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Mercury Concentration in 3 Species of Gulls, *Larus ridibundus*, *Larus minutus*, *Larus canus*, From South Coast of the Caspian Sea, Iran

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Abstract In this study, the mercury concentrations of liver, breast feathers and tail feathers in three species of Gull; Black-headed Gull (*Larus ridibundus*), Common Gull (*Larus canus*) and Little Gull (*Larus minutus*) from the South coast of the Caspian Sea in Iran were assayed. Mercury accumulation in liver, breast feathers and tail feathers of species were 1.69–3.16, 2.88–7.18 and 2.09–5.66 mg/kg, respectively. Mercury concentration hierarchy in tissues we tested was as follows: breast feather > tail feather > and liver. We found that despite its small size, Little Gull had highest (3.85–8.05 mg/kg) and Common Gull lowest (1.69–2.88 mg/kg) level of Hg in their bodies. An inverse relationship between body size and Hg levels in these Gulls was detected. Mercury in Little Gull and Black-headed Gull exceeded the 5 ppm threshold for adverse effect.

Keywords Mercury · Liver · Feather · Caspian Sea

Mercury occurs naturally in the environment but anthropogenic sources, such as fossil fuel combustion, non-ferrous metal production, and waste incineration, have been suggested to contribute significantly to the Hg contamination (Ochoa-acuna et al. 2002). Caspian Sea area, which is the largest landlocked body of water on earth and home to numerous ecosystems. The coastal wetlands of the Caspian basin include many shallow and saline water pools, which attract a variety of birds and support great biodiversity. Over 400 species of birds are unique to the Caspian Sea area (Bashkin 2006). Also serves as a sink for many contaminants and high concentrations of Hg have been found in coastal sediment and Caspian sturgeon (Mora et al. 2004; Agusa et al. 2004). Sources of Caspian pollution includes oil discharges and spills from Republic of Azerbaijan and untreated waste from the Volga (including drainage from heavy industry and municipal sewage), which seriously threaten flora and fauna of the area (Bashkin 2006).

In our view, therefore, there is an urgent need to investigate the extent of Hg pollution in the region to be used as a baseline for future risk assessment work. Our data can contribute to development of management programs for understanding the ecotoxicological status of the Caspian and its coastal environment. Aquatic ecosystem health has often been assessed using avian species as indicator of pollution exposure and toxicity. Sea birds may be exposed to significant concentrations of Hg and thus might serve as good monitors of spatial and temporal patterns of Hg presence in marine ecosystems (Ochoa-acuna et al. 2002) In the marine food-web seabirds such as Gulls *Larus* sp. are the top predators, and particularly sensitive to contamination (Helberg et al. 2005), they have been frequently used as bio indicators. Gulls are also a favorite bio indicator since they have wide geographical distribution and allow comparisons over broad regions (Albanis et al. 2003). Moreover, in freshwater basins, in densely populated and industrialized regions, as well as in arctic marine environments, Gulls have been used as sentinel biomonitor species (Hebert et al. 1999; Mineau et al. 1984; Savinova

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et al. 1995). The present study investigated levels of Hg in three species of Gulls from the Caspian Sea to determine usefulness of these species as a biomonitor for this region.

Materials and Methods

Eighteen birds of three species of Gulls were collected from the Southern coast of the Caspian Sea in the Iranian province of Mazandaran (Fig. 1). Freshly injured or killed bird carcasses had been confiscated from poachers by the Environmental Protection Agency guards in charge of bird conservation in the area during winter of 2008. The collections included Black-headed Gull (n = 8), Common Gull (n = 3) and Little Gull (n = 7). Table 1 shows length and weight of the specimens. Samples were brought to the laboratory right away, birds were dissected immediately. Liver, Breast feather and tail feather were removed from the bodies of the specimens.

Feathers were washed vigorously in deionized water alternated with acetone to remove loosely adherent external contamination and were air dried overnight. Liver samples were freeze-dried and homogenized. Finally they were changed into the powder (Zammani Ahmadmahmoodi et al. 2009).

Mercury was measured by the LECO AMA 254 Advanced Mercury Analyzer (USA) according to ASTM, standard No. D-6722. The LECO AMA 254 is a unique Atomic Absorption (AAS) that is specifically designed to determine total Mercury content in various solids and certain liquids without sample pre-treatment or sample pre-

Fig. 1 Sampling sites for Gulls along the South coast of the Caspian Sea

Table 1 Biometrics of three species of Gulls from South coast of the Caspian Sea

Species name	Length (cm)	Weight (g)
Little Gull (*Larus minutus*) n = 7	28 ± 0.5	98 ± 4
Black-headed Gull (*Larus ridibundus*) n = 8	40 ± 1	250 ± 16
Common Gull (*Larus canus*) n = 3	44 ± 0.5	440 ± 30

concentration. In order to assess the analytical capability of the proposed methodology, accuracy of the total Hg analysis was checked by running three samples of Standard Reference Materials (SRM), National Institute of Standards and Technology (NIST), SRM 1633b, SRM 2709, and SRM 2711 in seven replicates (Zolfaghari et al. 2007). Recovery varied between 94.8% and 103%. The detection limit of the method used was 0.001 mg/kg in dry weight.

The statistical analysis was carried out using SPSS soft ware version 11.5. The data were tested for normality using a Kolmogorov–Smirnov test. Data were normally distributed. Mercury concentrations in feather and liver were tested for mean differences among species using one-way analysis of variance (ANOVA). When significant differences were observed among the species and tissues, Tukey–Kramer multiple-comparison test was applied to determine which means were significantly different. Values are given as mean ± standard errors (SE) and we considered a p value <0.05 to be statistically significant.

Results and Discussion

Mercury concentrations of feather and liver in 3 Gull species from the coast of the Caspian Sea are shown in Fig. 2. Over all in this study, Hg concentrations in the feather were higher than in the liver. In Black-head Gull there was significantly higher Hg in feathers ($p = 0.01$); and similarly Little Gull had more Hg in feathers ($p = 0.05$). Generally in avian species, Hg concentration is highest in feather than in other tissues (Lee 1989). For example as Kim et al. (1996) reports feather of Northern Fulmar and Brown Booby contained about 40% of total Hg; while the liver held less than 25% of Hg in it. Braune and Gaskin (1987) also report that feathers of adult Bonaparte's Gull (*Larus philadelphia*) had 93% of total body Hg. It is hypothesized that one reason liver Hg is lower in adult birds is the phenomenon of molting. During the process of feather growth, liver Hg is depurated into feathers reducing Hg amounts in the liver (Furness et al. 1986; Lewis et al. 1993).

We considered two types of feathers in this study; breast feathers and tail feathers, mercury levels found in breast

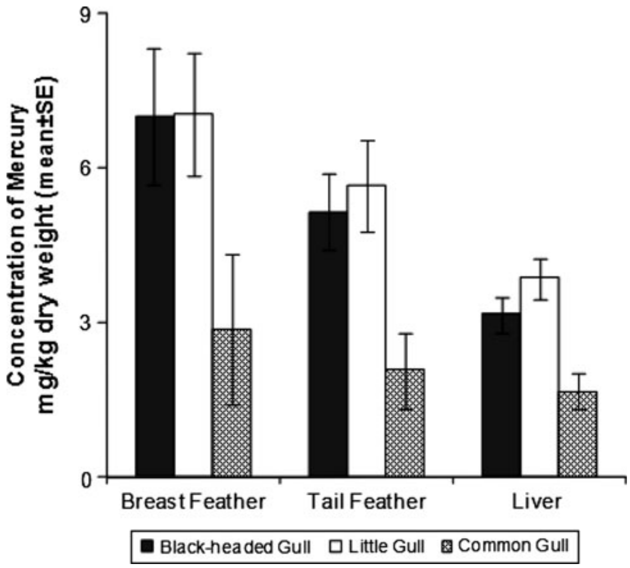

Fig. 2 Mercury concentrations in feather and liver of three species of Gulls from South Coast of the Caspian Sea

feather were higher than tail feathers however this difference was not significant (Fig. 2). Scientists generally believe that breast feathers are a more suitable indicator of Hg body load. This is because breast feather does not exhibit similar molting sequence as flight feathers. In addition, they usually show low variability in mercury level than primaries and tail feathers (Furness et al. 1986).

Little Gull had highest Hg while Common Gull had lowest Hg concentrations. Both Little Gull and Black-headed Gull had significantly higher concentrations of Hg than Common Gull ($p = 0.05$). There was no significant difference in Hg concentration between Black-headed Gull and Little Gull. Cramp and Simmons (1997) have explained this observation by emphasizing association of Little Gull with colonial nesting species especially with Black-headed Gull; which ultimately leads to two species having similar habitat and food items.

Gulls are migratory birds. Different migratory routes may explain this discrepancy in Hg concentrations among these three species. Common Gull and Black-headed Gull are seen throughout all coastal provinces of Iran in the south coast of the Caspian Sea. These birds have been spotted in Gilan and Gorgan provinces, but Little Gull has a small population and has only been seen in Mazandaran province. Common Gull winters exclusively in the Caspian while Black-headed Gull and Little Gull winter partly in the Caspian Sea and travel down to the Persian Gulf area for some of the winter (Mansoori 1999). Zammani Ahmadmahmoodi et al. (2009) report high levels of ubiquitous mercury, in birds wintering in the Persian Gulf region. In addition, heavily industrialized Persian Gulf region releases many pollutants including Hg into these habitats (Zolfaghari et al. 2007). In migratory birds, accumulation of Hg depends not only on the degree of pollution in the area of collection, but also on pollution in stopover sites and breeding grounds. We know that many birds that winter in Iran have their breeding grounds in Russia and Eastern Europe (Nakata et al. 1998); Gulls, which winter in the Caspian Sea, summer in western Siberia (Cramp and Simmons 1997) and high concentration of Hg has been reported in Gulls from Russia (Sagerup et al. 2009).

Generally, larger species that typically live longer and can eat larger food items are expected to have higher levels of pollutants in their bodies. But Burger and Gochfeld (2000), who found highest Hg in the smallest size birds, challenged this generalization and argued that larger animals may not always eat larger food items. Similar to their finding, in our study the highest Hg levels were found in the smallest bird; we found the highest Hg in Little Gull, which among the birds we studies, is the smallest in size (Table 1). Difference in metabolic rate can also attribute to varying Hg body burdens. Little Gull has a high metabolic rate which necessitates high caloric intake which also increases contamination intake. Similar to this study, Braune et al. (2007) found highest contamination level in smallest Ivory Gull and attributed this high level of contamination in a small bird to the bird's high metabolic rate.

Mercury concentrations have been reported in Gulls form many regions of the world including Canada (Braune and Gaskin 1987; Braune 1987), United States (Ochoa-acuna et al. 2002), Germany (Lewis et al. 1993), and the United Kingdom (Thompson et al. 1990). Our results indicate that total mercury in Gull populations living on the south coast of the Caspian Sea is higher than those in other regions. Other contributing factors to such high Hg in Gulls of the Caspian may be several polluting industries in this area including local pulp and paper mills, and the heavy industry in the West coast of the Caspian Sea in Azerbaijan, and the Northern Russian coast. On the other hand, Hg emissions appear to be increasing globally due to increased coal burning in Asia (Pacyna 2002). Scavenging habits of Gulls may have also exposed them to high Hg concentrations. In Iran they have been spotted eating garbage in landfills.

For a wide range of species, mercury levels of 5 ppm in feather are associated with reproductive deficits, such as lower clutch size and/or egg size, lower hatching rate, and decreased chick survival and other effects (Eisler 1987). Also mercury concentrations of 49–125 µg/g in liver have been reported for free-living birds found dead or dying (Thompson 1996). In Gulls liver maximum Hg concentrations were 4.9 mg/kg dry weight (Little Gull), and mean Hg in feather of Little Gull and Black-headed Gull exceeded 5 ppm, the threshold for adverse effect. Therefore, they may be at risk for adverse effects of this metal.

That the recent decrease in Little Gull population this area may then be attributable to this metal pollutant. We conclude that conservation measures are urgently needed to protect avail life in the Caspian Sea area. As clarification of the extent of pollution in the Caspian birds would constitute an important step towards protection of these ecosystems and will guide us in promoting sustainable development in this area.

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