ASPECTS OF THE ECOLOGY OF THE GYRFALCON IN THE CENTRAL ARCTIC, NORTHWEST TERRITORIES, 1983 AND 1984

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ABSTRACT

The ecology of gyrfalcons (*Falco rusticolus*) in the Central Arctic, Northwest Territories was studied in 1983 and 1984. 18 and 15 territories were active each year; 15 and 12 nest sites, respectively, were occupied; 11 nests produced young each year. Productivity, measured as the average number of young surviving to at least the late nestling stage, averaged 1.4 and 2.1 young per territorial pair. Successful pairs produced a mean of 2.3 and 2.8 young per pair. A mortality rate of 33% and 39% from egg to late nestling stage was observed in 1983 (n=4 nests) and 1984 (n=6 nests), respectively. The average date of initiation of egg-laying was 16 May in 1983 and 7 May in 1984. Rock ptarmigan (*Lagopus mutus*) appeared to be the most important food source early in the breeding season. Arctic ground squirrels (*Spermophilus parryii*) made up the majority (74% by mass) of prey used during the mid-nestling period. Observations of common ravens (*Corvus corax*), golden eagles (*Aquila chrysaetos*), tundra peregrine falcons (*Falco peregrinus tundrius*) and rough-legged hawks (*Buteo lagopus*), potential competitors of gyrfalcons for nest sites and/or food, were also recorded, including nesting density, nest site characteristics and productivity.

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INTRODUCTION

The gyrfalcon (Falco rusticolus), a predator superbly adapted to life in arctic regions (Cade 1982), is the largest falcon in the world. Studies of this naturally rare bird are difficult because it occurs at low density in remote habitat north of the 55th parallel (Brown and Amadon 1968). Although highly esteemed for centuries by falconers (Dement'ev 1960, Cade 1968), the ecology of the gyrfalcon has only recently been studied in detail (e.g., Hagen 1952, Cade 1960, Kishchinskii 1957, Langvatn and Moksnes 1979, Barichello and Mossop 1983, Bromley 1983).

Before 1980, the gyrfalcon had been studied in only a few locations of Canada's Northwest Territories (NWT): along the Anderson River north of Great Bear Lake (Fyfe 1966), in the Thelon River area (Kuyt 1980) and on Ellesmere Island (Muir 1975). These studies were usually limited in scope, of short duration, or concentrated on a small number of nest sites.

As a result of legislation enabling a commercial harvest of gyrfalcons in 1981, the Department of Renewable Resources (DRR), Government of the NWT, began baseline studies in 1982. These consisted of annual surveys by helicopter of nesting populations of gyrfalcon and other birds of prey in selected areas of the NWT (Bromley 1983). The 1982 survey identified an area on the Central Arctic mainland that harboured one of the highest recorded densities of gyrfalcons. Intensive study of the ecology of gyrfalcons in this area, named the Kilgavik study area, began in May 1983. Kilgavik is an Inuit term meaning falcon. The present paper reports on field work undertaken in 1983 and 1984, and incorporates some of the results of the preliminary 1982 aerial survey (Bromley 1983) for comparative purposes. The study is ongoing, with field work planned for 1985 and 1986.

The DRR maintains a policy of confidentiality of raptor nest site locations, in order to protect them from possible disturbance and illegal activity. Thus, in order to protect the study population, the area will be referred to as the Kilgavik study area and no reference will be made to common geographic names.

The ultimate goal of this study is to increase our understanding of gyrfalcon ecology in order to better comprehend the factors that regulate productivity and survival in the Central Arctic population.

The initial objectives were:

1. to establish continuing baseline studies of prey density, food habits, productivity and nesting phenology;
2. to locate and document the presence and use of all nest sites on the study area;
3. to assess the effectiveness of spring surveys using snowmobiles in locating gyrfalcon nests;
4. to describe gyrfalcon activity during the mid-nesting and post-fledging periods; and
5. to prepare for more intensive work on the study area.

Secondary objectives were to obtain data on nesting activities of other raptors, namely the golden eagle (Aquila *chrysaetos*), tundra peregrine falcon (*Falco peregrinus tundrius*) and rough-legged hawk (*Buteo lagopus*). The common raven (*Corvus corax*) may be considered a functional raptor (White and Cade 1971), and, as such, was also studied.

STUDY AREA

The study area was located in the Central Arctic region of the NWT on the coastal mainland. The intensive study portion of the Kilgavik study area consisted of approximately 1350 km^2 of contiguous land. A larger area, termed the extensive study area, incorporated the intensive study area as well as discontinuous patches of land, islands, a disjunct portion of land further along the coast, and sections of cliff terrain on the south side of a nearby peninsula. A total of 1800 km^2 was included.

Logistical constraints involving travel time and distances meant that sites located far from the centre of activity, such as those in the discontinuous regions of the study area, were visited less frequently than those on the intensive study area. Thus, our knowledge of the discontinuous areas was much less thorough than for the intensively studied region. All sites within the study area were, however, surveyed by helicopter during July of both years. The majority of data reported here pertain to the entire Kilgavik study area unless specified otherwise.

The mainland region of the Central Arctic area lies within the fourth phytogeographic province (Porsild and Cody 1980). The flora consists of wide-ranging, low-arctic tundra species. Willows (Salix spp.) and sedges (Carex spp.) are common. The study area falls into the "lush vegetation tundra wildlife zone" of Jacobson (1979:11). Porsild and Cody (1980) describe the distribution of plant taxa found within the study area.

The regional climate is cold and dry, with January and July mean daily maximum temperatures of approximately -30°C and 10°C, respectively, and precipitation of 100-150 mm annually (Maxwell 1980). Snow cover is prevalent for approximately 260 days of the year. Snow melt begins in mid- to late May. There is no permanent weather station in the immediate vicinity of the study area.

Granitic intrusions and diabase dykes and sills (Fraser 1964, Stockwell et al. 1970) form the main geological features of the area. They appear as lines of steep-sided cliffs or circular blocks of rock (sills) rising above the surrounding terrain and provide nesting cliffs facing a variety of directions. Elevations range from sea level to 375 m, with the highest elevations attained within the southwestern section of the study area.

METHODS

Definitions

Terminology referring to nesting activities is based on Postupalsky (1974) with some modifications, as follows:

Territory: an area containing one or more nest sites within the range of a known or inferred pair of actual or potential breeders. Includes the area around the nest site which is actively defended (nesting territory).

Nest site: the actual site of a nest. Two or more nest sites may be located within the territory of a pair of birds. Different nest sites may be used in alternate years. Nest sites were assigned unique numbers to distinguish them.

Active territory: a territory where a single bird or a pair of birds is present at some time during the breeding season, although eggs may not necessarily be present. Activity at distant territories may be determined by only one visit, although more frequent observations, especially in spring, are obviously preferred.

Occupied nest site: a nest site where nesting is evident, through the direct observation of eggs or young, or indirectly by the presence of an incubating female.

Productive or successful nest: a nest where a minimum of one chick is raised to an advanced stage of development and is assumed to fledge, or is actually observed to fledge.

Production: the total number of young fledged or raised to an advanced stage of development from all productive territories.

Productivity: the mean number of young per territorial pair.

Methodology by Season

A total of 37 and 52 days were spent in the field in 1983 and 1984, respectively. The field seasons were broken into three distinct periods, corresponding to nest initiation and incubation, mid- to late nestling stage, and post-fledging.

Nest Initiation and Incubation

Observation Periods: 10 May - 10 June 1983
9 May - 3 June 1984

Known nest sites and potential nesting cliffs were visited by snowmobile to determine occupancy. Signs of recent occupancy, such as fresh excrement, pellets or plucking rings were noted. New sites were often located by observation of white patches of excrement and/or presence of *Xantheria elegans* on the cliff face. *X. elegans* is an orange lichen that grows in nitrogen-rich environments. Parameters regarding the nest site, such as cliff height, nest height, percent of overhang, and aspect were visually estimated and recorded. Disturbance, especially during nest initiation and early incubation, was minimized as much as possible (see Fyfe and Olendorff 1976).

Prey remains and pellets were collected at sites occupied by gyrfalcons. The base of the cliff below the nest and obvious perches were searched, as was the nest itself where feasible. Only fresh remains and pellets were collected to ensure the identity of the source. Potential parasites encountered during examination of the nest site were also collected (Appendix B).

The colour phase and sex (based on size differences) of all gyrfalcons were noted. Wide variations in individual plumage occur (Cramp and Simmons 1980). Where possible, detailed notes describing unique colouring patterns of the plumage of each bird were recorded in order to facilitate recognition of individuals in subsequent years.

The numbers of all raptors observed, and their potential prey species, were recorded throughout the study area. This information was used to derive a species-specific abundance index, expressed as the number of individuals observed per observer-km. The first date that a species was sighted was also noted, providing a measure of differences in spring phenology between 1983 and 1984.

Plots, each 1 x 2 km in area, were established randomly at five locations in 1983. An additional plot (F) was located, non-randomly, near base camp during 1984, in what appeared to be medium quality ptarmigan habitat. These plots were censused to estimate density of rock ptarmigan (Lagopus mutus) and other potential prey species (e.g., arctic hare (Lepus arcticus) and passerines) on the study area. Surveys were carried out after the male ptarmigan had begun display on territory. The plots were surveyed during the morning in two traverses by three or four observers spaced at approximately 167 or 125 m intervals, respectively. The traverses were oriented with a compass so that they were parallel to the long axis of the plot. The number and sex of ptarmigan were observed and noted, as was the presence of other potential raptor prey species.

In 1983, three of the five plots were censused twice, and the remaining two plots were censused once. In 1984, due to restricted travel conditions brought about by an extremely mild and early spring, only two plots were censused. Plots B and F were surveyed a total of five times each.

To determine the proportion of juveniles in the rock ptarmigan population, 25 birds were collected in 1984. Care was taken not to collect ptarmigan in the vicinity of the census plots.

Mid- to Late Nestling Period

Observation Periods: 1-3 July and 13-15 July 1983
6-17 July 1984

A Bell 206B Jet Ranger helicopter on pontoons, carrying a pilot and two observers, was used 1-3 July and 13-15 July 1983 and 14-17 July 1984 to survey known nest sites and potential nesting cliffs within the study area. Flights beyond the extensive study area boundary were made to ensure that all cliffs that could potentially harbour gyrfalcons were surveyed. Approximately 20 h and 16 h of helicopter time were used in 1983 and 1984, respectively.

Cliff faces were usually examined with one slow (30-60 km/h) pass by the helicopter approximately 20-40 m from the cliff face. Two or more passes were made on tall cliffs or to verify observations.

Sightings were recorded in numerical order on sheets by the rear observer and keyed into a map location obtained by the front observer. At all nest sites the number of adults visible, the number of eggs or young present, and standard parameters on nest location were obtained. Opportunistic sightings of all raptors not associated with a nest site were also recorded.

When an occupied gyrfalcon nest was located, the age of the chicks was estimated. When the nest was inaccessible, the age of young was estimated from the helicopter. Otherwise, the eyrie was entered and the young were photographed. Later, slides of the young were compared with photographs of chicks of known age obtained by Muir (1975) from an eyrie on Ellesmere Island to further refine the age estimates. As before, all prey remains, pellets and parasites were collected. When gyrfalcon and golden eagle eyries were entered the eyases were banded. Eagle young were aged according to Ellis (1979).

In 1984, four occupied nests were observed for a total of 68.5 h. Observation distances ranged from 200-300 m, and 7 x 26 binoculars and 20x spotting scopes were used. Data on prey species captured, frequency of prey items brought to the nest, general behaviour and interspecific interactions were obtained. Gyrfalcons appeared to habituate rapidly to the observers, providing a low profile was maintained and movement kept to a minimum. A camouflage blanket was used when observation from close range was required.

Two lines of 10 Victor mouse traps, baited with cheese and peanut butter, were set on 10 x 40 m grids to obtain information on the microtine population. The grids were set up at two locations for a total of 180 trap-days, a day being defined as a complete 24 h period.

Post-fledging

Observation Period: 1-14 August 1984

Observations of the fledging and post-fledging stages of gyrfalcon development were conducted along the coast of the study area. An 18 foot (5.9 m) aluminum boat powered by a 55 hp engine was used for travel on the ocean. Five sites, on the coast or within 2 h walking distance from the coast, were visited.

Observations similar to those obtained during July were recorded. Observation distances varied greatly due to the increasing mobility of the fledged juveniles, but generally ranged from 150-400 m. Prey remains, pellets and parasites were collected. A total of 101 h of observations was obtained.

RESULTS AND DISCUSSION

Phenology

Spring phenology differed greatly between the 2 years of study. In 1983, spring conditions were average to slightly late on the study area, while in 1984, extremely early spring conditions occurred, according to the experience of local people and workers. These differences appeared to influence significantly subsequent events throughout the reproductive period.

The weather records also showed a significant difference in the onset of spring in 1983 and 1984 (Table 1). May 1983 was much colder than May 1984. This difference was reflected in both the timing of extensive snowmelt (60% on 4 June 1983 and 60% on 16 May 1984) and the arrival time of migrant birds (Table 2). Many of these birds are potential prey for raptors in the area. Species arrived on the study area an average of 10 days earlier in 1984 than the previous year.

The behaviour of rock ptarmigan was also correlated with the timing of spring. Other workers have noted that the timing of dispersal of winter flocks of willow ptarmigan (*L. lagopus*) is correlated with increasing temperature and snowmelt (Weeden 1959, Bergerud 1970). In May 1983, it was not uncommon to see rock ptarmigan in flocks of up to 50 individuals. This persisted until about 25 May, when they rapidly dispersed and became territorial. In contrast, rock ptarmigan were well dispersed and territorial when investigators arrived on the study area on 9 May 1984,

Table 1. Weather parameters for the Kilgavik study area, NWT, during May and early June.

Time Period	1983	1984
$\bar{X}$ daily minimum (°C)		
13 - 19 May	-16	-10
20 - 26 May	-19	-10
(27 - 31 May)[a]	- 3	- 3
27 May - 2 June	- 3	---
3 - 9 June	- 1	---
$\bar{X}$ daily maximum (°C)		
13 - 19 May	- 8	- 1
20 - 26 May	-11	+ 4
(27 - 31 May)	+ 5	+12
27 May - 2 June	+ 5	---
3 - 9 June	+ 8	---
Range (°C)		
13 - 19 May	-22, - 5	-16, + 6
20 - 26 May	-29, - 5	-16, +13
(27 - 31 May)	- 8, + 8	- 5, +17
27 May - 2 June	- 8, + 8	---
3 - 9 June	- 2, +15	---
Average daily high wind speed (knots)		
13 - 19 May	11	7
20 - 26 May	22	8
(27 - 31 May)	9	8
27 May - 2 June	7	---
3 - 9 June	8	---

a Weather records for the dates in parentheses are provided to enable direct comparison of weather parameters between years when 1984 recordings ended earlier than in 1983.

Table 2. First observation dates of selected species on the Kilgavik study area, 1983 and 1984.

Species	Date first observed[a] 1983	1984
Gyrfalcon (*Falco rusticolus*)	10 May	9 May
Golden Eagle (*Aquila chrysaetos*)	10 May	9 May
Common Raven (*Corvus corax*)	10 May	9 May
Rock Ptarmigan (*Lagopus mutus*)	10 May	9 May
Rough-legged Hawk (*Buteo lagopus*)	12 May	10 May
Snow Bunting (*Plectrophenax nivalis*)	13 May	9 May
Arctic Ground Squirrel (*Spermophilus parryii*)	14 May	14 May
Tundra Swan (*Cygnus columbianus*)	20 May	14 May
Canada Goose (*Branta canadensis*)	21 May	10 May
Glaucous Gull (*Larus hyperboreus*)	25 May	24 May
Peregrine Falcon (*Falco peregrinus*)	26 May	15 May
Sandhill Crane (*Grus canadensis*)	20 May	12 May
Greater White-fronted Goose (*Anser albifrons*)	27 May	14 May
Herring Gull (*Larus argentatus*)	28 May	25 May
Lesser Snow Goose (*Chen c. caerulescens*)	28 May	16 May
Redpoll (sp.) (*Carduelis* sp.)	29 May	19 May
Lapland Longspur (*Calcarius lapponicus*)	29 May	15 May
Horned Lark (*Eremophila alpestris*)	31 May	23 May
Northern Pintail (*Anas acuta*)	31 May	18 May
Baird's Sandpiper (*Calidris bairdii*)	3 June	27 May
Common Snipe (*Gallinago gallinago*)	3 June	27 May
Water Pipit (*Anthus spinoletta*)	3 June	24 May
Semipalmated Plover (*Charadrius semipalmatus*)	4 June	28 May
Oldsquaw (*Clangula hyemalis*)	5 June	27 May
Pectoral Sandpiper (*Calidris melanotos*)	5 June	23 May
Pomarine Jaeger (*Stercorarius pomarinus*)	6 June	29 May
Savannah Sparrow (*Passerculus sandwichensis*)	6 June	27 May
Tree Sparrow (*Spizella arborea*)	7 June	27 May
Red-breasted Merganser (*Mergus serrator*)	8 June	1 June

a The first seven species were likely present on the study area when observations began on 10 May 1983, and on 9 May 1984.

suggesting that the large flocks may have arrived in the area much earlier than in 1983. The largest flock noted in 1984 comprised four ptarmigan. The presence of large flocks earlier in 1984 would indicate that ptarmigan were available earlier that year than in 1983, although we were not present to document this occurrence. Further, the vulnerability of rock ptarmigan, particularly males, may increase as they become territorial. While the females molt into drab plumage as snowmelt progresses, the males remain completely white until mid- to late June. This characteristic, in combination with the open and dramatic behaviour associated with establishment and maintenance of territories, would likely increase the vulnerability (availability) of ptarmigan to gyrfalcons (Bergerud and Mossop 1984). If this is in fact the case, ptarmigan became more readily available to gyrfalcons considerably earlier in 1984 than in 1983.

Nest Site Occupancy and Production

Gyrfalcons were active on 18 and 15 territories within the Kilgavik study area in 1983 and 1984, respectively (Table 3). In 1983, 15 (83%) of the territories were considered to be occupied by nesting pairs; in 1984, 12 (80%). Eleven pairs were productive in each year. Eight new territories were discovered in 1983 and one new territory (site 935) was discovered in 1984. Twenty territories have been documented during the 3 years of study, 17 of which were found within the intensive study area (Table 4). All but two of the new territories located after the 1982 aerial survey were discovered during ground surveys by snowmobile.

Table 3. Summary of reproductive data for gyrfalcons breeding in the Kilgavik study area, 1982-1984[a].

	1982	1983	1984
Number of active territories	11+	18	15
Number of occupied nest sites	10	15	12
Number of productive nest sites	9	11	11
Mean clutch size based on May observations[b]	--	3.3	4.0
Total eggs accounted for during July survey (no. of nests)	22(8)	34(12)	40(11)
Total young produced	--[c]	25	31
Total young banded	0	22	29
Mean brood size of all productive pairs	--[c]	2.3	2.8
Mean brood size of all active pairs (productivity)	--[c]	1.4	2.1

a 1982 data from Bromley (1983).

b Clutch size is based on four nests in spring 1983 and six nests in 1984.

c Insufficient data available; 1982 survey conducted when only eggs and very small nestlings present.

Table 4. Summary of use of gyrfalcon nest sites within the Kilgavik study area, 1982-1984[a].

Territory number	1982 Site no.	1982 Status[b]	1983 Site no.	1983 Status[b]	1984 Site no.	1984 Status[b]
1	101	--	101	P-2	101	O
2	102	O	102	A	102	A
3	103	--	103	P-3	103 1195	-- P-2
4	104	P-3	104[c] 696	(raven) P-4	104 696	A (raven)
5	106	P-2	106 693	(raven) P-3	106 693 1210	-- (raven) P-2
6	107	P-4	107	P-2	107	--
7	108	--	108	A	108	A
8	110	(raven)	110	P-2	110 922	-- P-3
9	112	P-1+	112	O[d]	112	P-3
10	113	P-4	113	O	113	P-4
11	114	A	114	O	114	--
12	119	P-2	119 738	-- P-1	119 738	P-3 --
13	121	P-3	121	P-2	121	--
14	122	P-2	122 697	(eagle) A	122 697	(eagle)
15	132	P-2	132	P-2	132 954	-- P-2
16			671	O	671	P-2
17	--	--	672	O	672	--

Table 4 (continued)

Territory number	1982 Site no.	1982 Status[b]	1983 Site no.	1983 Status[b]	1984 Site no.	1984 Status[b]
18			689	(raven)	689	P-2
19			699	P-2	699	--
					955	P-4
20					935	P-4

a 1982 data from Bromley (1983).

b A = active territory; O = occupied nest site; P-2 = productive site, two young fledged (or alive at last observation); -- = inactive site.

c Multiple sites listed under one territory denotes alternate sites have been identified. The species name in brackets identifies the occupant of an alternate site.

d Site 112 contained two eggs in 1983 and would likely have been productive had human disturbance not caused failure of the two egg clutch.

Only three (20%) of the 15 nest sites occupied in 1983 were reoccupied in 1984, although 10 (67%) of the 15 territories with occupied nests were used in both years. In 3 years of observations, not one nest successfully produced young every year, although site 112 may have, had human disturbance not caused failure in 1983. However, three territories, 5, 12 and 15, fledged young in all 3 years (Table 4).

Within the study area, densities of one active territory per 100 km^2 (1983) to 120 km^2 (1984) were observed. Considering all territories known to have been active at some time during 1982-1984, a density of one territory per 80 km^2 (n=17) exists on the intensive study area, and one territory per 90 km^2 (n=20) exists when the larger study area is considered. On the intensive study area, the mean inter-nest (nearest neighbour) distance among 13 occupied nests in 1983 was 8.1 km ($\pm$5.0 SD), and among 11 nests in 1984 was 9.8 km ($\pm$3.4). Respective distances for the extensive study areas were 8.8 km ($\pm$5.0, n=15) and 11.0 km ($\pm$5.4, n=12). Distances between occupied nests ranged from 1.0 to 24.8 km. Since it is unlikely that the hunting grounds of all pairs were within the study area, these figures indicate nesting densities, not home ranges. In addition, since our present knowledge indicates that this study area and resulting densities are exceptionally high, these densities cannot be extrapolated to any other part of the NWT.

The density of territorial gyrfalcons found on the study area is among the highest reported. Bromley (1983) reported mid-summer densities across the mid-arctic latitudes of the NWT ranging from one pair per 300 km^2 to one pair per 1456 km^2. Barichello (1983) observed densities of one pair per 171 km^2 to one pair per 183 km^2 for a population in the Ogilvie Mountains of central Yukon. Roseneau (1972) found one pair per 916 km^2 on the entire Seward Peninsula of Alaska, with a maximum density of one pair per 170 km^2 in some sub-study areas of the Peninsula. Wayre and Jolly (1958) located seven eyries in 440 km^2 (one pair per 63 km^2) in Iceland. Other reported densities are generally much lower (see Cramp and Simmons 1980).

During incubation in 1983, two nests contained four eggs each, a third nest three eggs and a fourth, two eggs, for a mean of 3.3 eggs/clutch. Six nests were examined in May 1984; each contained four eggs (Table 3).

The mean brood size of all successful nests in 1984 (2.8 young/nest), as observed during the late nestling period, was moderate compared to that reported for other areas (Table 5), but was higher than that found on the study area in 1983 (2.4 young/nest). An early, mild spring in 1984 may have increased prey availability and thus resulted in larger clutches, along with increased hatching rate and nestling survival (Newton and Marquiss 1981, Barichello 1983).

It is difficult to determine the time and cause of egg and nestling mortality. Nevertheless, in 1983, nine eggs in three nests produced six young to at least the mid-nestling stage, giving an egg to early-nestling mortality of 33%. Two of the unsuccessful eggs were addled, but the third one was not found. During the July surveys, two small young disappeared from one nest with four young.

Table 5. Brood size of selected North American gyrfalcon populations.

Location	Year	No. of young per successful nests (no. of nests)	Age at observation (d=days)	Source
Alaska				
Colville River	1952	3.0 (4)	?	Cade 1960
	1956	2.2 (5)	?	Cade 1960
	1957	1.3 (3)	?	Cade 1960
	1959	2.4 (10)	?	Cade 1960
Average	1952-75	2.5	?	Platt and Tull 1977
	1983	2.6 (10)	35d-fledge	Dittrick and Moorehead 1983
North Slope	1957	2.3 (3)	?	Cade 1960
	1958	2.0 (2)	?	Cade 1960
Seward Peninsula	1968	3.3 (8)	fledge	Roseneau 1969
	1969	2.5 (44)	fledge	Roseneau 1970
Yukon				
North Slope	1973	2.8 (26)	?	CWS records
	1974	3.2 (55)	fledge	Mossop 1980
	1975	3.2 (36)	fledge	Mossop 1980
	1976	3.2 (64)	fledge	Mossop 1980
	1977	3.4 (50)	fledge	Mossop 1980
	1978	3.3 (55)	fledge	Mossop 1980
	1979	2.7 (70)	fledge	Mossop 1980
North Central	1978	2.6 (8)	various	Nelson 1978
Average	1978-82	2.1 (51)	?	Barichello 1983
Northwest Territories				
Thelon River	1961-69	2.9 (18)	7d-fledge	Kuyt 1980
Kilgavik	1983	2.4 (10)	8-31 d	This study
	1984	2.8 (11)	23d-fledge	This study

It was likely that most young observed during 1984 fledged, since the helicopter survey was conducted near the end of the nesting period. Post-fledging observations in August support this assumption. However, considerable mortality must have taken place earlier in the breeding period. In the six nests observed with four eggs per clutch in May 1984 a mean of 2.5 young fledged, which is a mortality rate of 39%. Only two of the nine "missing" eggs or young were located. One addled egg was collected from a site (112) that produced three fledglings. The badly decomposed remains of a 20-day-old chick were found beside another nest containing three 40- to 42-day-old eyases (site 922). Cause of death could not be determined.

Cade (1960) observed a 38% reduction at Alaskan sites from the number of eggs to number of gyrfalcon young fledged. Mortality of 29% from the egg stage to fledging has been documented for peregrine falcons (Ratcliffe 1980). Roseneau (1970) observed a loss of 31% from 28 eggs to 19 fledglings at eight gyrfalcon nests on the Seward Peninsula in 1969. Nestling survival was better, however, with 19 of 21 young fledging (9.5% loss). Perhaps more surprising were observations by Dittrick and Moorehead (1983) at seven nests on the Colville River, Alaska in 1983. These researchers reported that 3-week-old nestlings suffered a 37% mortality rate before they reached the age of 5.5 weeks.

The causes of early mortality likely vary. Cade (1960) believes that starvation is an important factor, especially during years of low prey abundance. Dittrick and Moorehead (1983) suggest other factors, including predation (they observed a golden eagle take one gyrfalcon nestling), starvation resulting from the death of one or both adults, and eyases being knocked out of the nest by siblings. Judging from conditions on the nest ledge and the position of the dead chick found at site 922, the latter factor may have caused the mortality in this instance.

Nest Site Characteristics

In 1983 and 1984, most productive gyrfalcon nests (91% and 64%, respectively) were in stick nests originally built by common ravens or golden eagles, with the former being more frequently used (Tables 6, 7). Of four occupied but unproductive gyrfalcon nests in 1983, one was a ledge nest, one a raven stick nest and two were stick nests of unknown origin. The one occupied but unproductive nest in 1984 was on a ledge. Use of nests built by rough-legged hawks was not documented in either year. The particular situation of a stick nest and the construction material used generally reveal which species built the nest, however, in older nests the type of construction can be unclear. Gyrfalcons are not known to construct stick nests (Cade 1982).

Nests with complete overhangs were frequently selected by gyrfalcons. Although only one site had little overhang in 1983, three sites (671, 935 and 954) had 25% or less overhang in 1984, and were quite exposed to the elements, although all three had a southern aspect (cf. Barichello 1983). Unprotected south-facing sites would tend to be free of snow earlier in the spring than other unprotected sites (Cade 1960, Platt 1976). Initiation of

Table 6. Characteristics of 15 occupied gyrfalcon nest sites on the Kilgavik study area, 1983.

Site no.	Nest type	Aspect	Over-hang (%)	Cliff height (m)	Nest height (m)	Walk in? (Y/N)	Protection[b] (assessment)
101	ledge	SW	80	35	12	N	good
103	raven stick	NE	100	30	15	N	good
107	raven stick	NW	100	20	10	Y	good
110	raven stick	E	100	14	9	Y	fair
112	eagle stick	E	75	30	15	Y	good
113[a]	stick	S	100	22	8	Y	good
114[a]	stick	E	100	20	10	N	good
121	raven stick	W	100	15	10	Y	excellent
132	eagle stick	W	80	22	10	N	good
671[a]	ledge	S	0	22	15	N	poor
672[a]	raven stick	S	100	30	15	N	excellent
693	raven stick	E	100	40	20	N	excellent
696	raven stick	NW	100	30	22	N	excellent
699	raven stick	SW	100	20	4	Y	excellent
738	raven stick	W	100	20	10	N	good
Average height				25	12		
(SD)				7.4	4.7		

a Unproductive nests

b Protection takes into account overhang, lateral exposure, aspect, height from cliff bottom and accessibility by terrestrial predators.

Table 7. Characteristics of 12 occupied gyrfalcon nest sites on the Kilgavik study area, 1984.

Site no.	Nest type	Aspect	Over-hang (%)	Cliff height (m)	Nest height (m)	Walk in? (Y/N)	Protection[b] (assessment)
101[a]	ledge	SW	80	35	12	N	good
112	eagle stick	E	75	30	15	Y	good
113	stick	S	100	22	8	Y	excellent
119	stick	W	100	20	12	Y	good
671	ledge	S	0	22	15	N	poor
689	raven stick	E	100	15	4	Y	excellent
922	raven stick	NE	100	10	4	Y	excellent
935	ledge	S	10	13	6	Y	poor
954	eagle stick	SW	25	25	15	N	fair
955	raven stick	SW	100	22	15	N	good
1195	raven stick	N	100	35	25	N	good
1210	raven stick	N	100	40	22	N	good
Average height				24	13		
(SD)				9.4	6.6		

a Unproductive nest.

b Protection takes into account overhang, lateral exposure, aspect, height from cliff bottom and accessibility by terrestrial predators.

c Site 922 began the season as a typical raven stick nest, but by fledging 95% of the sticks were gone and the nest was essentially a bare ledge.

egg-laying at sites 671 and 935 began relatively late, in comparison with the rest of the productive sites in the study area. However, at site 954, egg-laying occurred at the same time as the majority of other sites. Gyrfalcons may not require the same degree of protection from the environment at the nest site during mild years (e.g., 1984) as during years with more adverse conditions (e.g., 1983). Describing 31 sites in the northern Yukon, Platt (1976) stated that over two thirds of the sites were without well-developed projections over the nest. According to existing information, this is an exception to the general rule (Barichello 1983).

Gyrfalcons generally selected sites facing in a west to south to east direction (Fig. 1). Northwest- to northeast-facing cliffs were used in six cases. North-facing sites are generally not extensively used by gyrfalcons (Kishchinskii 1957, Bromley 1983), although some cases have been documented (Cade 1960). Although other factors must be taken into account, it should be recognized that in regions of 24 h daylight, northwest- to northeast-facing sites would receive solar radiation and heat during the coolest period of the day, and not receive direct sunlight from the south to west during the heat of the afternoon (Manniche 1910 _in_ Jenkins 1978). Behavioural responses by the nestlings to overheating were observed at three, west-facing sites (119, 121 and 738) during afternoon periods of sunshine and little wind. These responses included gular fluttering (panting) and movement to the shadiest part of the nest, behaviours which have been described elsewhere (Fletcher and Webby 1977).

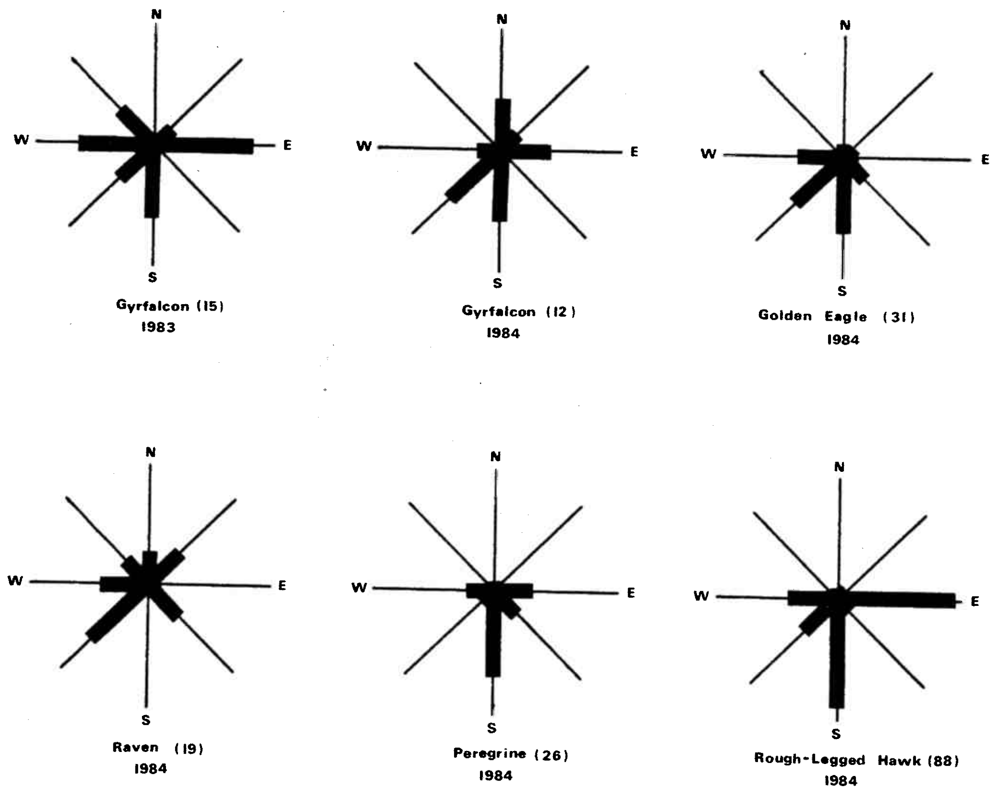

Figure 1. Aspect of raptor and raven nests on the Kilgavik study area.

Ravens also used sites with various aspects, while in general most sites used by golden eagles, peregrines and rough-legged hawks faced west to south to east (Fig. 1). One possibility is that the tendency to face the south may be inversely related to the average degree of overhang of sites used by the species. Thus, gyrfalcons and ravens, the two species with nests that had the greatest mean overhang, used sites that sometimes faced north, northwest or northeast. On the other hand, nests built by golden eagles and rough-legged hawks or occupied by peregrine falcons rarely faced these directions and had the least overhang (Table 8). By using well protected sites, gyrfalcons may increase the number of sites available to them, since the added protection may allow them to use sites with aspects (e.g., north-facing sites) not used to the same degree by other species.

Barichello (1983) suggested that gyrfalcons generally avoid small (less than 15 m high) cliffs. This was generally true on the Kilgavik study area. Twenty-three gyrfalcon nests averaged 12.5 m (+5.9) in height on 23.0 m (±9.6) cliffs, but these heights varied greatly (Tables 6, 7). Gyrfalcons, ravens and golden eagles generally used higher cliffs than other raptors (Table 8). Peregrines used cliffs of moderate height, while rough-legged hawks were found on the lower cliffs in the area. These results differed somewhat from those observed on the Colville River (White and Cade 1971) where, on average, peregrines and rough-legged hawks used higher cliffs than gyrfalcons and ravens.

Table 8. Characteristics of gyrfalcon, raven and other raptor nest sites on the Kilgavik study area, 1984.

		Cliff height	Nest height	Number of nests with overhang of			
Species	N	$\bar{X}$(SD)m	$\bar{X}$(SD)m	0-10%	11-90%	91-100%	$\bar{X}$%OH
Gyrfalcon	12	24(9.4)	13(6.6)	2	3	7	74
Raven	19	18(7.0)	8(4.6)	2	1	16	86
Golden Eagle	31	21(8.2)	12(5.1)	14	11	6	37
Peregrine Falcon	25[a]	16(7.3)	9(5.1)	19	6	1	12
Rough-legged Hawk	76[a]	13(5.3)	7(3.2)	57	9	14	20

a Overhang (OH) was described for 26 peregrine and 80 hawk nests.

Alternate Nest Sites

The use of alternate nest sites by gyrfalcons varies over their range and perhaps varies among years. Roseneau (1972) found that gyrfalcons on the Seward Peninsula of Alaska re-use specific nest sites infrequently and often shift to alternate cliffs. On the other hand, Barichello (1983) found little use of alternate sites in the central Yukon.

Alternate gyrfalcon nest sites have been identified for seven territories within the Kilgavik study area (Table 4). The alternates were close to each other, on the same cliff in six instances, but one was separated by 3500 m (Table 9). Many ecological factors, such as the parasite load at the nest, disturbance, availability of sites, or the success or failure of nesting likely influence the use of alternate nest sites within a territory (Newton 1979). Further study is needed to confirm that the same individual birds are using alternate sites within the territories identified.

Phenology of Nesting

The age of all gyrfalcon nestlings was estimated at the time of observation, enabling determination of the chronology of egg-laying, hatching and fledging by back-dating and forward extrapolation (Table 10). The incubation period was assumed to be 35 days (Cade and Weaver 1976, Platt and Tull 1977); the fledging period 47 days (Muir 1975, Jenkins 1978). Males fledge up to 2 days prior to females, probably due to their smaller body size (Hagen 1952, Jenkins 1978).

Table 9. Characteristics of alternate nest sites occupied bygyrfalcons on the Kilgavik study area, 1982-1984.

	Territory No. 3	4	5	8	12	15	19
1982 Site No.	—	104	106	—	119	—	—
1983 Site no.	103	696	693	110	738	132	699
1984 Site no.	1195	—	1210	922	119	954	955
Distance apart							
1982/83 (m)	—	800	200	—	160	—	—
1983/84 (m)	150	—	800	3500	160	200	50
Direction moved							
1982/83	—	ENE	SE	—	S	—	—
1983/84	W	NW	N	N	SE	NW	
Aspect							
1982/83	—	N/NE	—	W/W	—	—	
1983/84	—	NE/N	E/NE	W/W	SW/SW	SW/SW	
Overhang							
1982/83	100/100	100/100	—	100/100	—	—	
1983/84	—	100/100	100/100	100/100	80/25	100/100	
Cliff height							
1982/83 (m)	15/30	40/35	—	20/20	—	—	
1983/84 (m)	—	35/40	14/10	20/20	20/25	20/22	
Nest height							
1982/83 (m)	13/22	22/15	—	12/10	—	—	
1983/84 (m)	—	15/22	9/4	10/12	10/15	4/15	
Nest type[a]							
1982/83	Rav/Rav	Rav/Rav	—	Stick/Rav	—	—	
1983/84	—	Rav/Rav	Rav/Rav	Rav/Stick	Eag/Eag		
Rav/Rav							
Protection[b,c]							
1982/83	F/Ex	G/Ex	—	G/G	—	—	
1983/84	—	Ex/G	F/Ex	G/G	G/F	Ex/G	
Comments	same cliff	same cliff		same cliff	same cliff	same cliff	

[a]Rav = raven stick nest, Eag = eagle stick nest, Stick = stick nest of unknown origin.
[b]Protection = a subjective analysis of the degree of protection afforded by the site.
[c]F = fair, G = good, Ex = excellent.

Table 10. Phenology of productive gyrfalcon nests on the Kilgavik study area, 1983 and 1984.

Nest site no.	Initiation of egg-laying		Hatch		Fledging		Observation date	
	1983	1984	1983	1984	1983	1984	1983	1984
101	27/04	--	01/06	--	18/07	--	02/07	--
103/1195	20/05	30/04	24/06	04/06	10/08	21/07	14/07	14/07
106/693/ 1210	19/05	07/05	23/06	11/06	09/08	28/07	13/07	14/07
107	26/05	--	30/06	--	16/08	--	13/07	--
112	--	11/05	--	15/06	--	01/08	--	14/07
113	--	01/05	--	05/06	--	22/07	--	15/07
119/738	17/05	16/05	21/06	20/06	07/08	06/08	01/07	13/07
121	14/05	--	18/06	--	04/08	--	30/06	
671	--	11/05	--	15/06	--	01/08	--	15/07
689	--	09/05	--	13/06	--	30/07	--	11/07
696	08/05	--	12/06	--	29/07	--	02/07	--
922/110	26/05	01/05	30/06	05/06	16/08	22/07	13/07	17/07
935	--	11/05	--	15/06	--	01/08	--	15/07
954/132	22/05	07/05	26/06	11/06	12/08	28/07	14/07	16/07
955/699	13/05	04/05	17/06	08/06	03/08	25/07	14/07	16/07
Average dates	16/05	07/05	20/06	11/06	06/08	28/07		
Average dates 1982 (n=7)	18/05		22/06		08/08			

Egg-laying began approximately 10 days earlier in 1984 than in 1982 and 1983 (Table 10). The early and mild spring in 1984 was likely the major cause of the difference, possibly because prey were more available and gyrfalcons energy demands were not as great (cf. Newton 1979, Newton and Marquiss 1981). As noted earlier, clutch size and productivity were higher in 1984 than in 1983 (Table 3).

Post-fledging Period

In August 1984, young gyrfalcons remained on the cliff within 200-300 m of the nest (sites 112 and 1210) for the first 7-10 days after fledging. By the fourteenth day of the post-fledging period, the young were travelling further from the nest, up to 700-800 m away,often on separate cliffs. They would, however, return to the nest area on a regular basis, especially when prey was being supplied by one of the adults (sites 112, 113 and 1210). Fletcher and Webby (1977) observed some juveniles in northeastern Greenland move up to 1 km from the nest within the first few days of flight.

Numerous sessions of mock aerial combat (Muir 1975) were observed at site 1210, when the young were 10-11 days post-fledging. The two fledglings flew at a moderate height, turned, grappled, soared and generally exhibited play behaviour (Nelson 1978). Landings at this stage were awkward, especially in cross-winds.

Two sites (922 and 1195) were visited when the young were 16-19 days post-fledging. Healthy, 40-day-old young had been observed at both sites in July. Thorough searches up to 3 km from the sites uncovered only one brief observation of a juvenile gyrfalcon 800 m to the east site of 922. Kishchinskii (1957) stated that the young "roam about the region of the nest for approximately 3 weeks". Nelson (1978) observed that fledglings were still in the general vicinity of the nest up to 39 days after fledging. The reasons for the abandonment of the nest areas at sites 922 and 1195 are unclear, but may have resulted from migration to areas with more abundant prey. It is also possible that mortality of young occurred, but was undetected.

Plumage Colouration

Grey phase birds comprised 46% to 57% of the falcons during the three field seasons (Table 11). Only four white phase males were observed. The ratio of grey to white phase birds was 1.1:1 (n=70) during 1982-1984.

The consistency in the colour phase of individual birds on territory between the 3 years is noteable (Table 11). Only three cases of "disagreement" were documented, at sites 102, 113 and 1195. This consistency suggests both stability in the population and fidelity to nesting territories year after year (Newton 1979).

Observations of 29 pairs of gyrfalcons over 3 years, showed that a majority of the pairs were grey phase males and white females (59%, n=17). Eight (27%) grey male and female pairs, and four (14%) all white pairs were recorded. No white male and grey

Table 11. Colouration of adult gyrfalcons observed on the Kilgavik study area, 1982-1984[a,b]

	1982				1983				1984			
Site no.	Site[c]	M	Uk	F	Site[c]	M	Uk	F	Site[c]	M	Uk	F
101								W				W
102		G		G			G			G		W
103/1195					103	G		W	1195	W		W
104/696	104	W		W	696	W		W	104		W	
106/693/ 1210	106				693	G		G	1210		G	G
107				G		G		G				
108											W	
110/922					110	G		W	922	G		W
112		G		W		G		W		G		W
113			W			W		W		G		W
114			W				W					
119/738	119	G		W	738	G		W	119	G		W
121			W			G		W			G	
122/697	122	G			697	G		W				
132/954					132	G		G	954	G		G
671						G		W		G		W
672						G		W				
689										G		G
699/955									955	G		W
935										G		G
Yearly sum		6G,7W				15G,14W				16G,12W		
Ratio G:W		0.9:1				1.1:1				1.3:1		

a 1982 data from Bromley (1983).

b M=male, Uk=sex unknown, F=female, G=grey phase, W=white phase.

c Site number noted only where alternate sites occur within one territory.

female pairs were observed. In contrast, Cade (1960) stated that in grey phase birds in Alaska (white gyrfalcons are very rare there), the male tended to be the lighter of the pair.

Prey Abundance

Rock ptarmigan were still in large flocks when investigators reached the study area on 10 May 1983. By 21 May many were actively territorial, and most were territorial by 25 May. In contrast, rock ptarmigan were on territory and displaying by 10-12 May 1984 when observations began. The strutting displays and song flights (Johnsgard 1983) made them easy to detect.

In 1983, five randomly located 2 km^2 plots were censused eight times. A total of 32 male rock ptarmigan and two arctic hares were observed on the 10 km^2 of plots (Table 12), yielding density estimates of 2.2 ± 0.9 male ptarmigan/km^2 and 0.2 ± 0.3 hares/km^2. In 1984, only two plots (4 km^2) were surveyed on the study area, one from 1983 and one new plot (Table 13). Densities of male ptarmigan were $4.0 \pm 0.5/km^2$ and $0.6 \pm 0.4/km^2$ for an average for the plots of $2.3/km^2$. No arctic hares were seen.

Plot B was surveyed during both years, once in 1983 and five times in 1984 (Tables 12, 13). Densities were 3.5 and 4.0 male ptarmigan per km^2, respectively. We concluded that similar densities of ptarmigan were present each year, although there was insufficient information to make definitive comparisons.

The fairly constant number of rock ptarmigan observed on each plot repeatedly censused in 1983 and 1984 indicated that few repeat censuses are necessary for each plot. Although numbers

Table 12. Number of rock ptarmigan and arctic hares observed on five randomly located 1x2 km plots, Kilgavik study area, 1983.

Plot	Ptarmigan habitat quality[a]	Date censused	Male rock ptarmigan	Arctic hare
A	good	27 May	4	0
		04 June	5	0
B	good	28 May	7	0
C	poor-fair	30 May	4	1
		04 June	2	1
D	poor	31 May	2	1
		05 June	3	0
E	good	02 June	5	0
mean (SD)			4.4(1.8)	0.4 (0.5)

a Assessment based on habitat quality (willow cover, lushness of vegetation, subjective evaluation of rock cover and snow cover relative to surrounding terrain).

Table 13. Number of rock ptarmigan and passerines observed on two 1x2 km plots, Kilgavik study area, 1984.

Plot	Date	Male rock ptarmigan	Passerines
B	17 May	8	1
	20 May	9	4
	24 May	7	10
	27 May	7	51
	30 May	9	167
mean (SD)		8.0(1.0)	
F	15 May	0	2
	17 May	1	4
	23 May	2	2
	26 May	2	31
	30 May	1	117
mean (SD)		1.2(0.8)	

varied widely between plots, little variation occurred within plots and between censuses. Thus one or two censuses of a number of plots is adequate. The same randomly located plots should be censused each year, to yield a reliable annual index to ptarmigan numbers on the study area.

The multiple surveys on the two plots in 1984 documented the major influx of passerines into the area in late May (Table 13). Accurate passerine numbers were difficult to obtain after this influx. The most commonly observed passerines were the savannah sparrow (Passerculus sandwichensis), lapland longspur (Calcarius lapponicus), horned lark (Eremophila alpestris), and snow bunting (Plectrophenax nivalis).

From 12-30 May 1983 and from 10-29 May 1984, 1900 and 1545 km were travelled by snowmobile, representing 4335 and 3862 observer-km, respectively (see Methods). In 1983, 0.116 ptarmigan, 0.010 arctic ground squirrel and 0.0007 arctic hare were observed per observer-km. In 1984, 0.032 ptarmigan, 0.010 arctic ground squirrel and 0.0005 arctic hare per observer-km were recorded. Thus, the indices demonstrate that 3.6 times fewer ptarmigan, equal numbers of ground squirrels and slightly fewer arctic hares were observed in 1984 than in 1983. However, the early arrival of spring in 1984 may have influenced the number and dispersal of ptarmigan and other species observed. The visibility of larger flocks during snowmobile travel would be greater, biasing comparison of results between the 2 years, as larger groups were present in May 1983. Combining the ptarmigan plot and snowmobile index results, and considering the large differences in spring phenology, it appears that the 1984 spring ptarmigan population was similar to the 1983 spring population. Future experience on the study area may provide retroactive insight on this question.

The density of overwintering juvenile ptarmigan early in the gyrfalcon nesting cycle is correlated with nesting success of gyrfalcons in the central Yukon (Barichello and Mossop 1983). Prior to the spring molt, juvenile ptarmigan can be confidently identified in hand by examination of the outer primaries for colouration and wear (Weeden and Watson 1967). Twenty-five rock ptarmigan were collected prior to the spring molt in 1984. Thirteen males and 11 females were taken (sex unknown for one bird). Yearlings accounted for 48% (12/25) of the sample. Hannon (1983) found an average of 49% yearlings in a spring willow ptarmigan population (n=287) over a 3 year period in northwestern British Columbia. The spring proportion of yearlings in the population may be a good index of where the population of ptarmigan is in its 10 year cycle, if such a cycle exists in this area (Barichello and Mossop 1983). Apparently the proportion of yearlings in the spring population is quite low during periods of population decline. This trend reverses during population increases. This parameter will be monitored in subsequent years.

During July 1984, 180 trap-days produced 12 tundra red-backed voles (Clethrionomys rutilus) and two brown lemmings (Lemmus sibiricus), one capture per 13 trap-days. There was no direct evidence of unusually large populations of microtines, although the number of rough-legged hawks nesting on the study area steadily increased from 1982 to 1984, indicating a probable increase in microtines (Baker and Brooks 1981).

Use of Prey

In spring 1983, large numbers of castings were found scattered below several of the known gyrfalcon nest sites and perches. The castings, almost always of ptarmigan remains and occasionally with hare remains, were distributed through different layers of snow. We concluded that some gyrfalcons overwintered in the vicinity of nest sites, as has been suggested by others (e.g., Platt 1976).

Rock ptarmigan appeared to be the most heavily used prey species prior to and during the incubation period of gyrfalcons. Plucking rings were common, confirming the habit of the gyrfalcon of almost entirely defeathering their prey (Hagen 1952, Cade 1960, White and Weeden 1966).

Four nests were observed for 68.5 h in July 1984, when the eyases were 18-31 days old. Arctic ground squirrels were the predominant prey species eaten on the basis of biomass (Table 14). Juvenile squirrels were taken in at least 9 cases out of 15 (60%). The predominance of squirrels in the diet runs counter to the observations of many authors who report a larger dependence on ptarmigan for interior populations (e.g., Kishchinskii 1957, Cade 1960, Platt and Tull 1977, Langvatn and Moksnes 1979). Species other than ptarmigan do occur as major items in the diet of gyrfalcons in other regions, for example, collared lemmings (*Dicrostonyx groenlandicus*) and hares (Fletcher and Webby 1977),

Table 14. Use of prey at four gyrfalcon eyries, Kilgavik study area, July 1984.

Site	Hours observed	Age of young in days (No.)	Number of prey items: Arctic ground squirrels	Passerines	Arctic hares	Ptarmigan	Total
112	7	29d(3)	2	1	-	-	3
119	40	18-23d(3)	12	9	-	-	21
671	13.5	30-31d(2)	-	4	1	-	5
689	8	24-28d(2)	1	-	-	1	2
Total	68.5	18-31d	15	14	1	1	31
% by prey item			49	45	3	3	
Average weight (g)			400-700[a]	20[b]	2000[c]	500	
% by mass			74	3	18	5	

a 400 g was used for 9 immature ground squirrels, 700 g for 6 adult squirrels, pers. data.

b Based on an average weight for lapland longspurs and savannah sparrows, pers. data.

c Estimated weight of the rear half which was transported to the nest.

oldsquaw ducks (Clangula hyemalis) (Jenkins 1978), and other duck species (Bengtson 1971). Arctic ground squirrels figure prominently in the diet of some gyrfalcon populations in North America, e.g., Seward Peninsula, Alaska (Roseneau 1972), North Slope, Alaska (Cade 1960) and central Yukon (Barichello 1983).

Passerines were often fed to the young, but made a relatively insignificant contribution when the overall weight of prey items was considered. Feathers from the savannah sparrow and lapland longspur have been identified from some nests. As noted, both species were common throughout the study area.

Differences in prey selected between pairs of gyrfalcons on the study area were apparent, with some pairs appearing to concentrate on either ptarmigan, arctic hare or ground squirrels. The reason for the variation was not obvious, but may relate to local availability of prey or specialization in prey selected by individual pairs. Waterfowl, such as king eiders (Somateria spectabilis) and common eiders (S. mollissima), and glaucous gulls (Larus hyperboreus) were common on marine waters. Use of these species by coastal nesting gyrfalcons was not detected, however.

At site 119, where the most extensive periods of observation took place (40 h over 5 days), the average time between feedings was 1 h 39 min (n=16), ranging from 4 min to 3 h 56 min. The mean time between feedings of ground squirrels, the predominant large prey item, was 3 h 16 min (n=7). Platt and Tull (1977) observed a feeding every 3 h 4 min on average at one site in the Yukon.

The majority of ground squirrels brought to the nest had been decapitated. This behaviour was previously reported (Cramp and

Simmons 1980). In nests where the eyases were less than 25-30 days old, each squirrel was fed to the young by the adult (normally the female) such that virtually the entire carcass was consumed. The only evidence of the consumption of these ground squirrels were "gut piles" of lower intestines found on the nest. Nestlings older than 30 days would tear the prey apart themselves, more frequently leaving a majority of the fur unconsumed. Dried up squirrel skins were frequently found in nests with older eyases.

Caching of food on the nest cliff was observed. Such behaviour has been reported elsewhere (Platt and Tull 1977, Cade 1982). Caching made the determination of which adult actually killed which prey item difficult.

Observations of prey taken during the post-fledging period in August were more difficult to obtain because of the increased mobility of the young. Arctic ground squirrels were still the major prey item accounting for 8 of 12 items in one sample.

The adults were still providing food for the fledglings when the observations were terminated in August, at which time some young were up to 13 days post-fledging. Feeding of the young by adults appeared to become more hazardous for the adults as the young grew older because of fledgling aggression when prey was brought to the nest cliff. Similar aggressive behaviour by young towards adults was observed by Jenkins (1978) in Greenland.

Other Species

Common Raven

Nests built by ravens were frequently used by gyrfalcons. Ravens appear to have similar nesting requirements to gyrfalcons (Table 8) (Hagen 1952, Cade 1960, White and Cade 1971), and, therefore, may play an important role both in providing nest sites and in competing for them.

Active and inactive raven-built nests on the study area from 1982 through 1984 are described in Table 15. Ravens occupied from 6 to 11 nests on the study area each year. Raven nests used by gyrfalcons are excluded. Production at successful nests was 3.0 young/nest (n=5) in 1983 and 3.5 in 1984 (n=2) (Table 16). Based on accumulation of fresh guano at the nest site and observations from May, it is likely that 11 of 19 nests built by ravens were productive in 1984, an average density of one successful pair per 164 km^2.

Of the eight nests built by ravens but not occupied in 1984, most (5) faced either southeast or southwest. It is possible that preference for sites facing a particular direction varies for both ravens and gyrfalcons according to spring phenology. During an early, mild spring the birds may select northeast- to northwest-facing sites, while during a late, cool spring southeast- to southwest-facing sites may be selected. A further point of relevance is that six of the eight nests built by ravens but not occupied in 1984 were occupied by gyrfalcons in 1983. Perhaps ravens surrendered traditional use of these sites and established new nests in other locations due to competition with gyrfalcons.

Table 15. The number of nests and territories of ravens and various raptor species on the Kilgavik study area, 1982-1984[a].

Species/year	Number of occupied nests	Number of sightings representing active territories, occupied nest not seen	Total active territories	Unoccupied nests
Common Raven				
1982	6	—	6	5+[b]
1983	6	1	7	5+[b]
1984	11	—	11	8
Gyrfalcon				
1982	10	1[c]	11[c]	—
1983	15	3	18	—
1984	12	3	15	—
Golden Eagle				
1982	12	6	18	14[b]
1983	7	4	11	7[b]
1984	11	9	20	12
Peregrine Falcon				
1982	8	16	24	—
1983	8	10	18	—
1984	25	1	26	—
Rough-legged Hawk				
1982	4	9	13	123[b]
1983	13	5	18	60[b]
1984	32	9	41	47

a Data for 1982 from Bromley (1983).

b In 1982 and 1983 not all unoccupied nests were identified to species of origin. Unoccupied sites of golden eagles and ravens are minimum numbers, and numbers of rough-legged hawk nests may include a small unknown number of mistakenly identified nests actually built by golden eagles or ravens.

c Insufficient data available; 1982 survey conducted when only eggs and very small nestlings present.

Table 16. Production of ravens and raptor species on the Kilgavik study area, 1982-1984[a].

Species/year	Number of nests where eggs or young counted	Total number of eggs and/or young	Average number of eggs and/or young per nest - $\bar{x}$(SD)
<u>Common Raven</u>			
1982	4	14	3.4(1.0)
1983	5	15	3.0(0.7)
1984	2	7	3.5(-)
<u>Golden Eagle</u>			
1982	8	14	1.8(0.5)
1983	6	7	1.2(0.4)
1984	9	11	1.2(0.4)
<u>Peregrine Falcon</u>			
1982	0	--	--
1983	3	11	3.7(0.5)
1984	15	34	2.3(1.0)
<u>Rough-legged Hawk</u>			
1982	0	--	--
1983	2	7	3.5(-)
1984	32	96	3.0(0.9)

a Data for 1982 from Bromley (1983).

Although not observed, it was apparent that within 1-2 days of the young ravens' fledging at site 120 in 1984, the entire nest was dismantled and removed, presumably by the adults. If this occurred frequently, such behaviour would greatly affect the results of the surveys completed after fledging had taken place. Similar behaviour has been observed at a site in Yellowknife, NWT, when a group of ravens removed a nest from the scaffold of a cement plant (M. Haener and D. Heard, pers. comm.). This activity took place many weeks after fledging had occurred. Such activity could influence the number of potential nest sites available to gyrfalcons the following spring, since nests built by ravens are frequently selected by gyrfalcons.

Golden Eagle

The number of nests occupied by golden eagles varied between seven and twelve during 1982 to 1984 (Table 15); 11 to 20 active territories were recorded. In 1984, a total of 32 empty and occupied golden eagle nests were located, probably representing 29 potential territories (three pairs of nests were in close proximity to each other). Of these, 20 territories were active and 11 held occupied nests of which nine were productive.

The average number of young produced annually ranged from 1.2 to 1.8 young per successful nest. In 1983 one nest containing three eggs failed when the nest was completely buried under 40 cm of snow during a three day storm in late May. In 1984, 1.2 young per successful nest and 0.6 young per active territory were produced. One failed egg was observed. Figures for 3 years of survey in southern Yukon were 1.25 eaglets per active territory and 1.56 per successful site (n=71) (Blood and Anweiler 1984).

Three and two nestling eagles were banded in 1983 and 1984, respectively. Two of the three nests visited in 1983 contained fresh remains of arctic hare and goose (one was a greater white-fronted goose), as well as arctic ground squirrels. Lying beside the eaglet at site 675 in 1984 were the uneaten carcasses of five arctic ground squirrels, further suggesting competition with gyrfalcons for food on the Kilgavik study area.

Tundra Peregrine Falcon

Up to 26 active peregrine territories were located during aerial surveys each year (Table 15). In 1984, extra effort was dedicated towards locating occupied nest sites associated with territorial birds. However, it is likely that many active but unproductive territories were missed.

The density of active peregrine falcon territories over the entire study area in 1984 averaged one per 69 km^2, but varied considerably within the area. In one section of the study area, 10 territories were located, corresponding to a density of one per 28 km^2. Interestingly enough, no gyrfalcons have been documented in this area, despite the availability of at least seven unoccupied nests built by ravens and golden eagles for potential use. The density of peregrine territories was low in comparison with those observed near Rankin Inlet (one per 8.5 km^2; Gates 1982), but is comparable with the Wager Bay area (one per 50 km^2; Calef and Heard 1979).

During all surveys adult female peregrines exhibited an extremely strong tendency to sit tight on the nest despite the helicopter hovering nearby, probably indicating the presence of eggs close to hatching and/or small young. Because the surveys were not specifically concerned with peregrine production, and to minimize disturbance of the adults and eggs or young, no persistent effort was made to flush the females off the nest. Average clutch/brood sizes were 3.7 in 1983 (n=3) and 2.3 in 1984 (n=15) (Table 16).

In 1984, a majority (84%) of the nest sites were "grassy ledges", typically ledges on slightly sloping cliffs with no overhang, that had some covering of grass and low shrubs. Such sites were termed "vegetated shelves" by Ratcliffe (1980). In 1984, two sites (8%) were distinct bare ledges and two (8%) were rough-legged hawk stick nests. The preponderance of grasses and shrubs at most sites made it extremely difficult to locate the nest (eggs/young) or incubating adult peregrines. We concluded that our findings indicated minimum numbers of occupied peregrine nests on the study area.

The type of nest sites used by peregrines on the study area are seldom if ever, used by gyrfalcons. Thus, it is unlikely that competition for nest sites occurs between the two species. This does not, however, preclude the possibiility of competition for space along a cliff which might offer different types of nest sites attractive to either species and in close proximity to each other.

Rough-legged Hawk

There was a steady increase in the number of nests occupied by rough-legged hawks from 1982 to 1984, ranging from none observed in 1982 to 32 in 1984 (Table 15). We suspect that the increase in the number of occupied hawk nests reflected an increase in the microtine population. Rough-legged hawk population numbers generally follow microtine cycles (Baker and Brooks 1981). The large number of nests present on the study area indicate that there is potential for a large nesting population in some years.

During the 1983 survey, 13 occupied rough-legged hawk nests were located on the study area; a density of one nest per 138 km^2. Forty-one active territories were located during the 1984 helicopter survey (one active territory per 44 km^2). The section of the study area with a high density of peregrines also had a high density of hawks; one active territory per 14 km^2 (n=20).

The 32 occupied sites located in 1984 contained a minimum of nine eggs and 87 young, for an average 3.0 eggs/young per occupied nest (range 1-5) and 2.3 per active territory (Table 16). Rough-legged hawks appeared to be feeding predominantly on microtines and to a lesser extent on passerines, based on prey remains located in nests and observation of prey brought to nestlings.

Phenology of Nesting

The golden eagle began nesting in mid to late April, based on back-dating from the estimated age of three eaglets banded during

July 1983 and two eaglets banded during July 1984 (Fig. 2). It appeared to be the earliest nesting species on the study area. Gyrfalcons and ravens began laying in early May, while rough-legged hawks and peregrine falcons did not begin laying until June. These observations differ from those obtained by Platt (1975) on the Yukon North Slope where gyrfalcons began laying eggs in early April, the earliest of the four true raptor species in that area. Eagles and rough-legged hawks in the Yukon began laying in early May, a full month after the gyrfalcon. Eagles nest significantly earlier than gyrfalcons on the Kilgavik study area, which suggests a difference in the ecosystems of the Yukon and NWT study areas. Of the factors affecting the phenology of nesting, we suspect food availability to be different in the two regions.

Interspecific Interactions

Gyrfalcons interacted most frequently with rough-legged hawks. Rough-legged hawks nested and produced young within 150 m of nesting gyrfalcons at four sites. Hagen (1952) fittingly described the relationship between the two species as "armed neutrality". Most interactions involved little, if any, contact. To meet the diving gyrfalcon, the hawk would normally flip over, exposing its talons, as it was forced out of the falcon's air space.

Evidence of defense of gyrfalcon nesting territories early in the spring and during the summer was observed. On two occasions, when golden eagles approached, the gyrfalcons chased the eagles

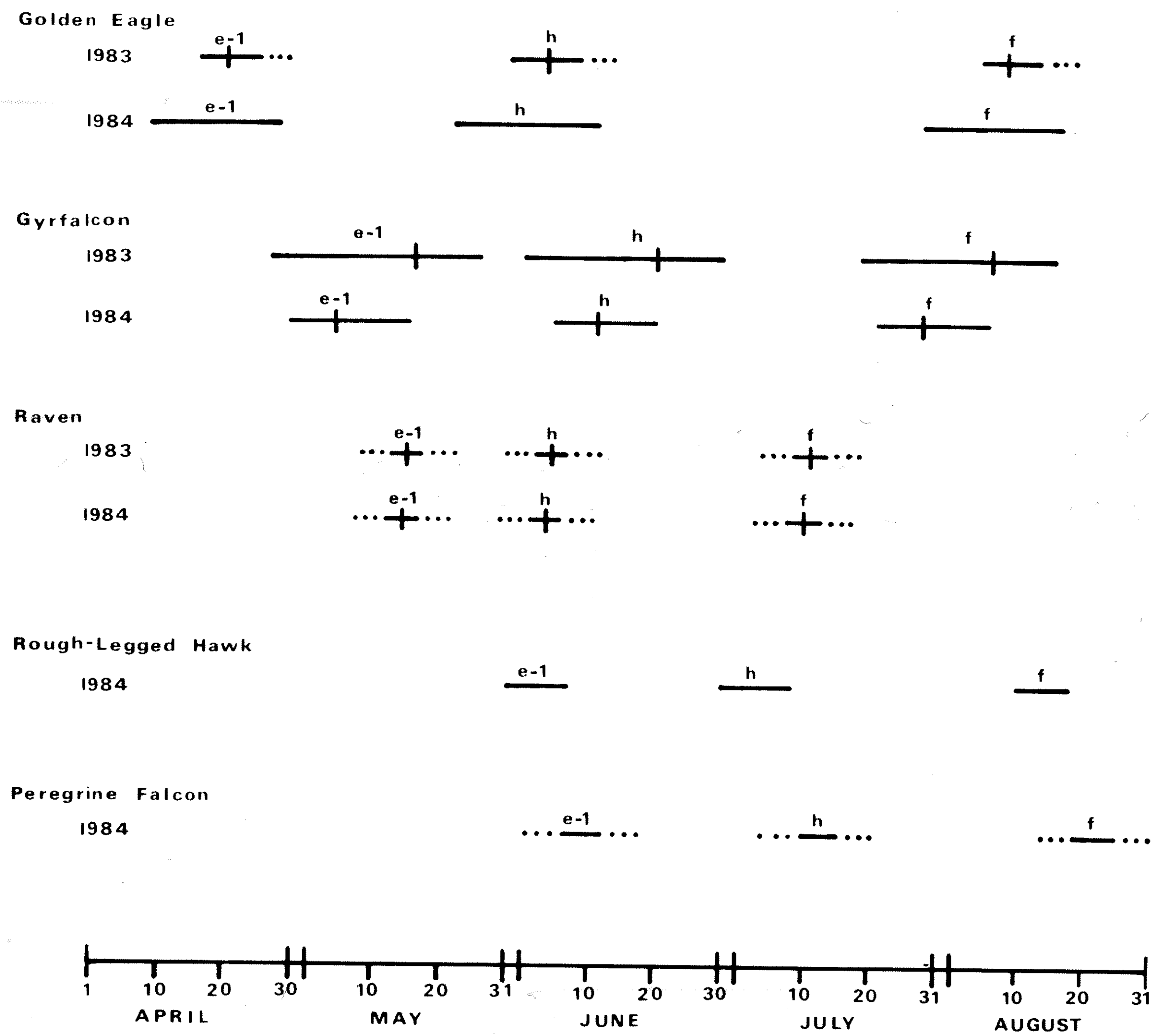

Figure 2. Nesting phenology of raptors and ravens on the Kilgavik study area, 1983 and 1984.

e-l=initiation of egg-laying; h=first hatch; f=first fledge. Data based on dating from estimated age of nestlings (gyrfalcons, golden eagles, ravens) or observation of hatching or very small nestlings (peregrines, rough-legged hawks). Denotes mean date and range.

Length and source of incubation (I) and nestling (N) periods used: Gyrfalcon I 35 d (Cade and Weaver 1976) N 47 d (Jenkins 1978); golden eagle I 44 d, N 67 (Brown and Amadon 1968); peregrine falcon I 33 d, N 40 d (Ratcliffe 1980); rough-legged hawk I 31 d, N 41 d (Brown and Amadon 1968); raven I 20 d, N 37 d (Terres 1980).

away from the nest area. Gyrfalcons appear to be particularly aggressive in their attacks on golden eagles (Platt 1975), which may point towards interspecific competition for nest sites and food, the real danger of predation on gyrfalcon nestlings by the eagles, or both (Dittrick and Moorehead 1983).

On several occasions gyrfalcons responded to ravens by stooping on them when they were in the vicinity of the gyrfalcon nest site, forcing the raven to seek shelter or vacate the area. Despite these interactions, ravens were observed to nest successfully as close as 65 m from productive gyrfalcon sites. Competition for nest sites between gyrfalcons and ravens, occasionally resulting in the death of the raven (Roseneau 1972, Jenkin 1978), has been documented (White & Cade 1971, Woodin 1980).

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APPENDIX A. Banding and Marking

Identification of individual gyrfalcons is necessary to adequately evaluate fidelity to nest sites and territories and to fully understand population dynamics. Adults were trapped at nests using a variety of techniques, not described here to further protect the species from poaching.

Captured adult gyrfalcons were banded on the right leg with a standard locking United States Fish and Wildlife Service (USFWS) numbered aluminum band. A blue colour band, engraved with a unique three character combination, was rivetted on the left leg. The colour band should enable subsequent identification without the need for recapture.

Gyrfalcon chicks were banded either in the nest or occasionally after being sent lifted to the top of the cliff for handling. A USFWS aluminum band was placed on one leg of the chick, and one or two non-engraved colour bands (blue, black or red), smaller than those used on adults, were rivetted on the other leg. In 1984, a blue band was placed on the left leg of each nestling. A 1-2 cm sample of feather was obtained from the fifth right secondary of each nestling for future use in trace element analysis (cf. Parrish et al. 1983).

The blue bands placed on the right legs of the juveniles in 1984 were visible at up to 300 m in good light. Future resighting should be possible if the opportunity for observation occurs.

One white phase, adult female was trapped in May 1983 and two white phase females were trapped in May 1984. They were caught at sites 121, 112 and 922, respectively. The female trapped and colour banded at site 121 in 1983 was not resighted in 1984. Although site 121 was occupied in both 1982 and 1983, it was not occupied in 1984.

In 1983, a total of 18 gyrfalcon young were banded with both regular and colour bands; 4 young received regular bands only. Twenty-nine young were banded and marked with coloured leg bands in 1984. Five golden eagle young were banded with regular bands over the 2 years.

APPENDIX B. Ectoparasites

Few parasites have been documented to occur on gyrfalcons (White and Springer 1965, Clausen and Gudmundsson 1981). Some investigators believe that parasites are at least partly responsible for gyrfalcons using alternate nests, to enable cleansing of heavily infested sites (Kishchinskii 1957).

Fleas (Order Siphonaptera) were collected from two gyrfalcon nests and one rough-legged hawk nest. Site 110 was a productive gyrfalcon site in 1983 but not occupied in 1984. During investigation of the nest in May 1984 it was found to be heavily infested with fleas. A moderate infestation of fleas was also observed in 1984 at site 922, alternate to 110, after the young had fledged. All fleas collected have been tentatively identified as Ceratophyllus sp.

Two Diptera larvae (Family Calliphoridae - blow flies) were collected from the upper breast of a live 16-day-old chick at site 119. The maggots were loosely attached to the skin. It is possible that the chick may have acquired the larvae from decayed prey remains. While Diptera infestations are likely rare they may be a mortality factor (Wobeser et al. 1981).