	22.3	19.4	22.1	1.7	0.1
Baird's sandpiper	0	0	1.0	0	0	0.2	0.4	2.2
Pectoral sandpiper	5.8	3.9	18.4	2.9	8.7	7.9	6.3	0.8
Dunlin	3.9	1.9	1.9	1.0	1.0	1.9	1.2	0.6
Stilt sandpiper	1.9	2.9	2.9	1.9	2.9	2.5	0.5	0.2
Buff-breasted sandpiper	0	0	6.8	1.0	2.9	2.1	2.9	1.3
Long-billed dowitcher	1.0	1.0	2.9	1.0	0	1.2	1.1	0.9
Red-necked phalarope	0	0	1.0	2.9	1.9	1.2	1.3	1.1
Red phalarope	1.9	2.9	1.9	0	1.0	1.5	1.1	0.7
Willow ptarmigan	1.9	0	0	0	0	0.4	0.8	2.2
Rock ptarmigan	0	1.0	2.9	0	0	0.8	1.3	1.6
Lapland longspur	15.5	19.4	18.4	35.0	26.2	22.9	7.8	0.3
Total waterfowl:	6.8	3.9	7.8	9.7	7.8	7.2	2.1	0.3
Total shorebirds:	41.7	38.8	64.1	35.9	42.7	44.6	11.2	0.3
Total other birds:	17.5	20.4	21.4	35.0	26.2	24.1	6.9	0.3
Total all birds:	66.0	63.1	93.2	80.6	76.7	75.9	12.1	0.2

Table 3. Bird nest densities (nests/sq km) for 1988-1992 on 3-L study plot in the Kuparuk Oilfield on the North Slope of Alaska. 1988 densities are derived from a single breeding season search on a 0.92 sq km plot; 1989-1992 densities are derived from three breeding season searches on a 1.49 sq km plot. \bar{x} = five year mean; s = standard deviation; cv = coefficient of variation (s/\bar{x}).

SPECIES	1988	1989	1990	1991	1992	\bar{x}	s	cv
Red-throated loon	0	1.3	0	1.3	0.7	0.7	0.7	1.0
Pacific loon	0	1.3	1.3	2.0	2.7	1.5	1.0	0.7
Tundra swan	0	0.7	0.7	0.7	0.7	0.6	0.3	0.5
Greater white-fronted goose	3.3	2.7	1.3	2.0	1.3	2.1	0.9	0.4
King eider	0	0.7	1.3	2.0	2.0	1.2	0.9	0.7
Oldsquaw	1.1	2.0	1.3	0.7	0.7	1.2	0.5	0.5
Black-bellied plover	1.1	1.3	2.7	1.3	2.7	1.8	0.8	0.4
American golden-plover	2.2	1.3	1.3	2.0	1.3	1.6	0.4	0.3
Semipalmated sandpiper	9.8	10.1	12.8	14.1	11.4	11.6	1.8	0.2
Western sandpiper	0	0.7	0	0	0	0.1	0.3	2.2
Pectoral sandpiper	9.8	4.0	23.5	7.4	18.8	12.7	8.2	0.6
Dunlin	3.3	6.7	2.7	4.0	3.4	4.0	1.6	0.4
Stilt sandpiper	0	0.7	2.0	2.7	5.4	2.2	2.1	1.0
Buff-breasted sandpiper	0	0.7	6.0	2.0	0.7	1.9	2.4	1.3
Long-billed dowitcher	0	0	4.0	1.3	2.7	1.6	1.7	1.1
Red-necked phalarope	0	0	0.7	1.3	1.3	0.7	0.7	1.0
Red phalarope	0	6.0	8.7	4.0	12.7	6.3	4.7	0.8
Willow ptarmigan	0	0	0	0.7	0	0.1	0.3	2.2
Parasitic jaeger	0	0.7	0	0.7	0	0.3	0.4	1.4
Lapland longspur	15.2	12.8	18.8	23.5	24.2	18.9	5.0	0.3
Total waterfowl:	4.3	8.7	6.0	8.7	8.1	7.2	1.9	0.3
Total shorebirds:	26.1	31.5	64.4	40.3	60.4	44.5	17.1	0.4
Total other birds:	15.2	13.4	18.8	24.8	24.2	19.3	5.2	0.3
Total all birds:	45.6	53.7	89.3	73.8	92.6	71.0	20.9	0.3

study, but Pacific loons and king eiders had equal or greater nest densities during the final three years.

Comparing the five years of study, total bird nest density was highest on plot 1-M in 1990, followed by 1991 and 1992. On plot 3-L total bird nest density was highest in 1992, followed by 1990 and 1991. On both plots total shorebird nest density was highest in 1990, while total nest densities for waterfowl and other birds were highest in 1991 (although total waterfowl nest density on plot 3-L in 1989 was equal to the high value of 1991).

Variability of nest densities among years was examined by calculating coefficients of variation (c.v.) for each species. Among common species ($5\text{-year } \bar{x} \geq 0.5$), those with the most stable nest densities among years (c.v. ≤ 0.5) on both plots were greater white-fronted goose, black-bellied and American golden-plovers, semipalmated sandpiper, and Lapland longspur. Other species showing low variability in nest densities among years were Pacific loon and stilt sandpiper on plot 1-M, and tundra swan, oldsquaw, and dunlin on plot 3-L. Common species showing high variability in nest densities among years (c.v. ≥ 0.9) included king eider, oldsquaw, and rock ptarmigan on plot 1-M; red-throated loon and stilt sandpiper on plot 3-L; and buff-breasted sandpipers, long-billed dowitchers, and red-necked phalaropes on both plots.

Bird Sightings

A total of 32 species were sighted on plot 1-M and 37 species on plot 3-L during 1988-1992 (Tables 4, 5, and 6). A "bird sighting index" (average bird sightings per square kilometer, described in the METHODS section) was used for relative comparisons between species, plots, and years. The term "abundance" is used to refer to the "bird sighting index" in order to simplify the following discussion of results.

Average total waterfowl sightings were almost identical between the two plots, but total shorebird sightings were higher on plot 3-L, and total sightings of Lapland longspurs were slightly higher on plot 1-M. Lapland longspur, semipalmated sandpiper, and pectoral sandpiper were the most abundant species on both plots. The most abundant waterfowl species were greater white-fronted geese and oldsquaw on plot 1-M, and oldsquaw and king eider on plot 3-L.

Lapland longspurs were the most abundant birds on both plots in all years. Among shorebird species, semipalmated sandpipers were the most abundant on plot 1-M in all years, and pectoral sandpipers were the most abundant on plot 3-L in all years except 1989, when semipalmated sandpipers were more abundant. The most commonly sighted waterfowl species on plot 1-M was greater white-fronted goose in 1988 and 1990, oldsquaw in 1989 and 1992, and king eider in 1991. The highest sighting indices among waterfowl species on plot 3-L were recorded for oldsquaw and greater white-fronted geese in 1988-1989, and for oldsquaw and king eiders in 1990-1992.

Table 4. Bird sighting index (average bird sightings/sq km) for 1988-1992 on 1-M study plot in the Kuparuk Oilfield on the North Slope of Alaska. 1988 index is derived from two breeding season censuses of a 1.03 sq km plot; 1989-1992 indices are derived from three breeding season censuses of the same plot. \bar{x} = five year mean; s = standard deviation; cv = coefficient of variation (s/ \bar{x}).

SPECIES	1988	1989	1990	1991	1992	\bar{x}	s	cv
Pacific loon	2.4	4.5	3.2	3.2	2.3	3.1	0.9	0.3
Greater white-fronted goose	13.1	11.0	10.7	7.4	10.4	10.5	2.0	0.2
Canada goose	0	0	0	0.6	0	0.1	0.3	2.2
Northern pintail	0.5	0.6	2.6	0.3	1.3	1.1	0.9	0.9
King eider	3.9	5.2	2.6	8.4	4.8	5.0	2.2	0.4
Oldsquaw	3.4	11.3	6.5	8.1	11.3	8.1	3.4	0.4
Black-bellied plover	14.6	15.2	11.0	6.8	10.0	11.5	3.5	0.3
American golden-plover	1.9	5.5	6.5	17.1	7.8	7.8	5.7	0.7
Semipalmated sandpiper	44.7	94.5	58.3	59.2	54.0	62.1	19.0	0.3
Baird's sandpiper	0	0	0.6	0	0	0.1	0.3	2.2
Pectoral sandpiper	22.8	37.2	39.8	15.5	38.2	30.7	10.9	0.4
Dunlin	13.6	18.8	7.8	11.6	15.5	13.5	4.1	0.3
Stilt sandpiper	4.9	15.5	7.4	6.8	8.1	8.5	4.1	0.3
Buff-breasted sandpiper	1.5	1.3	14.2	7.1	7.4	6.3	5.3	0.8
Long-billed dowitcher	2.4	7.4	6.8	4.9	11.0	6.5	3.2	0.5
Red-necked phalarope	3.9	3.6	5.5	13.3	9.4	7.1	4.1	0.6
Red phalarope	3.9	8.1	6.8	4.2	4.2	5.4	1.9	0.3
Lapland longspur (male)	69.4	85.1	50.8	91.3	73.8	74.1	15.7	0.2
Lapland longspur (female)	35.4	34.6	21.4	36.6	35.9	32.8	6.4	0.2
Willow ptarmigan	13.1	8.4	2.6	0	0	4.8	5.8	1.2
Rock ptarmigan	11.2	9.7	5.8	3.2	4.2	6.8	3.5	0.5
Pomarine jaeger	0	0.6	0.6	0	0	0.2	0.3	1.4
Parasitic jaeger	2.4	3.9	0.3	0.3	2.3	1.8	1.5	0.8
Long-tailed jaeger	0.5	1.3	1.0	0	1.0	0.8	0.5	0.7
Glaucous gull	1.0	1.0	0	0	0	0.4	0.5	1.4
Sabine's gull	0	0	1.0	2.9	1.0	1.0	1.2	1.2
Arctic tern	0	0	0	0.3	0	0.1	0.1	2.2
Savannah sparrow	0	0	0	0.3	0	0.1	0.1	2.2
Snow bunting	0.5	1.0	2.9	3.2	1.0	1.7	1.2	0.7
Total waterfowl:	23.3	32.7	25.6	28.2	30.1	28.0	3.7	0.1
Total shorebirds:	114.1	207.1	164.7	146.6	165.7	159.6	33.8	0.2
Total longspurs:	104.9	119.7	72.2	127.8	109.7	106.9	21.3	0.2
Total other birds:	28.6	25.9	14.2	10.4	9.4	17.7	9.0	0.5
Total all birds:	270.9	385.4	276.7	312.9	314.9	312.2	45.6	0.1

Table 5. Bird sighting index (average birds sightings/sq km) for 1988-1992 on 3-L study plot in the Kuparuk Oilfield on the North Slope of Alaska. 1988 index is derived from a single breeding season census of a 0.92 sq km plot; 1989-1992 indices are derived from three breeding season censuses of a 1.49 sq km plot. \bar{x} = five year mean; s = standard deviation; cv = coefficient of variation (s/ \bar{x}).

SPECIES	1988	1989	1990	1991	1992	\bar{x}	s	cv
Red-throated loon	0	1.6	0.2	0.9	0.2	0.6	0.7	1.1
Pacific loon	4.3	5.4	4.2	3.1	4.9	4.4	0.9	0.2
Tundra swan	0	0.7	0.7	0.7	0.4	0.5	0.3	0.6
Greater white-fronted goose	9.8	9.8	1.1	0.9	3.1	4.9	4.5	0.9
Brant	0	0.4	0.2	0	0	0.1	0.2	1.5
Canada goose	0	0	0	0.4	0	0.1	0.2	2.2
Northern pintail	2.2	0.9	2.5	2.9	0.4	1.8	1.1	0.6
King eider	5.4	9.2	4.5	8.9	6.9	7.0	2.1	0.3
Oldsquaw	12.0	13.6	5.8	4.2	6.7	8.5	4.1	0.5
Black-bellied plover	8.7	12.5	8.5	9.4	11.4	10.1	1.8	0.2
American golden-plover	2.2	6.3	4.9	8.0	6.0	5.5	2.1	0.4
Whimbrel	0	0	0	1.1	0	0.2	0.5	2.2
Semipalmated sandpiper	39.1	45.4	37.6	28.0	42.5	38.5	6.6	0.2
Western sandpiper	0	0.9	0	0	0	0.2	0.4	2.2
Pectoral sandpiper	68.5	40.7	80.3	43.2	53.7	57.3	16.9	0.3
Dunlin	15.2	16.6	15.2	11.6	11.0	13.9	2.5	0.2
Stilt sandpiper	1.1	10.7	9.6	7.2	14.3	8.6	4.9	0.6
Buff-breasted sandpiper	10.9	3.6	18.1	5.4	3.6	8.3	6.2	0.7
Long-billed dowitcher	1.1	24.6	19.5	12.5	22.8	16.1	9.6	0.6
Red-necked phalarope	1.1	1.6	4.5	2.7	4.3	2.8	1.5	0.5
Red phalarope	4.3	33.6	30.0	15.9	36.7	24.1	13.6	0.6
Lapland longspur (male)	75.0	61.5	53.7	72.7	74.9	67.6	9.5	0.1
Lapland longspur (female)	32.6	30.6	27.3	32.9	34.5	31.6	2.8	0.1
Willow ptarmigan	5.4	0.7	0.2	0.9	0	1.4	2.2	1.6
Rock ptarmigan	0	0.4	1.6	0.9	1.8	0.9	0.8	0.8
Pomarine jaeger	0	1.6	0	0	0	0.3	0.7	2.2
Parasitic jaeger	0	5.6	0	5.1	0	2.1	2.9	1.4
Long-tailed jaeger	1.1	0.4	1.1	0.9	1.3	1.0	0.3	0.4
Glaucous gull	0	0.2	0	0.2	0	0.1	0.1	1.4
Sabine's gull	0	0	0.2	0	0	0.04	0.1	2.2
Snow bunting	0	0	0.4	0	0	0.1	0.2	2.2
Total waterfowl:	33.7	41.6	19.2	22.1	22.8	27.9	9.4	0.3
Total shorebirds:	152.2	196.4	228.2	145.0	206.3	185.6	35.8	0.2
Total longspurs:	107.6	92.2	81.0	105.6	109.4	99.2	12.2	0.1
Total other birds:	6.5	8.9	3.6	8.1	3.1	6.0	2.6	0.4
Total all birds:	300.0	339.1	332.0	280.8	341.6	318.7	26.9	0.1

Table 6. Frequency of occurrence (number of census days on which the species was sighted / total number of census days during the breeding season) of birds flying over two study plots in the Kuparuk Oilfield on the North Slope of Alaska, 1988-1992. Species that were more commonly seen flying over plots than on the ground (aerial hunters), and species that were only seen flying, are included. Species that were most often seen on the ground but were occasionally seen flying are not included.

SPECIES	1988	1989	1990	1991	1992	Total
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PLOT 1-M

Pomarine jaeger	1/7	5/9	1/10	4/9	1/9	12/44
Parasitic jaeger	5/7	9/9	9/10	8/9	9/9	40/44
Long-tailed jaeger	4/7	7/9	5/10	5/9	6/9	27/44
Glaucous gull	5/7	8/9	5/10	5/9	8/9	31/44
Sabine's gull	1/7	4/9	3/10	3/9	4/9	15/44
Arctic tern	0/7	0/9	0/10	3/9	1/9	4/44
Snowy owl	0/7	1/9	0/10	0/9	0/9	1/44
Violet-green swallow	0/7	0/9	1/10	0/9	0/9	1/44
Common raven	0/7	3/9	2/10	1/9	2/9	8/44
Redpoll	0/7	0/9	0/10	1/9	0/9	1/44

PLOT 3-L:

Pomarine jaeger	1/2	4/8	1/10	0/11	1/11	7/42
Parasitic jaeger	2/2	8/8	5/10	9/11	6/11	28/42
Long-tailed jaeger	2/2	5/8	5/10	2/11	8/11	22/42
Glaucous gull	1/2	8/8	4/10	5/11	7/11	25/42
Sabine's gull	0/2	0/8	1/10	1/11	0/11	2/42
Arctic tern	0/2	0/8	1/10	2/11	3/11	6/42
Short-eared owl	1/2	0/8	0/10	0/11	0/11	1/42
Northern harrier	0/2	0/8	0/10	0/11	1/11	1/42
Peregrine falcon	0/2	0/8	0/10	0/11	1/11	1/42
Common raven	0/2	1/8	0/10	0/11	0/11	1/42
Sandhill crane	0/2	0/8	1/10	0/11	0/11	1/42
Spectacled eider	0/2	0/8	0/10	0/11	1/11	1/42

The total bird sighting index was highest on plot 3-L in 1992 (consistent with the highest total bird nest density) but highest on plot 1-M in 1989 (inconsistent with the highest total bird nest density). The greatest total waterfowl abundance was found on both plots in 1989; the greatest total shorebird abundance was found on plot 1-M in 1989 and on plot 3-L in 1990.

Since the sighting index only included sightings of birds seen on the ground, it did not adequately represent use of the plots by aerial predators, which were more often seen flying over the plots than on the ground. For this reason, a separate table was compiled for birds most commonly seen flying over the plots (jaegers, gulls, and raptors) and birds which were only seen flying over the plots (Table 6). Frequency of occurrence was represented by the number of days on which the species was observed, out of the total number of census days during the breeding season. Parasitic jaegers had the highest frequency of occurrence over both plots, followed by glaucous gulls and long-tailed jaegers. Pomarine jaegers were commonly seen in early June, but not on the later censuses. Sabine's gulls and common ravens were regularly seen over plot 1-M but seldom on plot 3-L. Other species were seen only occasionally.

Return Rates and Site Fidelity

"Nesting" and "sighting" return rates for Lapland longspurs and for ten shorebird species were calculated in two different ways (Table 7; see METHODS), with similar results.

Semipalmated sandpiper, black-bellied plover, stilt sandpiper, and dunlin had the highest degree of site fidelity, with known return rates generally greater than 50%. American golden-plover and Lapland longspur had somewhat lower return rates, ranging from 20-50%. Female pectoral sandpipers and male phalaropes had the lowest return rates, ranging from 4-17%. For two species, buff-breasted sandpiper ($n=11$) and long-billed dowitcher ($n=5$), we saw no returns of banded birds.

In those species where return rates could be calculated separately for males and females, the males always had a higher return rate than the females. This relationship was tested statistically for semipalmated sandpipers and Lapland longspurs, and we found that the probability of a bird returning (and being sighted) in any year subsequent to banding is dependent on gender for these two species; males are more likely to return than females ($\chi^2=3.02$, $df=1$, $P=0.08$ for semipalmated sandpiper; $\chi^2=5.45$, $df=1$, $P=0.02$ for Lapland longspur).

Table 8 shows return rates for each year subsequent to the year a bird was banded. The return rates for the first year after banding in Table 8 are slightly lower than the subsequent year return rates in Table 7, because the calculations for the latter may include more than one count of the same bird (if it returned in multiple successive years). Since a bird that returns once is more likely to return in subsequent years (see below), this multiple counting of the same bird tends to boost the "subsequent year" return rate.

Table 7. Return rates (in subsequent year and in any year) for 11 bird species banded on two study plots in the Kuparuk Oilfield on the North Slope of Alaska, 1988-1992. Return rates for "Subsequent Year" are calculated as the percentage of banded birds nesting on the plots in one year that returned to the plots in the year immediately following. Return rates for "Any Year" are calculated as the percentage of banded birds that returned to the plots in any subsequent year. N = Nesting return rate, calculated using only banded birds for which a nest was found; S = Sighting return rate, calculated from all sightings of banded birds, regardless of whether a nest was found; n = sample size (number of banded birds nesting on the plots in 1988-1991).

	Percent Return in Subsequent Year			Percent Return in Any Year		
	N	S	(n)	N	S	(n)
Black-bellied plover	69	69	(13)	60	60	(10)
male	100	100	(7)	100	100	(4)
female	33	33	(6)	33	33	(6)
American golden-plover	30	40	(10)	33	44	(9)
male	38	50	(8)	43	57	(7)
female	0	0	(2)	0	0	(2)
Semipalmated sandpiper	53	62	(227)	56	60	(133)
male	56	64	(121)	65	68	(65)
female	50	58	(106)	49	53	(68)
Dunlin	38	60	(40)	36	61	(28)
Stilt sandpiper	44	56	(18)	50	64	(14)
Long-billed dowitcher	0	0	(5)	0	0	(5)
Pectoral sandpiper (female)	6	6	(47)	7	7	(46)
Buff-breasted sandpiper (female)	0	0	(11)	0	0	(11)
Red-necked phalarope (male)	0	17	(6)	0	17	(6)
Red phalarope (male)	4	4	(23)	5	5	(22)
Lapland longspur	30	35	(122)	27	35	(100)
male	37	49	(41)	39	52	(31)
female	26	28	(81)	22	28	(69)

Table 8. Return rates (in first through fourth year after banding) for 11 bird species banded on two study plots in the Kuparuk Oilfield on the North Slope of Alaska, 1988-1992.
 N = Nesting return rates, calculated using only banded birds for which a nest was found;
 S = Sighting return rates, calculated from all sightings of banded birds, regardless of whether a nest was found; n = sample size (number of banded nesting birds); ND = no data.

Species	% Return 1st Year		% Return 2nd Year		% Return 3rd Year		% Return 4th Year	
	N	S (n)						
Black-bellied plover	50	50 (10)	50	50 (4)	100	100 (1)	100	100 (1)
male	75	75 (4)	100	100 (2)	100	100 (1)	100	100 (1)
female	33	33 (6)	0	0 (2)	ND	ND	ND	ND
American golden-plover	33	44 (9)	0	0 (2)	100	100 (1)	ND	ND
male	43	57 (7)	0	0 (2)	100	100 (1)	ND	ND
female	0	0 (2)	ND	ND	ND	ND	ND	ND
Semipalmated sandpiper	52	59(130)	35	46 (97)	30	34 (80)	28	30 (43)
male	57	65 (63)	40	52 (50)	38	40 (40)	32	36 (22)
female	47	53 (66)	30	39 (46)	23	28 (39)	24	24 (21)
Dunlin	29	50 (28)	16	48 (25)	25	30 (20)	13	25 (8)
Stilt sandpiper	43	57 (14)	29	29 (7)	25	25 (4)	ND	ND
Long-billed dowitcher	0	0 (5)	0	0 (4)	ND	ND	ND	ND
Pectoral sandpiper								
female	7	7 (46)	0	0 (35)	0	0 (19)	0	0 (10)
Buff-breasted sandpiper								
female	0	0 (11)	0	0 (7)	ND	ND	ND	ND
Red-necked phalarope								
male	0	17 (6)	0	0 (1)	ND	ND	ND	ND
Red phalarope								
male	5	5 (22)	0	0 (17)	0	0 (11)	0	0 (1)
Lapland longspur								
male	26	31(100)	17	27 (52)	13	16 (32)	ND	ND
female	35	45 (31)	27	47 (15)	33	33 (9)	ND	ND
	22	25 (69)	14	19 (37)	4	9 (23)	ND	ND

After the first year subsequent to banding, sighting return rates tended to decrease each succeeding year in a roughly linear fashion (Figure 6). Assuming that most of this decrease is due to mortality rather than emigration (for the site-faithful species), we were able to project the approximate lifespan after banding to be about 7 years for semipalmated sandpipers and dunlin, and 5 years for Lapland longspurs. These estimates do not take into account the age of a bird at the initial banding.

For semipalmated sandpipers, we also plotted sighting return rates for each year of the study, separately for males and females that were newly banded in the previous year vs. males and females that had been banded (and returned) at least one year previously (Figure 7). This graph indicates that birds that returned at least once tended to return at a relatively constant rate (around 70%), and the rate was virtually identical for males and females. Newly banded birds, however, showed much greater variability in return rates. As the study progressed, and the majority of semipalmated sandpiper adults were banded each year, newly banded birds would be predominantly young birds breeding for the first time and/or new immigrants to the plots.

Mate Fidelity

Mate fidelity is the tendency of returning birds to reform the same pair bonds from the previous year, and is measured by the proportion of banded pairs in a given year that return to the area and reunite in the following year. If only one member of a pair returns to the previous nesting area, it may not be known whether its former mate died or took a new mate. Therefore, to calculate mate fidelity we only considered pairs in which both members of the pair were banded and both members returned ("R" in Table 9). This restriction led to very small sample size for all species except semipalmated sandpiper, for which mate fidelity was 68% ($n=37$). Mate fidelity was 100% for black-bellied plover ($n=2$), and stilt sandpiper ($n=1$), 50% for dunlin ($n=2$), and 33% for Lapland longspur ($n=6$).

Site Tenacity

While site fidelity is the tendency to return to the same general area of a previous nesting attempt, site tenacity refers to the degree to which a bird chooses the same site or territory for nesting from one year to the next. Site tenacity may be measured by mapping territories, but a simpler measure of site tenacity is to calculate the distance moved between nest sites in subsequent years for returning individuals within the study area (Gratto et al. 1985).

In considering site tenacity, the actual distance moved is less important than whether or not a bird returned to the same territory. Since we did not map individual territories, we instead made a rough estimate of territory radius based on average nesting densities for each species found in our plots. This estimate is probably an overestimate, as it is based on an assumption of even distribution of nests, roughly circular territories, and utilization of every available

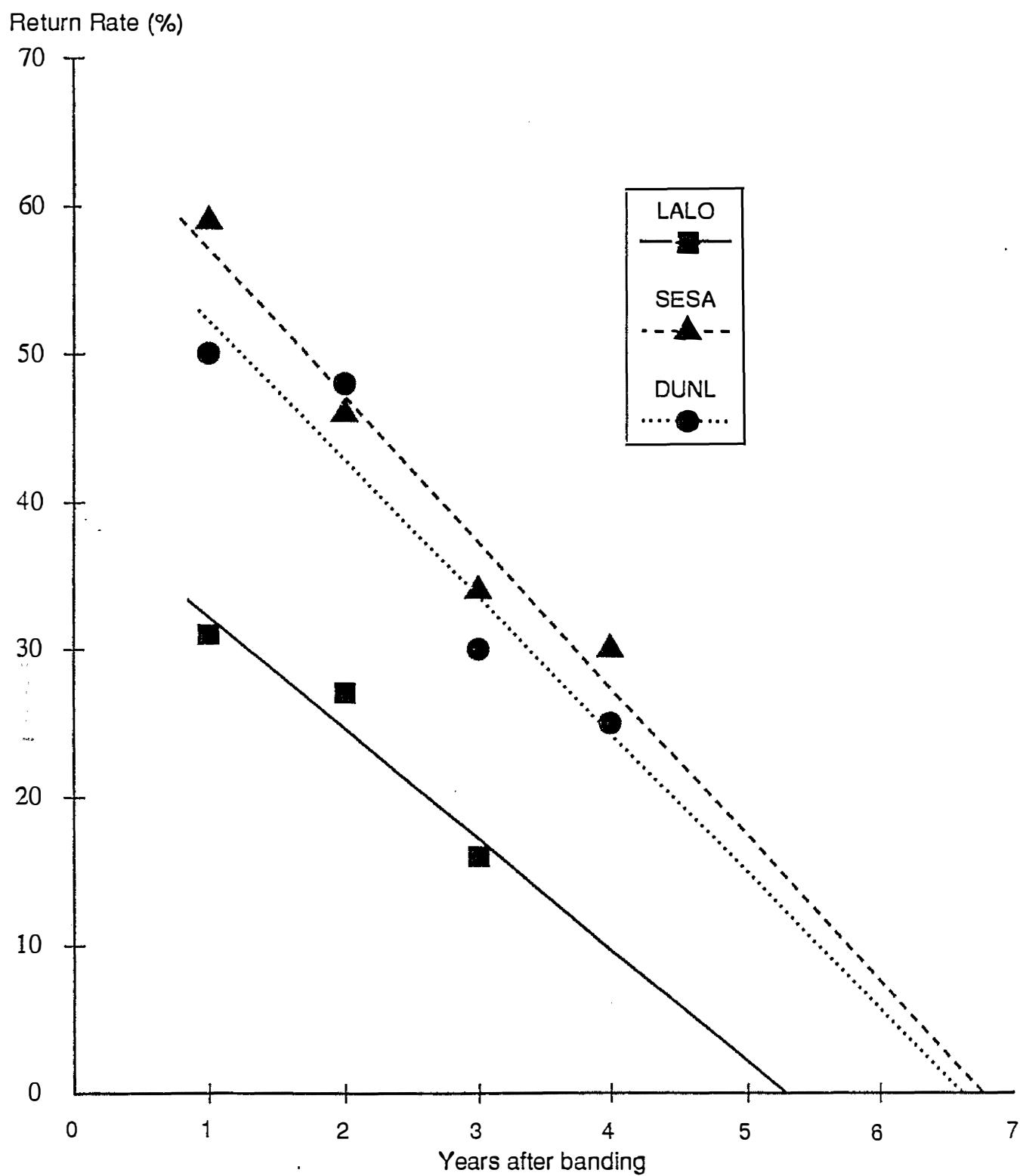


Figure 6. Return rates (percent of adult birds sighted in each year subsequent to being banded) for three bird species (LALO = Lapland longspur, SESA = semipalmated sandpiper, DUNL = dunlin) on two study plots in the Kuparuk Oilfield on the North Slope of Alaska, 1989-1992. Lines derived by linear regression.

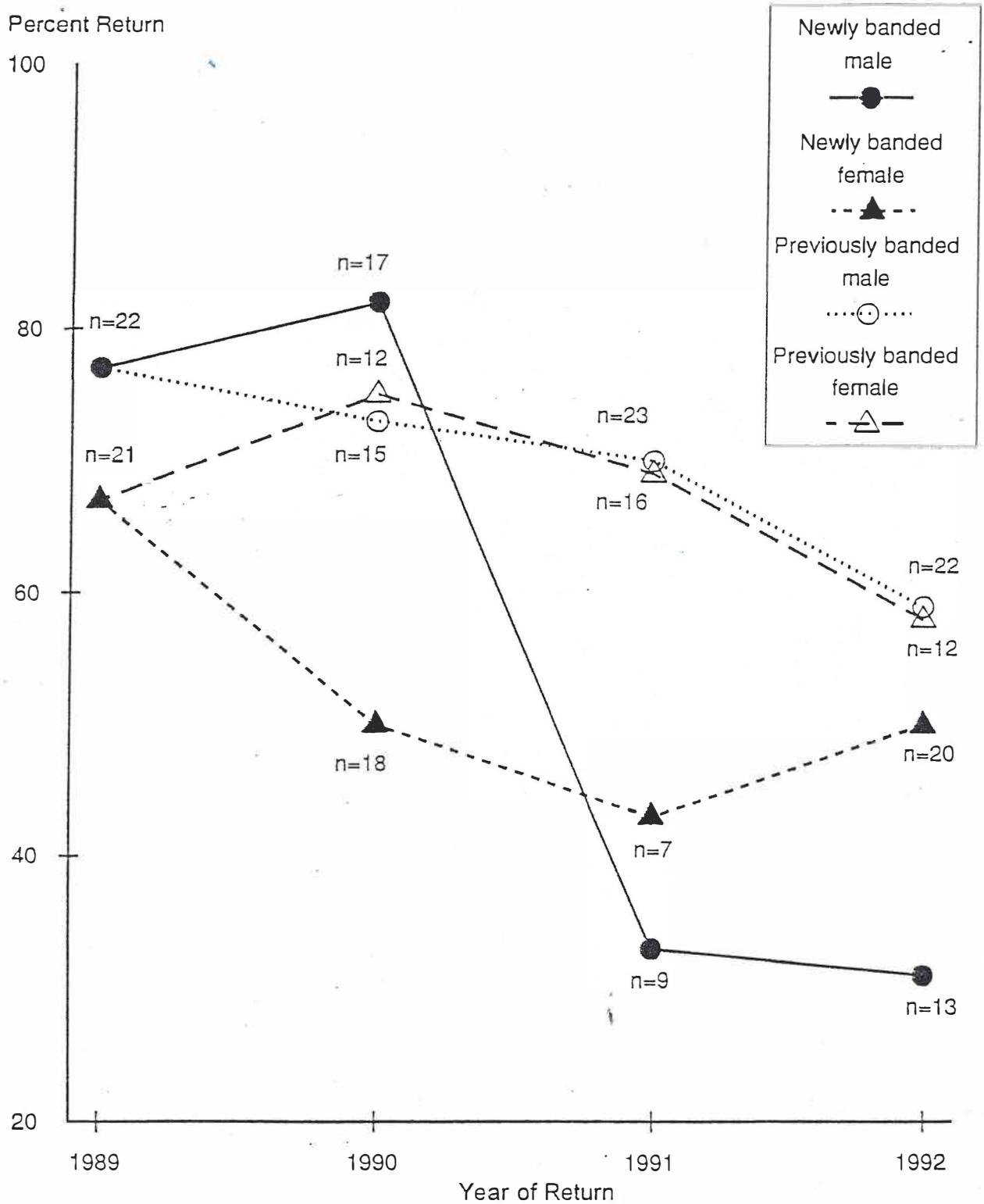


Figure 7. Sighting return rates (birds sighted in each year as a percent of those nesting on plots in the previous year) for semipalmated sandpipers banded on two study plots in the Kuparuk Oilfield on the North Slope of Alaska, 1988-1991.

Table 9. Fate of breeding pairs of seven bird species in the following year, in the Kuparuk Oilfield on the North Slope of Alaska, 1988-1992.

T = total number of pairs with both members banded, 1988-1991

R = number of pairs where both members were banded and both returned

R-B = number of pairs where both members returned and bred together again

R-N = number of pairs where both members returned but did not breed together

R-U = number of pairs where both members returned, unknown whether bred together

M = number of pairs where only the male returned

F = number of pairs where only the female returned

O = number of pairs where neither the male nor female returned

	T	R	R-B	R-N	R-U	M	F	O
Black-bellied plover	4	2	2	0	0	2	0	0
American golden-plover	2	0	0	0	0	1	0	1
Semipalmated sandpiper	87	37	25	10	2	23	14	13
Dunlin	8	2	1	0	1	5	1	0
Stilt sandpiper	4	1	1	0	0	2	0	1
Long-billed dowitcher	1	0	0	0	0	0	0	1
Lapland longspur	30	6	2	3	1	12	4	8

habitat type by every species. We found that for all shorebird species, the average distance moved between nest sites was less than our estimate of territory radius, suggesting that most returning birds are returning to the same territory, from one year to the next (Table 10). There were some individuals, however, especially females, that were probably switching territories between years (as indicated by the ranges of distances moved). For three of the four territorial shorebird species for which we have data on both sexes, the mean distance moved by males was less than the mean distance moved by females, but not significantly less for the two species we could test statistically (Mann-Whitney $\chi^2=0.17$, $df=1$, $P=0.68$ for semipalmated sandpipers; $\chi^2=0.94$, $df=1$, $P=0.332$ for dunlin).

In contrast with the shorebird species, mean distance moved between nest sites for Lapland longspurs (both male and female) exceeded our estimate of territory radius, suggesting that with this species there is more changing of territories between years. However, the range of distances moved indicate that some individuals of both sexes did return to the same territory from one year to the next. For Lapland longspurs, we found that females tended to move greater distances than males (Mann-Whitney $\chi^2=4.02$, $df=1$, $P=0.045$).

When we tested whether the probability of a bird returning to its territory in the subsequent year is influenced by gender and/or by type (shorebirds vs. Lapland longspurs), we confirmed that longspurs are less likely to return to the same territory than shorebirds ($\chi^2=19.65$, $df=1$, $P=0.001$). The magnitude of the χ^2 statistic was most influenced by the predominance of female Lapland longspurs that left their territories, and the predominance of male shorebirds that returned to the same territories.

Some individual stilt sandpipers, semipalmated sandpipers, and dunlin re-used the same nest-cup from one year to the next (i.e., distance moved = 0, in Table 10). The longest distances moved between years were documented for Lapland longspurs (509 m for males and 782 m for females). Since these distances were more than halfway across our plots, it suggests that many movements for this species were likely to have been completely off the plots, thus immigration/emigration may be a significant factor in our calculated return rate for that species, and the mean distance between nests may be biased downward.

Relating site tenacity to mate fidelity (Table 11), we found that for semipalmated sandpipers the highest degree of site tenacity was generally shown by individuals that returned with the same mate. When we compared intact pairs to males and females returning with a new mate, we found a difference among groups ($F=8.16$, $df=2$, $P=0.0007$). The *a posteriori* test revealed that while males and females with new mates moved similar distances, intact pairs moved less ($P<0.05$). Re-use of the same nest cup from one year to the next was most common among intact pairs. Sample sizes were insufficient to test differences between intact pairs and birds with new mates for other shorebird species.

For Lapland longspurs, when we compared intact pairs with males and females returning with a new mate, we found a difference among groups ($F=3.11$, $df=2$, $P=0.072$). The *a posteriori* test revealed that males with new mates moved significantly less than females with new mates

Table 10. Mean distances moved between nest sites in successive years for eight bird species on two study plots in the Kuparuk Oilfield on the North Slope of Alaska, 1988-1992.
 M = male; F = female; U = unknown.

Species	Sex	Radius of Territory (m)	Avg. Mean Distance Moved (m)	Range of Distances (m)	Sample Size
Black-bellied plover	M	412	252	116-436	6
	F		276	116-436	2
American golden-plover	M	425	175	46-289	3
Semipalmated sandpiper	M	144	109	0-387	71
	F		142	0-581	55
Dunlin	M	337	134	0-340	8
	F		195	23-428	6
Stilt sandpiper	M	366	88	0-217	5
	F		67	44-89	2
	U		363		1
Pectoral sandpiper	F	176 ^a	176	101-217	3
Red phalarope	M	329 ^a	319		1
Lapland longspur	M	123	193	22-509	14
	F		347	21-782	21

^a Non-territorial species; radius calculated for comparative purposes.

Table 11. Mean distances moved between nest sites in successive years for six bird species, as related to mate fidelity, on two study plots in the Kuparuk Oilfield on the North Slope of Alaska, 1988-1992.

Species	Radius of Avg. Territory (m)	Mean Distance Moved (m)	Range of Distances (m)	Sample Size
Black-bellied plover	412	276	116-436	2
intact pair male with new mate	267	231-303		2
American golden-plover	425	46	0-208 0-387 0-581	1
male with new mate			25 27 17	
Semipalmated sandpiper	144	82 148 277	0-208 0-387 0-581	25 27 17
intact pair				
male with new mate female with new mate				
Dunlin	337	23 79 428	0-158	1 2 1
intact pair				
male with new mate female with new mate				
Stilt sandpiper	366	44	1	1
intact pair				
Lapland longspur	123	208 174 470	134-281 22-509 35-782	2 10 6
intact pair				
male with new mate female with new mate				

($P=0.05$), but distance moved by intact pairs was not significantly different from either of these two groups.

Re-use of Nest Sites

A number of pairs and individual semipalmated sandpipers, stilt sandpipers, and dunlin re-used nest cups from one year to the next. We also noted re-use of nest cups by different individuals of the same species, re-use of nest-cups after intervals of longer than a year, and re-use of nest cups by individuals of different species (Table 12).

The highest rates of nest site re-use were observed for Pacific loons (71%) and tundra swans (67%). Among the shorebirds, semipalmated sandpipers, stilt sandpipers, and dunlin had the highest rates of re-use of nest sites (17%, 15%, and 10%, respectively). The majority of these re-uses occurred in successive years. In contrast, Lapland longspurs re-used nest cups only 3% of the time, and half of these re-uses occurred after an interval of two or more years. Two pectoral sandpipers re-used dunlin nest cups, and one American golden-plover pair re-used a stilt sandpiper nest cup.

Among semipalmated sandpipers, the majority (75%) of nest cup re-use was by the same individual or pair returning the following year or two years later. However, at least 14% of semipalmated sandpiper nest cup re-use was by pairs in which both members were known to be different from the previous occupants. In the remaining 11% of semipalmated sandpiper nest cup re-use, one member of the pair was known to be different, but the other was unknown. Only one semipalmated sandpiper nest cup was known to have been re-used three years in succession.

Nesting Phenology

Nest initiation dates from 1989 to 1992 varied among species and years (Table 13). The small sample sizes of many species in some or all years make it difficult to assess year to year trends. Among six species with at least three nests documented each year (semipalmated sandpiper, pectoral sandpiper, dunlin, stilt sandpiper, red phalarope, and Lapland longspur), we found that years of earlier or later nest initiation tended to be similar across species (Friedman test $T=7.95$, $df=3$, $P<0.05$). When we tested the hypothesis that mean nest initiation dates for these six species did not vary among years, we found four species had mean nest initiation dates that varied among years: semipalmated sandpiper, pectoral sandpiper, red phalarope, and Lapland longspur (Kruskal-Wallis $P\leq0.0005$). The multiple comparisons revealed that 1989 and 1991 were most similar (had later initiation dates - see Table 13), and 1990 was most different (had earliest initiation dates)(LSD $P=0.05$). Lapland longspurs and stilt sandpipers consistently had the earliest median nest initiation date, while buff-breasted sandpipers and long-billed dowitchers were the latest nesting shorebirds.

Table 12. Instances of known re-use of nest cups by birds on two study plots in the Kuparuk Oilfield on the North Slope of Alaska, 1989-1992. Re-use was by the same species unless indicated in footnotes. "Total Nests Found" includes only nests found in 1989-92 within plots or portions of plots that had been searched for nests in at least one previous year.

	Total Nests Found	Total Known Re-uses	No. of Re-used Sites	Re-used after 1 year	Re-used after 2 years ^a	Re-used after 3 years ^a	Re-used after 4 years ^a
Red-throated loon	4	1 (25%)	1		1		
Pacific loon	17	12 (71%)	7	9	3		
Tundra swan	3	2 (67%)	2	1		1	
King eider	14	1 (7%)	1	1			
American golden-plover	19	1 ^b (5%)	1		1		
Semipalmated sandpiper	168	28 (17%)	25	20	8		
Pectoral sandpiper	113	3 ^c (3%)	3	2	1		
Dunlin	29	3 (10%)	3	2	1		
Stilt sandpiper	27	4 (15%)	3	4			
Long-billed dowitcher	17	1 (6%)	1	1			
Red phalarope	50	1 (2%)	1	1			
Lapland longspur	222	6 (3%)	6	3	1	1	1

^a Re-used after x years means site was used in year 1 and year 1+x, but not in intervening years.

^b Re-use of a stilt sandpiper nest cup

^c Re-use of 1 pectoral sandpiper nest cup and 2 dunlin nest cups

Table 13. Median nest initiation dates for 21 bird species on two study plots in the Kuparuk Oilfield on the North Slope of Alaska, 1989-1992. Sample sizes are in parentheses.

SPECIES	1989	1990	1991	1992
Red-throated loon	-	-	12 July (1)	-
Pacific loon	21 June (1)	16 June (2)	-	19 June (4)
Tundra swan	-	1 June (1)	1 June (1)	-
Greater white-fronted goose	9 June (2)	1 June (1)	31 May (2)	7 June (1)
King eider	20 June (2)	15 June (1)	20 June (2)	17 June (3)
Oldsquaw	25 June (1)	-	-	-
Black-bellied plover	21 June (1)	12 June (2)	14 June (4)	9 June (4)
American golden-plover	11 June (1)	12 June (2)	8 June (4)	11 June (5)
Semipalmated sandpiper	12 June (28)	5 June (34)	13 June (35)	7 June (39)
Baird's sandpiper	-	30 May (1)	-	-
Pectoral sandpiper	17 June (7)	4 June (38)	14 June (11)	9 June (25)
Dunlin	10 June (7)	11 June (4)	8 June (6)	8 June (3)
Stilt sandpiper	8 June (4)	3 June (3)	7 June (6)	4 June (7)
Buff-breasted sandpiper	20 June (1)	12 June (10)	17 June (3)	11 June (2)
Long-billed dowitcher	3 July (1)	17 June (7)	18 June (2)	21 June (1)
Red-necked phalarope	-	7 June (1)	18 June (4)	18 June (4)
Red phalarope	10 June (6)	7 June (17)	18 June (6)	14 June (7)
Willow Ptarmigan	-	-	6 June (1)	-
Rock ptarmigan	-	6 June (1)	-	-
Parasitic jaeger	15 June (1)	-	7 June (1)	-
Lapland longspur	8 June (26)	3 June (48)	6 June (67)	5 June (62)

Median nest initiation dates for semipalmated sandpiper pairs at Kuparuk in which at least one member was previously banded were 3 days earlier in 1991 and 1 day earlier in 1992, than for pairs in which neither member was previously banded. There was no difference in median nest initiation dates between these two groups in the earlier years of our study, probably because many of the unbanded birds were actually returning birds that we had not managed to band in the previous year, whereas in the later years of the study most unbanded birds were likely birds that had not previously nested on the plots. In 1991, pairs in which both members of the pair were known to have been previously banded had a mean nest initiation date 2 days earlier than pairs in which only one member was known to have been previously banded, but this difference was not evident in 1992, a year when all birds nested earlier.

Few nest initiation dates were known or could be calculated for waterfowl nests, but some general trends were noted. Greater white-fronted geese tended to have early nest initiation dates; all nests were initiated by June 16 in 1989 and 1991, and by June 11 in 1990 and 1992. The earliest known initiation was two nests initiated on May 31, 1991. Tundra swans also initiated their nests early; the known dates were June 1 in 1990 and 1991, and swans had initiated their nests by June 10 in 1989 and 1992. The only northern pintail nest was found on June 10, 1990, with 9 eggs, so it also had an early initiation date.

Nest initiation dates for loons, eiders, and oldsquaw tended to be somewhat later in the season. All red-throated loon nests were found between June 19-29, except for one nest known to have been initiated July 12, 1991, which was likely a re-nest by a pair whose nest had failed. All Pacific loons were first seen on nests between June 17 and July 9, with known initiation dates ranging from June 15-24. King eider nests were all found in the latter half of June, with known initiation dates ranging from June 15-22. Oldsquaw nests were generally found in late June or early July; the only known initiation date was June 25, 1989, but at least one nest in 1990 was known to have been initiated by June 6. In general, among the four years 1989-92, the earliest dates for waterfowl nest initiation were in 1990 and 1991, while the later dates were in 1989 and 1992.

There were few nests in this study for which incubation periods could be determined with certainty (i.e., nests which were found with incomplete clutches, AND for which hatch dates were known), but most were consistent with values reported elsewhere (see Appendix C). Known incubation periods for semipalmated sandpiper were 19 days (5 nests) or 20 days (3 nests), with one nest that took 26 days to hatch. Known incubation periods for Lapland longspurs were 10 days (3 nests), 11 days (4 nests), or 12 days (4 nests). For American golden-plover we recorded incubation periods of 25, 26, and 27 days; for black-bellied plover 26 and 27 days; and for buff-breasted sandpiper 23 and 25 days (a single nest for each of these observations). Only one nest with known incubation period was recorded for the following species: dunlin (21 days), pectoral sandpiper (23 days), stilt sandpiper (20 days), red phalarope (20 days), and Pacific loon (25 days).

Nest Success

Probability of nest success, estimated using the Mayfield (1975) method, was calculated for 23 species nesting on the study plots in 1989-1992 (Table 14). In 1988, we determined fate for very few nests (due to limited time for observations): 12 of 32 Lapland longspur nests had known nest fates, of which 10 were successful. The only other known outcome in 1988 was a dunlin nest that was preyed upon by jaegers.

The common shorebird species with highest overall estimated nest success rates from 1989-1992 were semipalmated sandpiper (81%), dunlin (77%), and red phalarope (77%). The shorebird species with lowest overall nest success were American golden-plover (47%), black-bellied plover (64%) and buff-breasted sandpiper (67%). Overall estimated nest success of other common shorebird species ranged from 71-73%. The waterfowl species with highest overall nest success from 1989-1992 were Pacific loon (60%), tundra swan (51%), and king eider (50%). Other waterfowl species had overall estimated nest success of 16% or less. Lapland longspur overall estimated nest success from 1989-1992 was 79%. Fledging success was not determined by this study, but observations of chick predation suggested that fledging success was likely much lower than nest success.

Semipalmated sandpiper nest success was consistently high, ranging between 77-84% among years. Pectoral sandpipers also had fairly consistent nest success ranging from 68-76%. Most other species had less consistent nest success among years. Lapland longspur nest success ranged from 46-89%, dunlin from 58-86%, and red phalarope from 53-100%.

All shorebird species, as well as loons and eiders, had above-average nest success in 1989, but Lapland longspur nest success was below average in that year. In 1992, most shorebird species had below average nest success, with the exception of semipalmated sandpipers and long-billed dowitchers, which were above average in that year. Pacific loons, tundra swans, and king eiders also had below average nest success in 1992. No consistent trends in nest success were discernible in 1990 and 1991, although Lapland longspurs, American golden-plovers, greater white-fronted geese, and tundra swans had their highest rates of nest success in those two years.

Clutch Size

Mean clutch sizes for 23 bird species nesting on our study plots are presented in Table 15. Clutch sizes for red-throated and Pacific loons were most often two eggs but occasionally one egg. Clutch size for both known tundra swan nests was three eggs. Mean clutch sizes for geese and ducks are given as minimum estimates, because for the majority of nests only one count was made. After a nest was found, every effort was made not to flush the incubating birds on subsequent visits, so final clutch size was often unknown. Intense predation on waterfowl nests (evidenced by decreasing numbers of eggs on subsequent visits) also gave us reason to question whether we were seeing complete clutches. Greater white-fronted goose

Table 14. Estimates of nest success (based on Mayfield 1975) for 23 bird species on two study plots in the Kuparuk Oilfield on the North Slope of Alaska, 1989-1992. N = total number of nests found; F = number of nests known to have failed; P = estimated probability of nest success (with 95% confidence interval).

SPECIES	1989			1990			1991			1992			4-Year Total		
	N	F	P	N	F	P	N	F	P	N	F	P	N	F	P
Red-throated loon	2	2	0.17 ±0.09	0	-	-	3	3	0.07 ±0.11	1	1	0.13 ±0.15	6	6	0.11 ±0.06
Pacific loon	3	0	1.00 ±0.00	4	1	0.73 ±0.02	6	2	0.49 ±0.04	6	3	0.42 ±0.04	19	6	0.60 ±0.01
Tundra swan	1	1	0.25 ±0.09	1	0	1.00 ±0.00	1	0	1.00 ±0.00	1	1	0.16 ±0.11	4	2	0.51 ±0.03
Greater white-fronted goose	7	6	0.02 ±0.10	7	4	0.25 ±0.05	7	4	0.29 ±0.04	5	3	0.19 ±0.06	26	17	0.16 ±0.03
Northern pintail	0	-	-	1	1	0.00 ±0.43	0	-	-	0	-	-	1	1	0.00 ±0.43
King eider	2	0	1.00 ±0.00	4	1	0.63 ±0.04	5	2	0.45 ±0.05	6	3	0.36 ±0.05	17	6	0.50 ±0.02
Oldsquaw	4	3	0.05 ±0.13	2	1	0.00 ±0.36	3	1	0.25 ±0.11	2	1	0.06 ±0.21	11	6	0.07 ±0.08
Black-bellied plover	6	1	0.63 ±0.03	7	2	0.57 ±0.03	4	0	1.00 ±0.00	8	3	0.50 ±0.03	25	6	0.64 ±0.01
American golden-plover	5	1	0.53 ±0.05	4	1	0.62 ±0.04	9	3	0.54 ±0.03	6	4	0.29 ±0.05	24	9	0.47 ±0.02
Semipalmated sandpiper	45	5	0.84 ±0.01	47	7	0.78 ±0.01	44	7	0.77 ±0.01	43	5	0.84 ±0.01	179	24	0.81 ±0.00
Western sandpiper	1	1	0.03 ±0.30	0	-	-	0	-	-	0	-	-	1	1	0.03 ±0.30
Baird's sandpiper	0	-	-	1	0	1.00 ±0.00	0	-	-	0	-	-	1	0	1.00 ±0.00
Pectoral sandpiper	10	1	0.76 ±0.02	57	8	0.74 ±0.01	15	3	0.70 ±0.02	41	8	0.68 ±0.01	123	20	0.71 ±0.01
Dunlin	13	1	0.86 ±0.01	7	2	0.58 ±0.04	8	1	0.84 ±0.02	7	1	0.72 ±0.03	35	5	0.77 ±0.01
Stilt sandpiper	4	0	1.00 ±0.00	6	1	0.66 ±0.04	7	1	0.79 ±0.02	12	3	0.57 ±0.03	29	5	0.71 ±0.01
Buff-breasted sandpiper	1	0	1.00 ±0.00	17	3	0.75 ±0.01	4	2	0.42 ±0.05	4	1	0.54 ±0.05	26	6	0.67 ±0.01
Long-billed dowitcher	1	0	1.00 ±0.00	9	2	0.72 ±0.02	3	0	0.50 ±0.06	4	1	1.00 ±0.00	17	3	0.73 ±0.02
Red-necked phalarope	0	-	-	2	1	0.44 ±0.08	5	0	1.00 ±0.00	4	1	0.63 ±0.05	11	2	0.72 ±0.02
Red phalarope	12	1	0.89 ±0.01	17	1	0.86 ±0.01	7	0	1.00 ±0.00	20	5	0.53 ±0.03	56	7	0.77 ±0.01
Willow ptarmigan	0	-	-	0	-	-	1	0	1.00 ±0.00	0	-	-	1	0	1.00 ±0.00
Rock ptarmigan	1	1	0.00 ±0.43	3	2	0.24 ±0.08	0	-	-	0	-	-	4	3	0.14 ±0.08
Parasitic jaeger	1	0	1.00 ±0.00	0	-	-	1	0	1.00 ±0.00	0	-	-	2	0	1.00 ±0.00
Lapland longspur	40	11	0.46 ±0.04	51	3	0.88 ±0.01	77	4	0.89 ±0.01	70	7	0.81 ±0.01	238	25	0.79 ±0.01

Table 15. Mean clutch sizes for 23 bird species on two study plots in the Kuparuk Oilfield on the North Slope of Alaska, 1988-1992. Sample sizes are in parentheses. Clutch sizes with \geq symbol represent minimal estimates, based on a single visit to the nest.

SPECIES	1988	1989	1990	1991	1992
Red-throated loon	-	2.0 (2)	-	1.5 (2)	2.0 (1)
Pacific loon	2.0 (1)	2.0 (2)	2.0 (2)	1.5 (2)	2.0 (4)
Tundra swan	-	-	3.0 (1)	3.0 (1)	-
Greater white-fronted goose	≥ 4.6 (7)	≥ 3.7 (7)	≥ 3.1 (6)	≥ 3.6 (7)	≥ 4.0 (5)
Northern pintail	-	-	≥ 9.0 (1)	-	-
King eider	-	≥ 4.0 (2)	≥ 2.0 (3)	≥ 3.0 (4)	≥ 3.6 (5)
Oldsquaw	≥ 1.0 (1)	≥ 4.0 (4)	≥ 6.5 (2)	≥ 5.5 (2)	≥ 5.0 (2)
Black-bellied plover	4.0 (2)	4.0 (4)	4.0 (7)	4.0 (4)	3.9 (8)
American golden-plover	4.0 (3)	3.8 (5)	3.8 (4)	3.8 (9)	4.0 (5)
Semipalmated sandpiper	4.0 (30)	4.0 (46)	3.9 (46)	3.6 (40)	3.9 (42)
Western sandpiper	-	4.0 (1)	-	-	-
Baird's sandpiper	-	-	4.0 (1)	-	-
Pectoral sandpiper	3.9 (15)	4.0 (10)	3.9 (56)	4.0 (15)	4.0 (40)
Dunlin	4.0 (8)	4.0 (13)	3.7 (7)	3.9 (8)	3.9 (7)
Stilt sandpiper	4.0 (2)	4.0 (4)	4.0 (6)	3.9 (7)	3.9 (12)
Buff-breasted sandpiper	-	4.0 (1)	4.0 (16)	4.0 (4)	4.0 (4)
Long-billed dowitcher	3.0 (1)	4.0 (1)	4.0 (9)	4.0 (3)	4.0 (4)
Red-necked phalarope	-	-	4.0 (2)	4.0 (5)	4.0 (4)
Red phalarope	4.0 (2)	3.9 (13)	4.0 (15)	3.7 (7)	3.7 (16)
Willow ptarmigan	-	-	-	8.0 (1)	-
Rock ptarmigan	-	-	6.0 (1)	-	-
Parasitic jaeger	-	2.0 (1)	-	2.0 (1)	-
Lapland longspur	4.8 (13)	4.9 (38)	5.3 (50)	4.8 (69)	4.8 (62)

clutches which were known to be complete most commonly had four or five eggs, but clutches of six and eight eggs were also found. The only northern pintail nest had nine eggs. King eider clutches ranged from two to five eggs, and oldsquaw clutches ranged from two to seven eggs.

Shorebird clutch sizes were more consistent, usually four eggs but occasionally two or three. Mean clutch sizes for all shorebird species were close to 4.0 in all years. Clutch sizes for Lapland longspurs ranged from three to six eggs. Mean clutch size for longspurs was similar in all years except 1990, when it was slightly higher. Both parasitic jaeger nests had two eggs, and the only known clutch sizes for willow and rock ptarmigan were eight eggs and six eggs, respectively.

Brood Movements

On average, the distance of semipalmated sandpiper broods from their nest site increased gradually each day subsequent to hatch (Figure 8), although there was considerable variability in distance moved. Some broods remained in or adjacent to the grid square where the nest was located throughout the brood-rearing period, while others moved as far as 800 m from the nest site within seven days of hatch. Amount of movement is likely related to proximity of suitable brood-rearing habitat to the nest site. Plotting movements of individual semipalmated sandpiper broods on grid maps indicated that the majority of movements were toward lake-basin complex wetlands, or along lake shores.

Pectoral sandpiper, stilt sandpiper, and dunlin broods also, on average, moved increasing distances from their nest sites as they grew older (Figures 9, 10 and 11), and generally moved faster and farther than semipalmated sandpiper broods. No stilt sandpiper or dunlin broods remained in the vicinity (within same 50-m grid square) of their nest site more than one day after hatching. Maximum movements recorded were 696 m in 11 days for pectoral sandpiper, 912 m in 11 days for dunlin, and 1006 m in 14 days for a stilt sandpiper brood.

Brood observations for black-bellied and American golden-plovers, red and red-necked phalaropes, and buff-breasted sandpipers were too few to plot average distances moved, but these additional sightings are included in Table 16. Most broods of these five species were sighted within the first three days after hatching and in close proximity to the nest site. The longest brood movement recorded among these five species was for black-bellied plover broods seen 400 m from their nest sites on the fifth and tenth day after hatch.

Brood Attendance

Semipalmated sandpiper brood attendance for 1992 is shown in Figure 12. The cumulative total of nests that successfully hatched broods is shown for each day, as well as the number of banded males and females known to still be with a brood on each day. Initially all three lines

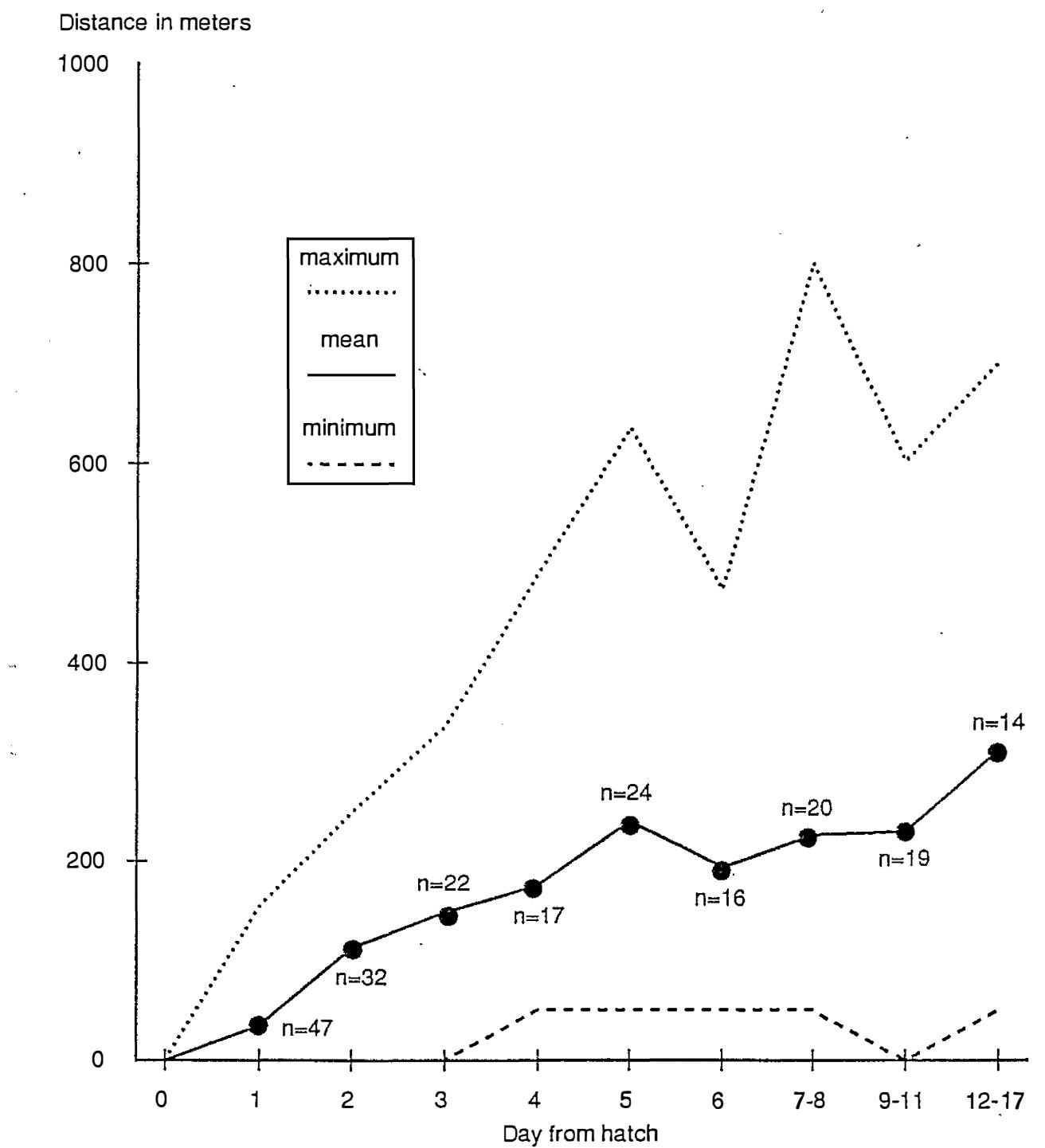


Figure 8. Semipalmated sandpiper brood movements (mean distance from nest site in meters) for each day after hatch, on two study plots in the Kuparuk Oilfield on the North Slope of Alaska, 1989-1992.

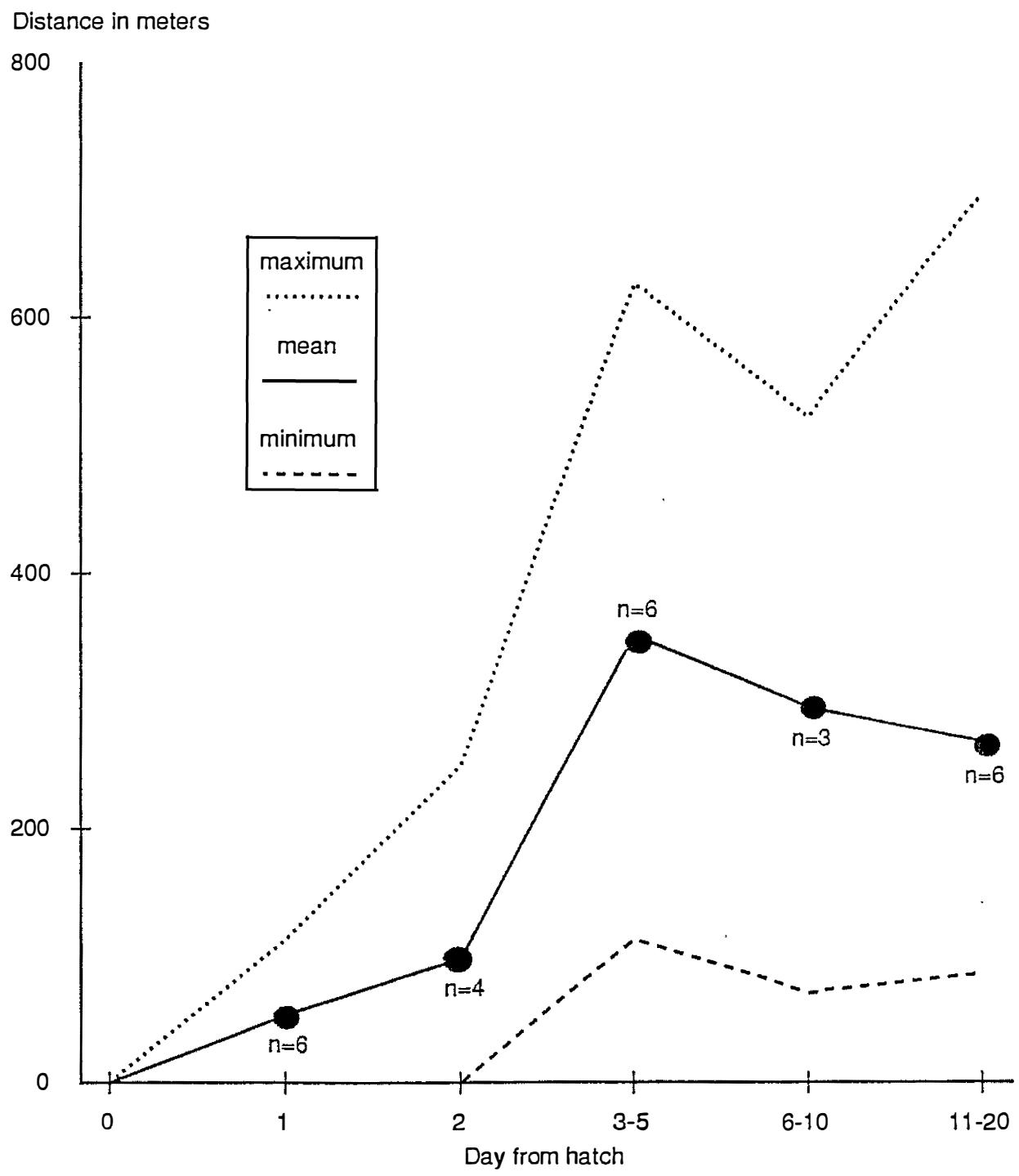


Figure 9. Pectoral sandpiper brood movements (mean distance from nest site in meters) for each day after hatch, on two study plots in the Kuparuk Oilfield on the North Slope of Alaska, 1989-1992.

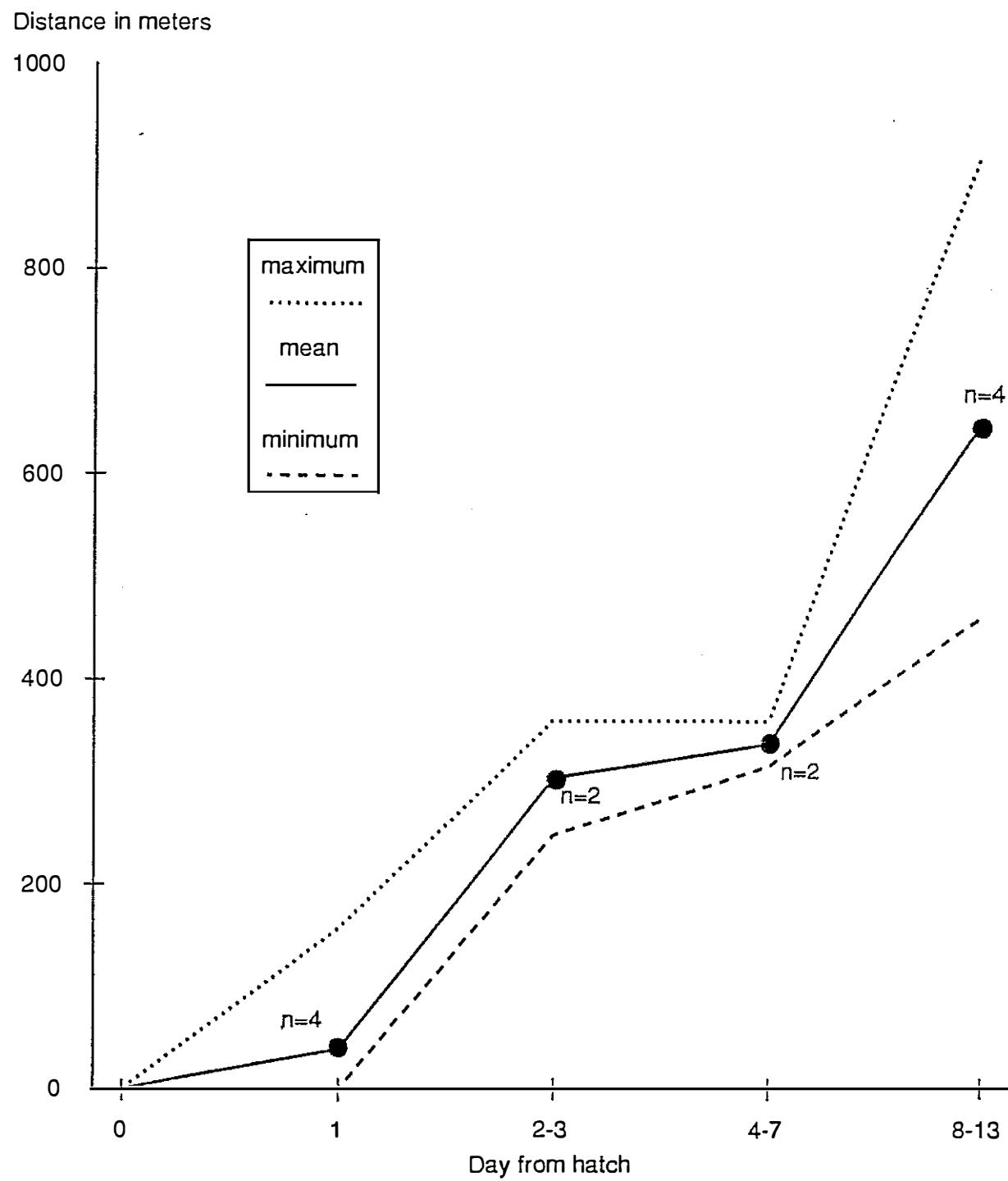


Figure 10. Dunlin brood movements (mean distance from nest site in meters) for each day after hatch, on two study plots in the Kuparuk Oilfield on the North Slope of Alaska, 1989-1992.

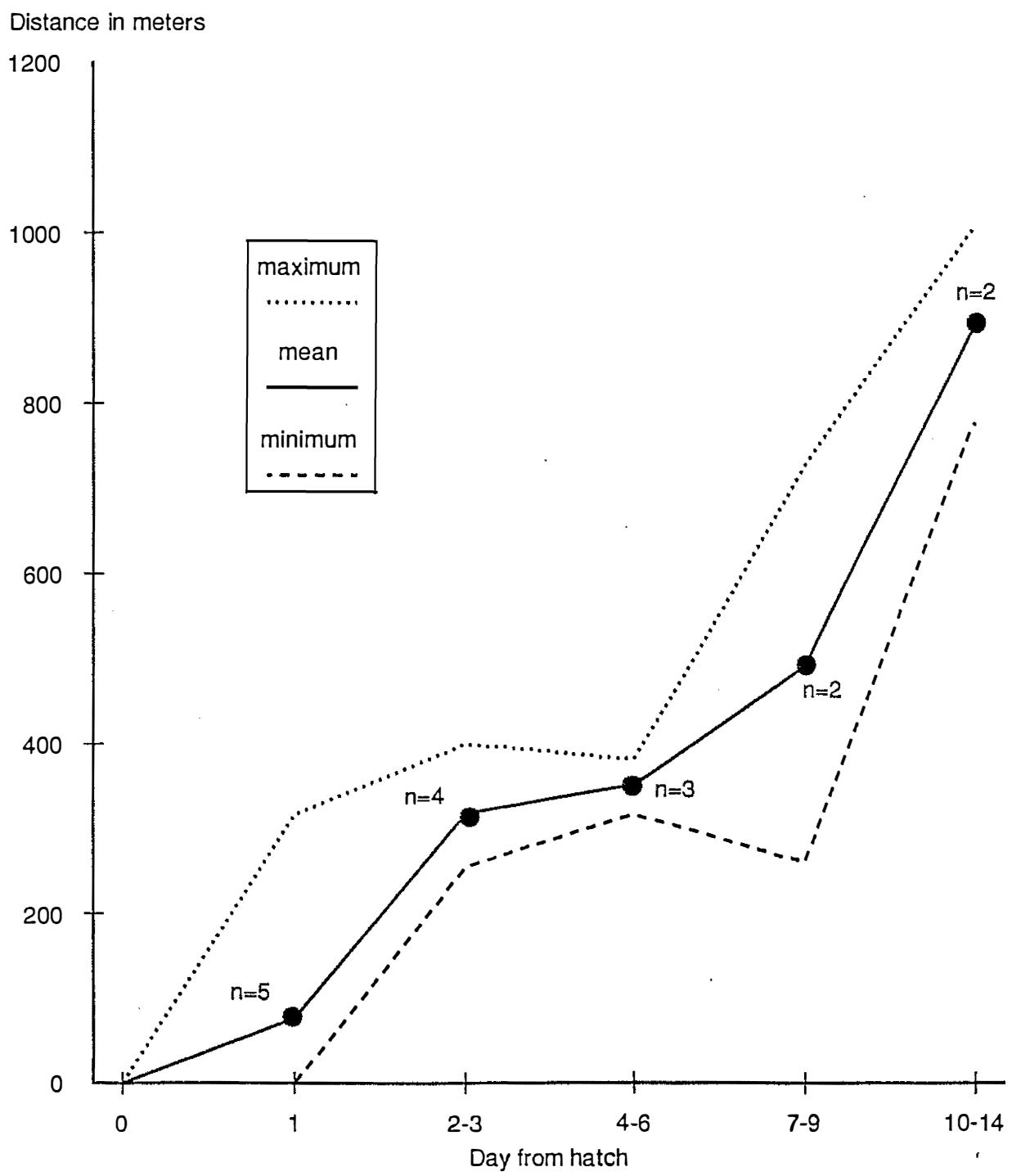


Figure 11. Stilt sandpiper brood movements (mean distance from nest site in meters) for each day after hatch, on two study plots in the Kuparuk Oilfield on the North Slope of Alaska, 1989-1992.

Table 16. Brood movements (\bar{x} = average distance moved from nest site in meters, n = sample size) of five shorebird species in two study plots in the Kuparuk Oilfield on the North Slope of Alaska. BBPL (black-bellied plover) and AMGP (American golden-plover) data are from 1991-92; REPH (red phalarope) data are from 1989-1991; RNPH (red-necked phalarope) data are from 1990-1992; and BBSA (buff-breasted sandpiper) data are from 1990.

Days after hatch	<u>BBPL</u> \bar{x} (n)	<u>AMGP</u> \bar{x} (n)	<u>REPH</u> \bar{x} (n)	<u>RNPH</u> \bar{x} (n)	<u>BBSA</u> \bar{x} (n)
1	0 (3)	140 (2)	0 (2)	83 (3)	0 (2)
2	0 (1)	0 (1)	0 (1)	250 (1)	
3	140 (1)			150 (1)	
5	400 (1)				
6			112 (1)		
10	400 (1)				

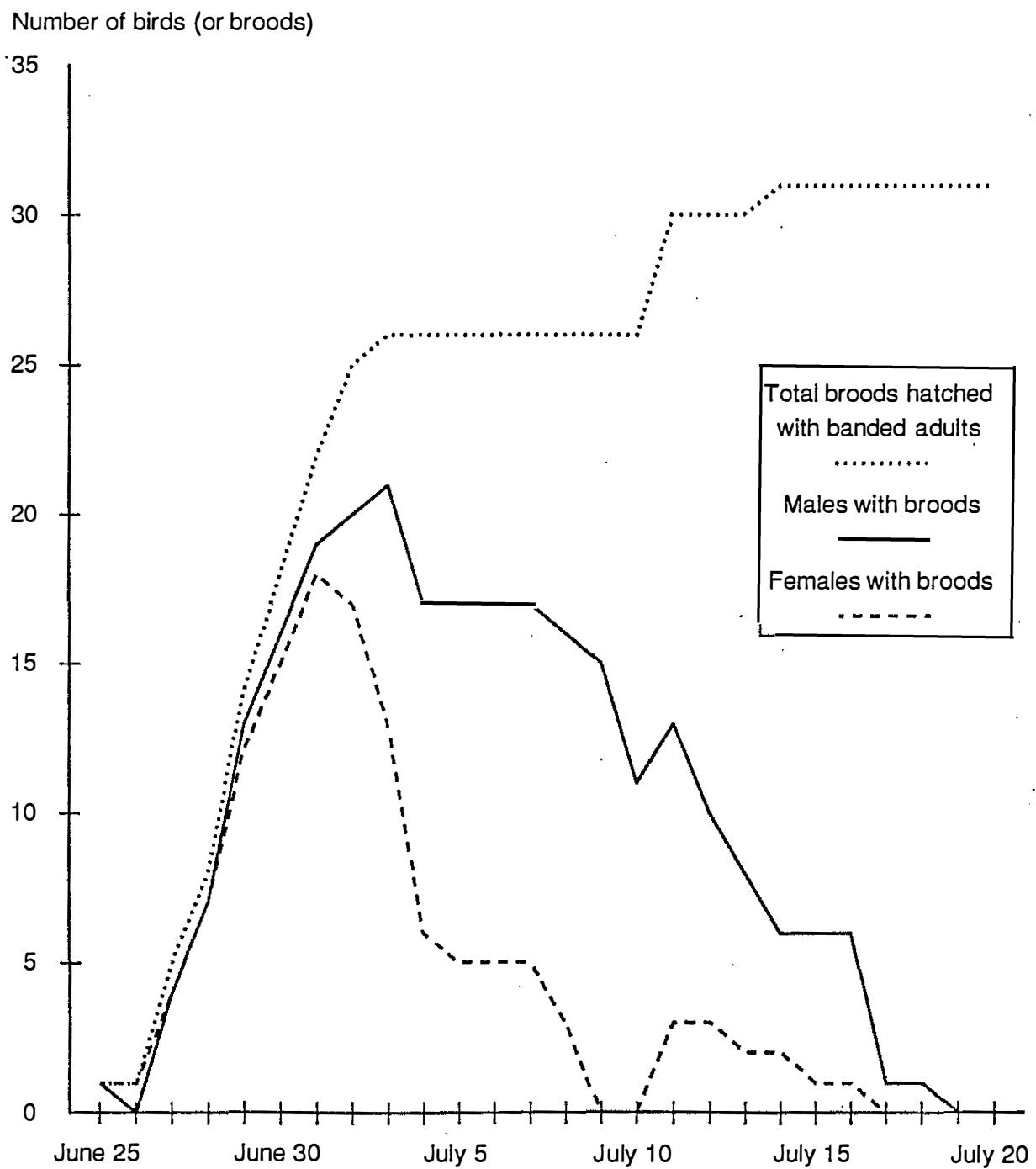


Figure 12. Semipalmated sandpiper brood attendance (number of males and females with broods, by date) in 1992, on two study plots in the Kuparuk Oilfield on the North Slope of Alaska.

three days, respectively. Brood attendance data for other shorebird species were scanty, but the following observations were made. Three pairs of stilt sandpipers that hatched broods on June 27-28 and one pair that hatched a brood on July 8, were seen with broods for only one day after hatch. One stilt sandpiper pair that hatched a brood on July 1 was observed with their brood seven days later. Three male dunlin that hatched broods June 28, July 2, and July 3 were observed with their broods for thirteen, eight, and seven days respectively. No female dunlin were observed with broods more than one day subsequent to hatch. One male and one female black-bellied plover that hatched separate broods on July 8, were seen with their broods for ten days and

been due to loss of broods to predation.

Hatching dates of successful pectoral sandpiper broods in 1992 were less synchronous than semipalmated sandpipers, and more evenly distributed from June 28 through July 19 (Figure 13). Pectoral sandpiper females perform all incubation and brood-rearing without participation by their mate. Number of females with broods peaked around July 5, and began to decline gradually after July 10. The average time that female pectoral sandpipers were observed with broods was six days, and the maximum time was 21 days. The low average times that adult pectoral as well as semipalmated sandpipers were seen with broods, may have been due to loss of broods to predation.

Average time that males and females were observed with broods was eight days and four days, respectively, and maximum times observed with broods were 18 days for males and 10 days for females. Within individual pairs of semipalmated sandpipers, 50% of broods had the male in attendance longer than the female; both adults were observed for the same time period for 37% of broods; and the female was in attendance longer than the male for 13% of the broods. Females remained with broods after July 8 from the initial June 25-July 2 hatching of nests; however, a few more females were observed with broods after additional nests hatched on July 11-14. Within individual pairs of semipalmated sandpipers, 50% of broods had the male in attendance longer than the female; both adults were observed for the same time period for 37% of broods; and the female was in attendance longer than the male for 13% of the broods. Females remained with broods after July 3, and declined gradually throughout the remainder of the brood-rearing period. The number of females with broods decreased more precipitously, and no rearing was a peak around July 11. The number of males with broods there was a second spurt of hatching around July 11. Most successful nests had hatched by July 2, although departure from the study area, July 20. Most successful nests had hatched by July 2, although in 1992, the semipalmated sandpiper brood-rearing period extended from June 25 until our

emigration of the broods off the plots, or abandonment of the broods by the adults. Number of broods hatched. This decline may be due to mortality of the broods (or adults), coincide, but the number of males and females with broods quickly drops below the total

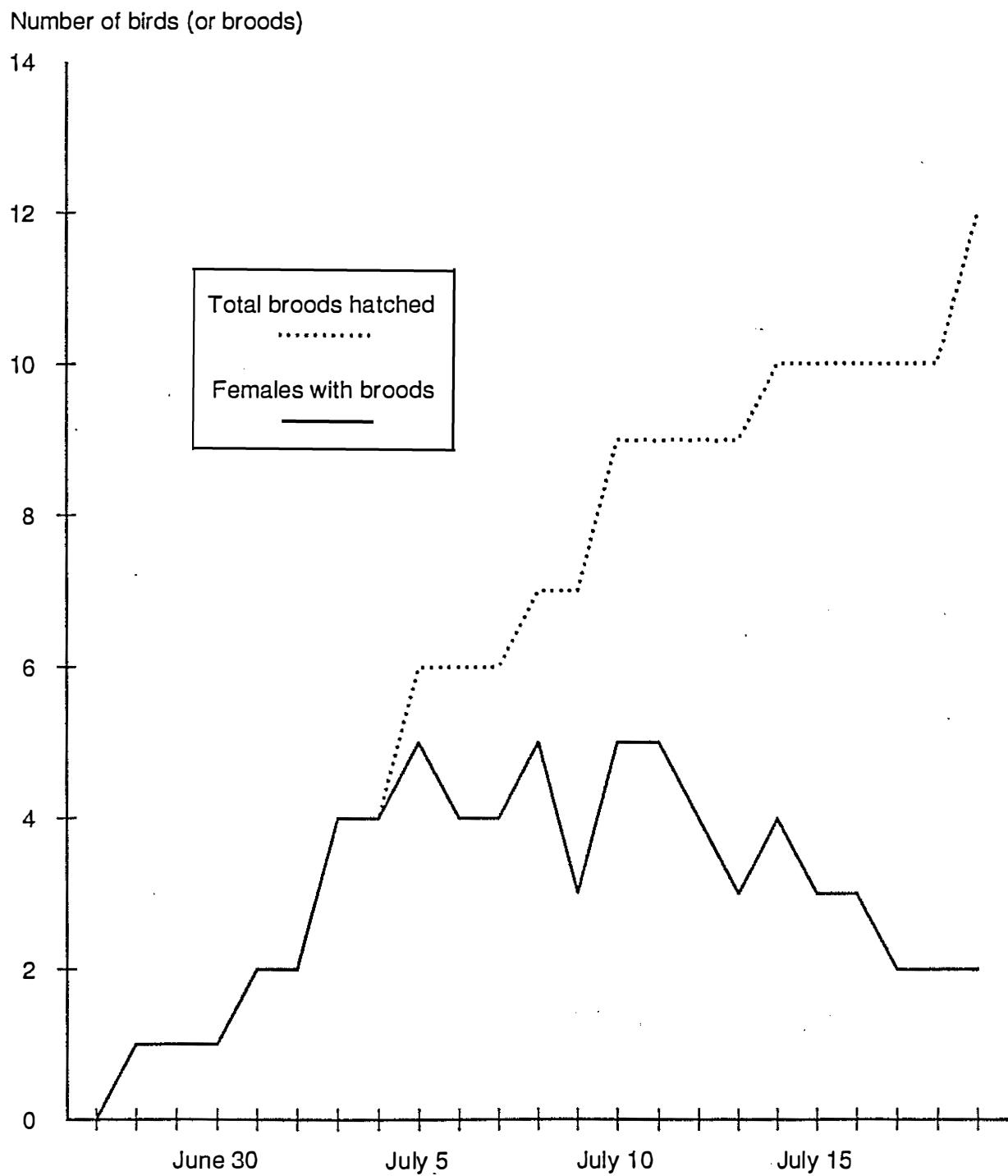


Figure 13. Pectoral sandpiper brood attendance (number of females with broods, by date) in 1992, on two study plots in the Kuparuk Oilfield on the North Slope of Alaska.

DISCUSSION

Bird and Nest Density

Because the arctic coastal plain is used by significant numbers of nonbreeding birds during the breeding season, censusing bird numbers alone cannot adequately assess changes in breeding bird populations. Troy (1992) found strong correlations between bird density and nest density for only three species (pectoral sandpiper, buff-breasted sandpiper, and red phalarope) during a nine-year study of breeding birds at Pt. McIntyre, near Prudhoe Bay. In this study we found average bird sightings/nest corresponded to breeding pairs only for loons and swans. For most shorebirds, Lapland longspurs, greater white-fronted geese, and king eiders there were 3-5 sightings/nest, but the ratio was 8/1 for long-billed dowitchers, and about 10/1 for oldsquaw and ptarmigan. Some of the skewed ratios may have been due to differences in sightability of birds and in our ability to find nests. In other cases, the numbers likely reflect the presence of a non-breeding component of the population (e.g., flocks of staging and feeding long-billed dowitchers observed on plot 3-L). Because of the variability of bird sightings relative to breeding populations, nest densities may be more useful in evaluating the status and trends of breeding bird populations, and in making comparisons of breeding bird densities between study areas, habitats, or years. Habitat requirements of nonbreeders, however, should also be considered in any assessment of relative habitat values.

Troy and Wickliffe (1990) summarized average nest densities reported from a number of sites across Alaska's North Slope, including Barrow, Pt. McIntyre, Prudhoe Bay Oilfield, Sagavanirktok River delta, 12 Mile TAPS (south of Prudhoe Bay), and six sites on the Arctic National Wildlife Refuge (ANWR). Overall average nest densities, as well as average total shorebird nest densities, at our two Kuparuk study sites were similar to those recorded at Prudhoe Bay and Pt. McIntyre, lower than at Barrow, 12-Mile, and the Canning River delta (ANWR), and higher than Sagavanirktok delta and the other five ANWR study sites.

Average total waterfowl nest densities at the Kuparuk sites were higher than at any other North Slope site (7.2/sq km at Kuparuk vs. 5.4/sq km at Barrow, the next highest site). The greatest contributor to high waterfowl nest densities at Kuparuk was greater white-fronted goose, whose average nest density (2.1/sq km on plot 3-L, 3.5/sq km on plot 1-M) was far greater than any of the sites summarized by Troy and Wickliffe (1990).

Average nest densities of semipalmated sandpipers and pectoral sandpipers at Kuparuk were exceeded by only two other North Slope sites, and average nest densities of black-bellied plovers and long-billed dowitchers were higher at Kuparuk than at any other site. These latter two species are relatively uncommon breeders on Alaska's North Slope (Johnson and Herter 1989), so their unusually high nesting densities at Kuparuk may indicate some local habitat factors which are particularly favorable for nesting of these species. Our habitat analysis (to follow) may further elucidate what those factors might be, but species-specific studies would likely be needed to determine precisely which factors favor the higher nesting densities of these less common species.

1970, Jehl 1973, Gratto et al. 1985), whereas those species thought to be more opportunistic predictably and defendable food sources have been shown to have high return rates (Soikkeli 1974, Greenwood 1980, Myers and Pitelka 1981). Arctic nesting shorebirds that use predicted by social organization, mating systems, and patterns of resource use (Pitelka et al. Some authors have suggested that patterns of dispersal and site fidelity in birds may be

Return Rates and Site Fidelity

Highest overall shorebird nest density at Kuparuk occurred in 1990, with pectoral sandpipers, buff-breasted sandpipers, and long-billed dowitchers making the greatest contribution to this peak. 1990 was the year with the warmest temperatures and earliest snowmelt out of the five years of this study, suggesting that weather may have been a factor influencing the high nest density. Waterowl nest density, however, peaked in 1991.

In a ten-year study (1981-1991) of bird nest densities at Pt. McIntyre (Troy 1992), among-year differences were significant only for pectoral sandpipers and Lapland longspurs. Highest densities for pectoral sandpipers occurred in 1990, consistent with our results at Kuparuk. Kuparuk we found high nest densities for Lapland longspurs in 1991 (and 1992), but 1988 had relatively low nest densities. At Kuparuk, snowmelt was later in 1988 than the other five years of the study, and June temperatures were below average, so weather may have been a factor influencing longspur nest densities.

The shorebird species consistently showing low inter-annual variability in nest densities at Kuparuk were semipalmated sandpipers, black-bellied plovers, and American golden-plovers, which are all monogamous and territorial species. Other monogamous and territorial species (dunlin and split sandpiper), however, showed low inter-annual variability on only one of the two plots. Among the non-territorial species in which a single sex incubates, high annual variability in nest densities might be expected based on their opportunistic strategy of resource use (Pitelka et al. 1974), but this did not consistently appear as a clear pattern on our plots (e.g., dunlin on plot I-M) were as variable as pectoral sandpipers on plot 3-L).

Compartison of breeding bird densities found at the various North Slope sites in these different studies can lead to only tenuous conclusions, however, due to differences in plot sizes, plot selection criteria, study objectives and methods, numbers of censuses per year, number of years of study, intensity of nest searches, and training of observers. Few of the studies, this one among them, used a plot selection method designed to provide overall characterization of the region. Most of them selectively placed plots in particular habitat types, or in particular spatial or geographic locations. Plot size selection may also affect comparisons; Spindler and Miller (1983) found that in three out of four habitat types, estimates of breeding bird density obtained from 2-3 replicate 10-ha plots differed significantly (up to 91%) from those obtained from a single large plot.

in selecting the best available habitat show low breeding site fidelity, when there is annual variation in favorable sites (Schamel and Tracy 1991).

The degree of site fidelity shown by monogamous shorebirds suggests that certain advantages are realized by returning to a previous nesting site. The advantages may include reuniting with an experienced mate, lower energy demands through abbreviated courtship, earlier nesting initiation and synchrony with favorable food resource availability, and familiarity with the territory. Presumably, other groups of birds that show a high degree of site fidelity, such as loons, realize similar theoretical advantages.

Whereas monogamous shorebird species apparently realize advantages by returning to the vicinity of a previous nesting attempt, there seems to be less advantage for species with non-monogamous mating systems, such as pectoral sandpipers, red phalaropes, and buff-breasted sandpipers. Pitelka et al. (1974) hypothesized that species with non-monogamous systems are able to realize an ecological advantage by exploiting areas of high-density food resources, a feature of the mating system that may lead to a clumped distribution of nesting birds. Regardless of whether the hypothesis of Pitelka et al. (1974) is valid for all non-monogamous species, low site fidelity and variable nesting density must be viewed as the result of an overall strategy of adaptation and not as a simple response to habitat conditions.

Oring and Lank (1984) tabulated the degree of site fidelity for 15 shorebird species, and characterized those species with the highest site fidelity as being monogamous, having biparental care, and exhibiting joint defense of breeding territories, while species that were not strongly site faithful were characterized by uniparental care and little territorial behavior. The return rates reported for monogamous species ranged between 38%-84%, most commonly above 60%; for non-monogamous species they ranged between 0%-79%, most commonly below 50%. Our findings of 56-69% return rates for four monogamous and territorial shorebirds (semipalmated and stilt sandpipers, dunlin, and black-bellied plover), and 0-17% for four non-monogamous species (pectoral and buff-breasted sandpipers, red and red-necked phalaropes) all fall within these ranges, and actually indicate a clearer separation between the two groups.

A problem inherent in measures of site fidelity, however, is the factor of scale, and what is considered a "site". Since most studies of shorebird site fidelity have focused on study areas of 100 ha or less, it is possible that the greater site fidelity reported for monogamous and territorial species is simply a reflection of their greater nest site tenacity (see below), while non-monogamous shorebirds returning to the general area, but not to the exact site of a previous nest, are detected at lower rates due to limitations of study area size. Since we lack the means to determine the dispersal distances and locations of the non-returning birds, it is difficult to draw any definitive conclusions about differences in site fidelity among species. We can, however, make some comparisons of our return rates for individual species with those found at other study sites, given similar study methods.

The degree of site fidelity for the semipalmated sandpiper in this study was similar to that determined in a five-year study of semipalmated sandpipers nesting in a sub-arctic environment at La Perouse Bay, Manitoba (Gratto et al. 1985), where nesting return rates ranged from 33% to 57%, calculated separately for males and females each year. We found nesting site fidelity of 50% for female and 56% for male semipalmated sandpipers, averaged over the five years of our study. A similar study conducted in the nearby Prudhoe Bay Oilfield in 1988-89 (Troy and Carpenter 1990) found nesting site fidelity of 57% for semipalmated sandpipers (both sexes combined).

Gratto et al. (1985) found semipalmated sandpiper return rates of 67% and 49% for two separate years of their study, but considered the higher value representative of the normal survival rate for the population studied. Our overall sighting return rate of 62% suggests that the survival rate in arctic populations is similar to the subarctic population at La Perouse Bay.

The 60% return rate for dunlin in our study indicates a high degree of site fidelity comparable with the subarctic Scandinavian population (*Calidris alpina schinzii*) studied by Soikkeli (1970). The latter study found an average return rate of 73% over an 8-year period. The degree of site fidelity may be magnified in that study, however, since the study site was a group of isolated patches of nesting habitat 100 km distant from the next nearest permanent nesting population. A similar study in the Prudhoe Bay Oilfield yielded a nesting return rate of 50% for dunlin (Troy and Carpenter 1990).

Our average sighting return rates for black-bellied plovers (69%) and American golden-plovers (40%) were somewhat lower than the average return rates of 78% for male and 77% for female Eurasian golden plovers (*Pluvialis apricaria*) returning in five years (1974-78) to breeding grounds in northeast Scotland (Parr 1980). Johnson et al. (1993) reported site fidelity of 100% for eight males and 25% for four females of the Pacific golden-plover (*Pluvialis fulva*) during 1988-1991 near Nome in western Alaska. Troy (TERA, pers. comm.) obtained a nesting return rate in the year subsequent to banding of 67% for 3 black-bellied plovers and 31% for 29 American golden-plovers banded in 1988-91 in the Prudhoe Bay Oilfield, which is consistent with our results. Whether the lower return rate of American golden-plovers compared to black-bellied plovers in North Slope oilfields is due to a lesser degree of site fidelity or to a higher mortality rate is unclear.

Schamel and Tracy (1991) reported site fidelity (based on percent return in any year) of 9% for male red phalaropes breeding at Barrow, and 16% at Cape Espenberg, Alaska. Those return rates were somewhat higher than the 5% return rate for male red phalaropes at Kuparuk. Schamel and Tracy also reported site fidelity of 56% for male red-necked phalaropes at Cape Espenberg, which was significantly greater than found by Reynolds and Cooke (1988) at La Perouse Bay, Manitoba (34%), and also considerably greater than the 17% return rate for male red-necked phalaropes at Kuparuk.

Custer and Pitelka (1977) estimated adult survival of Lapland longspurs in a six-year study at Barrow, Alaska as 43% for males and 45% for females, based on returns of banded birds.

Our sighting return rate of 49% for male Lapland longspurs was similar, but our rate of 28% for females was much lower than Custer and Pitelka's value. Our lower return rate for female Lapland longspurs may have been due to higher emigration rates from our plots, as might be expected based on the longer distances moved between nest sites by females returning with new mates. Consistent with our results, Troy and Carpenter (1990) found nesting return rates of 30% for Lapland longspurs (primarily females) banded in 1988 in the Prudhoe Bay Oilfield.

Our estimates of longevity for Lapland longspurs (5 years), semipalmated sandpipers (7 years), and dunlin (7 years) are consistent with what others have reported. Maximum lifespan reported by Custer and Pitelka (1977) for Lapland longspurs at Barrow was 6 years; Hanson (pers. comrn.) reported return of a banded semipalmated sandpiper for 9 years. Longevity for Eurasian golden plovers in northeast Scotland, based on survival of banded chicks, was calculated to be just over 6 years (Parr 1980). Gratto (1988) found that most semipalmated sandpipers began breeding at age two, although some began at one year and some later. Parr (1980) found that both sexes of Eurasian golden plovers bred successfully in their first year. Dunlin may breed in their first summer (Holmes 1966), although in Finland most do not breed until their second year (Soikkeli 1967).

Site Tenacity

Gratto et al. (1985) examined nest site tenacity for semipalmated sandpipers at La Perouse Bay, Manitoba, by measuring distances between nest sites in subsequent years. They found median inter-nest distances of 40 m for reunited pairs, 41 m for males with a new mate, and 174 m for females with a new mate. These distances are somewhat smaller than our corresponding median values of 73 m, 140 m, and 299 m, respectively. However, the population studied by Gratto et al. nested at a much higher density (approximately 50 nests/sq km) than the population at Kuparuk (10-24 nests/sq km). Thus, the shorter inter-nest distances moved at La Perouse Bay are likely indicative of the smaller average territory size (about 2 ha) compared to Kuparuk (about 8 ha). Results of the two studies are consistent in showing that the distances moved by intact pairs and by males with a new mate tend to be less than the average distance between territories, indicating that most male semipalmated sandpipers return to the same territory in successive years, whereas females with a new mate are more likely to move to a new territory.

Gratto et al. (1985) found 13 instances out of 305 (4%) in which semipalmated sandpiper pairs re-used their nest cup from the previous year, compared to 16 instances out of 168 (10%) in our study. Our total rate of nest cup re-use by semipalmated sandpipers was even higher (17%), as some pairs used nest cups that were previously occupied by a different pair, or by the same pair after a two-year interval. We did not find any instances in which semipalmated sandpipers used nest cups that were previously occupied by a different species, whereas Gratto et al. (1985) found semipalmated sandpipers occupying nest cups that had

previously been occupied by red-necked phalaropes (4), horned larks (1), savannah sparrows (1), and dunlin (1).

Although our sample sizes were small for dunlin, our results for site tenacity in this species were consistent with a study in western Finland on *Calidris alpina schinzii* (Soikkeli 1970). In that study most intact pairs and males with new mates moved <200 m between nest sites from one year to the next, while females with a new mate often moved much longer distances. Again, Soikkeli (1970) was studying a dunlin population with much higher local nesting densities than at Kuparuk. Johnson et al. (1993) reported movements between nest sites in successive years were usually less than 100 m for the Pacific golden-plover (*Pluvialis fulva*) near Nome in western Alaska, and in at least one instance the same nest cup was used in successive years.

Of eleven pairs of stilt sandpipers reunited during the second year of a study at Churchill, Manitoba, seven (64%) used the same nest cup the following year (Jehl 1973). The other four pairs nested within 100 m of the previous year's nest site. Our findings of 15% re-use of nest cups (4 out of 27 nests) and a mean distance between nest sites of 117 m for eight banded stilt sandpipers (44 m for 1 reunited pair) suggests that arctic nesting populations are also site-tenacious. Our nesting return rate of 44% was similar to the rate of 43% found by Troy (pers. comm.) for stilt sandpipers at a study site in the Prudhoe Bay Oilfield.

Mate Fidelity

The degree of mate fidelity (68%) found for semipalmated sandpipers in this study is somewhat lower than the 81% reported by Gratto et al. (1985) for semipalmated sandpipers at La Perouse Bay, Manitoba. Soikkeli (1970) found mate fidelity of 75% for dunlin in western Finland. Consistent with those studies, we found that the effect of mate change for monogamous species was strongest in females, i.e., females that changed mates on average moved farther to a new nest site than males with a new mate. Soikkeli (1967), Holmes (1971), and Jehl (1973) have suggested that most sandpipers mate after arrival on the breeding grounds. In territorial species, the territory is established by the male, so females pair with their previous mate only if they return to the same territory. Thus, mate fidelity may be simply a fortuitous consequence of site tenacity (Soikkeli 1970; Gratto et al. 1985). The longest distance moved by an intact semipalmated sandpiper pair in our study was 208 m, only slightly farther than the estimated radius of the average territory. Failure to reunite in monogamous species is usually caused by the death or delayed arrival on the breeding grounds of one of the pair (Soikkeli 1967; Jehl 1973).

Some shorebird studies have found correlations between nesting site fidelity and nest success (Oring and Lank 1982; Redmond and Jenni 1982; Thompson and Hale 1989); others have not found such correlations (Dowding and Chamberlin 1991; Schamel and Tracy 1991). Gratto et al. (1985) found that semipalmated sandpipers that had unsuccessful nests returned the following year at a lower frequency than birds that had been successful, but found no

significant differences in site tenacity (distance moved between nests) for successful vs. unsuccessful nesters. They also found no significant difference in nesting success between birds that changed mates vs. those that did not; however, reunited pairs nested slightly, but significantly earlier than birds that had changed mates (Gratto-Trevor 1991). At Kuparuk, the high degree of nest success on our plots did not allow us an adequate sample size of unsuccessful nests to draw any meaningful conclusions from this type of analysis.

The 71% re-use of nest sites by Pacific loons at Kuparuk is consistent with Davis (1972), who found that a high percentage of territories of both Pacific and red-throated loons were reoccupied in successive years and concluded that the same pairs would re-use nesting territories and, not uncommonly, nesting sites. The 67% re-use of nest sites by tundra swans in this study, as well as aerial survey data from the Kuparuk and Prudhoe Bay Oilfields (USFWS unpublished data), indicate that tundra swan pairs also probably reoccupy nesting territories in consecutive years.

Nesting Phenology and Success

Nesting phenology at Kuparuk was generally comparable to other North Slope sites, but some differences were noted. Holmes (1966) found that at Barrow, Alaska, most sandpipers, except for red phalaropes and pectoral sandpipers, arrived and dispersed on similar early schedules. Median nest initiation dates for most shorebirds and Lapland longspurs tended to be slightly earlier at Kuparuk than at Pt. McIntyre (Troy 1992), 35 km east of our study site, and this trend was more pronounced in the colder years. For example, in 1990, the year with warmest temperatures and earliest snowmelt during our study, median nest initiation dates at Kuparuk generally differed from those at Pt. McIntyre by only a few days, and for several species (American golden-plover, semipalmated and stilt sandpipers, dunlin, and red-necked phalarope) median nest initiation dates were earlier at Pt. McIntyre. Buff-breasted sandpipers, however, initiated three weeks later at Pt. McIntyre than at Kuparuk in 1990. In 1989 and 1991 all reported median nest initiation dates were later at Pt. McIntyre than at Kuparuk, and some were ≥ 10 days later (semipalmated sandpiper and red phalarope in 1989, Lapland longspur and buff-breasted sandpiper in 1991, and American golden-plover in both years). 1989 had colder than average temperatures in May, and 1991 had colder than average temperatures in June. Most of the Pt. McIntyre plots are nearer to the coast than either of our Kuparuk plots, so later snowmelt at coastal sites may have contributed to the later nest initiations at Pt. McIntyre in the colder years.

Nesting phenology may vary between species for many reasons related to differences in breeding biology. Water birds in general are later nesters than shorebirds and passerines in part because they require open water for courtship and feeding. Greater white-fronted geese and tundra swans, however, nested as early as the shorebirds at Kuparuk. The geese are terrestrial nesters and feeders, and therefore less tied to open water. Tundra swans are presumed to be monogamous and mate-faithful (Palmer 1976), and returning to the same site with the same mate may reduce their courtship time. Pacific loons, however, which also seem

There is evidence that experience and age may be factors in variation of nesting phenology. Pairs of stilt sandpipers (Jehl 1973) and dunlin (Sokkeli 1967) that reunited after a previous breeding attempt initiated nests earlier than pairs mated for the first time. Gratto et al. (1985) found that returning pairs of semipalmented sandpipers nested earlier in 3 of 4 years of the study, but the difference was statistically significant only in one. Gratto et al. (1983) found that mean hatch date of yearling breeding semipalmented sandpipers at Churchill was 2-3 days later than for adult breeders. Although our data were insufficient to test statistically, the

subarctic are tied to a relatively inflexible breeding schedule.

It seems likely that many long-distance migrant species nesting in the arctic and 1968). It coincides with favorable food resource availability (Holmes 1996; Holmes and Pitelka 1996) found that hatching dates of arctic nesting shorebirds are coincident with those of semipalmented sandpipers (Holmes 1996; Holmes and Pitelka 1996). This conclusion is supported by other evidence that hatching dates of arctic nesting shorebirds are available between the two locations resulted in the similar nesting phenology. This difference in climate. They suggested that the similarity in timing of peak food resource site in Manitoba were similar to those reported at an arctic site in Barrow in spite of the and Cooke (1987) found that nest initiation dates for semipalmented sandpipers at a subarctic occurred at Kuuparuk during a spell of cold weather and snowfall in early June 1991. Gratto during incubation. A similar pattern of early nest abandonment, followed by renesting, change nest initiation of semipalmented sandpipers, but did lead to abandonment of nests that snow cover remaining one month longer than usual at La Perouse Bay, Manitoba did not delayed arrival dates by accelerated courtship and pairing. Gratto and Cooke (1987) found (1966) found that dunlin maintained a fairly constant breeding schedule in spite of weather-studies: e.g., dunlin (Holmes 1966) and Lapland longspur (Custer and Pitelka 1977). Holmes arctic and subarctic species have been found to vary little between years in several multi-year In spite of occasionally radical differences in spring conditions, nest initiation dates for many which would skew the median to a later date.

nest initiations than other shorebirds (some of which may not have been detected if there was have obscured some trends. Semipalmented sandpipers, for example, may have had more early renests (both known and unknown) in our calculation of median nest initiation dates, may nest initiation date was equal to or earlier than dunlin in two out of four years. Including nest initiated earlier than all other shorebirds but stilt sandpipers in 1990. Red phalarope median but nested earlier than all other shorebirds but stilt sandpipers in 1990. Red phalarope median vs. non-monogamous species. Pectoral sandpipers were late nesters in three out of four years, for the latter species. There is not such a clear difference, however, between all monogamous suitable nesting habitat in any particular year might explain the later timing of nest initiation opportunistic in nest site selection. The extra time required for courtship and selection of faithful, whereas the later nesting buff-breasted sandpipers are non-monogamous and site Among shorebirds, the early nesting stilt sandpipers are monogamous, territorial, and site adaptive strategy for predator avoidance.

Predators. Waiting until more open water surrounds their preferred nesting islands may be an smaller size and relative immobility on land makes them more vulnerable to terrestrial to have a high degree of site fidelity, are later nesters than the swans, perhaps because their

earlier median nest initiation dates for previously banded vs. newly banded semipalmated sandpipers suggest that "experience" may confer some advantage in securing favorable nesting sites early in the season, an advantage which may be most significant in years with harsher climatic conditions.

Pitelka (1959) found a peak in late June of a second wave of late arriving pectoral sandpipers on the Barrow breeding grounds, and although he did not mention late breeders, it is possible that these late arrivals were also late breeders. If this second wave represents a separate wintering population, then possibly differences in migration routes could influence nesting phenology. The distribution of nest initiation dates of pectoral sandpipers at Kuparuk in 1990 suggests the possibility of a "first wave" of pectoral sandpipers initiating nests in early June, and a "second wave" initiating in late June (see Appendix D, Figure D-3). The results for 1991 and 1992 were less clear. In 1991, there were no early nesting pectorals, and in 1992 few late nesters, but in general pectoral sandpiper nest initiation dates were less clumped than those of semipalmated sandpipers.

Early nesting birds may realize more favorable breeding cycle synchrony with food resource availability than late nesters (Holmes 1966; Soikkeli 1967). Studies have shown that early nest initiation can be associated with reunited pairs, experience, and higher productivity (summarized in Jehl 1973; Gratto et al. 1983). Experience and early nest initiation may also increase the probability of a renesting attempt. Early arrival and nesting may be advantageous in order to reoccupy an old territory or to set up territory in favorable habitats (Myers 1981). Our 1989 observation that a returning pair of semipalmated sandpipers was chased off its previous territory by an earlier nesting pair is consistent with this hypothesis.

Estimates of nest success at Kuparuk in the four years 1989-1992 showed no clear correlation with weather patterns, so were probably more influenced by other factors, with predation likely having the greatest effect. Predation rates on bird nests would depend not only on the population levels of the predators and of the birds, but also on population levels of alternate prey species, such as small mammals. Since we did not collect data on population levels of predators or alternate prey species, we are unable to draw any inferences from this study.

In general, shorebird nest success at Kuparuk was consistently high compared to other oilfield areas, such as P-Pad and Pt. McIntyre (Troy and Carpenter 1990; Troy 1992). For example, semipalmated sandpiper nest success at Pt. McIntyre ranged from 13% (in 1986) to 88% (in 1988), and overall averaged 60% in a 9-year study (Troy 1992), whereas four years at Kuparuk yielded a range from 77% (1991) to 84% (1989 and 1992), with an overall estimated success rate of 81%. Semipalmated sandpiper nest success rates at Kuparuk were estimated at 84% in 1989, 78% in 1990, and 77% in 1991, compared to 42%, 64%, and 53% reported for those three years at Pt. McIntyre (Troy 1992). Estimated nest success rates for Lapland longspurs were 46%, 88%, and 89% in three years at Kuparuk, and were 31%, 66%, and 61% during the same three years at Pt. McIntyre.

The validity of comparisons of nest success between this study and Troy's (1992) results may be confounded by the fact that Troy reported apparent nest success, while we have used a Mayfield (1975) estimate. For apparent nest success to accurately reflect actual nest success one must assume that all nests were found, and that the outcome for all nests was known. Our lack of confidence that these assumptions could be met in our study led us to the choice of using the Mayfield estimate in preference to apparent success.

Confidence in the assumption that all nests were found might vary among species (some species nests were easier to find than others), among years (depending on the number and experience of observers available in each year), and even between censuses within a year (for inexperienced volunteers, nest-finding skills tended to increase significantly in the later censuses). Apparent nest success rate can also be affected by plot visitation frequency; with less frequent visits, it is more likely that nests may have been initiated and failed without being found, resulting in fewer detections of failed nests. Although the three co-authors of this report were, of course, totally confident that no nests eluded their finely honed nest-finding skills, the necessity of training new and inexperienced volunteers in each year of the study, and the intervals of up to 12 (but usually 7-9) days that elapsed between censuses (Table 1), would likely invalidate the assumption that all nests in this study area were actually found. Most likely some early nest failures were undetected, which would result in apparent nest success rates being biased upward.

We also had a number of nests (especially some shorebird species) for which nest fate was recorded as unknown. These were usually nests which were found empty during a time period when hatch was likely to have occurred, but no definitive evidence of successful hatch or of failure was found. Excluding the "unknowns" from calculation of apparent success rates would tend to bias those results downward (since many of the "unknowns" were likely nests in which the eggs hatched successfully: we may not have observed chicks or defensive adults either because they had moved outside our study plot, or because predation occurred immediately after hatch). Using the Mayfield (1975) method for calculating probability of nest success allowed us to include data from all nests, including nests of unknown outcome, in our estimate.

Fox predation was a major factor in reducing nest success at the P-Pad study plot in the Prudhoe Bay Oilfield (D.M. Troy, TERA, pers. comm.). The two Kuparuk study plots were each within 1 km of an active fox den, and arctic foxes were seen traversing both Kuparuk plots almost daily during all years of our study, yet fox predation was not a major factor affecting nest success in the Kuparuk plots. It is unclear whether the difference was due to presence of alternate prey items (such as small mammals) at Kuparuk, or individual differences in foxes' prey preference. In a concurrent study in the Kuparuk Oilfield in 1992 that focused exclusively on pectoral sandpipers, there was a much higher nest predation rate by arctic foxes than occurred on our study plots (V. Estelle, NERC, pers. comm.). The difference may have been attributable to different methods. The pectoral sandpiper researchers made more frequent and lengthier visits to nests, and their "scent trails" led directly to the nests, in contrast to our plots where zig-zag censusing and less frequent nest-

checking may have left no reliable paths for a fox to follow to nests. Fox and jaeger predation did appear to have a major influence on nest success of greater white-fronted geese, king eiders, and other waterfowl species in our Kuparuk plots, so possibly the higher nesting densities of waterfowl species, which would be more desirable targets for predators, decreased the pressure on shorebirds and longspurs.

Shorebird Brood Movements and Brood Attendance

Although this study originally focused on breeding bird densities, return rates, movements, and habitat use in the Kuparuk Oilfield, during the last two years it was expanded to include a preliminary examination of movements and habitat use by brood-rearing shorebirds. The color-banding of adults allowed location of individual broods, and calculation of distances moved from their nest sites. Our particular interest in following the movements and fate of shorebird broods was prompted in part by our finding relatively high hatching success rates compared to other North Slope studies (e.g., Troy 1992). Assuming that chick mortality was probably higher after hatch than before, we concluded that adequate assessment of development impacts on shorebird life cycles would require more complete knowledge of habitat use, movements, and survival during the stage between hatching and fledging. This aspect of the study was expanded in a separate project (Walker, in prep.) in 1993.

Most studies documenting brood attendance by monogamous, territorial shorebirds with biparental care have shown a pattern of early desertion by one member of the pair. Female stilt sandpipers near Churchill, Manitoba, deserted their broods within a week, while males stayed with the chicks for about two weeks (Jehl 1973). About 16 days elapsed between hatching and fledging of semipalmated sandpipers at Barrow, Alaska, and females deserted the family 2-6 days after hatching (Safriel 1971). At La Perouse Bay, Manitoba, most female semipalmated sandpipers (86-97%) deserted their broods 0-11 days (average 6) after their eggs hatched (Gratto-Trevor 1991). Males left the brood an average of 8 days later, shortly before or after the chicks fledged. In the closely related least sandpiper (*Calidris minutilla*), females deserted an average of 6 days after hatching, and males on average 20 days after hatching (Miller 1985). Similar results were noted for a population of dunlin in Finland: average female desertion was after 6 days, and males after 19 days (Soikkeli 1967). Our documentation of earlier desertion of semipalmated sandpiper broods by females was consistent with these results.

Ashkenazie and Safriel (1979) and Gratto-Trevor (1991) found that the timing of female desertion was season-dependent; females stayed longer with broods that hatched earlier. Gratto-Trevor (1991) also reported some instances (3%-14% of broods) where males deserted and females stayed with the brood; in at least half of these the male was seen in subsequent years, so mortality was not the cause of desertion. This is consistent with our finding of 14% of semipalmated sandpiper broods in which the female was in attendance longer than the male. Cases have also been documented where females changed their behavior (deserting or staying) from one year to the next (Gratto-Trevor 1991).

In a study of greater golden-plover broods in northeast Scotland, 35 out of 38 broods were never seen more than 200 m from the nest; the other three moved 500–1200 m from the nest by 18–25 days after hatch (Part 1980). In this case, movements appeared to be dictated by availability of suitable cover habitat, which was limited to small patches of grass. A single brood of greater golden-plovers that was radio-tagged moved 900 m in 8 days, but the maximum distance moved from the nest was only 500 m (Yalden 1991). Our observations of black-bellied and American golden-plover brood movements were insufficient to allow meaningful comparison with these studies.

Silt sandpiper chicks near Churchill, Manitoba, were found up to 2 miles from the nest within 2 weeks of hatching (Jehl 1973). Movement patterns of semipalmented sandpipers at Barrow, Alaska, had two distinct phases (Ashkenazi and Safriel 1979); during the time when both parents were attending a brood, the family usually stayed in the vicinity of the nesting territory, but after the female left, there was a pronounced movement to another locality, up to 2–3 km away. The nesting territory was usually in an area of high-centred polygons, but the subsequent movement usually took the broods to wet meadows, along streams, near large ponds, or to areas of low-centred polygons. This movement of broods to wetter habitats for feeding is consistent with our observations, but our study design did not allow documentation of any long-distance brood movements.

CONCLUSIONS

Our originally proposed study was to make detailed observations of individually marked birds through a period of oilfield construction activity, to address the question of what happens to birds that are displaced by development impacts. We were unable to accomplish our original objectives, due to the cancellation of construction of the proposed development projects around which they were designed. We did, however, gather baseline information on bird population parameters in the Kuparuk Oilfield area, that may be useful in designing future impact assessment studies. The following paragraphs summarize what we have learned from this and other North Slope bird studies that may be relevant for designing future studies of oil development impacts on bird populations.

We know that the deposition of gravel for construction of oilfield facilities eliminates habitat, and that nesting densities for some species are lower in the areas surrounding roads and gravel pads than in undeveloped areas. Troy (1993) found nesting densities were lower along roads than 400 m away from roads in the Prudhoe Bay Oilfield for eight out of ten species reported; the results for semipalmated sandpipers, stilt sandpipers, and red phalaropes were statistically significant. Lacking data on bird populations and densities prior to development, however, there may still be room for argument as to whether these local effects on habitat occupancy affect overall populations.

When evaluating potential impacts of gravel road and pad construction in arctic wetlands, it may be important to consider the social organization and site tenacity of the species potentially affected, as well as nesting densities and habitat associations. Species with low site fidelity might show less immediate response to development impacts, as long as there are other areas of suitable habitat for them to move to, because moving to a new nesting site from one year to the next is standard behavior for such species. For those species with high site tenacity, however, displacement due to facility construction which forces them to search for a new nesting territory as well as a new mate, might be expected to diminish their nesting success, at least in the short term.

A concurrent study of bird displacement by facility construction was conducted at "P-Pad" in the Prudhoe Bay Oilfield (Troy and Carpenter 1990). At "P-Pad", return rates for birds of three species (Lapland longspur, semipalmated sandpiper, and dunlin) that were displaced by oilfield facilities construction were similar to return rates for birds that were not in the area affected by construction. Eight individuals of these three species returned and nested elsewhere after their previous nest site was affected by facilities construction. Nest success rate for these eight individuals was similar to the overall nest success rate for all birds in the study area subsequent to development. These results (similar return rates and similar nest success) were presented as evidence that there were no population effects attributable to the development impacts (Troy and Carpenter 1990). Some drawbacks of the "P-Pad" study were the small sample size, overall low nesting success in this study area, pooling results from multiple species, and comparison of nest success of displaced birds that were known to have returned (banded the previous year), with nest success of all birds (combining data for

A site tenacious species which is primarily regulated by habitat limitation might be expected to show less annual variability in nest density, as exceptionally "good" years for nesting success would not necessarily translate into subsequent higher densities in the nesting population, but would simply add to the pool of non-breeders available to fill territories as they became available. At Kuparuk, the relatively constant density of nesting semipalamed sandpipers on plot I-M may represent a population at carrying capacity of the available habitat. In general, the low coefficients of variation for nesting densities of the monogamous and territorial shorebird species suggest some degree of habitat limitation. The extent to

In a population regulated primarily by factors such as weather and predation, we would expect to see significant annual fluctuations in breeding numbers, reflecting the varying nest success and subsequent recruitment levels of "good" or "bad" years. At Kuparuk, we observed this high degree of annual variability primarily in the non-monogamous and non-territorial species, such as the phalaropes, pectoral sandpiper, and buff-breasted sandpiper. It is not clear, however, whether this variability in breeding numbers was due to fluctuations in recruitment, or due to inter-annual geographic shifts in breeding distribution.

For birds that are not habitat limited, dispalcement of birds through gravel placement might be expected to yield higher nesting densities in the surrounding areas subsequent to development. In the "P-Pad" study, Troy and Carpenter (1990) reported that nest abundance of five species decreased within 100 m of facilities, in the year following construction, but nest abundance of semi-palmated sandpipers and dunlin increased in areas > 100 m from facilities. Nesting densities for these two species also increased in control areas that year, however, so it is not clear what, if any, portion of the increase in nest density in the surrounding areas could be attributed to dispalcement of birds by road and pad construction. It is difficult to distinguish small changes in nesting density from the natural annual fluctuations that are typical of arctic populations.

Troy and Capeneter (1990) concluded from their study that "population size is being regulated by factors other than space on breeding grounds" and "habitat availability is not the resource limiting most bird populations at Prudhoe Bay". It is quite possible, however, that the results of similar return rates and similar nest success rates for displaced birds compared to unaffected birds in the year following development could be observed for habitat-limited species. With territorial shorebird return rates typically around 60%, the returning birds dispensed by gravel pad placement would likely be able to establish successful territories in the 40% of surrounding areas not occupied by other returning birds. The loss in available nesting habitat not produce an immediate effect on the returning birds, but might still affect the population as a whole through diminished opportunity for new recruits to enter the breeding pool (fewer territories available).

returning birds with those that may have been nesting for the first time). That some of the displaced birds returned and were able to nest successfully did, however, give us the basic information that those individuals were not immediately eliminated from the population.

which habitat limitation plays a role may vary geographically and by habitat; it is possible that an area of "preferred" habitat may be saturated and show little population fluctuation, while a nearby area of less desirable habitat would show considerable annual variability in nesting density.

Given what we have learned from this and other North Slope bird studies, we make the following recommendations for future impact studies based on assessment of breeding bird populations:

1. Small sample size is clearly a limitation. A study of displacement of marked birds is probably not worth repeating in a situation where the size of the proposed development project is relatively small, or where the habitats affected are expected to have low nesting densities. One of the factors contributing to small sample sizes in the "P-Pad" study (Troy and Carpenter 1990) was the fact that the road and pad were (appropriately) located in an area anticipated to have relatively low bird densities, following Service recommendations to minimize impacts. The study sites for the Kuparuk study were chosen based on the expectation of relatively higher bird densities, but this may ultimately have contributed to our failure to accomplish the original objectives of the study. Our documentation of high habitat values contributed to the withdrawal of the proposal to build a drilling pad at our 3-L study site.
2. While sample size consideration might dictate choosing the most common species for study, there are reasons to suggest concentrating future efforts on some of the less common species. While the "P-Pad" study (Troy and Carpenter 1990) produced no results for the less abundant site-tenacious species, other studies suggest that some of them may be sensitive to development effects. Troy's (1993) analysis of effects of proximity to roads and of fragmentation on bird nest densities in the Prudhoe Bay Oilfield found that stilt sandpipers showed significant effects of both roads and fragmentation (there were no stilt sandpiper nests on any roadside plot, and nest density away from roads was greater on plots in larger fragments). Troy (1993) also identified American golden-plover, along with semipalmated sandpiper and red phalarope, as showing a decreasing gradient in nest densities with increasing oilfield influence, giving "striking and rather compelling evidence of avoidance of roads by these species". The general practice of locating oilfield roads and facilities in areas of higher elevation (to minimize impact to lakes and ponds) raises additional concern for black-bellied and American golden-plovers, as these drier habitats are preferred by plovers for nesting. Additional habitat-specific and species-specific information is needed to adequately evaluate impacts on these and other uncommon species, such as long-billed dowitchers. There is value in considering development effects on bird communities as a whole, but concentrating on fewer species might allow a study covering a larger area.
3. Drawing meaningful conclusions from a single year's baseline is difficult. Successfully banding all the birds in a plot every year is also difficult if not impossible, yet this would be desirable for examining changes in recruitment. Ideally, several years of baseline study should be obtained prior to development, to document natural variations in densities, return

rates, nest success, recruitment, etc. In reality, we are unlikely to ever have that much advance notice of a proposed development project.

4. Given the difficulties inherent in banding studies, it might seem that just counting birds and nests and comparing densities would be more worthwhile. Because of the unique features of individual bird species biology, and population parameters that can only be determined by following individually marked birds over a long-term period of study, we suggest there is still benefit to be gained in establishment of some permanent long-term study plots with individually marked birds. Long-term data on return rates of banded birds are especially useful in establishing demographic parameters for a particular population. Survival rates, expected lifespan, recruitment rates, and reproductive success are all important factors in predicting the ability of populations to tolerate or recover from impacts that may be individually minor but cumulatively significant (e.g., gravel pad construction which may eliminate habitat for a number of nesting pairs), or catastrophic (e.g., habitat destruction from a major oil spill). All else being equal, a population of relatively short-lived birds with early maturity and high reproductive rates could be expected to recover more rapidly from a significant population decline than would long-lived species with lower reproductive rates.

5. Lacking definitive evidence to the contrary, we may continue to assume that habitat is limiting, at some level, to North Slope bird populations, and make recommendations for minimizing development impacts accordingly. Undoubtedly factors such as weather and predation play a significant role in affecting nest initiation and success in any particular year, and therefore level of recruitment to the breeding population in subsequent years. Wintering ground mortality and varying condition of migration stopovers also affect annual variations in return rates of adults. Because factors other than nesting habitat (such as predators and weather) may have drastic effects on nest initiation and success in certain years, we suggest that maximizing availability of suitable habitat may be vital to the recovery of populations in following years.

Previous North Slope studies (Martin 1983; Spindler and Miller 1983; Spindler et al. 1984; Moitoret et al. 1985; Troy 1984, 1986, 1988) have correlated nest and sighting densities with habitat types. This type of information is useful in habitat value assessments used in making recommendations on siting facilities and routing roads. Because the habitats found in the Kuparuk Oilfield differ somewhat from those described in other North Slope studies (i.e., Prudhoe Bay, Barrow, and the Arctic National Wildlife Refuge), future analyses of nest and sighting data in Kuparuk relative to habitat type should improve our ability to make reasonable predictions of impacts, and recommendations for mitigation. Further refinement of our understanding of individual bird species habitat preferences and requirements will allow us to continue making recommendations for facility siting that avoids the highest value habitats.

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Appendix A. Common and scientific names for all bird species observed in two plots in the Kuparuk Oilfield on the North Slope of Alaska, 1988-1992.

Common Name	<i>Scientific Name</i>
Red-throated loon	<i>Gavia stellata</i>
Pacific loon	<i>Gavia pacifica</i>
Tundra swan	<i>Cygnus columbianus</i>
Greater white-fronted goose	<i>Anser albifrons</i>
Brant	<i>Branta bernicla</i>
Canada goose	<i>Branta canadensis</i>
Northern pintail	<i>Anas acuta</i>
King eider	<i>Somateria spectabilis</i>
Spectacled eider	<i>Somateria fischeri</i>
Oldsquaw	<i>Clangula hyemalis</i>
Northern harrier	<i>Circus cyaneus</i>
Peregrine falcon	<i>Falco peregrinus</i>
Willow ptarmigan	<i>Lagopus lagopus</i>
Rock ptarmigan	<i>Lagopus mutus</i>
Sandhill crane	<i>Grus canadensis</i>
Black-bellied plover	<i>Pluvialis squatarola</i>
American golden-plover	<i>Pluvialis dominica</i>
Whimbrel	<i>Numenius phaeopus</i>
Semipalmated sandpiper	<i>Calidris pusilla</i>
Western sandpiper	<i>Calidris mauri</i>
Baird's sandpiper	<i>Calidris bairdii</i>
Pectoral sandpiper	<i>Calidris melanotos</i>
Dunlin	<i>Calidris alpina</i>
Stilt sandpiper	<i>Calidris himantopus</i>
Buff-breasted sandpiper	<i>Tryngites subruficollis</i>
Long-billed dowitcher	<i>Limnodromus scolopaceus</i>
Red-necked phalarope	<i>Phalaropus lobatus</i>
Red phalarope	<i>Phalaropus fulicaria</i>
Pomarine jaeger	<i>Stercorarius pomarinus</i>
Parasitic jaeger	<i>Stercorarius parasiticus</i>
Long-tailed jaeger	<i>Stercorarius longicaudus</i>
Glaucous gull	<i>Larus hyperboreus</i>
Sabine's gull	<i>Xema sabini</i>
Arctic tern	<i>Sterna paradisaea</i>
Snowy owl	<i>Nyctea scandiaca</i>
Short-eared owl	<i>Asio flammeus</i>
Violet-green swallow	<i>Tachycineta thalassina</i>
Common raven	<i>Corvus corax</i>
Savannah sparrow	<i>Passerculus sandwichensis</i>
Lapland longspur	<i>Calcarius lapponicus</i>
Snow bunting	<i>Plectrophenax nivalis</i>
Redpoll	<i>Carduelis sp.</i>

Appendix B. Mass, wing length, and bill length for 11 bird species found on two study plots in the Kuparuk Oilfield on the North Slope of Alaska, 1988-1992. \bar{x} = mean, s = standard deviation, n = sample size.

Species	mass (g)			wing length (mm)			bill length (mm)			(n)
	\bar{x}	s	range	\bar{x}	s	range	\bar{x}	s	range	
Black-bellied plover										
male	210 ^a	9.2	199-222	198	4.3	191-204	30.4	1.2	28.8-32.4	(6)
female	214 ^b	11.2	193-227	197	5.4	190-207	29.7	1.2	27.2-31.0	(9)
American golden-plover										
male	148 ^a	10.9	129-161	180	3.7	174-186	23.0	0.7	21.9-24.0	(7)
female	159	12.3	143-173	184	4.5	178-188	24.3	0.6	23.6-25.1	(3)
Semipalmated sandpiper										
male	25	1.6	22-29	94	2.3	86-99	17.0	0.8	15.5-19.7	(82)
female	27	1.9	22-32	96	2.5	90-102	18.8	0.8	16.6-20.5	(87)
Dunlin										
male	57	2.3	52-61	120	2.7	115-125	27.4 ^c	1.8	24.6-30.2	(12)
female	61	3.3	57-68	124	3.6	113-129	31.9 ^c	1.2	28.9-33.8	(17)
Stilt sandpiper										
male	57	3.0	53-63	132	2.3	129-137	39.7	1.2	37.8-41.7	(11)
female	62 ^a	2.2	60-66	135	3.6	129-140	41.6	0.9	40.5-43.4	(9)
Long-billed dowitcher										
male	114 ^b	1.0	113-115	144	0.7	143-145	60.8	2.9	58.0-65.4	(4)
female	119 ^b	10.2	105-129	149	2.7	146-153	71.3	2.5	67.5-75.2	(5)
Pectoral sandpiper										
female	63	4.4	52-73	130	3.5	120-141	27.9	1.2	25.2-30.6	(72)
Buff-breasted sandpiper										
female	57	5.8	47-67	127	1.8	125-130	18.2	0.6	16.8-19.2	(15)
Red-necked phalarope										
male	34	1.5	32-36	109	1.6	106-111	22.7	0.7	21.7-23.9	(9)
Red phalarope										
male	50	3.2	43-57	132	3.0	126-138	22.8	0.9	19.7-24.3	(31)
Lapland longspur										
male	28	1.6	24-32	94	2.1	89-98	11.3	0.5	10.4-12.3	(42)
female	27	1.8	23-32	88	2.4	82-95	10.6	0.5	9.3-11.9	(104)

^a sample size is one less than (n), because one bird was not weighed

^b sample size is two less than (n), because two birds were not weighed

^c culmen length was measured instead of bill length

Appendix C. Incubation periods used in calculating nest initiation dates and nest success for 23 bird species on two study plots in the Kuparuk Oilfield on the North Slope of Alaska, 1989-1992.

Species	Number of days	Reference
Red-throated loon	25	R.A. Davis (pers. comm.) in Johnson and Herter (1989).
Pacific loon	27	R.A. Davis (pers. comm.) in Johnson and Herter (1989).
Tundra swan	30	Hawkins (1986).
Greater white-fronted goose	28	Johnsgard (1978).
Northern pintail	23	Palmer (1976).
King eider	23	Parmelee et al. (1967).
Oldsquaw	24	Alison (1975).
Willow ptarmigan	22	Westerkov (1956).
Rock ptarmigan	25	Harrison (1978).
Black-bellied plover	27	Hussel and Page (1976).
American golden-plover	26	Parmelee et al. (1967).
Semipalmated sandpiper	20	Ashkenazie and Safriel (1979).
Western sandpiper	19	Palmer (1967).
Baird's sandpiper	21	Norton (1972).
Pectoral sandpiper	23	Norton (1972) and this study.
Dunlin	22	Holmes (1966).
Stilt sandpiper	21	Jehl (1973).
Buff-breasted sandpiper	24	This study.
Long-billed dowitcher	21	Ehrlich et al. (1988).
Red-necked phalarope	19	Reynolds (1987).
Red phalarope	20	Schamel and Tracy (1987).
Parasitic jaeger	23	Godfrey (1986).
Lapland longspur	12	Custer and Pitelka (1977).

**Appendix D. Nest initiation dates of 11 bird species on two study plots in the
Kuparuk Oilfield on the North Slope of Alaska, 1989-1992.**

Number of Nests

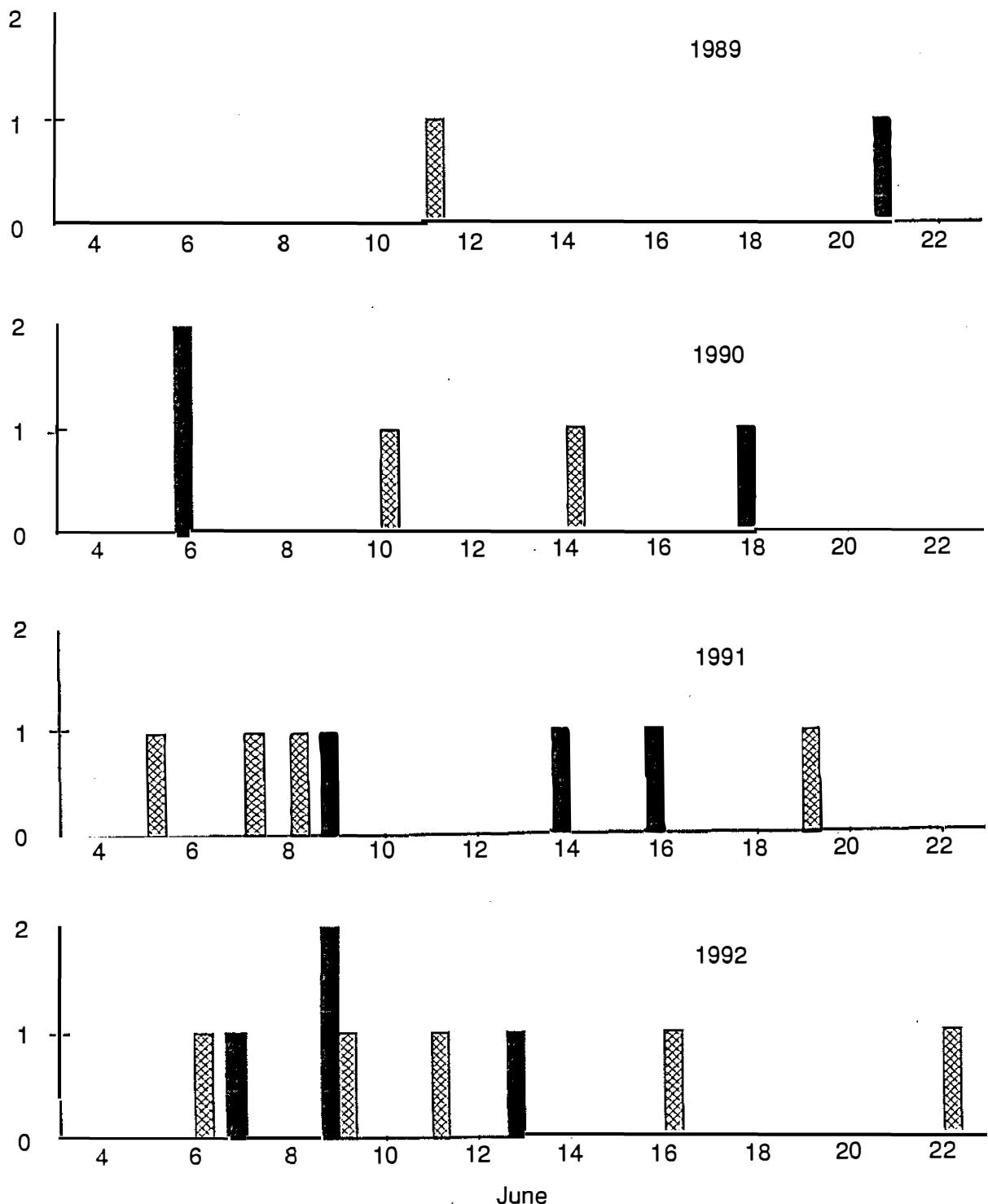
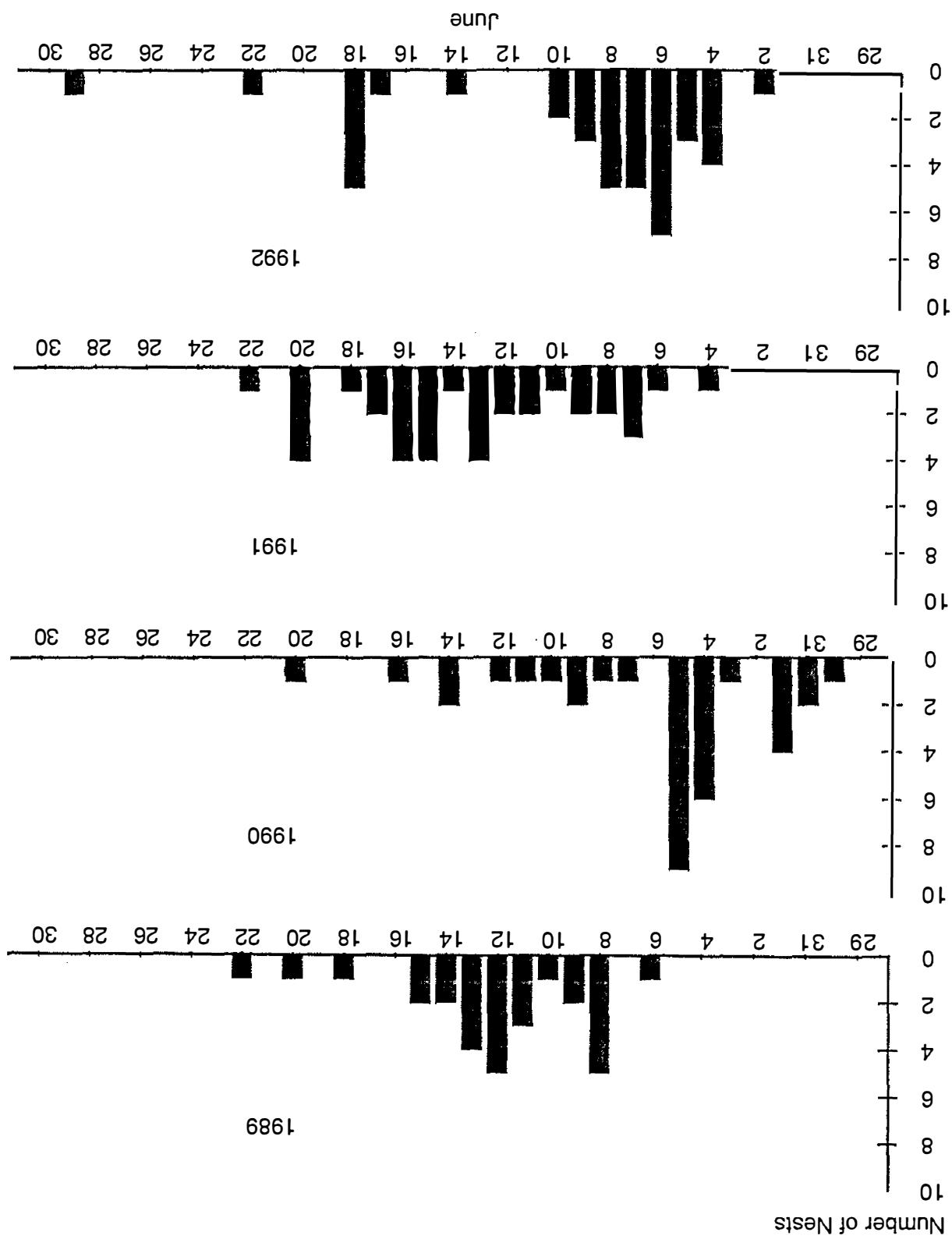


Figure D-1. Nest initiation dates of black-bellied plovers (solid bars) and American golden-plovers (cross-hatched bars) on two study plots in the Kuparuk Oilfield on the North Slope of Alaska, 1989-1992.

Figure D-2. Nest initiation dates of semipalmated sandpipers on two study plots in the Kuparuk Oilfield on the North Slope of Alaska, 1989-1992.



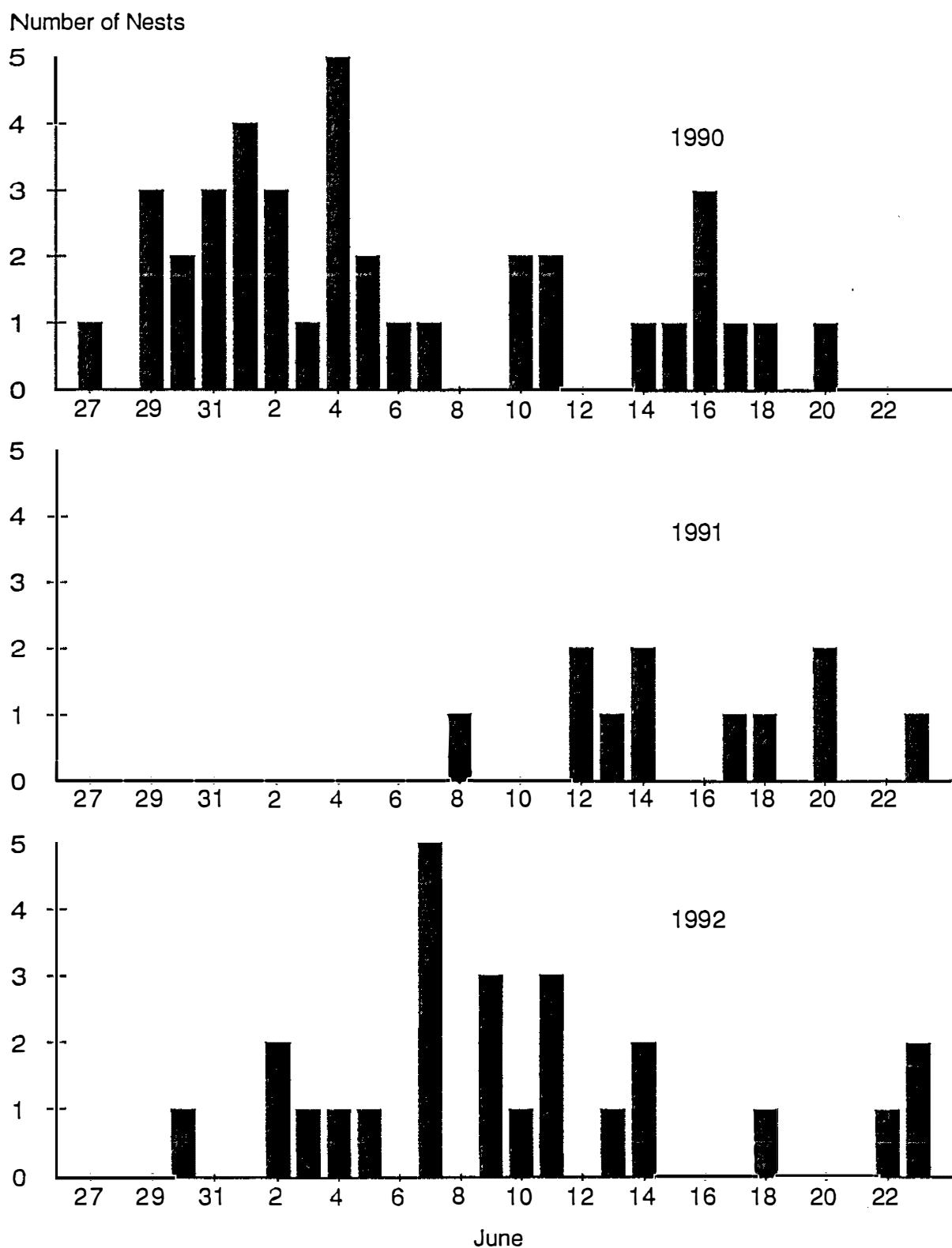


Figure D-3. Nest initiation dates of pectoral sandpipers on two study plots in the Kuparuk Oilfield on the North Slope of Alaska, 1990-1992.

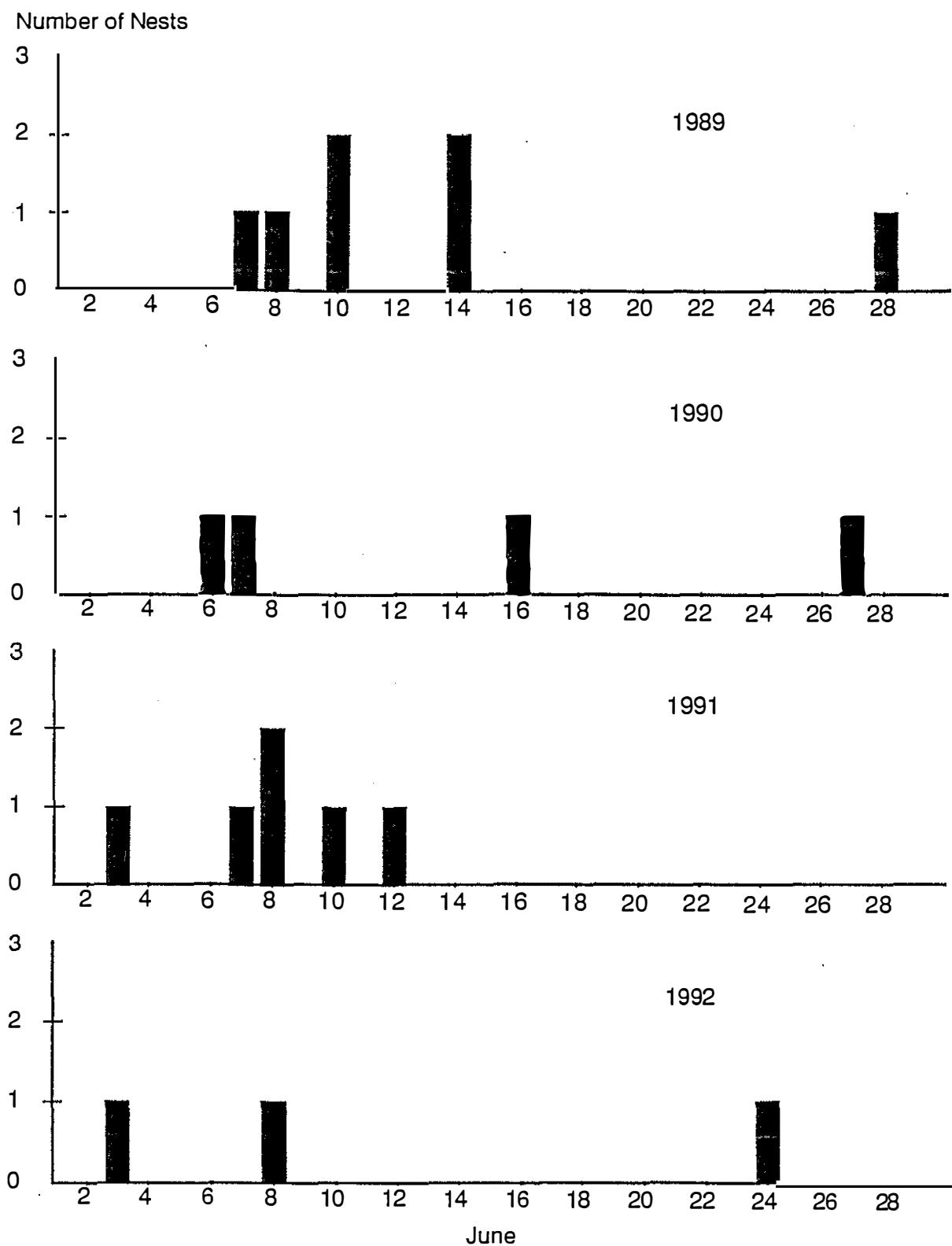


Figure D-4. Nest initiation dates of dunlin on two study plots in the Kuparuk Oilfield on the North Slope of Alaska, 1989-1992.

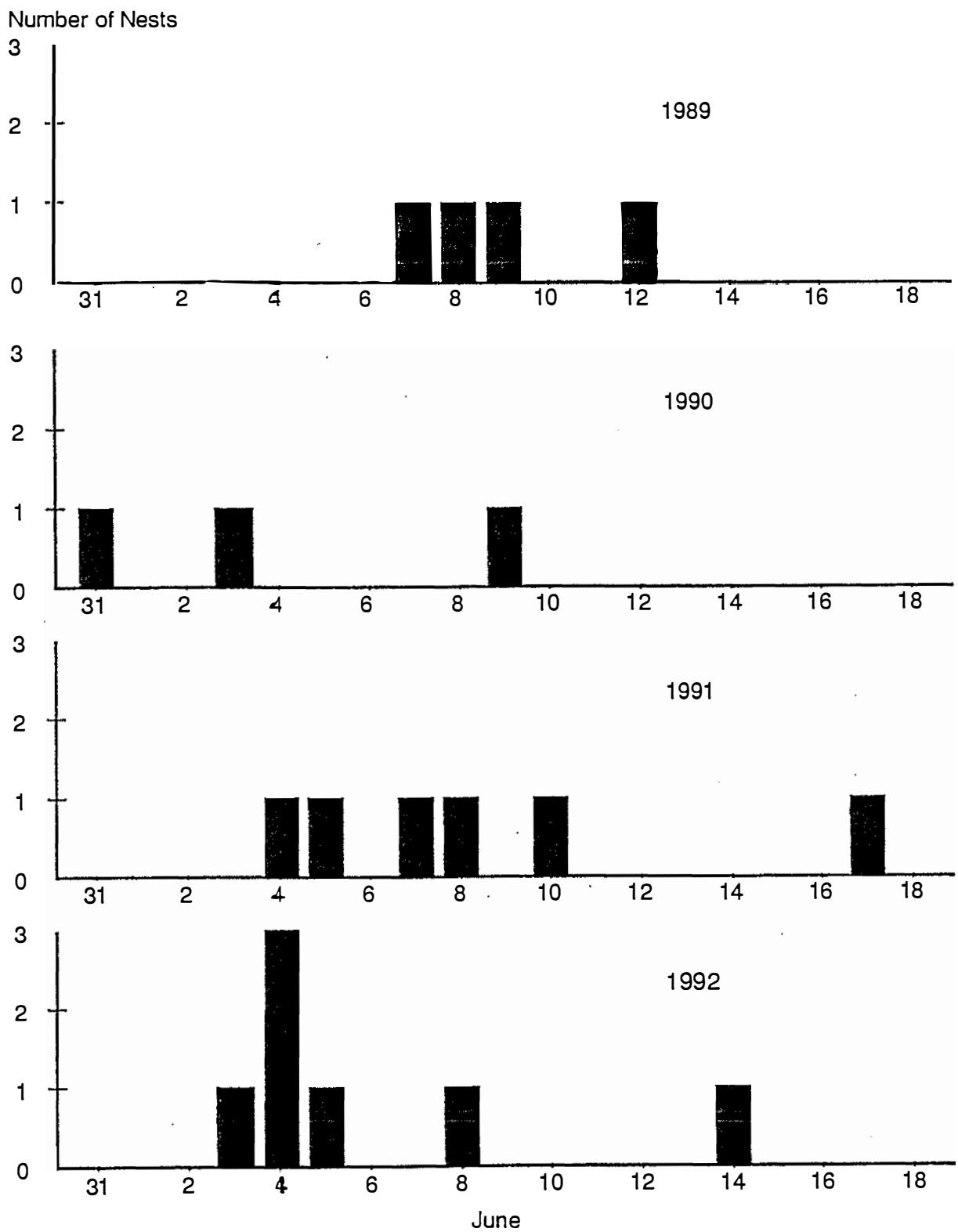
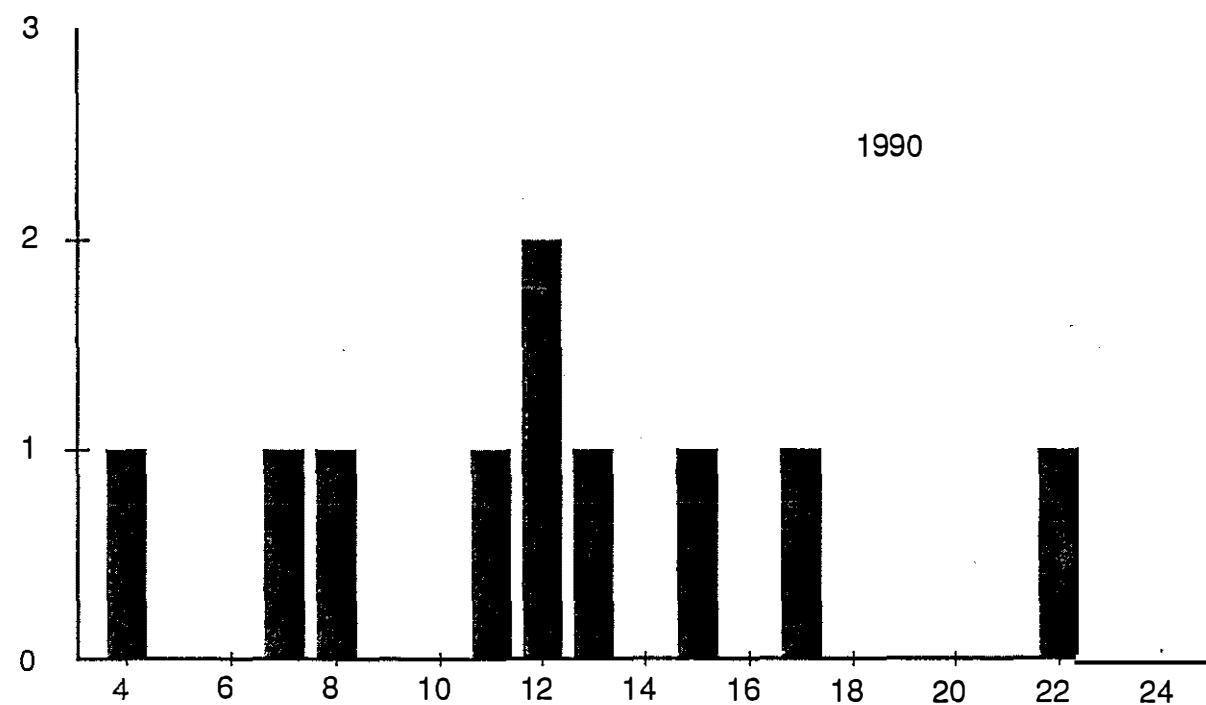
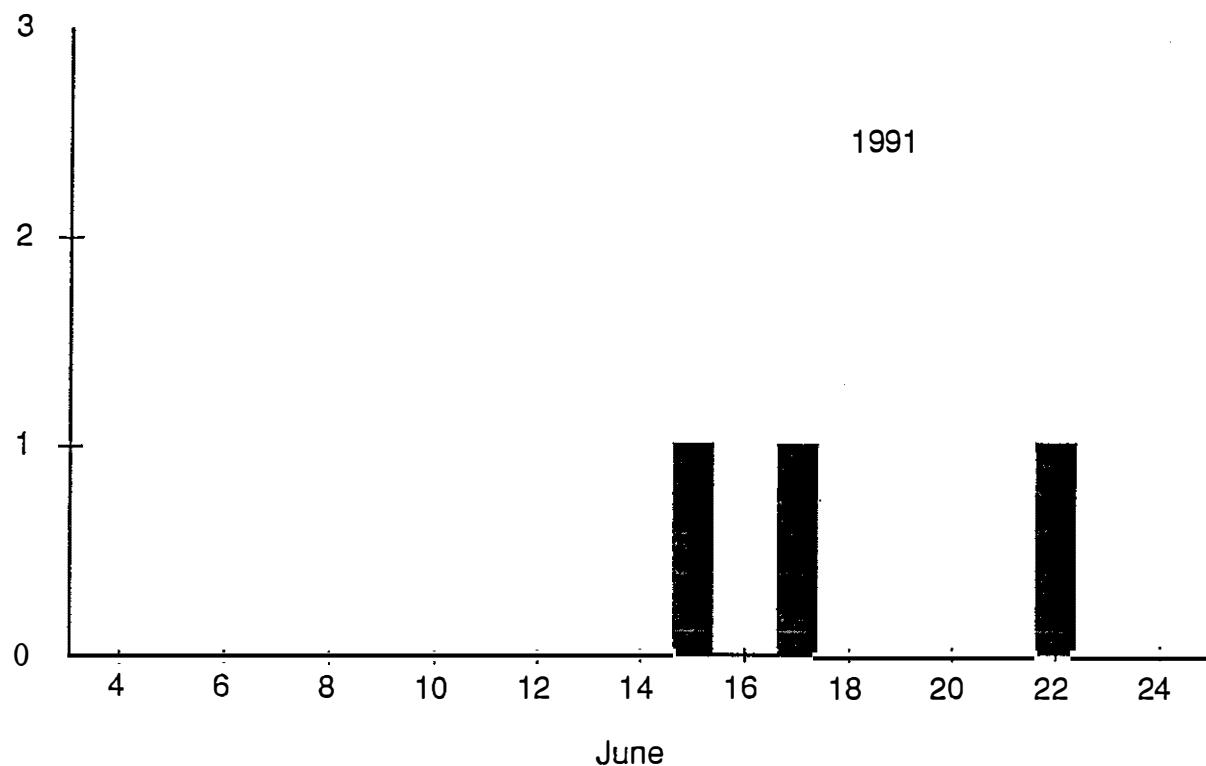


Figure D-5. Nest initiation dates of stilt sandpipers on two study plots in the Kuparuk Oilfield on the North Slope of Alaska, 1989-1992.

Number of Nests



1990



1991

June

Figure D-6. Nest initiation dates of buff-breasted sandpipers on two study plots in the Kuparuk Oilfield on the North Slope of Alaska, 1990-1991.

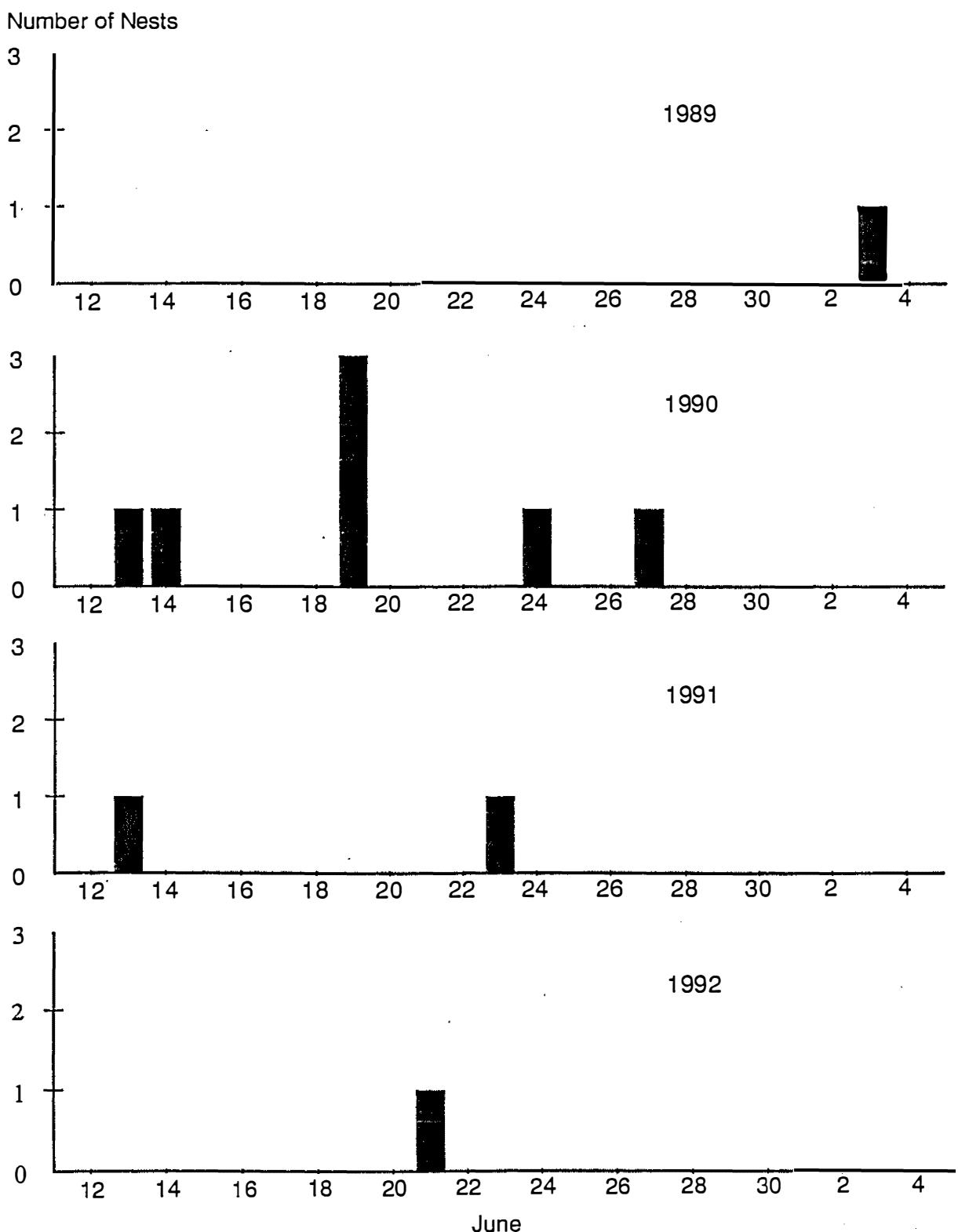


Figure D-7. Nest initiation dates of long-billed dowitchers on two study plots in the Kuparuk Oilfield on the North Slope of Alaska, 1989-1992.

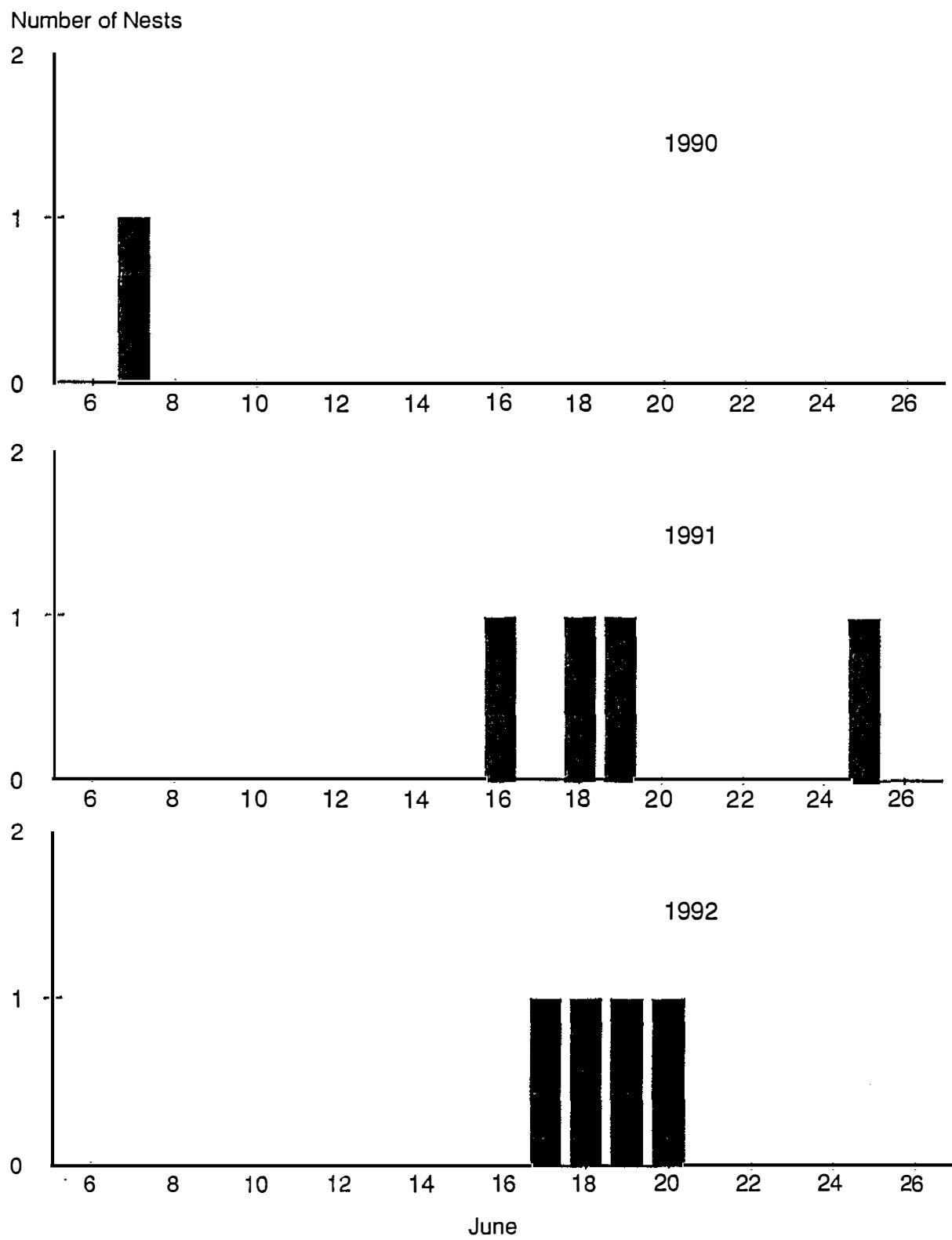


Figure D-8. Nest initiation dates of red-necked phalaropes on two study plots in the Kuparuk Oilfield on the North Slope of Alaska, 1990-1992.

Number of Nests

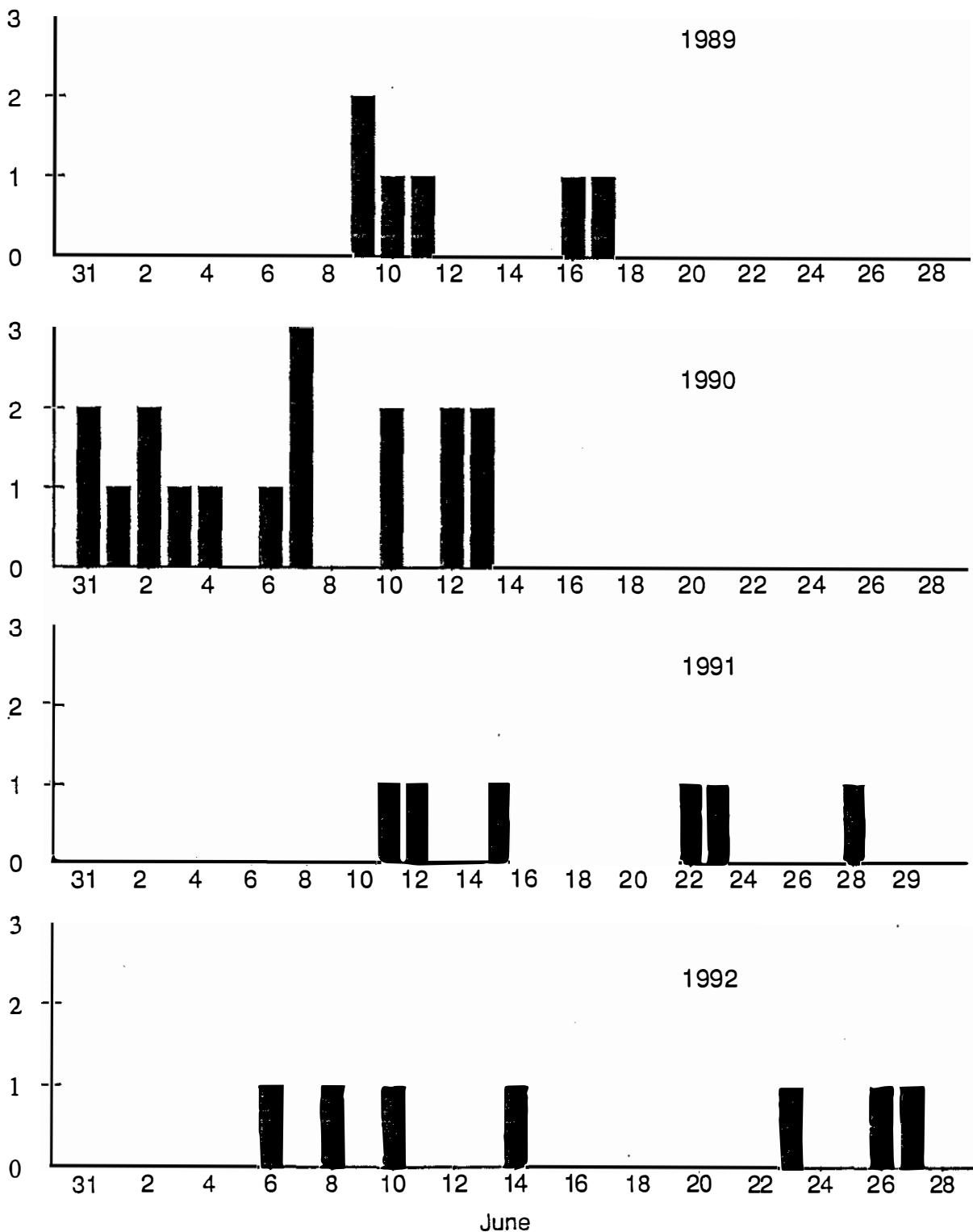


Figure D-9. Nest initiation dates of red phalaropes on two study plots in the Kuparuk Oilfield on the North Slope of Alaska, 1989-1992.

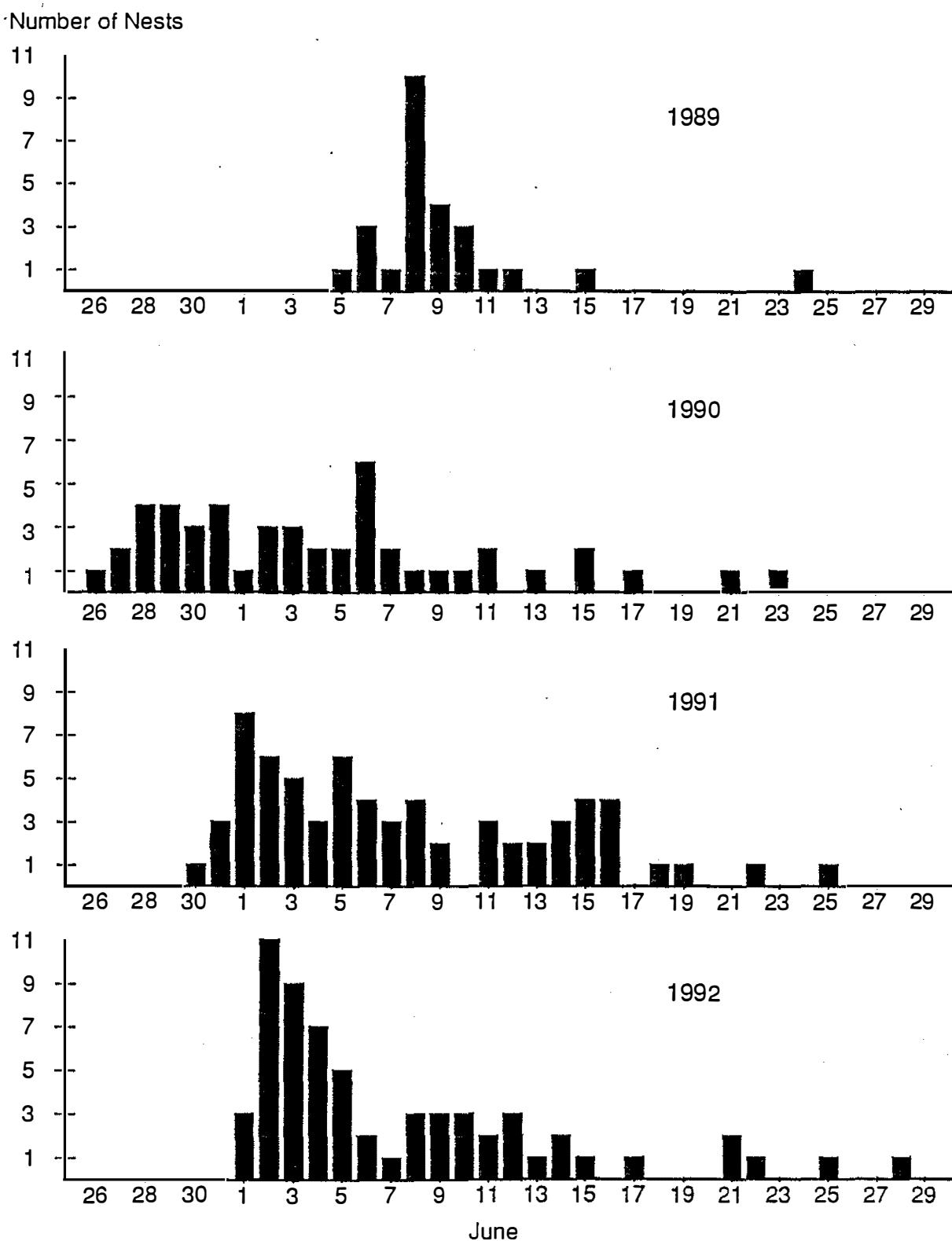


Figure D-10. Nest initiation dates of Lapland longspurs on two study plots in the Kuparuk Oilfield on the North Slope of Alaska, 1989-1992.

**Appendix E. Nest locations of 23 bird species on two study plots in the Kuparuk
Oilfield on the North Slope of Alaska, 1988-1992.**

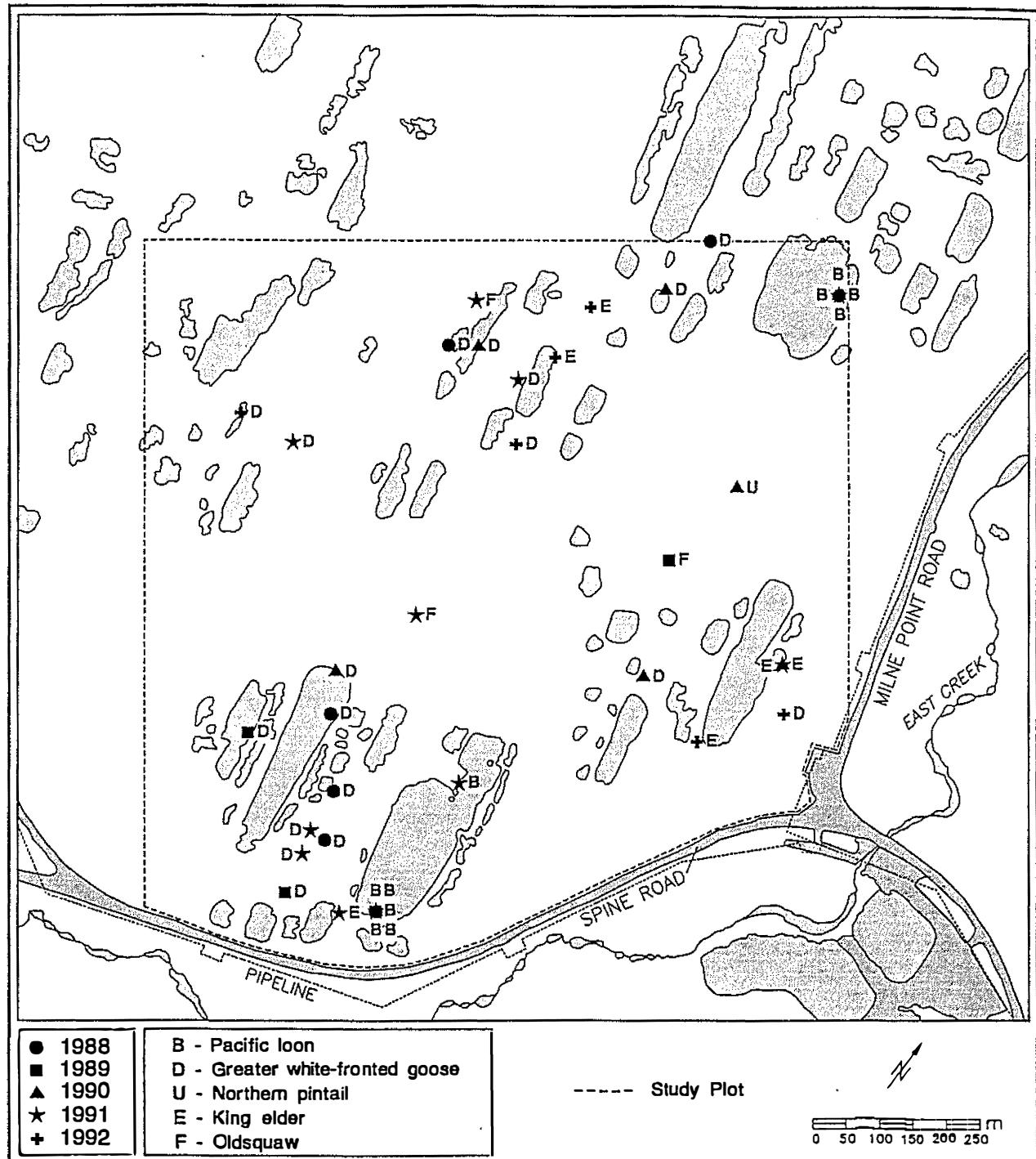


Figure E-1. Nest locations for five waterfowl species on plot 1-M in the Kuparuk Oilfield on the North Slope of Alaska, 1988-1992.

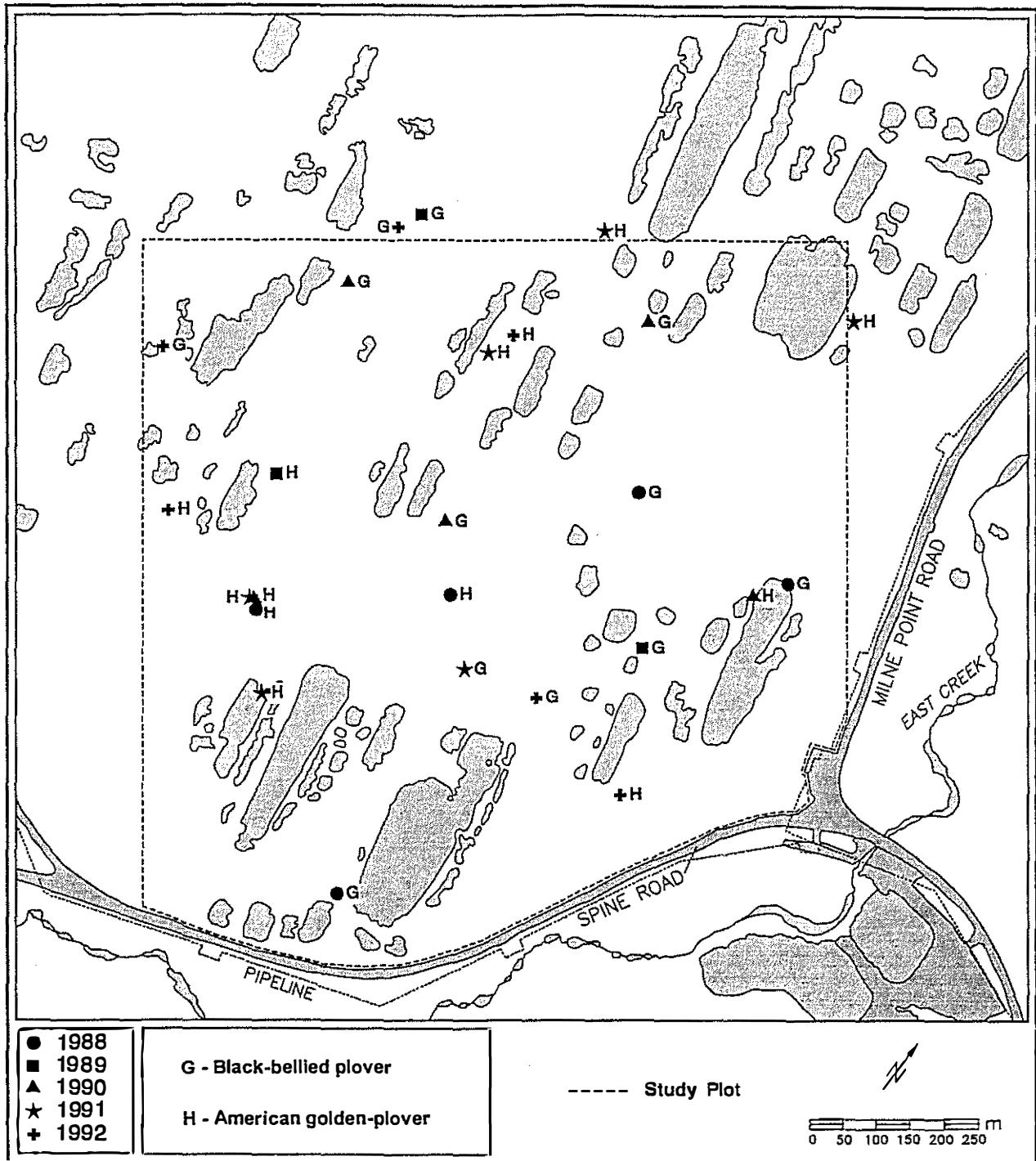


Figure E-2. Nest locations for black-bellied plovers and American golden-plovers on plot 1-M in the Kuparuk Oilfield on the North Slope of Alaska, 1988-1992.

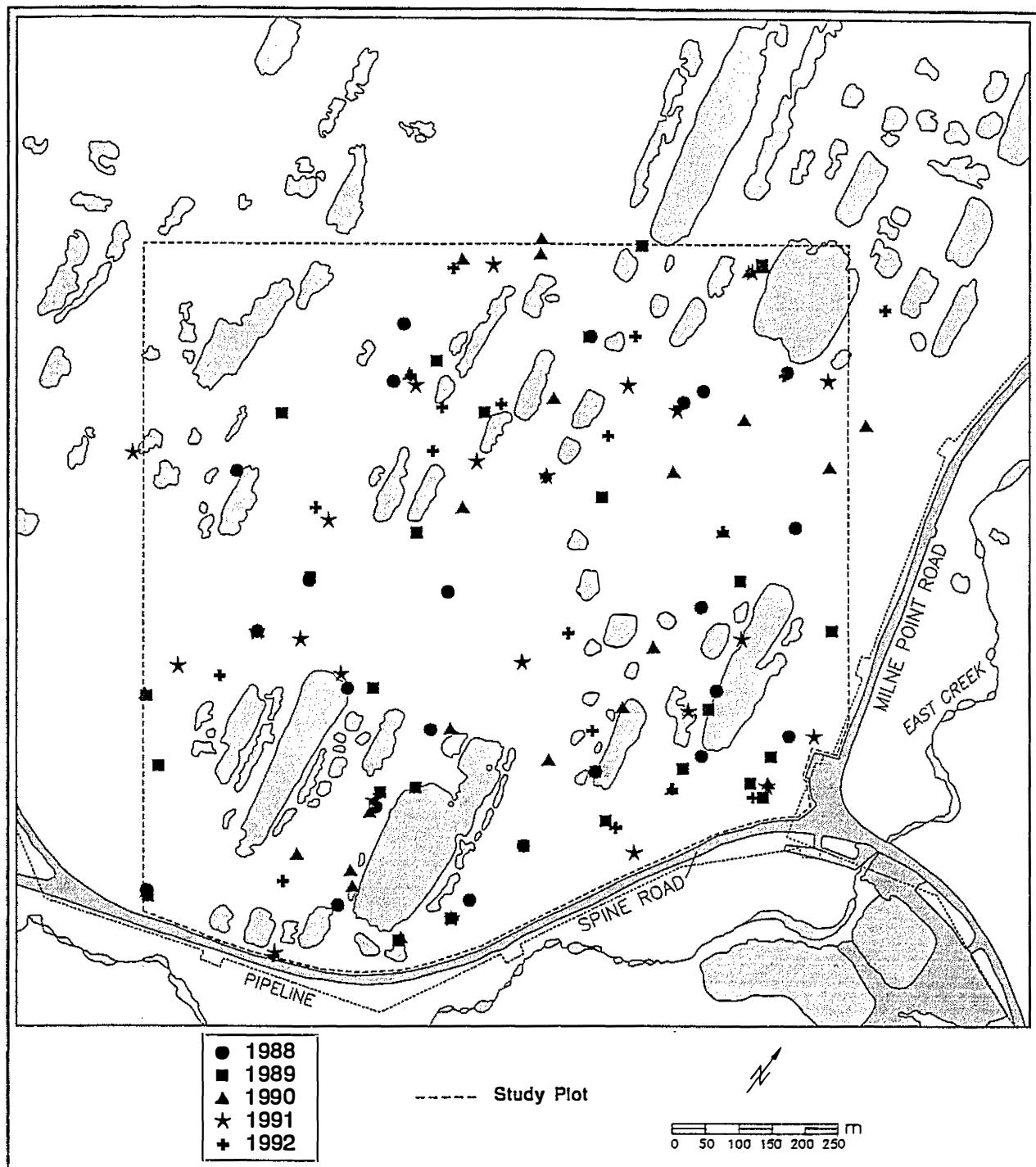


Figure E-3. Nest locations for semipalmated sandpipers on plot 1-M in the Kuparuk Oilfield on the North Slope of Alaska, 1988-1992.

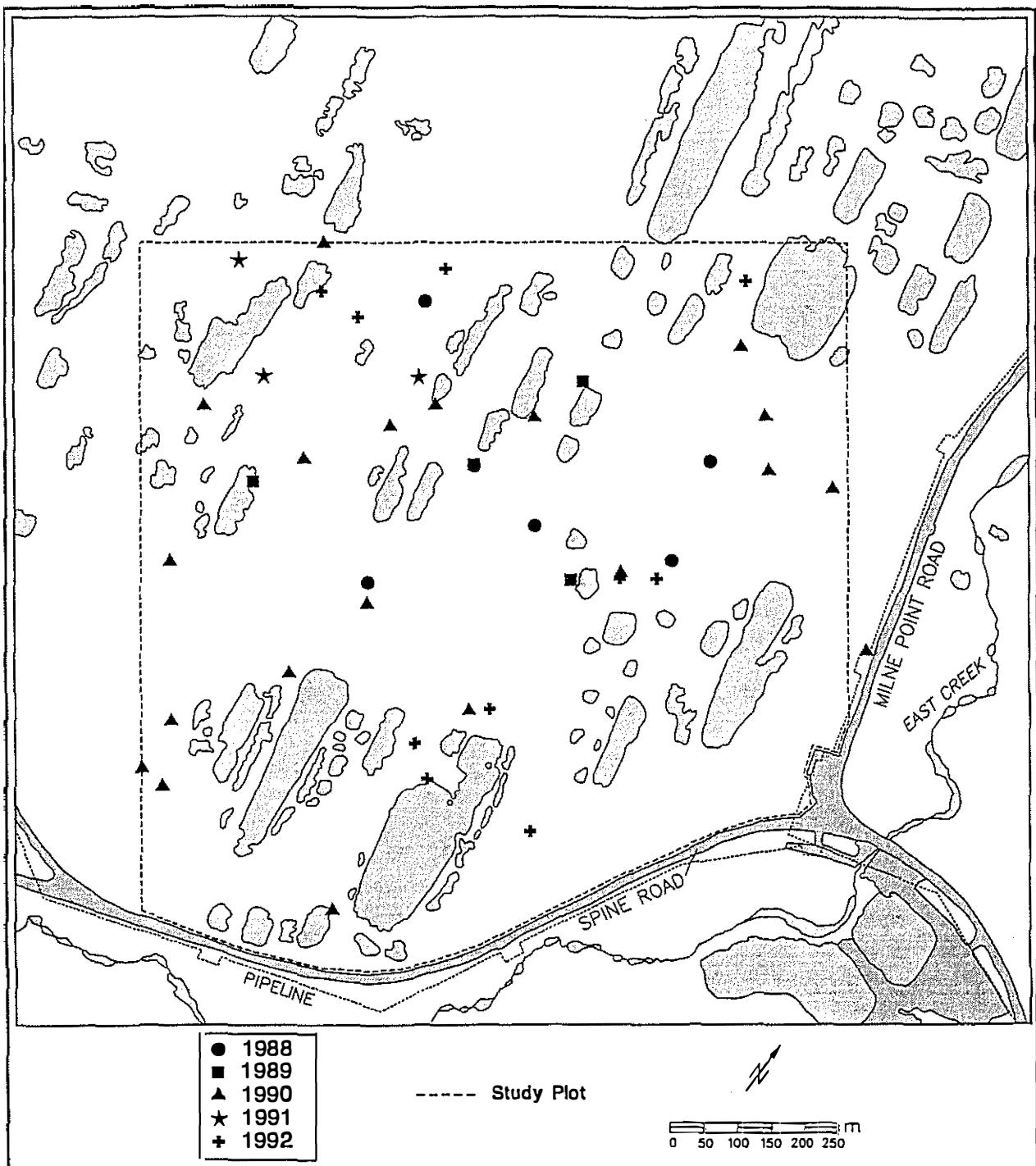


Figure E-4. Nest locations for pectoral sandpipers on plot 1-M in the Kuparuk Oilfield on the North Slope of Alaska, 1988-1992.

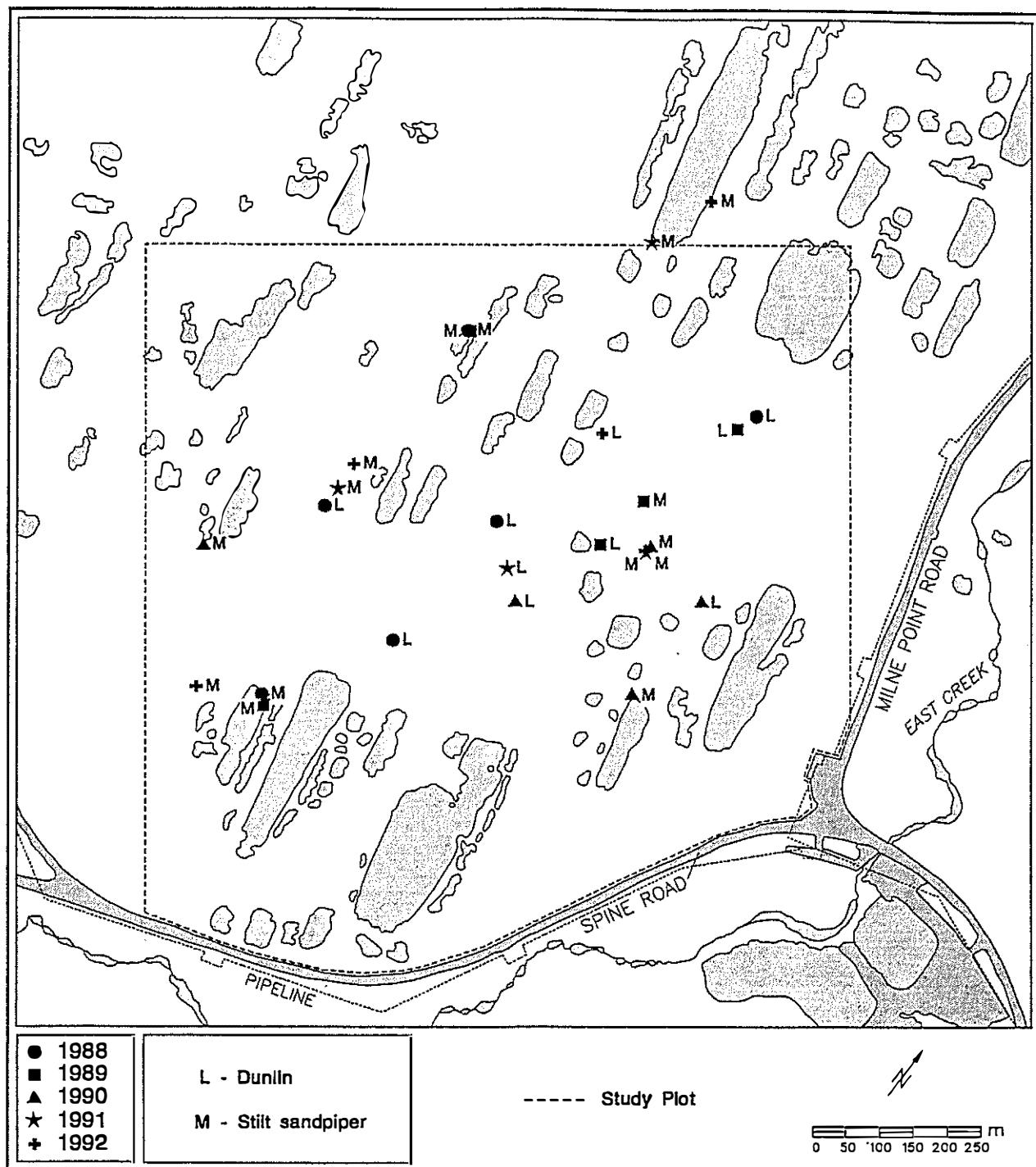


Figure E-5. Nest locations for dunlin and stilt sandpipers on plot 1-M in the Kuparuk Oilfield on the North Slope of Alaska, 1988-1992.

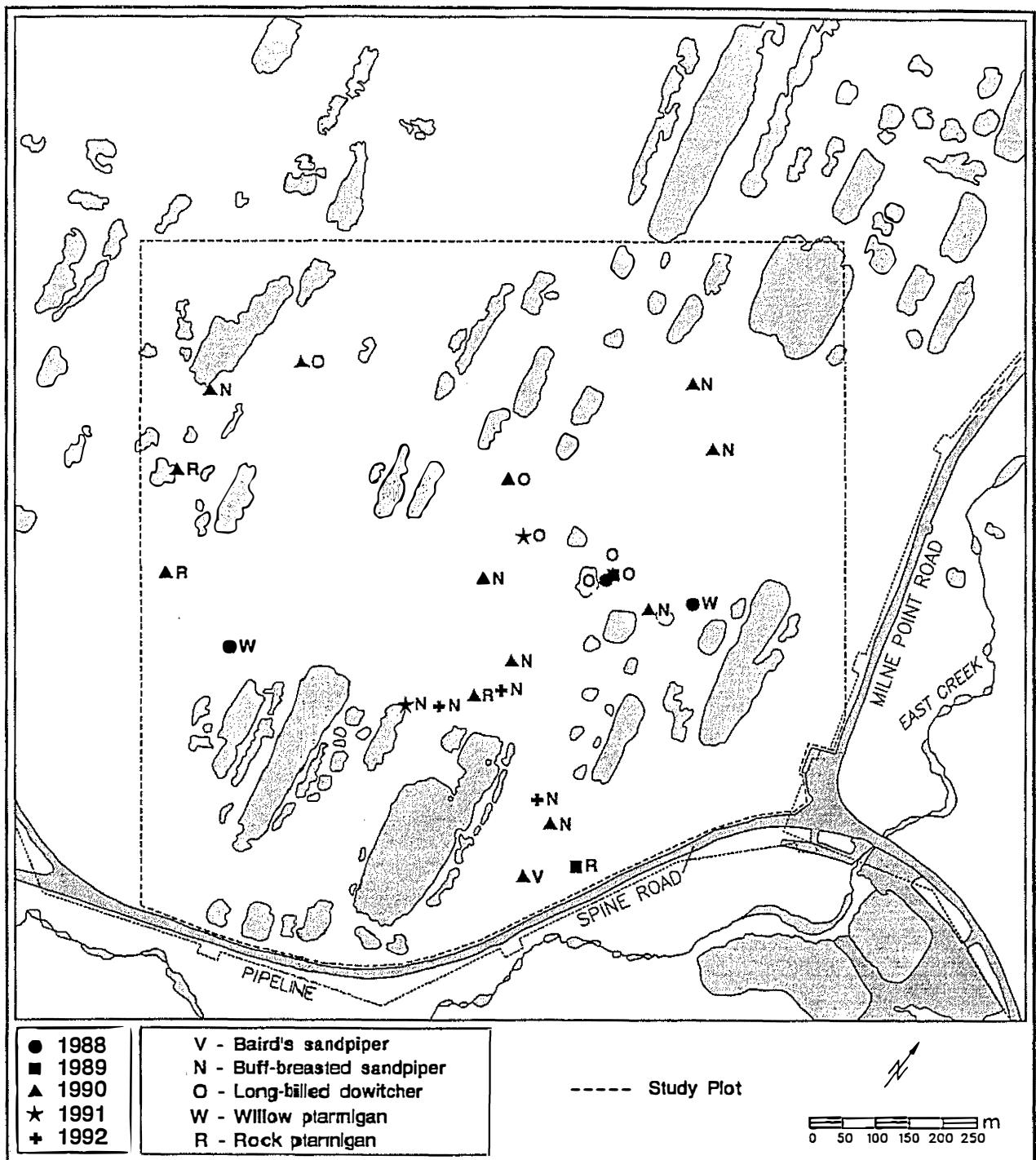


Figure E-6. Nest locations for five bird species on plot 1-M in the Kuparuk Oilfield on the North Slope of Alaska, 1988-1992.

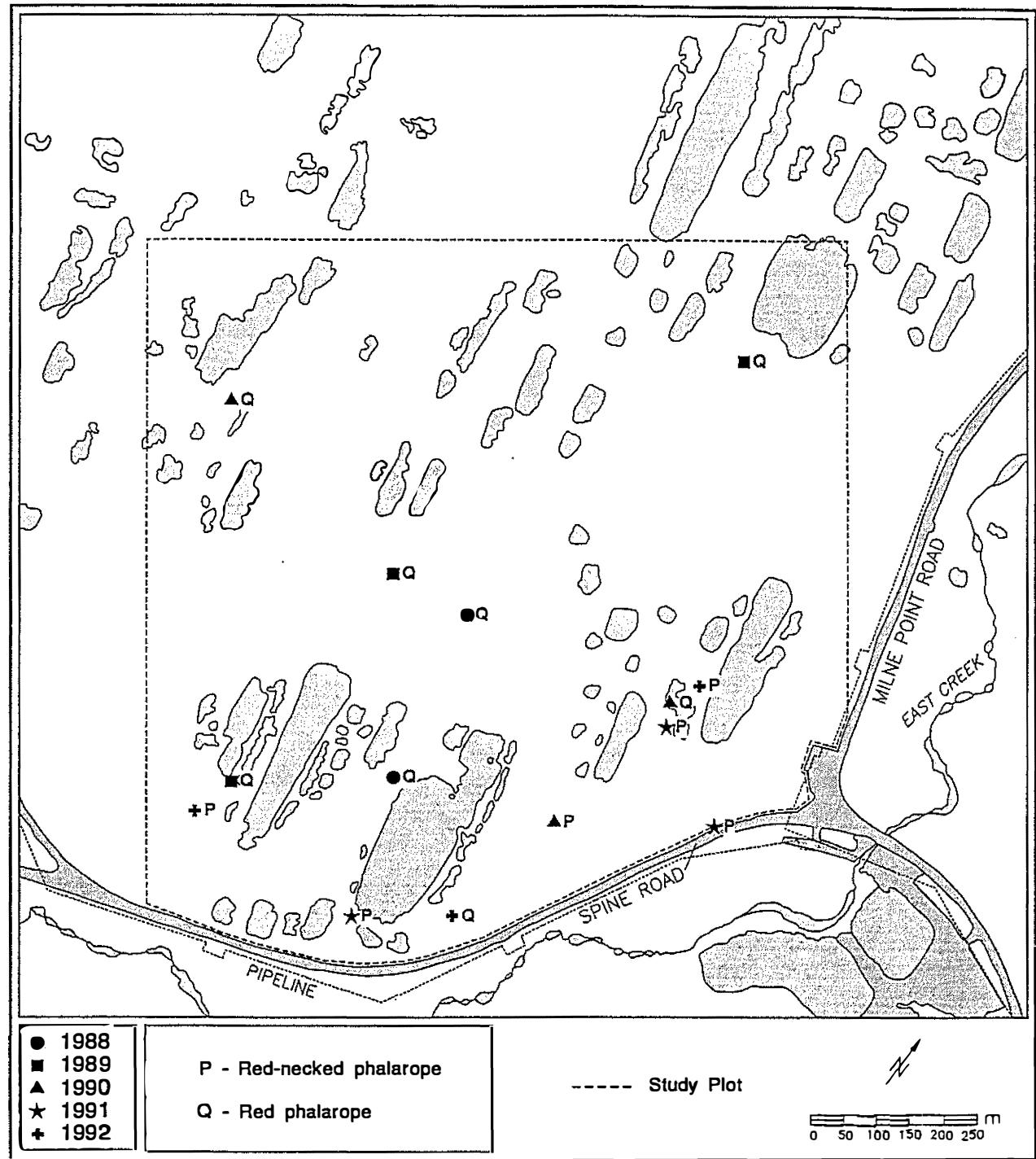


Figure E-7. Nest locations for red-necked and red phalaropes on plot 1-M in the Kuparuk Oilfield on the North Slope of Alaska, 1988-1992.

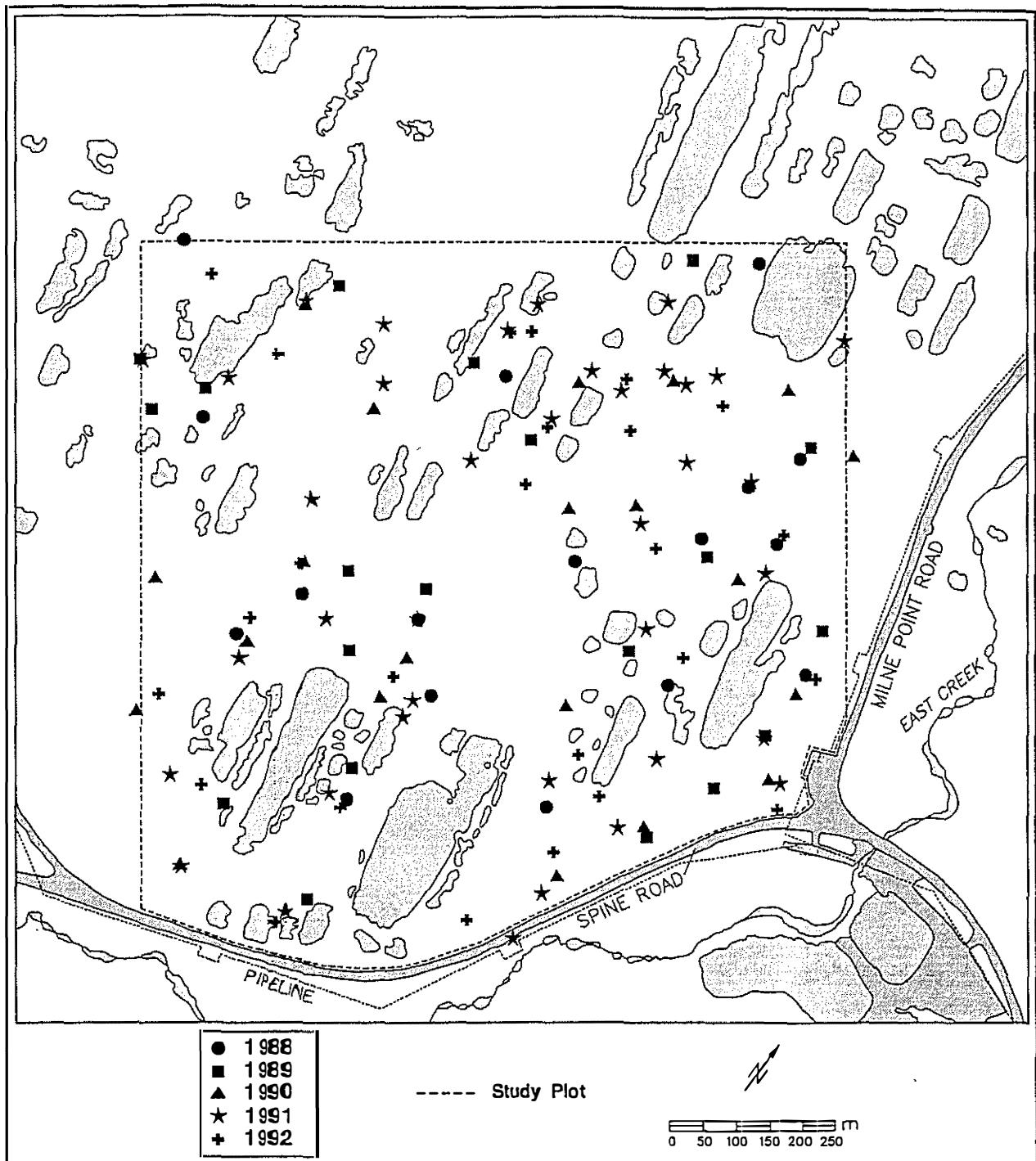


Figure E-8. Nest locations for Lapland longspurs on plot 1-M in the Kuparuk Oilfield on the North Slope of Alaska, 1988-1992.

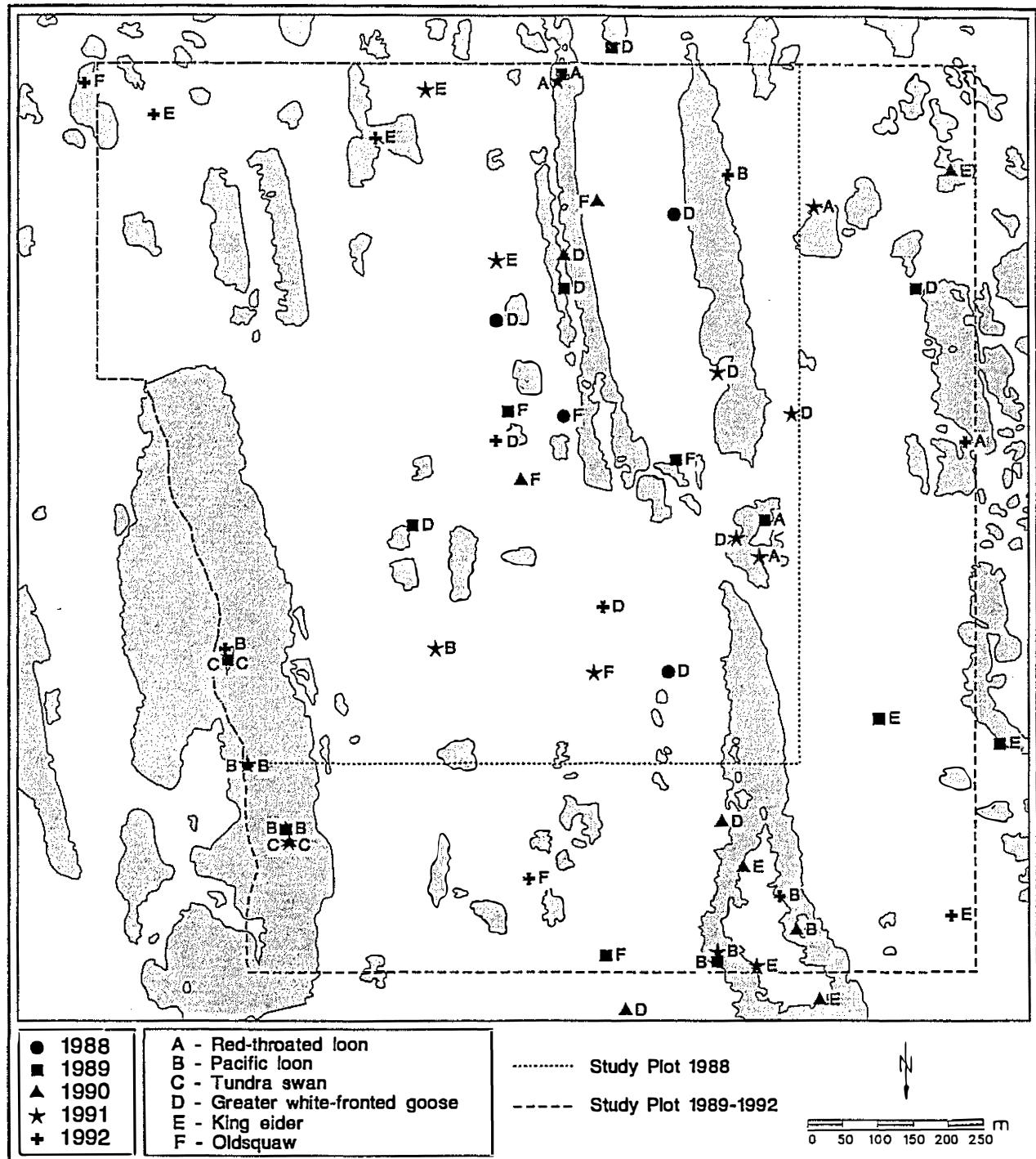


Figure E-9. Nest locations for six waterfowl species on plot 3-L in the Kuparuk Oilfield on the North Slope of Alaska, 1988-1992.

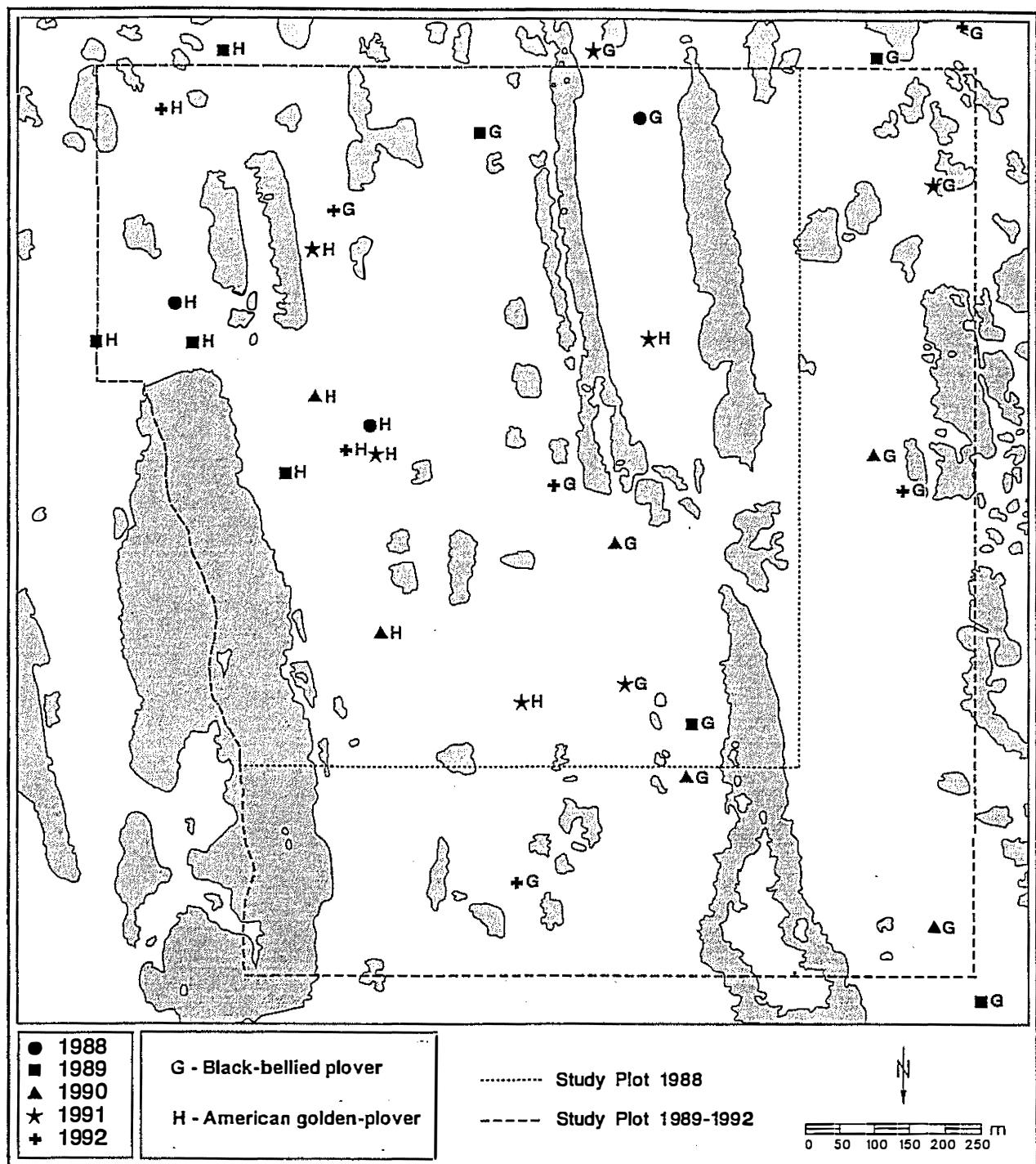


Figure E-10. Nest locations for black-bellied plovers and American golden-plovers on plot 3-L in the Kuparuk Oilfield on the North Slope of Alaska, 1988-1992.

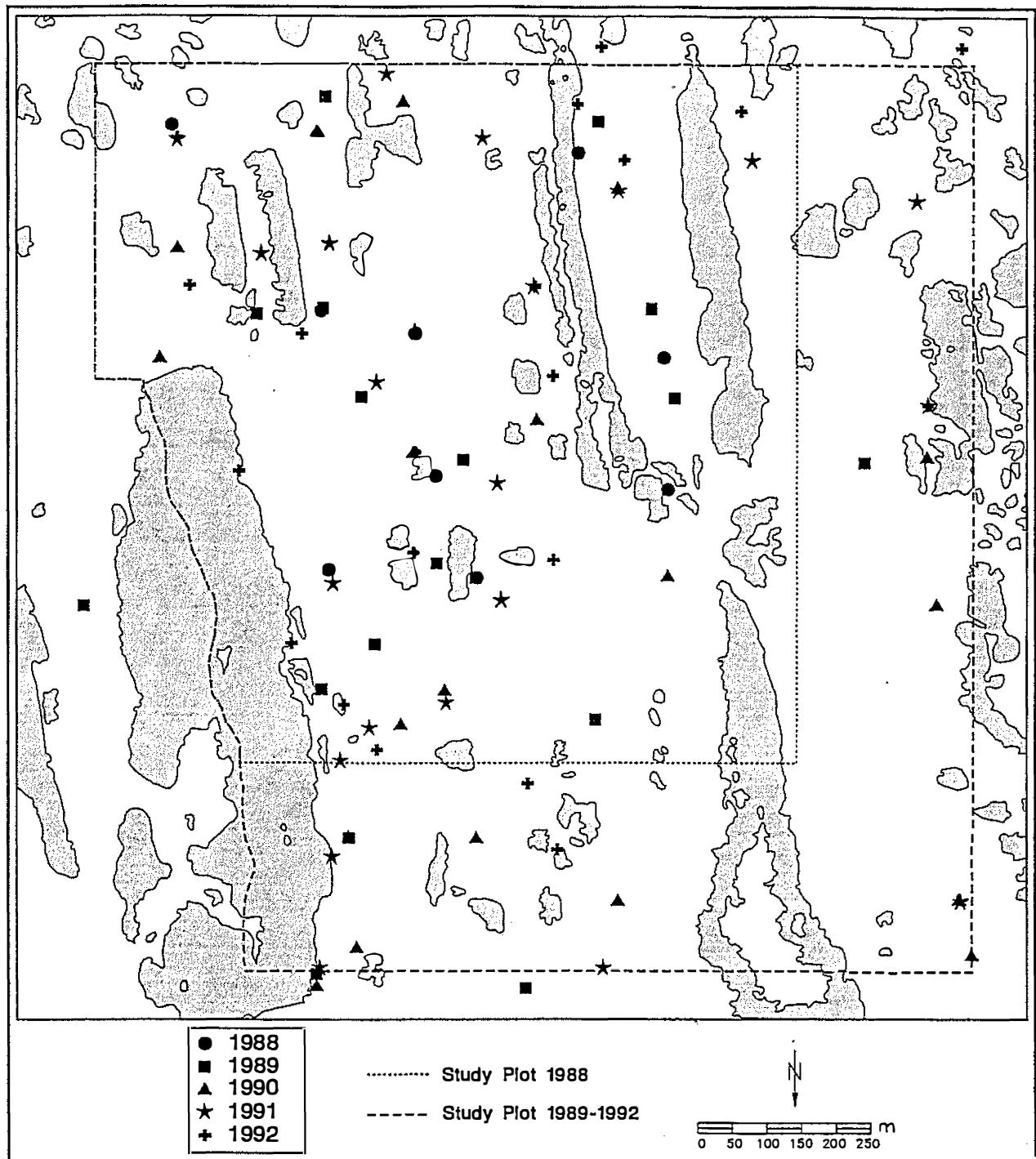


Figure E-11. Nest locations for semipalmated sandpipers on plot 3-L in the Kuparuk Oilfield on the North Slope of Alaska, 1988-1992.

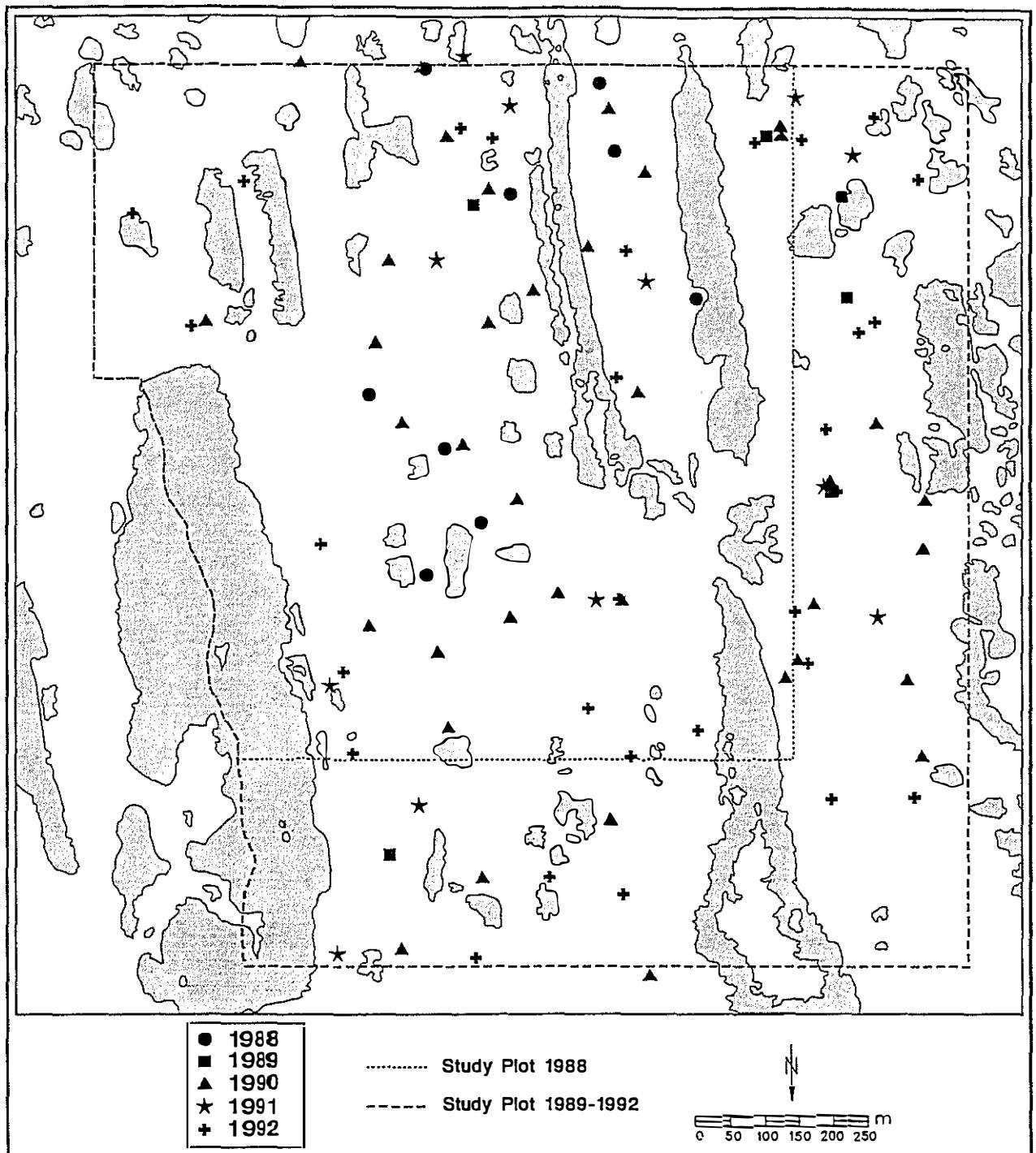


Figure E-12. Nest locations for pectoral sandpipers on plot 3-L in the Kuparuk Oilfield on the North Slope of Alaska, 1988-1992.

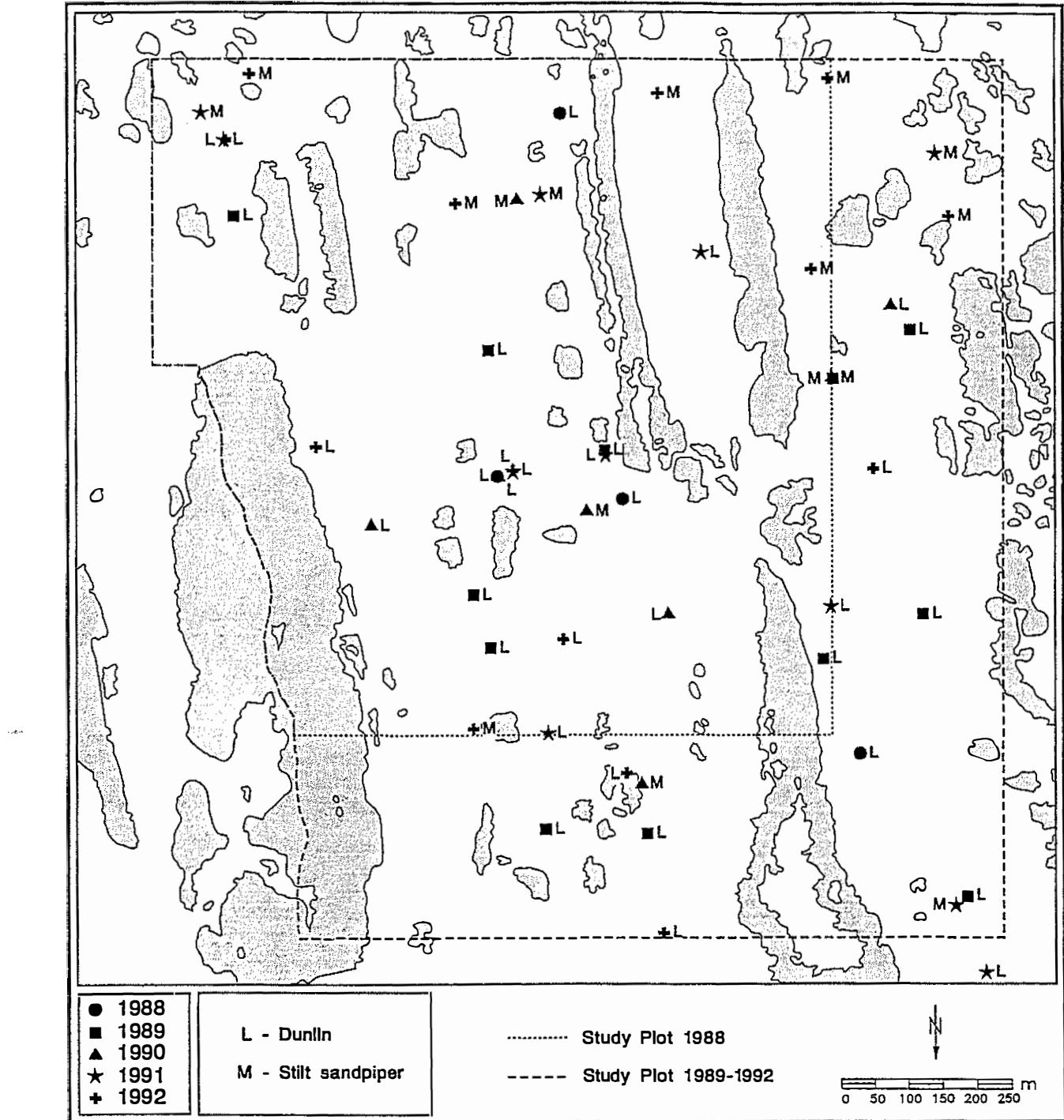


Figure E-13. Nest locations for dunlin and stilt sandpipers on plot 3-L in the Kuparuk Oilfield on the North Slope of Alaska, 1988-1992.

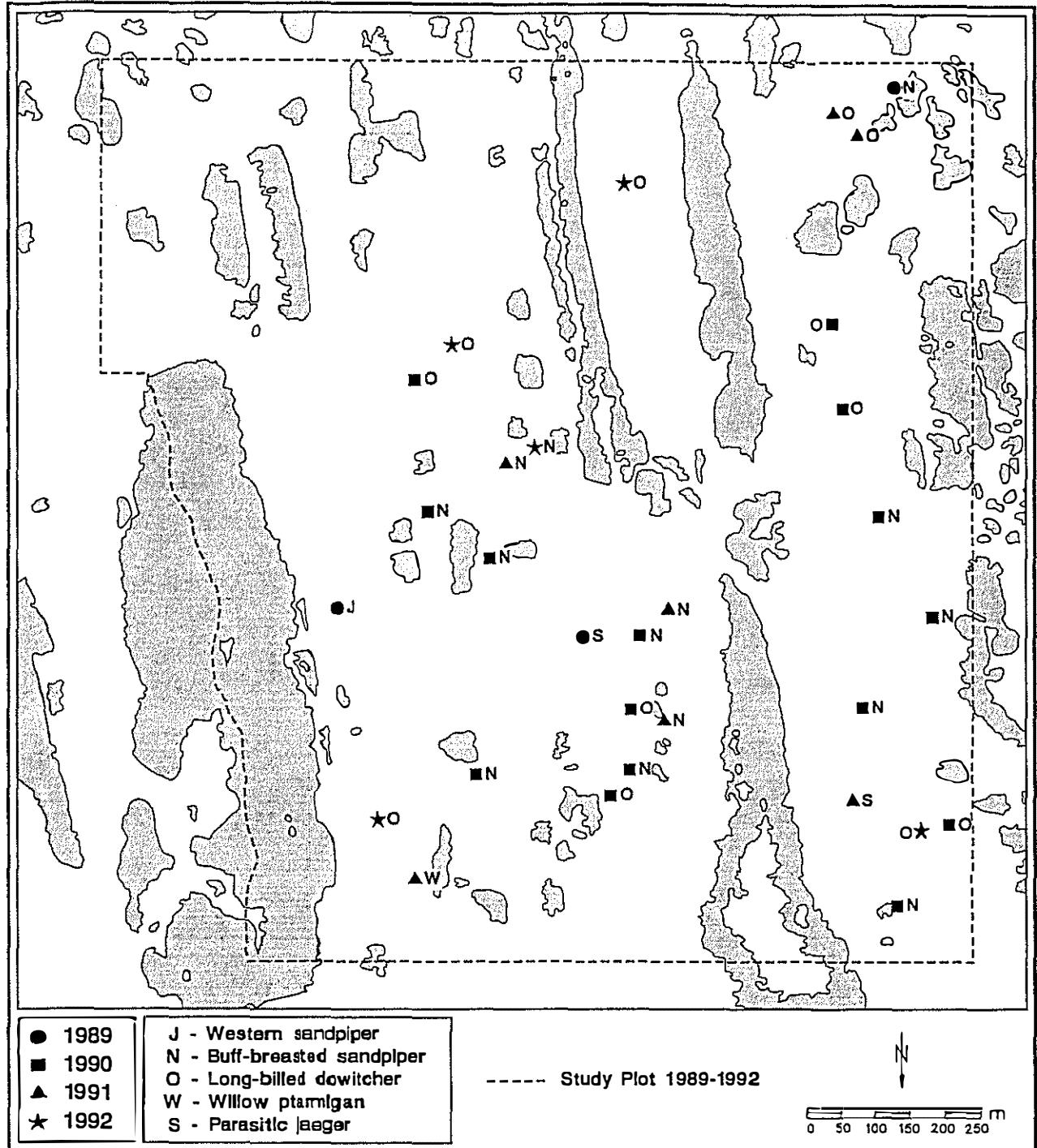


Figure E-14. Nest locations for five bird species on plot 3-L in the Kuparuk Oilfield on the North Slope of Alaska, 1989-1992.

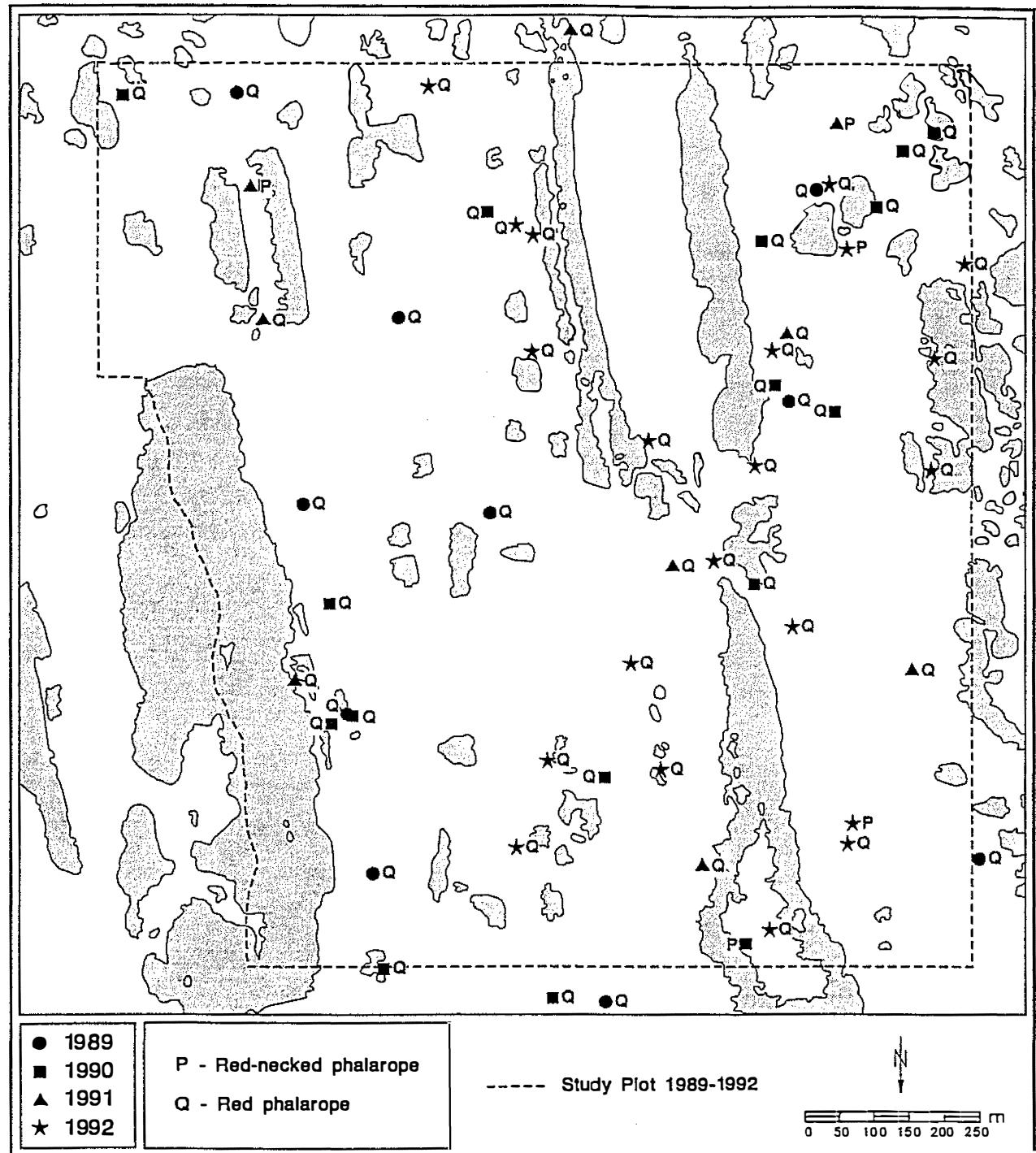


Figure E-15. Nest locations for red-necked and red phalaropes on plot 3-L in the Kuparuk Oilfield on the North Slope of Alaska, 1989-1992.

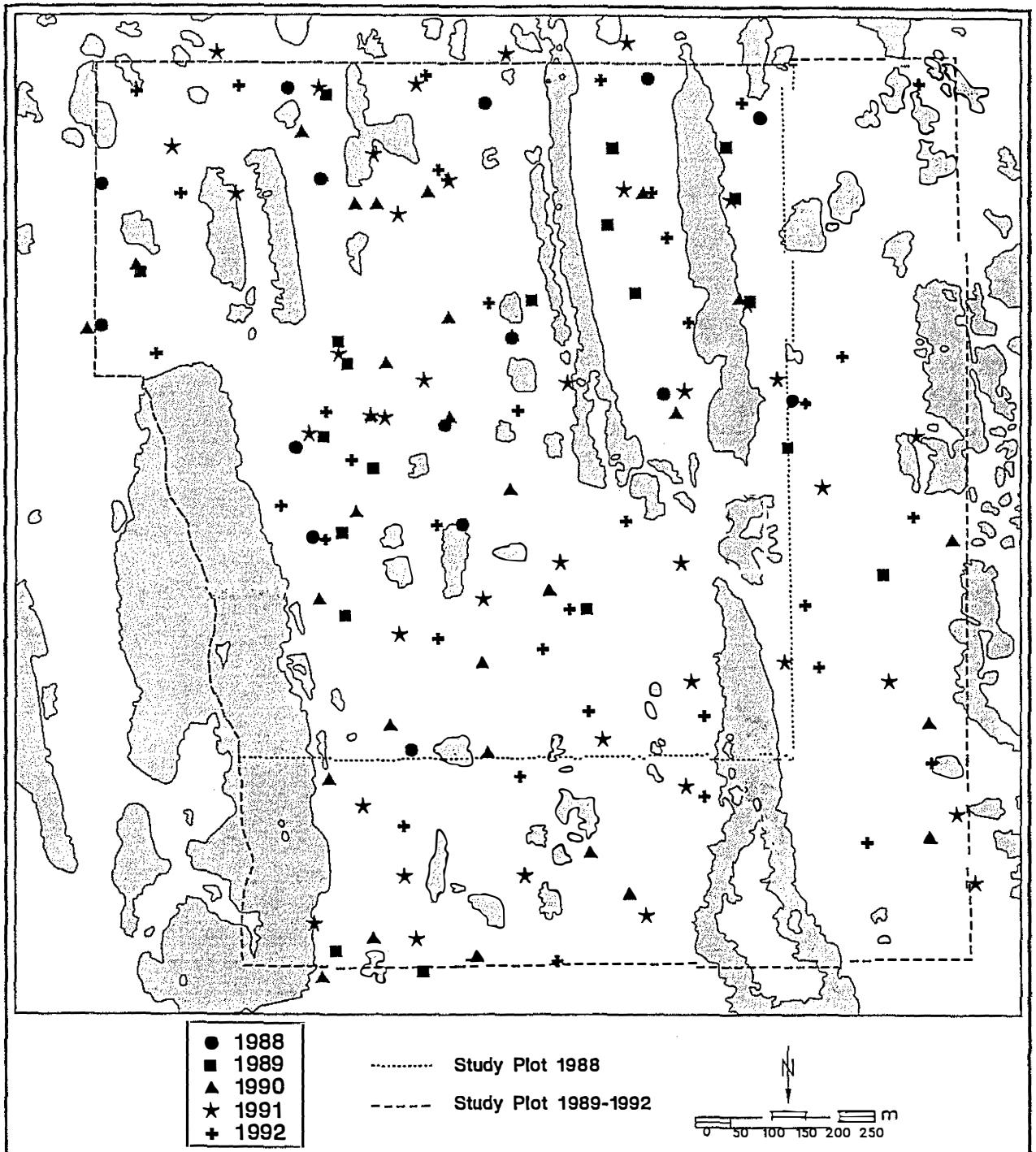


Figure E-16. Nest locations for Lapland longspurs on plot 3-L in the Kuparuk Oilfield on the North Slope of Alaska, 1988-1992.