LISBURNE TERRESTRIAL MONITORING PROGRAM - 1986 and 1987

THE EFFECTS OF THE LISBURNE POWERLINE

ON BIRDS

FINAL REPORT

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EXECUTIVE SUMMARY

- The Lisburne Terrestrial Monitoring Program was initiated in 1985 as a five-year study of the effects of construction and operation of Lisburne Development Project facilities on geese and swans. In 1986, another study component was added to assess the effects on all bird species of a new powerline, constructed during the winter of 1985-1986. The Lisburne powerline study was conducted during May-September in 1986 and 1987.

- The Lisburne Development Area (LDA) surrounds the southern portion of Prudhoe Bay and encompasses many of the existing Prudhoe Bay Oilfield facilities. This study focused on the 12.5 km of pole-supported powerline that traverses the northern half of the LDA from Drill Site (DS)-L4 to the eastern bank of the Putuligayuk River. The remainder of the powerline is suspended from vertical support members (VSMs) of pipelines running from East Dock Road to DS-L5 and from the Putuligayuk River to DS-L1.

- The goal of the Lisburne powerline study was to evaluate injury and mortality resulting from flying birds striking the powerline. To achieve this goal the following objectives were pursued:

  1) quantify the number of birds encountering the powerline, including information on species, season, behavior crossing the line, and flight altitude and direction;

  2) evaluate which species and age-classes of birds were affected most by the powerline, to evaluate which seasons, weather conditions, times of day, and powerline configurations were potentially hazardous to birds; and

  3) estimate how many birds struck the powerline and how many of these strikes resulted in injury or mortality.

- The total number of crossings (flights) of the Lisburne powerline was estimated at 252,874 and 267,004 in 1986 and 1987, respectively. These estimates are based on an average rate of 8-9 flights/h across each kilometer of powerline.

- A similar number of bird species was recorded each year, with 25 species observed in 1986 and 23 species in 1987. Glaucous Gulls dominated the observed flights and accounted for 38% and 26% of all sightings in 1986 and 1987, respectively.

- In both years, flight rates differed significantly among the three areas of the powerline, with more flights being recorded from DS-L3 to the Lisburne Production Center (LPC) (Area 2) and LPC to the Putuligayuk River (Area 3) than east of DS-L3 (Area 1). Season and time of day did not affect the flight rate for any area in 1986; in 1987 the flight rate declined significantly during brood-rearing in Area 1.

- For most birds, the potential for collision was low because of their behavior when crossing the powerline. Most birds (>75%) crossed over and at least 5 m from (>67%) the powerline in both years. Gulls, jaegers, and terns had the greatest potential for collisions, with the powerline given their tendency to fly within 5 m of the line (37% and 57% of observations in 1986 and 1987, respectively).

- Numbers of birds observed crossing the powerline were significantly different among these habitat types (dry, moist, and wet tundra) for all species combined in both 1986 and 1987, but several groups varied between years in their use of the different habitats. In general, more birds were recorded crossing the powerline in wet tundra than in moist or dry tundra.

- Numbers of birds observed crossing the three powerline configurations (simple, moderately complex, and complex) were not significantly different for all species combined in both 1986 and 1987. Only ducks had significantly different numbers of flights among the configuration types of the powerline for both years.

- Wind speed and direction also affected flights, but their effects varied among species groups. Fewer flights were observed during stronger wind conditions than during lighter wind conditions. Although winds were most often from the northeast in both years, most birds crossed the powerline in either a northerly or southerly direction, indicating that they crossed with a slight crosswind.

- Four collisions with the powerline, all involving waterfowl species, were observed during the two years of study; none of these collisions was known to be fatal. Human disturbance contributed to three of the four collisions.

- Similar numbers of bird remains were located in 1986 (15 birds) and 1987 (16 birds) during searches of the powerline corridor. The presence or absence of remains along the powerline was not apparently influenced by habitat under the powerline or configuration of the powerline.

- The estimated total number of bird collisions with the Lisburne powerline ranged from 43 to 249 collisions in 1986 and from 34 to 124 collisions in 1987, based on the minimum and maximum values of adjustments to the estimated total for biases inherent in the searches for dead birds. These collisions estimates were for birds medium-shorebird size or larger.

- The "calculated collision percentage" (CCP) based on our observations ranged from 0.017% to 0.098% in 1986 and from 0.013% to 0.046% in 1987. These values extrapolate to one collision per 1020-7692 flights across the Lisburne powerline, near the low end of values reported for other studies of bird mortality due to powerline collisions.

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INTRODUCTION

A component of the Lisburne Terrestrial Monitoring Program initiated in 1986 was a two year assessment of mortality and injury to flying birds caused by the powerline built in the Lisburne Development Area (LDA) during the winter of 1985-1986. High mortality rates for birds because of collisions with transmission lines (high-voltage powerlines) have been documented outside of Alaska (e.g., Malcolm 1982), and this study was implemented to assess the impact of the Lisburne powerline on birds in the LDA. The specific objectives of this study were:

1) to quantify the number of birds encountering the powerline, including information on species, season, and characteristics of their flight (i.e., altitude, direction);

2) to evaluate which species and age-classes of birds are affected most by the powerline and to evaluate which seasons, weather conditions, times of day, and powerline configurations are potentially hazardous to birds; and

3) to estimate how many birds strike the powerline and how many of these strikes result in injury or mortality.

Results of the first year of this study (1986) were included in the 1986 annual report for the Lisburne Monitoring Program (Murphy et al. 1987). The final year of the powerline study was conducted in 1987; this report presents the results from both years.

STUDY AREA

The terrestrial portion of the Lisburne Development Area (LDA) is a 63-km2 area surrounding the southern portion of Prudhoe Bay. The area is bounded on the west by West Dock Road, on the north by Prudhoe Bay, on the east by the Sagavanirktok River, and on the south by the Spine (MCC to PBOC) Road. The pole-supported portion of the Lisburne powerline (12.5 km) traverses the top half of the LDA from Drill Site (DS)-L4 to the eastern bank of the Putuligayuk River (Figure 1). The remainder of the powerline is suspended from the vertical support members of pipelines running from East Dock Road to DS-L5 and from the Putuligayuk River to DS-L1.

Landforms and vegetation in the LDA are typical of the Arctic Coastal Plain and have been described in detail by Walker et al. (1980) and WCC (1983). The LDA study area is described in detail in Murphy et al. (1987).

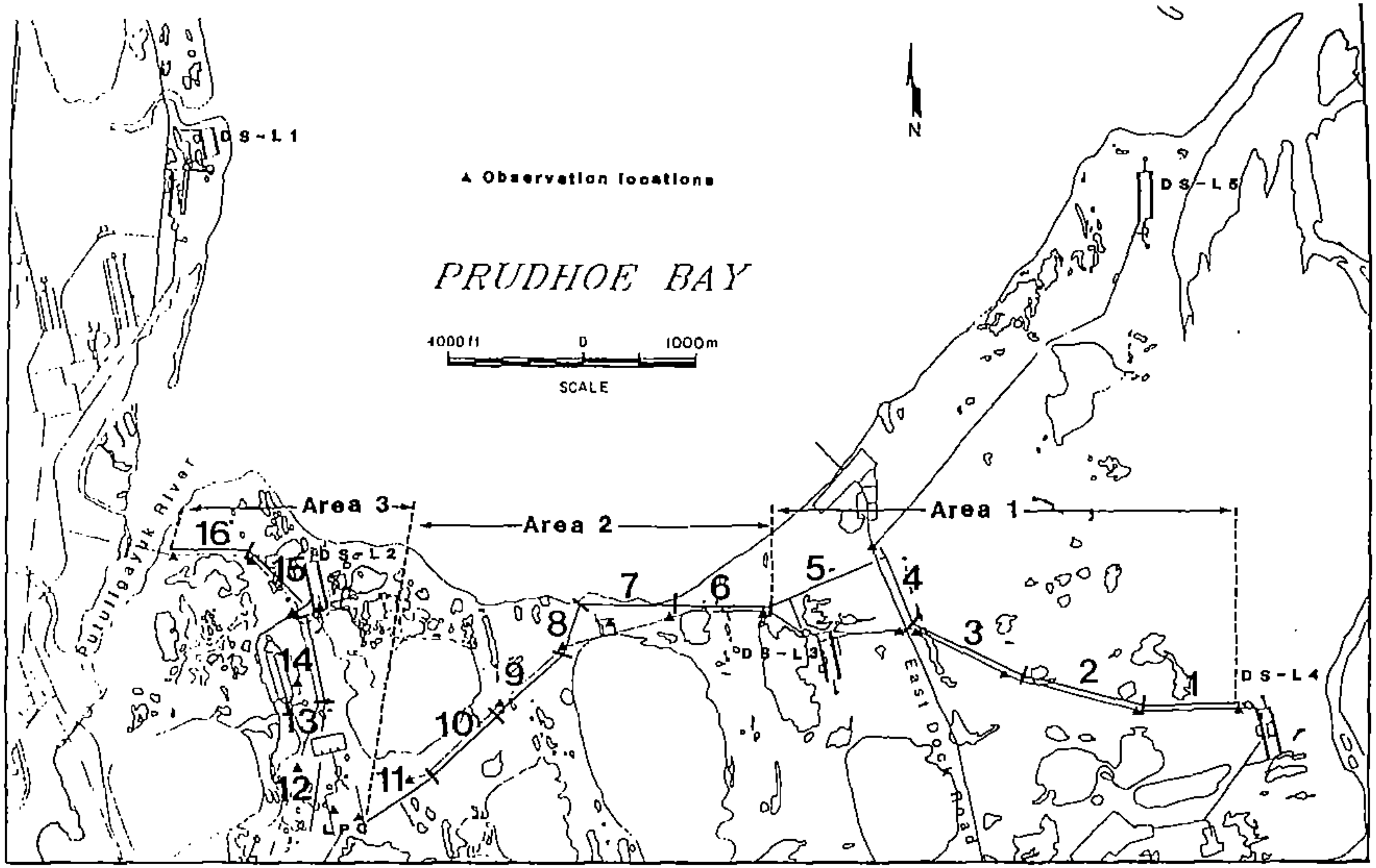

Figure 1. Location of the Lisburne powerline in the Lisburne Development Area, Prudhoe Bay, Alaska, and sections (1-16) for observing bird flights in 1986 and 1987. Observation locations varied based based on road traffic and weather conditions. Areas 1-3 were used in 1987 to stratify observations.

METHODS

The monitoring study for the Lisburne 13.8-kV powerline entailed two basic methods: observation of bird "flights" at the line (defined as a bird crossing, or attempting to cross, the powerline), and ground searches within the line corridor for dead, or injured, birds that collided with the powerline.

OBSERVATIONS OF BIRD FLIGHTS

Bird flights were systematically monitored from a stationary location at each of 16 observation sections along 12.5 km of powerline (Figure 1). We selected these sections according to three criteria: 1) uniformity of the line configuration; 2) natural breaks in the line, such as changes in direction; and 3) a length suitable for observation purposes. Data collected in 1986 indicated that bird flights were not distributed uniformly along the Lisburne powerline (Murphy et al. 1987). For observations in 1987, therefore, we divided the powerline into three areas for sampling purposes: 1) from DS-L4 to DS-L3 (Sections 1-5); 2) from DS-L3 to LPC (Sections 6-11); and 3) from LPC to the Putuligayuk River (Sections 12-16) (Figure 1). These areas correspond to the three general habitat types that are found near the Lisburne powerline (dry tundra, moist tundra, and wet tundra, respectively).

In both 1986 and 1987, bird flights were monitored during 30-min periods for approximately 8-10 h per week between mid-May and early September (Table 1). Observations were concentrated between 0600-1800 h during the peak period for bird activity in the LDA (Murphy et al. 1986). For each flight, the species, age/sex (if known), direction of flight, behavior and height when crossing the powerline, and the occurrence of

Table 1. Seasonal dates and number of hours of observations of the Lisburne powerline, Prudhoe Bay, Alaska, 1986 and 1987.

	Seasonal Dates		No. of Days		Hours of Observation	
Season	1986	1987	1986	1987	1986	1987
Pre-nesting	24 May-14 June	26 May-17 June	22	23	23.5	26.5
Nesting	15 June-13 July	18 June-14 July	29	27	30.0	29.5
Brood-rearing	14 July-21 August	15 July-15 August	39	32	25.5	27.5
Fall Staging	22 August-6 September	16 August-5 September	16	21	24.5	21.5
Total			106	103	103.5	105.0

collisions were recorded. Wind speed and direction, visibility, precipitation, and temperature were recorded for each observation period. In 1986, flight observations were restricted to birds of medium-shorebird size or larger, due to poor sightability of small birds. Small birds included small passerines (Lapland Longspurs and Snow Buntings) and small shorebirds (small Calidris sandpipers and phalaropes). In 1987, we attempted to record flight observations for these small birds, but again were unable to assess accurately the number of flights, due to poor sightability in some sections of the powerline. Therefore, data for small birds have not been included in estimates of total bird flights or total bird collisions.

The behavior and height at which birds crossed the line were used to determine whether avoidance behaviors occurred when birds encountered the line and to assess the potential for collisions with the line. The 15 behavioral and three height categories used when recording bird flights were combined into four behavioral and three height categories for analysis (Table 2). Behavioral observations recorded during searches for dead birds in 1986 were included in the 1986 data and subsequent analyses.

Whether habitat influenced the location of bird flights was evaluated by classifying each flight according to habitat type: dry tundra, moist tundra, and wet tundra. These habitats are general types and refer primarily to the relative availability of wetlands (which might attract birds) in each observation section.

Differences in the magnitude of bird flights were assessed for different line and pole configurations by assigning each section to one of three configurations: simple, moderately complex, or complex. Simple

Table 2. Behavioral and height categories used for the Lisburne powerline study, Lisburne Development Area, Alaska, 1986 and 1987.

Behavioral Categories

DATA COLLECTION	DATA ANALYSIS
Ascend/Over Line	Cross Over with Height Change
Descend/Over Line	
No Height Change/Over Line	Cross Over without Height Change
Ascend/Under Line	Cross Under with Height Change
Descend/Under Line	
No Height Change/Under Line	Cross Under without Height Change
Flare[a]/No Pass	Flaring
Flare/Pass	
Parallel/No Pass	Paralleling
Strike	Strike
Perched On Line	Perching
Perched On Pole	
Fly Between Wires	Fly Between Wires
Unknown	Unknown

Height Categories

DATA COLLECTION	DATA ANALYSIS
<5 m above or below line	<5 m above or below line
5-10 m above or below line	5-10 m above or below line
>10 m above or below line	>10 m above or below line

[a] A flare was defined as a sudden and/or deliberate change in flight direction by a bird when approaching the line.

configurations were those sections of the powerline (Sections 2, 3, 6, 7, 9, and 10) dominated by "wishbone" poles and containing only one "single" pole (Figure 2). Moderately complex configurations were powerline sections containing wishbone poles and grounded, short "triple-poles" (Sections 1, 11, 13, 14, 15, and 16). Complex configurations were identified as sections containing either tall triple-poles with adjacent shorter triple-poles (Sections 8 and 12) or sections containing a single, heavily guyed pole and short triple-poles (Sections 4 and 5). Chi-square analyses were used to test whether birds crossed in proportion to the availability of each line configuration and habitat. Observed numbers of birds were weighted to adjust for the different numbers of observation periods in each habitat and configuration type.

For all data analyses, observations of individual bird species were combined into the following groups: 1) geese and swans; 2) ducks; 3) loons; 4) shorebirds; 5) gulls, jaegers, and terns; and 6) raptors and ravens. Behavior and the influence of habitat and configuration were analyzed for each group, but groups were combined for calculations of estimated total number of flights and collision mortality.

Rates of bird flights in the three areas of the Lisburne powerline (described above) were tested with a Kruskal-Wallis test. Bird flight rates also were tested for seasonal and diel differences. If the initial test was statistically significant, a Kruskal-Wallis pairwise comparison test was calculated.

Estimated Total Flights

Estimated total number of flights (ETF) was calculated separately for 1986 and 1987. We assessed whether the rates of bird flights differed among the three areas of the powerline, among the four seasons,

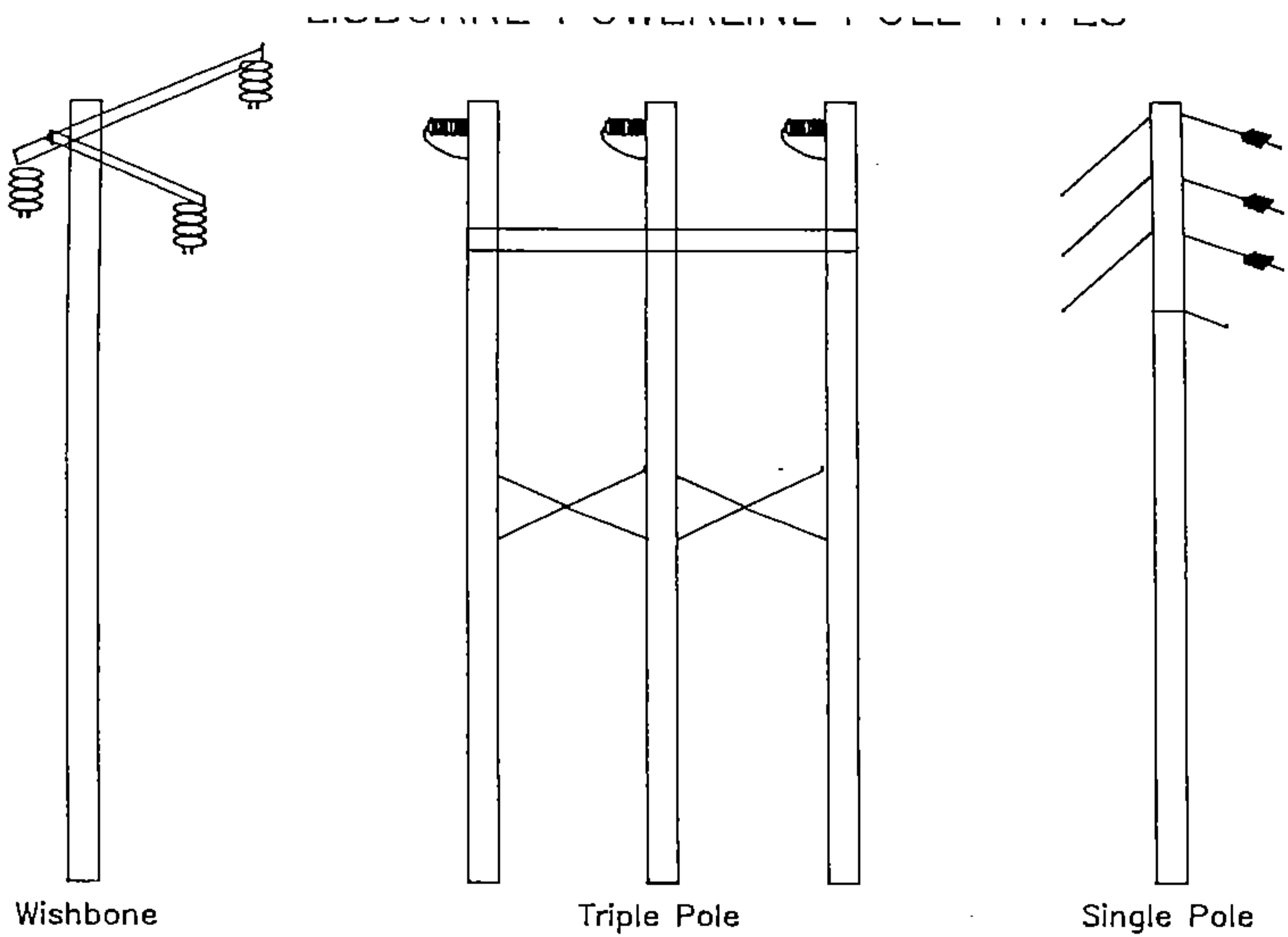

Figure 2. Representative types of powerline poles used for the Lisburne powerline, Prudhoe Bay, Alaska. Heights above ground level averaged 50 ft for wishbone, single, and short, triple poles and 84 ft for tall, triple poles (from as-built powerline specification tables).

and among the two time categories (0600-1759 h and 1800-0559 h ADT) before the estimate of total flights was calculated. Because the observation sections used to record bird flights were of unequal length, the flight rate was prorated by the length of each section to derive a rate of birds/h/km of powerline. The estimated total number of flights was then calculated for each year by using the formula:

ETF = birds/h/km x length (km) x time (h/day) x duration (days)

in which the rate of crossing (birds/h/km) was calculated for the appropriate length, time, and duration, based on the results of the analyses for differential rates by areas, seasons, and time of day. Rate calculations excluded birds whose behavior resulted in non-crossing of the powerline, including birds that perched on poles or lines.

ESTIMATION OF COLLISION MORTALITY

Data collection for estimation of collision mortality involved walking the entire powerline and searching for evidence of powerline collisions (i.e., bird carcasses, feathers, or injured birds). In 1986, three people spaced approximately 15 m (50 ft) apart searched the powerline approximately once every two weeks. In 1987, searches were conducted approximately every week by a team of two persons spaced 15 m (50 ft) apart. The width of the search corridor was reduced in 1987 because most dead birds were found within 15 m of the powerline in 1986.

For each dead or injured bird encountered, the species, observation section, line configuration, and approximate distance from the line were recorded. Each carcass was examined to evaluate the type of injuries and to estimate the probability that the death occurred because of a line strike. In 1986, we removed all evidence of collisions from the search corridor. In 1987, however, we left remains in the search corridor to better assess the rate of removal by scavengers. In both years, we also placed additional carcasses (when available) under the powerline and checked periodically to determine how long they remained before being removed by scavengers.

Estimated Collision Mortality

To calculate the estimated total number of bird collisions (ETBC), we used the ETF (described above) and the total number of dead birds found (TDBF). The ETBC and the calculated collision percentage (CCP) were calculated using the following formulas (James and Haak 1979):

$$ETBC = TDBF + SA + RA + HA + CA \qquad (1)$$

where

ETBC = estimated total number of bird collisions;

TDBF = total number of dead birds found;

$SA = \frac{TDBF}{PBF} - TDBF$ = search adjustment

(PBF = proportion of dead birds found in bias tests);

$RA = \frac{TDBF + SA}{PNR} - (TDBF + SA)$ = scavenger removal adjustment

(PNR = proportion of dead birds not removed by scavengers in tests);

$HA = \frac{TDBF + SA + RA}{PS} - (TDBF + SA + RA)$ = searchable habitat adjustment

(PS = proportion of birds found in habitat that was searchable under line); and

$$CA = \frac{TDBF + SA + RA + HA}{PBK} - (TDBF + SA + RA + HA) = \text{crippling adjustment}$$

(PBK = proportion of birds colliding with the line that fall within the search area).

Equation (1) reduces to

$$ETBC = \frac{TDBF}{(PBF)\ (PNR)\ (PS)\ (PBK)}$$

Thus, $CCP = \frac{ETBC}{ETF} \times 100$

in which

CCP = calculated collision percentage, and
ETF = estimated total number of flights.

These formulas allow for adjustments to the ETBC based on search bias, removal by scavengers, the amount of searchable habitat, and crippling rates.

RESULTS AND DISCUSSION

OBSERVATIONS OF BIRD FLIGHTS

We recorded 695 birds of 25 species encountering the powerline during 207 observation periods (total sampling effort = 103.5 h) between 24 May and 6 September 1986 (Table 3). The number of birds observed increased in 1987, when we recorded 922 birds of 23 species during 210 observation periods (total sampling effort = 105 h) between 26 May and 5 September (Table 3). If passerine observations are excluded from the 1987 total, the total number of birds observed decreases to 834, which is still a 20% increase from the total number observed in 1986.

Glaucous Gulls accounted for approximately 38% and 26% of all non-passerine sightings in 1986 and 1987, respectively, and were abundant during all seasons. Most other species were seasonally abundant, with different species and groups dominating each season's total. For example, geese and swans (in 1986) and ducks (in 1987) were the most abundant groups during pre-nesting, but were conspicuously absent during brood-rearing, when adults were molting or attending to flightless broods. Conversely, the activity of loons around the powerline increased during brood-rearing, because of their frequent foraging flights to and from Prudhoe Bay. The total number of birds was nearly equal among seasons in 1986, but fewer birds were observed during brood-rearing in 1987 than during other seasons (Table 3).

Estimated Total Number of Flights

We emphasize here that the values for estimated total number of flights presented for 1986 in Murphy et al. (1987) were not prorated for the length of each observation section and, therefore, were incorrect.

Table 3. Bird flights at the Lisburne powerline by group, species, and season, Prudhoe Bay, Alaska, 1986 and 1987. Scientific names for species are presented in Appendix A.

Species	TOTAL BIRDS BY SEASON[a]									
	Pre-Nesting		Nesting		Brood-rearing		Fall Staging		Total	
	1986	1987	1986	1987	1986	1987	1986	1987	1986	1987
LOONS	1	1	16	35	28	42	47	28	92	106
Red-throated Loon	-	-	5	16	3	3	2	8	10	27
Pacific Loon	1	-	8	16	71	28	43	9	73	53
Loon spp.	-	1	3	3	4	11	2	11	9	26
GEESE AND SWANS	75	41	28	23	-	-	20	38	123	102
Tundra Swan	3	10	1	2	-	-	2	1	6	13
Greater White-fronted Goose	24	15	12	2	-	-	9	12	45	29
Brant	32	8	4	11	-	-	-	-	36	19
Canada Goose	11	5	11	8	-	-	9	25	31	38
Goose spp.	5	3	-	-	-	-	-	-	5	3
DUCKS	8	83	11	23	4	-	15	30	38	136
Northern Pintail	3	59	2	2	2	-	15	24	22	85
Oldsquaw	5	22	9	14	2	-	-	-	16	36
Spectacled Eider	-	-	-	4	-	-	-	-	-	4
King Eider	-	2	-	1	-	-	-	-	-	3
Eider spp.	-	-	-	2	-	-	-	-	-	2
Duck spp.	-	-	-	-	-	-	-	6	-	6
RAPTORS AND RAVENS	-	-	3	-	4	-	-	-	7	-
Peregrine Falcon	-	-	-	-	3	-	-	-	3	-
Gyrfalcon	-	-	-	-	1	-	-	-	1	-
Common Raven	-	-	3	-	-	-	-	-	3	-
SHOREBIRDS	7	25	33	83	73	28	25	96	138	232
Black-bellied Plover	-	-	-	-	-	-	2	-	2	-
Lesser Golden-Plover	-	-	-	2	5	1	1	-	6	3
Plover spp.	-	-	-	-	-	8	-	-	-	8
Ruddy Turnstone	4	4	-	-	-	-	-	-	4	4
Semipalmated Sandpiper[b]	-	7	9	9	-	10	-	-	9	26
Pectoral Sandpiper	-	4	5	28	1	1	10	44	16	77
Dunlin	-	1	-	-	-	-	-	-	-	1
Stilt Sandpiper	-	1	-	-	5	-	-	-	5	1
Common Snipe	-	-	1	-	-	-	-	-	1	-
Red-necked Phalarope[b]	-	2	4	1	-	-	-	-	4	3
Shorebird spp.[c]	3	6	14	43	62	8	12	52	91	109
GULLS, JAEGERS, AND TERNS	64	72	98	80	89	52	46	54	297	258
Pomarine Jaeger	1	13	3	-	-	-	-	-	4	13
Parasitic Jaeger	-	-	5	3	1	9	1	3	7	15
Long-tailed Jaeger	-	-	1	1	1	1	-	-	2	2
Glaucous Gull	63	59	72	66	84	42	45	51	264	218
Sabine's Gull	-	-	17	9	2	-	-	-	19	9
Arctic Tern	-	-	-	1	1	-	-	-	1	1
PASSERINES[d]	-	13	-	19	-	25	-	30	-	87
Lapland Longspur[b]	-	6	-	3	-	10	-	4	-	23
Snow Bunting[b]	-	7	-	16	-	3	-	25	-	51
Passerine spp.[b]	-	-	-	-	-	12	-	1	-	13
TOTAL SPECIES	10	15	18	19	14	8	11	9	25	23
TOTAL BIRDS	155	235	189	263	198	147	153	276	695	921

[a] Seasonal dates are presented in Table 1.
[b] Small bird species excluded from analyses of estimated flights and collision mortality.
[c] Includes some small shorebirds that were excluded from further analysis.
[d] Observations of passerines were not recorded in 1986.

By not correcting the rates for the length of the observation section, the total estimated flights were vastly underestimated in 1987. We have recalculated these totals, using the proper corrections for section length; the correct values are presented below.

For both 1986 and 1987, differences in rates (birds/h/km) of bird flights among the three observation areas were tested before seasonal or diel differences were tested. Due to small sample sizes for some groups, differences in the rate of flights were tested for all species combined, without attempting a breakdown by groups. In both 1986 and 1987, the rate of flights differed among the three areas ($P<0.05$), with fewer birds crossing the powerline in Area 1 (Sections 1-5) than in the other two areas. During analyses for seasonal and diel differences within each area, we found no significant differences ($P>0.05$) among the four seasons or two time categories in 1986, and only brood-rearing was different from the other seasons in Area 1 in 1987 ($P<0.05$). Therefore, we have calculated the ETF for 1986 by using the mean flight rates for each area, the length of the powerline in each area, and the duration of the entire sampling period (106 days) without any seasonal breakdown (Table 4). In 1987, because seasonal rates were significantly different in Area 1, but not in Areas 2 and 3, we further stratified Area 1 by season and used the appropriate duration for each season, whereas flights in Areas 2 and 3 were calculated for the entire sampling period (Table 4).

The ETFs were relatively similar among years, with 252,874 flights in 1986 and 267,004 flights in 1987. Although these totals may appear at first to be extremely large numbers of flights, they translate to 104-108 flights/h across the entire 12.5 km of powerline, or 8-9 flights/h across one kilometer of powerline. It is important to remember that

Table 4. Calculations for the estimated total flights for the Lisburne powerline, Prudhoe Bay, Alaska, 1986 and 1987. (The formula for calculating estimated total flights is presented in METHODS.)

1986

Area 1[a] - 6.2 birds/h/km X 5.0 km X 24 h/day X 106 days = 78,864

Area 2 - 7.6 birds/h/km X 4.5 km X 24 h/day X 106 days = 87,005

Area 3 - 11.4 birds/h/km X 3.0 km X 24 h/day X 106 days = 87,005

Estimated Total Flights 252,874

1987

Area 1 -

Pre-nesting
9.9 birds/h/km X 5.0 km X 24 h/day X 23 days = 27,324

Nesting
5.2 birds/h/km X 5.0 km X 24 h/day X 27 days = 16,848

Brood-rearing
0.7 birds/h/km X 5.0 km X 24 h/day X 32 days = 2,688

Fall Staging
5.4 birds/h/km X 5.0 km X 24 h/day X 21 days = 13,608

Area 2 - 9.9 birds/h/km X 4.5 km X 24 h/day X 103 days = 110,128

Area 3 - 13.0 birds/h/km X 3.0 km X 24 h/day X 103 days = 96,408

Estimated Total Flights 267,004

[a] Areas of the powerline are delineated in Figure 1.

these numbers represent individual crossings of the powerline and not necessarily individual birds.

The relative contributions of each group to the ETF in each year may be evaluated by examining their rates of flights (Table 5); these rates were calculated for all areas and seasons combined, therefore, the sum of these flights will not equal the ETFs calculated above (Table 4). Gulls, jaegers, and terns contributed the largest proportion of both the flight rates (43.8-46.2 birds/h) and estimated bird flights (34-45% of total flights) for 1987 and 1986, respectively. Flight rates for the other groups were relatively similar between years, with the exception of ducks, which had a substantially greater flight rate in 1987 than in 1986 (Table 5).

Our estimated number of bird flights was relatively similar to those recorded from some areas outside of Alaska, but did not reach the magnitudes recorded for some waterfowl staging and wintering areas in the Pacific Northwest (Table 6). Most of these studies focused on short stretches (<2 km) of high-voltage (>200 kV) transmission lines supported by tall steel towers (line height approximately 25 m) that were often located across known flight corridors between feeding and loafing areas.

Behavior and Height of Bird Flights

For each flight, we assessed the potential for collision with the powerline by categorizing the behavior and height of the bird at the time of crossing (see METHODS; and Figures 3 and 4). In 1986 and 1987, most birds (89%) crossed over the powerline. Of those that crossed over the powerline, most (46%) were in the intermediate height category (5-10 m) in 1986, whereas, in 1987, birds were equally abundant in the two lower height categories (40% in each category) (Figure 4). Geese and

Table 5. Mean number of birds/h and estimated total bird flights by groups at the Lisburne powerline, Prudhoe Bay, Alaska, 1986 and 1987.[a]

	Mean Birds/h		Estimated Total Bird Flights	
Species	1986	1987	1986	1987
Loons	16.2	17.5	41,213	43,260
Geese and Swans	17.5	16.2	44,520	40,046
Ducks	5.0	23.8	12,720	58,834
Raptors and Ravens	0.8	--	2,035	--
Shorebirds	17.5	26.2	44,520	64,766
Gulls, Jaegers, and Terns	46.2	43.8	117,533	108,274

[a] Mean rates for groups are calculated for all areas combined and for the entire 12.5 km length of the powerline.

Table 6. Comparison of results of other transmission line studies with the Lisburne powerline study, Prudhoe Bay, Alaska, 1986 and 1987.

Year of Study	Mean Flights per Day	Estimated Total Flights	Length of Study (days)	Height of Line (m)	Length of Line (km)	Voltage of Line (kV)	Location of Study	Source
1986	2386	252,874	106	14-24	12.5	13.8	Prudhoe Bay, AK	This Study
1987	2592	267,004	103	14-24	12.5	13.8	Prudhoe Bay, AK	This Study
1973-75	7500	100,000	13	12-45	?	345	Lake Sangchris, IL	Anderson (1978)
1978	1565	143,980	92	14-30	0.4	500	Saddle Mountain Lake, WA	James and Haak (1979)
1978-79	463	69,450	150	30-50	1.0	500	Ringold Island, WA	James and Haak (1979)
1978	2343[a]	112,464[a]	48	41	0.7	500	Crab Creek, WA	Beaulaurier (1981)
1979	5307	615,612	116	41	0.7	500	Crab Creek, WA	Beaulaurier (1981)
1981	971	103,897	107	34	0.7	500	Crab Creek, WA	Beaulaurier (1981)
1978	6905[a]	220,960[a]	32	50	?	230	Bybee Lake, WA	Beaulaurier (1981)
1979	16,968	526,008	31	50	?	230	Bybee Lake, WA	Beaulaurier (1981)
1981	3684	265,248	72	3	?	230	Bybee Lake, WA	Beaulaurier (1981)
1980	1552[b]	53,504[b]	19	28-130	1.25	500	Crow Butte I.-river, WA	Willdan Associates (1982)
1981	785[b]	75,978[b]	18	28-130	1.25	500	Crow Butte I.-river, WA	Willdan Associates (1982)
1980	920[b]	44,536[b]	19	30-50	0.3	500	Crow Butte I.-slough, WA	Willdan Associates (1982)
1981	365[b]	48,467[b]	17	30-50	0.3	500	Crow Butte I.-slough, WA	Willdan Associates (1982)

[a] Day flights only.
[b] Ducks only.

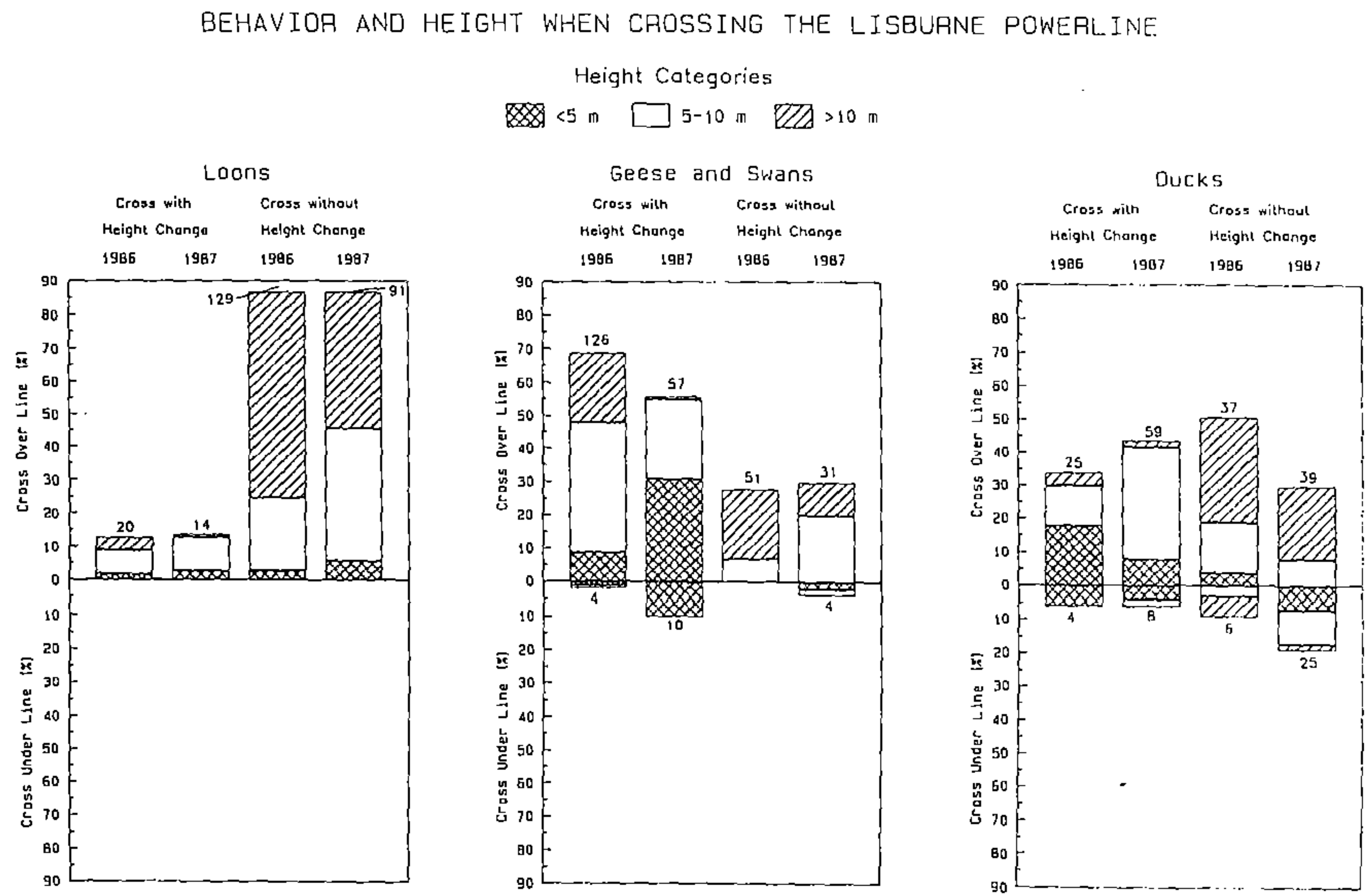

Figure 3. Flights (%) of loons, geese and swans, and ducks in different behavioral and height categories at [illegible] 1986 and 1987. Observations of birds crossing the

ma cat y a resented above or below the bars.

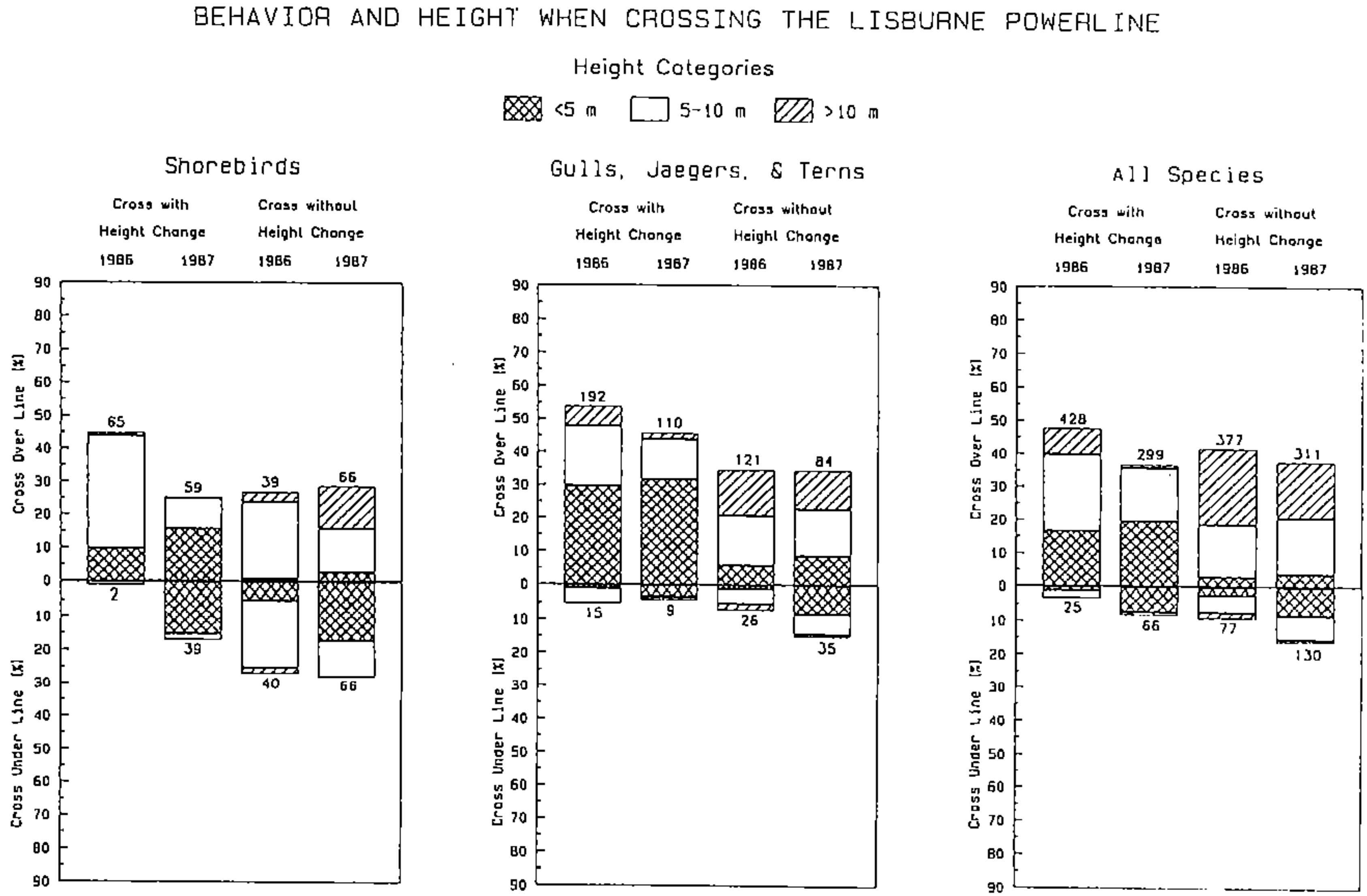

Figure 4. Flights (%) of shorebirds, gulls, jaegers, and terns, and all species in different behavioral and height categories at the Lisburne powerline, Prudhoe Bay, Alaska, 1986 and 1987. Observations of birds crossing the powerline recorded during searches for dead birds were included in the 1986 data. Sample sizes for each major category are presented above or below the bars.

swans apparently were aware of, and avoided, the powerline, as indicated by >50% of the birds changing height while crossing the line in both 1986 and 1987 (Figure 3). Loons had the least potential for collision, with the vast majority of birds crossing at heights >5 m above the line in both 1986 and 1987 (Figure 3). Gulls, jaegers, and terns had a greater potential for collision, with 37% and 52% of the birds crossing at heights <5 m from the powerline in 1986 and 1987, respectively (Figure 4). In addition, more than 50% of the gulls, jaegers, and terns crossed with a height change in both years (Figure 4), indicating avoidance behavior. Except for shorebirds, relatively few birds crossed under the line, where the potential for collision with the guy wires of some pole types is much greater (Figures 3 and 4).

Seasonal or rare flight behaviors may contribute markedly to the potential for collision. For example, chasing by conspecifics (e.g., courtship flights for shorebirds, "rape" flights for Oldsquaw and Northern Pintail) can result in birds concentrating less on avoiding obstacles such as the powerline and more on escaping from the chasing bird (Krapu 1974). Observations of geese at other powerlines in the LDA also indicated that birds may risk collisions when attempting to land under or adjacent to powerlines. We observed geese exhibit severe "flaring" behavior (i.e., rapid flapping to reverse or radically change direction of flight) on several occasions, but did not record any collisions. We also observed one Glaucous Gull fly between the wires in 1986; no contact with the wires was observed.

In addition to normal crossing behaviors, other types of behavior also resulted in birds not crossing the line. For example, three birds (Common Raven, Gyrfalcon, and Peregrine Falcon) in the raptors and ravens group used powerline poles as observation posts in 1986, and Glaucous Gulls commonly perched on poles in the vicinity of DS-L2 and LPC pads and on other poles along the powerline in both 1986 (n=17) and 1987 (n=10). Glaucous Gulls also exhibited what appeared to be overt avoidance of the powerline by deviating from their flight paths to detour around the ends of line sections (Sections 11-16). Parallelling the powerline without crossing was relatively rare in both 1986 (n=8) and 1987 (n=3).

Flaring behaviors that resulted in aborted crossings were observed on two occasions (number of birds = 7, <1% of all flights) in 1986 and on five occasions (number of birds = 7, <1% of all flights) in 1987. In 1986, six Brant made a gradual, wide turn away from the powerline that was considered a mild flare, and one Glaucous Gull flared abruptly after being pushed near the powerline by a strong gust of wind. Of the five observations of flaring behavior recorded in 1987, three observations were of single Glaucous Gulls and two observations were of pairs of Northern Pintails in courtship flight. Non of the flares in 1987 was considered a severe flare. The relative paucity of observations of flaring behaviors indicated that birds usually corrected their flight paths well before the point at which collision was imminent.

The behavior of birds encountering high-voltage powerlines has been reported in other studies. James and Haak (1979) and Beaulaurier (1981) noted that most waterfowl, when approaching a transmission line below line height, tended to gain altitude to cross above (rather than below) the line, a finding similar to that of our study (Figure 3). In contrast, Faanes (1987) reported that the most common behavior of birds (primarily waterfowl and gulls) crossing powerlines in North Dakota was "no reaction" (68%), followed by "flared and climbed" (25%). The

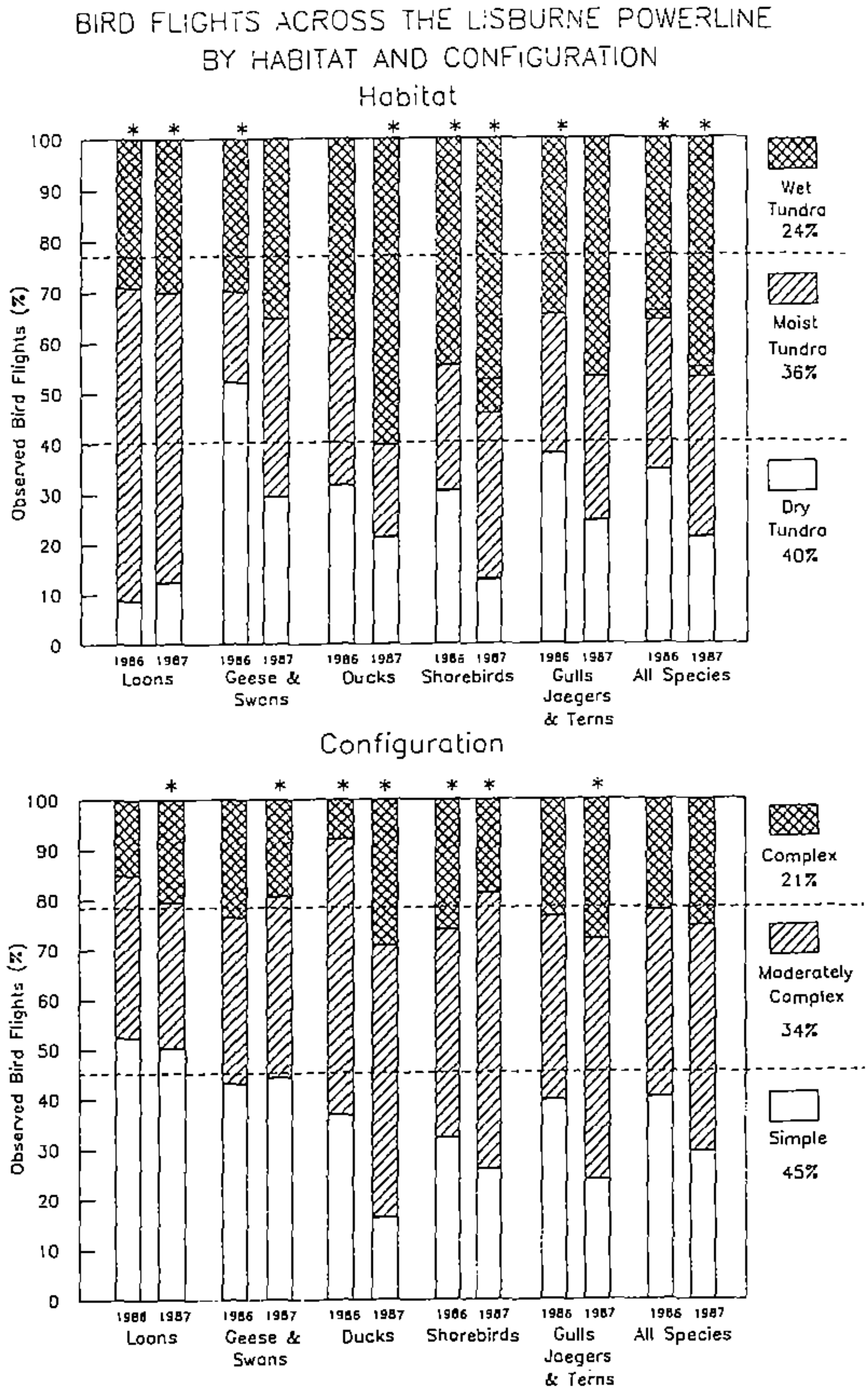

Figure 5. Bird flights (%) in different habitat and configuration types of Lisburne powerline, Prudhoe Bay, Alaska, 1986 and 1987. Dashed l indicate the relative percentage of the powerline in each habitat configuration type. Asterisks indicate significantly different i rates among types for the group (Chi-square tests, P<0.05).

had significantly different numbers of crossings in the three configurations ($P<0.05$), whereas, in 1987, all groups had significantly different numbers of crossings in the three configurations (Figure 5). For those groups that did differ significantly, in general, more birds crossed than expected in the moderately complex and complex configurations than in the simple configurations, based on the proportions of the powerline in each configuration. The influence of habitat and configuration may not be independent of each other, however, because the simple configuration type does not occur in wet tundra where most observed flights were recorded. It was apparent, however, that the more complex configurations were not avoided by birds crossing the Lisburne powerline.

The implications of these differences in flights for both habitat and configuration types are most important in the context of improving future site-planning of powerlines to reduce the potential for collisions. If, for example, fewer overall flights occur over dry tundra (the case in this study), it would be the preferred habitat for placement of powerlines, to reduce both the total number of flights across the line and the potential for collisions. In addition, complex configurations of the powerline may provide the greatest potential for collisions because of the presence of multiple-pole structures and the increased number of guywires.

Influence of Weather on Bird Flights

Weather conditions can affect the ability of birds to cross a powerline safely, through either the influences of wind speed and direction on flight control or the reduction of visibility of the powerline. Weather conditions during powerline observations in 1986 and 1987 are summarized in Appendix B. Strong winds (>32 km/h [>20 mph]) observed proportions of flaring behaviors, aborted crossings, and collisions were low at a transmission line across the Columbia River, Washington (Willdan Associates 1982). At a transmission line spanning the Mississippi River, most (>97%) waterfowl crossed >15 m above the line, greatly reducing the potential for collisions (Fredrickson 1983). Although species-specific differences in behavior have been noted, it appears that most birds are able to see and avoid transmission lines and powerlines under normal weather conditions.

Influence of Habitat and Line Configuration on Bird Flights

The influence of habitat and line configuration on bird flights was evaluated in both 1986 and 1987. The observed number of flights in each habitat for 1986 and 1987 (Figure 5) reflected these differences in use among the different habitats along the Lisburne powerline. The number of flights was different among habitat types for all species combined in both 1986 and 1987 ($P<0.05$) (Figure 5). The pattern in each year was similar, with the highest rate of crossing in the wet tundra habitat, and lower rates of crossing in moist tundra and dry tundra, respectively. For groups, however, only ducks in 1986, and geese and swans and gulls, jaegers, and terns in 1987, did not differ significantly in observed flights among the three habitat types ($P>0.05$). In general, groups crossed the powerline more often in wet tundra and less often in dry tundra than would be expected based on the proportion of the powerline in these habitats.

The influence of configuration on bird flights across the Lisburne powerline differed between years and among groups. In both years, flights for all species combined did not differ significantly among the three powerline configurations ($P>0.05$) (Figure 5). In 1986, only ducks were likely to affect flight control of birds crossing the Lisburne powerline. Strong wind conditions occurred infrequently (6%) during observations in 1986, but were more common in 1987 (18%) (Table 7). All groups (for which sample sizes were adequate) differed significantly ($P<0.05$) from an expected distribution of flights, estimated from the distribution of observation periods among different wind-speed categories (Table 7). In 1986 and 1987, both loons, and geese and swans flew more often than expected during calm and light wind conditions. In contrast, gulls, jaegers, and terns were recorded more often during light and moderate wind speeds in 1986, and during calm and moderate conditions in 1987.

The effect of wind conditions, particularly of strong wind speeds, on birds across powerlines and transmission lines has been reported in at least two previous studies. McNeil et al. (1985) observed three bird collisions within a period of several hours during strong winds along a transmission line in northwestern Venezuela. James and Haak (1979) reported that gulls flew at higher altitudes during winds >8 km/h, whereas waterfowl flew at lower altitudes under the same conditions; however, only one of nine observed collisions of waterfowl occurred when wind speeds exceeded 8 km/h. Although a clear-cut relationship was not demonstrated in that study, strong winds were implicated in at least some of the line collisions (James and Haak 1979). Combinations of low visibility, rain, and gale-force winds were responsible for increases in gull casualties at a 400-kV transmission line in Britain (Scott et al. 1972).

During observations periods in both 1986 and 1987, the prevailing winds within the LDA were primarily from the northeast (35% of

Table 7. Bird flights by wind speed categories, Lisburne powerline, Prudhoe Bay, Alaska, 1986 and 1987. Only observations for which wind direction, wind speed, and direction of flights were known were included. Expected values of flights for the Chi-square analyses were based on the proportion of observation periods in each wind category.

		Bird Flights by Wind Speed Category				
Species Group	Year	Calm (<1 km/h)	Light (1-16 km/h)	Moderate (17-32 km/h)	Strong (>32 km/h)	Total
Loons	1986	33	31	24	1***	89
	1987	0	47	52	7***b	106
Geese and Swans	1986	33	69	18	0***	120
	1987	10	34	46	12***b	102
Ducks	1986	7	17	14	0a	38
	1987	1	41	77	0***	119
Raptors and Ravens	1986	1	3	0	0a	4
	1987	0	0	0	0	0
Shorebirds	1986	13	68	54	2***	137
	1987	5	99	114	10***b	228
Gulls, Jaegers, and Terns	1986	27	173	58	19**	277
	1987	12	50	142	37***	241
TOTAL	1986	114	361	168	22*	665
	1987	28	271	431	66***	796
No. Observation Periods	1986	33	112	50	12	207
	1987	5	60	107	38	210
% of Observation Periods	1986	16	54	24	6	
	1987	2	29	51	18	

a Not tested due to low expected frequencies in one or more cells.
b Wing speed categories for calm and light winds were combined for analysis due to low expected values for the calm category.
* Chi-square significant at 0.01<P<0.05.
** Chi-square significant at 0.01<P<0.001.
*** Chi-square significant at P<0.001.

207 observation periods in 1986; 59% of 210 observation periods in 1987) (Appendix B). As expected, most bird flights occurred during northeasterly winds in both 1986 and 1987, but most birds crossed the powerline in either a northerly or southerly direction, indicating that they crossed with a slight crosswind (Figure 6). The preponderance of north-south flights also was influenced by the orientation of the powerline. The Lisburne powerline runs primarily east-west (36% of the total line length) and northeast-southwest (31%), with a lesser proportion of the line oriented north-south (19%) and northwest-southeast (15%). The directions of flight of different groups also could reflect different flight corridors used in the LDA (Table 8). Loons in particular tended to fly in a north-south direction (approximately 71% of all observations in both years), indicative of foraging movements between Prudhoe Bay and inland nesting lakes. Such pronounced directional movements were not as evident for other groups, however (Table 8). The influence of weather conditions, such as wind, on flights and collision rates should be considered during site planning for powerline corridors. Thompson (1978) recommended that prevailing wind conditions be evaluated during site planning and that, when possible, lines should be oriented parallel to prevailing winds, to reduce the probability that birds will be blown into powerlines.

Other weather conditions, such as fog, also may influence flights and collision rates. Foggy conditions were common in the LDA during this study, although fog was recorded during only 8% of the observation periods in 1986 and during only 16% of the observation periods in 1987 (Appendix B). During periods of heavy fog observations were not possible, which accounts for the low number of observation periods

BIRD FLIGHTS ACROSS THE LISBURNE POWERLINE

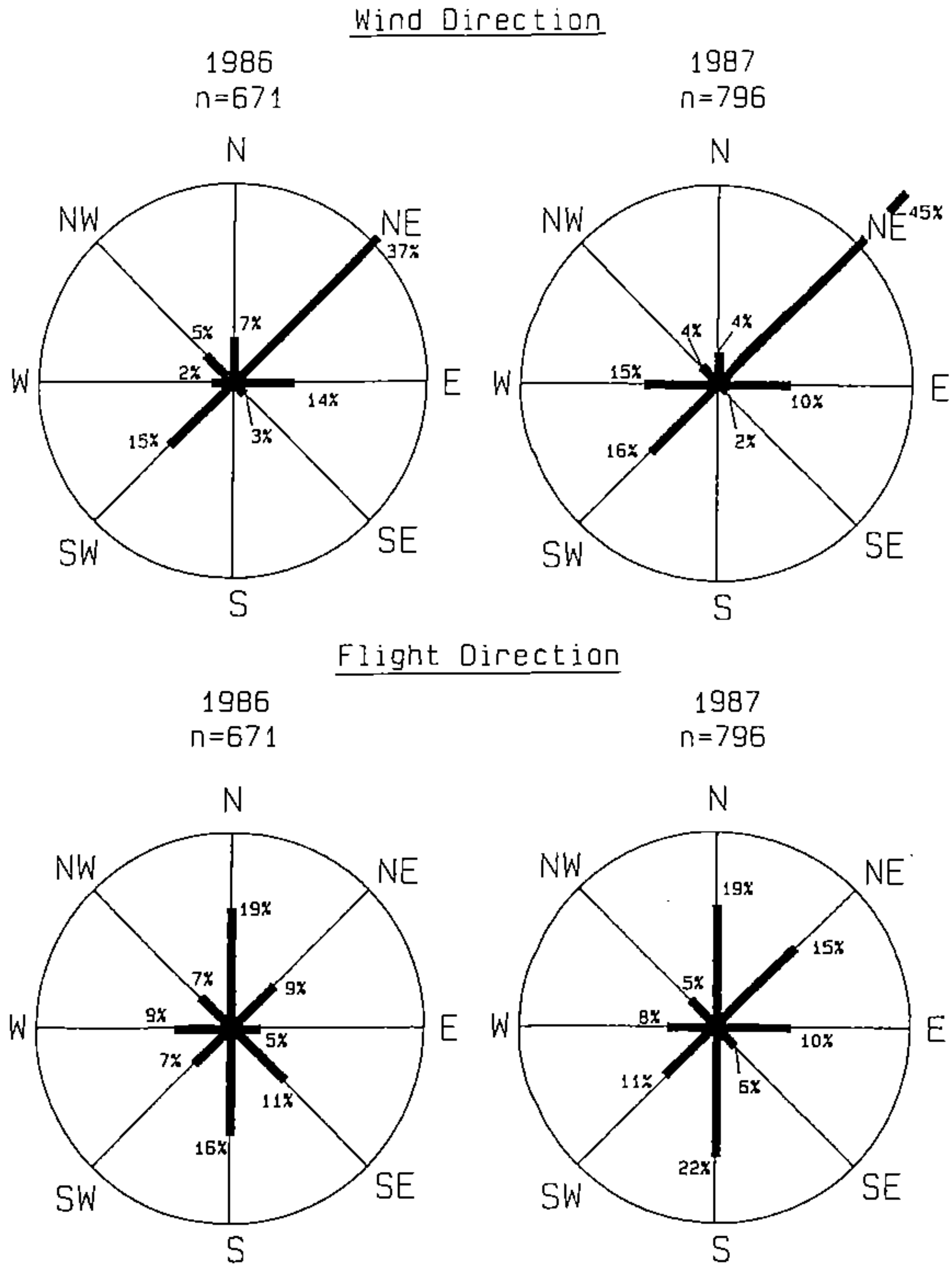

Figure 6. Bird flights (%) by wind direction and direction of flight for windy conditions (>1 km/h) at the Lisburne powerline, Prudhoe Bay, Alaska, 1986 and 1987. Percentages of bird flights during calm conditions w 17% and 44% in 1986 and 1987, respectively. Percentage of observat periods in each wind direction are presented in Appendix B.

Table 8. Bird flights by direction of flight under calm and windy (>1 km/h) conditions, Lisburne powerline, Prudhoe Bay, Alaska, 1986 and 1987. Only observations for which both wind direction and direction of flight were known were included.

Group/Wind Condition		Year	Bird Flights by Direction N	NE	E	SE	S	SW	W	NW	Total
Loons											
	Calm	1986	20	1	1	4	6	0	0	1	33
		1987	0	0	0	0	0	0	0	0	0
	Windy	1986	23	5	1	5	14	5	2	1	56
		1987	57	10	2	2	19	10	4	2	106
Geese and Swans											
	Calm	1986	0	0	0	2	28	0	2	1	33
		1987	3	0	0	1	3	3	0	0	10
	Windy	1986	25	1	7	16	12	5	6	15	87
		1987	24	22	9	11	7	3	0	16	92
Ducks											
	Calm	1986	2	5	0	0	0	0	0	0	7
		1987	0	0	1	0	0	0	0	0	1
	Windy	1987	10	7	1	3	3	4	1	2	31
		1987	13	28	9	13	11	25	13	6	118
Raptors and Ravens											
	Calm	1986	0	0	0	1	0	0	0	0	1
		1987	0	0	0	0	0	0	0	0	0
	Windy	1986	1	0	0	0	1	0	1	0	3
		1987	0	0	0	0	0	0	0	0	0
Shorebirds											
	Calm	1986	3	4	0	0	6	0	0	0	13
		1987	0	0	0	1	0	2	2	0	5
	Windy	1986	12	17	4	33	23	2	32	1	124
		1987	18	26	32	7	96	26	16	2	223
Gulls, Jaegers, and Terns											
	Calm	1986	8	4	1	2	2	5	4	1	27
		1987	0	1	1	1	0	7	1	1	12
	Windy	1986	54	29	23	15	55	32	16	26	251
		1987	42	36	29	14	38	21	33	16	229
TOTAL											
	Calm	1986	33	14	2	9	42	5	6	3	114
		1987	3	1	2	3	3	12	3	1	28
	Windy	1986	125	59	36	72	108	48	58	45	551
		1987	154	122	81	47	171	85	66	42	768

conducted during foggy conditions. Our general impression, however, was that the number of flights decreased markedly during periods when visibility was <50 m. Although poor visibility due to fog has been implicated as the cause of some bird-powerline collisions (James and Haak 1979, Beaulaurier 1981, Meyer and Lee 1981), it has not been determined to what extent fog affects either overall rates of flights or rates of collisions.

COLLISION MORTALITY

An assessment of collision mortality associated with the Lisburne powerline requires the calculation of several variables: 1) an estimate of the total number of flights across the powerline (ETF), 2) an estimate of the total number of dead birds resulting from collision with the powerline (ETBC), and 3) the percentage of the estimated total number of flights that result in a collision (CCP). The calculation of the ETF was discussed previously, and the following section deals with the estimation of the other two variables (ETBC and CCP). Before the estimated total number of bird collisions resulting from the Lisburne powerline can be calculated, several biases inherent in the search method for dead birds first must be addressed. In addition, the number of mortalities that were directly observed also must be considered.

Observed Collision Mortality

We did not observe any collisions with the Lisburne powerline during our regular 30-min observation periods in 1986 and 1987. However, we did observe four birds strike the powerline while we were conducting other field work. In 1986, one non-fatal collision of a male King Eider was observed during a search of the line for dead birds on 22 June. This collision took place in Section 9 (Figure 1), as the eider was descending to land. The bird hit the line with its right wing and fell stunned to the ground, but recovered and flew off before it could be examined. In 1987, three non-fatal collisions with the powerline were observed. Two collisions occurred during searches for dead birds: a juvenile Greater White-fronted Goose struck the line in Section 3 on 31 August 1987, and a Northern Pintail struck the line in Section 6 on 6 September 1987. Both collisions occurred after the birds were flushed by the search team walking along the powerline. The third collision was caused by the passage of a light truck on the road between LPC and DS-L3 in Section 6. The truck flushed a flock of six Greater White-fronted Geese feeding on the north side of the road, causing one goose to collide with the powerline.

In all observed collisions in both 1986 and 1987, the birds fell immediately below the line after the collision and all, except the Northern Pintail, flew away within minutes. Whether any injuries incurred in these collisions resulted in mortality is unknown. The behavior of the pintail after its collision with the powerline suggested relatively serious injuries, as it did not fly when approached by the search team, but instead crept away into the grass nearby; the bird had a bloody bill, which may have indicated traumatic injuries.

Searches for Evidence of Collision Mortality

During nine searches of the Lisburne powerline corridor in 1986, the remains of 15 collision victims were located (Table 9). In 1987, the number of remains found during 14 searches increased to 22, but six of these remains were one or more years old, leaving 16 remains that could be attributed to collisions during the 1987 monitoring season (Table 10).

Table 9. Bird remains found in the Lisburne powerline corridor (30 m) during searches for dead birds, Prudhoe Bay, Alaska, 1986. No remains were found during searches on 9 June, 2 August, and 24 August.

Species	Survey Date	Transmission Line: Section	Transmission Line: Closest Pole/ Configuration[a]	Habitat	Description of Remains
Waterfowl					
Pacific Loon	9 JL	6	wishbone/S	moist tundra	fresh whole carcass, broken neck
Goose spp.	14 JN	2	wishbone/S	dry tundra	sternum and wings, scavenged by fox (Brant?)
	4 SE	5	wishbone/MC	dry tundra	several primaries with attached skin - probable strike?
Oldsquaw	14 JN	3	wishbone/S	dry tundra	male, fresh carcass, near end of section adjacent to pipeline
	9 JL	16	wishbone/MC	wet tundra	female, whole carcass
Shorebirds					
Lesser Golden-Plover	14 JN	16	wishbone/MC	wet tundra	whole carcass
	4 SE	2	wishbone/S	dry tundra	whole carcass, broken neck
Semipalmated Sandpiper (2)*	22 JN	15	wishbone/MC	wet tundra	male with broken neck, female with broken wing
Red-necked Phalarope*	14 JN	14	wishbone/MC	wet tundra	male, whole carcass
	29 JN	14	wishbone & triple ground/MC	wet tundra	broken neck, partially eviscerated
	17 AU	4	wishbone/C	dry tundra	one wing only (perhaps predation event?)
Red Phalarope*	22 JN	8	wishbone/C	moist tundra	female, found wounded with dislocated wing, euthanized
	22 JN	14	wishbone/MC	wet tundra	male, broken neck
Gulls					
Glaucous Gull	29 JN	14	wishbone & triple ground/MC	wet tundra	left wing without primaries, may be part of carcass moved from near adjacent powerline - seen during 22 June survey

Total Species Found = 8
Total Remains Found = 15
Number of Surveys = 9
Mean Interval Between Searches = 10 days, SD = 6 days

[a] Configuration of powerline section: S=simple, MC=moderately complex, C=complex (see METHODS).
* Small bird species eliminated from calculations of total collisions.

Table 10. Bird remains found in the Lisburne powerline corridor (15 m) during searches for dead birds, Prudhoe Bay, Alaska, 1987. No remains were found during searches on 28 June, 13 July, 24 July, 29 July, and 17 August.

Species	Survey Date	Section	Closest Pole/ Configuration[a]	Habitat	Distance Centerline (m)	Description of Remains
			Powerline			
Waterfowl						
Brant	13 JN	5	wishbone/C	dry tundra	5	nearly completely scavenged, feathers only
Branta sp.	8 JL	2	wishbone/S	dry tundra	3	buried in sand, >1 year old
Greater White-fronted Goose	5 SE	14	wishbone/MC	wet tundra	3	juvenile, partially scavenged by gulls, observed removal by arctic fox, not found during search
Northern Pintail	20 JN	6	wishbone/S	moist tundra	1	50+ feathers scattered under centerline
	31 AU	5	triple pole/C	dry tundra	0	adult, whole carcass
Eider sp.	6 SE	3	wishbone/S	dry tundra	7	feathers and down with skin, gull droppings abundant
Oldsquaw	24 JN	15-16	single pole/MC	wet tundra	0	12 feathers, some bones and primaries
Duck sp.	20 JN	9	wishbone/S	moist tundra	10	20 contour feathers
	20 JN	15	wishbone/MC	wet tundra	3	50 feathers, probably from last fall
	31 AU	1	wishbone/MC	dry tundra	4	two clumps of breast feathers on skin, covered by sand, probably killed last year
Waterfowl sp.	30 JL	5	wishbone/C	dry tundra	5	recent feather pile, primaries and secondaries, plus coverts
Ptarmigan						
Ptarmigan sp.	9 JL	12	triple pole/C	wet tundra	4	feather pile, primaries and secondaries
Shorebirds						
Baird's Sandpiper	8 AU	1	wishbone/MC	dry tundra	2	adult, whole carcass
Long-billed Dowitcher	24 AU	5	triple-grounded/C	dry tundra	1	juvenile female, whole carcass, blood on head
Gulls						
Glaucous Gull	20 JN	5	triple pole/C	moist tundra	17	scattered feathers, may be a kill from last year
	20 JN	3	wishbone/S	dry tundra	8	remains appear to have been under snow, last year's kill
	20 JN	11	wishbone/MC	moist tundra	15	30 feathers
	24 JN	14	wishbone/MC	wet tundra	2	16 contour feathers
Passerines						
Lapland Longspur*	9 JN	5	wishbone/C	dry tundra	5	partially scavenged, probably killed last fall, wings only
	8 AU	3	single pole/S	dry tundra	2	juvenile, whole carcass
	8 AU	5	single pole/C	dry tundra	2	juvenile, whole carcass, <3 days old
Snow Bunting*	8 JU	9	wishbone/S	moist tundra	5	feathers only, primaries and secondaries
Unknown sp.	24 AU	7	wishbone/S	moist tundra	1	a few feathers, no species identification possible

Total Species Found = 10 (11)[b]
Total Remains Found = 22 (23)[b]
Current Year Remains = 16 (17)[b]
Number of Surveys = 14
Mean Interval Between Complete Searches = 5.2 days (SD=1.92)

[a] Configuration of powerline section: S=simple, MC=moderately complex, C=complex (see METHODS).
[b] Number in parentheses includes Greater White-fronted Goose found on 5 September prior to the 6 September search.
* Small bird species eliminated from calculations of total collisions.

In addition, we saw an arctic fox remove the carcass of a juvenile Greater White-fronted Goose from the search corridor the day before the last search of the powerline; no evidence of this carcass was visible in the area during the search on the following day. However, we have included this carcass in the list of remains, which increased the total number of remains to 17 for 1987.

In 1986, shorebirds constituted a majority (60%) of the carcasses found in the search corridor, with waterfowl (33%), and gulls (7%) accounting for the remainder. In 1987, the composition of carcasses was different, with waterfowl accounting for a majority (47%) of remains, followed by passerines (17%), shorebirds (12%), gulls (12%), ptarmigan (6%), and one unidentified species (6%).

The distribution of bird remains along the powerline in 1986 indicated that 53% occurred in wet tundra, 33% in dry tundra, and 13% in moist tundra. The distribution of remains in 1987 was different with more carcasses occurring in dry tundra (47%) and moist tundra (29%), and far fewer carcasses in wet tundra (24%).

The distribution of carcasses among the different types of powerline configurations also differed between 1986 and 1987. In 1986, 11 carcasses (73%) were located in line sections classified as moderately complex and complex. Although in 1987, 11 carcasses (65%) were again located in these more complex types, the relative proportion of carcasses in the simple configuration increased slightly. In both years, remains were found most often near wishbone-type poles (87% and 65% of all remains in 1986 and 1987, respectively) (Tables 9 and 10), which indicates that poles with more guy wires (a potential hazard) did not contribute to more collisions.

We combined the data from the 1986 and 1987 searches for dead birds to allow statistical analysis (Chi-square) of the relative effects of different habitats or configurations on the location of remains. This analysis indicated that the proportion of bird remains found in each habitat did not differ from the expected proportion based on the availability of each habitat ($P>0.10$) along the powerline (see Figure 5). Similarly, the analysis for the effects of the different configuration types indicated that collisions did not occur more than expected in the moderately complex and complex configurations than in the simple configuration ($P>0.25$).

Estimated Total Number of Bird Collisions

In 1986 and 1987, the total number of bird collisions was estimated using formulas provided by James and Haak (1979; also see METHODS). Because the estimates for total flights across the powerline were for larger birds and omitted small shorebirds and passerines, we elected to eliminate these smaller species from the total number of dead birds found in 1986 and 1987. The elimination of these small birds results in reductions of seven and four birds from the total number of dead birds found in 1986 and 1987, respectively (Tables 9 and 10). Therefore, estimates of total collisions were based on the number of dead birds (medium-shorebird size or larger) found during searches of the powerline corridor and adjustments for biases associated with locating remains.

Estimates of Biases in Dead Bird Searches

The biases introduced by variation in the searchability of habitat, the removal of carcasses by scavengers, the sightability of dead birds by searchers, and the effect of crippled birds landing outside the search area were estimated for both 1986 and 1987 (see METHODS). Ranges for each bias estimator were used in the final calculations of estimated total collisions. These ranges reflected our best assessment of the minimum and maximum value for each bias. Some bias estimators (e.g., searchability of habitat) that probably contributed little bias to the estimated total collisions were given small ranges, whereas bias estimators that made large contributions to the estimated total were given large ranges (e.g., scavenger removal). Except for bias due to scavenging, the same range of values was used for the other bias estimators in both years.

We attempted to improve the accuracy of these ranges by evaluating in the field the relative contribution of several of these biases. We assessed rates of carcass removal by scavengers by monitoring removal rates of dead birds found during searches of the powerline and by monitoring removal rates of dead birds placed within the search corridor. Mean scavenging rates were similar between years, with a carcass being removed within 72.7 h (SD=97.3 h; n=4; range 4.2-216 h) in 1986 and 79.4 h (SD=73.1 h; n=7, range=23-241 h) in 1987.

Because the mean interval between searches (10.7 days in 1986 and 6.2 days in 1987) was greater than the mean removal time for sample carcasses in both years, the potential for rapid removal necessitated the calculation of a relatively strong bias introduced by the removal of carcasses by scavengers. Therefore, we estimated the proportion of dead birds that would remain in the search corridor, and be found during a subsequent search, by using a computer simulation model that incorporated both the mean scavenging rate and the search interval for each year of the study. This model is described in Appendix C. From the model, we calculated a range of estimates for the bias introduced by scavenging of 0.12-0.28 in 1986 and 0.39-0.58 for 1987. In other words, we estimated that 12%-28% and 39%-58% of the bird carcasses resulting from collisions with the powerline would not be removed by scavengers between powerline searches in 1986 and 1987, respectively. As expected, the low values for 1986 represented both a rapid scavenging rate and a long interval between searches. Bias associated with scavenging decreased in 1987 when the search interval was shortened, although the scavenging rate was similar to that observed in 1986.

During a six-year study of transmission line mortality in Great Britain, Scott et al. (1972) found that scavengers associated the transmission line with a readily available food source and that carcasses were removed more rapidly when placed under the line than if they were placed away from the line. Observations of predators along the Lisburne powerline also indicated that Glaucous Gulls tended to fly along some portions of the powerline, especially between DS-L3 and LPC and between LPC and DS-L2. Arctic foxes also frequently were observed near the powerline, and often tracks were seen along the powerline in the sand dunes between East Dock Road and DS-L4.

Scott et al. (1972) also postulated that searches for dead birds underestimated the number of small birds (passerines) killed by transmission lines, but provided reasonable estimates for larger birds. A study of the removal of small passerine (songbird) carcasses from agricultural fields in Maryland demonstrated that approximately 72% of the carcasses were removed within 24 h and that over 58% were removed without leaving any evidence (Balcomb 1986). These studies suggest that for small species (e.g., shorebirds) periodic searches such as those used in this study may not provide accurate estimates of the number of collisions of small birds, because they are rapidly removed and leave little evidence of their presence.

Due to the limited availability of carcasses of different species, we were unable to assess adequately the differences in the sightability of different species by searchers, but we estimated that all birds medium-shorebird size or larger had an approximate sightability of 0.85-0.90. We also estimated that the likelihood of bias introduced by differences in the sightability of birds in different habitats was negligible, given the low height of vegetation in the search corridor. Furthermore, because a relatively small amount of the search corridor was underwater, we estimated that the proportion of habitat that was searchable was 0.90-0.99.

A critical evaluation of the degree of crippling and the tendency for collision victims to land outside of the search corridor was not possible because we observed only four collisions, all of which were not fatal and, apparently, not crippling. The locations of remains, however, seemed to indicate that birds killed on impact were likely to fall within the search area. This conclusion was supported by our observations of the non-fatal collisions: in all cases, birds fell almost directly below the point of impact and landed within the search corridor. For our calculations, we elected to use a range of values of 0.35 to 0.75 for the proportion of birds crippled by collision that fall and remain within the powerline search corridor; these values are larger than the average value (0.26) used for this estimator in recent powerline studies (Faanes 1987). However, these studies were of high-voltage transmission lines with relatively tall (≥30 m) towers where birds were likely to travel some distance after striking a conducting wire. The shorter poles in the Lisburne powerline probably cause crippled birds to fall in, or relatively near, the search corridor.

The movements of crippled birds was assessed experimentally by Faanes (1987) in North Dakota. Faanes (1987) attached radio transmitters to two Franklin's Gulls (Larus pipixcan) with broken wings, deposited the birds under a transmission line, and monitored their movements. The gulls moved only 2-3 m prior to their deaths and were not removed by scavengers after their death. This experiment tends to support the conclusion that birds severely crippled, but not immediately killed, by striking the powerline would not move far from the search corridor. However, the bias introduced by crippled birds leaving the search corridor is one of the major contributors to the estimated total number of collisions and we were not able to experimentally address this bias, thus, we have used a large range for the crippling bias associated with the Lisburne powerline.

Estimated Total Collisions and Calculated Collision Percentage

In 1986, a matrix of estimates for total collisions was calculated, based on a range of different values of each bias estimator. For this report, we have refined this approach and have calculated the most reasonable ranges of bias-adjustment values. Thus, we have provided maximum and minimum estimates for total collisions with the Lisburne powerline and the calculated collision percentages (CCP) (Table 11). To better understand the relative contributions of each bias estimator to the estimated total number of collisions (ETC), we have also provided a table of the number of collisions added to the estimated total by each bias adjustor (Appendix C). In addition, values for these bias

Table 11. Estimates of total bird collisions and the calculated collision percentages for the Lisburne powerline, Prudhoe Bay, Alaska, 1986 and 1987. Formulas used for calculation of estimated total bird flights, total collisions, and calculated collision percentage are presented in METHODS.

Year	Calculated Collision Percentage	Estimated Total Bird Flights	Estimated Total Bird Collisions	Total Dead Birds Found	Estimator Adjustments[a] PBF	PNR	PS	PBK
1986	0.098	252,874	249	8	0.85	0.12	0.90	0.35
	0.017	252,874	43	8	0.90	0.28	0.99	0.75
1987	0.046	267,004	124	13	0.85	0.39	0.90	0.35
	0.013	267,004	34	13	0.90	0.58	0.99	0.75

[a] The contribution of each bias estimator to the estimated total bird collisions is presented in Appendix C.

PBF = proportion of birds found during sightability tests (search bias).

PNR = proportion of birds not removed by scavengers (scavenger bias).

PS = proportion of birds in searchable habitat in the powerline corridor (habitat bias).

PBK = proportion of birds falling within the search corridor after collision (crippling bias).

estimators used in other studies were included (Appendix C).

The calculated collision percentage is an estimate of the percentage of flights across the powerline that would result in a fatal collision. The estimated CCP was 0.017%-0.098% in 1986 and 0.013%-0.046% in 1987 (Table 11). These values represent approximately one collision for every 1020-7692 flights across the Lisburne powerline and indicate that <0.1% of all bird flights in either year were likely to result in a fatal collision. The two-fold difference in the maximum number of estimated bird collisions (Table 11) between 1986 and 1987 may be due to the effect of the bias adjustment for scavenging or actual variability in the rate of collisions between years. The long search interval in 1986 (mean=10.7 days) and the rapid scavenging rate necessitated use of a strong bias adjustment and this strongly affected the estimated total collisions in 1986 (Appendix C). Collisions with the Lisburne powerline were relatively rare given the total number of flights across the line, and variability in the occurrence of these collisions may have resulted in more collisions in 1986 than in 1987.

We compared the estimated CCP values for the Lisburne powerline with other areas that supported different magnitudes of flights by birds (CCP values are adjusted for different flight magnitudes). For example, a CCP of 0.1% was reported for all waterfowl crossing high-voltage transmission lines in Washington (James and Haak 1979). CCPs ranged from 0.34% to 1.61% for duck species encountering 230-500 kV transmission lines in Washington (Beaulaurier 1981). Ducks crossing a transmission line spanning the Columbia River in Washington had low CCPs of 0.001-0.002% (Willdan Associates 1982). A recent study of collisions of birds with powerlines in prairie habitats in North Dakota (Faanes 1987) reported a collision rate of 1 per 86 flights, which translates to a CCP of 1.16%, the highest rate ever reported. The range of values for the Lisburne powerline falls near the lower end of these published values, indicating that the rate of collisions with the line was not abnormal or excessively high.

SUMMARY

The major goal of the Lisburne Powerline Monitoring Program was to evaluate the extent of injury and mortality of birds caused by the Lisburne powerline. We assessed the effects of the Lisburne powerline on birds by monitoring the number of birds that encountered the line and by searching the length of the line for birds killed in collisions.

We estimated that approximately 250,000-260,000 flights a year occurred across the Lisburne powerline during our sampling period (May-September) in 1986 and 1987. Gulls, jaegers, and terns encountered the line most often, followed in frequency by shorebirds, geese and swans, ducks, and loons. The relative contributions of each group varied slightly between the two years of this study, but the overall total continued to be dominated by the gulls, jaegers, and terns, and primarily by Glaucous Gulls.

The potential for collision with the powerline were assessed by categorizing the behavior and height of birds at the time of crossing. Most birds crossed over (76-89%) and at least 5 m from (68-80%) the powerline in both years. Gulls, jaegers, and terns had a greater potential for collision when crossing the powerline, with 37% and 52% of these birds crossing at heights <5 m from the line in 1986 and 1987, respectively. Weather, habitat, and line configuration influenced the magnitude of bird flights, but their effects varied in conflicting ways among different groups.

The number of remains located during searches of the powerline corridor for evidence of bird collisions was similar between years. No collisions were recorded during observations of bird flights across the Lisburne powerline in either year; however, a total of four collisions

were observed while conducting other field tasks; none of the collisions observed in either year were known to be fatal. Human disturbance contributed to three of the four collisions, with birds flushed by pedestrians accounting for two of the collisions and the passage of a truck for the third collision.

For each year, a range of estimates was calculated for the percentage of bird encounters that resulted in collisions, based on ranges for the estimators used to adjust for biases in the estimated total collisions. The range of estimates of the frequency of fatal collisions was 0.017-0.098% of the total number of flights across the powerline in 1986 and 0.013-0.046% in 1987. These estimates represented less than one collision per 1000 flights across the powerline and are within, and near the low end of, the ranges described by other studies of powerline-bird interactions.

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APPENDIX A. Scientific names of birds observed during the Lisburne powerline study, Prudhoe Bay, Alaska, 1986 and 1987.

Appendix A. Scientific names of birds observed during the Lisubrne powerline study, Prudhoe Bay, Alaska, 1986 and 1987.

Common Name	Scientific Name[a]
Red-throated Loon	Gavia stellata
Pacific Loon	Gavia arctica
Tundra Swan	Cygnus columbianus
Greater White-fronted Goose	Anser albifrons
Brant	Branta bernicla
Canada Goose	Branta canadensis
Northern Pintail	Anas acuta
King Eider	Somateria spectabilis
Spectacled Eider	Somateria fischeri
Oldsquaw	Clangula hyemalis
Gyrfalcon	Falco rusticolus
Peregrine Falcon	Falco peregrinus
Black-bellied Plover	Pluvialis squatarola
Lesser Golden-Plover	Pluvialis dominica
Ruddy Turnstone	Arenaria interpres
Semipalmated Sandpiper	Calidris pusilla
Baird's Sandpiper	Calidris bairdii
Pectoral Sandpiper	Calidris melanotos
Dunlin	Calidris alpina
Stilt Sandpiper	Calidris himantopus
Long-billed Dowitcher	Limnodromus scolopaceus
Red-necked Phalarope	Phalaropus lobatus
Red Phalarope	Phalaropus fulicaria
Pomarine Jaeger	Stercorarius pomarinus
Parasitic Jaeger	Stercorarius parasiticus
Long-tailed Jaeger	Stercorarius longicaudus
Glaucous Gull	Larus hyperboreus
Sabine's Gull	Xema sabini
Arctic Tern	Sterna paradisaea
Lapland Longspur	Calcarius lapponicus
Snow Bunting	Plectrophenax nivalis

[a] Scientific nomenclature according to the American Ornithologists' Union Checklist (1983).

APPENDIX B. Weather conditions during observation periods at the Lisburne powerline, Prudhoe Bay, Alaska, 1986 and 1987.

Appendix B-1. Number (%) of observation periods during different wind conditions at the Lisburne powerline, Prudhoe Bay, Alaska, 1986 and 1987.

Wind Speed/Year	Wind Direction: N	NE	E	SE	S	SW	W	NW	No Wind	All Directions Combined
Light (1-16 km/h)										
1986	11 (5.3)	51 (24.6)	17 (8.2)	3 (1.4)	-	10 (4.8)	4 (1.9)	16 (7.7)		112 (54.1)
1987	5 (2.4)	32 (15.2)	4 (1.9)	3 (1.4)	-	6 (2.8)	6 (2.8)	4 (1.9)		60 (28.6)
Moderate (17-32 km/h)										
1986	-	15 (7.2)	14 (6.8)	-	-	17 (8.2)	2 (1.0)	2 (1.0)		50 (24.2)
1987	4 (1.9)	58 (27.6)	14 (6.7)	-	-	9 (4.3)	16 (7.6)	6 (2.8)		107 (51.0)
Strong (>32 km/h)										
1986	-	7 (3.4)	1 (0.5)	-	-	4 (1.9)	-	-		12 (5.8)
1987	-	34 (16.2)	3 (1.4)	-	-	-	1 (0.5)	-		38 (18.1)
No Wind (<1 km/h)										
1986	-	-	-	-	-	-	-	-	33 (15.9)	
1987	-	-	-	-	-	-	-	-	5 (2.4)	
All Speeds Combined										
1986	11 (5.3)	73 (35.3)	32 (15.4)	3 (1.4)	-	31 (15.0)	6 (2.9)	18 (8.7)	33 (15.9)	207
1987	9 (4.3)	124 (59.0)	21 (10.0)	3 (1.4)	-	15 (7.1)	23 (11.0)	10 (4.8)	5 (2.4)	210

Appendix B-2. Number (%) of observation periods during different visibility and precipitation conditions at the Lisburne powerline, Prudhoe Bay, Alaska, 1986 and 1987.

	Year			
	1986		1987	
Condition	n	%	n	%
Visibility				
<1/2 mile	-		6	2.9
1/2-1 mile	17	8.1	21	10.0
>1 mile	188	90.8	180	85.7
Unknown	2	1.0	3	1.4
Precipitation				
None	174	84.0	141	67.1
Rain	8	3.9	20	9.5
Snow	8	3.9	15	7.1
Fog	17	8.2	34	16.2

Appendix B-3. Number (%) of observation periods at different temperatures at the Lisburne powerline, Prudhoe Bay, Alaska, 1986 and 1987.

	1986		1987	
Temperature (°C)	n	%	n	%
18	1	0.5	-	
17	-		1	0.5
16	3	1.4	-	
15	5	2.4	11	5.2
14	-		3	1.4
13	9	4.3	4	1.9
12	11	5.3	-	
11	1	0.5	-	
10	12	5.8	13	6.2
9	4	1.9	3	1.4
8	13	6.3	12	5.7
7	6	2.9	7	3.3
6	22	10.5	32	15.2
5	5	2.4	11	5.2
4	25	11.9	14	6.7
3	32	15.4	29	13.8
2	20	9.7	44	21.0
1	6	2.9	14	6.7
0	10	4.8	8	3.8
-1	11	5.3	1	0.5
-2	7	3.4	3	1.4
-3	-		-	
-4	-		-	
-5	2	1.0	-	
-6	-		-	
-7	2	1.0	-	

APPENDIX C. Contributions of the bias estimations to the estimated total bird collisions, bias estimator values used in other studies, and a computer simulation model for scavenging at the Lisburne powerline, Prudhoe Bay, Alaska.

Appendix C-3. Computer simulation model for estimates of bias due to scavenger removal of remains along the Lisburne powerline, Prudhoe Bay, Alaska, 1986 and 1987.

A. Computer model programming language = C.

B. Assumptions for the model:

1) Dead birds occur randomly during the sampling period.

2) Probability of a simulated dead bird being scavenged = 75%.

3) Length of time from simulated death to scavenger removal = 79 h (mean value for 1986 and 1987).

4) 100 mortalities simulated during the length of the sampling period (approximately 2000 h).

4) Search interval times used were actual interval lengths from the fieldwork in 1986 and 1987.

C. The simulation was run 1000 times for each year (1986 and 1987).

D. Results of the simulation model:

	1986	1987
Mean proportion of dead birds found during next search	0.20	0.49
95% confidence limits of mean	$0.20 \pm (1.96)(0.040)$	$0.49 \pm (1.96)(0.048)$
Minimum Value (L_1)	0.12	0.39
Maximum Value (L_2)	0.28	0.58