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Thallium Contamination in Wild Ducks in Japan

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ABSTRACT: Although thallium (Tl) is toxic to both humans and animals, there is little information on contamination in wildlife. In this study, Tl contents in wild ducks in Japan were determined. Contents of Tl in kidney and liver ranged from 0.42 to 119.61 and 0.10 to 33.94 μg/g dry weight, respectively. Significant correlations between Tl contents in kidney and liver were observed for all dabbling ducks except mallard (*Anas platyrhynchos*); similar correlations were not observed in diving ducks. Variation in Tl content was observed between sampling locations with the highest mean Tl content in the Eurasian wigeon (*Anas penelope*) collected in Ibaraki Prefecture.

Key words: Duck, thallium, wild bird.

Thallium (Tl) exists naturally in the environment (Mulkey and Oehme, 1993; Asami, 2001), and background levels of <0.00001 mg/l have been reported for fresh water and seawater (Mason, 1966). Concentrations in nonpolluted soil of 0.10–0.56 mg/kg dry weight (wt.) (Asami et al., 1996), 0.07–0.91 mg/kg dry wt. (Hoffer et al., 1990), and 0.292–1.172 mg/kg dry wt. (Qi et al., 1992) have been reported. In plants, concentrations do not generally exceed 0.05 mg/kg dry wt. (Wierzbicka et al., 2004) and, in animals, Tl levels are normally less than 1 ppb and 10 ppb in blood and tissues, respectively (Mulkey and Oehme, 1993). In humans, Tl has been detected in both kidney and liver, but concentrations were less than 4.05 and 1.42 ng/g wet wt., respectively (Weinig and Zink, 1967).

Although rodenticides and insecticides containing Tl have been regulated in many countries since the 1960s and 1970s (Asami, 2001), coal-burning power plants, certain cement plants, and mining and smelting operations can represent sources for this element (Pielow, 1979; Prinz et al., 1979; Sabbioni et al., 1984; Ewers, 1988). Nriagu and Pacyna (1988) estimated that the total emission of Tl from coal combustion and cement production ranged from 3,320 to $6,950\times10^3$ kg/yr. This metal and its compounds are also used in various industrial products, such as the production of sulfuric acid, dye and pigments, semiconductors, and superconducting ceramics (Mulkey and Oehme, 1993; Asami, 2001). Thallium has been suggested as a priority elemental pollutant with regard to human health (Keith and Telliard, 1979), and a significant positive correlation between the Tl content of moss and the incidence of circulatory disease in humans has been reported (Heim et al., 2002).

With the exception of reports of acute poisoning due to rodenticides and insecticides (Cromartie et al., 1975; Clausen and Karlog, 1977), there is little information on Tl contamination in wildlife. In this study, we determined levels of Tl in several species of wild ducks collected in various locations in Japan.

Samples were collected from 58 dabbling ducks representing five species and 15 diving ducks representing three species (Fig. 1). Dabbling ducks included spotbill ducks (*Anas poecilorhyncha, n*=19), mallards (*Anas platyrhynchos, n*=7), common teal (*Anas crecca, n*=6), northern pintails (*Anas acuta, n*=11) and Eurasian wigeon (*Anas penelope, n*=15). Diving ducks included greater scaup (*Aythya marila, n*=6), tufted ducks (*Aythya fuligula, n*=6) and pochards (*Aythya ferina, n*=3). Ducks were captured between 1993 and 1995 as a part of unrelated projects being conducted by the Japanese Ministry of the Environment. Other birds were supplied

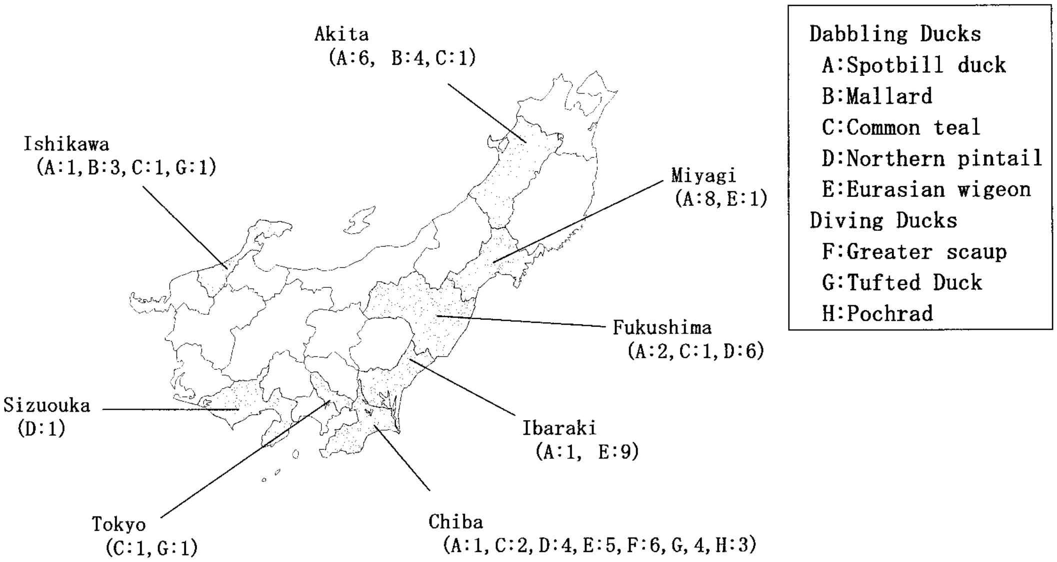

FIGURE 1. Sampling locations for wild ducks.

through the Gyotoku Bird Observatory in Chiba Prefecture.

Samples (approximately 200 mg) of kidney and liver from each duck were dried, weighed, and digested. Thallium contents were determined using an inductively coupled plasma atomic emission spectrometer (ICP-AES, Spectro A.I., Germany) as described in the previous reports (Mochizuki et al., 1999, 2002a, b, c). The detection limit for Tl was 0.007 ppm, and for statistical analyses, nondetectable values were estimated to contain half of the detection limit. Results are presented as mean±standard error (SE). Peason's correlation coefficients were calculated in Excel™ (Microsoft Corporation, Redmond, Washington, USA).

Thallium contents in kidney and liver for each species are shown in Table 1. Mean contents of Tl in kidney were greater than 4 μg/g dry wt. in all dabbling spe-

TABLE 1. Thallium contents (μ g/g dry wt.) in the kidney and liver of each species and the correlation between thallium contents of kidney and that of liver. The correlation with an asterisk shows significant correlation (**P<0.01, *P<0.05). n=number of samples.

Species	n	Kidney		Liver		Correlation
		Mean±SE	Range	Mean±SE	Range	
Dabbling ducks						
Spotbill duck	19	7.15±1.48	(0.91–23.73)	4.57±1.32	(0.60–26.62)	0.601**
Mallard	7	8.11±1.96	(2.65–15.76)	4.50±1.42	(1.09–11.86)	0.692
Teal	6	10.68±6.18	(2.12–40.33)	5.32±2.91	(0.37–19.12)	0.881**
Pintail	11	4.00±1.35	(1.01–15.70)	6.52±3.21	(0.12–33.94)	0.692*
Wigeon	15	20.38±8.08	(0.42–119.61)	4.27±1.14	(0.48–14.72)	0.848**
Total	58	10.46±2.34	(0.42–119.61)	4.93±0.85	(0.12–33.94)	0.411**
Diving ducks						
Scaup	6	2.10±0.32	(1.05–2.98)	2.71±1.15	(0.43–7.85)	0.214
Tufted duck	6	3.04±0.82	(1.02–6.60)	5.27±3.83	(0.10–24.33)	0.810
Pochard	3	2.13±0.33	(1.63–2.75)	2.09±0.85	(0.42–3.21)	−0.019
Total	15	2.48±0.36	(1.02–6.60)	3.61±1.56	(0.10–24.23)	0.745**

TABLE 2. Thallium contents (μg/g dry wt.) in the kidney and liver of each prefecture. *n*=number of samples.

	Dabbling ducks			Diving ducks		
Prefecture	*n*	Kidney	Liver	*n*	Kidney	Liver
Akita	11	8.43±2.05	5.73±2.32			
Chiba	12	3.32±0.78	2.83±0.70	13	2.28±0.22	2.04±0.59
Fukushima	9	4.08±1.56	6.93±3.94			
Ibaraki	10	28.25±11.44	5.26±1.55			
Ishikawa	5	14.73±6.74	6.96±3.13	1	6.60	24.23
Miyagi	9	7.80±2.15	3.99±0.74			
Sizuoka	1	8.71	1.93			
Tokyo	1	2.18	1.22	1	1.02	3.32

cies, while those in diving ducks were less than 3 μg/g dry wt. for all species. The total mean value for dabbling duck species (10.5 μg/g dry wt.) was approximately four times higher than the mean for diving duck (2.5 μg/g dry wt.). Although Tl levels in liver also were higher in species of dabbling ducks, mean values were less than 6.5 μg/g dry wt. in all species, and these differences were not statistically significant.

The Tl levels in ducks in this study were lower than those reported from birds of prey (63 ppm wet wt.) that died due to acute poisoning by Tl (Cromartie et al., 1975), and wood mice (kidney; 44.05, liver; 11.34 μg/g dry mass) and magpies (maximum value of kidney; 45 μg/g dry wt.) captured in a polluted area next to a zinc mine (Dmowski et al., 1998). Thallium contents in kidney and liver exceeding 0.5 ppm wet wt. (approximately 2 μg/g dry wt.) are believed to be indicative of poisoning (Clausen and Karlog, 1977). Mean contents of Tl observed for all species of ducks in this study (Table 1) exceeded this proposed threshold. There was no indication, however, that any of the ducks sampled in this study were physically affected.

Mochizuki et al. (1999, 2002a, c) reported spatial variation in contents of cadmium, molybdenum, and vanadium in wild birds, suggesting that birds may represent effective indicators of environmental contamination. This same relationship may exist with Tl contents in ducks, which approximated 10 μg/g dry wt. in all prefectures except Chiba Prefecture (Table 2). In Japan, high Tl contents have been reported in plants (28.9 mg/kg dry wt.) and bottom sediment (79.9 mg/kg dry wt.) associated with the Hosokura mines in Miyagi Prefecture (Asami, 2001). Background concentrations of 4.81 mg/kg dry wt. in sediments collected 20 km from this point source have also been reported. A high Tl content (maximum, 4.13 mg/kg dry wt.) has also been reported for one area near the copper mine in Ibaraki Prefecture and the maximum/background ratio of 10.7 was reported from soil near the mine. Although the authors could not find similar reports in other prefectures, the prefectures of Akita, Fukushima, and Ishikawa have active and idle silver, copper, lead, and zinc mines (Hata, 1997; Asami, 2001) that have been suggested as possible sources of Tl (Ewers, 1988). There are no such mines in the Chiba Prefecture, which may explain the low levels of Tl observed in ducks sampled from this location (Table 2).

With cadmium (Mochizuki et al., 2002a), vanadium (Mochizuki et al., 1999), and lead (Gerhardsson et al., 1995), a correlation between the contents observed in kidney and liver has been reported in wildlife species and humans. Similar correlations for Tl were obtained from all dabbling species except for the mallard and all diving species in the present study (Table 1). Sample sizes for individual species by location were too low for a meaningful comparison of kidney and liver Tl con-

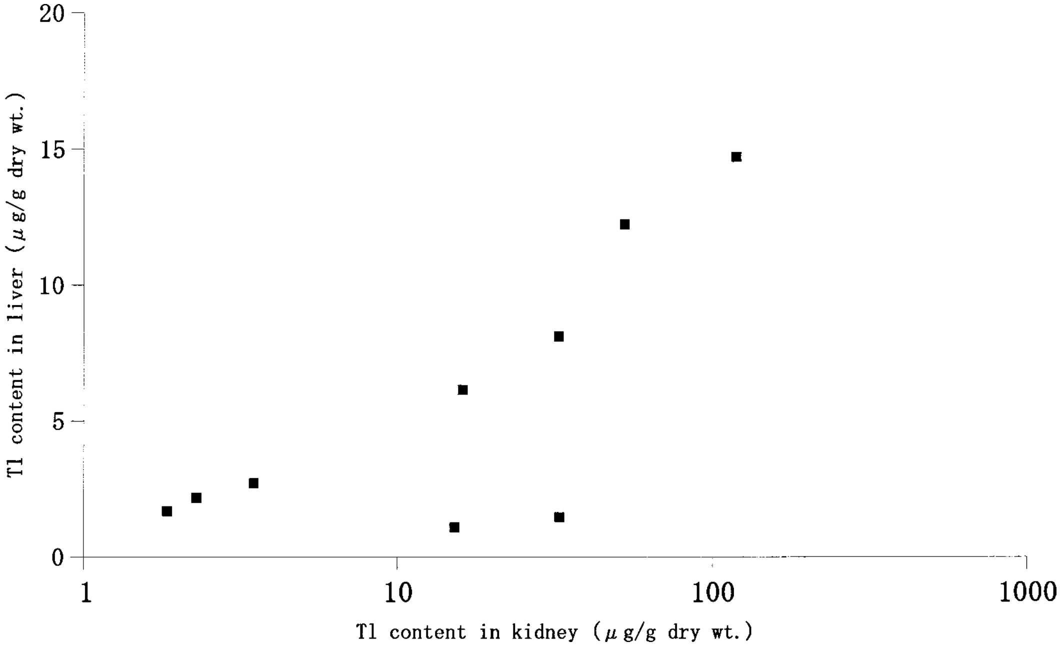

FIGURE 2. Relation between the Tl contents (μg/g dry wt.) in kidney and liver of Eurasian wigeon sampled from Ibaraki Prefecture.

tents. However, a significant correlation was obtained with the results from Eurasian wigeon (n=9) from Ibaraki Prefecture (R=0.856, P<0.01) (Fig. 2). Results of this study suggest that elevated contents of Tl are common in ducks in Japan but the potential clinical significance of these Tl levels is not understood. Additional monitoring of waterfowl may provide a means to better understand potential sources of Tl to wildlife populations.

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