

Are Peregrine Falcons in Northern Siberia still affected by organochlorines?

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ABSTRACT

Tundra-nesting Peregrine Falcons *Falco peregrinus calidus* in Northern Siberia are highly migratory. In the face of uncertainty about their exposure to pesticides on their wintering grounds, the breeding density and success of Peregrines on the Taymyr peninsula was monitored in 1996-98. The number of occupied territories per 100 km of river surveyed in 1996-98 was 3-4 times higher on the Pyasina and Pura Rivers compared with similar data from the early 1970s. Egg hatching success and nest productivity from 12 occupied territories in 1996, 21 in 1997 and 15 in 1998 all suggested that the population is not currently obviously affected by pesticides. Blood plasma samples taken from 5 adult and 17 young birds were analysed for p,p-DDE, HEOD, p,pTDE, p,pDDT and the most toxic PCB congeners. Pesticides were virtually absent in three of the five adults. One of the remaining two had moderate levels of both PCBs and DDE while the fifth had moderate levels of DDE. There is no evidence to suggest that the Peregrine population in western Taymyr is currently adversely affected by pesticides, although nesting attempts may occasionally fail due to high pesticide loading amongst some individuals.

INTRODUCTION

Approximately 19 races of the Peregrine Falcon *Falco peregrinus* are distinguished world-wide. Five of these breed at high latitudes and are highly migratory. The breeding grounds of the migratory *F. p. calidus* race are in the Eurasian Arctic above 62°N and eastwards from the White Sea just east of the Fenno-Russian border (35°E) to the Lena Delta (130°E) (White & Boyce 1988). The remoteness of their breeding grounds has meant that there is little recent information concerning the population's biology and to what extent they are currently affected by pesticides.

Many of those Peregrine populations that were severely affected by pesticides in the 1960s and 1970s have now largely recovered (various studies in Cade *et al.* 1988; Crick & Ratcliffe 1995) but there is still much concern for populations either breeding or wintering in many, predominantly third-world countries. Concern is justified on the basis of a lack of even a basic knowledge of some of these populations, coupled with the fact that organic pesticides are still widely used illegally. In Russia's 'Red Data Book', the Peregrine was listed as a rare species of special concern (Flint 1978).

Galushin (1977) stated that there was a general consensus in Russia that there had been a rapid decline in Peregrine populations throughout the USSR, although there are few data to demonstrate this. Kucheruk *et al.* (1975) found that six sites known to be occupied on the Yamal in the late 1930s were all empty in 1973. Significant egg-shell thinning was reported from Siberian eggs collected in the early 1960s and the presence of DDE in the shell membranes suggested the likely cause (Peakall & Kiff 1979).

There is little published information concerning the present status of Peregrines in Russia. Potapov (1996) sent a questionnaire to Peregrine workers throughout former member states of the USSR and found some evidence of a widespread decline, although he pointed out that monitoring was sporadic. Henny *et al.* (1994) found that presumed *calidus* Peregrines on the western edge of their range were breeding well and had variable, but low, levels of pesticides in 1991. Potapov (1994), however, recorded poor breeding success and high pesticide levels in a population of a different migratory race in eastern Siberia in the 1980s. In other parts of the world there is still evidence that organochlorine pesticides are affecting Peregrines. Egg shells from *F. p. tundrius* in Arctic Canada still have high levels of DDE which they get from prey on the wintering grounds in Central and South America where organic pesticides are poorly controlled (Johnstone *et al.* 1996).

In an attempt to assess the health of the *F. p. calidus* population in western Taymyr, their breeding density and success was studied from 1996-1998. The importance of this basic information is well illustrated by the statistics from Britain during the pesticide crash. Here territory occupancy in 1962 was down to 56% of the 1930-39 average, just 21% of territories produced young and fledging success was much reduced. To examine evidence for a long term change in the breeding density of Peregrines in Taymyr, we merge our data with those collected by others over the last 20 years and collated by Kokorev (1995). In addition, blood samples were taken from adult and young birds to determine levels of key pesticides, a less than ideal but nevertheless useful indication of likely pesticide levels in the eggshells themselves (Court *et al.* 1990; Johnstone *et al.* 1996).

STUDY AREA

The Taymyr Peninsula is the most northerly part of the Eurasian continent and stretches from 71° to 78° North, and 80° to 114° East. The study area was along 270 km of waterway in the Pura basin (including the Bystraya, Mala Bystraya, Buotangkaga tributaries) and 800 km of the Pyasina River (Fig. 1). The length covered in any one year varied. Taymyr shows the full range of geobotanical zones from polar desert to sub-arctic areas (Andreev & Aleksandrova 1981). Most of the study area is located in the southern Arctic zone of the tundra which is typically dissected by rivers and lakes flowing through loamy substrates. The upper reaches of the Pyasina River run through shrub tundra and, near Norilsk itself, the edge of the northern forests.

METHODS

Nest separation and density

Peregrines in most parts of the world usually nest near water (Ratcliffe 1993). This is supported by extensive surveys in Taymyr by one of us (YK). In parts of Alaska, however, it has recently been found that, as Peregrine density increased to levels higher than ever previously recorded, they began to occupy sub-optimal sites several kilometres from the river where they were once thought to be absent (T. Cade, *pers. comm.*). It is thought that densities in Taymyr are a lot lower than in Alaska and that such sub-optimal sites are not used in Taymyr. Searches for eyries in Taymyr were therefore limited to the banks of the main rivers and some of their tributaries.

Nest spacing and density estimates were calculated for 1997 when 1,050 km of river were surveyed. Locations where Peregrines were seen but where no nests were found were assumed to be territories where a nesting attempt had been made, if the habitat was suitable. Early-failed territories on the Pyasina may have been overlooked although on the Pura river, failed breeders normally stayed on their territories for most of the summer. To facilitate comparison of abundance found in

other areas, territory spacing was estimated in three ways by calculating: 1) the distance travelled along the river (DAR) between nests (starting from the mouth of each river, heading upstream); 2) the straight line distance (SLD) between nests on any given river (distances were not calculated between nests on different rivers; map used had scale 1:100,000); and 3) the linear density, i.e. the number of pairs per 100 km surveyed.

Detailed information on Peregrine abundance before the pesticide era was not available. Using data collated by Kokorev (1995), it was possible to compare linear territory densities estimated in this study for the Pura and Pyasina Rivers separately with estimates from the 1970s and 1980s. An estimate was included only when more than 100 km of river was surveyed on any one river in a given year. Data from 1998 on the Pura and 1996 from the Pyasina were much less comprehensive than in other years and were excluded from the comparison. Mean annual lengths of river covered for each river basin were as follows: Pyasina (mean 322 km, range 170-542 km) and the Pura (mean 219 km, range 140-288 km). Additional data are presented from the Agapa, a tributary of the Pyasina, (mean 194 km, range 100-450 km).

Detailed information on individual territory occupancy in any given year for the study area was not available so territory occupancy in the usual sense of the phrase could not be calculated. It was known, however, where eyries have been located in the Pura basin at some stage during the last 25 years. Our estimate of territory occupancy, therefore, reflects the proportion of possible territories currently occupied rather than the proportion that have ever been occupied in any one year. It is perhaps best viewed as an indicator of whether the current population is close to carrying capacity. Possible territories had to be more than 3 km apart to be classified as separate territories; those less than 3 km apart were classified as alternative eyries within the same territory.

The key physical features of nest-sites selected by Peregrines were also described to help assess, albeit subjectively, whether density within the area was likely to be restricted by the availability of nest sites.

Breeding success

A sample of nests was checked during incubation to record clutch size when the rivers became ice-free in early July making travel by boat possible. Brood size was recorded close to fledging time in 1997 (from 7-19 August); in 1996 and 1998 it was recorded when the young were at least two weeks old (late July). Although the available evidence suggests that most nest mortality in Peregrines occurs during incubation and early brood-rearing (Ratcliffe 1993), Peregrines bred 2 weeks later in 1998 than in 1996. This may have had a significant impact on survival of young owing to reduced availability of prey in late seasons. Nesting success was expressed in terms of 1) the numbers of young per successful nest and 2) the number of young per occupied territory. The latter was a conservative estimate because it included territories in which no eggs were laid and territories in which only a single bird was recorded.

Pesticide analysis in blood lipids

Blood samples were taken from the brachial vein of five adult falcons and 17 nestling falcons (2-6 weeks old). Mammals are thought not to accumulate organochlorines which means that blood samples taken from the young of lemming specialists, like the Snowy Owl and the Rough-legged Buzzard, should make a good control for contamination from other sources (e.g. Johnstone *et al.* 1996). Blood samples were taken, therefore, from three Snowy Owl and two Rough-legged Buzzard chicks. These 1-1.5 ml blood samples were stored initially for 1-2 months in sealed heparinized containers and preserved with several drops of formalin solution. They were later sent for analysis to the Institute of Terrestrial Ecology, Monks Wood, using Gas Chromatography (GC) with Electron Capture Detector in four different batches. Full details of how the samples were prepared and cleaned can be obtained from ITE, Monks Wood or from the authors on request.

Within each batch, a duplicate sample of blood was spiked with each organochlorine tested (i.e. the analyte), with concentrations varying from 0.1 to 1 µg and percentage recoveries measured. The number of different organochlorines used in the first two batches collected in 1996 was 15 and 30 in

Figure 1. Map of the Taymyr Peninsula showing the location of the Pyasina, Pura and Agapa Rivers. The 100°E line of longitude and 75°N line of latitude are shown.

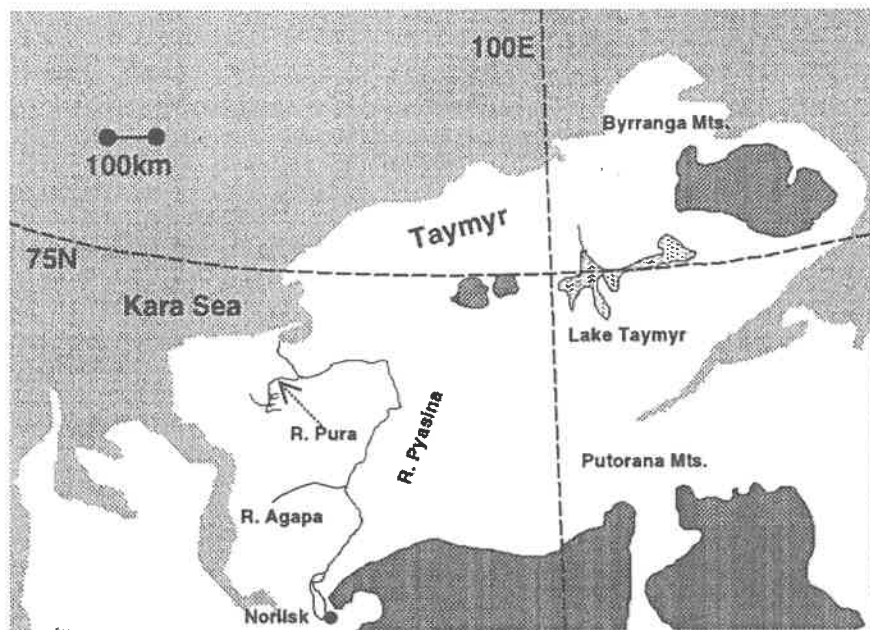
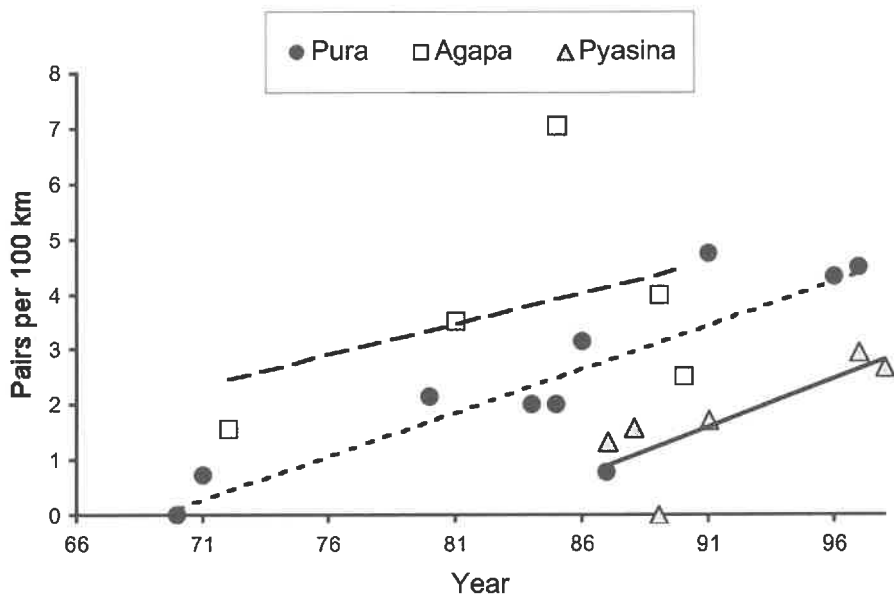


Figure 2. Numbers of occupied Peregrine territories per 100 km on the Pyasina, Pura and Agapa rivers in selected years over the period 1969 to 1997. The lines indicate the best-fit through the points.



the second two from 1997. A blank sample was spiked with each analyte which was then extracted and cleaned using the same procedure as for the real samples. Details of how the GC was calibrated and how the compounds were identified can be obtained from ITE, Monks Wood or from the authors. Individual Chlorobiphenyl congeners are numbered according to Ballschmitter and Zeil (1980) and include the primary list agreed for monitoring purposes by the International Council for the Exploration of the Sea (ICES). Limits of detection (LOD) were determined by analysing seven sample blanks and calculating the mean + 3 x standard deviations of the blank signals. LODs are expressed as total micrograms in the whole extract. For any given sample where an organochlorine was not detected, the LOD was calculated by dividing the given LOD for that compound by sample weight, the result representing the maximum level of that specific organochlorine that could have been in the sample but was not detected.

RESULTS

Territory spacing and occupancy

The average distance between occupied territories was 29.2 km along rivers or 3.37 territories per 100 km and 23.1 km in a straight line (Table 1). Territories were unevenly distributed within rivers. Large stretches held no eyries at all while others held clusters. Eyries on the Pura river were closer together (20.7 km) than on the Lower and Middle reaches of the Pyasina (36.1 km). There were no eyries on the Pyasina River south of 71°40'N to Norilsk, largely because the riverbanks were gently sloping and did not provide suitable habitat for Peregrine eyries. There was also considerable variation within each river, especially on the Pura where the DAR in section 1 was 7.2 km compared to 49 km on the rest of the river. One small stretch of the Pyasina held five pairs separated by an average DAR of 8 km compared to an average of 38 km for that whole section.

Table 1. Distance along rivers (DARs) and straight line distances between occupied Peregrine territories on the Pura River, selected tributaries and on the Pyasina River in 1997.

	<i>Total</i>	<i>Pura Basin</i>	<i>Section 1</i>	<i>Section 2</i>	<i>Tribut- aries</i>	<i>Lower and Middle Pyasina River</i>	<i>Lower Pyasina</i>	<i>Middle Pyasina</i>
<i>Distance along river</i>								
Mean (km)	29.2	20.7	7.2	49.0	19.3	36.1	35.4	38.0
Standard Error	4.7	6.3	2.5	13.9	7.2	6.5	8.3	9.8
Minimum	1	1.0	1	26.0	5.0	2.5	2.5	21
Maximum	90	74	16	74	28	90	90	66
Count	27	12	6	3	3	15	11	4
<i>Straight line distance</i>								
Mean (km)	23.1	15.6	6.3	34.5	15.3	27.6	27.9	26.8
Standard Error	4.2	4.9	2	14.8	5.5	6.0	7.2	12.2
Minimum	2	1	1	17.5	4.5	2	2	10
Maximum	80	64	13	64	22	80	80	63
Count	27	12	6	3	3	15	11	4

Of all eyries ever occupied in the Pura basin and lower Pyasina in the past, 60% were occupied in 1996 (n=20 territories checked), 63% in 1997 (n=24) and 67% in 1998 (n=15) (Table 2). The trends in number of pairs per 100 km were plotted against time for three rivers (Fig. 2). Data from at least two of the three rivers suggested an increasing trend in the breeding Peregrine population. In the Pura basin, there was less than 1 pair per 100 km in 1970 and 1971. By the early 1980s this

Figure 3. Features of Peregrine Falcon eyries in Taymyr, 1996-97.

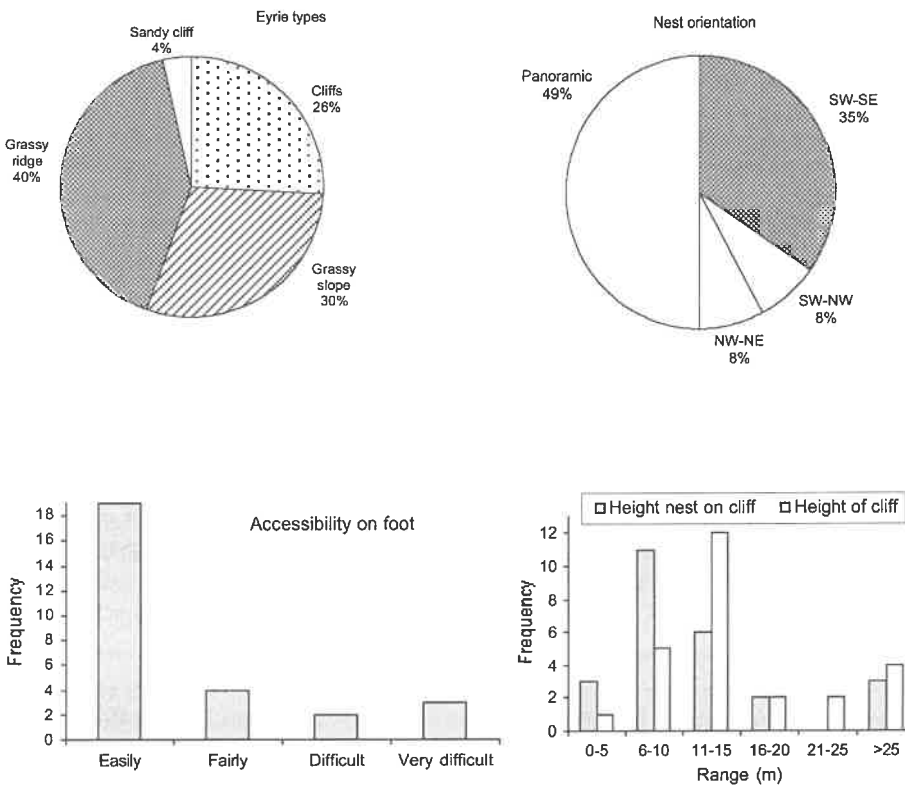
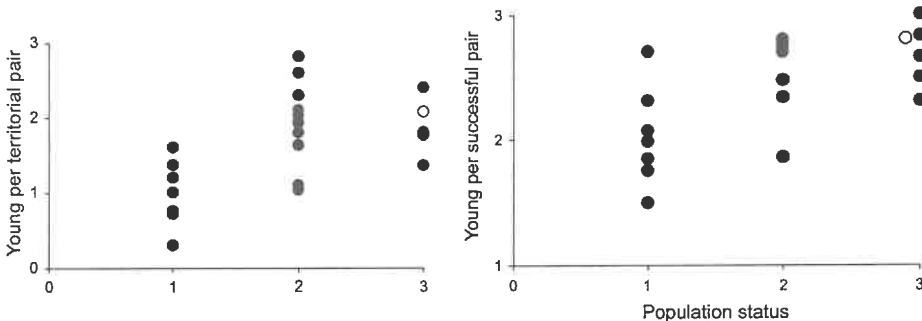


Figure 4. Breeding success of Peregrines in the Pura and Pyasina basins in 1996-98 (open circles, mean value, n = 3 years) compared with that found for other populations categorised into those thought to be depressed, recovering or close to normal (population status = 1, 2 or 3) as listed in Appendix 2.



increased to just over 2 pairs per 100 km and to 4-5 pairs per 100 km by the 1990s. Data from the Pyasina were available only from the late 1980s when densities were very low - fewer than 2 pairs per 100 km - compared to the almost 3 pairs per 100 km recorded in 1997. Data from the Agapa are less numerous and clear-cut. The general trend is increasing but an exceptionally high density was recorded in 1985 when 13 territories were found along 184 km. In other years, 3-4 territories per 100-114 km were recorded so a likely explanation is that the extra 70 km of river or so surveyed in 1985 held an unusually high density. The very low density recorded in 1970 was likely to be an accurate estimate because 450 km of river yielding just seven territories were surveyed. Except for 1985, it seems that densities on the Agapa increased from 1-2 territories per 100 km in the 1970s to 3-4 in the 1980s. In general, linear densities increased by about 3-400% from the 1970s to the 1990s but appear to be currently stable.

Table 2. Breeding productivity in Taymyr Peregrines in 1996 and 1997. "n/a" = not available.

Year	River basin	Terri-tories checked	Territories occupied (pair/single)	Clutch size	% Eggs Hatched (no. eggs)	Terri-tories successful (%)	Young per occupied territory ²	Young per successful territory
1996	Pura & Pyasina	20	12 (60%)	3.50±0.29 (4)	85 (14)	67	1.92±0.43 (12)	2.88±0.23 (8)
1997	Pura & Pyasina	n/a	n/a	3.50±0.22 (6)	95 (21)	81	2.24±0.30 (21)	2.77±0.22 (17)
	Pura	24	13 (63%)	n/a	n/a	84 ¹	2.33±0.53 (9)	3.00±0.38 (7)
	Pyasina	n/a	15	n/a	n/a	77	2.17±0.37 (12)	2.60±0.27 (10)
1998	Pura & Pyasina	21	17 (81%)	3.50±0.27(8)	86% (28)	73	2.0±0.38 (15)	2.73±0.27 (11)

¹ Includes two territories occupied by lone male falcons. Both females from these territories were satellite tagged in 1996; one probably died or was trapped on migration, the other was trapped. It is assumed that both would have bred successfully in 1997, had they not been tagged in 1996.

² Including territories occupied by lone birds.

Eyrie description

Of the seven eyries on the Pura River where eggs were laid in both 1996 and 1997, only one laid in exactly the same nest. The others moved distances of between 2 m and 1,500 m (mean 450 m ±200, SE). Twenty-six percent of all eyries (n=28) were on rocky cliffs but 41% were on sandy or grassy, river-bank ridges that normally ran perpendicular to the river and 30% were on grassy slopes (Fig. 3). Eyries were on average 20 m from water at time of survey and 6m from the highest spring water level mark (medians; n=29). Cliff or river-bank height on which eyries were located varied considerably from 3 m to 45 m (median 14 m) and the median location of nests on the cliff was 10m high. Sixty-four percent of eyrie-cliffs (n= 31) faced in a southerly and just 4% in a northerly direction. No nests faced in a northerly direction; the majority were on the tops of ridges (50%) or on south-facing slopes (35%). Eighty-two percent of nests were either easy or relatively easy to approach on foot from some angle while 11% were inaccessible on foot. Although many of the nests were accessible, this was normally only from a limited area around the nest. On average, nests were easy to approach over an angle of 20° (median; n=25). In summary, although there was a general tendency to avoid north facing slopes, eyries were found in a very wide variety of nest site types.

Breeding success

Mean clutch size (excluding pairs that laid no eggs) was 3.5 in all years (Table 1). Eighty-five percent of eggs that laid in 1996 (n=14) hatched successfully, 95% in 1997 (n=21) and 86% in 1998 (n=28). Of the 3 eggs that did not hatch in 1996 and 1997, one had broken from an unknown cause while the other two were unhatched. Most nests had very young nestlings by the second week of

July in 1996, by the first week of July in 1997, and by the second-third week of July in 1998. This suggests that clutches were completed in early June in early years and mid June in late years.

The percentage of occupied territories in a year that produced young to at least two weeks of age varied from 67% to 81% (Table 1). The number of young produced per successful territory was 2.88 (n=8) in 1996, 2.77 in 1997 (n=17) and 2.73 in 1998 (n=11) (Table 1), of which 43% (n=23), 36% (n=42) and 43% (n=30) were males respectively. The number of young per occupied territory was 1.92 (n=12), 2.24 (n=21) and 2.0 (n=15). Comparing the number of young per occupied territory on the Pura River, which is almost totally undisturbed, with the number on the Pyasina River, where hunter-fishermen operate on the rivers every 50-100 km, showed there was no difference between the two in 1997 (two-tailed $t=0.80$, $P=0.26$, $df=15$). The same was true for the number of young per successful territory ($t=2.18$, $P=0.87$, $df=12$).

Blood samples

One of the five adults (a male) had high levels of both DDE (3.31 ppm) and PCBs (4.1 ppm), another female had high levels of DDE (1.45) and the remaining three were almost totally clear of all organochlorines (Appendix 1). Male 92-1 bore the heaviest pesticide loading and tested positively for 22 of the 30 individual organochlorines tested. Spiked recoveries of samples taken from adults that contained high levels of pesticides were poor and the correction factor was therefore high. Whether or not this affected the accuracy of the test is unknown but caution should be exercised in interpreting these results.

DDE was detectable in very small amounts (0.01-0.09 ppm) in eight of the 17 juvenile falcon plasma samples and in one of the five control samples (0.03 ppm). Similar levels of HEOD were present in 7 young falcons but PCBs were almost totally absent from young falcons and control samples. Most of the young falcons that tested positive for HEOD and DDE were sampled when 4-6 weeks old (in 1997) while the falcons that tested negative were sampled when 2-3 weeks old (in 1996). Given that organochlorines are stored cumulatively, this may explain why the 2-3 week old young from 1996 tested negative.

DISCUSSION

Territory spacing and density compared to other countries

Peregrines in Taymyr occur in moderate density when compared to other parts of the world. Coastal populations in North America are particularly high, presumably because both food and suitable nest sites are more abundant. In the Keewatin district, Northwest Territories, for example, it was estimated a Peregrine territory was found in every 17 km² pair⁻¹ (Court *et al.* 1988) compared to 406 km² pair⁻¹ in this study (Quinn & Kokorev, in prep.). Various other higher estimates in Appendix 2 (from 186-285 km² pair⁻¹) are associated with coastal areas. It remains to be seen whether similar high densities are found on the Siberian coast. Density estimates for temperate Britain (21-119 km² pair⁻¹) are also much higher (Ratcliffe 1993) for similar reasons.

Pre-pesticide crash DAR estimates for the Colville and Yukon Rivers in the Alaskan interior (9.5 km and 20 km) suggest a higher density than most of the Pura and Pyasina where such high densities were found only on two small stretches of river. However, Cade's equivalent area per pair estimates were only 520 km² pair⁻¹ and 775 km² pair⁻¹ respectively, compared to 406 km² pair⁻¹ in Taymyr. The difference was presumably due to a lower density of rivers than in Taymyr. Based on data from several different areas in Taymyr from the 1970s and 1980s when the population was depressed, Yakushkin *et al.* (1993) estimated a density of 1,200-1,250 km² pair⁻¹. In Southern Yamal in the late 1980s, Mechnikova & Gizzatova (1991) estimated a density of 270-416 km² pair⁻¹ and Morozov (1991) estimated 592 km² pair⁻¹ in the Bolshezemel'skaya tundra (NE Europe). It is not clear whether comparisons between different studies are entirely valid because not all describe exactly how the estimates were made. Our estimate, nevertheless, agrees with those found in other parts of Siberia when the population was thought not to be depressed by pesticides.

Population trend: evidence for a recovery

The trends in nest density suggested that Peregrines were almost absent from western Taymyr in the early 1970s but that the population has increased substantially since then. No detailed information on densities has been published from Taymyr pre-1970s. Kretschmar and Leonovich (1967) found that eyries 'in some parts' of the Pyasina basin in 1960-62 were on average 7-10 km apart. Such high densities were also found on two stretches in 1997 so it is quite likely that population density today is not greatly different to the early 1960s. Similarly, territory spacing estimates from other parts of the *F. p. calidus* range before the pesticide crash are like those found in the Pura and Pyasina basins today. In the Lower Lena basin during the early 1960s, DARs were 10-20 km, similar to the best areas on the Pura and Pyasina in 1996-97, and on the Upper Lena, densities were similar (20-40 km) to the whole study area (Uspenskiy *et al.* 1962). Dementiev (1951) gives straight line distances between nests in Kolyma (north-eastern Siberia) and southern Yamal Peninsula (west of Taymyr) of 15-20 km, suggesting a slightly higher density than that found in Taymyr today.

It is difficult to say to what extent the increasing trend in western Taymyr reflects the situation in other parts of Siberia. Morozov (1991) estimated that 65-75 pairs nested in 41,500 km² in the Bolshyezemel'skaya tundra (NE Europe) or 592 km² pair⁻¹ compared to 406 km² pair⁻¹ for the Pyasina basin in 1997 (Quinn & Kokorev, in prep). On the Yamal Peninsula, Kucheruk *et al.* (1975) reported that Peregrines were absent from former historical haunts but, by the late 1980s, Mechnikova and Gizzatova (1991) found densities that suggested a recovery. Recent reports from expeditions to several other parts of Northern Siberia suggest good numbers of Peregrines (Lower Kolyma, NE Yakutia, Sokolov 1994; Lena Delta in 1997, Zockler *pers. comm.*; Logata River in 1997, eastern Taymyr, Aarvark *pers. comm.*). Peregrines were thought to be absent from Vaygach Island in the 1980s but 10 pairs were recorded there in the early 1990s (Morozov, *pers. comm.*). It seems, therefore, that the recovery has been widespread.

Kretschmar and Leonovich (1967) showed that Peregrines were still common on the Pyasina in the early 1960s. This suggests that the population crashed in the mid-late 1960s since active eyries were almost absent in 1971 from the same area. The timing of the decline in other parts of the world varied considerably. In North America, Peregrines were extinct over much of its range by 1965. Declines occurred later in areas where DDT was introduced later. For example Alaskan Peregrines that winter in Central and South America did not show a decline until after 1967 (White & Cade 1977) and it is probable that the decline in Siberian Peregrines also lagged behind that observed in the USA and western Europe.

Although the population on the Pura River seems to have stabilised, just 60-70% of territories that have ever been occupied are occupied today, perhaps suggesting a population below carrying capacity. The latter does not rule out the possibility that the population has returned to pre-pesticide crash levels but other limiting factors may be in operation. In Britain, for example, the number of territories occupied today is even higher than before the pesticide crash (Crick & Ratcliffe 1995) when, it is suggested, the population was held below carrying capacity through the effects of persecution. The population in Taymyr may well be still limited by another similar density independent factor. A lack of suitable nesting sites is unlikely to be one of these because we found that Peregrines nested in a wide variety of habitat types, many of them a seemingly unusual choice given the surrounding habitat. In one case Peregrines chose to nest on an accessible, unstable scree slope instead of an inaccessible cliff ledge overhead. It is more likely that winter mortality, trapping pressure on migration or food availability is important in limiting Peregrines in Taymyr.

Reproductive success

Clutch size estimates for Taymyr are similar to those found in other parts of the world (Appendix 2). In itself this says little about the exposure of birds to pesticides because other studies have shown that clutch size changed very little during the pesticide crisis. The proportion of eggs that hatch successfully is a better indicator. In Northern England and Southern Scotland, 36% and 48% of eggs laid failed to hatch at the height of the pesticide crisis in the 1970s respectively compared to 23% and 26% in the 1970s and 27% and 32% in the 1980s (Ratcliffe 1993). In this study 91% of eggs

hatched successfully suggesting that pesticide-related egg-shell thinning is not a current problem.

Ratcliffe (1993) suggests that mean fledged brood size was a good indicator of the health of the British population over the last 40 years. The estimate of 2.6-3.0 young per successful brood in this study is similar to the highest estimates from other parts of the world not affected by pesticides. Typical brood sizes from North America were from 2.6-2.8 young per successful pair when the population was not affected by pesticides, and 2.0 or less during the height of the pesticide crisis (Fig. 4a, Appendix 2). In Ungava Bay, Quebec, brood sizes were 1.71-1.78 during the pesticide crisis in 1970 and 1975 but from 2.36-3.21 during their recovery from 1980-85 (Bird & Weaver 1988). On the Colville river in Alaska, mean brood size from 1969-79 was 1.98 but 2.75 from 1980-85. Similar figures for the Yukon River in Alaska were 1.85 and 2.47 (Ambrose *et al.* 1988). The only data we could find from Russia that suggest a decline in breeding success was from Yamal. Osmolenskaya (1948) reported a breeding success of 2.7 young per nest in the early 1940s but Kalyakin (1983) recorded a breeding success of just 1.5 young per nest. From 1988-90 breeding success of Peregrines on Yamal increased again to 2.54 young (Mechnikova & Gizzatova 1991).

The number of young per occupied territory, as opposed to per successful pair, is thought to be a better indicator of a population's health. Once again the estimate for Taymyr in 1996-97 of 2.1 is similar to (if not higher than) healthy populations in other parts of North America (Fig. 4b, Appendix 2). For example, estimates for the depressed and recovery periods were 0.75 and 1.64 for the Colville, and 1.2 and 1.8 for the Yukon Rivers in Alaska (from Ambrose *et al.* 1988). Values below 1.5 were associated with populations suffering from exposure to pesticides. The breeding success of Peregrines in the Pyasina basin in 1996-98, therefore, suggests that the population is not currently seriously affected by pesticides.

Pesticide levels

Most published information on pesticide loading in birds of prey relates to residues in the lipid membranes on the insides of eggshells. Little has been published on residues in blood plasma and we have had to limit our discussion to DDE and PCBs. Organochlorines in blood plasma are thought to be a good predictor of organochlorines in the internal organs (Henny & Meeker 1981) but there is uncertainty as to how well they predict levels in egg membranes. Court *et al.* (1990) found the two were not very strongly correlated in individual Peregrines ($r = 0.66$) although Henny and Meeker (1981) did find a stronger correlation in other small raptors. Court *et al.* (1990) suggest that, despite these doubts, mean values derived from large samples taken from a large number of individuals should give an indication of pollution burden at the population level.

The mean DDE level in adult Peregrines from this study was 0.95 ppm ($n=5$) compared to 0.8 ppm in Peregrines in Rankin Inlet (North West Territories) during 1981-86 and 0.5 ppm during the early 1990s (Court *et al.* 1990; Johnstone *et al.* 1996). Maximum values obtained in 1981-86 were much higher (up to 8.2 ppm for males and 6.6 for females) than the 3.3 ppm in this study. They concluded that the average DDE levels in plasma samples from their study were representative of a population that did not face a critical pollution problem but that some of the nesting failures they witnessed could have been due to organochlorine poisoning. They also suggested that the high levels found in some of their birds could lead to direct mortality of adults in times of stress. We conclude the same is likely to be true of Peregrines on the Pura and Pyasina Rivers while acknowledging that our sample sizes are much smaller than those of the other studies and that more samples are needed. Some breeding attempts may fail due to pesticide poisoning, although the high hatching success we observed suggest these are infrequent. We cannot assume that the same conclusions can be made about *F. p. calidus* populations elsewhere because they have such a wide wintering range (see Eastham *et al.* this volume). Furthermore in North America it was found that individual populations of *F. p. tundrius* had markedly different pesticide burdens (Johnstone *et al.* 1996).

PCBs were virtually absent in young Peregrines and the control species, as they were in the Rankin Inlet birds during the 1980s but not in the 1990s. They were detected in significant quantities in one adult (4.1 ppm) and the mean value for five adults was 0.83 ppm. Although our sample size is very small, it suggests that PCB levels in Taymyr Peregrines may be twice as high as in those in Rankin Inlet (Court *et al.* 1990) and several times higher than in Greenland Peregrines (Jarman *et al.*

1994). PCB residues in eggshells have been implicated in nesting failure but it is not known how they relate to levels in blood plasma. As for DDE, we suggest that these levels are also not obviously damaging the productivity of the population in western Taymyr but future monitoring would be wise.

The very low levels of organochlorines detected in young Peregrines and their absence in the control species suggests that most of the pesticides found in adults originate primarily from prey taken on the wintering grounds and not from migratory prey species in the Arctic.

Reasons for population changes

In Russia, some believe that disturbance has been a significant factor in the decline of Peregrines (Borodin 1984). Kokorev (1995) felt that local declines in Taymyr Peregrines were primarily related to disturbance. Certainly river traffic is now lower in the Pyasina basin than it has been for many years (Kokorev, pers. obs.) and official protection measures, for example the creation of several reserves throughout Taymyr, have undoubtedly helped in the recovery of Peregrines. Given the inaccessibility and remoteness of the entire peninsula, however, and the fact that Peregrines are tolerant of some disturbance (Ratcliffe 1993), it is unlikely that disturbance had a major influence on the decline. The sheer width of the rivers means that obvious disturbance would only occur if boats landed on or near the river banks beside the eyrie, although for the last three weeks of the nestling period, Peregrines react to boats from a greater distance. On the Pyasina and Pura rivers, we found that most hunter-fishermen were aware of local 'Sapsan' eyries and on one occasion knew how many young were in the nest. Some were also aware of their potential monetary value but there was no evidence that any eyrie had been interfered with in any year.

The trapping of falcons for falconry has occurred in Asia for many hundreds of years. Traditional levels of falconry are intuitively sustainable provided the population is not under any pressure from other factors, yet little is known about the actual impact of falconry on Peregrine populations. Remple (1988) postulated that 3,000 falcons are "kept" annually on the Arabian Peninsula, approximately 30% of which are Peregrines (some of which belong to the *calidus* race). He suggests that traditionally about 60% of all falcons are released each spring, although the general consensus amongst concerned delegates at this conference was that this practice is rare and it seems that falcons may well suffer high mortality in captivity. EWRDA is currently conducting tagging studies of *calidus* Peregrines in Taymyr and elsewhere in an attempt to assess the impact of trapping on the population (Eastham *et al.*, this volume).

There is no reason to believe that trapping pressure has increased this century and, therefore, pesticides undoubtedly played a major role in the decline. Galushin (1977) believed pesticides were at least partly responsible for the then suspected decline. The timing of the decline in Peregrine populations in Taymyr seems to have coincided with the pesticide-induced decline observed elsewhere but this has not been fully established because it is based on scant data. It is likely that the timing of the decline varied geographically. There is some evidence of egg-shell thinning amongst museum egg specimens collected from Siberia in the early 1960s (Peakall & Kiff, 1979) although it is suggested in this paper that the densities of Peregrines on the Pyasina were similar in the 1960s to today. Critically high levels of DDE were found in Peregrine egg-shells collected from Kolyma in eastern Siberia in the 1980s (Potapov 1994) when the population was beginning to recover in Taymyr, although the birds in Kolyma were from a different race. More recently Henny *et al.* (1994) reported variable, but generally low, levels of organic pesticides in migratory Peregrines on the Kola Peninsula in north-western Russia and that the population was recovering.

Pesticides have been widely used throughout Asia but in the last ten years their use has been controlled in many countries like India and Pakistan. Some pesticides intended for malaria control are believed to be sold on the black market but it is unlikely the level of usage is anywhere near as high as in previous decades. Nevertheless it was noticeable that there is a distinct lack of precise information on the level of POP usage in Asia and it is suggested that there is a clear need to review the current situation throughout Asia.

One other factor could theoretically have at least contributed to a large scale decline in the *F. p. calidus* population. Ratcliffe (1993) mentions that some high altitude nesting Peregrines in Britain

fail to breed if their haunts remain snow bound late in the season. In the Canadian Arctic it was found that high variability in breeding success over a 13 year period was associated with severe weather (Bradley *et al.* 1997) although apparently even severe weather could be survived as long as it was not prolonged. Although poor weather may directly affect breeding success through its effects on the progeny, indirect affects through reducing prey availability may be more important. Peregrines on the Aleutian Islands bred less successfully when rough seas in spring forced seabirds to spend more time far offshore (White 1975). There is some evidence that weather could have been important in Taymyr. Unpublished information on weather patterns in Taymyr show that, while mean June temperature from 1929 to 1990 was in the order of 5°C on average, it was only 2°C between 1961 and 1965 (data not available for 1966 to 1976, J. Mooiji, unpublished data). Although it seems unlikely that an unusual run of bad springs could alone have led to population decline on the scale that is thought to have occurred in Taymyr, it may well have been a contributory factor.

CONCLUSIONS

A comparison of present with historical data suggest that the Peregrine population in Taymyr seems be recovering well from low populations in the 1970s and 1980s. The presumed decline was likely to have been pesticide linked. Breeding productivity data suggest that the population in western Taymyr is not currently adversely affected by organochlorines. Two of the five adults tested did hold high levels of organochlorines in their blood plasma, however, while the others were almost completely clean. This suggests that organochlorine usage on the wintering grounds is patchy but it also shows that we need to continue to monitor the breeding success and pesticide burden of *F. p. calidus* throughout their range.

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Appendix 1. Concentrations of organochlorine pesticides (numbers in column heading refer to names of specific PCBs) found in blood plasma taken from Peregrines and control species (young Snowy Owls and Rough-legged Buzzards) on the Pura & Pyasina Rivers in Taymyr. Batches 50 and 51 were collected in 1996; batches 90 and 91 in 1997. All concentrations are given in micrograms per gram (i.e. ppm). Total A is sum of all pesticides detected excluding PCBs. Total B is sum of PCBs detected which is not the total amount of PCB in the sample since not all PCBs were measured. These values are therefore minima. Underlined values indicate samples where the organochlorine tested was detected; these were corrected for recovery of chemicals from spiked samples. All other values are for samples where the chemical was not detected; values given refer to the detection limit of the test; i.e. due to sensitivity of chemical tests, concentrations below the given values would not have been detected if they were present. "nt" = sample not tested for the given organochlorine; "nd" = not detected.

Sample Batch- Species weight (g)	Age	Adult Peregrines	e-HCH	g-HCH	p,p'-DDE	HE-OD	p,p'-TDE	p,p'-DDT	8	18	28	31	52	77	101	105	114	118	124	126	128	138	149	153	156	157	167	169	170	180	209	Tot A Tot B		
Adult Peregrines																																		
50-5 PF-M A	0.34	nt	0.03	0.02	0.00	0.00	0.00	0.00	0.00	0.00	nt	nt	nt	0.00	0.00	0.00	nt	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	nt	nt	0.00	0.00	0.00	nt	nd		
92-1 PF-M A	0.39	0.03	0.02	0.00	0.12	0.01	0.11	0.00	0.00	0.00	0.00	0.00	0.02	0.01	0.01	0.04	0.12	0.13	0.00	0.01	0.06	0.45	0.00	1.20	0.17	0.01	0.02	0.08	0.39	0.82	0.02	3.6	4.1	
50-9 PF-F A	0.24	nt	nt	nt	0.00	0.00	0.00	0.00	0.00	0.00	nt	nt	nt	nt	nt	nt	nt	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	nt	nt	0.00	0.00	0.00	nt	nd		
51-5 PF-F A	0.42	nt	nt	nt	0.00	0.00	0.00	0.00	0.00	0.00	nt	nt	nt	nt	nt	nt	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	nt	nt	nt	0.00	0.00	0.00	nt	0.01	nd	
92-4 PF-F A	0.42	0.00	0.00	0.00	0.01	0.00	0.05	0.00	0.00	0.00	0.00	0.02	0.01	0.01	0.01	0.00	0.00	0.01	0.00	0.00	0.01	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	1.51	0.04	
Young Peregrines																																		
50-1 PF Y	0.52	nt	nt	nt	0.00	0.00	0.00	0.00	0.00	0.00	nt	nt	nt	0.00	0.00	0.00	nt	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	nt	nt	0.00	0.00	0.00	nt	nd	nd	
50-3 PF Y	0.52	nt	nt	nt	0.00	0.00	0.00	0.00	0.00	0.00	nt	nt	nt	0.00	0.00	0.00	nt	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	nt	nt	0.00	0.00	0.00	nt	nd	nd	
50-4 PF Y	0.37	nt	nt	nt	0.00	0.00	0.00	0.00	0.00	0.00	nt	nt	nt	0.00	0.00	0.00	nt	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	nt	nt	0.00	0.00	0.00	nt	nd	nd	
50-6 PF Y	0.51	nt	nt	nt	0.00	0.00	0.00	0.00	0.00	0.00	nt	nt	nt	0.00	0.00	0.00	nt	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	nt	nt	0.00	0.00	0.00	nt	0.65	0.01	
51-3 PF Y	0.37	nt	nt	nt	0.00	0.00	0.00	0.00	0.00	0.00	nt	nt	nt	0.00	0.00	0.00	nt	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	nt	nt	0.00	0.00	0.00	nt	nd	nd	
51-3 PF Y	0.51	nt	nt	nt	0.00	0.00	0.00	0.00	0.00	0.00	nt	nt	nt	0.00	0.00	0.00	nt	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	nt	nt	0.00	0.00	0.00	nt	0.03	nd	
91-4 PF Y	0.63	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	nt	nt	0.00	0.00	0.00	0.00	0.00	0.00	
91-5 PF Y	0.58	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	nt	nt	0.00	0.00	0.00	0.00	0.00	0.00	
91-6 PF Y	0.53	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	nt	nt	0.00	0.00	0.00	0.00	0.00	0.00	
91-7 PF Y	0.25	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	nt	nt	0.00	0.00	0.00	0.00	0.00	0.00	
91-8 PF Y	0.51	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	nt	nt	0.00	0.00	0.00	0.00	0.00	0.00	
92-2 PF Y	0.55	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	nt	nt	0.00	0.00	0.00	0.00	0.00	0.00	
92-3 PF Y	0.59	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	nt	nt	0.00	0.00	0.00	0.00	0.00	0.00	
92-5 PF Y	0.55	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	nt	nt	0.00	0.00	0.00	0.00	0.00	0.00	
92-6 PF Y	0.49	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	nt	nt	0.00	0.00	0.00	0.00	0.00	0.00	
92-6 PF Y	0.49	0.00	0.00	0.00	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	nt	nt	0.00	0.00	0.00	0.00	0.00	0.00	
92-7 PF Y	0.37	0.00	0.00	0.00	0.00	0.00	0.06	0.00	0.00	0.00	0.00	0.00	0.03	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	nt	nt	0.00	0.00	0.00	0.00	0.00	0.00	
92-8 PF Y	0.39	0.00	0.00	0.00	0.00	0.00	0.06	0.00	0.00	0.00	0.00	0.00	0.02	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	nt	nt	0.00	0.00	0.00	0.00	0.00	0.00	
Controls																																		
50-2 SO Y	0.51	nt	nt	nt	0.00	0.00	0.00	0.00	0.00	0.00	nt	nt	nt	0.00	0.00	0.00	nt	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	nt	nt	0.00	0.00	0.00	nt	nd	nd	
51-2 SO Y	0.47	nt	nt	nt	0.00	0.00	0.00	0.00	0.00	0.00	nt	nt	nt	0.00	0.00	0.00	nt	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	nt	nt	0.00	0.00	0.00	nt	nd	nd	
51-4 SO Y	0.57	nt	nt	nt	0.00	0.00	0.00	0.00	0.00	0.00	nt	nt	nt	0.00	0.00	0.00	nt	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	nt	nt	0.00	0.00	0.00	nt	0.03	nd	
50-8 RLB Y	0.31	nt	nt	nt	0.00	0.00	0.00	0.00	0.00	0.00	nt	nt	nt	0.00	0.00	0.00	nt	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	nt	nt	0.00	0.00	0.00	nt	0.03	nd	
51-1 RLB Y	0.56	nt	nt	nt	0.00	0.00	0.00	0.00	0.00	0.00	nt	nt	nt	0.00	0.00	0.00	nt	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	nt	nt	0.00	0.00	0.00	nt	0.03	nd	
Proportion recoveries																																		
Batch	Proportion recoveries		nt	nt	nt	0.94	0.87	1.00	0.75	nt	nt	nt	nt	nt	0.92	0.83	nt	0.93	nt	0.93	nt	0.97	0.97	0.96	0.92	0.96	nt	nt	0.94	1.00	0.98	nt	nd	nd
LODs (ug)																																		
SO&51	LODs (ug)		0.10	0.10	0.20	0.10	0.20	0.10	0.20	0.20	0.24	0.25	0.26	0.24	0.31	0.26	0.33	0.32	0.32	0.32	0.33	0.33	0.33	0.33	0.33	0.34	0.34	0.34	0.34	0.34	0.34	0.35	0.35	
Proportion recoveries																																		
Batch	Proportion recoveries		0.23	0.22	0.22	0.23	0.28	0.30	0.30	0.24	0.24	0.25	0.26	0.24	0.31	0.26	0.33	0.32	0.32	0.32	0.33	0.33	0.33	0.33	0.33	0.34	0.34	0.34	0.34	0.34	0.34	0.35	0.35	
91&92	LODs (ug)		0.13	0.14	0.09	0.40	0.27	0.09	6.67	0.23	0.46	0.12	0.18	2.21	0.73	0.99	0.36	0.10	0.82	0.08	0.09	0.39	0.96	0.13	0.77	0.22	0.15	0.06	0.06	0.17	1.48	0.17	0.17	

Appendix 2. Breeding density and success of British and Arctic Peregrine Falcons around the world. The symbols ¹, ², and ³ represent areas where the populations were thought by the original authors to be depressed, recovering or close to (or actually) normal. Entries without a symbol are for areas where status was unknown or where the time spanned periods of variable status.

<i>Location</i>	<i>Distance along river (km)</i>	<i>Straight line distance (km)</i>	<i>Density km² per territory</i>	<i>% territories occupied</i>	<i>%pairs fledged young</i>	<i>Clutch size</i>	<i>Y_{pair}</i>	<i>Y_{succ pair}</i>	<i>Reference</i>
NORTH AMERICA									
Macenzie River Valley, NWT, USA 1969-85				22-53			1.4-2.3	2.2-2.9	Bromley & Matthews (1988)
¹ Aleutian Islands 1970-72		7-11			66		1.77	2.66	White (1975)
² West Greenland 1981-85				70	80		2.4	3.0	Mattox & Seegar (1988)
³ S. Greenland 1981-85			240	70	73		1.8	2.7	Falk & Møller (1988)
¹ Colville River, Northern Alaska 1980-85				74	56		1.64	2.75	Cade (1960); Ambrose <i>et al.</i> (1988)
¹ Yukon River, Interior Alaska 1970-80				55.7	71		1.8	2.47	Cade (1960); Ambrose <i>et al.</i> (1988)
¹ Ungava Bay, Quebec 1980-85				64	77		2.3-2.9	2.4-3.2	
¹ Kittikmeot, Northwest Territories 1982-85			186	44			2.8 ¹		Bromley (1988)
¹ K'ecwaat District, Northwest Territories 1981-86			17 (50% water)		73	3.62	2.03	2.79	Court <i>et al.</i> (1988)
¹ Baffin, Northwest Territories 1982-85			285	59	85		2.8 ²		Bromley (1988)
¹ West Greenland 1972-81		7.7		45	89		2.3	2.7	Burnham & Mattox (1984); Mattox & Seegar (1988)
¹ Ungava Bay, Quebec 1970 & 1975				56	65		1.3-1.8	1.7-1.8	
¹ Yukon River, Interior Alaska 1951-68	20		775	58	35		1.2	1.85	Cade (1960); Ambrose <i>et al.</i> (1988)
¹ Colville River, Northern Alaska 1969-79	9.5		520				0.75	1.98	Cade (1960); Ambrose <i>et al.</i> (1988)
SIBERIA									
¹ Pura-Pyasina 1996-97	29	24	406	63	70	3.5	2.08	2.83	This study; Quinn & Kokorev, in prep.
¹ Yamal Peninsula (1940s)								2.7	Osmolovskaya (1948)
¹ Lower Lena, Northern Siberia	10-20								Glutz <i>et al.</i> (1971)
¹ Upper Lena, Northern Siberia	30-40								Glutz <i>et al.</i> (1971)
¹ NE Yakutia	15-20								Uspenskiy <i>et al.</i> (1962)
¹ R. Pyasina, Taymyr 1960-62		7-10 (n=207)				3.5	1.94		Kreischmar & Leonovich (1967)
¹ Kola Peninsula 1987-91									Henny <i>et al.</i> (1994)
¹ Boisstezel'skaya Tundra, NE Europe 1980s			592						Momzov (1991)
¹ Yamal Peninsula, early 1980s			800						Kalyaev (1983)
¹ Southern Yamal, late 1980s			270-416					1.5	Mednikova & Gizzalova (1991)
¹ Tributaries of Pyasina, Taymyr, 1970s & 1980s	74 & 42							2.54	Kokorev (1995)
¹ Central Taymyr, 1970s & 1980s	69 & 79								Kokorev (1995)
¹ Eastern Taymyr, 1970s & 1980s	81 & 53								Kokorev (1995)
¹ Lower Kolyma, NE Siberia 1988-92						3.4	1.04		Potapov (1994)
¹ Lower Kolyma, NE Siberia 1983-87						3.75	0.30		Potapov (1994)
FINLAND									
¹ Northern Finland 1981-85	15.9		300			3.1	2.1	1.86	Lindberg <i>et al.</i> 1988; Wilman (1990)
¹ Southern Finland 1981-85							1.0		Lindberg <i>et al.</i> 1988
BRITAIN									
Britain, up to 1979			21-119			3.63	1.36	2.23	Ratcliffe (1993)
¹ Great Britain 1980-91				120	63		1.1	2.31	Ratcliffe (1993)
¹ S. Scotland 1974-82				62	47	3.53	0.71	2.33	Mearns & Newton (1988)
¹ Great Britain 1960-70					20			2.07	Ratcliffe (1993)