

# Status of Gyrfalcon *Falco rusticolus* Populations in the Northwest Territories, Canada

C. C. Shank and K. G. Poole

## ABSTRACT

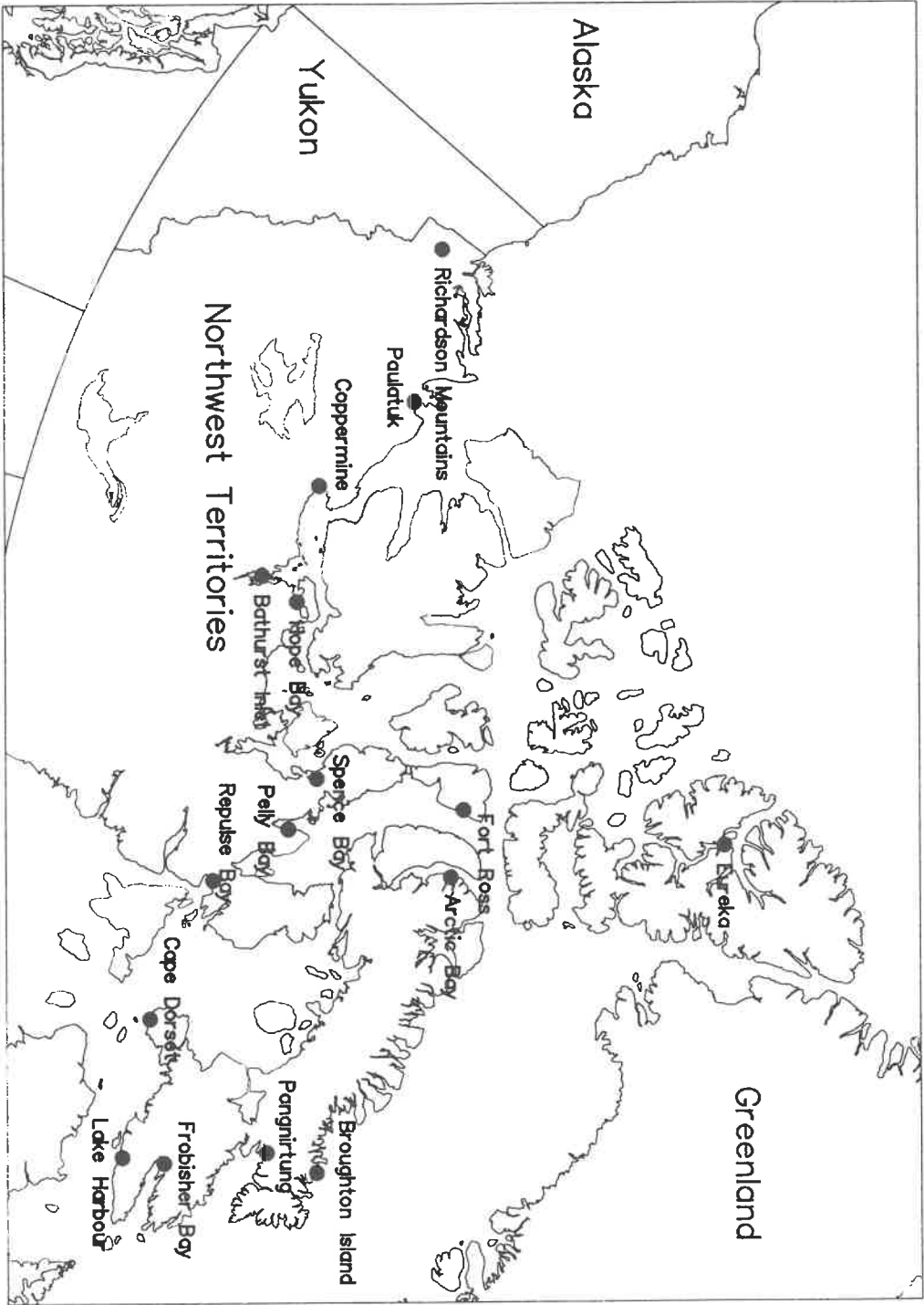
Gyrfalcon (*Falco rusticolus*) population surveys were conducted during 1982-1991 in 16 areas of the Northwest Territories (NWT), Canada, to document abundance and productivity of breeding populations. Most surveys were conducted by helicopter during the early to mid-nestling period. Fifty-four individual surveys were conducted, totalling 632 hours of helicopter survey time. Some areas were surveyed infrequently to establish nest locations and internest distances, and other areas were monitored more regularly to establish trends. Trends in the size of local breeding populations were assessed by four methods; proportional occupancy, search effort, mean internest distance, and total counts. No trends in breeding numbers or productivity were detected. Gyrfalcon breeding populations in the NWT appeared to neither increase nor decline over the 10 years of the study. Mean internest distances were smaller in regions with higher mean July temperatures and taller willow (*Salix* sp.) growth forms, corresponding to more productive habitats. Breeding population size in the NWT is estimated very roughly at 1300 pairs. Assuming equal numbers of adult breeders and non-breeders, the total adult population size in the NWT is estimated to be in the range of 5000 individuals.

## INTRODUCTION

The Gyrfalcon (*Falco rusticolus*) breeds throughout the Northwest Territories (NWT), Canada, in suitable arctic and alpine tundra habitat. Interest in Gyrfalcons in the NWT increased in the 1980s as a result of attempts to develop a commercial harvest for the aboriginal Inuit and the listing of the species on Appendix I of the Convention on the International Trade in Endangered Species (CITES). Little information was available on the population biology of the Gyrfalcon. Therefore, in 1982, the Department of Renewable Resources, Government of the NWT, initiated studies to gather baseline data and establish long-term monitoring of the species.

The purpose of this paper is to summarize information on abundance and productivity of Gyrfalcon breeding populations in the NWT between 1982 and 1991.

Figure 1. Location of Gyr Falcon survey areas within the NWT, 1982-1991.



## STUDY AREAS

Sixteen areas were surveyed over the course of the study (Figure 1). Because of logistical constraints, most surveys were conducted within about 200 km of a community. Study areas were chosen on the basis of suitable nesting terrain and sighting reports by naturalists and Inuit hunters.

All study areas are characterized as tundra habitat, although they encompass riverine, marine, upland and alpine habitats. For example, the Richardson Mountains study area is, strictly speaking, alpine tundra despite being north of the Arctic Circle. Sparse trees are found in protected river valleys in the Paulatuk (encompassing the Anderson, Horton and Hornaday rivers) and Coppermine study areas.

Mean July temperature (Table 1) is used as an index of climate severity during the breeding season. Habitat productivity is indexed by percent plant cover and as willow (*Salix* sp.) growth form (Table 1).

## METHODS

Of the 54 surveys undertaken, 47 were done by helicopter (Bell 206B Jet Ranger) representing a total of 632 hours of survey time (Table 2). The remaining seven surveys were conducted by boat (Table 2). Helicopter surveys were done by slowly (20–60 kph) flying along all suitable nesting cliffs in the study areas. Many of the nests were entered using climbing gear, and the nestlings were banded. We leg-banded 338 (42%) of the 803 nestlings observed. Locations of occupied nests were marked on 1:250,000 topographical maps and were re-visited in subsequent surveys.

Most surveys were conducted in early to mid-July, when Gyrfalcon nestlings were of banding age (3–5 weeks old). The Richardson Mountains are characterized by an earlier breeding phenology and were therefore surveyed in late June. Studies of breeding population size are best done in spring by examining the number of pairs initiating courtship, because many pairs fail to produce a brood through to the advanced nestling stage and are therefore uncounited in summer surveys. However, helicopter surveys during egg-laying and incubation can cause nest abandonment (Platt 1976) and ground surveys are practical only for a few of the more accessible study areas.

Definitions used here are appropriate specifically to helicopter surveys of Gyrfalcons. The term “nest” refers to a specific nest site with features allowing it to be recognized in subsequent years. Gyrfalcon nests are generally under overhangs and are heavily marked with “whitewash” and orange nitrophilus lichens. They consist of rocky ledges, or nests built by Common Ravens (*Corvus corax*) or Golden Eagles (*Aquila chrysaetos*). In different years, individual Gyrfalcon pairs use alternative nests often on distinct but nearby cliffs. A “territory” is therefore conceptually defined as the area containing all nests used interchangeably by a pair regardless of whether the identity of the breeders changes from year to year. The term “occupied” refers to the territory when at least one adult was seen in the territory, or to the nest when it contains eggs or young. The term “productive” means that an occupied nest contained live young at the time of the survey.

Trends in the size of raptor breeding populations can be examined in a variety of manners. For intensively studied areas, the total number of pairs nesting within a defined area can be compared among years (the Total Count Method). For less detailed studies in which search effort is not intense or varies from year to year, trends can be sought using three other measures. In the Proportional Occupancy Method the proportion of previously occupied territories which are seen to support a breeding pair is assessed and compared among years. In the Search Effort Method the trend in number of occupied nests relative to the number of helicopter hours used is monitored. The mean distance between nests is compared among years for the Internest Distance Method.

Each of these methods has its pitfalls. The Total Count Method is expensive and one can never be certain that every pair has been counted. One is never sure, therefore, whether to ascribe the discovery of new pairs to an increasing breeding population or to inadequacy of previous surveys. The Proportional Occupancy Method makes assumptions regarding complex behavioural aspects of territory definition and fidelity to territory, and contains a bias toward higher occupancies early in multi-year studies. The Search Effort Method also contains an underlying bias. As the researcher becomes more familiar with the study area, the catalogue of nest sites becomes larger and search routes become more efficient, generally resulting in an increasing number of nests seen per hour

**Table 1 Latitude, mean July temperature, vegetative cover class, and willow growth form at each study area.**

| Area                 | Latitude (N) | Mean July Temperature (C) <sup>1</sup> | Percent Cover <sup>2</sup> | Willow Form <sup>3</sup> |
|----------------------|--------------|----------------------------------------|----------------------------|--------------------------|
| Richardson Mountains | 68           | 14                                     | >50                        | 1                        |
| Paulatuk             | 69           | 11                                     | >50                        | 1                        |
| Coppermine           | 68           | 9                                      | >50                        | 1                        |
| Pelly Bay            | 69           | 8                                      | 25-50                      | 3                        |
| Spence Bay           | 70           | 7                                      | 25-50                      | 3                        |
| Repulse Bay          | 67           | 7                                      | 25-50                      | 2                        |
| Lake Harbour         | 63           | 7                                      | 25-50                      | 1                        |
| Frobisher Bay        | 64           | 7                                      | 25-50                      | 2                        |
| Pangnirtung          | 66           | 7                                      | 25-50                      | 2                        |
| Hope Bay             | 68           | 6                                      | 25-50                      | 2                        |
| Bathurst Inlet       | 67           | 6                                      | 25-50                      | 2                        |
| Cape Dorset          | 64           | 6                                      | 25-50                      | 3                        |
| Fort Ross            | 73           | 5                                      | <25                        | 3                        |
| Broughton Island     | 68           | 5                                      | <25                        | 4                        |
| Arctic Bay           | 73           | 5                                      | <25                        | 4                        |
| Eureka               | 80           | 5                                      | <25                        | 4                        |

<sup>1</sup> from Figure 2 in Edlund (1987), except for Richardson Mountains and Paulatuk which are taken from Environment Canada (1982).

<sup>2</sup> from Figure 4 in Edlund (1986).

<sup>3</sup> Willow growth forms are defined after Edlund (1986:Figure 5): 1 = erect *Salix* thickets > 1 m tall;; 2 = erect *Salix* thickets < 1 m tall; 3 = *Salix* capable of erect growth; 4 = *Salix arctica* dominance.

**Table 2 Number of hours flown by helicopter in surveying for Gyrfalcon nests, 1982-1991. Paulatuk refers to the Anderson, Horton and Hornaday rivers.**

| AREA                 | '82 | '83 | '84 | '85 | '86 | '87 | '88 | '89 | '90 | '91 | Σ   |
|----------------------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| Richardson Mountains | -   | -   | -   | -   | -   | 13  | 15  | 11  | -   | -   | 39  |
| Paulatuk             | -   | -   | -   | -   | -   | *   | *   | *   | *   | *   | -   |
| Coppermine           | -   | 17  | 15  | 18  | 17  | 12  | 14  | 15  | 13  | 14  | 135 |
| Pelly Bay            | 17  | -   | -   | -   | -   | -   | -   | -   | -   | -   | 17  |
| Coppermine           | 26  | 9   | -   | -   | -   | -   | -   | -   | -   | -   | 35  |
| Repulse Bay          | 14  | -   | -   | -   | -   | -   | -   | -   | -   | -   | 14  |
| Lake Harbour         | 11  | 14  | -   | 6   | -   | -   | -   | -   | -   | -   | 31  |
| Frobisher Bay        | 12  | 8   | 19  | 12  | 13  | 9   | *   | *   | 15  | -   | 88  |
| Pangnirtung          | -   | -   | 13  | 12  | 14  | -   | -   | -   | -   | -   | 39  |
| Hope Bay             | 30  | 21  | 15  | 12  | 12  | 10  | 11  | 14  | 11  | 16  | 152 |
| Bathurst Inlet       | -   | -   | -   | 10  | -   | -   | -   | -   | -   | -   | 10  |
| Cape Dorset          | 13  | 13  | -   | 6   | -   | -   | -   | -   | -   | -   | 32  |
| Fort Ross            | -   | 7   | -   | -   | -   | -   | -   | -   | -   | -   | 7   |
| Broughton Island     | -   | -   | 6   | -   | -   | -   | -   | -   | -   | -   | 6   |
| Arctic Bay           | -   | -   | -   | -   | -   | 16  | -   | -   | -   | -   | 16  |
| Eureka               | -   | -   | -   | -   | -   | -   | 11  | -   | -   | -   | 11  |
| TOTAL                | 123 | 89  | 68  | 76  | 56  | 60  | 51  | 40  | 39  | 30  | 632 |

“\*” denotes survey by boat.

flown in succeeding years of a multi-year study. A decline in survey efficiency may be considered evidence for a decline in the number of breeding pairs. Because areas differ in mean interest distance, the interest distance technique can be used only to compare individual areas among years.

Even in intensive studies, it is difficult to determine which nests are alternatives within a territory. We used "average linkage cluster analysis" (SAS Institute, Inc. 1988) as an objective means for differentiating territories and defining alternative nest sites. This allows rapid and automatic determination of territory clusters from location data. Cluster analysis has often been used to determine bird territories from point data (i.e., Scheffer 1987).

Cluster analysis was first done for Hope Bay, our most intensive study area (Poole and Bromley 1988). At a fusion distance of 3.75 km, the technique separated 43 nest sites into 21 territories, compared to 20 empirically known territories. The only disagreement was a case of three nests clustered mathematically into one territory, whereas in actuality there were two territories simultaneously occupied in 3 of 9 years. The two territories are on opposite sides of a large, steep outcrop where the pairs would be effectively isolated from each other. We do not expect this technique to completely mirror a reality as complex as raptor territory occupancy, but we are confident that it is superior to using the nest as the counted unit and that it is accurate enough to allow qualitative conclusions.

We make no statements about density (pairs/unit area) because of practical difficulties created by diversity of Gyrfalcon dispersion. In the Arctic, Gyrfalcon nests are often distributed in a linear fashion as a result of the distribution of both nest sites and prey availability. Nesting cliffs are most commonly a result of erosional processes along rivers and coastlines, where Gyrfalcon prey species are also most common. Gulls (*Larus* sp.), Black Guillemots (*Cepphus grylle*), and ducks are found near coastlines, whereas the shelter of river valleys allows willow growth and the associated occurrence of Ptarmigan (*Lagopus* sp.). In the high Arctic, vegetative cover declines dramatically at 50 - 100 m above sea level, effectively restricting prey to low-lying coastal strips. In lower-latitude alpine areas and low Arctic tundra, nest sites used by Gyrfalcons are more commonly distributed two-dimensionally. This results from prey being more uniformly distributed, which causes nest site availability to become a larger factor in nest distribution. Suitable nest locations tend to be numerous and evenly distributed in mountainous areas and those characterized by igneous intrusions (e.g., diabase dyke swarms). This makes it possible for Gyrfalcons to space themselves widely in two dimensions. One-dimensional measures of dispersion (distance between nests) are not easily comparable with two-dimensional ones (density). We therefore present all data in terms of interest distance although we speak of "density" in a generic sense.

We have attempted to provide a very rough estimate of the number of breeding pairs of Gyrfalcons present in the NWT using the protocol described in Appendix I. Our reasoning rests on the assumption that suitable hunting and nesting habitats must coincide. In many areas with good nesting cliffs (e.g., the Queen Elizabeth Islands), the habitat is too barren to support a Gyrfalcon prey base. Conversely, many areas (e.g., the Keewatin Barrens in the eastern portion of mainland NWT) are characterized by suitable prey but very few nest locations. We calculated average dispersion in good nesting habitat within ecological zones of the NWT, and then discounted this estimate by an intuitive estimate of the ubiquity of nest sites within these zones.

The slopes of linear regressions were tested for statistical significance by use of t-tests. Single classification analysis of variance was used to test for differences in mean brood size among geographic areas characterized by differing willow heights. Chi-square analysis was used to test whether proportions of different brood sizes differed with the amount of vascular plant ground cover in the geographic area. In all cases, the level of statistical significance was set at 0.05.

## RESULTS

### Stability in Number of Productive Pairs

Total Count-- The Total Count Method was undertaken only for the two most intensively studied areas, Hope Bay and Coppermine (Figure 2). At Hope Bay, the number of productive nests has varied between 9 and 12 between 1983 and 1991 (not all of the study area was searched in 1982). At Coppermine, the number of productive nests has varied more widely (4 - 13). Despite

differences among years in number of productive nests, there is no evidence of trend. This suggests long-term stability in the breeding populations.

**Proportional Occupancy--** In total, territories were checked 797 times, 430 (54%) were occupied and 340 (43%) were productive (Table 3). Figure 3 shows yearly changes in proportion of territories observed to be productive in three study areas over 10 years. There is no relationship between year and proportional occupancy for Coppermine ( $R^2 = 0.17$ ,  $df = 7$ ,  $P = 0.28$ ) or Frobisher Bay ( $R^2 = 0.07$ ,  $df = 7$ ,  $P = 0.51$ ). However, the negative trend apparent for Hope Bay is statistically significant ( $R^2 = 0.41$ ,  $df = 8$ ,  $P = 0.05$ ).

The very slight negative trend at Hope Bay cannot be considered indicative of a decline in size of the breeding population. In a stable population, we expect proportional occupancy to decline in succeeding years of multi-year studies. This results from two factors. First, all newly discovered territories are necessarily occupied leading to a bias toward higher proportional occupancy early in a long-term study. Secondly, the rough categorization of territories utilized here fails to capture the complexity of actual territorial dynamics. At Hope Bay, the number of territorial pairs has remained constant despite a continuing increase in number of defined territories and identified nest sites, because pairs have shifted the geographic focus of their nesting activities. Through cluster analysis techniques, we interpret this as abandonment of an old territory and creation of a new one, whereas it actually comprises an adjustment of an existing territory. Uncritically considering human-defined raptor territories as fixed entities can lead to misinterpretation of proportional occupancy data.

**Search Effort--** The number of nests observed per hour of helicopter search time has not increased or declined through time at Coppermine ( $P = 0.56$ ) or Hope Bay ( $P = 0.08$ ) (Figure 4). The absence of a decrease in survey efficiency suggests that there has been no decline in the number of breeding pairs in these two study areas.

**Interneest Distance--** Mean distance between nests varied from 5 km along a 35 km stretch of the Hornaday River near Paulatuk to 93 km at Arctic Bay (Table 4). The large increases seen at Spence Bay and Cape Dorset result from the small number of helicopter hours used in nest searches in the later years (Table 2). Internest distances from 1982 - 1991 for Hope Bay, Coppermine, and Frobisher Bay (Figure 5) do not show a significant trend in interneest distance through time (Coppermine  $P = 0.69$ , Hope Bay  $P = 0.07$ , Frobisher Bay  $P = 0.07$ ).

The four methods are not independent representations of population trend. However, conclusions of these four viewpoints are consistent in suggesting that there is no long-term trend in densities or numbers of breeding Gyrfalcons in the NWT.

### **Stability in Brood Size**

Mean brood size for the 10 study years was 2.54 ( $n = 316$ ) (Table 5). Mean brood size from all surveys combined did not show any trend over the 10 years ( $R^2 = 0.01$ ,  $P = 0.75$ ). There was no trend in mean brood size at Coppermine ( $R^2 = 0.04$ ,  $df = 7$ ,  $P = 0.61$ ), Hope Bay ( $R^2 = 0.01$ ,  $df = 8$ ,  $P = 0.84$ ), or Frobisher Bay ( $R^2 = 0.25$ ,  $df = 6$ ,  $P = 0.20$ ) (Figure 6). Chi-square analysis shows that in none of the 10 years was the distribution of brood sizes different than expected from the 10 year mean (all  $P > 0.05$ ). Although brood sizes have varied widely during the course of the study, there are no trends detectable.

### **Geographical Trends in Internest Distance**

Several interrelated environmental factors are associated with differences in mean interneest distance. Nests are significantly closer together in areas with higher mean July temperatures (Figure 7) ( $F = 19.19$ ,  $df = 49$ ,  $P < 0.001$ ) and in areas with taller willows (Figure 8) ( $R^2 = 0.13$ ,  $df = 47$ ,  $P = 0.01$ ). This suggests, as expected, that Gyrfalcon densities are higher in more productive habitats.

### **Geographical Trends in Brood Size**

Brood size did not vary with mean July temperature (Figure 9,  $R^2 = 0.03$ ,  $df = 43$ ,  $P = 0.25$ ). Brood sizes of 3 and 4 were observed more commonly in study areas having more than 50% vascular plant cover (Figure 10) but these differences are not statistically significant ( $\chi^2 = 4.69$ ,  $df$

**Figure 2.** Number of productive Gyrfalcon nests within the Hope Bay and Coppermine study areas, 1982-1991. Survey incomplete for Hope Bay in 1982.

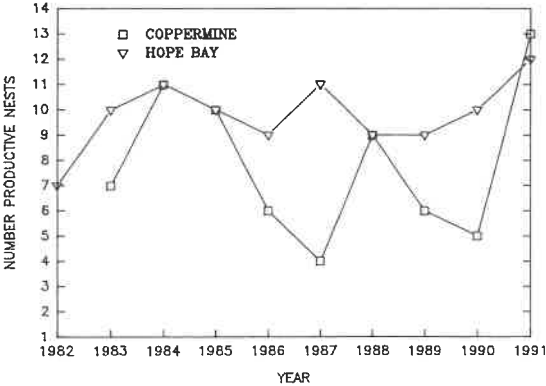


**Figure 3.** Proportion of known Gyrfalcon territories that were productive each year in the three intensive survey areas.

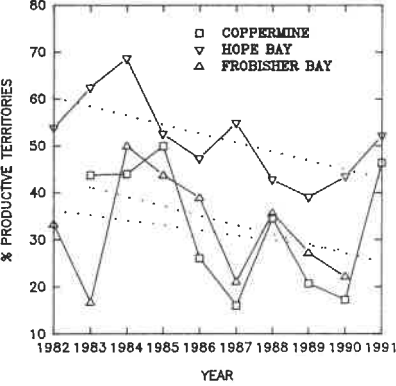


**Figure 4.** Productive Gyrfalcon nests observed per hour of helicopter survey within the Hope Bay and Coppermine study areas, 1982-1991.

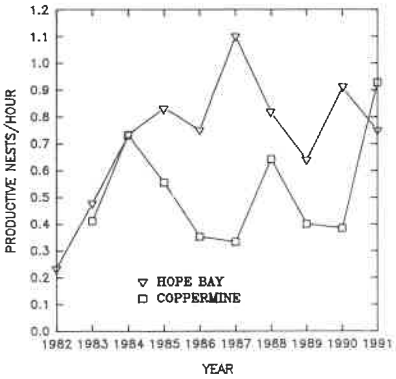


**Table 3** Territories checked (C), occupied (O) and productive (P) between 1982 and 1991. Data are only from June/July production surveys. All surveys were conducted by helicopter except for the 1988-1989 Frobisher Bay surveys and all Paulatuk surveys. The Paulatuk surveys refer to the Anderson, Horton and Hornaday rivers. % O/C = the percentage of checked territories which were occupied by Gyrfalcons. % P/C = the percentage of checked territories in which a productive Gyrfalcon nest was observed.

| Area           | 1982<br>COP | 1983<br>COP | 1984<br>COP | 1985<br>COP | 1986<br>COP | 1987<br>COP | 1988<br>COP | 1989<br>COP | 1990<br>COP | 1991<br>COP |
|----------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|
| Rich. Mtns.    | ----        | ----        | ----        | ----        | ----        | 10 7 7      | 16 12 12    | 18 13 12    | ----        | ----        |
| Paulatuk       | ----        | ----        | ----        | ----        | ----        | 26 19 17    | 8 8 8       | 6 5 2       | 32 23 6     | 22 20 9     |
| Coppermine     | ----        | 16 9 7      | 25 13 11    | 20 10 10    | 23 8 6      | 25 5 4      | 26 11 9     | 29 6 6      | 29 6 5      | 28 16 13    |
| Pelly Bay      | 1 1 0       | ----        | ----        | ----        | ----        | ----        | ----        | ----        | ----        | ----        |
| Spence Bay     | 6 4 4       | 6 3 3       | ----        | ----        | ----        | ----        | ----        | ----        | ----        | ----        |
| Repulse Bay    | 2 2 2       | ----        | ----        | ----        | ----        | ----        | ----        | ----        | ----        | ----        |
| Lake Harbour   | 7 6 5       | 9 3 2       | ----        | 7 4 3       | ----        | ----        | ----        | ----        | ----        | ----        |
| Frobisher Bay  | 6 2 2       | 6 2 1       | 16 12 8     | 16 7 5      | 18 8 7      | 19 7 4      | 14 6 5      | 11 3 3      | 18 5 4      | ----        |
| Pangnirtung    | ----        | ----        | 15 11 9     | 11 8 5      | 14 7 6      | ----        | ----        | ----        | ----        | ----        |
| Hope Bay       | 13 9 7      | 16 15 10    | 16 11 11    | 19 12 10    | 19 15 9     | 20 11 11    | 21 11 9     | 23 10 9     | 23 10 10    | 23 12 12    |
| Bathurst Inlet | ----        | ----        | ----        | 6 3 2       | ----        | ----        | ----        | ----        | ----        | ----        |
| Cape Dorset    | 9 9 8       | 7 3 3       | ----        | 9 2 2       | ----        | ----        | ----        | ----        | ----        | ----        |
| Fort Ross      | ----        | 1 1 1       | ----        | ----        | ----        | ----        | ----        | ----        | ----        | ----        |
| Broughton I.   | ----        | ----        | 3 2 2       | ----        | ----        | ----        | ----        | ----        | ----        | ----        |
| Arctic Bay     | ----        | ----        | ----        | ----        | ----        | 2 2 1       | ----        | ----        | ----        | ----        |
| Eureka         | ----        | ----        | ----        | ----        | ----        | ----        | 6 3 1       | ----        | ----        | ----        |
| % O/C          | 47          | 59          | 65          | 53          | 51          | 50          | 56          | 43          | 62          | 66          |
| % P/C          | 40          | 44          | 55          | 42          | 38          | 43          | 48          | 37          | 45          | 48          |

**Table 4 Mean internest distance for productive nests, 1982-1991. Number in parentheses = SD. Number in brackets = number of distances = number of nests - 1. Data are presented separately for the rivers (Anderson, Horton, Hornaday) comprising the Paulatuk data set.**

|                  | x internest distance in km (SD) [n] |                     |                      |                     |                     |                     |                      |                     |                     |                     |
|------------------|-------------------------------------|---------------------|----------------------|---------------------|---------------------|---------------------|----------------------|---------------------|---------------------|---------------------|
|                  | 1982                                | 1983                | 1984                 | 1985                | 1986                | 1987                | 1988                 | 1989                | 1990                | 1991                |
| Rich. Mtns.      | -                                   | -                   | -                    | -                   | -                   | 20<br>(8.5)<br>[6]  | 12<br>(7.7)<br>[12]  | 12<br>(6.5)<br>[11] | -                   | -                   |
| Anderson River   | -                                   | -                   | -                    | -                   | -                   | 23<br>(-)<br>[1]    | -                    | -                   | -                   | -                   |
| Horton River     | -                                   | -                   | -                    | -                   | -                   | 15<br>(9.6)<br>[16] | -                    | 11<br>(0.9)<br>[3]  | 9<br>(6.4)<br>[18]  | -                   |
| Hornaday River   | -                                   | -                   | -                    | -                   | -                   | -                   | 5*<br>(2.5)<br>[6]   | -                   | 23<br>(21.9)<br>[4] | -                   |
| Coppermine       | -                                   | 29<br>(13.7)<br>[7] | 22<br>(14.0)<br>[12] | 28<br>(20.7)<br>[9] | 28<br>(19.2)<br>[7] | 44<br>(21.3)<br>[4] | 21<br>(10.8)<br>[10] | 32<br>(16.1)<br>[5] | 30<br>(11.4)<br>[4] | 16<br>(9.7)<br>[15] |
| Pelly Bay        | [0]                                 | -                   | -                    | -                   | -                   | -                   | -                    | -                   | -                   | -                   |
| Spence Bay       | 57<br>(10.1)<br>[3]                 | 91<br>(-)<br>[1]    | -                    | -                   | -                   | -                   | -                    | -                   | -                   | -                   |
| Repulse Bay      | 61<br>(-)<br>[1]                    | -                   | -                    | -                   | -                   | -                   | -                    | -                   | -                   | -                   |
| Lake Harbour     | 20<br>(14.4)<br>[5]                 | 28<br>(5.0)<br>[2]  | -                    | 24<br>(15.7)<br>[3] | -                   | -                   | -                    | -                   | -                   | -                   |
| Frobisher Bay    | [1]                                 | [1]                 | 31<br>(12.5)<br>[11] | 31<br>(10.3)<br>[6] | 25<br>(10.7)<br>[7] | 33<br>(20.1)<br>[6] | 34<br>(16.0)<br>[5]  | ##                  | 45<br>(24.9)<br>[4] | -                   |
| Pangnirtung      | -                                   | -                   | 42<br>(38.3)<br>[9]  | 33<br>(34.8)<br>[8] | 32<br>(26.7)<br>[6] | -                   | -                    | -                   | -                   | -                   |
| Hope Bay         | 16<br>(9.3)<br>[7]                  | 12<br>(5.7)<br>[14] | 12<br>(4.5)<br>[10]  | 14<br>(9.2)<br>[11] | 13<br>(9.6)<br>[14] | 18<br>(8.9)<br>[10] | 18<br>(9.7)<br>[10]  | 19<br>(14.6)<br>[9] | 19<br>(10.5)<br>[9] | 15<br>(9.4)<br>[11] |
| Bathurst Inlet   | -                                   | -                   | -                    | 25<br>(8.8)<br>[3]  | -                   | -                   | -                    | -                   | -                   | -                   |
| Cape Dorset      | 27<br>(21.2)<br>[6]                 | 45<br>(27.0)<br>[2] | -                    | 91<br>(-)<br>[1]    | -                   | -                   | -                    | -                   | -                   | -                   |
| Fort Ross        | -                                   | [0]                 | -                    | -                   | -                   | -                   | -                    | -                   | -                   | -                   |
| Broughton Island | -                                   | -                   | [0]                  | -                   | -                   | -                   | -                    | -                   | -                   | -                   |
| Arctic Bay       | -                                   | -                   | -                    | -                   | -                   | 93<br>(-)<br>[1]    | -                    | -                   | -                   | -                   |
| Eureka           | -                                   | -                   | -                    | -                   | -                   | -                   | 56<br>(13.0)<br>[2]  | -                   | -                   | -                   |

## - Incomplete boat survey, data insufficient.

\* - Inclusion of outlier point yields mean of 21, SD = 38.8 and n = 7.

Table 5 Frequencies of Gyrfalcon brood sizes observed at 13 study areas, 1982-1991.

|                  | 1982    | 1983     | 1984      | 1985     | 1986      | 1987     | 1988      | 1989     | 1990     | 1991     | Total         | Mean N          |
|------------------|---------|----------|-----------|----------|-----------|----------|-----------|----------|----------|----------|---------------|-----------------|
| Brood Size       | 1 2 3 4 | 1 2 3 4  | 1 2 3 4   | 1 2 3 4  | 1 2 3 4   | 1 2 3 4  | 1 2 3 4   | 1 2 3 4  | 1 2 3 4  | 1 2 3 4  | 1 2 3 4       |                 |
| Rich. Mfns.      |         |          |           |          |           | 0 1 1 3  | 0 3 5 4   | 1 1 7 3  |          |          | 1 5 13 10     | 3.10 29         |
| Paulauk          |         |          |           |          |           | 0 1 6 1  | 1 3 2 0   | 0 1 1 0  | 2 1 2 0  | 1 4 4 0  | 4 10 15 1     | 2.43 30         |
| Coppermine       |         | 3 1 1 1  | 1 2 7 1   | 4 1 2 4  | 0 2 4 2   | 0 0 3 2  | 1 4 3 1   | 1 2 3 0  | 0 3 2 0  | 4 6 2 1  | 14 21 27 12   | 2.50 74         |
| Spence Bay       | 0 0 0 1 | 0 0 1 2  |           |          |           |          |           |          |          |          | 0 0 1 3       | 3.75 4          |
| Repulse Bay      | 0 1 1 0 |          |           |          |           |          |           |          |          |          | 0 1 1 0       | 2.50 2          |
| Lake Harbour     | 0 1 2 0 | 0 1 0 0  |           | 0 1 1 1  |           |          |           |          |          |          | 0 3 3 1       | 2.71 7          |
| Frobisher Bay    |         | 0 2 0 0  | 0 3 2 4   | 2 1 2 0  | 0 3 3 1   | 0 2 2 0  | 2 0 3 0   | 2 0 1 0  | 2 1 1 0  |          | 8 12 14 5     | 2.41 39         |
| Paungnitung      |         | 1 5 3 0  | 1 2 1 1   | 1 2 1 1  |           |          |           |          |          |          | 3 9 5 2       | 2.32 19         |
| Hope Bay         | 0 5 1 1 | 1 6 2 1  | 0 5 3 3   | 2 7 2 1  | 1 3 2 2   | 2 3 5 1  | 1 2 4 3   | 2 3 4 1  | 0 3 6 1  | 1 4 3 1  | 10 41 32 15   | 2.53 98         |
| Bathurst Inlet   |         | 0 2 0 0  |           |          |           |          |           |          |          |          | 0 2 0 0       | 2.00 2          |
| Cape Dorset      | 2 0 2 0 | 0 3 0 0  |           |          |           | 0 1 1 0  |           |          |          |          | 2 4 3 0       | 2.11 9          |
| Broughton Island |         |          | 0 2 0 0   |          |           |          |           |          |          |          | 0 2 0 0       | 2.00 2          |
| Arctic Bay       |         |          |           |          |           | 0 0 1 0  |           |          |          |          | 0 0 1 0       | 3.00 1          |
| TOTAL            | 2 7 6 2 | 4 13 4 4 | 2 17 15 8 | 9 15 9 7 | 2 10 10 6 | 2 7 18 7 | 5 12 17 8 | 6 7 16 4 | 4 8 11 1 | 6 14 9 2 | 42 110 115 49 | 2.54 316 Σ= 803 |

Figure 5. Mean internest distance in the three intensive survey areas, 1982-1991.

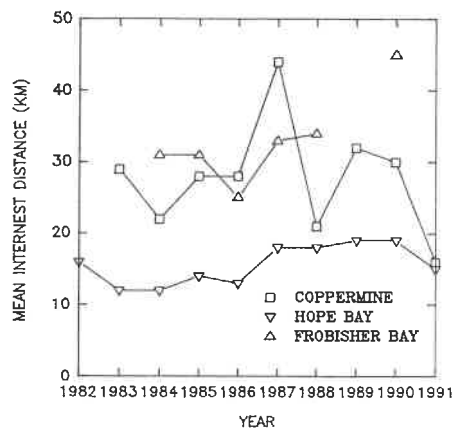


Figure 6. Mean brood size in the three intensive survey areas, 1982-1991.

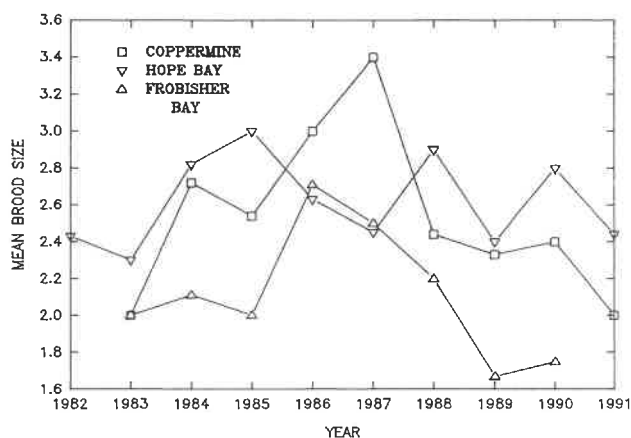


Figure 7. Annual mean internest distance relative to long-term mean July temperature.

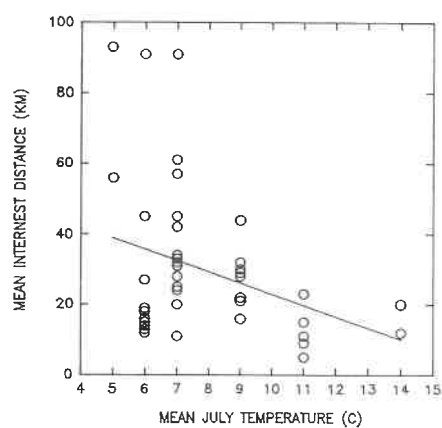


Figure 8. Annual mean internest distance relative to willow height class (Edlund 1986)

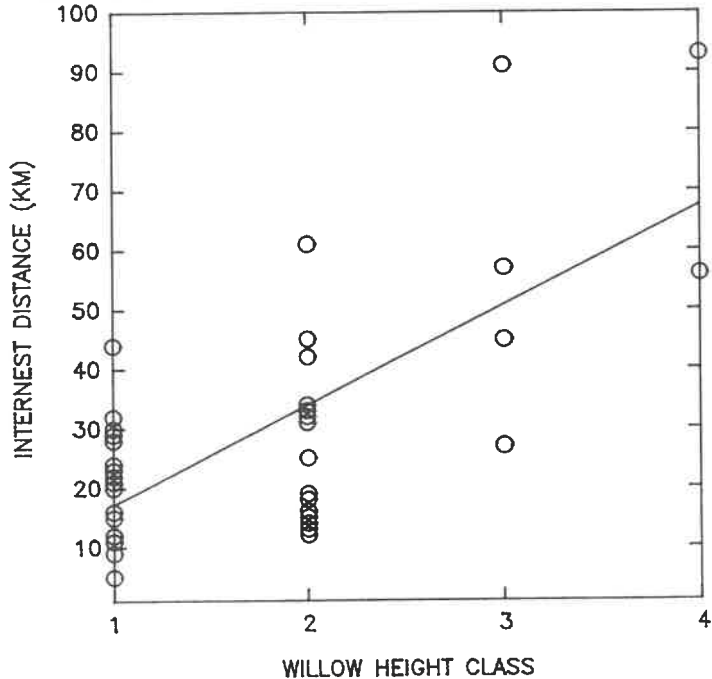


Figure 9. Annual mean brood size relative to long-term mean July temperature.

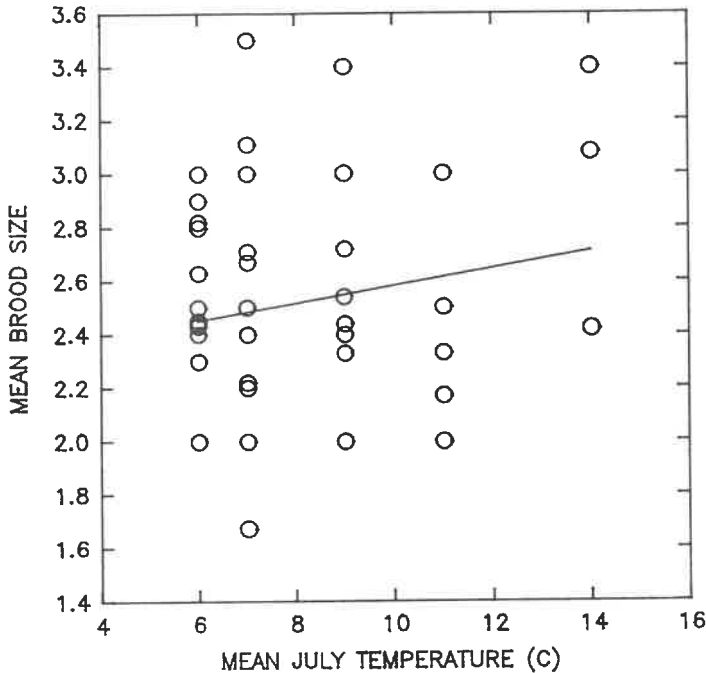


**Figure 10.** Percentage of total broods with 1, 2, 3 or 4 nestlings in areas of >50% or <50% vascular plant cover. Plant cover from Edlund (1986).

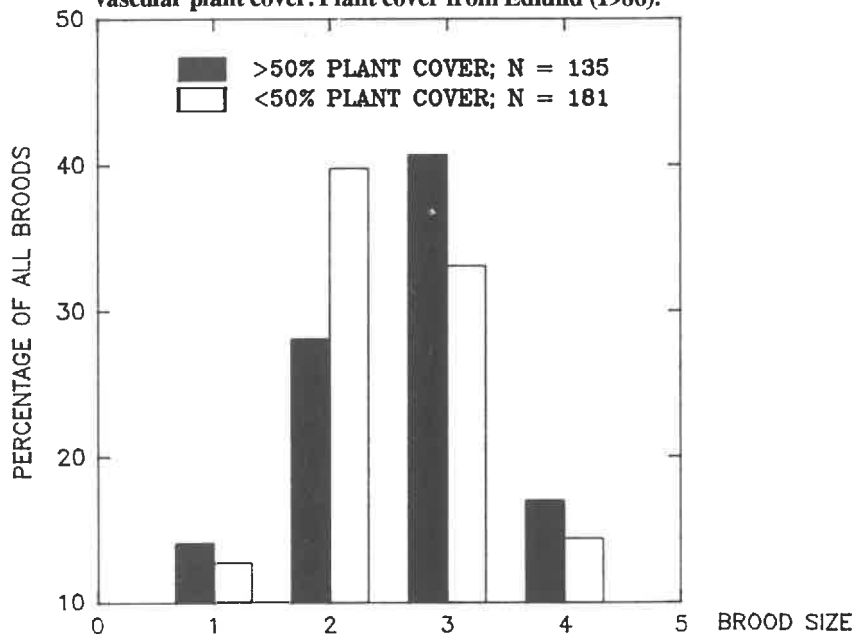
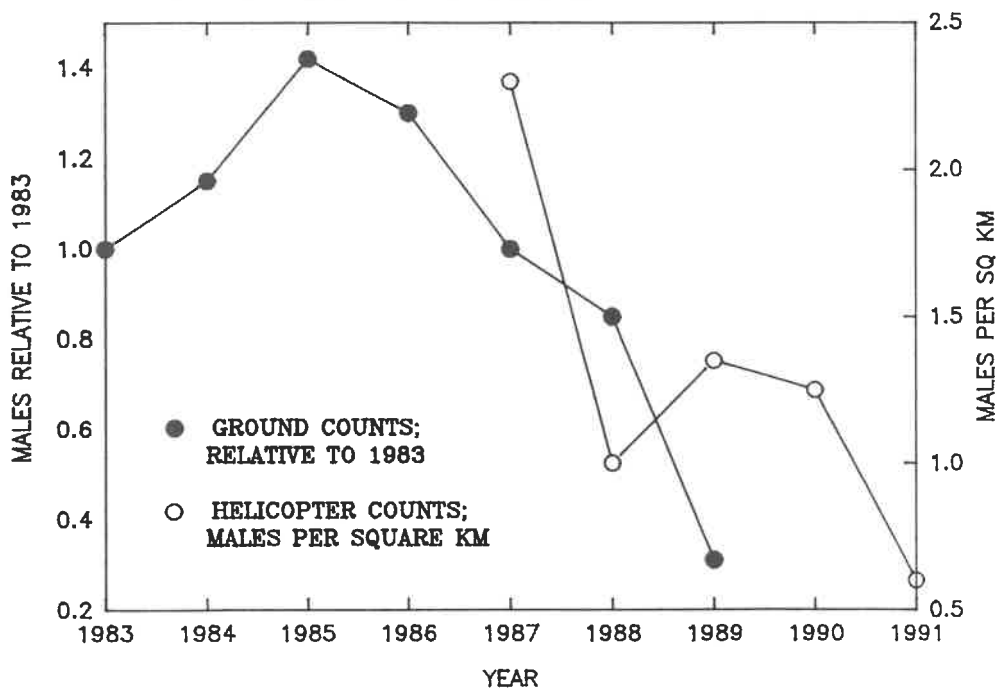


**Figure 11.** Male Rock Ptarmigan ground counts (1983-1989) and helicopter counts (1987-1991) at the Hope Bay study area.



= 3,  $P = 0.20$ ). Analysis of variance showed no difference in mean brood sizes among areas of differing willow height classes ( $F = 0.15$ ,  $df = 45$ ,  $P = 0.87$ ). Environmental factors do not seem to have as great an influence on brood size as on population density. In general, the large amount of inter-year variability in mean brood size overshadows any geographical trend which might exist.

### Effect of Ptarmigan Populations on Gyrfalcon Populations

Parallel data on Ptarmigan and Gyrfalcon numbers are available only for the Hope Bay study area. Rock Ptarmigan (*L. mutus*) numbers peaked in 1985 and declined through 1991 (Figure 11). Correlation coefficients of number of productive Gyrfalcon nests with indices of Ptarmigan numbers are not significant for either the ground counts ( $R^2 = 0.13$ ,  $df = 5$ ,  $P = 0.44$ ) or for the helicopter counts ( $R^2 = 0.00$ ,  $df = 3$ ,  $P = 0.94$ ). At Hope Bay, the number of successfully breeding Gyrfalcons is apparently unaffected by density of Ptarmigan, their primary prey (Poole and Boag 1988).

## DISCUSSION

In 1975, Fyfe (1977) stated that too little data were available to assess the current population trend in Gyrfalcons in Canada. Although the four methods we employed to examine trend in breeding populations of Gyrfalcons in the NWT from 1982-1991 are interrelated to varying degrees, we suggest that taken together they indicate that Gyrfalcon populations in the NWT have neither increased nor declined in the past 10 years, although there has been considerable variability in reproductive success among years and among areas.

This long-term stability is not unexpected. Human disturbance and habitat alteration in the Canadian North have been minimal. The NWT covers 3,380,000 km<sup>2</sup>, approximately two-thirds of which includes potential Gyrfalcon nesting habitat. Few roads exist (<500 km) within this vast breeding area, and less than 25,000 people live in 32 widely scattered communities. Access to most areas of the Arctic requires aircraft. Pesticides, which have greatly affected some raptor populations (Peakall *et al.* 1990), have likely had little or no impact on Gyrfalcon productivity (Noble and Elliott 1990). Gyrfalcon diet in many areas in the NWT is formed primarily of resident mammalian and resident or short-distance migratory avian prey (Poole and Boag 1988). In addition, available evidence suggests little or no migration in most northern Gyrfalcons (Platt 1976, Poole and Bromley 1988), so that pesticide loads are not increased on the wintering grounds.

Gyrfalcon population densities are governed by the simultaneous presence of suitable nesting locations and sufficient prey biomass. In the presence of suitable nesting habitat, Gyrfalcon breeding populations appear to be denser in regions of higher productivity as indexed by mean July temperature and willow growth form and vascular plant cover.

There was no indication of trend in mean brood size over the 10 years of the study. The variability was very wide from year to year, which masked any underlying tendency for brood size to vary with environmental productivity.

The number of productive Gyrfalcon pairs at Hope Bay has remained remarkably constant despite a continuous decline in Ptarmigan numbers from 1985-1991. We are uncertain as to how widespread this lack of a direct relationship between Gyrfalcon and Ptarmigan numbers is in other areas of the NWT. Gyrfalcon breeding populations are known to fluctuate with Ptarmigan numbers in Iceland (Nielsen 1986). The greater among-year variability in territory occupancy and breeding numbers seen in areas such as Coppermine and Frobisher Bay leads us to suspect that the Hope Bay situation may be a regional or local phenomenon.

Given the circumpolar nature of the Gyrfalcon and its use of generally isolated tundra and alpine habitats, few regional population estimates are possible or available (Cade 1982). The widespread and extensive surveys we conducted over the past decade have offered the opportunity to provide an estimate of the numbers of Gyrfalcons in the NWT. We utilized extrapolated internest distances or densities (*sensu strictu*) from our study areas, and coarsely divided the NWT into roughly similar regions of available Gyrfalcon habitat. Because many of our surveys were conducted in what was believed to be optimal habitat for the region, we have added conservative "fudge factors". We estimate about 1300 breeding pairs of Gyrfalcons for the NWT (Appendix 1). If we assume an equal number of adult non-breeders then the total adult population for the NWT is about 5000 birds.

## ACKNOWLEDGEMENTS

We thank the numerous field assistants and Department of Renewable Resources staff who have assisted in the surveys conducted over the past decade. They are too numerous to mention individually, but we would particularly like to acknowledge the contribution of Robert G. Bromley in initiating the study program. That the hundreds of helicopter hours flown were completely free of accidents is a tribute to the many skilled helicopter pilots who flew "low and slow" under often difficult conditions. Funding and logistical support for this research came from the NWT Department of Renewable Resources and the Polar Continental Shelf Project, Department of Energy, Mines and Resources. We thank L.A. Wakelyn for reviewing an earlier draft of this manuscript.

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C.C. Shank and K.G. Poole  
Department of Renewable Resources  
Government of the Northwest Territories  
Yellowknife, NT  
Canada X1A 2L9

## APPENDIX 1

### ESTIMATING NUMBERS OF GYRFALCONS IN THE NORTHWEST TERRITORIES

#### QUEEN ELIZABETH ISLANDS

Gyrfalcons will be limited to coastlines and major river valleys. Measured internest distance is about 75 km. There are about 17,000 km of coastline in the Queen Elizabeth Islands if one smooths out major irregularities. Most does not contain reasonable habitat. Assume that density estimates are 5 times average coastal density. Accordingly, we estimate 1 pair for every 375 km of coast or a total estimate for the Queen Elizabeth Islands of 45 pairs.

#### LOW ARCTIC ISLANDS

Gyrfalcons will be limited to the coastlines and major rivers although not as strictly as in the high arctic islands. Measured internest distance is about 50 km. There are about 26,000 km of low arctic island coastline if one smooths out major irregularities. Most will not contain reasonable habitat. Assume that density estimates are 3 times average coastal density. Accordingly, we estimate about 1 pair per 150 km of coastline or 175 pairs for the Low Arctic Islands.

#### MAINLAND COAST

Assume that Gyrfalcons will be at high density along a 20 km wide strip of habitat along the coastline. At best, densities approach 1 pair per 175 km<sup>2</sup>. There are about 8500 km of arctic mainland coast north of the Arctic circle if major irregularities are smoothed. Assume that measured density is about 5 times average. Accordingly, we estimate 1 pair per 875 km<sup>2</sup> or 195 pairs for the Mainland Coast.

#### MAINLAND

We know very little about Gyrfalcons densities in the mainland. They tend to occur along rivers and to a lesser extent along lakes. We assume a density of 1 pair per 2000 km<sup>2</sup> over 900,000 km<sup>2</sup> of area north of treeline and not included in the coastal estimate. Accordingly, we very tentatively estimate 450 pairs for the mainland tundra. This is considered the weakest component of the estimate.

#### MACKENZIE AND RICHARDSON MOUNTAINS

Assume that Gyrfalcons can occur at densities of 1 pair per 350 km<sup>2</sup>. Nest sites are not expected to be limiting. With an aerial extent of approximately 150,000 km<sup>2</sup>, the NWT portion of the Mackenzie and Richardson mountains probably sustain a population of about 425 pairs.

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Accordingly, the estimate of breeding pairs of Gyrfalcons for the entire Northwest Territories is 1300 pairs. Assuming an equal number of adult non-breeders, the total adult population size of the NWT is *ca.* 5000.