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Liver and Breast Feather Mercury in Piscivorous Birds of the Caspian Sea: Monitoring Changes

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Abstract Mercury in the liver and breast feathers of the Common Cormorant, and in three species of Grebes from the southern coast of the Caspian Sea, were determined. The Common Cormorant had significantly more mercury in its tissues (liver: 8.5 ± 1.5; feather 8 ± 1 mg/kg dry weight) than Grebes (Great Crested Grebe: 3 ± 0.5, 8 ± 1.5; Black-necked Grebe: 3 ± 0.5, 5.5 ± 1; Little Grebe 2.5 ± 0.5, 4 ± 0.5). Unlike Common Cormorants, Grebes had less mercury in the liver than in breast feathers. Mercury in the Common Cormorant was not different between 2002 and 2008 collections. The mercury threshold for adverse effects is currently 5 ppm, which was exceeded by all but Little Grebes in this study.

Keywords Mercury · Liver · Feather · Caspian Sea · Common Cormorant · Grebe species

Habitat destruction, caused by metal pollution, poses a critical global challenge. A dramatic two to ten folds increase in Hg levels during the past one and half centuries has made Hg contamination a growing international concern (Swain et al. 1992; Wiener et al. 2003). The Caspian Sea is an important wintering ground for up to 12 million aquatic birds that come to the Caspian from as far away as the Nile basin and western Siberia. The unique habitats of the Caspian are believed to be in danger of serious degradation and collapse due to Hg pollution.

Caspian pollution is primarily due to inflow from the Volga, which contributes >80% of the total inflow, and the municipal and industrial waste that are released into this ancient lake (Karpinsky 1992). Each day, the Pulp Mill Plant of Mazandaran releases over 10,000 m^3 of untreated sewage into the Caspian Sea (Center for Data and Scientific Documents of Iran). Chlor-alkali industrial plants of Azerbaijan have released significant Hg into the Caspian and have caused serious contamination of the sediment. Mercury contamination of the sediment, fish, and birds of the Caspian have been reported (Agah et al. 2007) and a decline in the number of Caspian birds has been observed. Conditions of the Caspian Sea are common in many ecosystems worldwide where reckless human activity and negligence has culminated in serious ecosystem decline and destruction. But, despite the seriousness of global Hg pollution, no international legally-binding agreement exists to curb Hg release.

In Iran, public awareness and demand has led to the installation of some basic pollution prevention and remediation measures to protect the vulnerable ecosystems of the southern Caspian region (Rahbar 2002). To determine the effectiveness of these efforts, we measured and compared Hg levels in liver and breast feather of common shorebirds that were collected as early as January 2002 with those that were collected 6 years later, in 2008.

Materials and Methods

In December 2008, twenty-five freshly injured or killed bird carcasses were confiscated from poachers by the Environmental Protection Agency guards responsible for

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bird conservation in the southern coast of the Caspian Sea. Figure one illustrates location of Mazandaran Province in Iran, where the birds, including Common Cormorant (*Phalacrocorax carbo*) n = 9, Great Crested Grebe (*Podiceps cristatus*) n = 6, Black-necked Grebe (*Podiceps nigricollis*) n = 7, and Little Grebe (*Tachybaptus ruficollis*) n = 3 were obtained. Birds were brought to the laboratory immediately and were dissected at once. Liver and breast feather were removed. Feathers were washed vigorously in deionized water alternated with acetone to remove loosely adherent external contamination, then dried for 12 h in an oven at 80°C (Saeki et al. 2000) (Fig. 1).

Mercury was analyzed using LECO AMA 254 Advanced Mercury Analyzer (USA) according to ASTM, standard No. D-6722. Each sample was analyzed 3 times. In order to assess the analytical capability of the method, accuracy of the total Hg analysis was checked by running three samples of Standards Reference Materials (SRM), National Institute of Standards and Technology (NIST), SRM 1633b, SRM 2709, and SRM 2711 (AL-Majed and Preston 2000). Recovery varied between 94.8 and 103%. The detection limit of the instrument was 0.001 mg/kg in dry weight. SPSS software (Version 11.5) was utilized for statistical analysis. Data were tested for normality using a Kolmogorov–Smirnov test. Differences in concentration of Hg among different species were evaluated by one-way analysis of variance (ANOVA). When significant differences were observed among the different species, Tukey–Kramer multiple comparison test was applied to determine which means were significantly different.

Six years earlier, in December 2002, 14 Common Cormorants had been collected from the same area and liver and breast feather had been analyzed for Hg contamination in the same manner.

Independent t-test was used to compare Hg concentration in Common Cormorant tissues from 2002 with samples taken in 2008; $p < 0.05$ was set to indicate significance.

Results and Discussion

The breeding grounds for many wintering Caspian birds are in central and northern Russia and northern Kazakhstan where increasing pollution of sediment, bottom dwelling organisms, and birds has been reported (Sagerup et al. 2009). In the current study, the highest and lowest Hg concentration of liver was in the Common Cormorant (8.7 ± 1.3) and the Little Grebe (2.6 ± 0.3), respectively ($p < 0.01$, Fig. 2). Similar to our findings, Houserova et al. (2005) has reported significantly higher Hg in Cormorant liver when compared to Great Crested Grebe, from the Czech Republic.

Liver Hg can vary significantly between species due to the biotransformation capability of the species, and the bioavailability of Hg in the environment. Feeding habits and physiological and biological processes (like molting, growth, reproduction, and ageing) can also affect metal levels and distribution in bird tissues (Kim et al. 2007). In organs like liver and kidney, birds demethylate organic Hg to inorganic forms which are then transported and

Fig. 1 Sampling area is indicated in black, along the South coast of the Caspian Sea, Iran

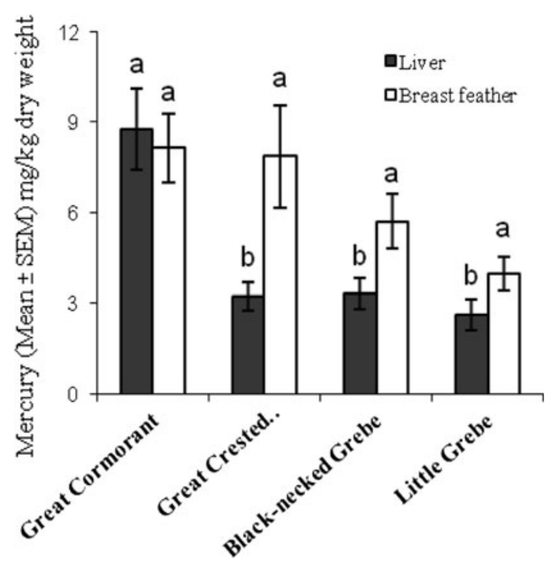

Fig. 2 Mercury in feather and liver of three species of Grebe and Common Cormorant collected in 2008 from south coast of the Caspian Sea, Iran. Different letters indicate statistical difference at $p = 0.01$

deposited in various tissues. In this fashion, Hg eventually accumulates in the body of the exposed organism. Levels of some heavy metals in bird tissues drop during molting. When molting is completed and the birds begin to feed on contaminated food once again, levels of some heavy metals in the internal organs will rise until the next molting period. The process of detoxification by molting is repeated the following year (Dauwe et al. 2003). Thus, molting plays a major role in Hg redistribution in bird tissues. On the whole, the Hg burden in birds is often associated with diet, molting strategies, and variable lifespan.

Average Hg concentrations in the feathers of birds, in the present study, varied from 8 ± 1 in the Common Cormorant, to 4 ± 0.5 in the Little Grebe. The Common Cormorant and the Great Crested Grebe, which feed on the same trophic level, had similar Hg concentrations in their feathers. Both birds are predominantly fish predators that occasionally feed on aquatic invertebrates. In addition, they have comparable migration routes and therefore they also share similar feeding grounds. All Grebe species in this study, as in previous reports, had significantly higher Hg in their feathers than in their livers (Kim et al. 1996). Saeki et al. (2000), has reported similar Hg in the liver and feather of Common Cormorants from Japan. Similarly, Houserova et al. (2005) found higher Hg concentrations in the liver of the Cormorants compared to the liver of the Great Crested Grebe, but the levels of Hg they report from the Czech Republic is over four folds higher than the levels we document in the Caspian birds.

Generally, for a wide range of species, mercury levels of 5 ppm in feathers are associated with reproductive deficits (Eisler 1987). Furthermore, 1–2 μg total mercury/g wet weight in the liver of birds may cause behavioral abnormalities (Henny et al. 2002). Except for the Little Grebe, in

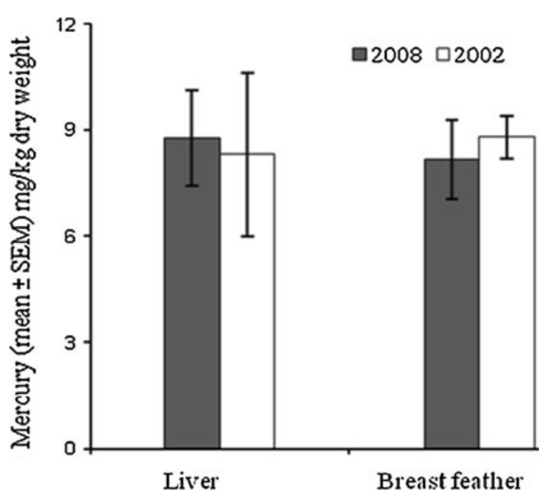

Fig. 3 Mercury in liver and breast feather of Common Cormorant collected in 2002 and 2008 in Mazandaran Province, south coast of the Caspian Sea, Iran ($p = 0.05$)

this study, the average mercury concentrations in the liver and feathers of all species exceeded the threshold for adverse effects. Our findings suggest that the birds of the Caspian are at risk for adverse reproductive and behavioral impairments that can have population level effects.

Bird liver samples from 2008 and 2002 had similar Hg (Fig. 3), indicating that birds' exposure to environmental Hg has remained unchanged. This finding strongly suggests that the pollution prevention and remediation measures which had been introduced in the area have been largely ineffective. More effective measures must be implemented to protect the Caspian's unique and vulnerable ecosystems from further degradation by Hg pollution. Such measures will enhance the Caspian ecosystem's stability and will strengthen global environmental health and integrity.

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