

Mercury levels in fish from artisanal gold mining ponds in the Peruvian Amazon are higher than fish in natural lakes, and may represent an elevated risk of mercury exposure for fish consuming populations

Mercury levels in novel anthropogenic aquatic ecosystems created by artisanal gold mining in the Peruvian Amazon

Claudia M. Vega, Shamir Delgado, Julio Araujo-Flores, Miguel Macedo, Francisco Roman, Cesar Ascorra, Miles R. Silman, Luis E. Fernandez

Centro de Innovación Científica Amazónica (CINCIA), Puerto Maldonado, Madre de Dios, Peru;
Center for Energy, Environment and Sustainability, Wake Forest University, Winston-Salem NC USA

Background

- The region of Madre de Dios is considered a global biodiversity hotspot, but since 2012 has suffered an unprecedented gold rush.
- Tens of thousands of miners have deforested >115,550 ha of *terra firme* rainforests (Caballeros 2018), and release an estimated 185 tons of elemental mercury per year (AGC 2018).
- ASGM turned large tracts of terrestrial ecosystems into heavily degraded aquatic ecosystems where an estimated 15.6 % of areas deforested by mining (~ 18,000 ha) have been converted from highly biodiverse rainforests into water-filled mining ponds (CINCIA *in press*).
- Though now a large part of this landscape, the basic characteristics (biodiversity, hydrology, and chemistry) of these mining ponds is largely unknown.
- Starting in 2018, improved government enforcement allowed CINCIA researchers to access mining areas to start studies of mercury concentrations of fish and benthic sediments in ASGM mining ponds to begin to better understand the dynamics and impacts of possible mercury contamination on wildlife and in fish-consuming human populations.

Methods

Sampling Sites

Benthic sediment and fish samples were collected from 13 sampling sites located in and outside gold mining areas in the Madre de Dios river basin. Twenty four water bodies were sampled - 15 mining ponds and 9 natural oxbow lakes which were used as control sites (fig. s1).

Sample Collection

Benthic sediments: 98 benthic surface sediment samples were collected using Eckman dredges.

Fish: 1,187 specimens of 40 species of fish were collected from mining ponds and natural lakes using drag and gill nets.

Mercury Analysis

Total mercury concentrations of all collected samples were measured by Direct Mercury Analysis (EPA Method 7473) using a Milestone DMA-80 mercury analyzer located at the *Laboratorio de Mercurio y Química Ambiental* (LAMQA) operated by the Wake Forest University's Center for Amazonian Scientific Innovation (CINCIA) in Puerto Maldonado, Madre de Dios, Peru.

Results and Discussion

Mercury in Benthic Sediments

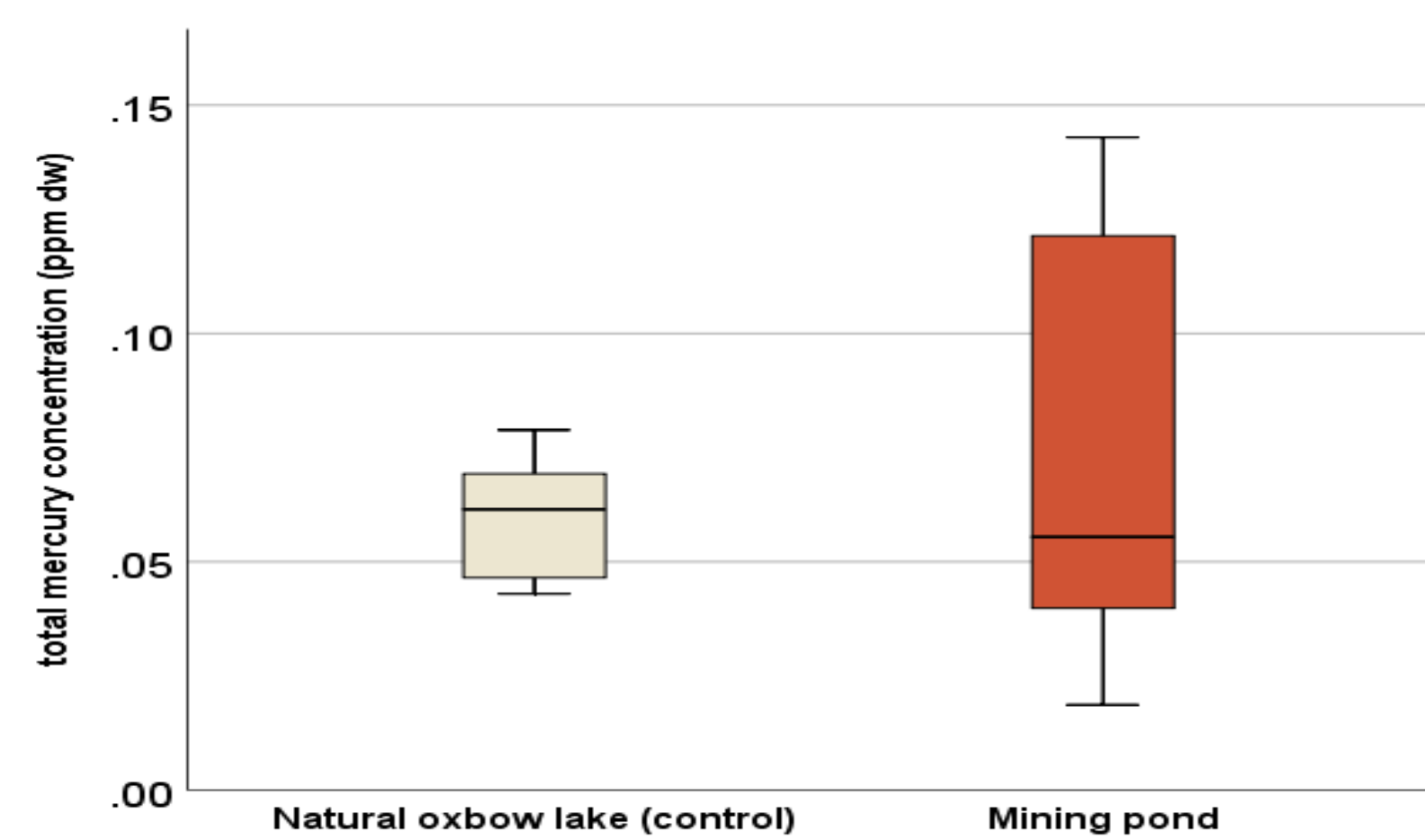


Figure 1. Mercury levels in benthic sediment samples in natural lakes (control) and ASGM mining ponds.

- There was no significant difference between mean mercury concentrations of benthic surface sediments in mining ponds compared to natural lakes.
- Mercury levels in benthic sediments have greater variation in mining ponds and high maximum levels compared to natural lakes

Mercury in Fish

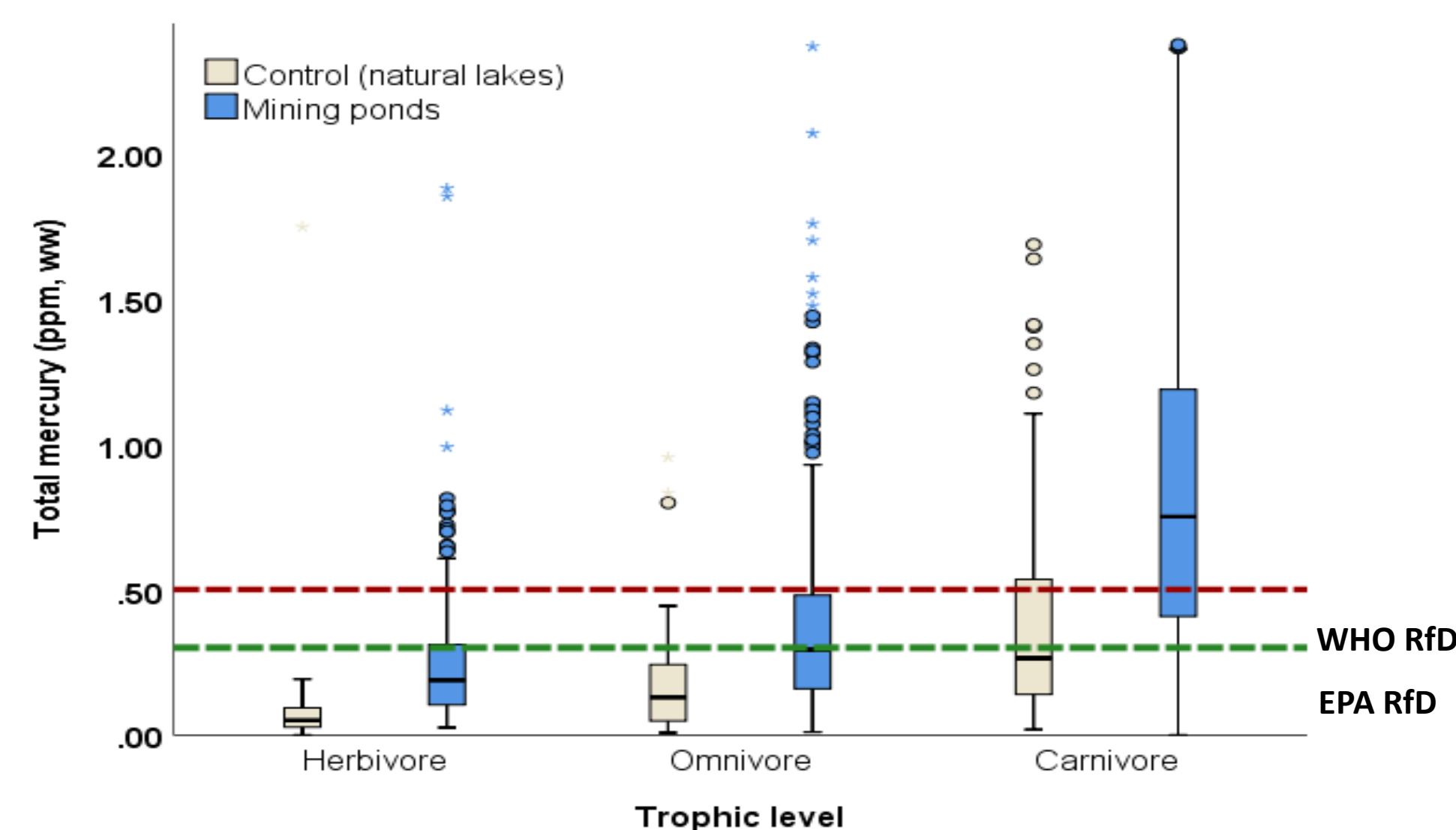


Figure 2. Mercury levels in fish samples by trophic level in control and mining site. The dotted lines represent reference levels WHO (0.5 mg/kg) and EPA (0.3 mg/kg).

- Mean fish mercury concentration increased by trophic level indicating biomagnification of mercury in food chains, and this effect was higher in mining ponds vs natural lakes.
- Mean fish mercury concentrations in mining ponds were above EPA and WHO fish consumption reference levels (0.3 ppm, 0.5 ppm respectively), suggesting an elevated risk to human populations consuming high trophic level fish from mining ponds.

Supplemental Information

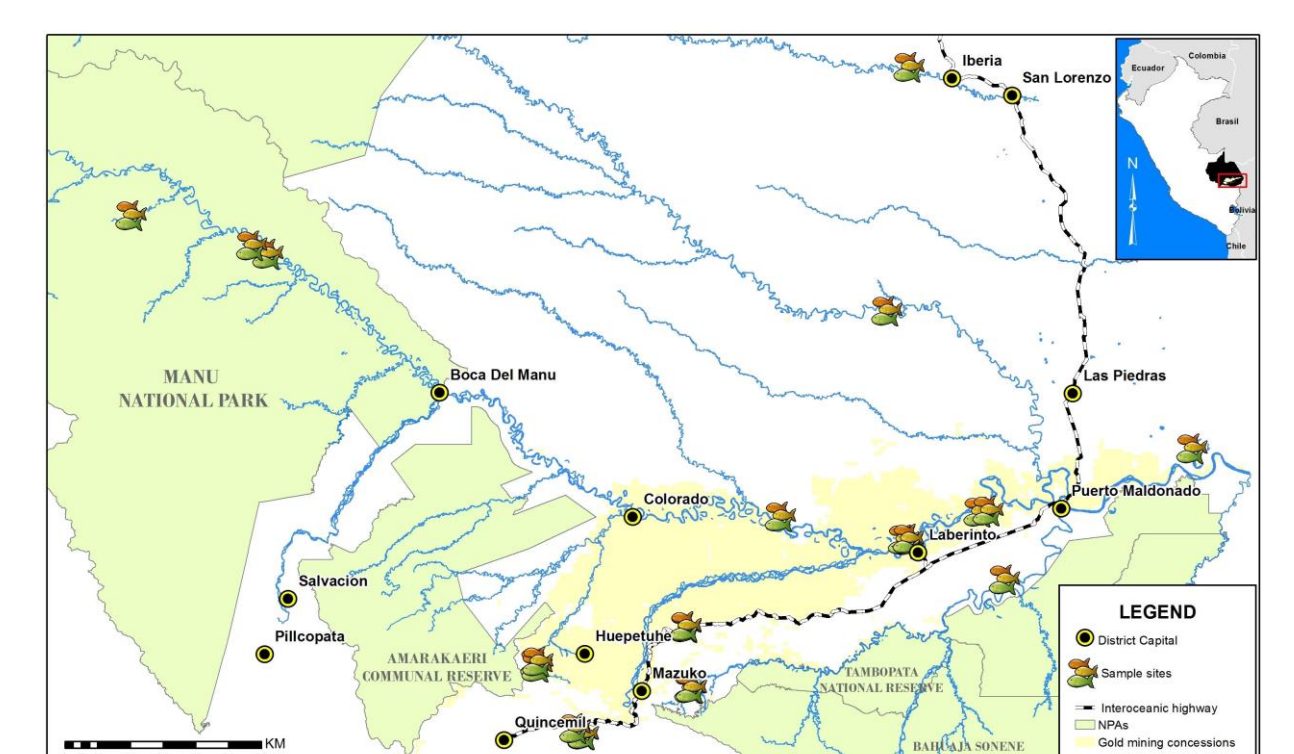


Figure s1: Location of study sampling sites distributed in and outside of artisanal mining zones in Madre de Dios, Peru.

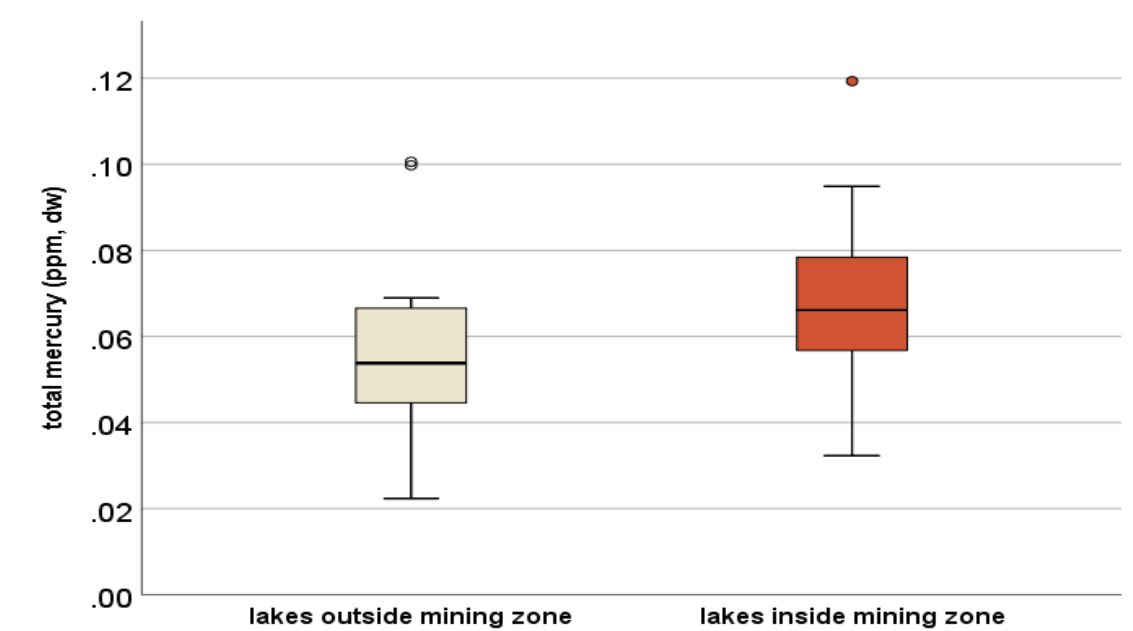


Figure s2: Mercury levels in benthic sediment samples in natural lakes (control) and ASGM mining ponds.

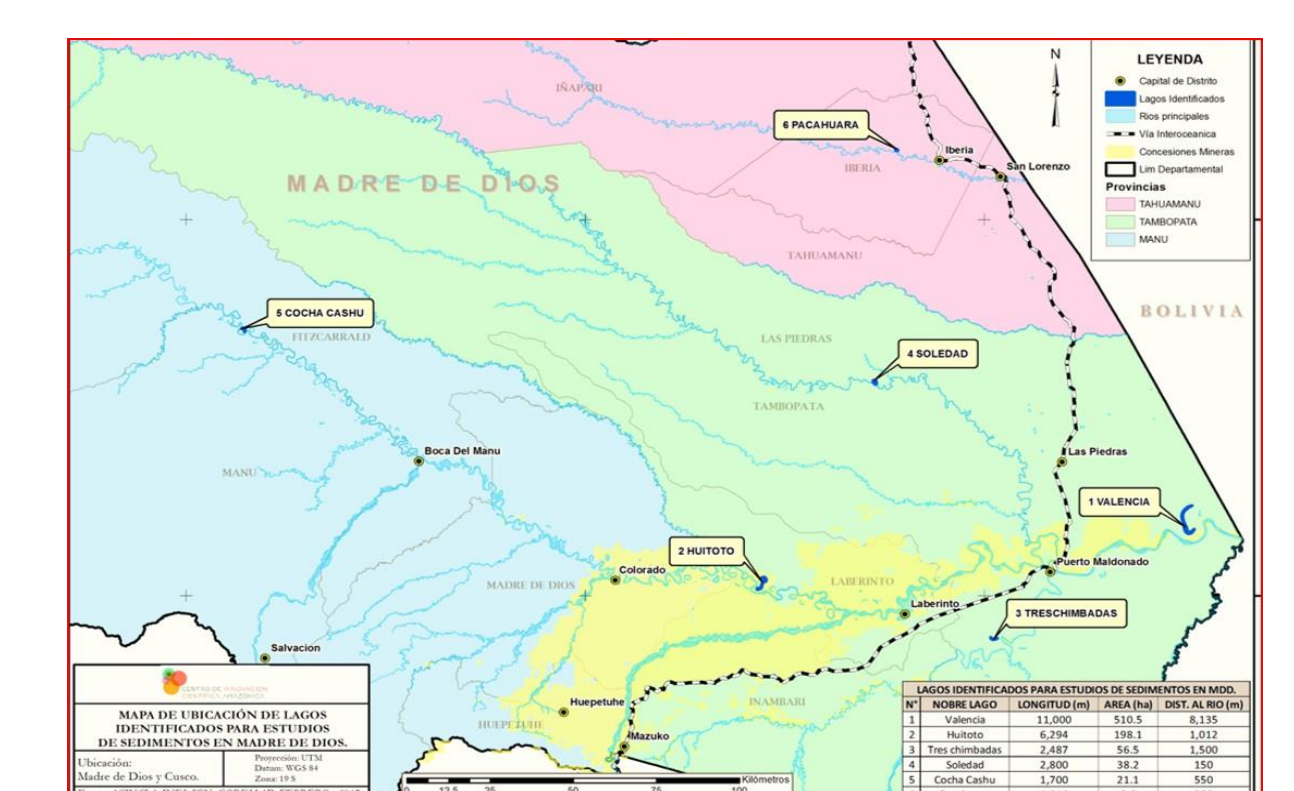


Figure s3: Location of natural lakes sampled distributed in and outside of gold mining zones in Madre de Dios, Peru.

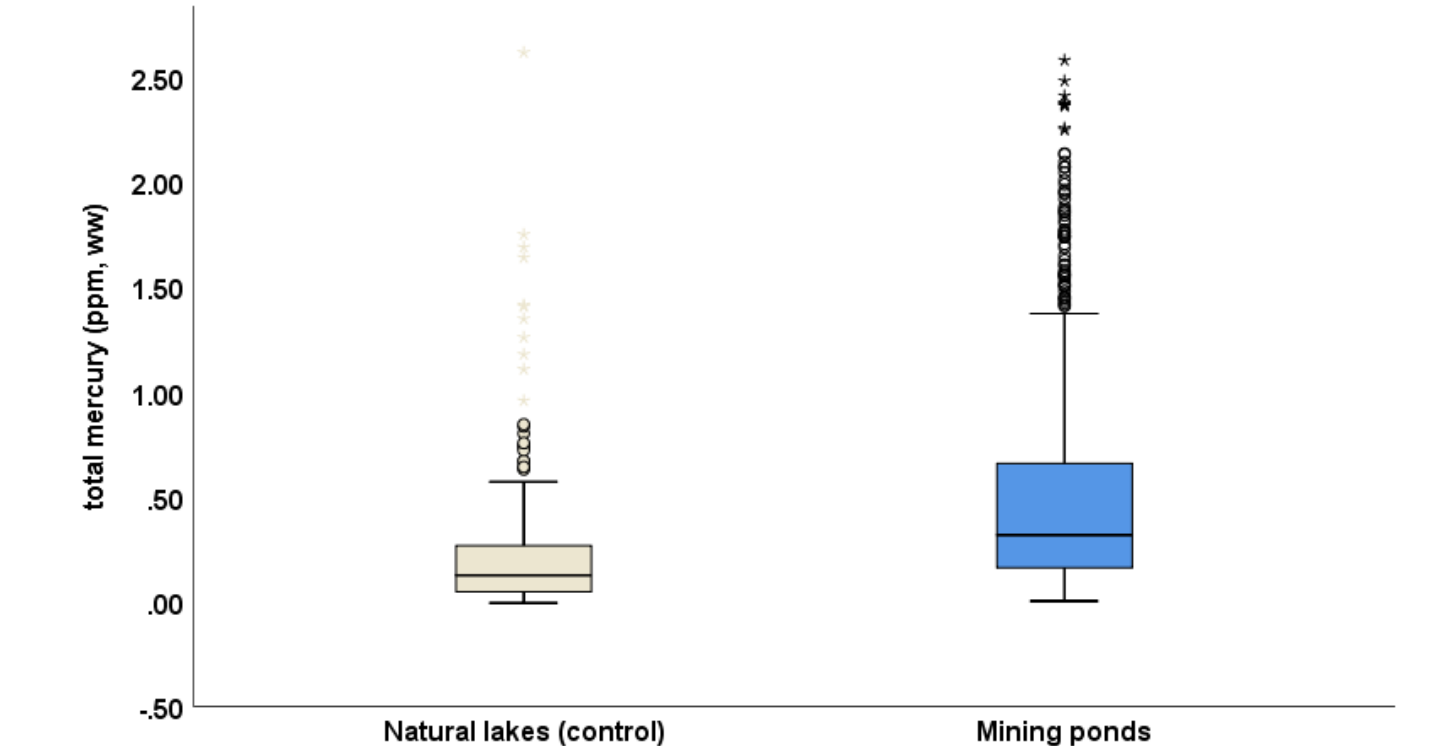


Figure s4: Mean mercury concentrations were higher in fish from mining ponds (N: 238, mean: 0.514 + 0.566 ppm, ww) compared to fish in control natural lakes (N:931; mean: 0.249 + 0.387 ppm, ww).

Table s1: Percentage of fish with mercury concentrations that exceed WHO fish consumption reference level (0.5 ppm), mining pond vs control

TROPHIC LEVEL	ASGM DISTURBANCE	
	Control (natural lake)	Mining pond
Herbivore		
Above WHO reference level (< 0.5 mg/kg)	98.9 % (86)	90.2% (296)
Below WHO reference level (> 0.5 mg/kg)	1.1% (1)	9.8% (32)
Total N	87	328
Omnivore		
Above WHO reference level (< 0.5 mg/kg)	94.4% (51)	75.9 (223)
Below WHO reference level (> 0.5 mg/kg)	5.6% (3)	24.1% (71)
Total N	54	294
Carnivore		
Above WHO reference level (< 0.5 mg/kg)	73.9%(68)	32.7% (97)
Below WHO reference level (> 0.5 mg/kg)	26.1% (24)	67.3% (200)
Total N	92	297

