MERCURY CONTAMINATION IN THE ENDOCRINE GLANDS OF BLACK-TAILED GULLS *LARUS CRASSIROSTRIS* ON KABUSHIMA (KABU ISLAND), JAPAN

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ABSTRACT

NIIZUMA, Y., TANI, H., YAMASHITA, Y., ITO, M. & MAEDA, M. 2021. Mercury contamination in the endocrine glands of Black-tailed Gulls *Larus crassirostris* on Kabushima (Kabu Island), Japan. *Marine Ornithology* 49: 329–333.

A colony of about 30 000 pairs of Black-tailed Gull *Larus crassirostris* nest on Kabushima (Kabu Island), which is located on the northeast mainland coast of Japan (Sanriku Coast, Honshu Island). There, the surface-water Hg concentration is higher than in the North Pacific Ocean. We collected carcasses from the breeding colony to assess the level of mercury (Hg) contamination. We measured Hg concentrations in 10 body tissues, including the endocrine glands. The relative mercury concentrations in the tissue samples (μg/g dry weight) were as follows: adrenal glands > livers > kidneys > blood > pituitaries > gonads > breast muscles > thyroid glands > pancreases > brain stems. Correlations existed between blood mercury levels and all body tissues except for the adrenal glands. Based on these results, we suggest that mercury levels in blood may not be a good indicator for hypothalamic-pituitary-adrenal axis impacts in Black-tailed Gulls.

Key words: gull, marine pollution, Sanriku coast, upper trophic level predator, seabird

INTRODUCTION

Mercury (Hg) is present in elemental, inorganic, and organic forms in the marine environment. Because environmental Hg bioaccumulates and biomagnifies, organisms at high trophic levels, such as seabirds, are exposed to elevated levels of Hg contamination (Furness & Camphuysen 1997, Burger & Gochfeld 2002). As a result of increases in Hg levels in the Atlantic and Arctic oceans, some top-level predators, such as Northern Gannet *Morus bassanus*, Atlantic Puffin *Fratercula arctica*, Great Skua *Stercorarius skua*, Manx Shearwater *Puffinus puffinus* (Thompson *et al.* 1992), and Ivory Gull *Pagophila eburnea* (Bond *et al.* 2015) now have higher total body burdens of Hg than in the past. In the Pacific Ocean, Hg concentrations have also risen in predators such as Black-footed Albatross *Phoebastria nigripes* (Vo *et al.* 2011). Elevated body burdens of Hg in avian piscivores is likely linked to increases in anthropogenic Hg emissions (Bond *et al.* 2015).

Many studies have shown that Hg causes a wide range of neurological, physiological, reproductive, and behavioral effects through the disruption of hormone secretion in wild birds and humans (Burger & Gochfeld 2002). The abnormal alteration of the endocrine system through accumulation of Hg can have negative impacts on health (Franceschini *et al.* 2017). While it is recognized that Hg accumulates appreciably in kidneys and livers (Kim *et al.* 1996, Goto *et al.* 2018), little is known about Hg accumulation in the endocrine glands of seabirds.

Asian anthropogenic emissions have increased atmospheric Hg deposition in the Pacific Ocean over the past several decades (Lamborg *et al.* 2014). It has been demonstrated that the surface-water Hg concentration in the North Pacific Ocean is higher on the western side, especially off Japan's Sanriku Coast, than in other waters (Sunderland *et al.* 2009). Black-tailed Gulls *Larus crassirostris* breeding at the colony on Kabushima (Kabu Island), which is at the northernmost point of the Sanriku Coast, range over an area where surface water has high Hg concentrations (Sunderland *et al.* 2009, Yoda *et al.* 2012). It has been reported that Black-tailed Gulls accumulate total Hg in their body tissues at higher levels than other larid species (Goto *et al.* 2018).

Studies of the impact of Hg on the endocrine system usually rely on measurements of Hg concentrations in blood as an index of body burden (Tartu *et al.* 2013, Franceschini *et al.* 2017). However, there have been no studies examining the relationship between Hg concentrations in blood and in the endocrine glands. In this study, we collected carcasses of Black-tailed Gulls from the breeding colony on Kabushima to analyze Hg concentrations in various tissues and described the relationship between Hg in the blood and endocrine glands.

METHODS

Thirty-five Black-tailed Gull carcasses were collected from the breeding colony on Kabushima during April and May 2017. The gulls likely were killed by either red foxes *Vulpes vulpes* or domestic cats *Felis catus* (Tomita *et al.* 2010). Specimens were placed in plastic bags then frozen at −20 °C until dissection.

For analysis, the frozen specimens were thawed then dissected to remove the following tissues from all specimens: blood (as clots from hearts), livers, kidneys, breast muscles, adrenal glands, and gonads (testes of males [n = 17], ovaries of females [n = 18]). The thyroid glands from 34 specimens, the pancreases from 33 specimens, and both the pituitaries and brain stems from 30 specimens were also removed. Livers, kidneys, breast muscles, and ovaries were cut into small pieces. These pieces and other tissues were dried at 50 °C for 96 hours to a constant mass. Total Hg concentrations in these tissues were measured by thermal decomposition using a Direct Thermal Decomposition Mercury Analyzer (MA-3000; Nippon Instruments).

We tested differences between tissues and sexes using a linear mixed model of total Hg concentrations in all tissues with an identity link function and normally distributed errors. We included the total Hg concentrations of each organ as independent variables, tissues and sexes as explanatory variables, and the individual as a random effect in the model. We used the likelihood-ratio test to assess the effect of sex on total Hg concentrations. We tested, using the linear model, whether total Hg concentrations in blood explained the concentrations in each organ. The results were considered significant when $P < 0.05$. All statistics were performed using R, version 3.5.1 (R Core Team 2018).

RESULTS

Total Hg concentrations differed significantly among tissues ($\chi^2 = 258.16$, $df = 9$, $P < 0.001$), but not between sexes ($\chi^2 = 0.74$, $df = 1$, $P > 0.05$). Therefore, we combined the sexes in assessing total Hg concentrations in linear models. The sequence of Hg concentration (mean ± standard deviation, measured as μg/g dry weight) in Black-tailed Gull tissue samples was: adrenal glands (21.0 ± 20.4) > livers (4.86 ± 2.16) > kidneys (4.26 ± 1.70) > blood (4.00 ± 1.39) > pituitaries (2.29 ± 2.00) > gonads (1.51 ± 0.56) > breast muscles (1.42 ± 0.54) > thyroid glands (1.38 ± 0.61) > pancreases (1.25 ± 0.44) > brain stems (1.11 ± 0.51) (Table 1).

Total Hg concentrations in blood significantly predicted those in livers ($F_{1,33} = 12.14$, $R^2 = 0.247$, $P < 0.01$), kidneys ($F_{1,33} = 14.21$, $R^2 = 0.280$, $P < 0.01$), pituitaries ($F_{1,28} = 6.02$, $R^2 = 0.148$, $P < 0.05$), gonads ($F_{1,33} = 17.51$, $R^2 = 0.327$, $P < 0.01$), breast muscles ($F_{1,33} = 18.86$, $R^2 = 0.344$, $P < 0.01$), thyroid glands ($F_{1,32} = 4.70$, $R^2 = 0.101$, $P < 0.05$), pancreases ($F_{1,31} = 12.19$, $R^2 = 0.259$, $P = 0.01$), and brain stems ($F_{1,28} = 5.82$, $R^2 = 0.142$, $P < 0.05$). However, concentrations in blood did not predict those in adrenal glands ($F_{1,33} = 0.04$, $R^2 = -0.029$, $P > 0.05$) (Fig. 1).

DISCUSSION

It is traditionally recognized that Hg accumulates particularly in kidneys and livers (Kim *et al.* 1996, Goto *et al.* 2018). However, while we found that wild Black-tailed Gulls accumulated higher levels of total Hg in their adrenal glands than in their other tissues, there was neither significant correlation between total Hg concentrations in the adrenal glands and blood nor significant difference in total Hg concentrations between sexes.

The highest total Hg concentrations in adrenal glands could be related to the physiological properties of endocrine glands. It is known that endocrine glands are richly supplied with blood (Nelson 2005) and that Hg compounds ingested with food and water may be carried to the endocrine glands by blood flow (Monteiro & Furness 1995). Hg compounds may be accumulated in the endocrine tissues, especially the adrenal glands, during the early process of accumulation in body tissues under lower-level Hg exposure. In a study of exogenously administered $HgCl_2$ in mice, Hg(II) accumulation within adrenal glands was mainly in the medulla, where it was localized to the chromaffin granules (Kozma *et al.* 1996). The chromaffin granules in medullary cells may have a high affinity for Hg(II).

Hg contamination in birds may have deleterious effects via the hypothalamic-pituitary-adrenal (HPA) axis, which regulates corticosterone concentrations. However, the studies that have assessed the level of Hg exposure in birds have not provided consistent results. In studies of Tree Swallow *Tachycineta bicolor* adults (Franceschini *et al.* 2009) and Common Eider *Somateria mollissima* adults (Provencher *et al.* 2016), Hg was observed to negatively impact blood levels of corticosterone. However, a positive impact was shown for adult male Common Loons *Gavia immer* (Franceschini *et al.* 2017), while no impact was found in Black-legged Kittiwakes *Rissa tridactyla* (Tartu *et al.* 2015). The reasons for these differences in results are unclear. Although blood can be collected from birds with relatively non-invasive methods, and although it is possible to investigate many physiological indices from blood, the lack of a relationship between Hg levels in adrenal glands and blood suggests that blood concentrations may not be a good indicator for the HPA axis in Black-tailed Gulls and, by extrapolation, other seabird species.

We found no statistical difference between the sexes in terms of total Hg concentrations in the internal tissues, which contradicted previous studies by Thompson *et al.* (1991). Although Black-tailed Gulls are sexually dimorphic in size, with males larger than females (Chochi *et al.* 2002), there is no evidence of a sexual difference in foraging behavior or diet during the incubation period (Yoda *et al.* 2012). Male and female Black-tailed Gulls are likely to be exposed to similar trophic levels of Hg. Since we collected gull specimens during the early breeding season, most females may have just produced or laid their eggs. Although female birds could excrete Hg from their bodies into their eggs and thus reduce their Hg body burden (Lewis & Furness 1993), our results do not support the hypothesis that female gulls depurate Hg into their eggs, thereby leading to sex differences in the concentration of Hg.

The total Hg concentrations found in the muscles, livers, and kidneys of Black-tailed Gulls during this study are higher than those previously recorded in gulls, with the exception of Slaty-backed Gulls *L. schistisagus* on Teuri Island, Japan, and European Herring Gulls *L. argentatus* in northwestern Ontario, Canada (see Table 1 in Goto *et al.* 2018). The Black-tailed Gull mainly forages on pelagic fishes such as Japanese anchovy *Engraulis japonica* and Pacific sardine *Sardinops melanostictus*, in relation to their availability (Yoda *et al.* 2012). In the western Pacific during 1973–1980, Hg levels in pelagic fishes were reported as 0.027 μg/g in Pacific sardines and 0.074 μg/g in Pacific saury *Cololabis saira* (Tamase *et al.* 1982). During 1978–1989, the levels were 0.105 μg/g in Pacific sardine and 0.076 μg/g in Pacific saury (Yamamoto *et al.* 1992). During the 2000s they were 0.05 μg/g (Yamashita *et al.* 2011) and 0.14 μg/g (Ishii *et al.* 2014) in Japanese anchovy, and 0.10 μg/g in Pacific sardine and 0.30 μg/g Pacific saury (Yamashita *et al.* 2011). Black-tailed Gulls collected during the non-breeding season at Matsuyama, Japan in 1974 carried 0.08, 0.58, and 0.69 μg/g wet weight of total Hg in their muscles, livers, and kidneys, respectively (Lee *et al.* 1987). Those during the breeding season on Rishiri Island in the Sea of Japan in 1999–2001 carried 0.60, 2.1, and 1.5 μg/g dry weight of total Hg in their muscles, livers, and kidneys, respectively (Agusa *et al.* 2005). The increase in Hg concentrations in Black-tailed Gulls may be related to the increase in Hg emissions in Asia over the past several decades (Lamborg *et al.* 2014), which is transferred through the intake of contaminated pelagic fishes (Frederick *et al.* 2004).

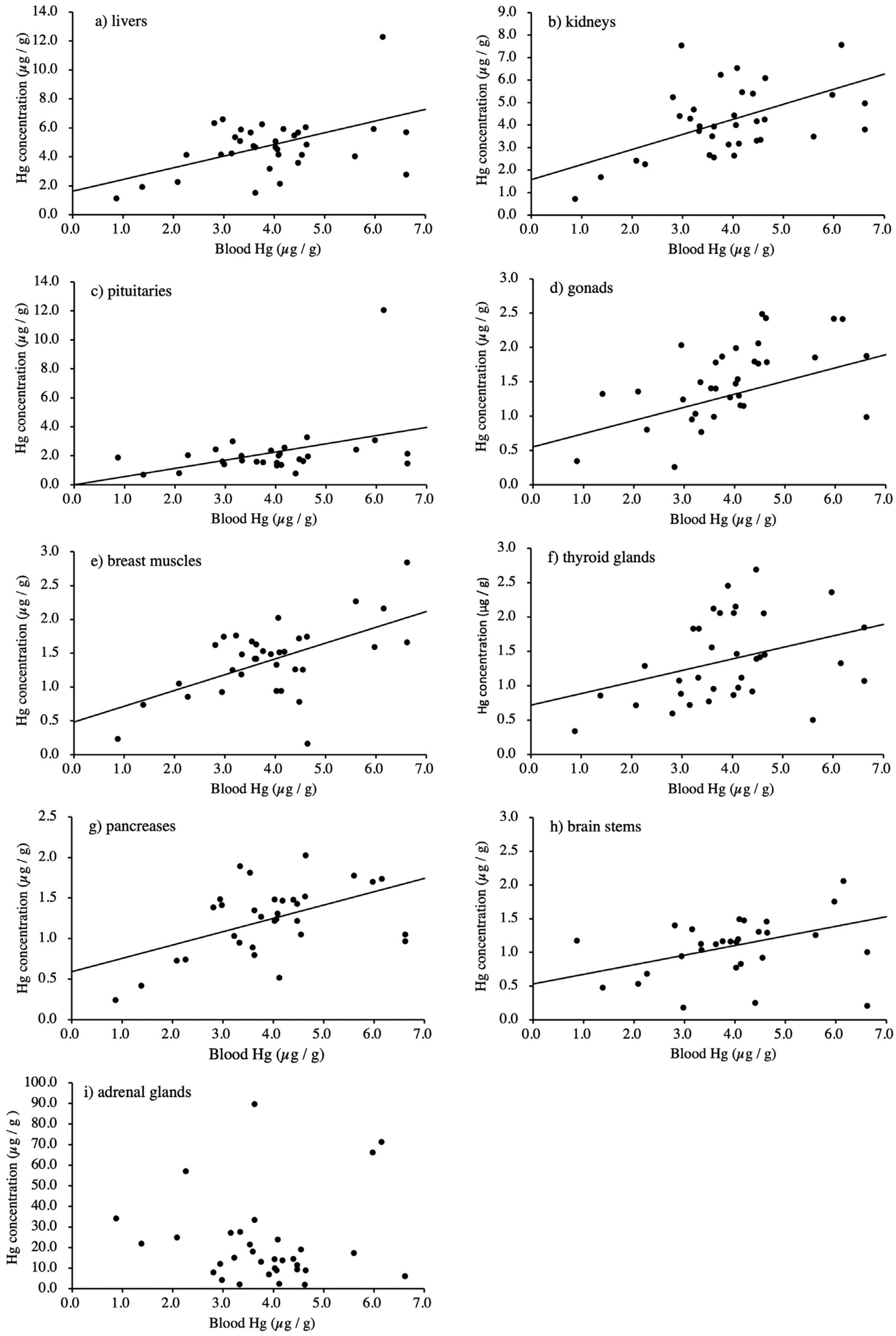

Fig. 1. Relationships between total Hg concentrations of blood and (a) livers, (b) kidneys, (c) pituitaries, (d) gonads, (e) breast muscles, (f) thyroid glands, (g) pancreases, (h) brain stems, and (i) adrenal glands.

TABLE 1
Total Hg concentrations (µg/g dry weight) and results of linear mixed model of mercury concentrations in 10 tissues. Concentrations are given as mean ± standard deviation with sample sizes in parentheses.

Tissues	Hg concentrations		Results of linear mixed model	
	Male	Female	Estimates	Standard error
Adrenal glands	22.82 ± 21.40 (17)	19.28 ± 19.93 (18)	20.67 (35)	1.20
Livers	5.49 ± 2.62 (17)	4.26 ± 1.45 (18)	−16.14 (35)	1.58
Kidneys	4.43 ± 2.01 (17)	4.10 ± 1.70 (18)	−16.74 (35)	1.58
Blood	4.14 ± 1.72 (17)	3.87 ± 1.02 (18)	−17.00 (35)	1.58
Pituitaries	2.71 ± 2.87 (14)	1.92 ± 0.57 (16)	−18.67 (30)	1.65
Gonads	1.73 ± 0.58 (17)	1.30 ± 0.47 (18)	−19.49 (35)	1.58
Breast muscles	1.28 ± 0.59 (17)	1.55 ± 0.45 (18)	−19.58 (35)	1.58
Thyroid glands	1.52 ± 0.64 (16)	1.25 ± 0.57 (18)	−19.61 (34)	1.60
Pancreases	1.32 ± 0.50 (17)	1.19 ± 0.37 (16)	−19.77 (33)	1.61
Brain stems	1.23 ± 0.60 (14)	1.00 ± 0.41 (16)	−19.85 (30)	1.65

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