Mercury content in feathers of the Kestrel *Falco tinnunculus* L. in Finland

Martin Lodenius & Seppo Kuusela

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The breast feathers of 58 Kestrels were analysed for mercury. The birds, found in different parts of Finland, were mostly deposited in five Finnish museums of natural sciences during the years 1895–1982. The mean and median contents, 2.9 mg and 1.9 mg/kg d.w., respectively, were similar to the mercury levels reported earlier in other terrestrial birds of prey. The contents were significantly higher before than after 1963. No statistically significant differences were detected between birds of different age or sex, or between seasons or areas. The results support the hypothesis that the population decline was caused by the combination of the cold winter of 1962/63 and pesticide contamination. However, differences in population trends between different areas are left unexplained because the life history of the individuals preserved is extremely laborious to reconstruct. It is suggested that the present status of the breeding population can be influenced by other short-term pressures than mercury due to changes in the habitats on agricultural land.

Martin Lodenius, Department of Environmental Science, University of Helsinki, SF-00710 Helsinki, Finland, and Seppo Kuusela, Department of Zoology, University of Helsinki, SF-00100 Helsinki, Finland

Introduction

Methyl mercury compounds are known to accumulate in food chains, resulting in high mercury concentrations in predatory animals. In Sweden, where methyl mercury was widely used for seed dressing between 1938 and 1966, high mercury concentrations were found in birds of agricultural food webs (e.g. Johnels et al. 1979). In Swedish Gyrfalcons *Falco rusticolus*, which mainly inhabit the mountain areas, the mercury contents are low (Lindberg 1984). Since 1966 the mercury concentrations in predatory birds have decreased in Sweden (Odsjö & Sondell 1977, Broo & Odsjö 1981). In Finland, where only small amounts of methyl mercury have been used in agriculture, elevated mercury concentrations have been found mainly in fish-eating birds, but also in the Sparrowhawk *Accipiter nisus* (Solonen & Lodenius 1984), and the Peregrine Falcon *Falco peregrinus* (Lindberg et al. 1983).

A pronounced decline in the Kestrel population was observed in southern Finland after winter 1962/63 (Linkola & Myllymäki 1969). This was assumed to be caused by the interaction of a hard winter and pesticides. However, no data were available on the content of pesticides in Finnish Kestrels. This paper reports an investigation of the mercury levels in the feathers of this species.

Material and methods

The samples were obtained from the Zoological Museum at the University of Helsinki (N=21), the Biological Museum at the University of Turku (11), the Kuopio Museum, Division of Natural History (6), the Zoological Museum at the University of Oulu (14) and from private persons (6). Breast feathers (3–5 per individual) were used for the chemical analyses. The birds were collected between 1895 and 1982. Most of them were preserved with arsenic compounds. All the records of the sex, collecting time and place were considered. For the chemical analysis, the samples were dried in +50°C and dissolved in 5 ml of concentrated sulphuric and nitric acid (4:1) for 4 hours in a +60°C water bath (cf. Särkkä et al. 1978). The mercury contents were measured using cold vapour atomic absorption spectrometry (Perkin-Elmer, Coleman MAS-50).

As the measured values had a skew frequency distribution, non-parametric tests were used. Analysis of variance (ANOVA) was also applied to detect the effects of seasons and sex. In the latter analysis the samples were randomized, and the same number of observations was used in each group. All the samples from the Zoological Museum, University of Helsinki, collected prior to 1921 were disregarded, because they had obviously been contaminated (mercury contents 13–94 mg/kg).

Results

The mercury contents varied from below 0.02 to 13 mg/kg (dry weight). The mean was 2.9 mg/kg (± 3.0 SD) and the median 1.9 mg/kg. The values before the critical year 1963 were significantly higher than the values from 1963 to 1982 (Median test, $\chi^2 = 14.9$, $P<0.001$). Also, a significant declining trend was found from 1895 to 1982 (Spearman rank correlation, $r^s=-0.575$, $P<0.01$; see also Fig. 1). However, no trends were detected within the periods 1895–1962 or 1963–1982. The years 1953–1982 were examined further in 5-year periods (Table 1). The number of samples between 1963 and 1967 is only two, but the levels from this period were lower, though not significantly so, than those from the period 1958–1962 (randomization test, $P=0.107$, one-tailed). No statistical differences were found between adults and juveniles (Mann Whitney U-test). The material includes only two nestlings (<0.02 and 0.11 mg/kg).

The material was then grouped into "agricultural Finland" and "other parts of Finland". The results did not indicate any regional differences in the mercury contamination within the long-term periods mentioned above (Median test). The samples from the museums in Helsinki and Turku both showed higher mean concentrations than those from the museums in Oulu and Kuopio, probably because the samples from the former museums were mainly collected before 1963. The collection in Turku had significantly higher levels than that in Helsinki (Mann-Whitney U-test; $P<0.001$), because the latter had a much lower median for the period 1963–1982 than for 1895–1962.

Table 1. The mean, standard deviation and median content of mercury (mg/kg) in feathers of Kestrels in Finland calculated for five-year periods from 1953 to 1982.

Period	Mean	SD	Median	N
1953-57	2.90	1.33	2.60	5
1958-62	3.42	2.73	2.10	6
1963-67	1.07	0.90	1.07	2
1968-72	2.45	3.26	1.00	7
1973-77	0.17	0.12	0.14	7
1978-82	0.28	0.12	0.41	6

Discussion

The role of pesticides as a decisive factor in the population crash of Finnish Kestrels has been questioned, because the crash was observed only in Häme, southern Finland, and measurements of the egg shells did not show any thinning trend (S. Kuusela unpubl.). The ringing data on Kestrels in Finland show that persecution has decreased; between 1958 and 1967 23 out of 1000 ringed Kestrels were killed, as against five between 1968 and 1977 (Saurola 1979). The annual survival rate of Finnish Kestrels is about 50 % (S. Kuusela unpubl.). Ringing recoveries of Danish Kestrels show that the survival correlates with the protective legislation (Noer & Secher 1983), having increased twice, in 1931 and 1967. The decrease in survival that took place in Finland between 1970 and 1980 happened gradually. If mercury has reduced the survival rate, it has a secondary connection with the breeding success. More exact explanations should be obtained of the causes of the death of ringed birds. In any case a large amount of mercury is eliminated from the population in the moult and the maximum levels found have been sublethal. The mercury level in a feather corresponds to the level in the blood during the growth of the feather (Westermark et al. 1975). Outside the breeding season it is difficult to deduce on the basis of feather analyses in what surroundings the mercury uptake occurred.

Other biocides besides mercury may have reduced the Kestrel populations. In 1982 the sale of pesticides in Finland totalled 4400 t and that of mercury (as alkoxy ethyl mercury compounds) 4.9 t (Tiittanen & Blomqvist 1983). The sale of pesticides intended for cereal crops was sufficient to treat 73 % of the total grain acreage. Methyl mercury compounds were used for seed dressing in the years 1956–1967, but the amount was only 5 % of the total amount of mercury used for this purpose (Markkula & Tiittanen 1969).

Mercury may have reduced adult survival, because the mercury contents declined after the exceptionally cold winter of 1962/63. However, when the present state of the population is considered, account must be taken of other short-term pressures. It is important to note that the breeding success of Finnish Kestrels was not lower after winter 1962/63; only the breeding densities decreased (Linkola & Myllymäki 1969, Kuusela 1983). However, the long-term comparisons of the breeding success on agricultural land do not seem to reveal any significant differences, possibly because the habitat classification is rather crude (Kuusela 1983). The main breeding habitats on agricultural land have changed rapidly and become more homogeneous, and this may have reduced the opportunities for pair formation and the choice of breeding sites. In most cultivated agricultural areas the densities of Finnish Kestrels appear to be considerably lower now than before 1963. In addition it has been assumed that the fluctuations in the Kestrel population have increased during the last years as a result of a more nomadic behaviour (Saurola 1985).

The variation in mercury levels in different collections raises the question whether we measured the contamination of the collections or the levels reached during the growth of the breast feathers. The decreasing values from the Zoological Museum of the University of Helsinki do not support the former interpretation; contamination should increase with time. It seems that the two explanations suggested earlier for the population decrease, the interaction of a hard winter and pesticides, and low environmental heterogeneity, are not mutually exclusive alternatives.

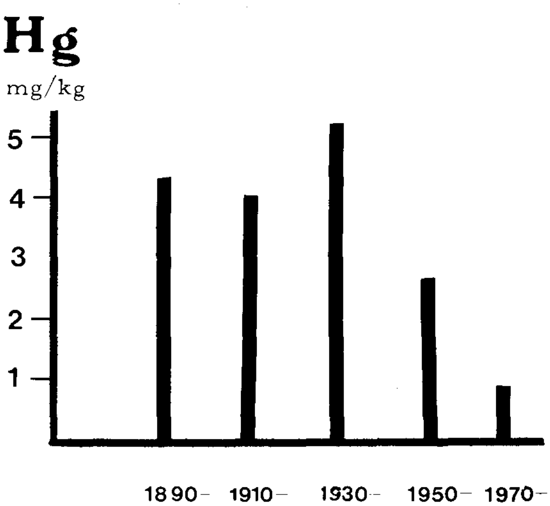

Fig. 1. The long-term changes in the mercury contents (mg/kg) of feathers of Finnish Kestrels.

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Selostus: **Tuulihaukan höyhenten elohopeapitoisuus Suomessa**

Kanta-Hämeessä talven 1962/63 jälkeen havaitun tuulihaukkakannan pienentymisen on otaksuttu johtuneen kylmän talven ja torjunta-aineiden yhteisvaikutuksesta, koska rasvakudoksiin kertyneet myrkyt tällaisissa olosuhteissa voivat vaikuttaa elintoimintoihin. Kirjoittajat tutkivat tuulihaukan sulkien elohopeapitoisuuksia linnuista, jotka on tallennettu Helsingin ja Oulun yliopiston eläinmuseoon, Kuopion museon luonnonhistorian osastoon, Turun yliopiston biologian museoon sekä yksityisiin kokoelmiin. Rintahöyhenten pitoisuudet (N=58) vaihtelivat <0.02–13 mg/kg kuivapainoa. Pitoisuuksien keskiarvo oli 2.9 mg/kg ja mediaani 1.9 mg/kg. Nämä arvot ovat samaa tasoa kuin Ruotsissa tutkittujen muuttohaukkojen ja kanahaukkojen pitoisuudet 1940-luvulla. Elohopeapitoisuudet olivat tilastollisesti merkitsevästi korkeampia ennen vuotta 1963 kuin tämän jälkeen.

Elohopea joutuu verenkierron mukana sulkiin näiden kasvuvaiheessa. Emme havainneet eroja elohopeapitoisuuksissa alueiden, sukupuolten tai ikäluokkien välillä. Suomessa on viljan peittaukseen käytetty lähinnä alkoksialkyylielohopeayhdisteitä. Luonnossa helpommin rikastuvaa metyylielohopeaa käytettiin vuosina 1956–67 pieniä määriä peittausaineena. Käytön loppuminen on saattanut vaikuttaa tuulihaukan elohopeapitoisuuksien vähenemiseen 1960-luvulla. On kuitenkin mahdollista, että myrkyt ja ankara talvi yhdessä ovat aiheuttaneet talven 1962/63 kannanromahduksen. Alueellisten erojen selittämiseksi tarvitaan kuitenkin yksityiskohtaisia tietoja tuulihaukkojen elämänkaaresta, sillä Suomen tuulihaukkakannan alueellisiin ja ajallisiin vaihteluihin vaikuttavat monet muutkin tekijät. Esimerkiksi maatalousalueiden rakenteen nopea muutos homogeenisiksi (ts. entistä yksipuolisemmaksi) voi vaikeuttaa parinmuodostusta ja pesäpaikan valintaa.

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