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Mercury in Wetland Birds of Iran and Iraq: Contrasting Resident Moorhen, *Gallinula chloropus,* and Migratory Common Teal, *Anas crecca,* Life Strategies

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Abstract We document mercury distribution in tissues of two waterfowls; moorhen (*Gallinula chloropus;* n = 6), and Common Teal (*Anas crecca*; n = 6) from Shadegan wetlands in Southwestern Iran. Mean value of mercury in moorhen liver was (0.36 Hg μg g^{-1} dry weight), Common Teal had (4.34 Hg μg g^{-1} dry weight) mercury. In all tissues, Common Teals had significantly higher mercury concentrations than moorhens (*U* test, $p \leq 0.05$). Mercury was 12, 9, 8, and 6 times higher in liver, muscle, kidney, and feather of Common Teals. These birds have comparable diets but Common Teals are migratory and moorhens are residents of Shadegan wetlands.

Keywords Mercury · Wetlands of Iran · Moorhen · Common Teal

Anthropogenic pollutants such as industrial, municipal, and agricultural wastes finally end up in wetlands; exposing waterfowl to a variety of environmental pollutants. Birds are an excellent bioindicator of metal contamination and can be used to effectively, and accurately monitor metal level for several reasons. (1) Birds are abundant in numbers, (2) have wide geographic distribution range, (3) feed at different trophic levels, and (4) many birds are long-lived. Migratory birds can be used to assess exposure in distant regions (Rothschild and Duffy 2005) while resident species can indicate local levels of pollutants. Further, feeding habits as well as physiological and biological processes like molting, growth, reproduction, and ageing can influence metal concentration and distribution in bird tissue (Kim et al. 2007).

The present study documents mercury distribution in tissues of two species of waterfowl, moorhen (*Gallinula chloropus*), and Common Teal (*Anas crecca*) which were obtained from Shadegan wetlands located in Southwestern Iran that continue into Iraq.

Common Teal is a migratory species of these wetlands, but moorhens are resident. Every autumn, Common Teals migrate to these wetlands in Iran/Iraq and stay throughout the winter. These populations appear to come from central and Northern Russia (Volga-Ural, Ob-Irtysh basins), and North Kazakhstan to South Caspian and further down to Shadegan wetlands in Iran/Iraq. Some birds that molt in Volga delta disperse South through Turkey and East Mediterranean into Egypt where they many overwinter in the Nile valley. Common Teals have been recovered in Northeast to Kami, Sverdlovsk, and Omsk. Birds wintering in Iran/Iraq wetlands are most likely from these populations. Since our test species had differing life strategies, resident versus migratory, which leads to exposure to compounds at different location and environments, we hypothesized that mercury levels in tissues of the moorhens and Common Teals will be dissimilar.

Materials and Methods

Shadegan marshes are located on the lower Jarrahi River in Khuzestan province of Iran, at the head of the Persian Gulf

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(Fig. 1). This area is adjacent to the Tigris and Euphrates alluvial salt marshes of Iraq. Shadegan marshes are the largest area of wetland in Iran covering ~400,000 ha; an extremely important wintering habitat for a wide variety of waterfowl (Scott 1995). Major sources of contamination in this area include agricultural use of fertilizers, herbicides, pesticides, and spills of hazardous substance from various refineries, and Bandar Imam Petrochemical Factory.

Moorhens (n = 6) and Common Teals (n = 6) of this study were collected from hunters who had shot them on the 20 of October 2007. We obtained the birds the same day and immediately froze them at −20°C. All birds were kept in polyethylene bags and stored until they were identified, weighed, and dissected. Dissections started on 23 October 07 and were completed during the same week. Liver, kidney, pectoral muscle, and breast feathers were removed. Except for feathers, all other samples were freeze-dried and homogenized (Ruelas-Inzunza and Paez-Osuna 2004), then ground by a mortar and pestle. Feathers were washed vigorously in deionized water, as described previously, then in acetone for 5 min to remove loosely adherent external contamination, then air dried overnight (Dauwe et al. 2004).

Mercury was measured by the LECO AMA 254 Advanced Mercury Analyzer according to ASTM standard No. D-6722. In order to assess the analytical capability of the proposed methodology, accuracy of 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 (Al-Majid and Preston 2000). Recovery was between 94.8% and 105%. The detection limit of the instrument used was 0.001 μg g^{-1} of dry weight. Statistical analyses were carried out using SPSS software version 11.5. Data were tested for normality using a Shapiro–Wilk's test. Data were not normally distributed therefore a non-parametric test was used for analysis. Mercury concentrations in feather, liver, kidney, and muscle were tested for mean differences between species using Mann–Whitney *U* test. Mercury concentrations were expressed as μg g^{-1} of dry weight. Values are reported as mean ± standard errors (SE) and a probability level of $p = 0.05$ was set to indicate statistical significance.

Fig. 1 The *arrow* indicates the location of the sampling area

Results and Discussion

Variations in mercury concentration of feather, liver, kidney, and muscle for the Common Teals and moorhens are presented in Fig. 2. In general, the average mercury concentrations in tissue of the Common Teals, from highest to lowest, were as follow: liver > kidney > feather and muscle. In moorhens the highest mercury levels were found in the kidney > liver > feather > muscle. Other investigators have reported the highest mercury concentrations in avian feathers, followed by liver, kidney, heart, and muscle tissues (Burger 1993). In our study the highest levels of mercury in Common Teals tissue were detected in liver. But in moorhens, kidney had more mercury. Once metals are taken up and ingested, they can be stored in internal tissues such as the kidneys and liver (Ek et al. 2004). Birds are known to demethylate mercury, in organs like liver and kidney, to inorganic forms which then accumulate in various tissues. During molting, levels of some heavy metals in tissues drop as they are sequestered in the feathers that are molted. When molting is completed and the birds begin to feed on contaminated food, once more, levels of some heavy metals in the internal organs will raise until the next molting period when the process of detoxification by molting is repeated (Dauwe et al. 2003). Thus, molting plays a major role in mercury redistribution in bird tissues Table 1.

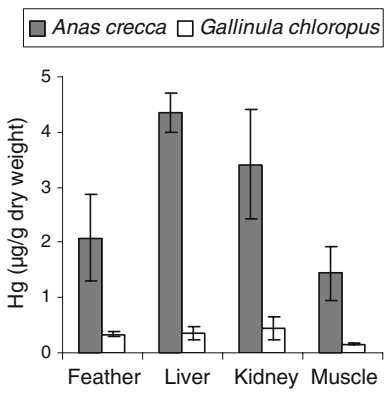

Fig. 2 Mercury levels in birds collected from Shadegan wetlands located in Southwestern Iran continuing into Iraq

Table 1 Biological features of the Common Teals and moorhens collected in Shadegan Wetland, Southwestern Iran continuing into Iraq

Species	Common name	Life strategy	Mean weight (g) ± SE	Diet composition	Sex
Anas crecca	Common Teal	Migratory	252 ± 7	Aquatic and terrestrial invertebrates, plant material	2 Females 4 Males
Gallinula chloropus	Moorhen	Resident	216 ± 3	Seeds and invertebrates	2 Females 4 Unknown

Mercury levels of 5,000 ppb in feather are known to cause sub-lethal and reproductive impairments. A comparative study of mercury levels between species is essential because it will allow us to identify the more sensitive species by plotting mercury levels against reported behavioral or reproductive abnormalities. For a wide range of species, mercury levels of 5,000 ppb in feathers are associated with reproductive deficits such as lower clutch size and egg size, lower hatching rate, decreased chick survival, and overall decreased reproductive success (Eisler 1987). In this study, with the exception of one bird (a Common Teals), mercury levels in the feathers of both species were below the threshold for adverse effects.

Mercury concentrations of 49–125 μg g^{-1} in liver have been reported for free-living birds found dead or dying (Thompson 1996). Maximum observed mercury concentration in the liver of Common Teals of the present study was 8.76 μg g^{-1}, and moorhen's liver had 0.92 μg g^{-1} mercury. In addition, nephrotoxicity and kidney lesions have been documented in birds with kidney mercury concentrations range of 5–13 μg g^{-1} (Nicholson and Osborn 1983). Three Common Teals and all moorhens in this study had mercury levels that were below the threshold level for nephrotoxicity. It is essential, for our understanding of the potential risk to birds from metal contamination, to know not only the mean and standard error, but the range of values. While the metal levels may be low for most species, some individuals may be more at risk because they are at the high end of the range, and these individuals may be neglected when only mean and variance measures are considered.

Concentrations of mercury in the different tissues of birds in this study were comparable to those of other aquatic birds. Common Teals from Southwestern Iran had higher levels of mercury in muscles than Common Teals from Western Alaska (Rothschild and Duffy 2005). Moorhens in this study had higher levels of mercury in muscle and kidney than moorhens from Japan, but liver of our birds had lower concentrations of mercury than liver of birds from the same area in Japan (Horai et al. 2007). Common Teals from Shadegan had higher levels of mercury in liver, feather, and muscle than Cinnamon Teal from Southeast Gulf of California (Ruelas-Inzunza et al. 2007).

In this study, Common Teals had significantly higher mercury concentrations in liver ($p = 0.01$), kidney ($p = 0.01$), muscle ($p = 0.02$) and feather ($p = 0.05$) than moorhens. Concentrations of mercury in tissues of Common Teals were considerably higher than in moorhens. For example mercury was 6 times higher in feather, 12 times higher in liver, 8 times higher in kidney, and 9 times higher in muscle of Common Teals when compared to moorhens.

Diets of both species are similar since they are intermediate consumers who feed mainly on invertebrates and plants. More specifically; Common Teal feed on aquatic and terrestrial invertebrates as well as plant material (Sterry et al. 2001), while moorhens eat plant seeds and invertebrates found in the wetland. As some metal are known to biomagnify, higher metal levels in consumer tissues can result from foraging at different trophic levels.

Overall, these two species feed at comparable trophic levels and exhibit similar foraging behavior. The only distinction is that moorhen (residents of Shadegan) only have access to local food, whereas Common Teal, which are migratory, can obtain food from other regions. Monteiro et al. (1999) reported that mercury levels in feathers of adult migratory species may reflect both exposures to mercury in breeding and non-breeding area. We conclude that mercury concentrations in moorhens closely reflect mercury contaminant in Shadegan wetlands, but mercury burden of Common Teals is a reflection of diversity in food items from wider geographical locations with perhaps much higher mercury pollution than wetlands of Iran and Iraq.

Since mercury bioaccumulates, metal levels we found in the Common Teals of this study indicate pollution in stopover sites plus their breeding or wintering grounds. Here we restate that avian species are useful bioindicators to elucidate mercury contamination status. For example birds' reproduction in this area can be affected by mercury pollution. Mercury is associated with lower clutch size and egg size, decreased chick survival. Furthermore, the fact that migratory birds did not have as high a mercury burden, pollution in their breeding grounds can be presumed to be lower. However, exposure to mercury during their stay in wintering grounds or stopover sites may adversely affect their reproductive activities (Kunisue et al. 2003). This

means to protect migratory birds, it is necessary to improve the environment not only in breeding grounds but also in stopover sites and wintering grounds.

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