

Long Term Trends in the Breeding Density and Productivity of Gyrfalcon *Falco rusticolus* in the Yukon Territory, Canada

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ABSTRACT

Demography of Gyrfalcon has been studied from 1973-1991 in 15 of the 22 ecoregions of the Yukon Territory. Data are from 2,500 nest site visits and survey by helicopter of 86,624 km². 259 different nesting territories have been identified, monitoring has involved 172. All have been cliff nest sites, secondarily associated with overhangs, tundra communities, and in the southern Yukon with altitudes above 1,500 m. Variation in nesting density between extreme ecoregions was 0.6 to 6.1 pairs per 1,000 km²; within ecoregions nesting density was highly uniform.

Extrapolating these densities yields an estimated breeding population of 750 pairs over the 482,681 km² territory of which about 75% is acceptable breeding habitat (overall average breeding density: 1 pair per 453 km²).

Productivity has varied in a 10-year periodicity from a high of 90% of territories being attended by adults and 70% producing young, to a low of 40% attended by adults and 10% producing young. Brood size at fledge varied in synchrony with other productivity parameters from a low of 2.1 young per successful nest to a high of 3.3. Changes in breeding chronology have not tracked productivity; instead this remained relatively constant over the initial 10 years, then in the last five has shown a steady trend to be earlier. The productivity and estimated non-breeding population is discussed in light of Gyrfalcon breeding strategies to deal with fluctuating prey base.

INTRODUCTION

The Yukon Territory in the extreme northwestern corner of Canada, represents a significant portion of the mountainous western subarctic region of North America (Figure 1). The Gyrfalcon (*Falco rusticolus*) occurs in its grey to dark brown colour phase throughout the region. It is resident year round (Platt 1976). Prior to the mid 1970s no systematic study of the species had been carried out in the Yukon, but about that time, its management began to demand a vastly improved data base. This led to an organized field survey which has lasted over a decade and a half (1974-90), and now gives a valuable picture of the species' ecology in the Yukon and the Canadian Northwest.

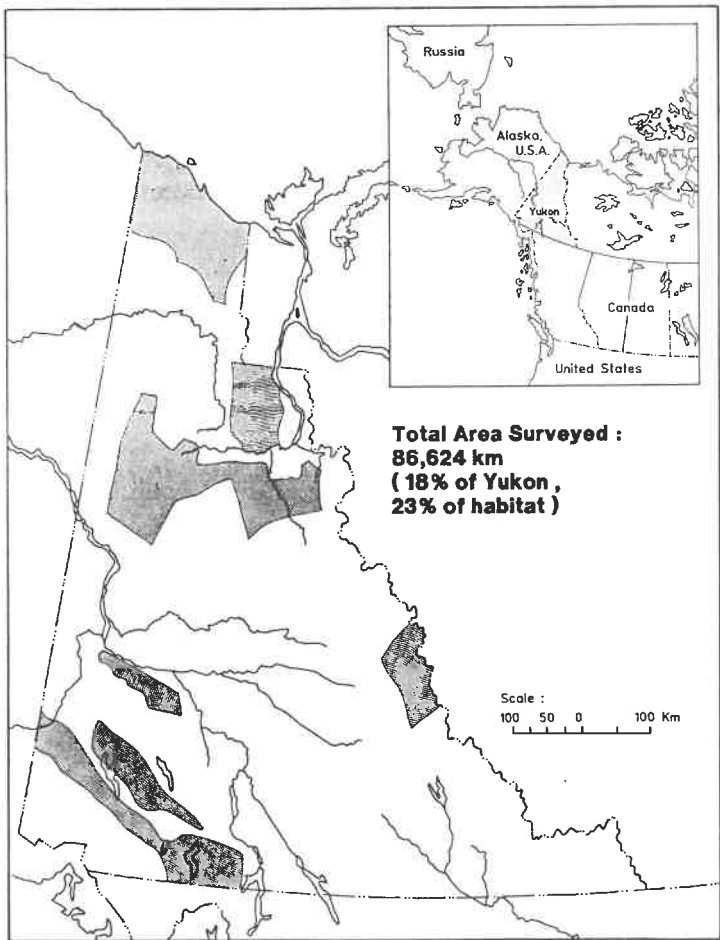
The priority was to establish a data base upon which to build management options for the species including harvest of live birds. Surveys in Alaska (Cade 1960; White & Cade 1971;

Roseneau 1972) gave some indication of densities that could be expected in the Pacific Northwest but there was no evidence they were expandable to larger areas. In particular measures of overall abundance, productivity and differences between sub-regions were needed; there was also a need to sort out the difference between short term fluctuations and long term trends.

SURVEY DESIGN

The Yukon survey was designed to systematically catalogue nesting pairs over representative areas of the territory. Sample areas were then monitored annually to follow changes over time. The objective was to produce long term measures of breeding density, productivity and habitat use in representative areas which could then be extrapolated. In fact, the areas of survey tended to be planned opportunistically, often in association with funding made available through development proposals. To counter this, survey technique and data storage were standardized to facilitate territory-wide analysis. A significant proportion of the Yukon land area has now been covered by these surveys (Figure 1).

Figure 1. The Yukon Territory, Canada, showing locations of areas surveyed for breeding Gyrfalcons.



All initial surveys and subsequent monitoring surveys have been conducted by helicopter. A variety of types have been used; the present analysis involves about 2,500 visits to Gyrfalcon nests of which 1,593 have resulted in usable data. Although surveys almost always had additional objectives to Gyrfalcon survey, roughly 2,000 hours of flying time have been spent collecting these data.

The basic survey technique has been a total search of defined study areas. In practice this has involved search of all the cliff faces in the study area. (All known Gyrfalcon nest sites in the Yukon have been associated with cliffs. Because these surveys were also designed to locate other species of nesting raptors, it is unlikely Gyrfalcons using non-cliff nest sites would have been overlooked). The helicopter search pattern varied but normally watercourses were used to break the search blocks into manageable pieces. A carefully followed standard routine was adopted to facilitate observation of all nests and minimize disturbance. During subsequent monitoring surveys a sample area was visited with a similar helicopter search which focused on known nest sites, but also involved search of intervening habitat.

Data collection and handling

Criteria for data collection were standardized (Hayes & Kale 1982). A **"nesting territory"** was a cliff face or series of cliffs where there was evidence the area was or had been defended by one or more adults. In some instances this identification was inferred from the presence of excrement (wash) at the cliff, but in these instances follow-up surveys normally confirmed the identity of the occupying adults and in all cases the observation used as evidence was recorded. The nest location at the territorial site was recorded separately. Information recorded at newly discovered territories included a series of observations of the habitat including cliff size, rock type, altitude, aspect, distance of nest ledge from top, percent of overhang above the nest, distance to water and vegetative cover in the general area. An **"occupied site"** was a nesting territory where there was evidence of the presence of adults in the current year. This normally meant seeing an adult in the vicinity or observing the presence of obviously fresh wash. A **"productive site"** was a territory where there was direct evidence of young being produced in the current year. At these sites, the observations included the number of young and/or eggs in the nest, and an estimate of the age of the young. Ground visits to nests were conducted on a less regular basis. On these visits all young were banded and a sample of prey remains was collected. Over a period of 4 years (1977-80) these visits were prioritized. All data were coded and entered as a SAS (Statistical Analysis Systems - SAS Institute 1985) data set on an IBM mainframe and analysis was via procedures of the SAS programme.

Study areas

Seven intensive search areas have been covered, scattered from the Yukon's north coast to its southern border (Figure 1 and Table 1). In total 86,624 sq. km. of the Yukon's 482,681 sq. km. area have been intensively searched. Between, extensive areas totalling about 20,240 sq. km. have also been covered in survey incidental to other field research. The total area surveyed is approximately 18% of the area of the Yukon.

The Yukon has been subjected to ecoregion analysis since the mid-1970s in an attempt to describe regions with comparable landscape, bedrock, surficial geology, climate, soils and vegetation (Oswald & Senyk 1977). Twenty-two polygons have been recognized averaging 22 thousand sq. km. each. Gyrfalcon survey has been conducted in 15 of the 22 ecoregions:

a) North Slope/Old Crow basin (17,500 sq.km.): This area lies almost exclusively in the Northern Mountains and Coastal Plain ecoregion of Oswald and Senyk (1977). It is mostly treeless tussock tundra with a lush growth of shrub and shrub tundra associated with drainages. Scattered black and white spruce occur on protected sites. It is the area of longest study, survey began in 1973 (Platt & Tull 1977) and monitoring has been systematically conducted annually until 1990. Riverside cliffs and ridge top tors provide abundant nesting habitat for Gyrfalcons throughout.

b) Southern Richardson Mountains (9,070 sq. km.): This study area is part of a southern extension of the Northern Mountains and Coastal Plain ecoregion. It grades from treeless tussock tundra at higher elevations to closed spruce at its lower elevations. The rivers draining to the east and west have well developed cliffs providing ample nesting habitats. The area was subjected to

initial search in 1977-78 but monitoring since has been sporadic and incomplete.

c) Nahoni Range (8,000 sq. km.): In the North Ogilvie Mountains ecoregion, this area has extensive areas of treeless tundra and shrub tundra at upper elevations with white spruce in lower and protected areas. An identifiable treeline occurs at about 900m a.s.l. Initial search was in 1979 and monitoring has been incomplete and of an incidental nature since.

d) Ogilvie Mountains (6,166 sq. km.): This study area straddles the South and North Ogilvie Mountain ecoregions. It covers an area of the upper Klondike river of the Yukon river basin and the upper Peel river basin. It is an area of diverse, relatively productive alpine tundra, shrub and open white and black spruce forest. Treeline is about 1,050m a.s.l. The area was initially searched in 1977-78 and was the subject of intensive research into Gyrfalcon breeding strategies over a three year period (Barichello 1983). The area has since been systematically monitored on a periodic basis averaging about every five years.

e) Dawson Range (5,030 sq. km.): This area in the Dawson Range ecoregion is mostly treeless shrub tundra with extensive areas of wet treeless habitats occupying flat drainage valleys. Tree line is approximately 1,200m a.s.l. Initial search was in 1980-81 and monitoring has been systematic, averaging about once in five years.

f) Macmillan Pass area (10,595 sq. km.): This study area lies mostly in the Logan Mountains ecoregion. The area is mostly wet alpine treeless tundra with some alpine fir and shrub in a relatively extensive subalpine. Treeline is at approximately 1,400m a.s.l. The area was searched initially in 1981 and monitoring has not been carried out in any systematic way.

g) Coast Mountains (10,023 sq. km.): This area lies in the Coast Mountain and Ruby Range ecoregions. Relatively lush alpine tundra predominates with open white spruce forest at lower elevations. Treeline is at about 1,200m a.s.l. and extensive mountain cliff habitat provides an abundance of nesting habitat. The area was searched initially in 1978-80 and monitoring has been systematic, conducted annually since. All measurements of area were made with a digital-reading automatic planimeter from an air photo mosaic at a scale of 1:2,500,000.

Table 1. Breeding Gyrfalcons on seven study areas surveyed in the Yukon Territory, 1973-1991.

Study Area	Area searched (sq. km.)	nesting territories	breeding density (prs/1000 km ²)
N. Slope	17,500	106	6.06
S. Richardson/Werneke	15,947	17	0.58
Ogilvie Mountains	17,302	58	3.35
Dawson Range	5,030	10	1.98
Kluane Range	10,227	6	0.59
Hess/Logan	20,695	7	0.66
Coast Mountains	10,023	36	3.59
TOTAL	86,724	240	2.77

RESULTS

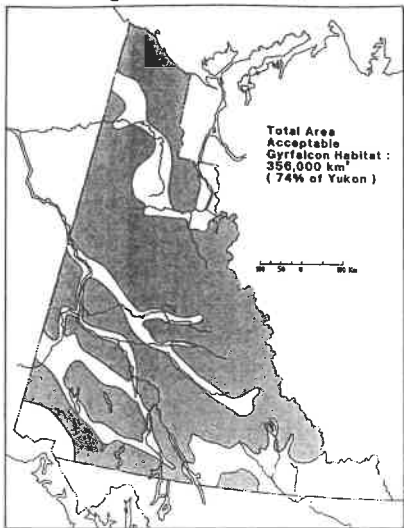
The breeding population

Area of occupied habitat: There is no doubt these highly mobile birds make use of the whole of the Yukon Territory; wherever species lists have been kept the species has eventually been recorded. Breeding birds are, however, not found in all habitats. In an attempt to characterize what constitutes acceptable habitat in the territory, we examined the 227 different nest sites where measurements of physical parameters were recorded. Breeding Gyrfalcons were always associated with cliff faces. This fact was not a surprising conclusion for the Pacific northwest (Cade 1960; Roseneau 1972; Barichello 1983). In over 2,000 visits to Gyrfalcon nests, none were found in situations other than cliff faces. Unfortunately the presence of cliffs is not obviously useful in

characterizing acceptable Gyrfalcon breeding habitat on a large scale. Virtually all habitats in the Yukon in all ecoregions probably have cliff faces available within reasonable flight range for a Gyrfalcon. Even though there may be areas of extensive flat country (for example in the Eagle plains of the north central Yukon) where this feature could conceivably limit Gyrfalcon breeding, it is almost impossible to conceive of a method for broad remote habitat characterization using it.

More useful measures, because of the ease with which they could be mapped, were the altitude above sea level and the vegetative community in which nests were located. The nest sites in the southern half of the territory predictably ($p=0.05$) were found above 1500 m a.s.l. (In the northern half of the territory, no such association was evident). Characterization of the vegetation within 5 km. of nests as forested, open taiga, shrub tundra or tundra likewise showed a strong association with one identifiable feature: tundra. Treeless tundra predominated (67%). Open taiga accounted for 24% and the remaining 9% were classified as shrub tundra. No sites were characterized as being associated with forested habitat. Combining these features and assuming a Gyrfalcon may travel some distance (at least 10 km) from 'acceptable' habitat to use a nest site, the area of the territory which can conceivably be considered Gyrfalcon breeding habitat is about 74% of the Yukon, 356,000 sq. km., — of which 24% was surveyed (Figure 2).

Figure 2. Estimated area of acceptable Gyrfalcon breeding habitat based on elevation and distance from tundra vegetation communities, Yukon Territory.



Breeding numbers: The maximum breeding densities on the seven study areas varied greatly from a high of 6.1 to a low of 0.6 pairs, per thousand sq. km. (Table 1). Additionally, an apparent feature of the Yukon Gyrfalcon populations was a remarkably uniform spacing between nest sites which showed a highly significant departure from a random spacing (nearest neighbour spatial relation test, Clark and Evans, 1954, $p < .0001$ and Table 2).

Table 2. Nearest neighbour measurements, Gyrfalcon breeding territories in the Yukon Territory

	(km)	(s.d)
N. Slope	8.1	2.3
Richardson	18.2	8.6
Ogilvie	11.0	3.9
Dawson	25.6	11.2
Kluane	-	-
Hess	96.7	14.6
Coast Mountains	12.4	3.5

Based on this apparent uniform spacing of the nesting pairs regionally, extrapolation of the territory-wide population was by ecoregion. Pooling ecoregions with equal Gyrfalcon density or obvious climatic and vegetative similarities, seven larger ecological regions emerged (Figure 3). Extrapolating Gyrfalcon breeding density to the acceptable habitat within these areas suggests a total maximum population of about 750 pairs for the whole of the Yukon Territory (Table 3).

Fluctuations in breeding numbers: The number of adult pairs observed has fluctuated significantly on all areas monitored. This variation has followed an apparent 10-year period (Figure 4). The variations recorded were in the order of 25-60% with a suggestion of higher amplitudes in the more northern sections of the territory. Additionally, over the 15 years of this study, the peak population levels have remained remarkably stable. In fact, we feel the apparent fluctuation in adults may be misleading. In the 'down' phases of the cycle adults attending nesting territories are far less faithful to the site; the accurate focus on the actual number of breeding adults is likely limited to the peak populations when most pairs at least attempt to breed and are 'available' for us to count.

Figure 3. Regions of similar Gyrfalcon breeding density within which extrapolations of total breeding populations were made, Yukon Territory, Canada.

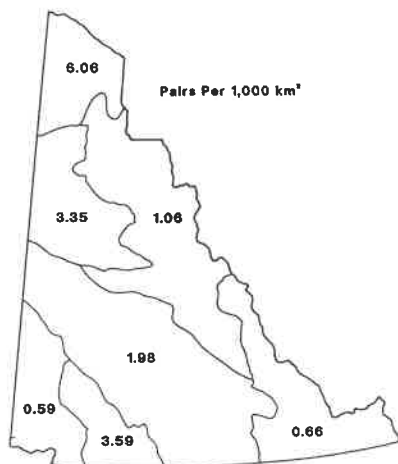


Table 3. Extrapolations of Gyrfalcon breeding numbers by ecoregion areas in the Yukon Territory.

Gyrfalcon 'regions'	Area of Gyrfalcon habitat (km ²)	Breeding density (prs/1000 sq. km.)	Total pairs
1.	42,436	0.66	28
2.	25,550	3.59	92
3.	18,906	0.59	11
4.	78,450	1.98	155
5.	85,200	1.06	90
6.	54,903	3.35	184
7.	31,020	6.06	188
TOTAL			748

Figure 4. Cyclic changes in the number of breeding adults over fifteen years, shown are the proportions of nest sites attended by breeders in years surveyed.

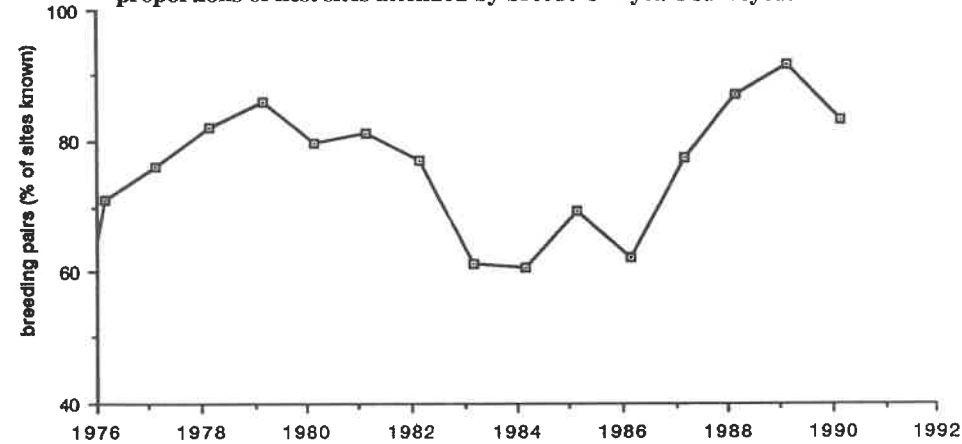


Figure 5. Variations in production of young over time, compared to changes in adult numbers counted.

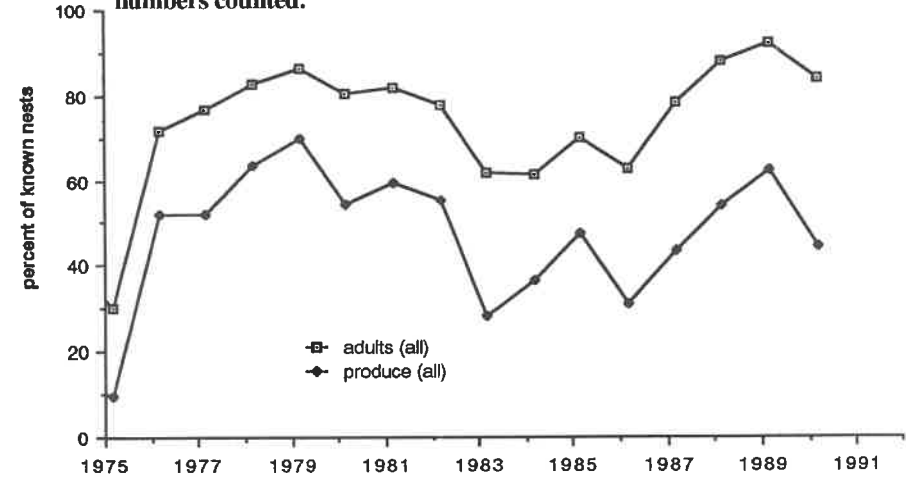


Figure 6. Variation in the number of young produced by successful pairs over time.

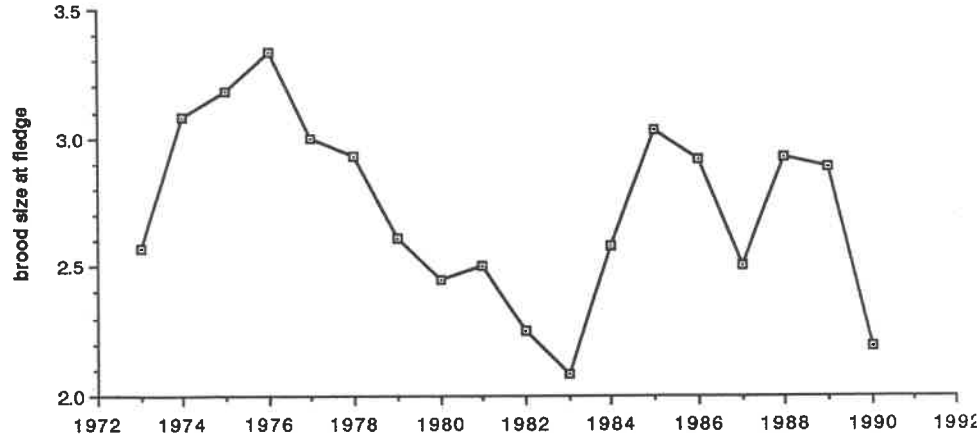
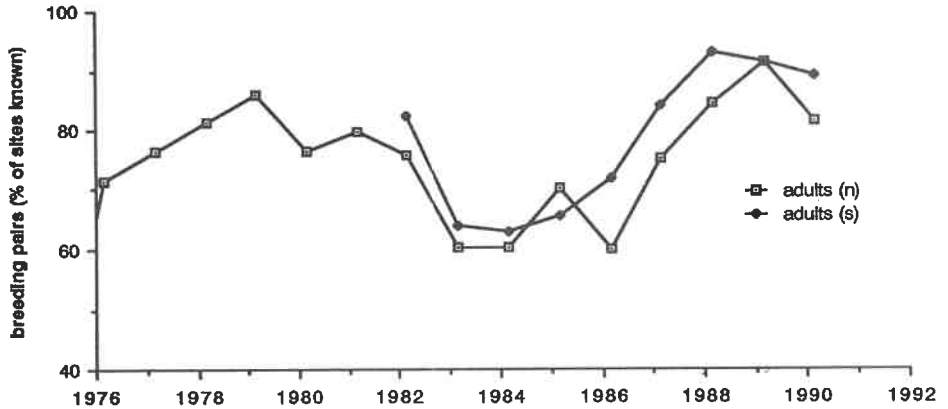


Figure 7. Comparison of the cyclic changes in Gyrfalcon demographics in the northern and southern halves of Yukon, 1976-1990.



Production of young: The fluctuations we recorded probably relate more to changes in productivity than to changes in the number of adult breeders. The number of young raised to fledging on the various study areas all varied greatly, in a regular cycle approximating a 10-year period that mirrored the cycle observed in adult attendance (Figure 5). In peak years approximately 60% of breeding pairs produced young, in lows as few as 10% did so. In synchrony, the number of young fledged by successful pairs varied significantly ($p=0.05$) from 3.3 young annually to 2.2 (Figure 6). Moreover the cyclic productivity changes were a territory-wide phenomenon; there were no significant differences between any of the study areas or even between pooled samples from the northern and southern halves of the territory (Figure 7).

Prey abundance: The close links between Gyrfalcon population performance and ptarmigan abundance has been the focus of research in the Yukon (Barichello & Mossop 1983; Mossop 1988). A very close correlation between the classic 10-year cyclic changes in (notably) Willow Ptarmigan (*Lagopus lagopus*) population dynamics and Gyrfalcon population cycles has been documented (Figure 8). Gyrfalcons in the Yukon are apparently totally dependent on ptarmigan in the early breeding season.

Nesting chronology: Hatch dates determined from back-dating from the age of young observed suggests a latitudinal adjustment toward later hatch in the northern study areas: Southern Yukon hatch date: May 16 (S.D. = 10 days); Northern Yukon hatch date: June 1 (S.D. = 14 days). Although significant variation occurred in all years in all populations, overall, hatch dates remained relatively stable at similar latitude in spite of the cyclic phase of the population through the major portion of the study period.

A possible feature is a suggestion of change in the mean hatch date over the last 5 years (Figure 9). The trend may be occurring toward earlier nest initiation/hatch, notably in the southern portions of the territory. Although the overall change involved is still within the long term variation observed ($p=0.05$) the fact that an increasing change in chronology has been observed in 4 of 5 consecutive years (notably in the southern half of the territory) lends some significance to this observation.

Figure 8. The relationship between Willow Ptarmigan(*Lagopus lagopus*) numbers and Gyrfalcon demographics in the Yukon, 1975-1990.

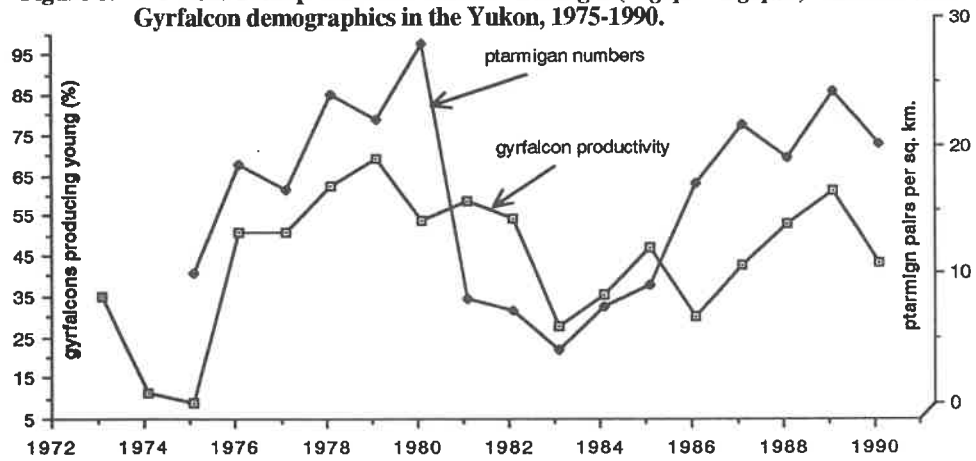
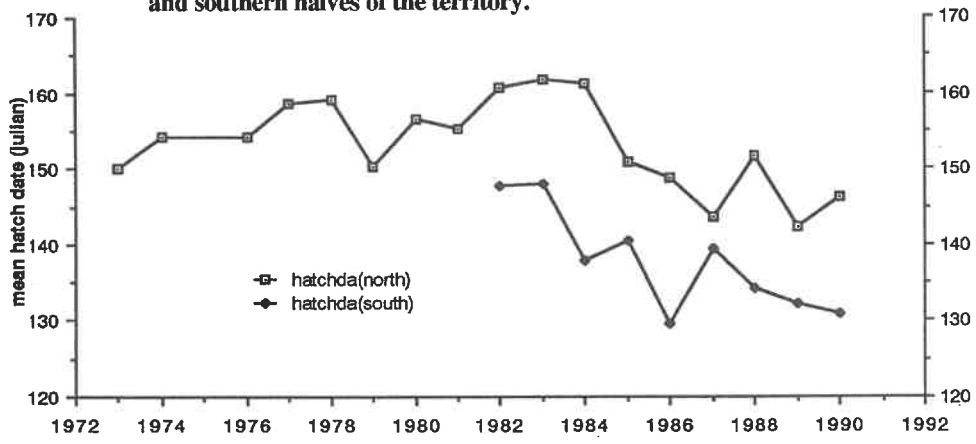


Figure 9. Mean hatch dates of Gyrfalcon in the Yukon, 1973-1990 comparing the northern and southern halves of the territory.



DISCUSSION

Population size and trend: These data are mostly of value in providing evidence for long term stability in the cyclic Gyrfalcon populations of the North American western arctic and western sub-arctic regions. Population densities over this large area, in the long term, have varied mostly between habitats, presumably reflecting productivity of differing ecoregions. Over at least the last 15 years, the species has been exhibiting remarkably uniform cycles in abundance and reproductive performance, suggesting a tracking of cycling factors in the environment but exhibiting no overall trend. The dynamics of the prime prey species in the Yukon, the three species of ptarmigan, closely resemble the cycles observed and provide the best explanation for all the temporal variation observed in Gyrfalcon demographics.

A breeding population of about 750 pairs in the Yukon is higher than was predicted based on earlier surveys in Alaska (Cade 1960). Fall numbers based on production numbers observed and non-breeding subadults estimated, may average 2,490 to 4,180 birds depending on the stage of the population in its cycle.

A feature of the Gyrfalcon ecology in the Yukon is its apparent simplicity, based as it is on a single critical non-migratory prey. This simplicity may contrast to the larger eastern areas Gyrfalcon inhabit in Northern America (Poole & Bromley 1985). The less complicated community association in the Yukon lends a level of confidence to the extrapolations of numbers and conclusions we have drawn about trend analysis at the population level. The dominant nesting strategy of even spacing over their nesting habitat is key in providing some of the best evidence for a broad estimate of numbers of Gyrfalcon in a relatively large northern area. A clumped nesting strategy may be the norm in other areas of the north, making extrapolation of population size to the rest of the habitat in those areas almost impossible (Poole & Bromley 1985). The area to which our conclusions can safely be extrapolated will wait field testing; we feel confident large areas of the North American 'Pacific Northwest' will follow suit, including large portions of Alaska as well as the North West Territories west of the Mackenzie River.

Breeding strategies to deal with fluctuating prey base: Clearly a predator like the Gyrfalcon, dependent on a prey that undergoes regular 6 to 10 fold changes in abundance, will have to develop profound strategic adaptations to deal with this problem. A simple modelling of the numeric responses observed gives some insight into the mechanism and may have implications for the management of the species. Assuming adult mortality that may be as high as 25% and mortality of fledged young of at least 50% (Newton 1979), at the population level Gyrfalcons are probably not replacing themselves in almost half the breeding seasons over the long term (Mossop & Hayes 1982). It is probably key for managers to understand this strategy by which reproduction effort is so finely tuned to the prey base. Work on the breeding territories has led to a general understanding of the role of courtship and prey abundance during early courting in determining reproductive output (Barichello & Mossop 1983; Bente 1981). Unfortunately the ecology of birds in the downward phases of the cycle, when the breeding territories are far less faithfully attended, is almost totally unknown simply because the birds become 'invisible' to normal study techniques.

From a management perspective the immediate concern must be to understand the vulnerability of the species at all stages in the cycle. There is no known evidence that either juvenile or adult mortality is static throughout the cycle. Nor are there any data on the simple whereabouts of adults (and especially non-breeding sub-adults) during the down turn phases when nesting territories are abandoned. Clearly prey utilization strategies at that time may be far more critical to understand than even those on the breeding grounds. As well, a strong research initiative at least tracking ptarmigan demography is likely an essential companion to any Gyrfalcon population work in the North American Pacific Northwest.

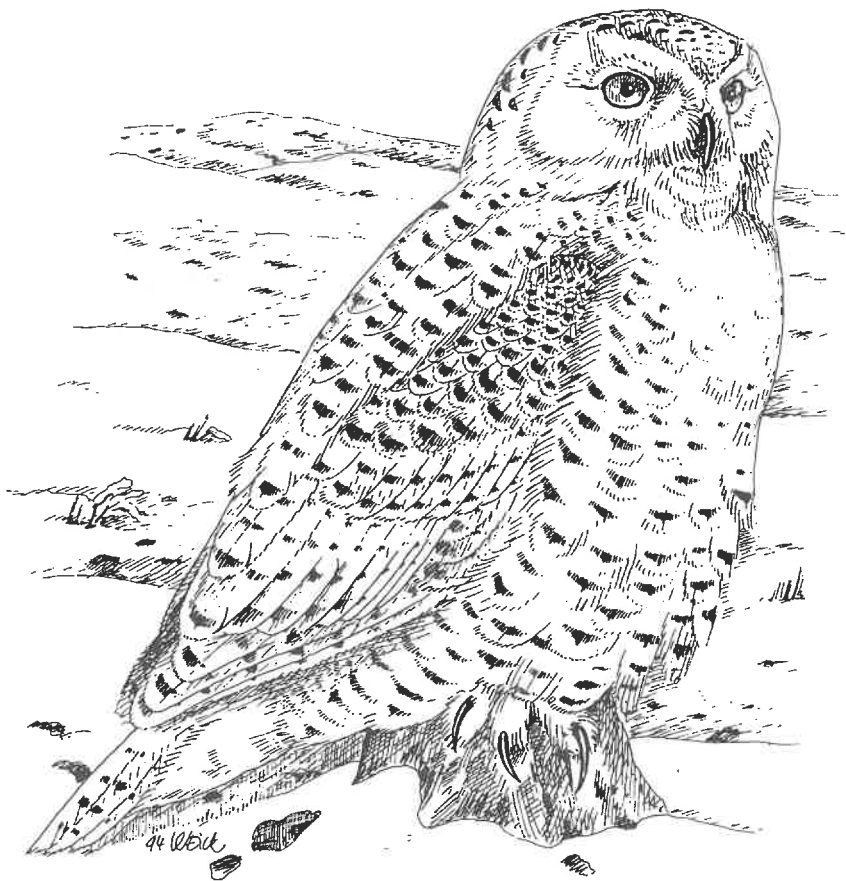
Changing breeding chronology: Enhanced nest success associated with early spring and hence early nest initiation has been observed in Peregrines (Mearns & Newton 1988) and several other raptor species (Newton 1979). In arctic-adapted species like the Gyrfalcon which clearly pursue a breeding strategy in which timing is critical, it would seem logical to predict a very close association between breeding output and chronology. All things being equal, birds subject to equal environment situation should breed roughly at the same time. Our findings of standard nesting periods over time but tending to be earlier in the southern Yukon would seem to bear this out.

Although we were unable to demonstrate statistical significance, there is a suggestion an anomaly may have arisen in the most recent period, 1986-91: nesting chronology seems to have been advancing. The ecology of northern systems has been the subject of much speculation as supposedly highly sensitive to world climate, presumably as a result of atmospheric pollution. Instruments are apparently on the edge of being able to measure the predicted climatic changes which seem to suggest a warming northern climate (Cohen 1990). It may be that birds like the Gyrfalcon, whose reproductive strategies are designed to take advantage of short arctic summers, may be offering a sensitive indication of climate change.

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Snowy Owl *Nyctea scandiaca*