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Metal Content in Feathers of Wild and Zoo-kept Birds from Hokkaido, 1976–78

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Feathers of wild and domestic birds have been used often as analytical materials for pollutant metal analysis. In those reports, flight feathers were usually used as the analytical materials though without sufficient reasons (BERG et al. 1966, DRIVER & DERKSEN 1980, INOUE et al. 1974, LINDBERG & MEARNS 1982). Flight feathers were probably chosen because they are strong, attractive and easy to treat. Differences were found between the parts of a feather (BERG et al. 1966, TSUZUKI et al. 1976) or between the parts of wings (SHIRAI et al. 1979) in the concentrations of metals depending on the metals.

The present authors analysed copper, iron, mercury, manganese and zinc in the feathers of various species of fish-eating seabirds, grain-eating birds and omnivorous birds by atomic absorption spectrophotometry.

MATERIALS AND METHODS

Locality of captive sites. Nemuro City is located at the eastend of Hokkaido, has a population of 43,000 and consists primarily of fisheries and marine product industries. There is no big chemical industry near the city. There are many nesting places of various species of birds, especially seabirds, all around eastern Hokkaido. Many of those birds migrate to northern parts, e.g. Siberia, Alaska and the Arctic, during summer and breed there. Therefore these birds are considered to have minimum contamination by artificial sources of heavy metal pollutants.

Asahikawa City is located in the central Hokkaido and has a population of 360,000. The population is growing larger and has increased by 55,000 in the last 10 years. There is a big paper mill, a number of woodworking plants and a brewery. The Ishikari River and its tributaries run through Asahikawa City. Waste water from the paper mill and the brewery pour into the Ishikari River basin, and waste water from the paper mill is contaminated by mercury which was revealed to have its source in pulpwood. An abandoned mercury mine is located at the riverhead of a tributary stream. Daces captured in the stream were found to be accumulating high concentrations of mercury, which consisted largely of methylmercury compound (DOI &

FUKUYAMA, 1980).

Sapporo City is the capital of Hokkaido and has a population of 1,370,000. Eutrophism of the lower Ishikari and its tributaries and air pollution by particulate asphalt dust in the winter season are the major problems in environmental pollution in the city. The municipal Zoo of Sapporo is located on the top of a hill southwest of central Sapporo and is surrounded by a forest.

Birds and analytical materials: Seabirds examined in this study were obtained off the coast of Nemuro City during the period from May 1976 to May 1978. These birds were captured and drowned accidentally in fish-nets. Crows were captured by a trap at a slaughterhouse in the suburbs of Asahikawa during January and February 1978. Some bird specimens were given by courtesy of Mr. H. KANEDA, the chief breeder of the Municipal Zoo of Sapporo. These birds had died in the zoo from various causes and were examined by autopsy. The bird species examined in this study are shown in Table 1.

Analytical materials were collected from the wings, tail, abdomen and dorsum. Two types of feathers were collected from the wings; i.e. flight feathers and wing coverts. Flight feathers and tail feathers were subdivided into shaft and barbs. Wing coverts and the feathers from the abdomen and dorsum were used whole as analytical materials. Downs were involved in the feathers from the abdomen and dorsum. These materials were rinsed thoroughly in tap water, distilled water and with acetone, and were dried at 60°C in a drying furnace overnight.

Analytical procedures: About 1 gram of each sample was weighed precisely and wet-ashed in a mixture of nitric acid and sulfuric acid with a Kjeldahl apparatus. Approximately 50 ml of nitric acid and exactly 1.0 ml of sulfuric acid were used for ashing a sample. The ashed sample solution was diluted with distilled and deionized water and was adjusted to a volume of precisely 50.0 ml. The diluent was analysed directly by air-acetylene flame method with an atomic-absorption spectrophotometer, Shimadzu AA 640-13, or after extraction with DDTC (Sodium diethyldithiocarbamate) and MIBK (Methyl isobutyl ketone).

For total mercury analysis a sample was combusted in a atmosphere of oxygen (0.6 - 1.2 L/min). Mercury vapor was absorbed into 40 ml of 0.2% potassium permanganate solution acidified with sulfuric acid and subsequently extracted with 0.002% dithizone in chloroform. Mercury-dithizonate in chloroform was placed in a ceramic boat, and mercury was atomized by heating after evaporation of chloroform. Mercury content was determined by a cold-vapor atomic-absorption spectrophotometer, Toshiba-Beckman MV-253.

Table 1. Species of Birds Examined.

Species	n(sex)	Captive Site	Date of Capture or (Death)
Temminck's cormorant *(Phalacrocorax filamentosus)*	5 (F)	Nemuro	Dec.,'77
Red-throated diver *(Gavia stellata)*	5 (M)	Nemuro	June, Nov.,'77
Ancient auk *(Synthiliboramphus antiquus)*	4 (M)	Nemuro	Nov., Dec.,'77
Red-breasted merganser *(Mergus serrator L.)*	1 (F)	Nemuro	Nov.,'77
Asiatic common gull *(Larus canus kamtschatschensis)*	1 (F)	Nemuro	Nov.,'77
Bering Island guillemot *(Uria aalge inornta)*	1 (?)	Nemuro	Nov.,'77
Partridge auk *(Brachyramphus marmoratus perdix)*	1 (M)	Nemuro	Nov.,'77
Hornbilled puffin *(Cerorhinea monocerata)*	1 (M)	Nemuro	Nov.,'77
Japanese jungle crow *(Corvus macrorhynchos japonensis)*	4 (M)	Asahikawa	Jan., Feb.,'78
Japanese brown thrush *(Turdus chrysolaus chrysolaus T.)*	1 (M)	Asahikawa	May, '78
Whooper swan *(Cygnus cygnus cygnus)*	1 (?)	Sapporo	(Mar.,'77)
Flamingo *(Phoenicopterus antiquorum)*	1 (?)	Sapporo	(June,'76)

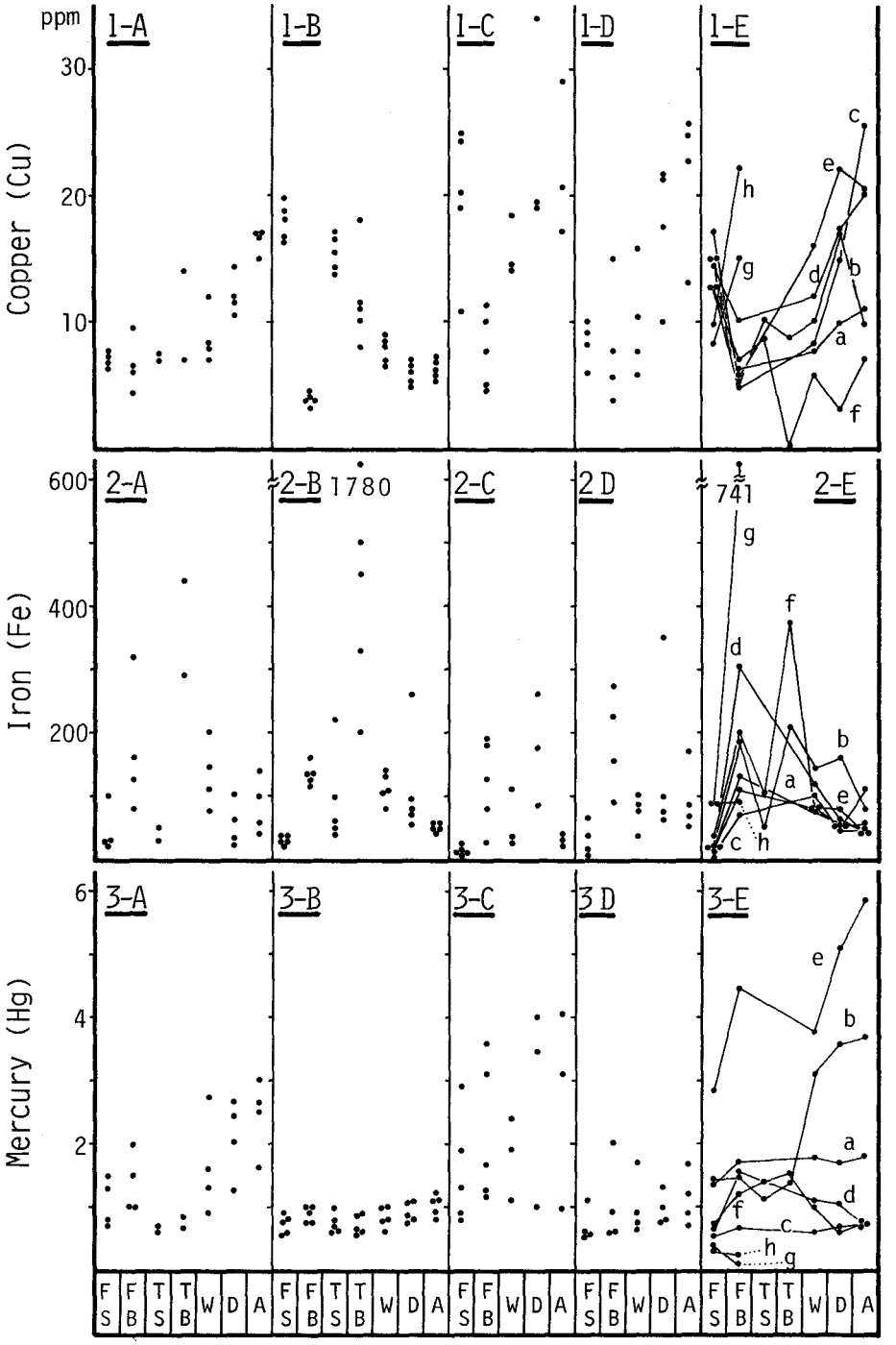
RESULTS

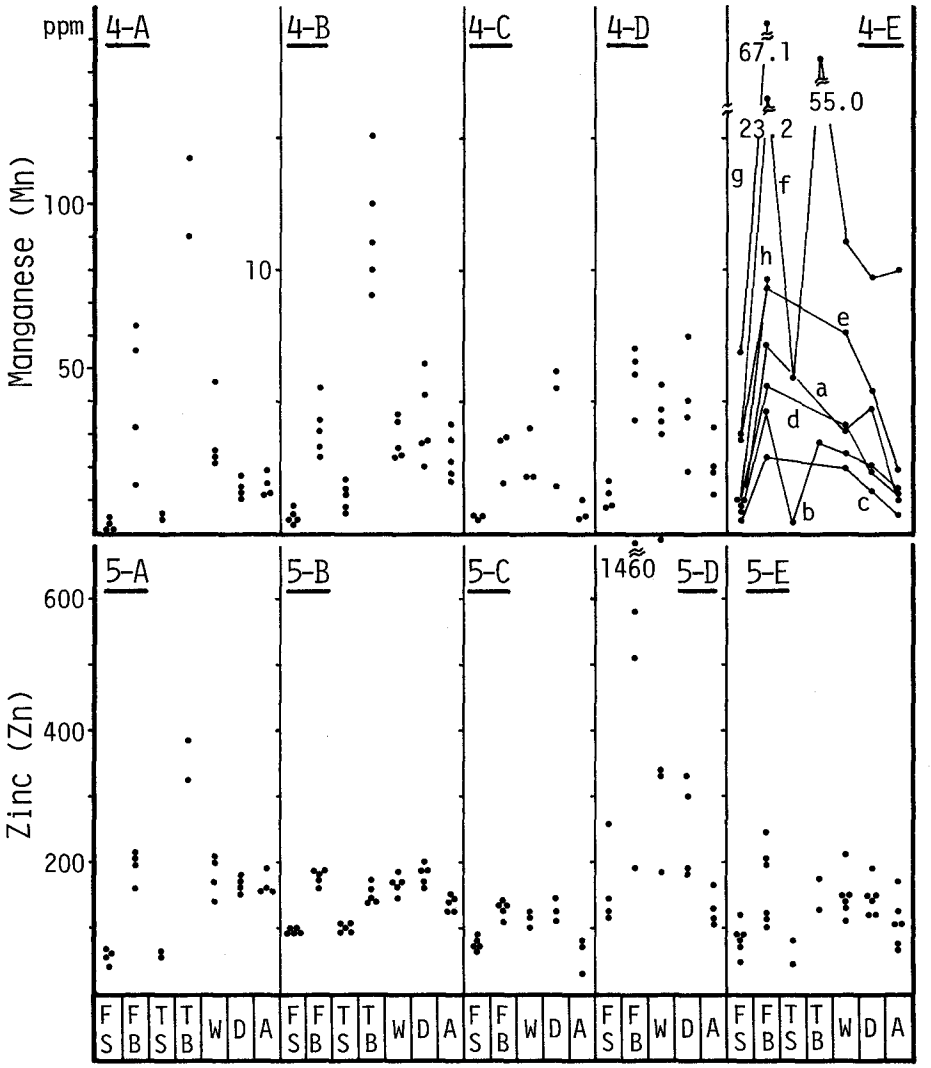
The analytical results are shown in Figures 1 - 5.

Copper: Copper concentration was higher in the shaft than in the barbs of a feather, though the reverse may occur in some cases (Fig. 1). In the feathers of a whooper swan and a flamingo which died in the Municipal Zoo of Sapporo, Cu concentration was higher in the barbs than in the shaft (Fig. 1-E). Copper concentration was highest in the feathers collected from the abdominal surface, and decreased in the order of flight feathers, tail, wing coverts and dorsum. The order of concentration inverted completely in the feathers of Temminck's cormorant (Fig. 1-B).

Iron: Iron concentration was higher in the barbs than in the shaft, and decreased in the order of abdomen, dorsum, flight feathers, wing coverts and tail (Fig. 2). The highest concentration was found in the tail feathers of a

Figures 1-5. Metal Content in Feathers of Wild and Zoo-kept Birds from Hokkaido, 1976-78*.





Species: A: *C. m. japonensis*, B: *P. filamentosus*, C: *G. stellata*, D: *S. antiquus*, E-a: *M. serrator*, E-b: *L. c. kamtschatschensis*, E-c: *U. a. inornta*, E-d: *B. m. perdix*, E-e: *C. monocerata*, E-f: *T. c. chrysolaus*, E-g: *P. antiquorum*, E-h: *C. c. cygnus*.

Abbreviations: FS: shaft of a flight feather, FB: barbs of a tail feather, TS: shaft of a tail feather, TB: barbs of a tail feather, W: wing coverts, D: dorsal feathers, A: abdominal feathers.

*: Each point shows the metal concentration in a sample.

Temminck's cormorant. This was thought to be due to artificial contamination on the decks of fishing boats.

Mercury: Mercury concentration was higher in the barbs than in the shaft, and decreased in the order of flight feathers, tail, wing coverts, dorsum and abdomen (Fig. 3). The highest Hg concentration was found in the abdominal feathers of a hornbilled puffin. Mercury levels in the feathers of these seabirds were generally low in spite of the fact that they fed entirely on fish. In Temminck's cormorant, differences in Hg concentrations between individual birds and between bodily parts from which feathers were collected were the lowest among the birds used in this study. It was notable that among terrestrial birds, only the feathers of crows had Hg concentrations as high as some seabirds.

Manganese: Manganese concentration was higher in the barbs than in the shaft, and decreased in the order of abdomen, dorsum, wing coverts, flight feathers and tail (Fig. 4). The highest Mn concentration was found in the tail feathers of a crow. Manganese levels in the feathers of this species were approximately 10 times higher than those of other species examined in this study.

Zinc: Zinc concentration was higher in the barbs than in the shaft, and decreased in the order of abdomen, dorsum, wing coverts, flight feathers and tail (Fig. 5). The highest Zn concentration was found in flight feathers of an ancient auk. Differences in Zn concentration between bird species and between bodily parts from which feathers were collected were much smaller than in the other metals examined in this study.

DISCUSSION

Feathers have attracted attention for a few decades as analytical material for environmental monitoring, because various metals accumulate in feathers from the environment or from food. A number of reports have been published on Hg accumulation in feathers of various species of birds. BERG et al. (1966) analysed Hg contents in feathers of Swedish terrestrial birds including museum specimens which were collected a century ago. They found a sudden increase of Hg contents in feathers which were collected during the period from 1940 to 1966. They concluded that this sudden increase of Hg contents in feathers was chiefly attributable to the use of alkylmercury seed-dressing agents which were in general use in the early 1940's in Sweden. BERG et al. (1966) also described the differences of Hg content in the parts of a feather, i.e. shaft, barbs and quill. HENRIKSSON et al. (1966) reported on high Hg content in the organs and feathers of Finnish white tailed eagles. JOHNELS et al. (1968) found that Hg content in the primary feathers of migrating bird, the osprey (*Pandion*

haliaetus), reflect the general level of Hg contamination of the place where the feathers were forming and growing. JERNELOV (1976) investigated Hg accumulation in rodents and seed-eating birds in Iraq following the outbreak of organomercury poisoning in 1972, and found that Hg accumulation in seed-eating animals in and around storehouses for dressed seeds does not cause any large scale spread of Hg into natural foodwebs and chains. DRIVER & DERKSEN (1980) found statistically significant relationships for the Hg concentration in feathers to breast muscle, feathers to liver and breast muscle to liver in ducks collected during 1971 and 1972 in Manitoba, Canada. LINDBERG & MEARNS (1982) found that peregrines transported from Scotland to Sweden showed a decrease in Hg levels in feathers in the second moult. The present authors could not find the cause of considerably low Hg levels in feathers of Temminck's cormorant, though various possibilities such as low Hg levels in the fish that they feed on and the effect of age were assumed to be the causes.

Normal distribution has been reported for essential trace elements such as Cu and Zn in human tissues while log normal distribution has been found for non-essential trace elements such as Sb, As and Hg (LIEBSCHER & SMITH 1968, TIPTON & COOK 1963). Similar findings were described on heavy metal contents in feathers of crow (SAITO et al. 1979, TSUZUKI et al. 1976). Statistically significant differences due to age in the levels of Zn and Cd (SCANLON et al. 1979a), differences between captive sites in Pb levels in woodcock feathers (SCANLON et al. 1979b) and differences between hunting seasons in Zn concentrations in ruffed grouse feathers (SCANLON et al. 1980) were described.

Species differences in the distribution of metals might be the subject for much further investigation. In the present study, Cu was higher in the shaft than in the barbs of Temminck's cormorant, while the order was inverted completely in feathers of other species. These phenomena are considered to result from some special biological or biochemical mechanism. Blood Hg levels in various species of animals and various strains of mice after methylmercury administration were found to be determined mainly by the number and position of cysteinyl residues in hemoglobin molecule of the species or strains (DOI & TAGAWA 1983, DOI et al. 1983).

According to the results obtained in this study, the present authors recommend using abdominal feathers for analytical materials for Hg because the highest Hg concentration was found in these feathers of almost all seabirds examined in this study. An effort to avoid unnecessary disturbances on natural ecosystem accompanying sample collection should be made at all times.

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