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Mercury Bioaccumulation in Fishes of Three Gorges Reservoir After Impoundment

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Mercury (Hg) can biomagnify up to 1000-fold through food webs (Morel et al. 1998), and the mercury pollution in fish has been widely reported (Jackson 1988; Stephens 1995; Sswanson et al. 2003). The World Health Organization (WHO) has recommended that at-risk groups, such as frequent fish consumers, pregnant women, and young children, consume fish with no more than 200 ng/g total mercury (THg) (World Health Organization 1990), and the Chinese government safe standard of freshwater fish is less than 300 ng/g THg (after the 1995 food hygiene standards of China). The concentration of Hg in reservoir fish can be increased due to the effect of mercury reactivity (Jackson 1988; Stephens 1995), and can be biomagnified through the food chain (Morel et al. 1998). The Three Gorges reservoir (TGR) is located within the high background mercury zone of China (Xu et al. 1999), and thus, there is concern for the safety of the aquatic products in TGR. Although Jin and Xu (1997) reported on the concentration of Hg in fish of this region before the construction of the TGR, there have been no studies on mercury pollution in fishes of the TGR after its impoundment in June 2003. In this study, we determined the THg concentrations and the nitrogen stable isotopic values of several important fish species from the TGR. Our purpose was to compare Hg concentration in fish before and after the impoundment of the TGR, and to determine that how Hg accumulates in different fishes species.

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Materials and Methods

Fishes were captured from the main stem of the TGR between December 2004 and July 2005 (Table 1), about 18–24 months after the impoundment of the TGR. All fish were less than two years old. White muscle tissue was removed from each fish, and kept at –20°C before being transported to the laboratory. In the laboratory, the samples were oven-dried at 60°C to a constant weight, homogenized to a fine powder, and sealed in a desiccator with a silica gel desiccant. Dry weight samples were converted to wet-weight samples assuming 80% water content (Jin and Xu 1997). Hg concentration was determined via atomic fluorescence spectroscopy (AFS; 9130, Beijing Titan Instruments) after microwave digestion (Morales-Rubio et al. 1995); the limit of detection was 1.0 ng/L. Nitrogen isotope ratios were analyzed with Delta plus continuous flow isotope ratio mass spectrometer (CF-IRMS; Finnigan). Isotope ratios were expressed as parts-per-thousand (‰) difference from a standard reference material using the equation: $\delta^{15}N$ (‰) = $(R_{sample}/R_{standard} - 1) \times 1000$, where R is the corresponding $^{15}N/^{14}N$ ratio, and the standard reference material is atmospheric nitrogen (Xu et al. 2005). More than 20% of the samples were analyzed for two or more times and the standard errors of replicate analyses were approximately ± 0.2‰. All statistical studies were

Table 1 Mean (with range) of total length (TL), weight (Wgt), THg and $\delta^{15}N$ (‰ ± SD) for studied fish species from the Three Gorges Reservoir (*n*, number of samples)

Species	*n*	TL (cm)	Wgt (g)	THg (ng/g ww)	$\delta^{15}N$ (‰)
Coreius heterodon	25	20.9 (16.4–30.2)	169.6 (49.1–194.2)	64.7 (50.5–87.3)	12.3 ± 1.2 (11.8–14.8)
Cultrichtys erythropterus	13	17.8 (13.8–21.4)	57.5 (22.4–113.2)	115.8 (82.6–135.8)	12.2 ± 0.9 (10.2–12.9)
Culter mongolicus mongolicus	15	21.9 (16.8–24.9)	135.2 (32.1–196.3)	122.6 (86.4–159.8)	12.0 ± 1.6 (10.4–13.7)
Cyprinus carpio	11	19.1 (13.4–31.2)	210.5 (54.5–649.5)	61.6 (37.8–90.8)	7.0 ± 1.1 (5.5–9.1)
Silurus asotus	10	26.4 (21.2–31.9)	157.9 (93.6–241.7)	134.8 (74.4–248.8)	11.7 ± 0.9 (10.8–13.1)

performed using SPSS 12.0 software for Windows (SPSS Inc., Chicago, Illinois, USA).

Results and Discussion

Of the studied fish species, *Silurus asotus* had the highest mean concentration of THg (134.8 ng/g), and *Cyprinus carpio* had the lowest mean value (61.6 ng/g). The THg concentration of one *S. asotus* exceeded the WHO recommended limit (Table 1, Fig. 1). Compared with results from before the impoundment of the TGR (Jin and Xu 1997; Xu et al. 1999), the THg concentrations of *Coreius heterodon* had a 148.9% increment (Table 2), and the increased percent of *Culter mongolicus mongolicus* and *C. carpio* were 22.6% and 31.2%, respectively. However, the THg concentrations of *S. asotus* decreased, which might be partially attributed to only two years between the collections of sampled fish, and the short time of bioaccumulation. Our results were comparable with the prediction of Xu et al. (1998) that the concentration of mercury in fish might increase 40% after impoundment of the TGR. THg concentrations significant correlated with weight for the five fish species (*t* test, $p < 0.05$). We also estimated the weight at which THg concentrations in fish reach the limit of Chinese government (300 ng/g ww): *Cultrichtys erythropterus* and *S. asotus* exceeding 561.4 g and 351.4 g, respectively, should not be consumed by humans (Table 2).

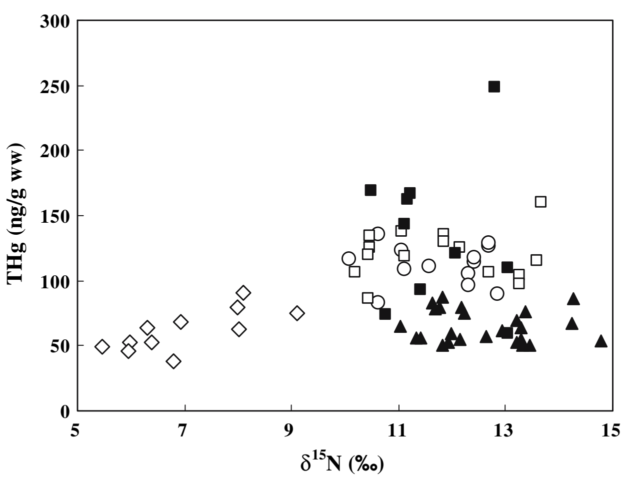

Fig. 1 Detailed comparison of THg and $\delta^{15}N$ of five fish species, Coreius heterodon (▲), Cultrichtys erythropterus (○), Culter mongolicus mongolicus (□), Cyprinus carpio (◇), Silurus asotus (■)

It is widely accepted that there is a positive relationship between trophic position and bioaccumulative contaminant load (Cabana and Rasmussen 1994; Kidd et al. 1995). In this study, *C. heterodon* had the highest nitrogen stable isotopic value (12.3 ± 0.8‰), which was similar with the stable isotopic values of *C. erythropterus*, *C. m. mongolicus* and *S. asotus* (Fig. 1). This suggests that the trophic positions of these fishes were similar, since the $\delta^{15}N$ isotopic signatures of an animal are a reflection of its trophic position (Vander Zanden et al. 1997; Xu and Xie 2004; Xu et al. 2005). However, *C. heterodon* had a lower mean THg concentration (64.7 ng/g) than *C. erythropterus*

Table 2 Comparison of THg (ng/g ww) in fish muscle before (Jin and Xu 1997; Xu et al. 1999) and after (this study) impoundment of the TGR. Regressions of weight and THg for the five fish species, and the estimated fish weight (EWgt) where THg concentrations reach the Chinese government limit (300 ng/g ww)

Species	Comparison of THg (ng/g ww) in fish muscle (before vs after impoundment)			Regressions of weight vs Hg, EWgt		
	Before impoundment	After impoundment	Increased percent	r^2	*p*	EWgt
Coreius heterodon	26	64.7	148.9%	0.589	0.013	3738.7
Cultrichtys erythropterus	—	115.8	—	0.514	0.016	561.4
Culter mongolicus mongolicus	100	122.6	22.6%	0.522	0.012	911.3
Cyprinus carpio	47	61.6	31.2%	0.421	0.033	4967.9
Silurus asotus	166	134.8	–18.8%	0.473	0.027	351.4

(115.8 ng/g), *C. m. mongolicus* (122.6 ng/g) and *S. asotus* (134.8 ng/g). This resembles the results of the study by Swanson et al. (2003) on rainbow smelt and forage fish communities in Northwestern Ontario lakes. Our findings support that a high trophic position does not always result in high contaminant bioaccumulation, and thus challenge the general assumptions of food web theory and contaminant bioaccumulation (Swanson et al. 2003).

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