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Fluorosis in Birds of Prey

David M. Bird, Daniel Carriere & J. Laird Shutt

INTRODUCTION

Fluorides occur naturally in the environment in mineral formations in the earth's crust and from volcanic activity. However, the preponderance of cases of environmental contamination involving fluoride compounds result from the industrial processing of fluoride-containing materials (1).

Industrial activity has dramatically increased the flow of fluoride contaminants through the ecosystem. Particulate and gaseous fluoride are carried to the soil and water through direct deposition and precipitation (2), while effluent-borne compounds are added directly to the water supply.

Environmental accumulation of fluoride in certain industrial areas has aroused much public concern, especially dealing with fluorosis in domestic animals (3) and in humans (4). Zahvoronkov & Strochkova (5) estimated that 20 million people world-wide suffer from toxic levels of fluorides.

The primary route of exposure of wild animals to fluoride is assumed to be via the ingestion of contaminated water and forage (6). A clear positive relationship between levels of fluorides in the bones of wild animals and corresponding environmental levels has been established (7, 8). Rose & Marier (1) concluded that environmental fluoride pollution has a serious effect on wildlife, but sufficient data to assess the extent of this impact are lacking.

The effects of high level fluoride ingestion have been studied since the 1930s (9). Classical responses recorded from human and domestic animals include fluorosis of the bone, teeth and soft tissues (10), as well as appetite depression and subsequent weight loss (11). Newman (6) has reviewed many of the responses of wildlife to fluoride toxicity. These include the symptoms mentioned above, as well as reduced reproduction with bioaccumulation. While extensive research has been conducted on the effects of fluoride on wildlife, little is known of the movements of these compounds through a predator-prey system and the extent of fluoride-induced injury to wild birds (12).

SPECIFIC OBJECTIVES

1) To determine whether fluoride administered for 10 days (via water consumption) to one-day old cockerels would accumulate in bones and eggshells of kestrels feeding on the treated cockerels, as well as any potential effects of accumulated fluoride on the reproductive performance of captive falcons;

2) To determine the first signs of fluorosis (if any) in growing falcon chicks administered sodium fluoride and to examine the effects of dietary fluoride on more discrete growth parameters;
3) To take a preliminary look at possible influences of fluoride contamination in falcons nesting in the wild.

MATERIALS AND METHODS

1) Twenty-four pairs of captive American Kestrels (*Falco sparverius*) were forced to renest by removal of their first clutches 6 days after their completion. Immediately following, each of 3 groups of 8 pairs was randomly assigned to 1 of 3 daily dietary regimes for 10 days:
   a) 8 pairs received daily 3 one-day old cockerels containing background concentrations of fluoride (62.4 +/- 51.0 ppm, mean +/- SD)
   b) 8 pairs received daily 2 ten-day old cockerels containing 4,512 +/- 810.9 ppm in their femurae
   c) 8 pairs received daily 2 ten-day old cockerels containing 7,690.5 +/- 1,412.3 ppm in their femurae.
2) Twenty-nine 7-day American Kestrel chicks from captive stock were randomly assigned to 1 of 3 dietary regimes:
   a) 10 birds (4 males and 6 females) were fed 4 times daily with cockerel mash with no addition of NaF
   b) 10 birds (5 males and 5 females) were fed daily 5g of cockerel mash containing 0.00112g of F- per g of food (1,120 ppm of F-) prior to normal feed rations
   c) 9 birds (6 males and 3 females) were fed daily 5g of cockerel mash containing 0.00224g of F- per g of food (2,240 ppm of F-) prior to normal feed rations.
3) a) Wild American Kestrels were collected in the vicinity of an aluminium smelter in Beauharnois, Quebec, and the mean fluoride concentration determined in their femurae. The clutch size and egg fertility were noted in kestrel pairs nesting in this area.
   b) In 1986 a second field study examined the reproductive performance, i.e. clutch size, fertility, fledging success, in kestrel pairs nesting in the above area.

RESULTS

1) Fluoride levels in femurae of treated kestrels were significantly ($p < 0.0025$) higher than those of control birds. Clutch sizes tended to be smaller as more fluoride was added to the diet, but not significantly so, due to an increase of the variance in the treatment group. Percent fertility and hatchability were not significantly affected by treatment. The fluoride content in eggshells in the fluoride-treated groups differed significantly ($p < 0.001$) from those of the control group. Moreover, a re-analysis of data from an earlier study by Bird and Massari (13) revealed that their fluoride treatments had no significant effects on clutch size, fertility, hatchability or fledging success.
2) Standard anatomical measurements, i.e. body weight, skull width, bill depth, tarsus length and diameter, and antebrachium and manus length were not significantly affected by treatment. No significant differences were found among the 3 groups for length of duodenum, jejunum and ileum. Rectum length was found to be significantly ($p < 0.05$ for group a; $p < 0.01$ for group b) smaller as more fluoride was added to the diet. Weight of adrenals, brain, gizzard, spleen, heart, kidney, liver, pancreas and pectoral muscle were also not affected, but kidneys, spleen and adrenals tended to become heavier. Percent bone ash was significantly ($p < 0.05$) increased, while bone-breaking strength was significantly ($p < 0.05$) decreased by treatment.
3) a) The mean fluoride concentration (dry fat-free basis) in femurae of 3 males was 1,244 +/- 672.2 (mean +/- SD) ppm and in 3 females, 1,061.5 +/- 672.2 ppm. The fluoride content of the femurae of 1 pair collected in an industrial-free area was 638.1 and 502.9 ppm for the male and female, respectively. The increased fluoride concentration in the bones of kestrels was not associated with any impaired clutch size (mean of 5 eggs per nest) or fertility (100%).
   b) A preliminary analysis of the 1986 field study revealed the following. In 22 active nests, average clutch size was 4.91 eggs, mean fertility was 82%, and mean hatching success of fertile eggs was 95%.

CONCLUSIONS

1) Through its ability to consume and digest osseous material, the American Kestrel can accumulate fluoride in both its bones and eggshells from the fluorotic bones of prey items.
2) No significant effects on reproductive performance were noted; however, the short-term exposure to fluoride in this study may not have permitted a clear assessment. A chronic exposure study would better model the situation faced by birds of prey inhabiting areas exposed to fluoride emissions.
3) Growing kestrel chicks administered dietary fluoride accumulated fluoride at 10,272 ppm with no inhibition of growth of selected body parameters, including ultimate organ size. Bones, however, were affected via a decreased breaking strength and increased mineralisation.
4) Although fluoride did accumulate in the bones of kestrels nesting in a region of low to moderate fluoride exposure, there was no obvious evidence of any serious effects on their reproductive performance at this time.

FUTURE RESEARCH

1) A study is currently under way to examine the influence of fluoride exposure on the reproductive behaviour, testosterone levels, testicular histology and reproductive performance of fluoride-treated male kestrels paired with untreated females.
2) Data on behavioural observations of adults and growth patterns of nestlings are currently being analysed from a kestrel population nesting near Beauharnois, Quebec. Fluoride content is also being determined in collected nestlings, eggshells, and sample prey items (rodents).
3) A laboratory study is planned for 1987 to measure the rates of incorporation and excretion, as well as storage in the bone matrix, of two common forms of fluoride (NaF and AlF) in American kestrels. The synergistic action of fluorine and a metal ion on intestinal digestibility of fluoride will also be measured.

LITERATURE CITED

(1) ROSE, D. & J. R. MARIER 1977. *Environmental fluoride 1977.* Nat. Res. Counc. Canada, Publ. No. 16081. Ottawa.
(2) **BODNAR, J. R. 1972.** *Fluorides as environmental contaminants.* Inst. Environ. Sci. Eng., Univ. Toronto, Publ. No. ES-16.
(3) **KROOK, L. & G. A. MAYLIN 1978.** Industrial fluoride pollution: Chronic fluoride poisoning in Cornwall Island cattle. *Cornell Vet.* 69: Suppl. 8.
(4) **CZERWINSKI, E. & W. LANKOSZ 1978.** Skeletal changes in industrial and endemic fluorosis. *Fluoride* 11: 29-32.
(5) **ZAHVORONKOV, A. A. & L. S. STROCHKOVA 1981.** Fluorosis: Geographical pathology and some experimental findings. *Fluoride* 14: 182-191.
(6) **NEWMAN, J. R. 1979.** Effects of industrial air pollution on wildlife. Biol. Conserv. 15: 181-190.
(7) **KAY, C. E., P. C. TOURANGEAU & C. C. GORDON 1975.** Industrial fluorosis in Mule deer and White-tailed deer from western Montana. *Fluoride* 8: 182-191.
(8) **NEWMAN, J. R. & M. H. YU 1972.** Fluorosis in Black-tailed deer. *J. Wildl. Dis.* 12: 39-41.
(9) **MEHDI, A. W. R., K. A. AL-SOUDI, N. A. J. AL-JIBOORI & M. K. AL-HITI 1983.** Effect of high fluoride intake on chicken performance, ovulation, spermatogenesis and bone fluoride content. *Fluoride* 16: 37-43.
(10) **KOUR, K. & J. SINGH 1980.** Historical findings of mice testes following fluoride ingestion. *Fluoride* 13: 160-167.
(11) **STODDARD, G. E., G. Q. BATEMAN, L. E. HARRIS, J. L. SHUPE & D. A. GREENWOOD 1963.** Effects of fluorine on dairy cattle: I.V. Milk production. *J. Dairy Sci.* 46: 720-726.
(12) VAN TOLEDO, B. 1978. Fluoride content in eggs of wild birds (*Parus major L.* and *Strix aluco L.*) and the common house-hen (Gallus domesticus). *Fluoride* 11: 198-207.
(13) **BIRD, D. M. & C. MASSARI 1983.** Effects of dietary sodium fluoride on bone fluoride levels and reproductive performance of captive American kestrels. *Environ. Pollut.* (Series A) 31: 67-76.

David M. Bird, Daniel Carriere and J. Laird Shutt
Macdonald Raptor Research Centre of McGill University,
21, 111 Lakeshore Road,
Ste. Anne de Bellevue,
Quebec H9X 1C0 Canada