

# Disparities in methylmercury exposure among subpopulations of concern in Madre de Dios, Peru

David J.X. Gonzalez,<sup>1,2\*</sup> Katy Ashe,<sup>3</sup> Julio Araujo-Flores,<sup>2,4</sup> Jesus Oliviero-Verbal,<sup>5</sup> Karina Caballero-Gallardo,<sup>5</sup> Christopher B. Field,<sup>6</sup> and Luis E. Fernandez<sup>2,4,7</sup>

1. Emmett Interdisciplinary Program in Environment and Resources, Stanford University, Stanford, CA, USA; 2. Center for Amazonian Scientific Innovation, Madre de Dios, Peru; 3. Youth Development Labs, Berkeley, CA, USA; 4. Center for Energy, Environment, and Sustainability, Wake Forest University, Winston-Salem, NC, USA; 5. Environmental Chemistry Group, Universidad de Cartagena, Cartagena, Colombia; 6. Woods Institute for the Environment, Stanford University, Stanford, CA, USA; 7. Department of Global Ecology, Carnegie Institution for Science, Stanford, CA, USA

\* david.gonzalez@stanford.edu, 473 Via Ortega Suite 226, Stanford, CA, USA 94305

## Background

- Mercury contamination has been previously found across Madre de Dios, a region in the Peruvian Amazon with a highly active artisanal and small-scale gold mining sector
- Recent studies have found high levels of mercury exposure among residents of Madre de Dios, including women of childbearing age, a subpopulation of concern
- Prior studies have not considered intersectional identities, specifically, individuals belonging to two or more marginalized groups, such as indigenous women working in artisanal gold mining

## Objectives

- To quantify methylmercury (MeHg) exposure and assess risk factors among residents of Madre de Dios, including four subpopulations of concern: residents of indigenous communities, workers in mining, females, and children (< 18 years)
- To compare exposure among residents belonging to multiple intersectional groups

## Methods

- We conducted a cross-sectional assessment of 1,031 residents of 23 communities throughout Madre de Dios (Fig. 1)
- We collected hair samples from each participant to analyze for hair total mercury (THg) concentration and administered a survey of diet, demographics
- To assess associations between exposure and potential risk factors, we used general linear mixed regression models (GLMM) with a community random effect

**Table 1.** Characteristics of the study population.

	a. Indigenous	b. Miners	c. Female	d. Children	All
n	244	234	521	460	1,031
Age (years), mean ± SD	32.9 ± 19.4	29.9 ± 15.8	26.1 ± 16.3	12.2 ± 3.1	26.0 ± 16.9
Indigenous, %	100.0	26.5	25.5	11.3	23.7
Female, %	54.5	34.2	100.0	47.2	50.5
Work in mining, %	25.4	100.0	15.4	14.6	22.7
Weekly fish meals, mean ± SD	3.3 ± 2.2	1.9 ± 1.7	2.0 ± 1.9	1.6 ± 1.8	2.0 ± 1.9
Hair THg conc., mean ± SD	5.1 ± 3.9	3.8 ± 4.1	3.0 ± 3.2	2.1 ± 2.4	3.0 ± 3.2
Hair THg conc. > 2.2 µg/g, %	83.2	56.4	45.7	30.2	44.6

**Table 2.** Results from the GLMM for each subpopulation ( $e^{\beta}$ )

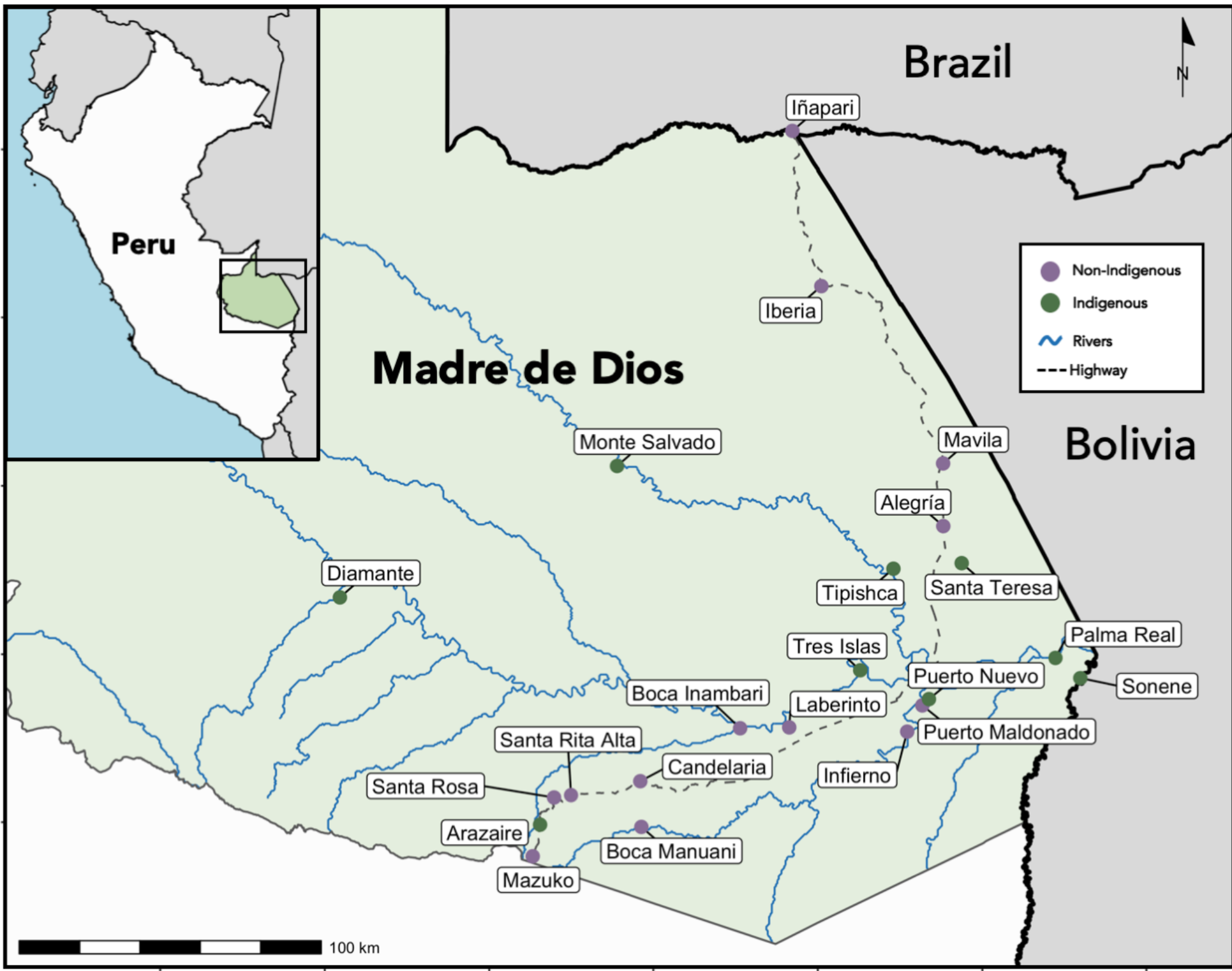
Variable	a. Indigenous	b. Miners	c. Female	d. Children	All
Intercept	1.58	0.90	1.53	1.65*	1.60*
Age (years)					
0-4	1.00	—	1.00	1.00	1.00
5-9	0.84	1.00	0.80	0.72	0.79
10-14	1.09	1.08	0.71	0.69*	0.73
15-49	1.22	1.54	0.88	0.64*	0.89
50-64	1.22	1.37	1.02	—	0.95
65+	1.39	1.45	0.84	—	0.83
Indigenous status					
Non-indigenous	—	1.00	1.00	1.00	1.00
Indigenous	—	1.28	1.95***	2.16**	1.75**
Sex					
Female	1.00	1.00	—	1.00	1.00
Male	0.95	1.10	—	0.92	0.93
Worked in mining					
No	1.00	—	1.00	1.00	1.00
Yes	0.81*	—	1.11	1.36**	1.22**
Fish consumption					
None	1.00	1.00	1.00	1.00	1.00
Low	2.27	1.67*	1.37*	1.59***	1.44**
Medium	2.29	2.39**	1.60**	1.69***	1.65***
High	2.46*	2.00*	1.59*	1.65**	1.69***

## Results

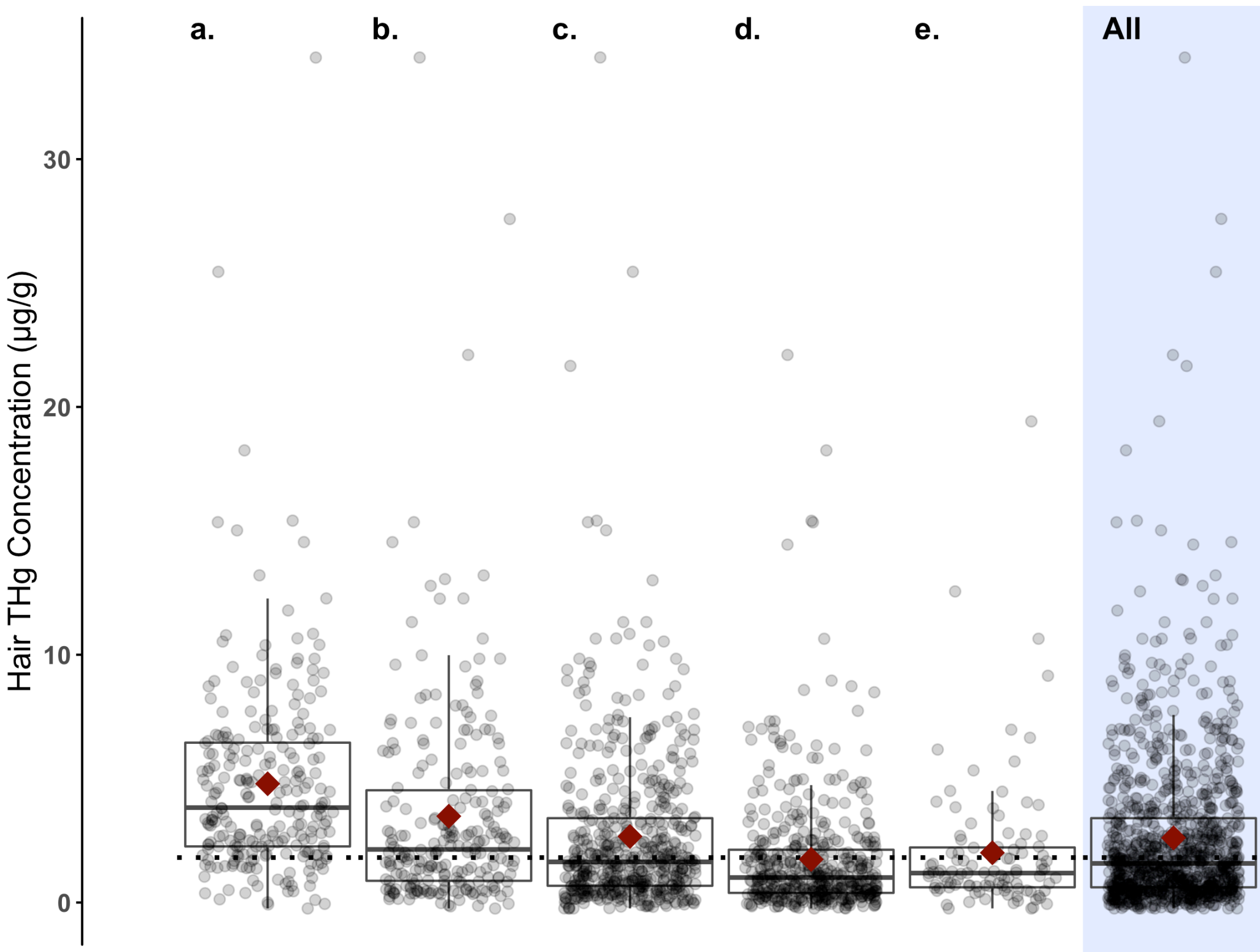
- Mean hair THg concentration ( $\pm$  standard deviation) in the study population was  $3.0 \pm 3.2 \mu\text{g/g}$  (Table 1)
- 44.6% were above the WHO limit of  $2.2 \mu\text{g/g}$  (Fig. 2)
- Residents of indigenous communities had the highest mean exposure ( $5.1 \pm 3.9 \mu\text{g/g}$ ), 83.2% were above  $2.2 \mu\text{g/g}$
- Among all study participants, higher exposure was significantly associated with residing in an indigenous community, work in mining, and higher fish consumption (Table 2)
- Participants with intersectional identities, i.e., those belonging to multiple subpopulations, had the highest observed exposure (Fig. 3)

## Discussion

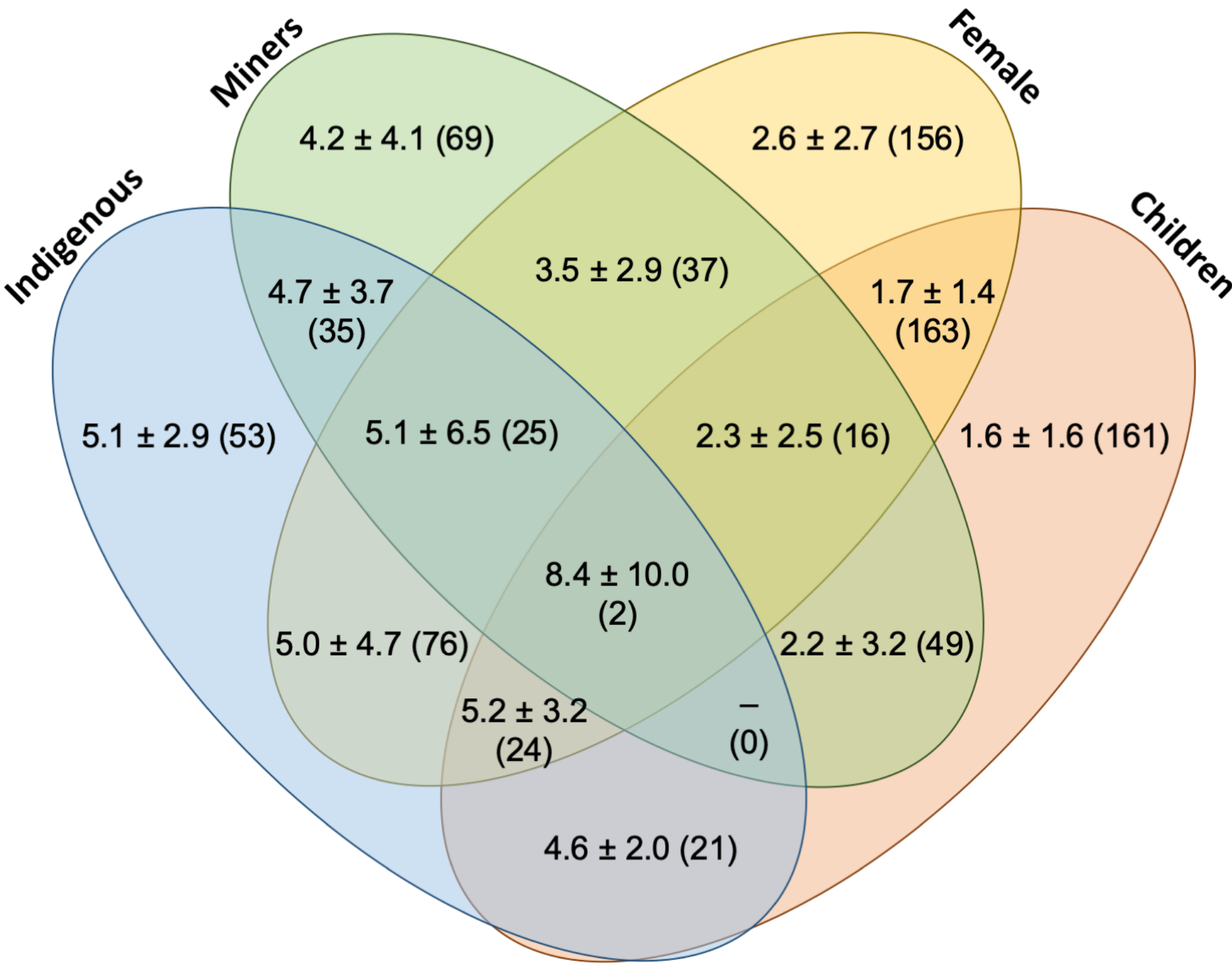
- Methylmercury exposure was widespread throughout Madre de Dios, corroborating recent human exposure studies from the region (Fig. 4)
- Individuals belonging to multiple marginalized groups had disproportionately high exposure



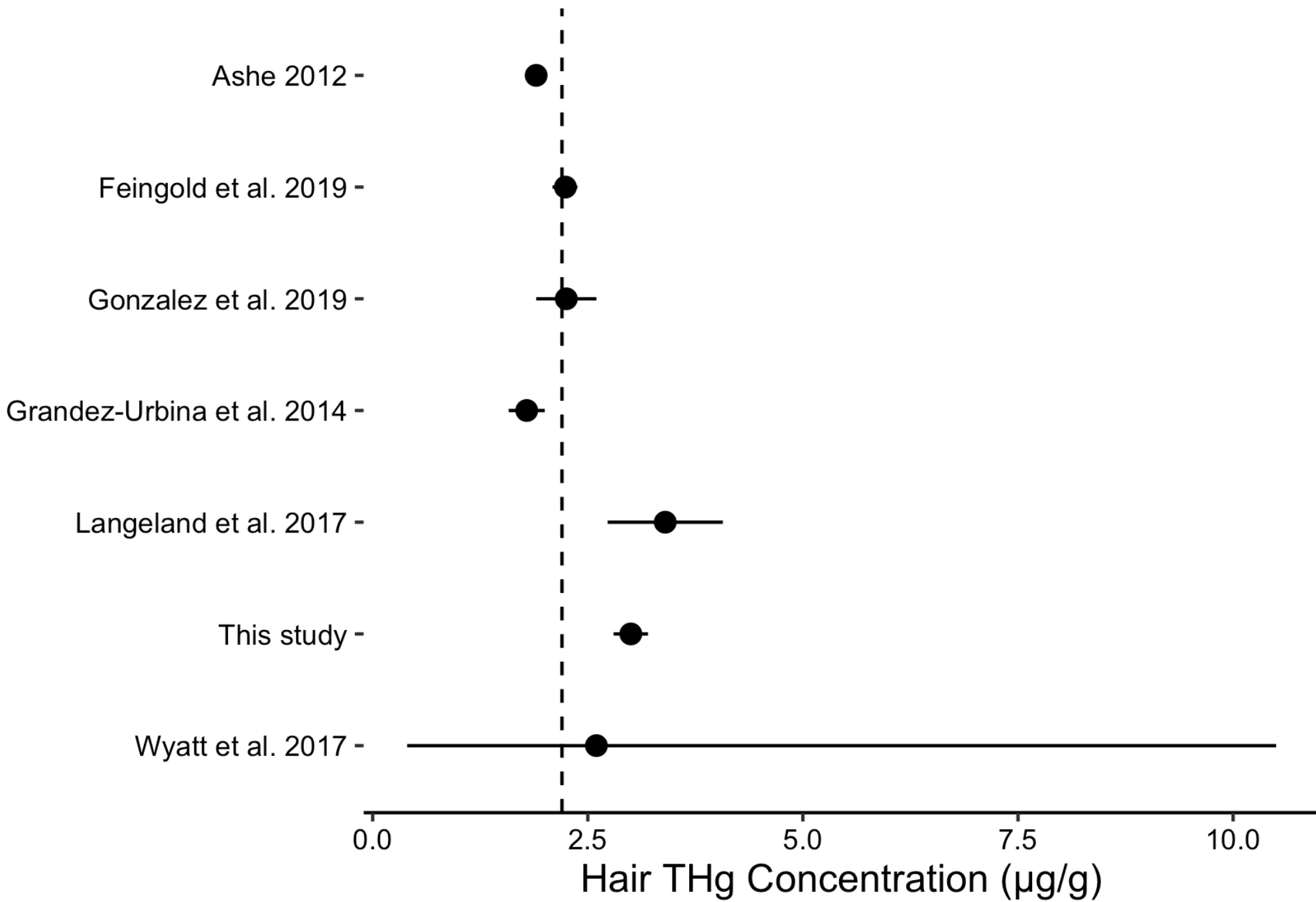
**Figure 1.** Study sites in the Madre de Dios region of Peru. Residents from 23 communities participated in the study, including both indigenous and non-indigenous communities.



**Figure 2.** The distribution of hair THg concentration for the full study population (all), each of the four subpopulations (a, indigenous; b, miner; c, females; d, children), and participants not belonging to any subpopulation (e). The subpopulations are not mutually exclusive. The dashed line represents the WHO provisional dose of  $2.2 \mu\text{g/g}$ .



**Figure 3.** Exposure for the study participants belonging to one or more subpopulations, including participants with up to four intersectional features. Reported as mean hair THg  $\pm$  standard deviation (n).



**Figure 4.** Results for hair THg concentrations reported in the current study compared to findings from other recent studies in Madre de Dios, Peru.