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Elevated Mercury Levels in Fish Resulting from Reservoir Flooding in Thailand

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Abstract

Mercury concentrations in fish from Thai reservoirs were studied to determine if the presence of mercury constitutes a problem in such tropical reservoirs. Fish were collected from three sites located in the Mae Klong River Basin (about 100 km west of Bangkok): 1. the Khao Laem Reservoir (a reservoir impounded five years ago); 2. the Srinakarin Reservoir (a reservoir impounded 10 years ago); 3. the area proposed for the Nam Choan Reservoir.

Fish in the Khao Laem and Srinakarin Reservoirs contained higher mercury lev-els than fish in the Nam Choan area. Mercury levels in some of the fish from the (older) Srinakarin reservoir were lower than fish from the (younger) Khao Laem Res- ervoir. We conclude that mercury levels in tropical reservoirs may be elevated for shorter periods of time than in temperate and subarctic reservoirs.

Introduction

Mercury contamination in aquatic environments has been studied as a critical issue since the outbreak of mercury poisoning in Minamata, Japan, caused by the consumption of contaminated fish (Hartung and Dinman 1972; Park et al. 1980). Elevated mercury levels in freshwater fish have resulted from point-source discharges of mercury (e.g., Armstrong and Scott 1979) and from lake acidification (Wiener et al. 1990).

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In newly flooded reservoirs, mercury concentrations in fish have been observed to be higher than in the original unflooded lakes. This observation has been made in reservoirs in many temperate and subarctic areas of the world (Abernathy and Cumbie 1977; Bodaly et al. 1984; Boucher et al. 1985; Verta et al. 1986). Elevated methyl mercury levels in fish in recently impounded reservoirs are caused by increased rates of bacterial methylation of naturally occurring inorganic forms of mercury found in flooded soils and vegetation (Canada-Manitoba Mercury Agreement 1987; Hecky et al. 1991; Ramsey et al., in press). Bacterial production is stimulated by the presence of easily degraded organic matter in soils and vegetation. Methylmercury has a high affinity for aquatic biota and is taken up effectively by fish. Concentrations of mercury in fish in subarctic reservoirs frequently exceed health guidelines for commercial sale of fish in Canada (0.5 $\mu g\ g^{-1}$ wet weight) and the USA (1.0 $\mu g\ g^{-1}$ wet weight) (e.g., Boucher et al. 1985).

In Thailand, there are many reservoirs which have been constructed for hydroelectric power or irrigation purposes. These reservoirs have flooded large areas of both forested and agricultural land. There are 18 major reservoirs which cover a total surface area of about 230,000 ha. Most are shallow and productive (Pawaputanon 1986).

The purpose of this study was to determine whether mercury concentrations in fish are elevated in these tropical reservoirs. Mercury concentrations in fish from two Thai reservoirs, aged 5 and 10 years, were compared to those in fish from an unflooded reference site. It was predicted that mercury concentrations in fish would be higher in the reservoirs than in the unflooded site. Comparison of mercury in fish in the two reservoirs of differing age was intended to provide an initial indication of the duration of elevated levels of the element in tropical reservoirs. This study constitutes the first examination of mercury in tropical reservoirs and is intended as a guide to future studies and to assist in the protection of consumer health from mercury contamination.

Materials and Methods

Samples of fish were collected from three locations (Fig. 1): the Srinakarin Reservoir, the Khao Laem Reservoir, and the area of the proposed Nam Choan Reservoir.

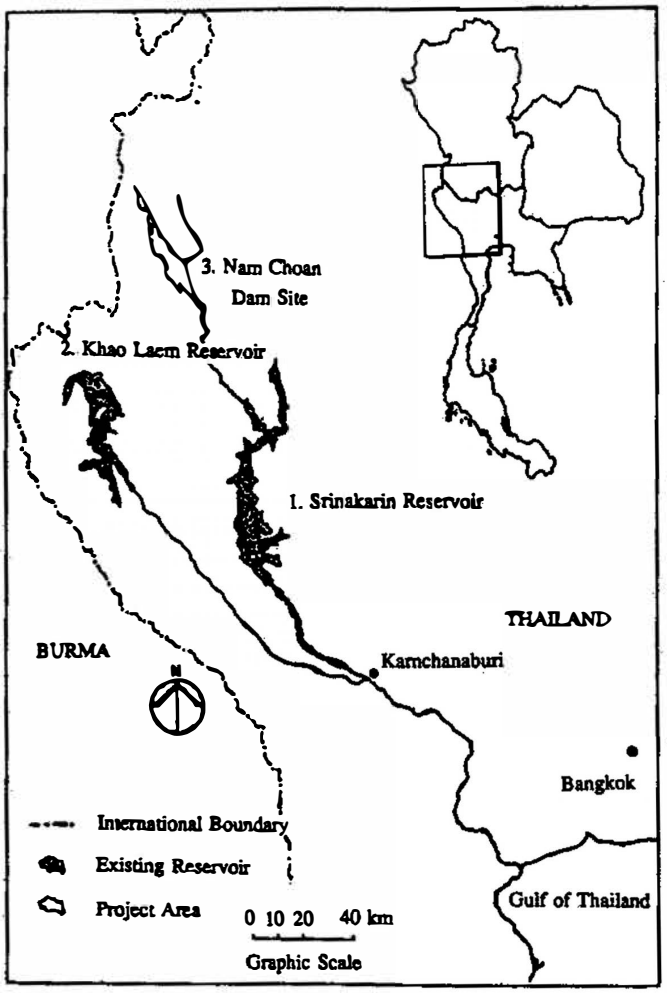

Fig. 1. The project site. Samples of fish were collected from three locations: the Srinakarin Reservoir, the Khao Laem Reservoir and the area of the proposed Nam Chaon Reservoir.

The Srinakarin Reservoir was created 10 years ago by the damming of the Kwae Yai River. It has a surface area of 419 km^2. The Khao Laem Reservoir is five years old and is located on the Kwae Noi River. It has a surface area of 338 km^2. The Khao Laem and Srinakarin catchment areas were complex mountain systems before the implementation of dam projects and agricultural land use was relatively rare. However, there was some slash-and-burn or "shifting" cultivation in the area. The flooded areas were mainly

forested with a variety of tropical vegetation (Pal Consultants Co. and Aggie Consult Co. 1990; B. Chaopaknam, pers comm.).

Fish were collected during July and August 1990. Samples were purchased from fishers and from fish markets in each location. Results from four species of fish are reported here. Sample sizes ranged from 13 to 20 fish from each site (Table 1). Fork lengths were determined for all fish to the nearest mm (Table 1). A sample of approximately 10 g of muscle was removed from each fish and frozen soon after sampling. Samples were transported frozen to the Freshwater Institute, where they were analyzed for total mercury content (on a wet-weight basis) using cold vapor flameless atomic absorption spectrophotometry (Hendzel and Jamieson 1976).

Because muscle mercury concentrations are highly dependent on fish size, adjusted mean mercury concentrations were calculated for each species from each site by linear adjustment to a standard fork length for each species. Log_{10} mercury concentration was regressed against log_{10} fork length and adjusted mean concentrations were determined by interpolation to the following fork lengths for each species: *Pristolepis fasciatus* (175 mm); *Puntioplites proctozysron* (175 mm); *Hampala macrolepidota* (260 mm); *Morulius*

Table 1. Sample sizes, mean lengths and mercury concentrations for *Pristolepis*, *Puntioplites*, *Hampala* and *Morulius* from two reservoirs and an unflooded reference site (Nam Choan Area) in Thailand. Letters next to adjusted mean mercury concentrations refer to results of multiple comparison tests (see Methods and Materials). The same letters next to adjacent means indicate that the means are not significantly difference (P>0.05) by Duncan's and least significant different tests; different letters indicate that the means are significantly different (P<0.05).

	Site	Genus	n	Mean fork length (mm)	Range of [Hg] ($\mu g\ g^{-1}$)	Adjusted mean [Hg] ($\mu g\ g^{-1}$)	
1.	Srinakarin Reservoir	*Pristolepis*	20	153	0.06-0.21	0.12	a
		Puntioplites	20	197	0.03-0.10	0.05	b
		Hampala	20	285	0.02-0.36	0.10	a
		Morulius	20	285	<0.01-0.06	0.02	a
2.	Khao Laem Reservoir	*Pristolepis*	13	265	0.05-0.59	0.09	ab
		Puntioplites	20	149	0.03-0.12	0.07	a
		Hampala	20	245	0.15-0.63	0.33	b
		Morulius	17	143	0.01-0.04	0.03	a
3.	Nam Choan Area	*Pristolepis*	20	131	0.03-0.15	0.06	b
		Puntioplites	20	181	<0.01-0.08	0.01	c

chrysophekadion (210 mm). These fork lengths were chosen to approximate the grand mean lengths of all fish for each particular species. The significance of differences observed between sites was tested using one way analysis of covariance. If statistically significant differences were observed among sites ($P<0.05$), multiple comparison tests (Duncan's test and least significant difference tests) were used to determine which sites had significantly different mean mercury concentrations. In all cases, the results of the two multiple comparison tests agreed.

Results

Results of the studies are summarized in Table 1. Raw data and detailed results of calculations and statistical analyses are found in Yingcharoen (1991).

Pristolepis fasciatus (Nandidae). This species is herbivorous. Adjusted mean Hg concentrations in *Pristolepis* were 0.06-0.12 $\mu g\ g^{-1}$ wet weight. One way analysis of covariance indicated a statistically significant difference among the three sites sampled. Mean mercury concentrations between the two reservoir sites were not significantly different (Table 1). Mercury concentrations in *P. fasciatus* from Khao Laem Reservoir and the unflooded site were also not significantly different; however, the mean mercury concentration from Srinakarin Reservoir was significantly greater than from the unflooded site.

Puntioplites proctozysron (Cyprinidae). This species is omnivorous. Adjusted mean Hg concentrations were 0.01-0.07 $\mu g\ g^{-1}$ wet weight. There were significantly different mercury levels at all three locations. Mercury concentrations in fish from the Khao Laem Reservoir were the highest, while fish from the unflooded site contained the lowest mercury concentrations (Table 1).

Hampala macrolepidota (Cyprinidae). This is a predatory fish which feeds mainly on insects and other fish. Adjusted mean Hg concentrations in *H. macrolepidota* were the highest of the four species tested, 0.10-0.33 $\mu g\ g^{-1}$ wet weight. Some individuals from the Khao Laem Reservoir exceeded 0.5 $\mu g\ g^{-1}$ Hg. As for *P. proctozysron*, *H. macrolepidota* from Khao Laem Reservoir contained significantly higher mercury concentrations than fish from the Srinakarin Reservoir (Table 1).

Morulius chrysophekadion (Cyprinidae). This species is generally herbivorous. Adjusted mean Hg concentrations in this species were the lowest of the four species tested, 0.02-0.03 $\mu g\ g^{-1}$ wet weight. Mercury concentrations in this species were not significantly different between Srinakarin and Khao Laem Reservoirs.

Discussion

This study demonstrated that mercury levels in some fish were higher in two newly flooded tropical reservoirs than in a nearby unflooded area. In both species for which comparisons could be made (*Pristolepis* and *Puntioplites*), mercury concentrations were significantly higher in one or both reservoirs than in the unflooded site. In the Khao Laem Reservoir area, there are mining activities which include the extraction of lead, zinc and copper (Pal Consultants Co. and Aggie Consult Co. 1990). However, there are no activities such as the smelting of ores to extract metal that could result in mercury contamination in the reservoir. Therefore, elevated mercury concentrations in fish muscle are probably not due to these mining activities. Furthermore, other local sources of anthropogenic mercury, e.g., energy and manufacturing-related activities, do not exist in the area. Mercury concentrations in fish are, therefore, probably elevated due to bacterial methylation of Hg in flooded soils.

This study is the first demonstration of the effect of reservoir flooding on elevated mercury concentration in fish outside the temperate and subarctic zones. Although mean mercury levels measured in this study did not exceed general health limits (e.g., 0.5 $\mu g\ g^{-1}$ wet weight in Canada), they may exceed limits recommended for frequent fish consumption (0.2 $\mu g\ g^{-1}$ wet weight), especially in the first few years after impoundment. Mercury concentrations were highest in predatory fish, lowest in herbivorous species and intermediate in omnivorous species. Mercury levels in fish that are exclusively piscivorous would be expected to be higher than those measured in this study.

Studies on subarctic reservoirs have shown that elevated mercury levels in fish can persist for many decades after reservoir construction (Hecky et al. 1991; Ramsey et al., in press). Although our studies included only two tropical reservoirs of five and 10 years of age, respectively, there is an indication from our results that

mercury levels in fish were higher in the five-year-old Khao Laem Reservoir. It is reasonable to suppose that the time course involving elevated mercury concentrations in tropical reservoirs could be faster than in subarctic reservoirs. When flooded organic material in soils and vegetation is degraded, the elevation of rates of mercury methylation should slow and begin to resemble rates in natural lakes. However, further studies are required to define more precisely the duration of elevated mercury levels in such tropical reservoirs.

Mercury levels in fish in reservoirs are correlated with the amount of flooding (Bodaly et al. 1984; Johnston et al. 1991). Other factors, e.g., pH, climate, soil type, vegetation type, calcium concentration and water hardness, may also be important factors. In Thai reservoirs, large amounts of soils and vegetation are often flooded, especially in reservoirs in areas of low relief. Fish in these reservoirs may therefore contain mercury levels higher than those in reservoirs located in mountain areas. The degree of flooding in the Srinakarin and Khao Laem Reservoirs was similar because the two reservoirs exhibit similar relief and their surface areas after impoundment are also similar (419 and 388 km^2, respectively). Therefore, differences in mercury levels between these two reservoirs were probably not influenced by the degree of flooding.

Monitoring of mercury in fish in recently impounded tropical reservoirs should be carried out to avoid possible health problems and to better define the problems that could occur due to impoundment. Moreover, elevated mercury levels in fish should be taken into account in future environmental impact assessments of all reservoir projects.

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