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Breeding biology and ecology of the peregrine falcon (Falco peregrinus) in West Greenland

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BREEDING BIOLOGY AND ECOLOGY OF THE PEREGRINE FALCON (*FALCO PEREGRINUS*) IN WEST GREENLAND

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INTRODUCTION

During the last twenty years marked declines in Peregrine Falcon populations have occurred in many parts of the world (Hickey, 1969). During recent years the peregrine has been placed on the list of Endangered Species. Several factors have been suggested as the cause of its decline. These include changing climatic conditions (Porter and White, 1973), human disturbance (Mattox, pers. comm.), and introduction of chlorinated hydrocarbons as pesticides into the environment (Ratcliffe, 1970). The third factor, introduction of chlorinated hydrocarbons, has occurred on the American, European and Asian continents. Even peregrines nesting in locations far from human population concentrations are exposed to chemical pollutants on migratory flights south, in nesting areas and in the wintering range. Most of the small birds utilized by the peregrine as prey in the north also migrate south every winter, many moving into farming areas where insecticides are frequently used. By feeding in these areas the passerines accumulate substantial amounts of chlorinated hydrocarbons which are stored in fat tissues. As the peregrines feed on these small birds, body levels of chlorinated hydrocarbons gradually increase. If subsequent levels are high enough, they may cause death (Porter, 1972). In most cases, however, lethal levels are never reached: instead the lower levels produce eggshell thinning and breakage (Porter and Wiemeyer, 1969) which may be an important reason for world-wide decline in peregrine populations (Hickey and Roelle, 1969). Peregrines in the western United States have shown a 20% decrease in eggshell thickness since DDT was introduced (Enderson and Craig, 1974).

When the eggshell thinning and decline of nesting peregrines were detected, research was initiated in North America and Europe to determine the status of the species. Substantial data were collected on many geographical populations of peregrines by the late 1960's, but no research was initiated in Greenland until the summer of 1972 with the start of this research (refer to Mattox et al., 1972 and Burnham et al., 1974 for preliminary results). The purpose of this study was to determine the reproductive status, chlorinated hydrocarbon levels, density, nesting requirements, prey species and interspecific competition of the Peregrine Falcon in Greenland.

DESCRIPTION OF STUDY AREA

The study area is located in the widest portion of ice-free land of West Greenland just above the Arctic Circle, with an east-west transect of 78 km. from the edge of the inland ice-cap stretching toward the outer coast (50° W. to 51° 45' W. long.). The north-south width of the sample area is 61 km. from 66° 45' N. to 67° 15' N. lat.

The area is mountainous with relief up to 810 m. above sea level. The many mountains and valleys are divided by Søndre Strømfjord and are dotted with nearly a thousand lakes. Four rivers, three of which are glacial, traverse the area. The vegetation in the area consists predominately of low Willow brush (*Salix*) and Dwarf Birch (*Betula*) that seldom reach 1 m. in height and are sparsely scattered.

Since the study area is inland, temperatures are slightly warmer than the coastal area in summer and colder during winter with temperatures dropping to -50° C. The area is quite continental with an annual mean precipitation of 15 cm. Most precipitation comes in the form of rain during July and August. The climatic conditions from May through September are the most important and have the greatest effect on the Peregrine Falcon. Falcons arrive from mid-to-late-May and depart in September. Temperatures during these months usually remain above freezing. However, temperatures were collected very near sea level. The mean summer temperature changes considerably with an increase in elevation. When temperatures were in the high 40's, snow was accumulating at elevations above 450 m. in summer.

Mountain ranges in the northern portion of the study area run in a northeast to southwest direction while those in the southern sector lie more on a northwest to southeast plane. Glacial erosion has produced cliff faces 7.5 to 180 m. in height.

A total of 25 different species of birds has been seen within the study area (refer to Table 12). Only five undomesticated species of mammals have been seen. These include Musk Ox (*Ovibos moschatus*), Harbor Seal (*Phoca vitulina*), Arctic Fox (*Alopex lagopus*), Caribou (*Rangifer tarandus*) and the smallest mammal, the Arctic Hare (*Lepus arcticus*). No small mammals occur naturally in the area.

METHODS

Two historically known peregrine nesting sites (Mattox, pers. comm.) were checked for occupancy upon arrival. Other nests were found by conducting from one to ten day backpacking trips into unknown areas during the two month period of investigation in 1972. The available maps were of little help because of the size of contour intervals. In 1973 a small aircraft was used for locating possible new nesting locations of peregrines. In 1973, as in 1972, the actual checking for occupancy of all sites had to be done by foot. Aircraft could not be used to determine occupancy because birds were missed.

Boat transportation was used when feasible and available. Interested Danish citizens supplied rides on the fjord and a small rubber raft was carried for crossing rivers. Floating rivers to locate nesting sites was not feasible due to width, shallowness, quicksand and, in some cases, rapids which are unsurpassable. Limited helicopter support was available for crossing rivers and establishing supply points.

All cliffs located were checked to determine occupancy. This was accomplished by walking directly below the cliff, then discharging a firearm or yelling to dislodge any resident birds. When a probable nesting location was found but no birds were observed, time was spent in observation and climbing of the cliff. Once occupancy by peregrines was determined, nests were located and climbed or rappelled into in order to determine nesting progress and to collect data such as prey remains, physical measurements of the cliff and ledge, etc. If a falcon was found at a cliff before or during incubation, researchers immediately withdrew from the area and did not return until young had hatched and were several days old.

Prey remains were analyzed in the laboratory by the following method. First the collection was sorted, separating primary wing and tail feathers of passerines and Northern Phalarope (Lobipes lobatus) from feathers of non-passerines. Because of the very limited use of avian species other than passerines, even the smallest body feathers of other birds were sought. All pellets were examined for hair, feet or bones.

Observations suggest that each passerine captured was plucked to about the same extent before being brought in to the young. Using this assumption, the portion each prey species contributed to the diet was estimated. For example, if 145 tail and wing feathers from a Lapland Longspur (Calcarius lapponicus) and one from a Snow Bunting (Plectrophenac nivalis) were found in the nest, it was estimated that .9 (1.0 equals total intake) of the diet was longspur while .1 or less was Snow Bunting. When only a few feathers were found, possibly body feathers, it was assumed that .1 or less of the diet was made up of that species.

In an attempt to precisely measure nesting requirements, data were collected on height of nest cliff, distance of nesting location from the bottom and top of cliff, altitude of nesting locations and cliff, closest available water, closest nesting raptor, prey availability, directional exposure of cliff, type and size of nesting location, and the vertical and horizontal exposure of the scrape.

The exposure of the nesting location to the sun and elements is probably the hardest of the parameters to measure. Because of this, a new method was devised to collect these type of data. It was necessary to have a point of reference from which to take measurements. The center of the nesting scrape (a shallow, bowl-like structure scratched in the dirt in which the falcon lays her eggs) was selected for the site because this is the one location which the falcon most precisely selects. It is also the location in which the eggs and very young nestlings are maintained during a critical period of their life.

To measure the exposure, a compass was placed in the center of the nest scrape and sightings were taken to determine at what horizontal angle obstructions occur. For example, if the scrape was placed in a pocket of rocks with only one horizontal opening to the front, the compass would be orientated to magnetic north; then the number of degrees would be determined at which the rays of the sun would no longer reach the scrape (north = 0° and south = 180°), and when the sun first reached the scrape. For example, this could give 183° when sun rays would first strike the scrape and 263° when the sun rays last strike the scrape that day. These data allow the calculation of the time of day when the sun is on the scrape as well as the total degrees of horizontal exposure (for the above example the scrape would have 80° exposure) and duration in hours. To calculate the time of day a correction was first made from magnetic north to true north. Referring to the Smithsonian Meteorological Tables (List, 1951) and correcting to local time and the proper longitude, the exposure times were calculated.

For calculation of the vertical exposure of the scrape a protractor was placed in the center of the scrape and the vertical angle was determined at the far right and left corners of the horizontal exposure. Following that, the vertical angle was calculated halfway between the far right and left exposures of the horizontal angle. Any overhanging obstacle which would produce a lesser number of degrees of vertical exposure than the middle angle were noted. This method gives three angles of vertical exposure. By referring to the meteorological tables used above, the angle the sun is above the horizon at a given time of day can be calculated. With the sun data it was determined if the vertical exposure blocked out the sun from the nest during certain time periods of horizontal exposure. In this way the amount of overhead protection from the sun or environmental elements was calculated.

Data were collected from all Gyrfalcon nests found for comparative purposes. The only other large, cliff-nesting raptorial birds in the survey were White-tailed Eagles (Haliaetus albicilla) and Northern Ravens (Corvus corax). Only one nesting location of sea eagles was found during the research, and it was located late in the 1973 season with the aircraft. Ravens nested within the area, and in 1973 data were collected from numerous nesting locations.

Densities were compared using the method described by Ratcliffe (1969). This method determines density by calculating the average minimum distance between each pair and its nearest neighbor. The Greenland data have also been computed in this manner and can be seen in Table 6.

During the 1973 research period a small bird census was incorporated into the study to determine prey density. This was accomplished by walking 1000 paces (900 m.) counting and identifying all birds flushed or heard calling within 15 m. on either side. This gives the approximate number of birds occurring in a 27,000 $m.^2$ area. It is probable that some birds were missed on these counts and that a slightly higher number existed than counted.

Some areas were walked more than once daily in an attempt to check for large fluctuations due to poor technique. The technique appeared to be quite satisfactory on the low Greenland tundra.

The small bird census was divided into two parts, intermittant counts and standardization counts. The intermittant counts were transects taken frequently while walking over the tundra. These counts had no set areas or types of terrain and were all taken at different locations.

Standardization counts were conducted in a restricted area with permanent markers. The area was established at the beginning of the 1973 field work and periodic counts were taken over the area in an attempt to detect population changes due to nesting activities and molt.

NESTING REQUIREMENTS

Height of Cliff

Peregrines have been found nesting on cut banks or on low, sandy mounds in the Canadian Arctic (Hickey and Anderson, 1969). However, this was not the situation in West Greenland. Of the 18 nesting attempts witnessed during the two summers all were on cliffs between 27 m. and 117 m. in height with a mean vertical distance of 79 m. The largest vertical escarpment was 117 m. Below most cliffs there was an area of talus slope which was rather steep but was not included in cliff size. Adequate cliff height appears to be important; there were no nests on small, broken cliffs.

In all sites found during the 1972 and 1973 work, the nestings were on a cliff which was raised above and overlooked a substantial area. However, in 1971, the year before the study started, a peregrine was reported by a native hunter to have produced young on a very low, north-facing escarpment. The area was checked during the spring of 1972 and again in 1973 but no falcons were seen. An absence of lichen and the presence of excreta which would have indicated previous nesting was also noted. Three small excarpments existed in the area but a recent dirt and rock slide covered one location. It is possible that the eyrie had been on the destroyed cliff.

During an observation study of one eyrie, the adults frequently used their superior elevation at the eyrie to initiate attacks on prey (Clement and Harris, pers. comm.). The nesting cliff not only provides a launch location for attacks, but also produces thermal air currents which the peregrines can ride to gain elevation before moving away from the cliff. Thus, the high cliffs overlooking large areas could have numerous beneficial effects and reasons for falcons choosing to nest on them.

Another possible reason for Peregrine Falcons choosing to nest on high cliffs could be protection from predators. A population of Arctic Fox exists within the survey area. Other than man and a very occasional Polar Bear, the fox is the only mammalian predator which could possibly feed on young peregrines. The fox could conceivably place pressures on the peregrine that would be great enough to cause evolutionary selection favoring cliff rather than ground-nesting peregrines. Disturbance of ground-nesting raptors by foxes has been witnessed in the Aleutian Islands off Alaska where Bald Eagle (Haliaetus leucocephalus) populations have been affected and similar conclusions drawn (Sherrod, 1974).

Man can not be discounted as a predator and a cause for peregrines choosing high cliffs since young Peregrine Falcons are considered palatable to Eskimos.

Considering height of the nesting location on a percentage basis with the upper half being from 0% to 50% (top is 0%), it was found that falcons nested from 29% to 69% with a mean nesting height of 41% (Table I). This infers that the Peregrine Falcons in the survey area prefer to nest in the upper half of the cliff. Most cliffs in the area

Table I

Cliff Height and Location of Nest on Cliff*

Eyrie Number	Year	Top of Nesting Cliff		Distance of Nesting Ledge from Top of Cliff		
		Height	Elevation above Sea Level	Height	Elevation above Sea Level	Percentage (0% = top)
1	1972	75	539	45	494	46%
	1973	84		39	500	50%
2	1972	117	385	45	340	39%
	1973	117		81	304	69%
3	1972	90	477	45	436	50%
	1973	90		45	437	50%
4	1972	93	575	48	---	51%
	1973	93		48	402	51%
5	1972	68	477	24	453	33%
	1973	72		24	453	33%
6	1972	45	385	15	370	33%
	1973	25		12	373	36%
7	1972	105	373	24	349	29%
	1973	105		24	349	29%
8	1972	60	300	30	260	33%
	1973	45		15	270	50%
9	1972	--	340	--	---	---
	1973	27		9	468	33%
10	1972	--	152	--	---	---
	1973	90		30	122	33%
Mean		79	400	34	375	41%

*Approximate measurements calculated in meters

Different cliff heights at the same eyrie number reflect the falcons moving to a new location on the same cliff.

are rounded near the top due to glacial activity and subsequent weathering. This rounded condition does not produce good nesting locations near the crown. Many ledges which are available can be reached by fox or humans. Below the crown most cliffs have a sheer, vertical (or nearly vertical) portion before adequate ledges are present. About 30% of the cliffs do not have good nesting ledges or locations in the upper portion of the cliff.

After conducting observations from a blind at one nesting site, Clement and Harris (pers. comm.) suggested that the falcons did not nest in the upper portion of the cliff because clouds frequently covered it, making vision difficult when the birds were hunting from the cliff. This could be true for certain cliffs. However, due to different elevations and locations of cliffs and to fog patterns, it certainly could not be true for all sites.

Altitude of Cliff Nesting Sites

Temperature varies considerably according to elevation in West Greenland. The temperature would usually be warmer on a low mound than on a cliff of greater elevation. During late June, snow exists on the top of cliffs while the valley below is snow-free. Peregrines seemingly should select cliffs of lower, warmer elevation, but elevation does not appear to be a critical factor. One pair of Peregrine Falcons nested at an elevation of 500 m. (Table I). The lowest elevation at which a falcon was found nesting was 122 m. The critical aspect of nesting altitude appears to be determined by a ready supply of available prey species. Cliffs examined at higher altitudes which did not overlook an area where small passerines were nesting had no Peregrine Falcons (refer to Prey Species).

Altitude could be a factor affecting the placement of nesting scrapes on cliffs. The amount of data available does not suggest a positive correlation between lower nest ledges at cliffs of higher elevation (Table I).

Directional Exposure of the Nesting Cliffs

All nesting cliffs in the study area have a southern exposure. This exposure is substantially warmer than cliffs facing north. The north facing cliffs usually appear to be much wetter and may be covered, at least in part, by the tundra-mat type vegetation. The amount of vegetation and frost action is more evident on north facing hillsides as well as cliffs. The directional exposure, other than southern, does not seem critical because most cliffs have ledges with either a southeastern or southwestern exposure.

Nesting Ledge

Of all nesting requirements the actual nesting ledge is probably the single most critical factor effecting the survival of the young falcons. The size of an escarpment or the general directional exposure may be what attracts the falcons to a given location, but the cliff must contain adequate nesting sites before it is occupied. On cliffs with more than one good nesting location, many scrapes have been found. At one nesting site, one ledge contained five deep scrapes, each several meters apart, while eggs were actually laid 30 m. away on a different ledge. Multiple scrapes have been suggested as being the result of the male falcon making several scrapes so the female may select one. "Scraping" has also been considered as a means of enforcing pair bonds. Rather than the above, perhaps multiple scrapes are simply the result of indecision about choosing that location which is most suitable considering environmental and nesting ledge conditions during a particular year.

Generally, the location chosen is a long, narrow ledge with clumps of grass and a slight overhang of rock (refer to Table 2 for detailed description of each location). Young have been observed behind the grass clumps on unusually warm arctic days and they may furnish protection from excessive heat. On a noon visit to an eyrie where vegetation was lacking, three young less than a week old were found showing signs of over-heating until shaded by the researcher. The parent falcon apparently had been shading the young falcons before being interrupted by the researchers.

Initially, clumps of grass were thought to be a feature the peregrines were looking for when selecting a nesting location. However, after further observation it appeared that little nutrient matter for plant growth was contained on the ledges composed mainly of windblown silt, and that the grass was probably a result and not necessarily a cause of the falcons nesting there. The fecal matter deposited by the young falcons increases the soil nitrate concentration substantially. Prey remains scattered near the scrape, along with castings, act as a compost holding moisture as well as conditioning the soil. These positive growth factors combined with seeds transported to the nest by peregrines in the crops of many prey species probably produced these dense growths. The vegetation may be desirable, but several ledges which almost completely lacked vegetation were used. Some factor other than vegetational protection was attracting the falcons to the ledge. The lack of vegetation would also suggest that the ledge had been used for only a short time.

Table 2

Description of Nesting Scrape Locations at Eyries

Site	Year	Description
1	1972	Located on a long, grassy, clumped ledge 150 cm. deep. The scrape was placed behind a clump of grass and some overhang was present.
	1973	Located on a short narrow ledge (50 cm. deep and 120 cm. wide) with almost no grass. No overhang protection was present for scrape.
2	1972	Placed on a long, narrow ledge (50 cm. deep) with high, dense grass on the front edge. The ledge was overhung and the scrape very well protected.
	1973	Placed on a ledge approximately 60 cm. wide with clumps of grass in front of the scrape. Little protection offered to scrape by overhang, but young could move back and gain limited protection.
3	1972	Placed on a long ledge 1 m. deep. There was considerable protection from willow bushes for the scrape and young.
	1973	Placed on a long ledge approximately 75 cm. wide. Very little protection for scrape with almost no overhang. Young could move back and gain limited protection from above.
4	1973	Located on a long ledge that was 1 m. deep with clumps of grass and protective overhang.
5	1972 & 1973	Located on a 1 m. by 75 cm. ledge which was slightly overhung. There were clumps of grass in front of the scrape.
6	1972	Located on a 2.5 m. by 2 m. projection from the c cliff with clumps of grass and a 50 cm. rock in front of the scrape. No overhead protection.

Table 2 (Continued)

Description of Nesting Scrape Locations at Eyries

Site	Year	Description
6	1973	Located on a ledge 3 m. long and 1 m. wide with some grass but no overhang. Young could move back and gain limited protection from above.
7	1972 & 1973	Located in a 2 m. by 2 m. pocket with some overhang and rounded pocket in back. Complete overhead protection.
8	1972	Located on a 50 cm. long and 35 cm. deep ledge with some overhang. Grass was present on all sides of the scrape.
	1973	Located on a 4 m. by 3 m. ledge with clumps of grass and some overhang.
9	1973	Located on a 120 cm. by 90 cm. ledge which could be walked into from above. Grass was present on the ledge.

Except for site number 9 and number 6 all had at least a slight overhang of rock protecting the nesting scrape (Table 3). Site number 9 in 1973 which showed no overhang protection for the scrape did have a protective overhang area which young could utilize during inclement weather. Site number 6 contained four eggs early in the nesting cycle and only one sickly-appearing young was raised to ringing age. Even though the nesting scrapes at many eyries may be only partially protected from above, they are similar to site number 9 in offering the young protection once they are old enough to move about.

When selecting a nesting ledge or pocket, Peregrine Falcons appear to require certain criteria. The total surface area of the location does not appear critical. The only critical factor in total surface area seems to be that there be room for the young to lay down. The composition of the soil on the ledge also appears not to be critical, as great variation exists.

Exposure

The exposure of a nesting location is the vertical and horizontal area which is open to the environment. To determine this parameter, measurements were taken from the center of the nesting scrape. The mean horizontal exposure was 160° for 17 nesting attempts. The mean horizontal directional exposure for the total group of locations was 102° to 262° (Table 4). This mean gives a southerly directional exposure for the nesting locations. The falcons at site number 7 both in 1972 and 1973 used the same unusual location. Their scrape was placed in a warm pocket with a southwestern exposure totaling only 76°.

Table 3

Vertical Sunlight Exposure of Nesting Scrape in Degrees

	1972			1973		
Site Number	Angle 1	Angle 2	Angle 3	Angle 1	Angle 2	Angle 3
1	90	40*	90	80	78	75
2	60	85	40	60	70	55
3	85	85	85	85	85	85
4				90	75	50
5	50	85	50	50	85	50
6	90	130	90	40	87	90
7	47	58	61	40	58	61
8	60	65	55	35	82	30
9				90	90	90

Angle 1 = the vertical angle taken from the center of the nest scrape to the northernmost upper edge of horizontal exposure

Angle 2 = the vertical angle midway between the other two from the center of the scrape

Angle 3 = the vertical angle taken from the center of the nest scrape to the southernmost upper edge of the horizontal exposure (refer to procedure for a further explanation of technique used)

*This is the only vertical angle which would restrict the amount of direct sun which would strike the scrape. The angle of the sun above the horizon (zenith angle of the sun) was calculated for all horizontal exposures.

Measurements may vary slightly.

Table 4

Horizontal Sunlight Exposure of Nesting Scrape

Site Number	1972 Directional Exposure	1972 Total Horizontal* Exposure	1973 Directional Exposure	1973 Total Horizontal* Exposure
1	135° - 293°	158°	129° - 307°	178°
2	83° - 264°	181°	103° - 274°	171°
3	77° - 267°	190°	84° - 262°	178°
4			91° - 271°	180°
5	62° - 239°	177°	62° - 239°	177°
6	95° - 288°**	193°	110° - 243°	133°
7	165° - 241°	76°	165° - 241°	76°
8	123° - 256°	133°	105° - 263°	158°
9			73° - 253°	180°
10			78° - 248°	170°

Mean Directional Exposure 102° and 262 °

Mean Horizontal Exposure 160°

*This is the horizontal exposure from the center of the scrape or the number of degrees of exposure to the scrape on a horizontal plane.

**There was a rock measuring approximately .5 m. in front of the scrape blocking approximately 35° of the horizontal exposure.

Measurements may vary slightly.

By using the extreme directional horizontal exposures, the total hours of sun on the scrape were calculated. The time when the sun first reaches the scrape as well as when it leaves was determined. There is considerable variation for both of these measurements (Table 5), i. e., the time of day when the sun first strikes the nesting scrape (01:35 to 08:15) and the time when the sun leaves the scrape (12:10 to 17:05). Little can be said about these values other than that the falcons appear to choose locations where the sun hits their scrape in early morning and leaves during the afternoon. However, when the total hours of exposure are examined, a more constant value is available. If site number 7 is deleted from the calculations because of its unusual characteristics, and measurements are used from the other 15 nesting attempts, there is a mean exposure time of 9 hrs., 54 min. By using a statistical F max. test for variation, the amount of variation from the mean was determined for total horizontal degrees of exposure, time sun first strikes the scrape, time sun leaves the scrape, and total hours of exposure. A statistical significance (at alpha = .01) between total hours of exposure and the other three sets of values was found. Total hours of exposure is seemingly the most constant parameter and possibly may be significant to the success of the nesting attempt.

Total hours of exposure appear to be a compromise between the warmth which can be gained from the sun and the protection of the cliff face. If the peregrine places the scrape on a projection of rock or far out on a ledge, it gains exposure to the sun but sacrifices vertical protection and is subjecting its eggs and young to increased environmental factors (wind, rain and snow) as well as falling rocks from above. Falling rocks may be much more of a hazard than would be suspected.

Table 5

Hourly Sunlight Exposure of Nesting Scrape

to Direct Sun Rays July 7

	1972 Exposure Time				1973 Exposure Time			
Site No.	Rays First Strike Scrape	Rays Leave Scrape	Total hours	minutes	Rays First Strike Scrape	Rays Leave Scrape	Total hours	minutes
1	06:35	16:00	9	25	06:20	17:05	10	45
2	03:10	13:50	10	40	04:40	14:35	9	55
3	02:45	13:00	10	15	03:20	13:40	10	20
4					03:40	14:25	10	45
5	01:35	12:10	10	35	01:35	12:10	10	35
6	04:10	15:40	10	5*	05:10	12:25	7	15
7	08:15	12:20	4	5*	08:15	12:20	4	5*
8	06:00	13:10	7	10	04:50	13:45	8	55
9					02:25	13:10	10	45
10					02:45	13:45	11	00

Mean Time of Exposure omitting site 7 = 9 hours 54 minutes

Mean Time of Exposure including site 7 = 9 hours 13 minutes

*This scrape had a .5 m. rock in front which blocked out approximately 1 hour 25 minutes of direct sun. Therefore the total hours of exposure above is 10 hours 5 minutes, not 11 hours and 30 minutes as would be calculated excluding the rock.

**This scrape was located in an eroded pocket of black rock which was 2 m. in diameter and very warm. This location was extremely different than all others and it should not be considered when calculating exposures of the eyries.

because the cliffs in the study area contain much loose rock due to frost action and debris left from glacial movements. At the other extreme, if peregrines place their nest under a large overhang, as Gyrfalcons (Falco rusticolus) often do, considerable protection is gained but exposure to the sun is lost. Perhaps the numerous scrapes found on many cliffs indicate that the falcons are testing the location which best compromises their need for warmth and protection.

PEREGRINE FALCON DENSITY IN THE STUDY AREA

Within the area a total of 16 historical and presently occupied nesting sites are known (Table 6). An occupied site is defined as one where at least one Peregrine Falcon has been seen actively defending an escarpment of rocks or displaying other nesting signs. Of the 16 sites, 14 were known of, then were occupied and seven produced young in 1972. One of the occupied but not producing sites (site no. 13) was reported active by local residents in early June of 1972. At that time the falcons appeared to defend the cliff, but when researchers checked the cliff in late June no falcons were present. The other two observations in 1972 were made by researchers. Of these two sites, one had a pair of peregrines actively defending it throughout the nesting season (site no. 4). When researchers went to the cliff to band young in late July, a nesting scrape, castings, feathers of prey and young peregrine down were found. However, no young falcons were located. A hunter's camp was situated within hearing distance of the eyrie and there is a possibility that the hunters could have disposed of the young. No signs of human activity or fox predation were noted, however. The last site found (site no. 9), which did not produce young in 1972, had a lone female

Table 6

Peregrine Falcon Nesting Site Occupancy

Site Number	Prior to 1972	1972	1973
1	known to be active for many years	produced young	produced young
2	unknown before 1972	produced young	produced young
3	unknown before 1972	produced young	produced young
4	unknown before 1972	adults and down from young but no young found	produced young
5	unknown before 1972	produced young	produced young
6	known by local residents before 1972	produced young	produced young
7	known by local residents before 1972	produced young	produced young
8	unknown before 1972	produced young	produced young
9	unknown before 1972	one lone female present and defensive	produced young
10	unknown before 1972	no birds present when cliff checked	pair appearing late in season acting defensive but no eggs were laid
11	unknown before 1973	no bird present when cliff checked	one lone female defended cliff for a short time early in spring
12	reported to have produced young in 1971	no birds present	no birds present
13	young peregrine was believed to have been taken from it in the 1940's	two birds reported by local residents to be defending cliff early-gone by late June	no birds present

Table 6 (Cont.)

Peregrine Falcon Nesting Site Occupancy

Site	Prior to 1972	1972	1973
14	known to be active for many years until approximately 1968 when both adults were captured	no birds present	no birds present
15	birds reported to be defending a cliff by a geologist in 1970	unknown	no birds present
16	birds reported to be defending a cliff by a geologist in 1970	unknown	no birds present

peregrine defending it. Approaching the cliff the falcon was mildly aggressive and soon left the area. Although considerable observation was given this site, neither a mate nor young were ever observed.

In 1973 eleven of the 16 known sites were active; nine produced young. Both of the nonproductive sites (no. 10 and no. 11) had been checked during 1972 and no birds were seen. Of these two sites, site 11 was located approximately 300 m. from a Gyrfalcon nest. This location was defended by a lone female for no longer than a week early in the nesting cycle (late May). After that time no peregrines were seen at that cliff. In mid-June a pair was observed at site 10, located approximately 2 km. away from site 11. This pair made a scrape and displayed early courting behaviour in the form of bowing and calling. They also showed moderate aggression toward intruders. There is a possibility that the lone female from site 11 was one of this pair and had not found a mate until late in the season. Site 10 was checked on a regular basis because two Gyrfalcon nesting sites were being studied, each located approximately 2 km. on either side of the peregrine site and the cliff was not occupied earlier by peregrines or Gyrfalcons.

Even though falcons occupying a nesting site do not produce young, they do defend a given area and the sites must be included in the total occupancy counts. The only time this would not apply is when falcons move into an area very late in the nesting season. When late occupancy occurs the falcons probably would not be an influencing factor in that years total density. Because of late occupancy, density values for 1973 were calculated on a ten site occupancy instead of eleven (site 10 deleted in calculations) while density figures for producing pairs were computed on a nine site basis. Density in 1972 was computed on ten occupied sites and seven producing sites.

The size of the study area was larger in 1973 than in 1972. In both years, however, about 12% of the total area was comprised of a portion of a fjord and two fingers of glacial ice extending from the inland ice-cap. Neither areas are used for hunting or as buffer zones between eyries and are excluded from calculations (Table 7). The tundra, containing no cliffs, and the lakes are included in calculations as the lakes may act as buffer zones between eyries and cliffless tundra acts as hunting areas.

By refering to Table 7 it can be seen that the mean density of the Peregrine Falcon within the survey area for 1972-1973 was one occupied site per 200 $km.^2$ and one producing site per 244 $km.^2$ based on a 1937 $km.^2$ study area.

Breeding density for inland peregrines can be measured as pair per mean area, but coastal breeders have a linear distribution. Thus a

Table 7

Peregrine Falcon Density Based on $Km.^2$

	1972		1973		Mean for 1972 and 1973	
	Based on $2072\ km.^2$*	Based on $1823\ km.^2$**	Based on $2330\ km.^2$*	Based on $2050\ km.^2$**	Based on $2201\ km.^2$*	Based on $1937\ lm.^2$**
Producing Sites	$1/296\ km.^2$ (n = 7)	$1/260\ km.^2$ (n = 7)	$1/259\ km.^2$ (n = 9)	$1/228\ km.^2$ (n = 9)	$1/278\ km.^2$	$1/244\ km.^2$
Occupied Sites	$1/207\ km.^2$ (n = 10)	$1/185\ km.^2$ (n = 10)	$1/233\ km.^2$ (n = 10)	$1/205\ km.^2$ (n = 10)	$1/220\ km.^2$	$1/200\ km.^2$

*Total area

**Area less 12% fjord and glacial ice

comparison of densities is difficult at best, and probably inaccurate. Hickey (1969), however, has suggested that in order to compare peregrine densities on a broad basis, a technique developed by Ratcliffe (1969) should be used.

For much of England, Wales, and southern Scotland, Ratcliffe (1969) worked out a value of 4.8 km. between occupied sites, which he felt was fairly constant. This was for the time period of 1930-39 and for both coastal and inland nesting grounds. The nesting density is presently much lower due to decline in the population between 1955 and 1965. From these data the peregrines in certain locations in England during the 1930's appear to have been more dense than within the Greenland survey area in 1972 or 1973. Using Ratcliff's technique, a linear distance of 6.3 km. (average of occupied sites for 1972-73) was calculated for the survey area (Table 8) and compares favorably with Ratcliffe's values for the southern Highlands and many coastal districts of the entire Highlands in England. That density for the southern Highlands and coastal districts was 5.5 - 6.4 km. for 1930-39.

It is of interest to compare Greenland with other areas in North America. In 1939, in the Eastern United States, Herbert, Spofford and Hickey (Hickey, 1942) found 18 pairs of peregrines and one unmated male in 25,900 $km.^2$ or one pair per 1364 $km.^2$. Bond (1946) estimated slightly more than one pair of peregrines for every 5,180 $km.^2$ in western North America. Fyfe (1969) discussed Peregrine Falcon densities in Canada by ranking areas numerically into groups as indicated by habitat suitability. Assuming the survey area in Greenland is comparable to prime Canadian habitat (Fyfe's Group I) then Canadian peregrines are more dense in many areas. Fyfe's data indicate that Group I areas of Mainland Northwest

Territories and Arctic Islands have one pair per 50 $km.^2$. However, if Group 2 habitat, such as the Anderson River and the Adelaide Penninsula, are compared to the Greenland research area, then Greenland peregrine populations are equally dense.

Table 8

Peregrine and Gyrfalcon Nesting Density*

Falcon	Year	Mean Minimum Distance Between Producing Sites	Mean Minimum Distance Between Occupied Sites
Peregrine Falcon	1972	8.5 km.	6.0 km.
	1973	6.9 km.	6.5 km.
	mean	7.7 km.	6.3 km.
Gyrfalcon	1972**	12.9 km. (n=6)	12.9 km. (n=6)
	1973***	11.7 km. (n=5)	7.8 km. (n=7)
	mean	12.3 km.	10.4 km.
Combined Density		6.7 km.	6.3 km.

*Mean minimum distance between nesting sites

**In 1972 three nesting sites were not known of so were not checked that year.

***In 1973 one of the 1972 producing nesting sites was not checked because it was located across a river and could not be reached.

GYRFALCON AND PEREGRINE FALCON DENSITY

Nesting density calculated on a combined total of peregrines and Gyrfalcons gives a considerable difference in numbers of falcons per $km.^2$ (Table 9). The combined mean density is one occupied site per 118 $km.^2$ This compares to one occupied site per 200 $km.^2$ for peregrines alone. These values were based on the total mean survey area less 12% for fjord and glacial ice. Recalculating the data by Ratcliff's (1969) method (Table 8) gives the mean minimum distance between occupied and producing sites.

Table 8 shows a difference for producing sites of one km. between combined peregrine and Gyrfalcon nesting density and nesting density for peregrines alone. There is no difference in distance between the two densities when occupied sites are compared (Table 8). These values seem to be erroneous when they are compared to density values figured by $km.^2$, but because some Gyrfalcon nesting sites were located on the periphery of the survey area, the average minimum distance between sites remains about the same. When only the density of Gyrfalcons is examined (Ratcliff's method) it can be seen that the number of pairs producing young are widely dispersed with a mean distance of 12.3 km. (Table 8).

PEREGRINE FALCON PRODUCTIVITY

Considering the declining status of world Peregrine Falcon populations, probably the single most important topic of any research conducted on the species is nesting productivity. Productivity is defined here as the number of young a given population is capable of

Table 9

Peregrine and Gyrfalcon Density Km^2

	1972		1973		Mean for 1972 and 1973	
	Based on 2072 km.^{2}*	Based on 1823 km.^{2}**	Based on 2330 km.^{2}*	Based on 2050 km.^{2}**	Based on 2201 km.^{2}*	Based on 1937 km.^{2}**
Producing Sites	1/159 km.^{2} (n=13)	1/140 km.^{2} (n=13)	1/166 km.^{2} (n=14)	1/146 km.^{2} (n=14)	1/163 km.^{2}	1/143 km.^{2}
Occupied Sites	1/130 km.^{2} (n=16)	1/114 km.^{2} (n=16)	1/137 km.^{2} (n=17)	1/121 km.^{2} (n=17)	1/134 km.^{2}	1/118 km.^{2}

*Total area

**Area less 12% for fjord and glacial ice fledging into the wild per nesting pair. Population density and pesticide levels are also critical factors in predicting the present and future condition of a population. If a population is not producing enough young to replace juvenile and adult mortalities, it is then decreasing in number and possibly its chances for survival are reduced. If a species is numerically decreasing, one must determine how long the trend will continue until it is extinct.

Within the study area it appears that extirpation is not a present danger. The 1972 and 1973 productivity data indicate that the peregrines are fledging enough young to maintain their breeding population. If one agrees with Hickey and Anderson (1969) that an estimated 1.16 young per year are required to be fledged from all pairs of breeding peregrines to maintain a stable population, then the breeding population in the study area is stable. The average productivity rate per occupied site for the two years is 2.05 young/year assumed to have fledged (Table 10).

Refering to Table 10 it can be seen that in 1972-73 a mean of 2.55 young were fledged per producing site, and 2.05 young were fledged per occupied site (refer to Table 10 for production of each site). The variation between the number of young fledged in 1972 and 1973 could be due largely to an unseasonably cold spring in the survey area during 1972. Rain, snow and low temperatures occurred during the incubation period and for a period following hatching. Production for the Greenland birds then compares favorably to production rates prior to introduction of DDT, as obtained by Ryves (1948) and Hickey (1942) in England and America in 1939-40. The number of young reared per successful pair in England and America was 2.4 and 2.5 respectively. Values for young reared per occupied site were 1.7 for England and 1.2 for America. Considering just the reproductive statistics, the Peregrine Falcons in the study area appear to be a healthy, thriving population.

Table 10

Productivity of Peregrine Falcons

	Producing Sites*	Occupied Sites**
1972 mean	2.43 fledged/site	1.70 fledged/site
1973 mean	2.67 fledged/site	2.40 fledged/site
combined mean	2.55 fledged/site	2.05 fledged/site

*Productivity was calculated by using only sites which produced young (successful sites).

**Productivity was calculated by using all sites occupied by one or more falcons whether producing young or not.

To determine the exact number of young which were raised to the age of leaving the nest is difficult. Accuracy in fledging statistics requires the maintainence of a constant vigilance at every eyrie until the young first start flying. One research team can not collect exact fledging data from several different nests because most young are at a similar age and nests are a considerable distance apart. Even when an investigator goes to a nesting cliff and counts young which have already begun flying, exact values can not be obtained because some young which have wandered may be missed. Thus, productivity within the study area may be slightly different than that previously given, but I believe the values are between 1.90-2.20, probably much closer to the mean of 2.05 given.

Within this study area there appear to be two critical times during the reproductive cycle when nestling mortality is greatest. The first critical time is during the period of hatching and the following week. Three different nests that were checked for clutch size during the research each had four eggs. There were also two nests with four young, and one with three young plus an addled egg. This suggests that at least a large portion of the falcons lay four eggs. Some of the eggs laid may be infertile, resulting in some decrease in number hatched. Hickey (1942) suggests that one egg per clutch is infertile. Ricklefs' (1969) data also show high raptorial nesting mortality during this period. Some of the early mortality could also be due to young dying while hatching or shortly after as well as infertility. Mortality of eggs and/or very young falcons is approximately 35% in the survey area assuming four egg clutches.

Eggs are spaced at approximately two days between each laying or one egg every other day up to a total of four. If the falcon starts incubation after the second egg, which is frequently the case with captive falcons, then a space of four days or more in age could exist between young hatched. A four day age difference can be a critical length of time among nestlings when the youngest is a small male and the older young are large females because of competition to escape from environmental exposure and, later, competition for food. Site no. 7 in 1973 had three young, one of which was at least six days younger than the other two. The youngest disappeared from the nest before it reached one week of age. The large age difference of these young could be explained if the third egg laid did not hatch and the fourth egg was the young male.

The second critical period appears to be just prior to or shortly after fledging. In 1973 young peregrine remains were found at two of the 1972 nesting sites. Feathers from one young, approximately 30 days of age, were found on the nesting ledge of site no. 2. The second dead falcon was found below a nesting cliff. Bones as well as feathers from a young bird over 50 days old were found at this site (no.7). There was a Greenlandic hunting camp in the area and, since Peregrine Falcons fledge and are near the eyrie during caribou hunting season, the bird may have been shot. There is a good possibility that more dead young were on or below other nesting sites. Time did not allow for thorough searches at other sites. This second critical period is not reflected in fledging success ratios and could be an important factor, considering the fact that 12% of the Peregrine Falcons which were assumed to have fledged in 1972 were found dead.

During the two year survey one other dead young was found. This bird was from a very late hatching egg (six days after the others). The small male lived until the age when the other young were tearing up and eating the birds brought in by the parents. At this point the selective feeding by parents ended and he apparently could not compete (Clement and Harris, pers. comm.). A management suggestion could be made here that when an extreme age difference is observed between hatched young at an eyrie, the odd individual be placed in another nest with young the same age.

Table 11

Nesting Site Productivity of Peregrine Falcons in the Study Area

Site Number	Production in 1972	Production in 1973
1	3 fourth young died at about 25 days after hatching	3
2	3 one young was found dead in 1973 and was about 30 days of age	3
3	3	1
4	0 prey remains, scrape and down from young were found but no young were present	4
5	1	3
6	1 addled egg collected	3
7	3 only one could be caught and the possibility does exist that more than the two others seen were present	2 a third late hatching young was present on the first visit but gone when revisited a short time later
8	3 addled egg collected that had been fertile and had fallen behind a rock	2 addled egg collected
9	0 only one falcon present	3

PREY SPECIES

Prey remains were collected from a total of 13 different nesting attempts. The remains consisted of wings, bones, feathers and pellets (an elliptical ball of feathers and some bones that many falconiforms cast up several hours after a meal). The amount and type of remains varied from nest to nest. The prey remains represent those species captured to feed the young peregrines, as well as what the adults are feeding on during the nesting season. This is verified by observations made (Clement and Harris, pers. comm.) where adults fed on food brought in for the young. One nesting attempt occurred where eggs were never laid. Prey remains were collected at this scrape and corresponded to those taken by other pairs feeding young.

Table 12 lists all birds observed within the study area. This list includes those birds which are prey species for peregrines nesting in the area, unusual species and species rare to the area. A long list of prey species has been compiled from many areas where the Peregrine Falcon has been studied (White and Cade, 1971). In the present study a much different food situation was found. There are only four small Passeriformes occurring regularly in the area; these include the Lapland Longspur, Snow Bunting, Wheatear (*Oenanthe oenanthe*)and Common Redpoll (*Acanthis flammea*). All four are summer residents arriving for the most part during May. After nesting they depart between the last two weeks of August and mid-October (refer to Salomonsen (1967) for additional information on these passerines). All four of these passerines are preyed upon by the Peregrine Falcons in West Greenland during the summer.

Table 12

Species of Birds Seen in Study Area During 1972-73 Research

(Alphabetical Order)

Common Name	Scientific Name	Abundance
Brent Goose	*Branta Bernicla*	uncommon (only one flock of 12 seen on migration)
Canada Goose	*Branta canadensis*	rare (one group of three seen)
Common Loon	*Gavia immer*	common*
Common Redpoll	*Acanthis flammea*	common**
Cormorant	*Phalacrocorax carbo*	common* (one colony in study area)
Glaucous Gull	*Larus hyperboreus*	common*
Grey Heron	*Ardea cinerea*	rare
Gyrfalcon	*Falco rusticolus*	common*
Herring Gull	*Larus argentatus*	rare
Iceland Gull	*Larus glaucoides*	common*
Ivory Gull	*Pagophila eburnea*	unusual
Lapland Longspur	*Calcarius lapponicus*	common**
Mallard	*Anas platyrhynchos*	common*
Northern Phalarope	*Lobipes lobatus*	common**
Northern Raven	*Corvus corax*	common*
Old-squaw	*Clangula hyemalis*	common**
Peregrine Falcon	*Falco peregrinus*	common*
Red-breasted Merganser	*Mergus serrator*	not unusual*
Red-throated Loon	*Gavia stellata*	common*
Rock Ptarmigan	*Lagopus mutus*	common**

Table 12 (Continued)

Species of Birds Seen in Study Area During 1972-73 Research

Common Name	Scientific Name	Abundance
Sabines Gull	Xema sabini	uncommon***
Snow Bunting	Plectrophenax nivalis	common**
Wheatear	Oenanthe oenanthe	common**
White-fronted Goose	Anser albifrons	common**
White-tailed Eagle	Haliaetus albicilla	not unusual****

*Birds which breed in study area

**Species eaten by Peregrine Falcons

***At least one and usually two of this species were seen regularly at a gull colony on the fjord during both years. It is not known is they are nesting in the area.

****Both immature and mature eagles have been seen within the study area. Three large stick-nests were found by aircraft on a section of cliff more than 120 meters high. However, time did not allow the checking of these nests to determine if the eagles were nesting there during the study period.

Another small avian-prey species is the Northern Phalarope. This bird arrives in large numbers in late May and populates most of the low altitude ponds and lakes. The phalarope is the first to migrate, and most of them have departed by the first day of August.

Also nesting on many ponds and lakes are the Old-squaws (Clangula hyemalis). These rather noisy Anseriformes break the arctic silence with their courting displays starting in late May when they arrive. Their arrival corresponds to the ice breakup on the lakes and fjords. The majority of these birds are present by mid-June and groups of six to ten can be seen perched on receding ice shelves that cover most lakes. Nothing, not even the calling of the White-fronted Goose (*Anser albifrons*) which nest in the area, can drown out the rhythmic chorus of the Old-squaws.

Rock Ptarmigan (*Lagopus mutus*) remains have also been found in a peregrine nest. This galliform is preyed upon heavily by the Gyrfalcon and probably comprises the main staple of its diet. The ptarmigan weighs approximately 5 g., which makes it a more difficult quarry for the small peregrine than for the larger Gyrfalcon.

As indicated earlier, no microtine rodents are known to exist within the study area. The smallest mammal present is the Arctic Hare. When young, it is preyed upon regularly by Gyrfalcons (Jenkins, 1974). These mammals weigh several kilograms and as an adult would be very difficult prey for peregrines. It is assumed, therefore, that only young animals are taken, and those probably only occasionally.

Approximately .7 of the Peregrine Falcon diet in the survey area was comprised of Lapland Longspur (Table 13). This brings up the question of whether peregrines hunt selectively to take this particular species or if they simply utilize the most abundant food source. To examine this question a small bird census was conducted within the research area employing the method used by C. White, T. Cade and J. Haugh (1967, unpublished data) on the tundra near the Colville River.

A total of 122 counts were taken during the 1973 portion of the research. Some counts which were taken in areas where no peregrines nested are not included and will be discussed later. Table 14 summarizes the small bird census and should be referred to as only portions of it will be discussed.

Table 13

Prey Species and Portion Taken

Nest Attempt	Lapland Longspur	Snow Bunting	Wheatear	Common Red Poll	Northern Phalarope	Rock Ptarmigan	Old-squaw	Arctic Hare
1	.7	.3	.1*	.1*	.1*			
2	.6	.3	.1			.1*	.1*	.1*
3	.9	.1				.1*		
4	.8	.2						
5	.6	.3		.1*	.1			
6	.9	.1			.1*			
7	.8	.2						
8	.8	.1				.1*		
9	.5	.2			.2	.1		
10	.5	.5	.1*		.1*			
11	.9	.1	.1*		.1*			
12	.9	.1*			.1*			
13	.9	.1						
Mean	.7	.2	.1*	.1*	.1	.1*	.1*	.1*

*Those species taken less than .1 of the time.

1.0 = total diet of the Peregrine Falcon during nesting season.

Table 14

Small Bird Counts*

Intermittent Counts**

	Lapland Longspur	Snow Bunting	Wheatear	Common Redpoll
Mean number of small birds seen in 1000 steps	4.89	.44	.44	.04
Approximate percent of small birds seen in 1000 steps	84%	8%	8%	1%
Maximum number seen during one, 1000 foot count	12	3	5	1
Minimum number seen during one, 1000 foot count	0	0	0	0

Standardization Count***

	Lapland Longspur	Snow Bunting	Wheatear	Common Redpoll
Mean number of small birds seen in 1000 steps	4.71	.32	.62	.13
Approximate percent of small birds seen in 1000 steps	80%	6%	11%	2%
Maximum number seen during one, 1000 foot count	19	4	9	4
Minimum number seen during one, 1000 foot count	0	0	0	0

*Mean number of passerines/1000 steps before hatching and early fledging = 5.96. Mean number of passerines/1000 steps after hatching and early fledging = 5.80. The decrease is felt to be due to the hiding of many unsure young and molting adults.

**Total Intermittent Counts = 5.82 birds/1000 steps.

***Total Standardization Count = 5.78 birds/1000 steps.

The small bird census does not indicate the number of waterfowl or phalaropes present in the survey area. No accurate way was devised to determine approximate numbers of ducks and phalaropes that summer in the area. The phalarope is quite abundant and more can be seen in a day than either Wheatears or Redpolls. Old-squaws are by far the most common duck in the region, and at certain times during the summer are more abundant than Redpolls.

Tables 13 and 14 indicate a small difference between prey availability and consumption. A slightly higher predation of Snow Buntings appears than was expected. This could possibly be explained by two functions. First, Snow Buntings tend to nest in very rocky areas and especially on escarpments. By placing their nests on these near-vertical surfaces and restricting their activities to the immediate vicinity, some may have been missed during transects. Second, the greater predation could be due to their contrasting plumage. With the white wing and tail feathers of these birds they do not blend into the dark background of the tundra as well as the longspurs. Peregrines in the survey area have been seen hunting from the nesting cliff and in pursuit of Snow Buntings nesting on the same cliff (Clement and Harris, pers. comm.).

The numerical values given for this study area can not be used to generalize for all of Greenland or even for coastal areas on the same latitude. According to Salomonsen (1950-51), the coastal areas are cooler and wetter in the summer, and this restricts the number of Lapland Longspurs, Wheatears and Common Redpolls that nest there. All three of these passerines prefer interior country. The Snow Bunting, Greenland's most abundant passerine, is the only small passerine whose numbers do not diminish substantially near the coast (Salomonsen, 1950-51). Both to the north and at higher elevations, a shift in passerine species and numbers is evident. As altitude is gained, the vegetation quickly affects the redpoll, which is dependent on vegetation for food and nesting. The longspur, preferring a mixed dwarf brush-heath, is also restricted by the diminishing density of vegetation.

POSSIBLE RESTRICTIONS IMPOSED BY PREY AVAILABILITY

The mean number of passerines per transect (27,000 $m.^2$) refers only to that portion of the survey area where falcons were found nesting (Table 14). The southwest corner of the survey area was a region where passerine transects taken had mean numbers of birds falling below 1.0. No falcons were found nesting in this area. Some of this area could be considered undesirable because of altitude and lack of cliffs; however, that is not the case for the total area. In 1969-70 two Peregrine Falcon nesting sites were reported there (Pen Brink, pers. comm.). These cliffs were checked along with the others in the area and no falcons were present. Several cliffs appeared quite desirable, according to information gathered from occupied sites. A number of the cliffs had both lichens and excrement present. Two pairs of ravens were found within the area. Not only was there a substantial decrease of small passerines but also a decrease in phalaropes, ptarmigan and ducks.

Transects conducted along the Colville River in Alaska by White, Cade and Haugh (1967, unpublished data) produced very different results. They conducted 23 transects with a mean number of 32 birds per transect. The maximum number per 1000 paces was 122 birds, while the minimum number was 10. When the species of birds seen during these transects is compared to prey items of the peregrines in the area (White and Cade, 1971) there is almost no difference. The transects do not reflect small mammal populations which are also raptor food items. With prey density this high, factors other than prey availability probably would limit that population.

Considering the vast difference in prey density between the Colville River (mean = 32) and inland Greenland (mean = 5.8) and realizing that the Greenland survey area has a slightly higher peregrine nesting density than the Colville River seems to question the hypothesis that peregrine density in Greenland is restricted by prey density. However, all parameters must be examined.

On the Colville River in Northern Alaska, Gyrfalcons have been found nesting within 36 m. of peregrines on the same cliff (White and Cade, 1971). On the Colville a wide variety of small birds, water birds, and microtines as well as ptarmigan are found. The prey density has been shown to be much higher in the Alaska area than in the Greenland study area. With a wide diversity and large number of prey species available to both Gyrfalcons and Peregrine Falcons on the Colville, it appears that food is not a restricting factor and allows the falcons to share nesting cliffs. The combined raptor density per linear km. on the Colville is 1 occupied territory per 2.5 km. The Greenland study area has a combined raptor density of 1 occupied site per 6.3 km. In West Greenland where prey variety and numbers are limited, these falcons must be more dispersed in their nesting to have an adequate food supply to reproduce. This not only indicates some interspecific competition between Gyrfalcons and peregrines, but also reinforces the statement that prey availability is a factor, perhaps the major factor restricting falcon density in the study area. If prey variability and availability resembled that found on the Colville River, then the two falcons would possibly nest on the same cliffs. Gyrfalcons nesting in Greenland use passerines as prey items for newly hatched young, and occasionally all during the nesting period. Foxes also place pressure on the passerines, and many longspur nests have been found destroyed by these predators. Nests of the other three passerines are usually placed above the ground and are not as easily reached by foxes. The low passerine density and species diversity combined with the pressure from not only peregrines but also Gyrfalcons and foxes helps to make prey availability a critical factor.

The southwest corner of the survey area further illustrates that prey density is a limiting factor by having low numbers of prey species and an accompanying lack of peregrines. During the two summers spent in Greenland, limited observations were made on both the east and west coastal areas. From these observations it appears that prey availability is also a critical factor on coastal areas. Unless a concentration of prey is available, such as sea bird colonies, I believe that coastal populations of peregrines will be widely dispersed throughout coastal areas (refer to Appendix).

INTERSPECIFIC COMPETITION AND INFLUENCING SPECIES

Two raptors nest in the study area, the peregrine and Gyrfalcon, with a third species, the White-tailed Eagle, occupying a cliff just over the northern perimeter. The Northern Raven, another large cliff-nesting bird which occupies the area, has been referred to as a functional raptor by White and Cade (1971). Because of the raven's occasional predatory role it could possibly be listed here as a raptor.

Each of the birds listed above may influence the nesting density of the others. White-tailed Eagles are not numerous anywhere in Greenland, so their effect on falcon density as a result of occupying cliff sites appears to be minimal at best. Ravens are very numerous in the survey area; there are in excess of 30 nesting pairs present. This bird is found nesting on the same cliff as both Gyrfalcons and peregrines. Nesting activities by ravens begin very early and eggs are laid before even the earliest nesting Gyrfalcons. Ravens do not appear to have a direct effect on peregrine density. Their diet is quite broad-based, and there appears to be little prey interaction. However, assuming that Gyrfalcons do not build their own nest, the Gyrfalcons would have difficulty finding favorable nesting sites in the study area without the raven's nest building ability. Ravens build a well constructed stick nest, usually under a substantial overhang of rock. All but two Gyrfalcon nests examined during the two years research was a stick nest that was probably built by ravens. If no stick nest had been present on the cliff, there would have been no suitable ledge sites with the type of overhangs that Gyrfalcons prefer.

Gyrfalcons appear to have the most direct influence on Peregrine Falcon density. As previously stated, in no case were peregrines and Gyrfalcons found successfully nesting on the same cliff in the study area. The only time the two were seen occupying the same cliff was in 1973 when a lone female peregrine was defending a section of cliff that the Gyrfalcons were nesting on (site no. 11). The peregrine occupied the site only from early to mid-June. Since essentially every adequate site was occupied by Gyrfalcons and peregrines, with ravens nesting near both and occupying undesirable escarpments, nesting may possibly be a limiting factor is suggested. Furthermore, when one considers that Peregrines and Gyrfalcons are not seen nesting on the same cliff it appears that the two species may have a mutually density-limiting effect.

Ptarmigan, the main staple of the Gyrfalcon diet, were not numerous and were very widely scattered. The Gyrfalcon's dependence for food on a bird so widely scattered may act to disperse the Gyrfalcons in comparison to the peregrine, which uses prey items with higher densities. Although the Gyrfalcon does rely heavily on ptarmigan it also preys on small birds, Arctic Hares, ravens and ducks. The Peregrine Falcon, taking mainly small birds with an occasional ptarmigan, has some diet overlap with Gyrfalcons. Hence, it appears some interaction exists between Gyrfalcons and peregrines for food items.

Although the peregrines maintain a slightly higher density than Gyrfalcons in the study area, I do not believe that peregrines physically displace the Gyrfalcons. Cliffs which had Gyrfalcons producing young in 1972 or that were occupied in 1973 by Gyrfalcons and vacant in 1972 did not have peregrines on them either year. Although the Gyrfalcons may not nest on a given cliff every year, they appear to maintain dominance over the area. By analyzing prey remains and observing a decreasing number of nesting Gyrfalcons and ptarmigan, the ptarmigan density seems to be the most influential factor in determining frequency of nesting and density of Gyrfalcons in the study area. Cade (1960) suggests that Gyrfalcons frequently did not breed in low prey years in Alaska. This also appears to be true for the Greenland study area; but even though the Gyrfalcons do not breed, they still occupy the area and influence the Peregrine Falcon nesting density and amount of prey. It would appear that they can maintain themselves with a limited prey supply, but because of energy expenditures in capturing small prey items they can not successfully reproduce.

The availability of nesting sites may also be a factor limiting density. If more cliffs occurred in the areas which have higher prey densities, then the peregrine density would possibly increase to the point at which prey species density was a limiting factor.

CHLORINATED HYDROCARBONS

An almost world-wide decline in breeding peregrines has been noticed in the last ten years. There is much evidence available to show a positive correlation between increased chlorinated hydrocarbon levels and Peregrine Falcon eggshell thinning, nesting failures and declines (Hickey, 1969; Enderson and Berger, 1968; Anderson and Hickey, 1972; Cade et al., 1971).

Two addled eggs were collected in 1972 from separate locations in the study area. These were analyzed and a mean of 332 ppm. lipid DDE was found (Walker et al., 1973). In addition, eggshell fragments of seven hatched eggs from six different eyries were collected. The mean thickness for the total number of eggs (nine) was 0.298 mm. ± 0.018 (95% C.L.: range 0.26-.33). When this measurement was compared with 42 peregrine eggs from Greenland that were collected prior to 1940 (0.347 mm. ± 0.018), a 14% decrease in eggshell thickness was noted (D.W. Anderson, unpublished data).

Eggshell thinning of the Greenland peregrine does not appear to be as severe as for some other geographical populations. In Ungava a decrease of 21% in shell thickness has been found (Berger et al., 1970) and a 20% decrease was noted for western United States peregrines

(Enderson and Craig, 1974). Both of these areas have experienced population declines. The amount of DDE contamination and eggshell thinning the Greenland peregrine presently is experiencing places that population at the critical point where an increase in the DDE levels would endanger the population (Walker et al., 1973).

Prey species of the peregrine were collected in areas where the falcon nested. Results of chemical analyses for DDE residues are given in Table 15. Lapland Longspurs (n=3) and Snow Bunting (n=1) collected from Amchitka Island, Alaska, were analyzed and had mean residue levels for DDE of 0.112 and 0.031 (ppm. net wt. basis) (White, Emison and Williamson, 1973). The mean levels for Amchitka birds are lower than for those collected in West Greenland. The Amchitka Lapland Longspur winters mainly in western North America while the Greenland birds move into eastern North America, with some overlap in mid-North America. The difference in DDE residue levels probably reflects the different types of agriculture employed between eastern and western America and the different amount of corresponding pesticide application.

Table 15

DDE Levels in Peregrine Falcon Prey Species

(residue concentrations are on a ppm. wet wt. basis)

Species	Number	Mean (ppm.)	Range (ppm.)
West Greenland			
Lapland Longspur	5	0.43	0.02-1.70
Snow Bunting	1	0.08	
Northern Phalarope	3	0.06	0.02-0.10

Table 15 (Continued)

DDE Levels in Peregrine Falcon Prey Species

(residue concentrations are on a ppm. wet wt. basis)

Species	Number	Mean (ppm.)	Range (ppm.)
East Greenland			
Lapland Longspur	1	0.04	
Snow Bunting	2	0.07	0.06-0.07
Wheatear	2	0.18	0.12-0.23

MOVEMENTS

The Peregrine Falcon is a highly migratory bird and after spending its summer months in Greenland goes south to Central and South America. Two peregrines which were banded in Greenland were recovered, one near Cienfuegos, Cuba, and another near the Windigo River in Quebec, Canada (Mattox et al., 1972). The bird in Cuba was found in December while the one in Quebec was recovered in October. There is a sizable peregrine migration observed on the east coast of the United States every fall, starting in late September and lasting through October (Ward and Berry, 1972). The bird recovered in Quebec was probably on its migration south. Two peregrines banded on Assateague Island in Maryland (U.S.A.) during October in 1956 and 1957 were both shot in Greenland. The one banded in 1956 was killed at 67° 50' N. in November, 1959, and the second, banded in 1957, was shot at 70° 40' N. in September of 1958 (Shor, 1970). It does not appear that all peregrines migrate from Greenland, however, as sightings have been made near Kap Farvel, Greenland's southern tip, during winter months (Salomonsen, 1950-51).

During 1972 and 1973 an attempt was made to band all young peregrines with Danish zoological bands to gain more information on their migratory habits, migratory pathways and age longevity. This required catching and handling the young peregrines. If these young are too advanced in age, premature fledging can occur, causing possible injury and death. Because of a desire to wait as late as possible to collect fledging data, and yet not cause premature fledging, an attempt was made to band and count the young as near to 30 days old as possible. Young leave the nest on their own or make the first attempts to fly at about 38 days of age. They will, however, flee from the nest at about 33 days old whenever approached. A total of 37 peregrines were banded which is more than had been previously ringed in Greenland.

SUMMARY

The Peregrine Falcons in West Greenland usually nest in the upper portion of large vertical escarpments with southerly exposures. The most constant feature of their nesting location in the number of hours of exposure to the sun that the scrape receives. The peregrines appear to desire the maximum protection the cliff offers as well as the maximum warmth that can be received from the sun. The exact location of the scrape is a compromise between these desires.

Within the study area the peregrine nests with a high density of one producing pair per 244 km.^{2} and a mean minimum distance of 7.7 km. between producing sites. The major limiting factor of peregrine density appears to be prey density. In certain areas where prey density decreased, peregrines did not nest even where adequate cliffs were available. Some overlap of prey does exist between Gyrfalcons and Peregrine Falcons and this could act as a secondary density-limiting factor. The Peregrine Falcon feeds mainly on small passerines taking that which is most abundant and, possibly, easiest to catch. The Gyrfalcon diet depends most heavily upon ptarmigan but this falcon also feeds on small passerines, especially when the Gyrfalcon nestlings are very small.

The productivity data indicate that during the two years the Peregrine Falcon produced at a high rate of 2.55 young fledged per producing site and 2.05 young fledged per occupied site. The productivity indicates a healthy population but substantial levels of chlorinated hydrocarbons exist in the Peregrine Falcons and a 14% decrease in eggshell thickness has been witnessed.

APPENDIX

During 1974 a third summer of research was conducted in West Greenland. The effort was concentrated in the Disko Bay area which is located between 69° 15' and 70° 15' N. latitude. The location is approximately 300 km. north of the 1972-1973 survey area and is a coastal location. The Disko area was selected because of availability of boat transportation and reports of nesting Peregrine Falcons (Salomonsen, pers. comm.). Local inhabitants were contacted for knowledge about known nesting locations of peregrines and Gyrfalcons. A total of 18 Gyrfalcons and six peregrine nesting sites were reported. Of these, 14 Gyrfalcon and five Peregrine Falcon nesting sites were examined. One of the five peregrine sites examined was occupied. The pair had four young, one of which probably did not survive to fledging. None of the Gyrfalcon nesting sites examined were producing; however, adults were found occupying the cliffs at many locations. Ptarmigan populations in the inland survey area and Disko Bay area appeared extremely low, the lowest seen during the three year study. Not seeing a single ptarmigan in a days walk was not unusual. Ptarmigan comprise a very large part of the Gyrfalcon diet. The lack of nesting Gyrfalcons was noted in the inland area as well as on the coast. A correlation between the non-breeding of Gyrfalcons and low ptarmigan density seems extremely likely.

A total of 395 linear km. of coastline was examined in the Disko Bay area. The 14 Gyrfalcon and five peregrine nesting sites were located within this area. If the nesting sites reported by local inhabitants are accurate, then the mean minimum distance between Peregrine

Falcon nesting sites is 55 km. This value is for those years that all five sites were occupied by falcons; a much more realistic value would be one pair per 100 km. (mean minimum distance between sites). The mean minimum distance between nesting sites for the inland area was 6.3 km. Two sites not occupied in 1974 were reported to have been in use in 1973. One of these two is an historical site, and peregrines were reported there in 1877.

The Peregrine Falcons at the active site were feeding almost totally on small passerines and only one ptarmigan bone was found from a previous year's use. The passerine density in the coastal area is extremely sparse with less than one bird per 1000 steps (using the 1973 prey density measuring parameters). The Lapland Longspur is not the predominant passerine in coastal areas as it is inland. Salomonsen (1950-51) states that the harsh, wet weather condition of coastal areas severely restricts small passerine species with the Snow Bunting occurring most often. Two reported peregrine nesting sites in the northern portion of Disko Bay were located only three km. apart and very near an alluvial flood plain. The flood plain had a high concentration (15 birds per 1000 steps) of Purple Sandpipers (Calidris maritima) with intermixed Ringed Plovers (Charadrius hiaticula). None of the peregrine nesting sites were located to take advantage of large Kittiwake (Rissa tridactyla) colonies or sea birds in the bay.

All available data suggest that small passerines and some waders comprise the bulk of the peregrine diet in the Disko area. Since peregrines take small prey in the Disko and inland area, the possibility exists that the peregrines in Southern Greenland also feed on small birds. If this is true then small passerine density is the major controlling factor of Peregrine Falcon density in Greenland.

The ratio of Peregrine Falcon to Gyrfalcon nesting sites in the inland area surveyed was approximately one to one. Using reported nesting sites, the peregrine to Gyrfalcon ratio for the coastal area is one to three. The mean minimum distance between Gyrfalcon nesting sites for the coastal area was 15 km. while inland it was 10.4 km. This shows a Gyrfalcon nesting density which is very similar for the two years.

Five of the 1972 and 1973 inland peregrine eyries were active in 1974. All nesting falcons were banded. On October 13, 1974, an immature male Peregrine Falcon banded in the inland area was trapped at Cape Charles, Virginia. This was the first peregrine banded in Greenland ever to be recovered in the United States.

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VITA

BREEDING BIOLOGY AND ECOLOGY OF THE PEREGRINE FALCON (*FALCO PEREGRINUS*) IN WEST GREENLAND

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ABSTRACT

During the summers of 1972-1974 research was undertaken on the Peregrine Falcon (*Falco peregrinus*) in West Greenland. The research was conducted inland (1972 and 1973) and in coastal areas (1974). The population in the inland survey area had a mean production for 1972 and 1973 of 2.55 young fledged per producing site and 2.05 young fledged per occupied site. The mean minimum distance between occupied sites for the inland area was 6.3 km. (one pair per 200 km.^{2}). If all known sites had been occupied in the coastal survey area the mean minimum distance between occupied sites would be 55 km. The Peregrine Falcon density was dependent upon prey availability while the effect of Gyrfalcon (*Falco rusticolus*) density has a secondary influence.

The peregrine nested on large vertical escarpments with southerly exposures. Nesting parameters were measured and the most constant requirement was the total hours of direct sunlight the scrape received. The total exposure to sunlight appeared to result from the falcons pla-cing their nesting scrape in a location which receives maximum warmth from the sun as we'll maximun protection from the cliff.

COMMITTEE APPROVAL