POPULATION STATUS, PESTICIDE IMPACT AND CONSERVATION EFFORTS FOR THE PEREGRINE (*FALCO PEREGRINUS*) IN SWEDEN, WITH SOME COMPARATIVE DATA FROM NORWAY AND FINLAND

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ABSTRACT

The Fennoscandian Peregrine population probably reached its lowest level at the beginning of the 1970s with a 95–97 percent reduction of its pre-war population size. Decreased reproduction (egg-shell thinning) and increased mortality due to pesticide contamination, both on breeding and wintering grounds, were the main reasons behind the decline. The known Peregrine population in Sweden during the 1970s was about ten pairs. During the late 1970s Peregrine populations in Norway and Finland increased, possibly as a result of the restrictions in the use of DDT, PCB and alkyl-mercury in several Northwest European countries.

The average levels of DDE ranged between 123 and 360ppm lipid weight in samples of unhatched eggs from different Peregrine populations in Fennoscandia. Comparatively high PCB-levels were noted, with a range between 451 and 919ppm lipid weight. DDE was mainly involved in hatching failures for certain pairs.

Conservation efforts are focused on nest-guarding, double-clutching, artificial incubation of thin-shelled eggs and captive breeding for reintroduction of falcons in southern Sweden.

INTRODUCTION

The migrating Fennoscandian Peregrine (*Falco peregrinus*) population declined greatly during the 1950s and 1960s and probably reached its lowest level at the beginning of the 1970s, with a 95–97 percent reduction of its pre-war population size. Impact of pesticides, accumulated both in winter quarters in Western Europe and on breeding grounds, was the main reason for the decline (Lindberg 1977a; Ratcliffe 1980). During the late 1970s both productivity and the number of breeding pairs increased in Finland and Norway (Wikman, in press; Schei, pers. comm.). Likewise the decline of Peregrine populations in the boreal regions of North America stopped in the mid 1970s, and by 1980 most populations had begun to recover (Cade 1982). Such a positive trend has not yet been observed in Sweden where the number of known pairs is less than ten.

Since 1972 the Swedish Society for the Conservation of Nature has conducted a Peregrine project involving both research and management. Cooperation with Norwegian and Finnish biologists (WWF/IUCN project 1504) on matters concerning pesticides, colour ringing and captive breeding started in 1978. In this paper I shall summarize some data on the Swedish population, pesticide impact and captive breeding, and then discuss the future for Fennoscandian Peregrines.

POPULATION STATUS AND REPRODUCTION

The Peregrine was formerly fairly evenly distributed throughout Sweden, although the density varied according to prey abundance and suitable nest sites. In the mountains of the north, the species is replaced by the Gyrfalcon (*Falco rusticolus*). During recent decades the remaining Peregrine pairs have formed two subpopulations, in northern (lat 64–68°N) and southwestern Sweden (lat 56–59°N) respectively. The birds in these areas can be considered to be geographically isolated with no regular genetic exchange.

Extensive surveys of suitable cliffs throughout the country were performed in 1972–78. Much of the work was concentrated in optimal habitat in the three northern counties (lat 62–68°N, area approx. 200,000km^2), where it would have been impossible to register all breeding pairs. However, the unknown part of the population is not expected to deviate significantly in reproduction and trend from the controlled one. Helicopters were used in 1976–78 to check about 1000 cliffs in rugged low mountain terrain, and three 'new' pairs were found. A total of 11 territories were identified in the two northern counties (Västerbotten and Norrbotten) during 1972–78, and all sites were assumed to have been occupied since 1972. These sites were checked yearly and by 1982 only four breeding pairs and two single birds remained (*Figure 1*). We found no evidence that any of the pairs that deserted one locality had moved elsewhere, and thus we suspect mortality, mainly during winter, as the cause of territory desertion. None of the deserted sites has been reoccupied by pairs or single birds. Based on the above assumptions the population showed a significant decline ($p < 0.01$, $r_s = -0.979$, Spearman rank correlation test).

Annual reproductive rates varied between 0.29 and 2.75 young/attempt (=eggs laid) (*Figure 1*). Sample sizes were small and no significant trend emerged, but in 1981/82 broods with three to four young were observed—a possible indication of a lowered pesticide impact. Four of the eleven territories produced 73 percent of all fledged young during the period concerned, so the effective population size (N_e) was small and may have increased the risks from inbreeding. The mean nearest-neighbour distance between nests in 1972 was 67km and in 1982 it had increased to 123km.

In southwestern Sweden the population of about 65 pairs has been followed since the mid 1950s (Lindberg 1975). In 1970, seven occupied territories remained and of these, two were held by pairs and two by single birds in 1982. The mean reproductive rate in the years 1970–77 was 1.2 young/attempt.

IMPACT OF ORGANOCHLORINES AND MERCURY

The decline of the Fennoscandian Peregrines during the 1950s and the 1960s was closely associated with the use of both organochlorines and organo-mercurial pesticides. Thin-shelled eggs were documented for the first time among Swedish

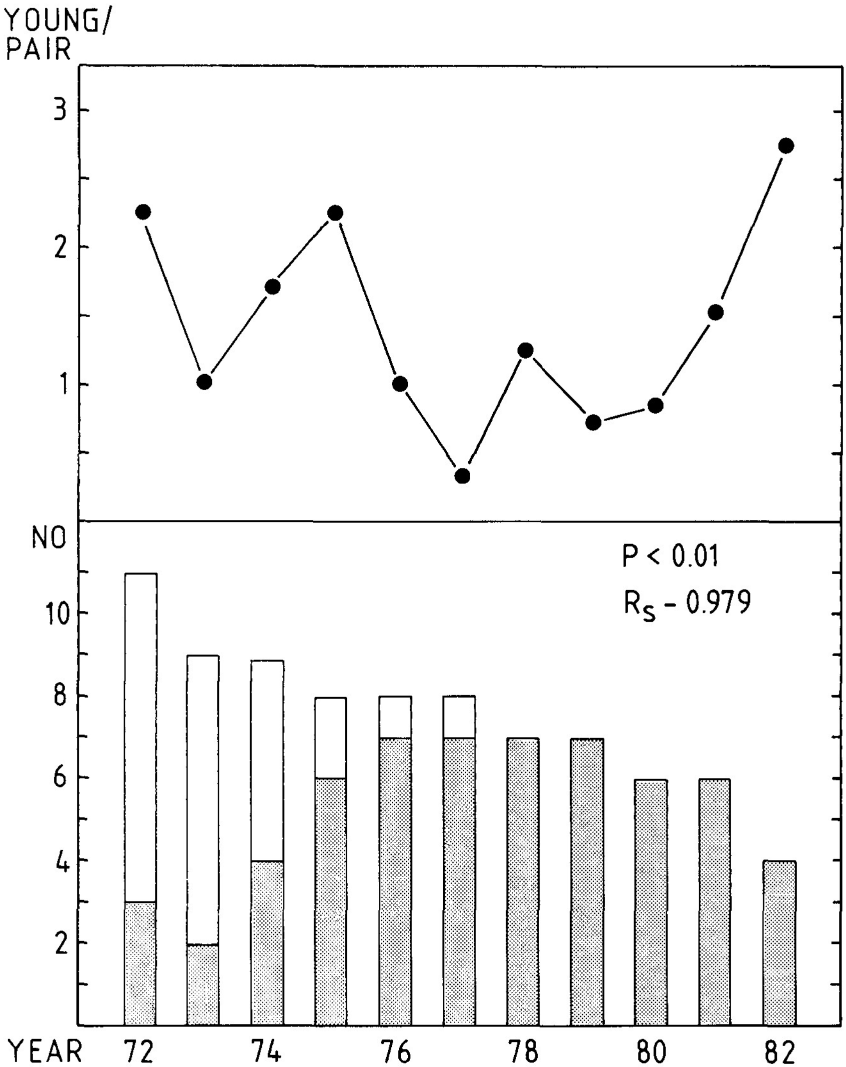

Figure 1: Reproductive rate and number of pairs in the two northern counties of Sweden. Productivity based on large young/breeding attempt. Filled bars = number of controlled pairs.

Peregrines in 1947 (Odsjö & Lindberg 1977). Since 1972, pesticide levels have been monitored in eggs, feathers and prey species. Mercury levels in feathers of adult and nestling Peregrines collected in Fennoscandia and Scotland in 1972–78 were determined, using the neutron activation method (Lindberg & Mearns 1982; Lindberg & Odsjö 1983). Great regional differences were found, with the lowest levels among Scottish Peregrines and the highest in northern Fennoscandian ones. Peregrines in northern Sweden had significantly higher levels than those in southern Sweden, associated with Hg-levels in prey species (Lindberg & Odsjö 1983). The average level of mercury in pectoral muscle of prey (mainly aquatic birds) in northern Sweden was estimated at 0.20ppm and in southern Sweden (mainly terrestrial birds) at 0.07ppm. This was in good agreement with a ratio of 1 : 3 found in Peregrine nestlings in the two areas. However, mercury levels, both in the Peregrines and their prey, were low compared to those found in the alkyl-mercury period 1940–66 and were probably insignificant to reproduction.

In 1972–81 some 116 eggs from 63 clutches collected both from wild pairs in Sweden and Finland and from captive pairs were analysed for OCs and Hg (Lindberg 1981, 1983). Analyses were based on lipid levels, and as the lipid content of the egg is reduced during incubation, the stage of embryonic development was considered (Peakall *et al.* 1979). Levels of DDE and PCB (ppm lipid weight = l.w.) in eggs from Fennoscandia and Scotland (Ratcliffe 1980) are summarized in *Figure 2*. The mean level of DDE in infertile/small embryo eggs did not differ significantly ($p > 0.05$, Mann-Whitney U-test) between the Fennoscandian regions, and ranged from 123 to 360ppm l.w.

The PCB levels did not differ between Finland ($\bar{x} = 451$ppm l.w.) and northern Sweden ($\bar{x} = 515$ppm l.w.), but significantly higher levels were found in eggs from southern Sweden ($\bar{x} = 919$ppm l.w.). However, sample size was restricted, as most clutches in southern Sweden were from only one territory, and on the exclusion of one clutch with a high level, the significance disappeared.

Peakall *et al.* (1975) estimated that 15–20ppm wet weight (400–500ppm l.w.) caused Peregrine eggs to fail, but Ratcliffe (1967) found that only 14.3 percent of Peregrine nests were successful when sampled eggs contained more than 10ppm DDE w.w. (about 250ppm l.w.). Levels of DDE between 400 and 500ppm l.w. correspond roughly to 20 percent shell thinning and a high incidence of egg breakage. During the 1970s DDE and possibly PCBs reduced the productivity of Fennoscandian Peregrines, although this impact varied between populations, due to differences in food choice, age structure and wintering areas. In Finland, the mean levels of DDE and PCBs in the period 1972–78 were 307 and 451ppm l.w. respectively. During the same period a significant improvement in productivity estimated at 0.06 extra young/pair/year was observed (Wikman, in press), implying that the pesticide levels found had little effect on productivity. However, the sampling of the Finnish eggs may also have been biased towards certain females with high levels, and thus not representative of the whole population.

The Swedish egg sample was collected over ten years, during which time levels may have varied. In the early 1970s, the use of OCs was reduced by regulations in many countries of northern Europe. In Sweden DDT was banned for agricultural purposes in 1970 and in forestry in 1975. The use of PCBs was restricted in 1972. Monitoring studies of OCs in starlings (*Sturnus vulgaris*) from terrestrial habitats in Sweden and of several bird species, other animals and fish from the Baltic Sea showed decreasing levels during the 1970s (Olsson 1978; Koivusaari *et al.* 1980; OECD 1980; Bernes 1982). Small sample size, and large inter-territory variations in levels, make a trend analysis of Peregrine eggs questionable. However, eggs with large embryos from northern Sweden showed a significant decrease in DDE-levels during recent years ($0.02 < p < 0.01$, $r_s - 0.665$, Spearman rank correlation test, two-tailed, $n = 13$). In none of the other groups, nor for the other pesticides, was any trend discernible.

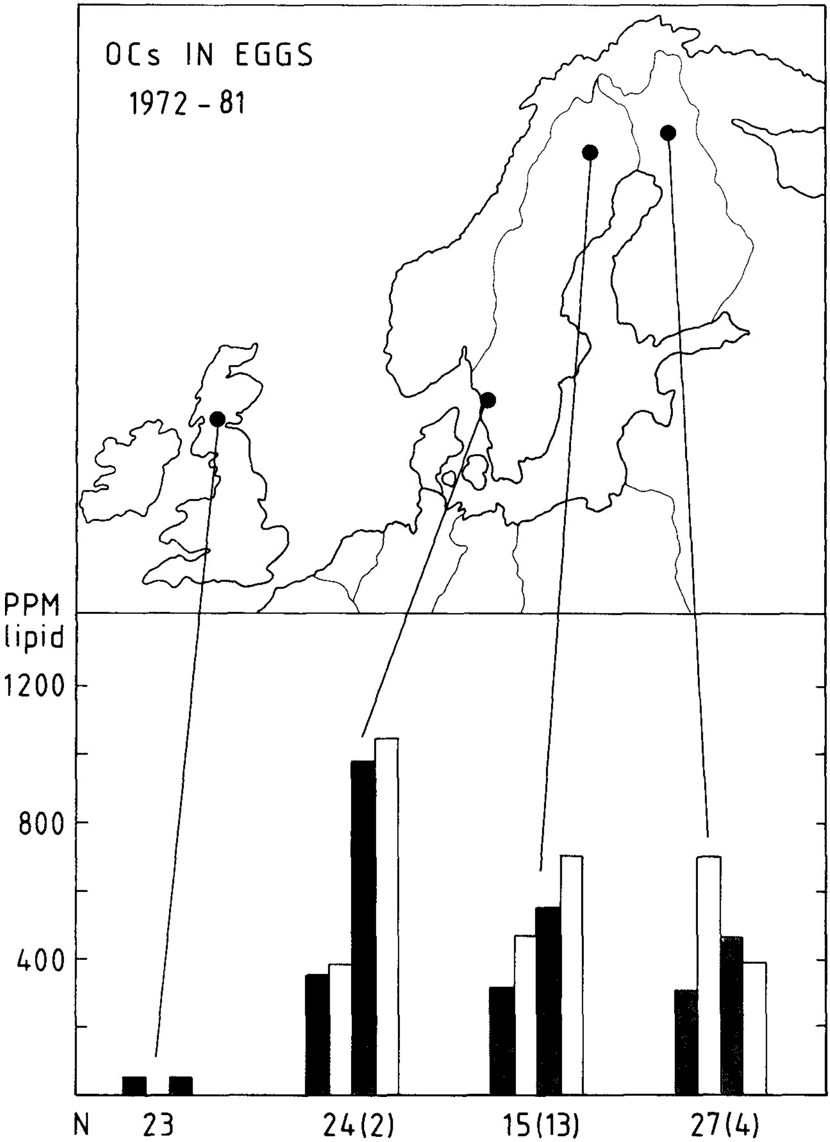

Figure 2: Arithmetic mean levels of organochlorines (ppm lipid weight) in Peregrine eggs from northern Europe. The two left bars denote DDE and the two right bars PCB. Filled bars = infertile eggs or addled eggs with small embryos; Unfilled bars = eggs with large (>4cm) embryos. Sample size within parentheses are eggs with large embryos. Eggs from Scotland collected 1972–78 (based on Ratcliffe 1980), from Finland 1972–78 and from Sweden 1972–81.

CONSERVATION AND CAPTIVE BREEDING

Since the late 1960s, all nests in southern Sweden have been guarded during the breeding season to restrict human disturbance (Lindberg 1977). In addition, a management programme has been conducted involving double-clutching, introduction of new individuals, and captive breeding. First clutches were collected for artificial incubation on eight occasions in 1978–82, and replacement clutches were laid in all cases. Mean egg number per female increased to 6.6 and young to 4.0 (including young hatched in an incubator), which could be compared with 1.2 young/breeding attempt (n = 32) in 1970–77.

Captive breeding was started in 1974 in close cooperation with Finnish and Norwegian colleagues (Lindberg 1983). The main goal was to produce falcons for restoration (cf. Fyfe 1976; Cade & Temple 1977) of a population of about 30 breeding pairs in approximately 15,000km^2 of SW Sweden, equivalent to about 50 percent of the pre-war population size of that area. Assuming a survival rate for reintroduced birds of 40 percent during the first year (S_0) and 80 percent thereafter (S), a breeding age of 2 years (3K), an equal sex ratio, a productivity (P) of 1.5 young/pair of breeding age, and with all surviving birds entering the population, a steady release of 200 young over a ten-year period would result in a population of 32 breeding-age pairs after 15 years.

The captive breeding stock was founded in 1974 with a male Swedish falcon hatched in an incubator. Subsequent establishment of an effective breeding population was slow because of difficulties both in collecting falcons from a dwindling population and in getting them to breed in captivity. Most of the birds were collected as nestlings from Sweden and Finland, plus a small number from Norway and Scotland (*Figure 3*). The minimum effective size of a captive breeding group has been estimated at ten unrelated pairs. Given that only 30–50 percent of mature pairs produce fertile eggs, it will be necessary to maintain a captive stock of 20–30 pairs to achieve a minimum production of 20 young/year.

The falcons are kept in outdoor aviaries with a floor area of 16–36m^2 and a maximum height of 5m. The project depends on interested keepers who take care of the birds mainly on a voluntary basis. Groups of two, three and four cages are located at six locations in southern Sweden and in addition four cages are used in a larger unit in Denmark. In 1982, the project had the capacity for housing 22 pairs. Between 1978–82, seven pairs laid 94 eggs, of which only 37 were fertile, resulting in 29 fledged young (*Table 1*). Laying pairs were double-clutched and the

Table 1: Breeding data from captive Peregrine pairs in 1978–82. Origin of birds: S = Sweden, F = Finland, E = Scotland.

Females Origin and age (year) at first egg laying	*Males* Origin and age	Total number of eggs laid	Number of fertile eggs	Number of fledged young	Hatching success (%)
S2	S2	24	21	17	81
F2	F2	32	13	10	77
S3	S3	14	0	0	0
F5	F1	8	0	0	0
F6	F3	4	0	0	0
E6	E6	7	1	0	0
E7	E7	5	2	2	100
Total		94	37	29	78

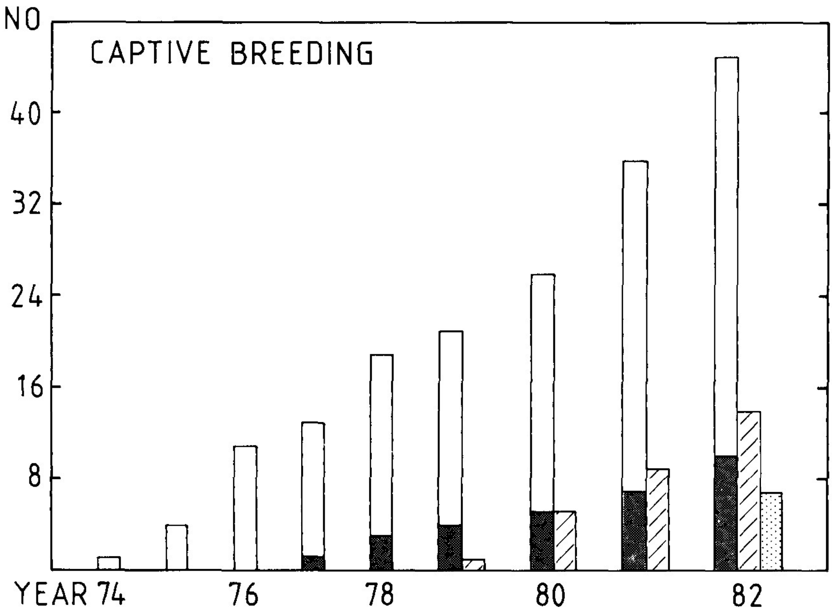

Figure 3: The development of a captive breeding stock of Peregrines in Sweden. Unfilled bars = number of birds; Filled bars = number of pairs older than two years; Striped bars = number of fledged young; Spotted bar = number of released young.

first clutches were artificially incubated (Lindberg 1981). Hatched young were hand-fed for several weeks with siblings before they were fostered either to wild or captive birds. To increase genetic diversity, captive-produced young were exchanged with wild nestlings in Norway and Sweden. Reintroduction in SW Sweden started in 1982, with seven young successfully released by hacking (Lindberg 1982). Large-scale reintroductions are planned to start when the captive stock consists of ten productive pairs, a figure that could be achieved in the mid 1980s.

FUTURE OF FENNOSCANDIAN PEREGRINES

Analyses revealed that levels of toxic chemicals in Fennoscandian Peregrine eggs during the 1970s were among the highest in Europe (Lindberg 1983). However, levels of Hg had significantly declined compared to earlier decades. There are also indications of declining levels of DDE, following restrictions in many European countries. Hopefully, levels of DDE will further decrease during the 1980s so that productivity among falcons can improve.

Wikman (this volume) found improved breeding success among Finnish falcons during late 1970s, and the number of known pairs increased from 17 in 1975 to 47 in 1982. To some extent this was due to a more intense search effort during later years, but it also reflected population growth. Using the trend from 1975–82 in an exponential function, the number of pairs should exceed 90 in 1990 and 250 in 2000.

Table 2: Productivity/breeding attempts of Peregrines in Fennoscandia during 1976–80. Figures based on national reports from Wikman (Finland) and Schei (Norway).

Country	Population size/pairs	Number of breeding attempts	Number of young	Productivity
Finland	>30–35	118	220	1.86
Norway	>20–25	49	101	2.06
Sweden	>10	50	51	1.02
	60–70	217	372	1.71

Note: Productivity = large young per breeding attempt.

Figures from Norway are more scanty but a trend similar to that in Finland was noted (Schei, pers. comm.). The number of Peregrines seen on migration has also increased in southern Norway, Sweden and Denmark, as has the number of wintering birds in Holland (Jonkers *et al.* 1981), giving further evidence for population increase.

Table 2 compares the productivity in different Fennoscandian countries during 1976–80. Average productivity (large young/breeding attempt) was significantly lower in Sweden than in Finland ($p < 0.001$, $x^2 = 7.01$, $df = 1$) and Norway ($p < 0.001$, $x^2 = 7.16$, $df = 1$). A population increase has not been noted in Sweden in contrast to Norway and Finland. Possibly the Swedish population has declined beyond a threshold level, making an increase improbable even if depressing factors such as pesticide impact are reduced. Low productivity, and the dispersal of productive pairs over a large area, presumably make new pair formation difficult. When it does occur, the risk of matings between close relatives (inbreeding) is high, due to a large inter-territory variation in productivity and high probability that birds will return to the vicinity of their birth place. Swedish ringing data showed that 94 percent of 27 birds recovered during breeding season older than two years were found within 100km of their birth place. In small dwindling populations, genetic drift and inbreeding can significantly alter genetic constitution, which in turn can lower individual fitness (Soulé 1980). To my knowledge there are no examples from Europe of local Peregrine populations of less than 20–30 pairs that have recovered, if they have not been supplemented with immigrants from neighbouring populations. Population size in Finland, southwest Germany, eastern France and possibly Norway (all areas where Peregrines have lately increased in number), have never been less than 20 pairs. In this respect the situation for the remaining pairs in southern Sweden is not encouraging, and the most certain way to restore a population to this area is through the reintroduction of captive produced birds. In northern Sweden, immigration from Finland may help recovery.

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