



# Environmental Health Impacts from Artisanal Gold Mining

Observations from the Carnegie Amazon Mercury Project

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GLOBAL ECOLOGY

# Carnegie Amazon Mercury Project - CAMEP

Primary scientific research on mercury contamination from gold mining in Madre de Dios





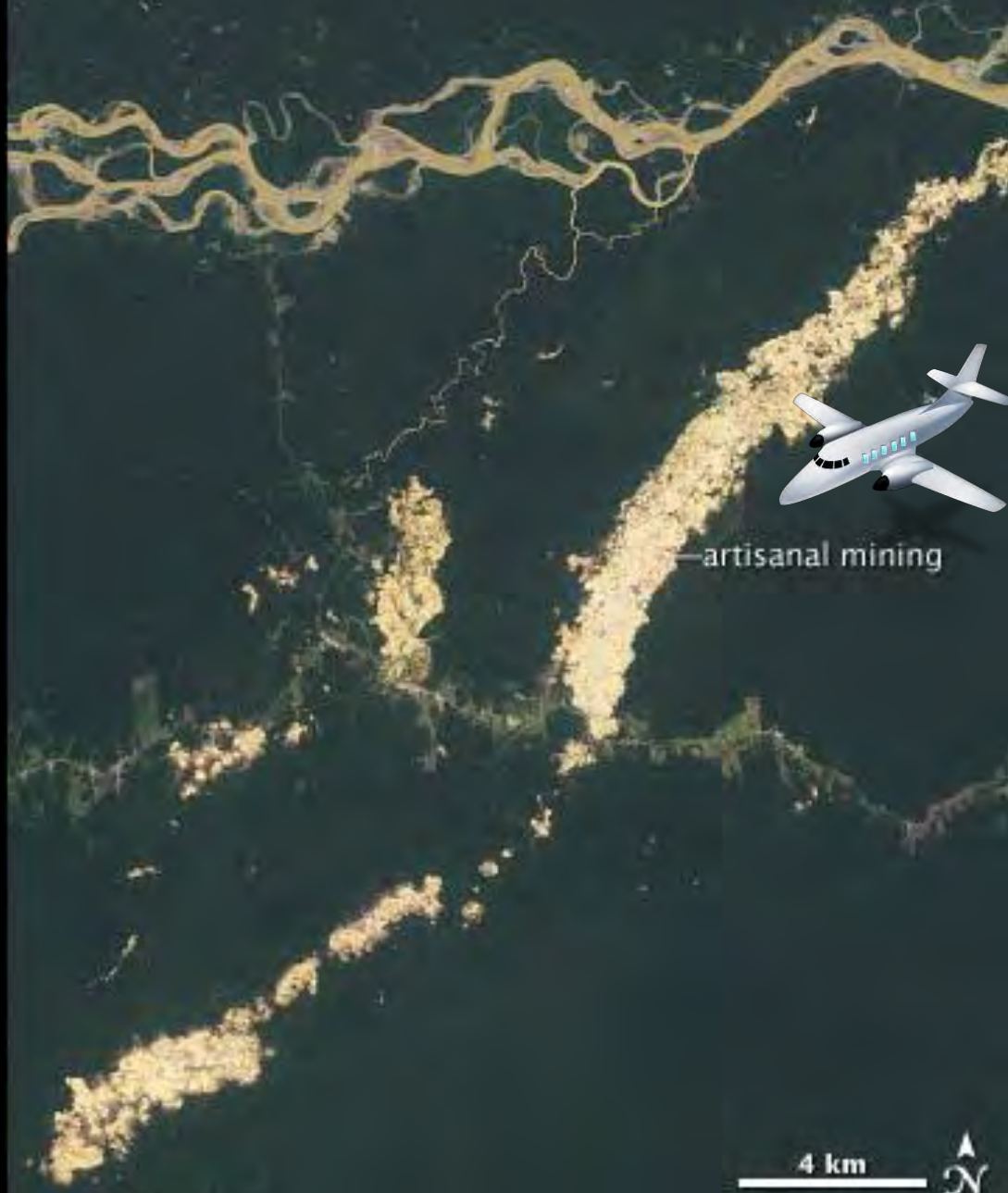
2003



*Inambiri River*

Interoceanic Highway

2011







# Artisanal Gold Mining in Madre de Dios

30 – 40 tonnes of Hg / year





CALIDAD DE EXPORTACION



MERCURIO  
EL -  
ESPANOL

CE ISO 9002 MANUFACTURE QUALITY SYSTEM

MERCURIO  
EL -  
ESPANOL

Pedidos Lima Telf.: (01) 372 7234







# Rural Release and Exposure

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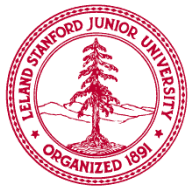
Guacamayo, Madre de Dios



# Rural Release and Exposure

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# Urban Release and Exposure



La Rinconada, Puno



Puerto Maldonado, MDD

Mercury, in all of its forms is considered a toxic substance of global concern because of its:

- significant negative impacts on the ecosystems and human health
- ability to **bio-accumulate** and **bio-magnify** food chains and ecosystems
- persistence in the environment



Source: World Health Organization (WHO)

# Effects of Methyl-Mercury on Human Health

**Methyl-mercury is the most toxic form of mercury and causes a range of health effects**

- Permanent damage to the central nervous system, especially infants and children - 5 to 10 times more vulnerable
- Effects on intelligence, vision, coordination, muscular control etc.
- Damages immune and genetic systems
- Transferred through the placenta to the fetus– and can permanently affect the child's nervous system and brain.

**Consumption of contaminated fish is the primary exposure pathway for methylmercury**

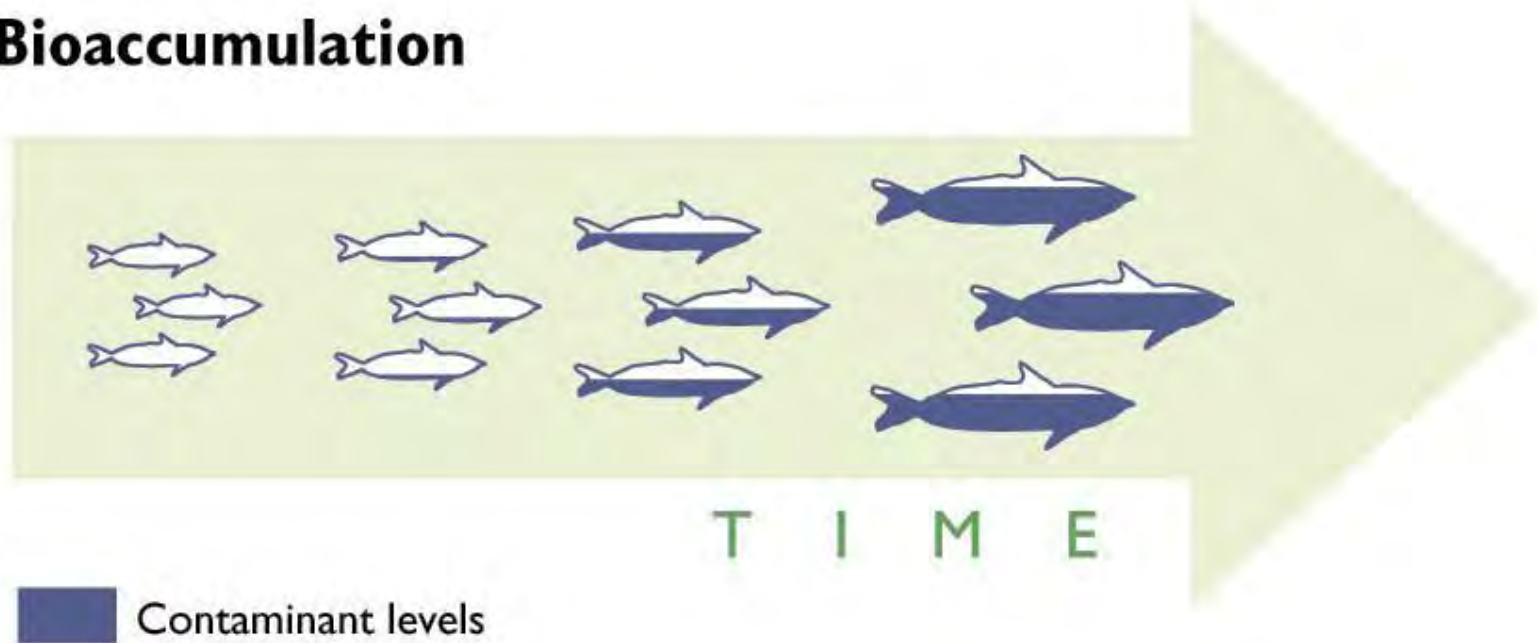


**Impacts on the development of children occurred due to the exposure to Methyl Mercury in fish in Minamata, Japan, 1956 – 1968**

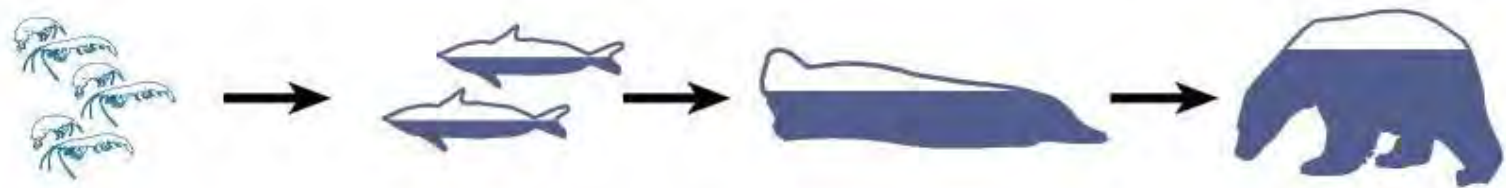



# Why is Mercury Such a Problem in the Environment?

## Bioaccumulation



# Why is Mercury Such a Problem in the Environment?

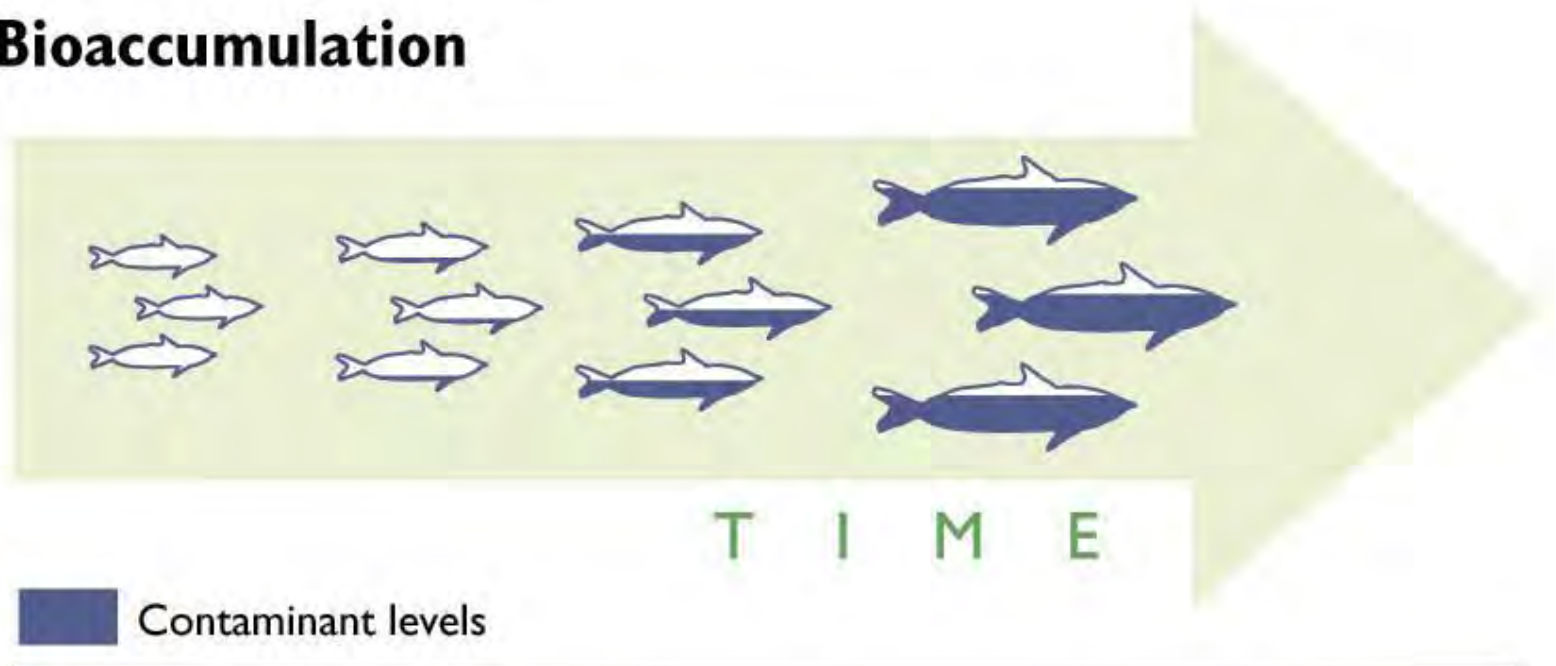


 Contaminant levels

**Biomagnification**

# Why is Mercury Such a Problem in the Environment?

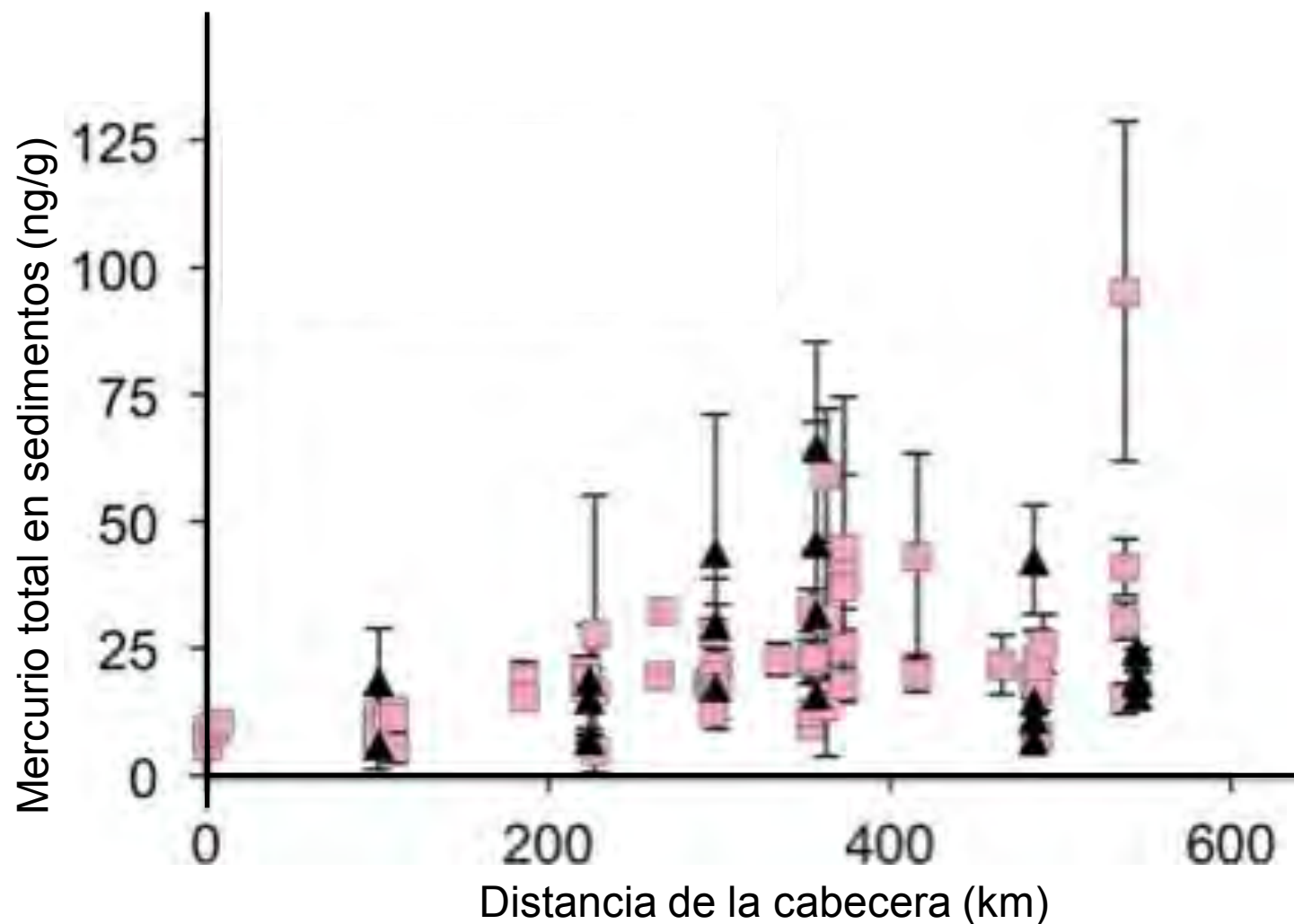
## Bioaccumulation



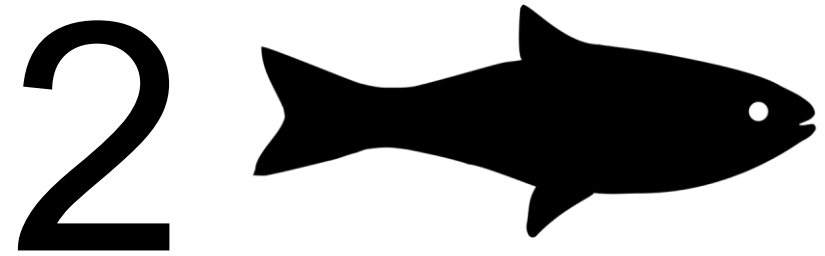
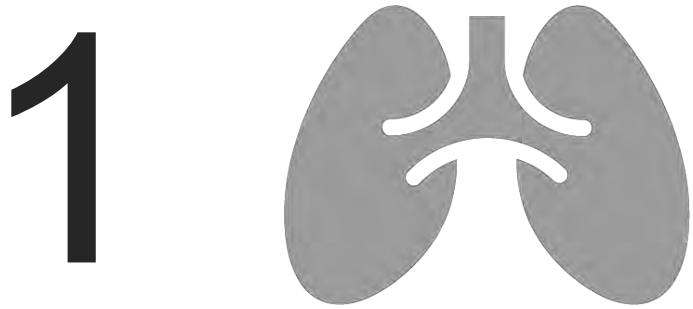
## Biomagnification

# Elevated Hg concentrations in river sediments >500 km downstream from gold mining sites

Diringer et al. 2015

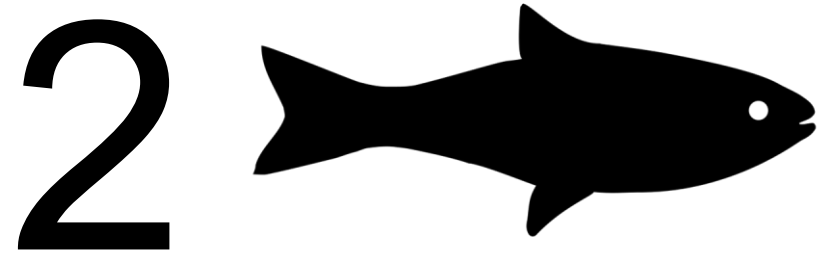
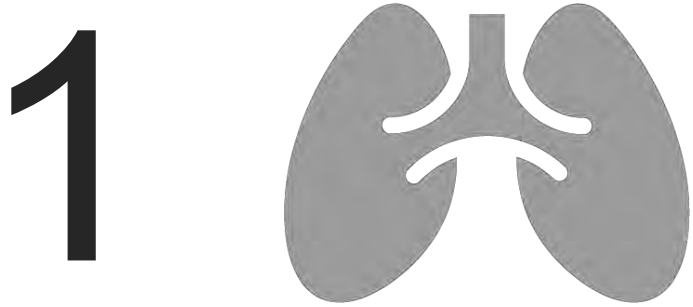


# Routes of Mercury Exposure in MDD



**Inhalation of Mercury  
Vapors in the Air**

# Routes of Mercury Exposure in MDD



**Inhalation of Mercury  
Vapors in the Air**

**Consumption of Mercury  
in Local Fish**

# Sampling

Gold shops - Puerto Maldonado



# Field Sampling

Gold shops - La Rinconada, Puno





# Sampling

Gold shops - Puerto Maldonado

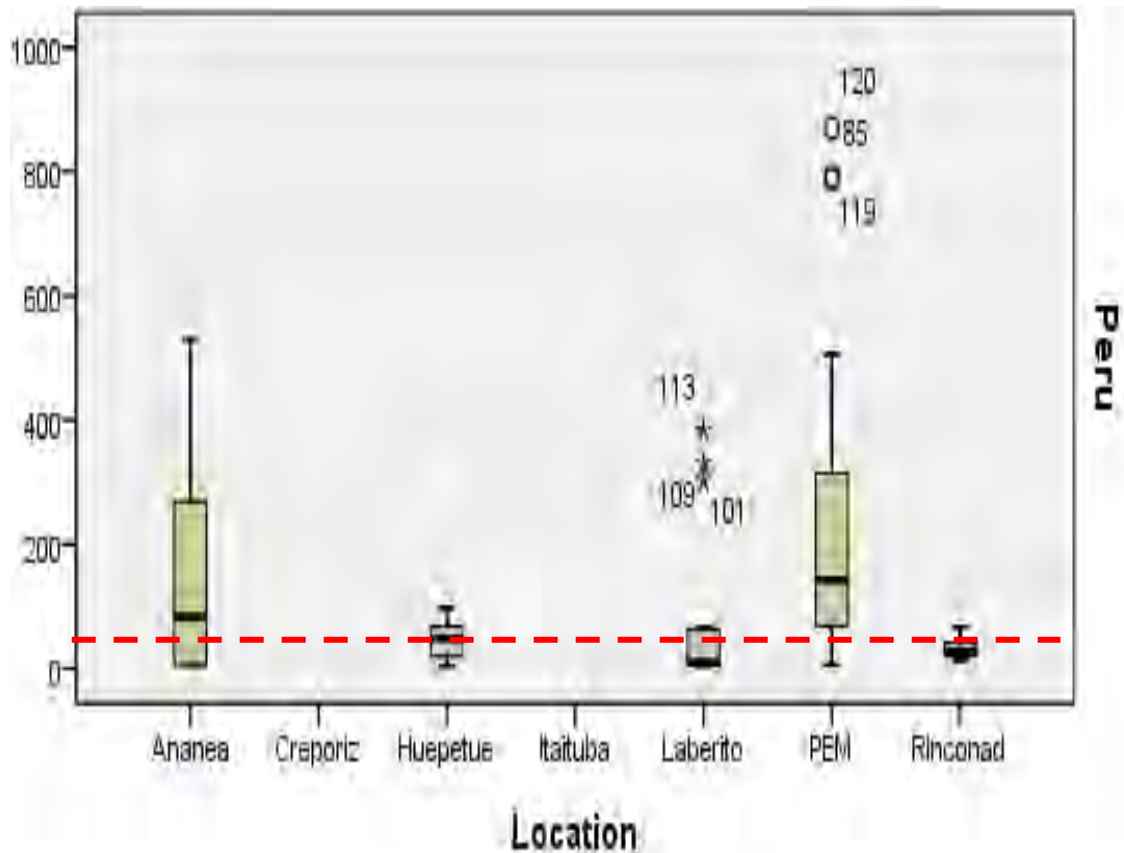




# Urban Mercury Emissions

## Hg concentracions in Gold Shops

All gold shops have Hg levels above occupational reference standards - 20  $\mu\text{g}/\text{m}^3$

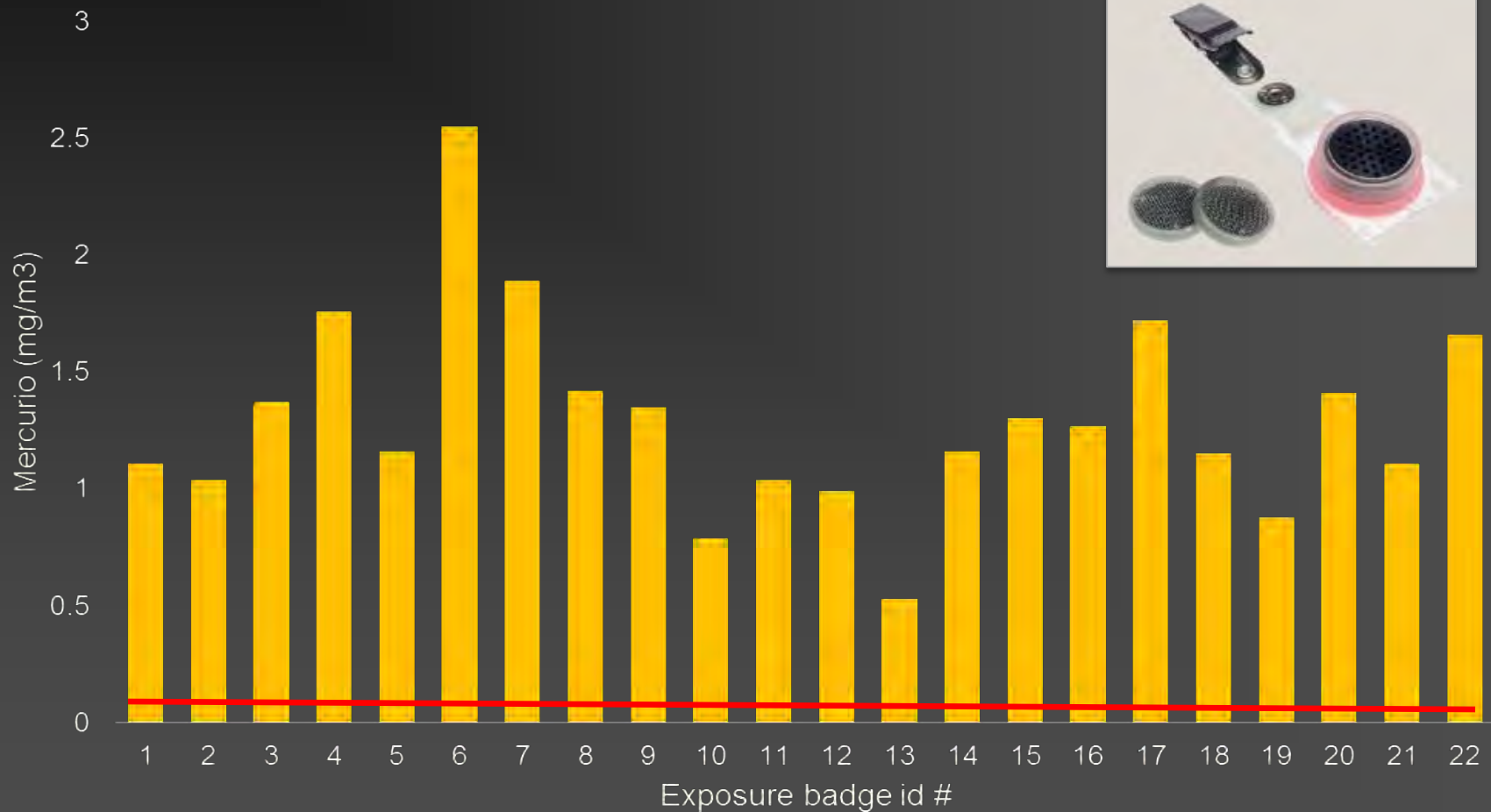


OMS/ ACGIH Valor de Referencia – Hg(0)– exposicion ocupacional 8r TLV = 20  $\mu\text{g}/\text{m}^3$

Fernandez et al . (2011). Proceedings of ICMGP 2011 Halifax

# Results

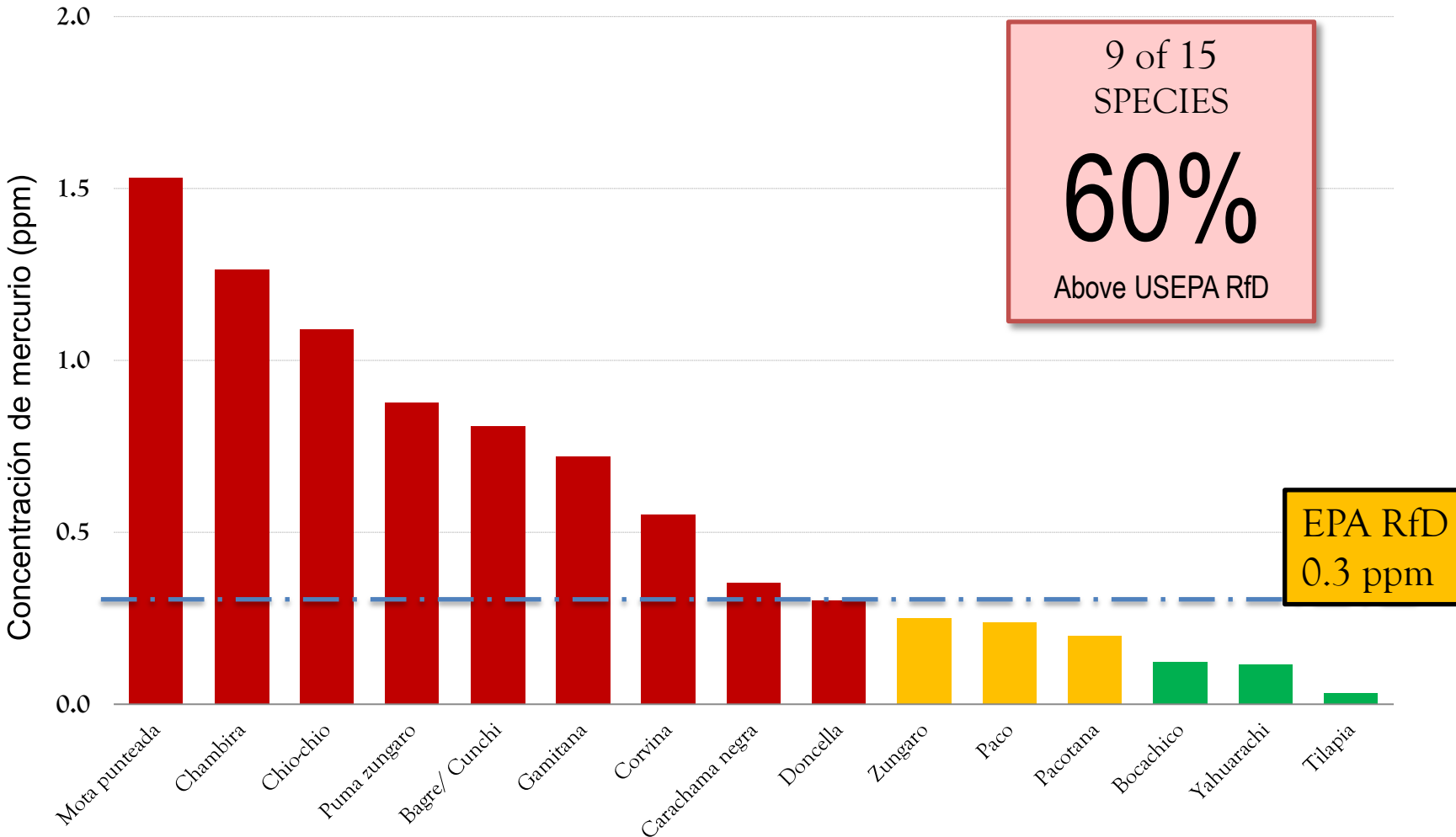
Mercury concentration : personal exposure



--- OMS/ ACGIH Valor de Referencia – Hg(0)– exposicion ocupacional 8 hr TLV = 20 µg/m<sup>3</sup>



# Mercury concentrations of fish sold in MDD markets



# Mercury levels in wild caught fish 2009 and 2012

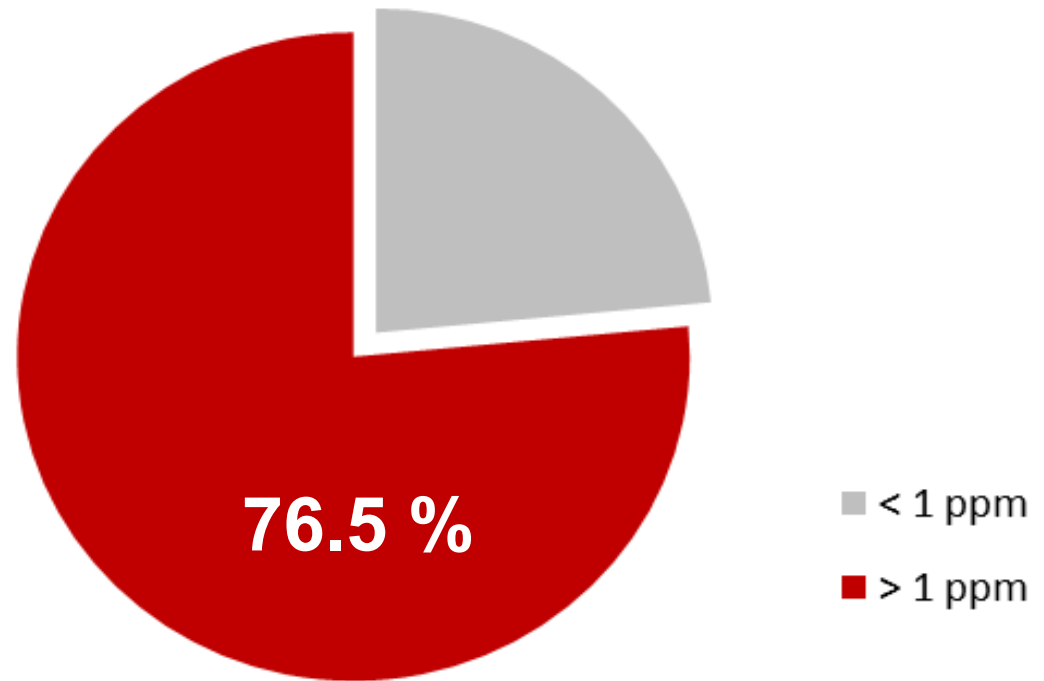
10 of 11 SPECIES  
**90%**  
 Increased Hg levels

Mercurio en Peces de Mercados de Puerto Maldonado: 2009 - 2013

Species (Scientific Name)	2009 (ppm)	2012 (ppm)	Change
Bagre/Cunchi ( <i>Prochilodus nigricans</i> )	0.12	0.81	↑
Bocachico ( <i>Prochilodus nigricans</i> )	0.04	0.12	↑
Carachama ( <i>Prochilodus nigricans</i> )	0.02	0.35	↑
Chambira ( <i>Prochilodus nigricans</i> )	0.59	1.26	↑
Corvina ( <i>Prochilodus nigricans</i> )	0.09	0.55	↑
Dancella ( <i>Prochilodus nigricans</i> )	0.32	0.30	↑
Mota Puntada ( <i>Prochilodus nigricans</i> )	1.12	1.53	↑
Paco ( <i>Prochilodus nigricans</i> )	not detected	0.24	↑
Puma Zungaro ( <i>Prochilodus nigricans</i> )	0.18	0.88	↑
Yahuaschi ( <i>Prochilodus nigricans</i> )	0.04	0.12	↑
Zungaro ( <i>Zungaro zungaro</i> )	0.70	0.25	↓



### Percent of People with Mercury Levels above WHO Maximum Levels

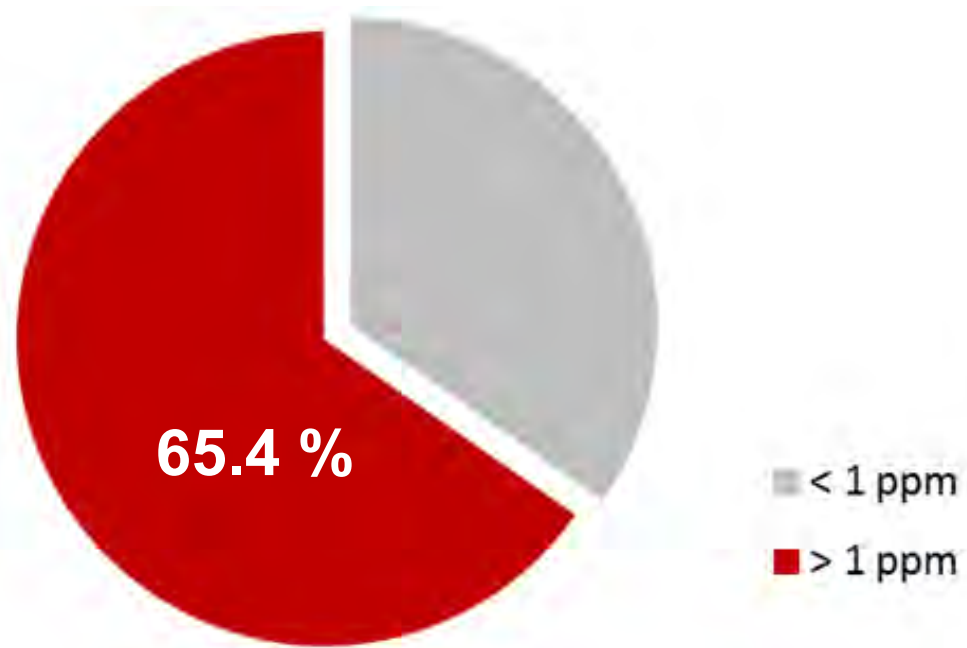


N – 1029; range: 0.1 ppm – 34 ppm

US EPA MeHg Reference Human Hair. (EPA RfC): 1 ppm



## Percent of Children with Mercury Levels above WHO Maximum Levels



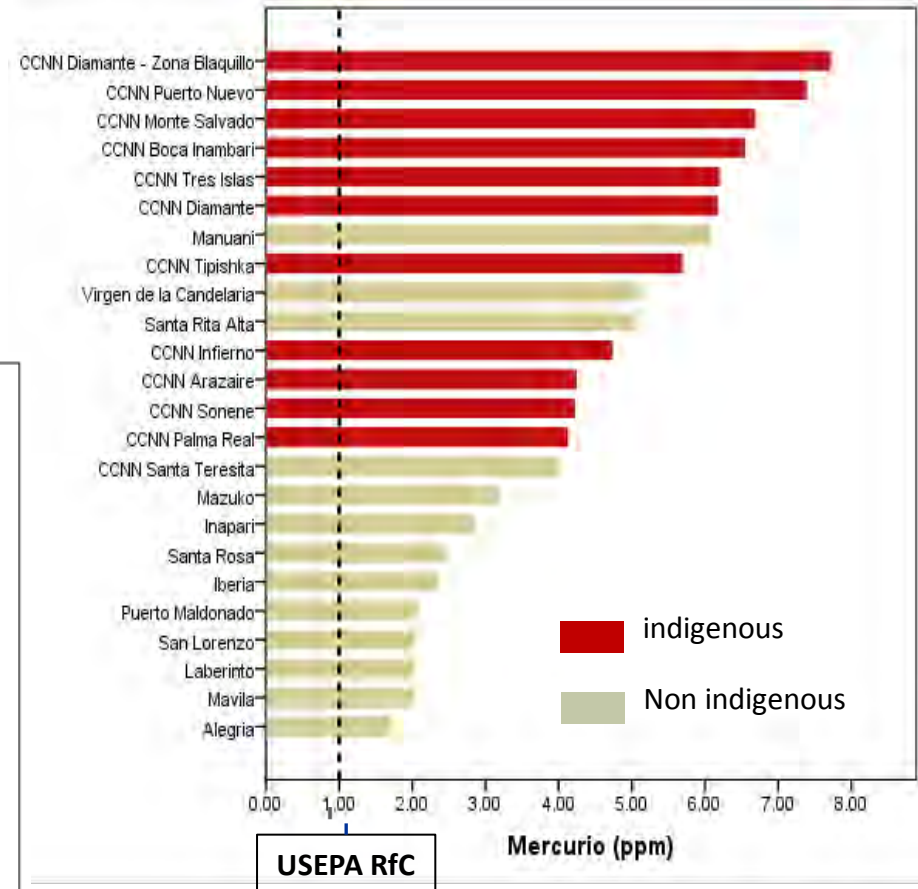
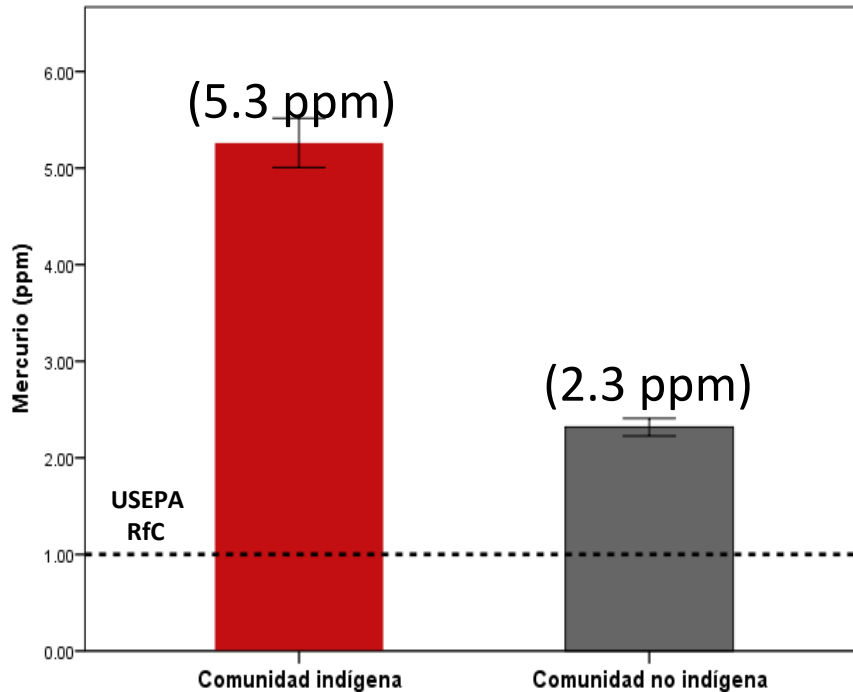
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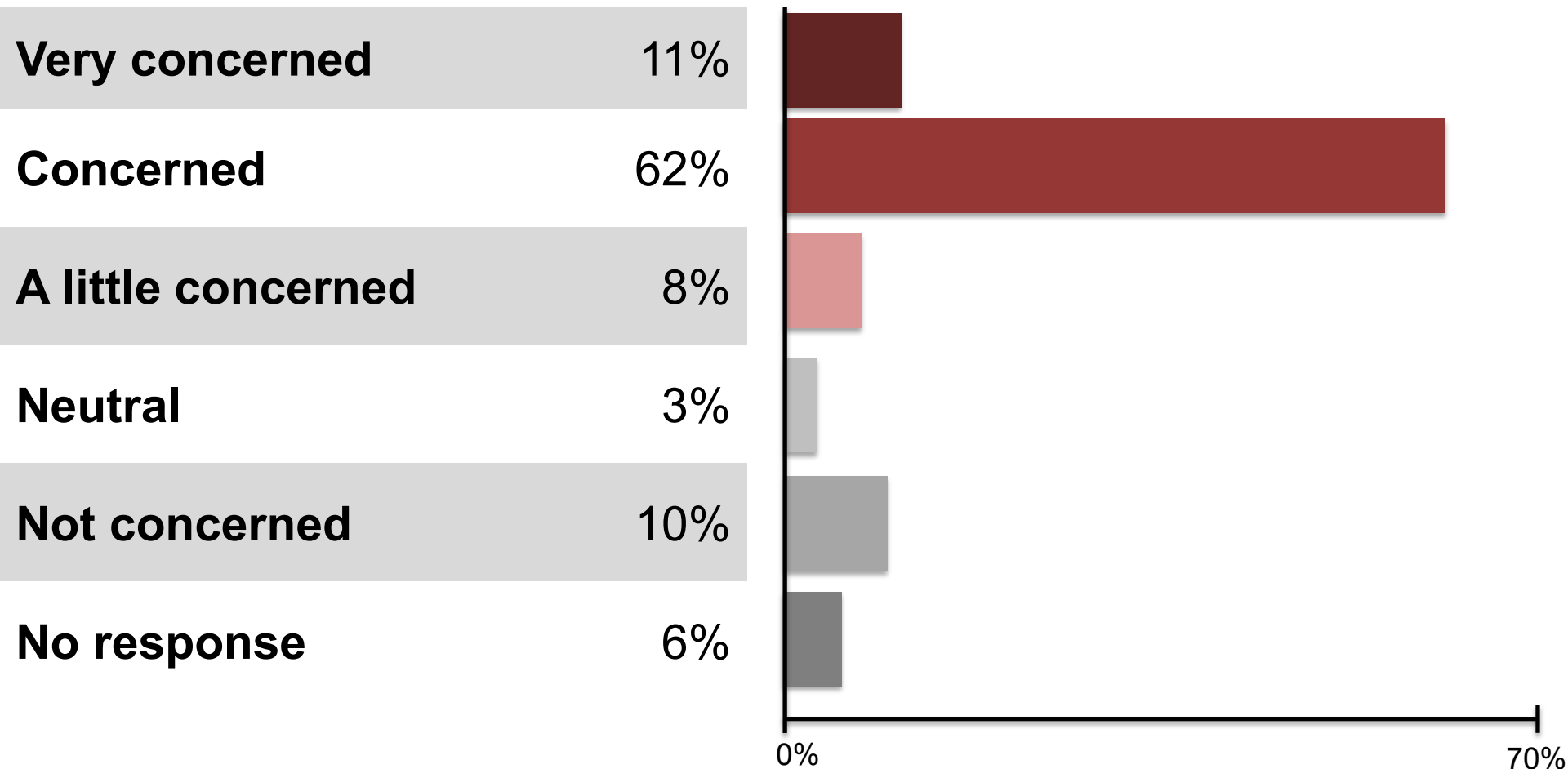
# Human Mercury Levels in Madre De Dios

## Indigenous Communities Most Affected

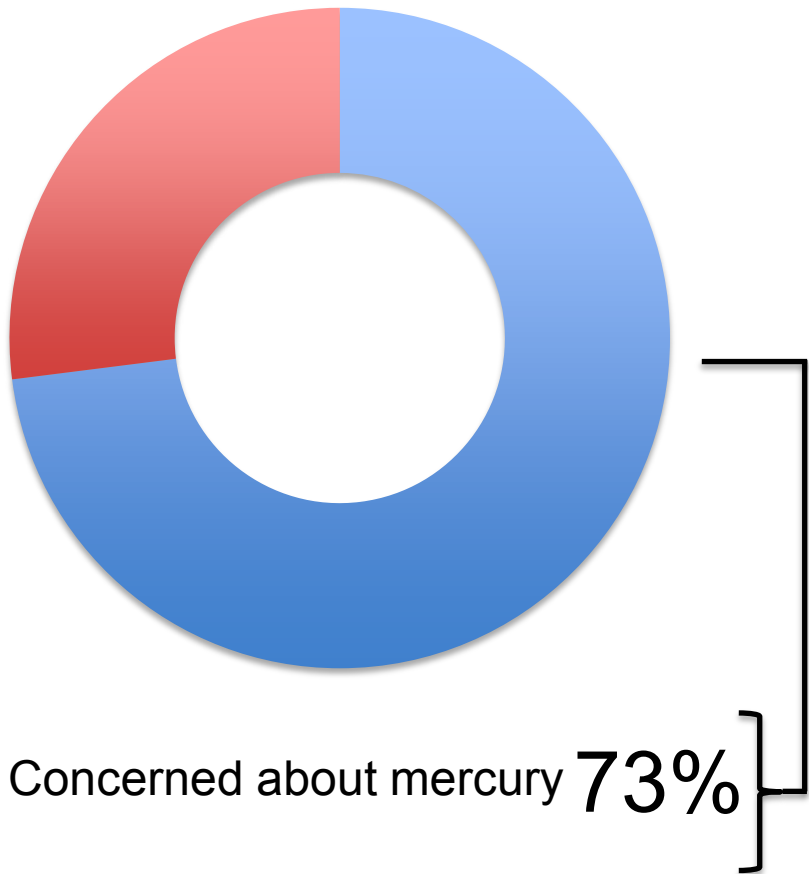


**7 of the 10 communities with the highest mercury levels were indigenous**

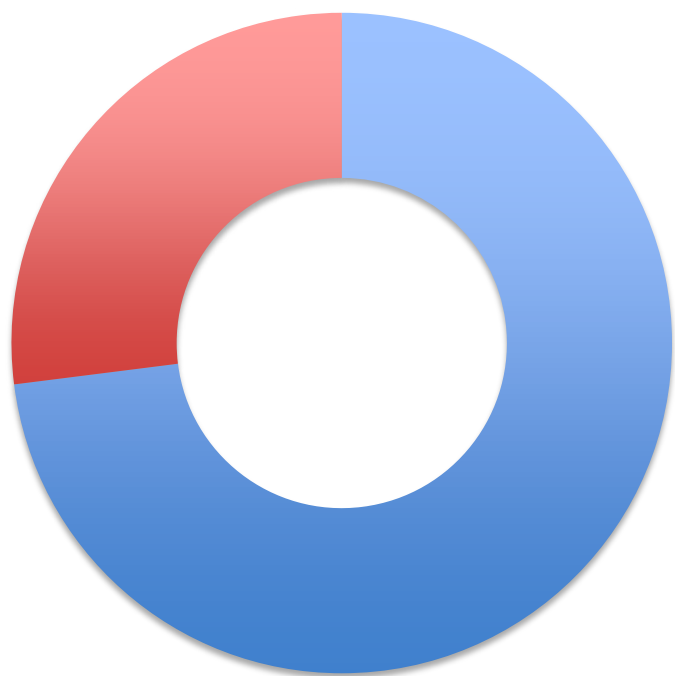
# Most women are concerned about mercury contamination



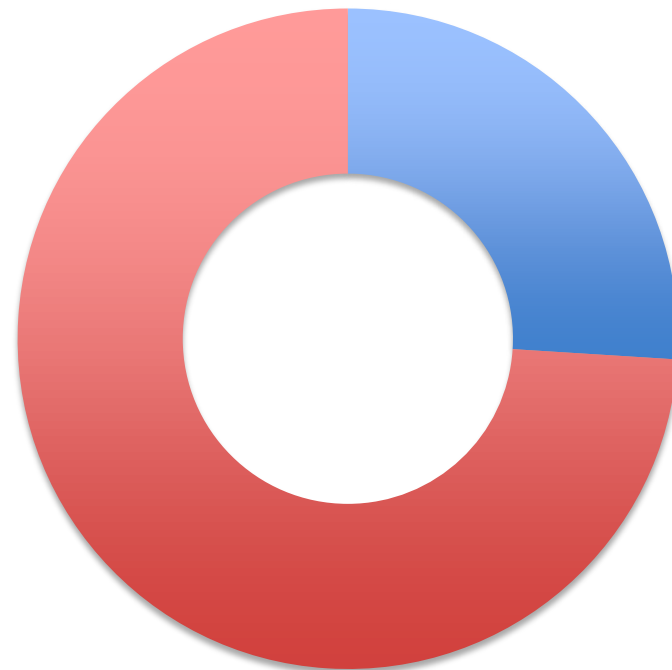
# A gap between concern about mercury and knowledge of the risks of mercury contamination



# A gap between concern about mercury and knowledge of the risks of mercury contamination



Concerned about mercury **73%**



**74%** Have little or no knowledge of the effects of mercury

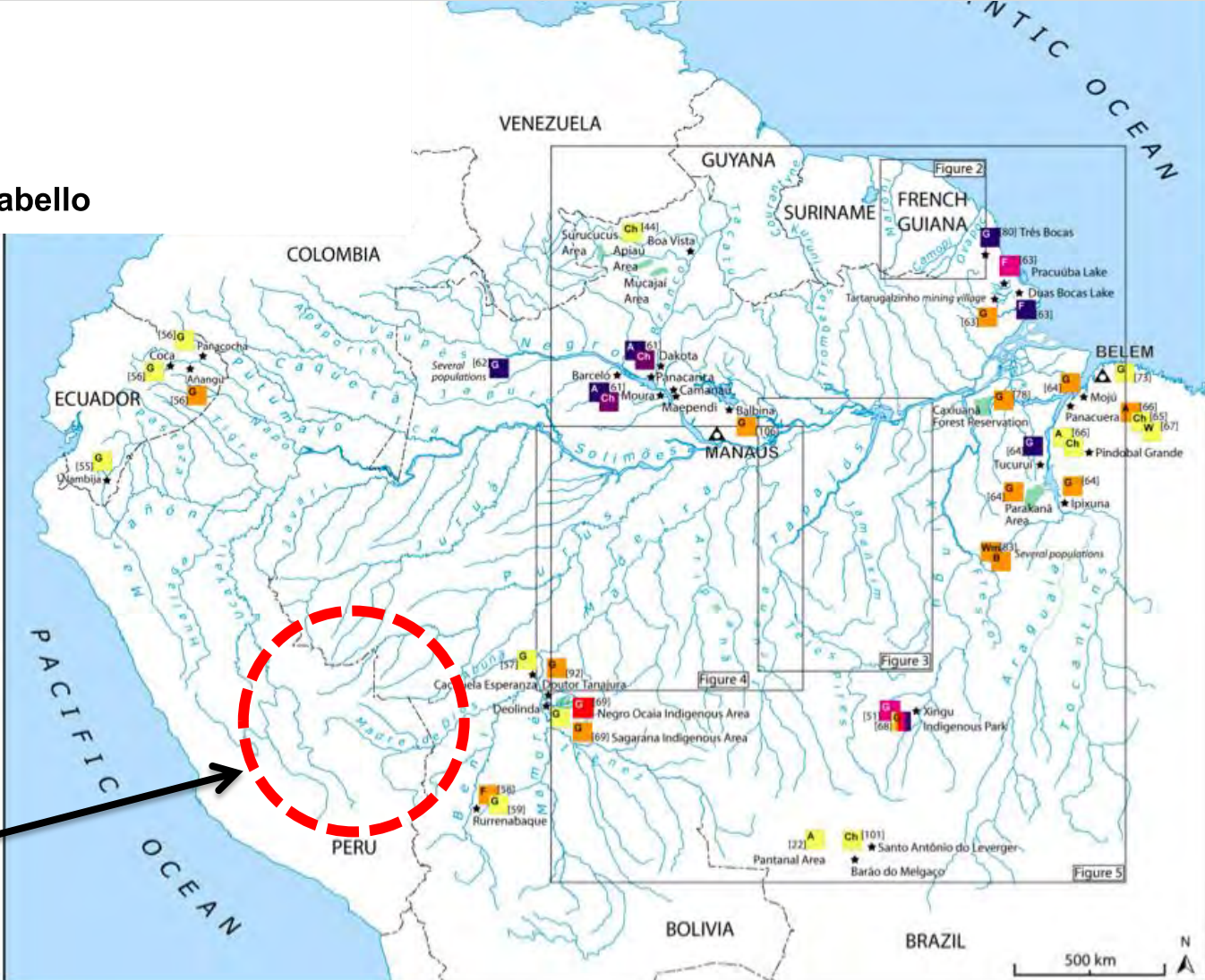
# Implications

## The study of the health impacts from ASGM Mercury is just beginning in Peru

Amaz3n Basin

### LEYENDA

Concentraci3n de Hg en el cabello



Madre de Dios

# Science about mercury in ASGM in MDD

Limited awareness and importance of the issue as a policy priority – **especially locally** – still exists

# Mercury Awareness Fairs in Central Plazas in MDD



**New  
Scientific  
Conferences  
On Hg in MDD**

I Forum on Mercury and Environmental Health in Madre de Dios  
Nov 17-18, 2014

II Forum on Mercury and Environmental Health in Madre de Dios  
Nov 7-8, 2015

**6 de cada 10**  
**pescados consumidos**

en Puerto Maldonado tienen  
niveles de mercurio **SUPERIORES** al  
**máximo** permisible para salud



**8** de cada  
pobladores  
en Puerto  
**10** Maldonado



Presenta niveles de  
**mercurio**  
**3 veces más altos**  
que el máximo permisible para la salud

Fuente: Estudio "Concentraciones de mercurio en peces y seres humanos de Puerto Maldonado", Carnegie Amazon Mercury Ecosystem Project (2012)





INDEPENDENCIA  
Y VOTA CIUDAD

# El Comercio

EL SEGURO DEL DÍA  
\$ 0.05

DIRECCIÓN GENERAL: FRANCISCO GONZÁLEZ B. | DIRECCIÓN DE ADMINISTRACIÓN: J. J. LÓPEZ

ENTREVISTA AL ECOLOGÓLOGO TROPICAL LUIS FERNÁNDEZ (A 74)

## “El mercurio de la minería ilegal afecta más a los indígenas”

**Muerte lenta.** Contaminación en niños nativos de Madre de Dios es hasta 4 veces más alta que la de adultos en la ciudad.

**Peligrosa dieta.** Peces tienen elevados índices de mercurio. Doreado, zungaro y dorado son las especies más afectadas.



### EL IMPERIO DE LA INFORMALIDAD DOMINA LA SIENA - Clan Baca-Casas no deja de destruir y extraer oro

El clan Baca-Casas, que controla la minería informal en la zona de Madre de Dios, continúa destruyendo y extraer oro en la zona de Madre de Dios, pese a las denuncias de la comunidad y la presión internacional.

El clan Baca-Casas, que controla la minería informal en la zona de Madre de Dios, continúa destruyendo y extraer oro en la zona de Madre de Dios, pese a las denuncias de la comunidad y la presión internacional.

### Perú Posible evalúa darle licencia a Toledo

Exclusivas del Caso Eneiza

Se retomará la licitación "para que no perjudique al parador", explica el dirigente Juan Saez por (A 10)

### Maduro denunció 11 intentos para matarlo en 8 meses

Intentos de asesinato que culminaron

Las constantes denuncias no han afectado en ningún proceso judicial o condena. (Suplemento 1)

### San Isidro entre los distritos con mejor atención a vecinos

Un estudio indica que los barrios 4 son Magisterio del Mar, La Pampa, La Perla y Puro de Lino. (A 14)

### Tokio será la sede en el 2020 de los Juegos Olímpicos

Se construirán 22 instalaciones para las competencias que costarán US\$4.380 millones. (A 17)

últimas en Día 2

Especto número 1

La venta de acciones de los países creciendo en China y otros regiones.

¿Cómo mejorar a un banco?

Qué trabajos de corto plazo pueden servir para mejorar la economía.

# ACERS

# Amazon Center for Environmental Research and Sustainability

Powering Scientific Capacity | Sustainable Innovation | Solutions for Madre de Dios

## OUR SOLUTIONS

**Build Science Capacity** | ACERS will serve as a new hub for Peruvian and foreign scientists to collaborate on critical priorities

**Restoration and Reforestation** Create local ability to assess the damage done to forests and wetlands due to illegal gold mining, and develop and disseminate scientifically-guided techniques to accelerate forest regeneration and restoration.

**Environmental Mercury Mitigation** Build the analytical capacity to assess threats to ecosystems, biodiversity, and human communities resulting from mercury emissions due to illegal gold mining, and generate solutions to mitigate or reverse its effects.

**Engage and Empower the Community** | ACERS will empower the Madre de Dios community to take on critical conservation challenges

**Sustainable Business Initiative** Develop capacity in the private sector for identifying alternative economic opportunities and implementing innovative solutions for conservation by developing close and intentional links with the emerging science community.

**Research Apprenticeship Program** Secure future scientific and economic capacity in Madre de Dios by working with pre-college and college students and educators to strengthen career pipelines for science, conservation, and restoration.

**Public Engagement Program** Enhance the two way flow of information between the scientific community and the general public — especially women and indigenous populations—by communicating and applying knowledge of conservation threats and restoration solutions.

## ACERS | The Amazon Center for Environmental Research and Sustainability



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DEPARTMENT OF  
GLOBAL ECOLOGY



Asociación Huarayo



Consorcio Madre de Dios



UNIVERSIDAD NACIONAL MAYOR DE  
**SAN MARCOS**  
Universidad del Perú, DECANA DE AMÉRICA

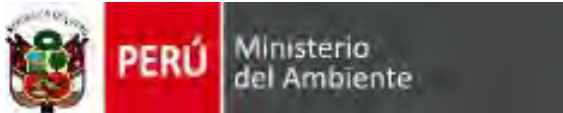


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# Research briefs for policymakers and the public

## MERCURY IN MADRE DE DIOS

### MERCURY CONCENTRATIONS IN FISH AND HUMANS IN PUERTO MALDONADO

CAMEP  
CARNEGIE AMAZON MERCURY ECOSYSTEM PROJECT

CAMEP
Research Brief #1
Mercury, Amazon, Environment, Peru, Public Health | March 2013

**A new study of fish and humans in the Peruvian Amazon finds that mercury is a serious and increasing environmental and public health problem in the gold mining region of Madre de Dios. High mercury concentrations found in a majority of people and in most of the wild caught fish sold in markets in the capital city, Puerto Maldonado, indicate that the scope and intensity of mercury contamination by artisanal gold mining in Madre de Dios is greater than previously thought.**

#### Introduction

Mercury is a powerful neurotoxin and a persistent environmental contaminant that accumulates in the tissues of fish in contaminated watersheds. The consumption of contaminated fish is one of the primary mercury exposure pathways for humans living in these regions. A previous study conducted in 2009 by the Carnegie Institution for Science's Department of Global Ecology found that many of the consumed fish species sold in the markets of Madre de Dios, an Amazonian region in southern Peru, had levels of mercury well above international reference limits. This indicated a serious public health and environmental problem existed in the Western Amazon.

To better understand how mercury from artisanal gold mining is affecting ecosystems and human populations, in 2012 the Carnegie Institution for Science established the Carnegie Amazon Mercury Ecosystem Project (CAMEP), a scientific research effort that brings together 10 Peruvian universities and NGOs with Carnegie scientists to focus on the pressing problem of mercury in Madre de Dios.

This first CAMEP research brief presents the results of two studies that examined the effects of mercury on the urban community of Puerto Maldonado, the capital city of the department of Madre de Dios.

#### Research Design

CAMEP researchers analyzed the mercury concentrations of the muscle tissue of 15 species of commonly consumed wild caught fish which were purchased in several markets in Puerto Maldonado during August 2012. To determine the effect of eating these fish and the levels of general mercury exposure of the population, the CAMEP project offered free mercury hair testing to 226 adults in Puerto Maldonado during May to August 2012. A survey was given to the participants, asking about fish consumption and mercury exposure history. These fish and hair samples were analyzed for total mercury at a dedicated mercury analysis laboratory established at the Environmental and Computational Chemistry Group at the University of Cartagena, Colombia.

#### Major Findings

**Mercury in Fish:**  
**60% of the species of fish sold in in Puerto Maldonado had mercury levels that exceeded international mercury concentration limits for fish.** Mercury levels of 9 of the 15 most consumed fish species had average levels of mercury above the international mercury reference limit (0.3 ppm).

**Mercury in Humans:**  
**78% of adults in Puerto Maldonado had hair mercury concentrations above international mercury reference limits for human hair.** More than three out of four adults analyzed in Puerto Maldonado had mercury concentrations higher than the reference limit. Average mercury concentrations of adults were 2.7 ppm – about three times the reference value of 1 ppm (Figure 2). Mercury levels in human hair ranged from 0.02 ppm to a high of 27.4 ppm, a level more than 27 times the international limit for mercury in human hair.

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<http://www.carnegie.org/>

**Figure 1. Average levels of mercury in consumed fish in Puerto Maldonado, compared to the reference limit for mercury in fish (0.3 ppm).**

Fish Species	Mercury Concentration (ppm)
1	2.8
2	2.5
3	2.2
4	1.8
5	1.5
6	1.2
7	1.0
8	0.8
9	0.6
10	0.5
11	0.4
12	0.3
13	0.2
14	0.1
15	0.1

**The most vulnerable population: Women of Child Bearing Age, had the highest average mercury levels.**  
 Women of child bearing age (between 14–49), a group most at risk from the neurotoxic effects of mercury, had the highest hair mercury levels of adults in Puerto Maldonado with average levels of 3.0 ppm (Figure 2, red column). Women of child bearing age are particularly at risk because mercury can be passed to the developing fetus across the placental barrier and cause severe and permanent neurological damage to the unborn child.

**The human population of Puerto Maldonado has a very high risk of mercury exposure and associated health effects due to high consumption of local contaminated fish, experience in gold mining, and from inhalation of airborne mercury from gold buying shops.** The majority of participants (92%) in Puerto Maldonado reported that they consume local river and lake fish regularly. 64% of respondents said they consume at least one high mercury species weekly, while 25% eat two or more on a weekly basis. Occupational exposure is also an important factor, as 25% of adults report working directly in gold mining. Lastly, the study results indicate that another significant exposure source of mercury exists in Puerto Maldonado and is contributing to the extremely high levels of mercury found in the adults of Puerto Maldonado. Suspected sources are the gold buying shops located in the center of Puerto Maldonado that release large amounts of mercury vapor, exposing thousands of people daily to toxic air levels.

**Figure 2. Mercury levels of 226 adults in Puerto Maldonado, compared to the reference limit for mercury in human hair (1.0 ppm).**

Group	Average Mercury Concentration (ppm)
All Adults	2.7
Men	2.5
Women	2.8
Women (Child Bearing)	3.0

**Reference Values**  
**Mercury in Fish Tissue:**  
 0.3 ppm US Environmental Protection Agency (USEPA)  
 Mercury Reference Concentration (MRC) Fish, 2001  
**Mercury in Human Hair:**  
 1.0 ppm US Environmental Protection Agency (USEPA)  
 Mercury Reference Concentration (MRC) Human Hair, 2001  
Source: www.epa.gov/mercury/03rhc.html

**Research Sponsors**  
 This research was supported by a grant from the Blue Room Fund under the Andes-Amazon Program.

**CAMEP Research Partners**  
 Universities and Research Institutions  
 Carnegie Institution for Science – Global Ecology  
 Universidad Nacional Amazonica de Madre de Dios  
 Universidad de San Martín de Porres – Instituto Del Perú  
 Universidad de Cartagena – Grupo de Química Ambiental y Computacional

**Non-governmental Organizations**  
 Asociación para la Conservación de la Cuenca Amazónica  
 Asociación para la Investigación y el Desarrollo Integral Amazonico Peruano  
 Caritas Peru – Madre de Dios  
 Comarcas Madre de Dios  
 Sociedad Ecológica de Franklin Fava

**Carnegie Institution for Science**  
 The Department of Global Ecology, founded in 2002 on the campus of Stanford University, located in Palo Alto, California, USA, conducts basic and applied research on the interactions among the earth's ecosystems, land, atmosphere, and ocean. For more information, visit [dgs.stanford.edu](http://dgs.stanford.edu).

**Carnegie Amazon Mercury Ecosystem Project**  
 Established in 2012, the Carnegie Amazon Mercury Ecosystem Project (CAMEP) brings together researchers of eight Peruvian universities, non-governmental organizations, and Carnegie Institution for Science to conduct ecological and public health studies over the issue of mercury in the region of Madre de Dios, Peru.

**For More Information**  
 Luis E. Fernandez, Director, CAMEP  
[luf@stanford.edu](mailto:luf@stanford.edu)

**Summary of findings**

- High levels of mercury in the environment of Madre de Dios are strongly affecting the human population of Puerto Maldonado, resulting in a grave and mounting threat to public health.
- Mercury levels of the people of Puerto Maldonado are extremely elevated and mercury contamination is more extensive than previously identified.
- Mercury contamination of wild caught fish sold in the markets of Puerto Maldonado is much more extensive than previously identified and is increasing. This may indicate that the ecosystems of Madre de Dios are becoming more severely affected by artisanal gold mining.
- Regular consumption of wild caught fish species contaminated with high concentrations of mercury and occupational exposure to mercury through gold mining is likely contributing to the high levels of mercury found in adults in Puerto Maldonado.
- Other sources of mercury, such as the high levels of mercury vapor released by "gold shops", small businesses that buy and refine gold in populated urban areas, are also likely contributing to the high mercury levels found in people.

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Carnegie Amazon Mercury Ecosystem Project

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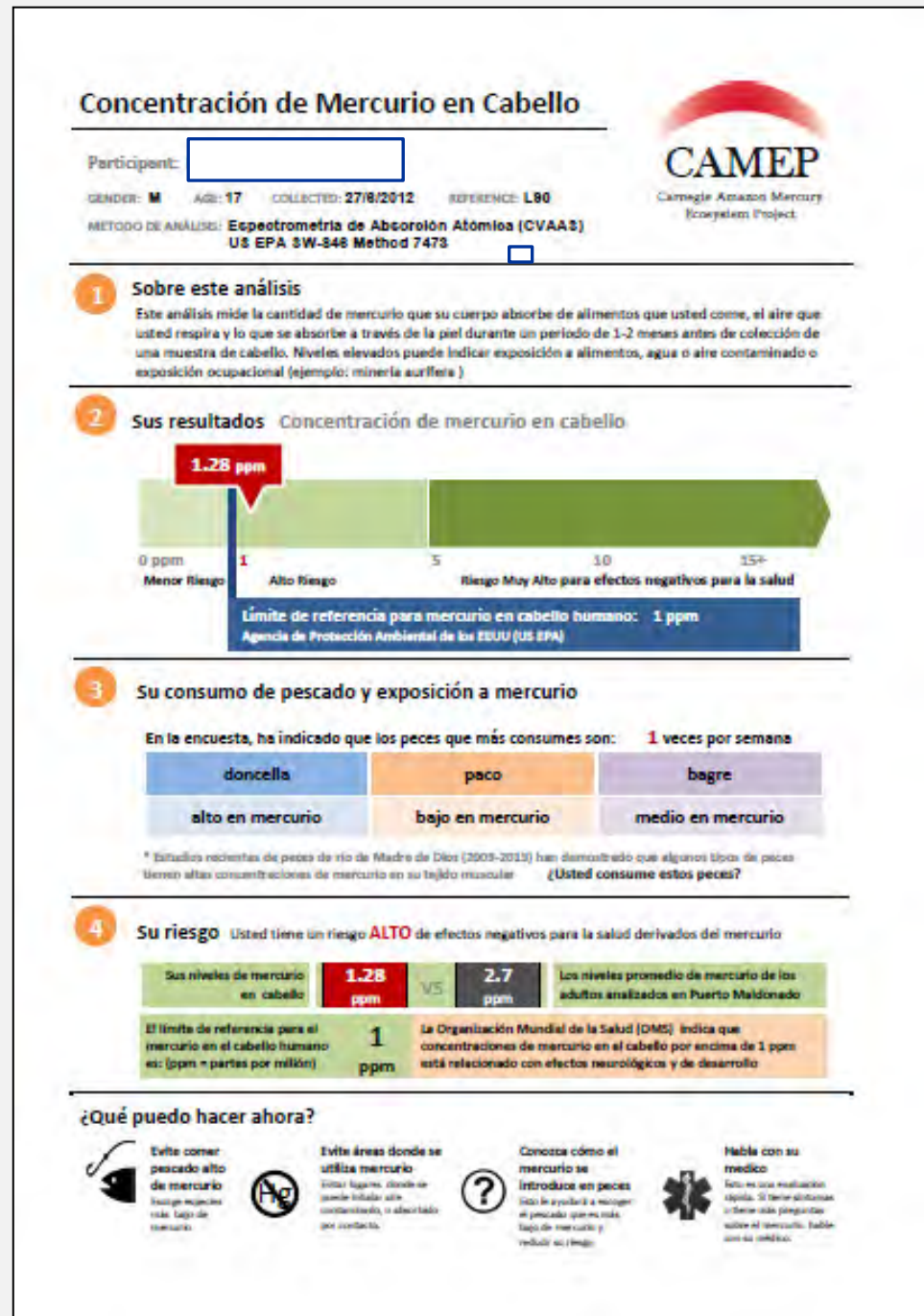
# Can Information Empower People to Improve Decisions and Change Behavior ?

## Simplified Personalized Reports on Mercury Levels

All participants have received the analysis results of their hair sample ~1100 people

➤ Personalized evaluation of the danger presented by fish that the participant named as his/her most consumed fish

➤ Comparison of his/her personal level to the average level of his/her village/town



# Small success story: Closing the gold shops in Puerto Maldonado

Gold shops burn mercury in urban downtowns releasing massive quantities of toxic Hg vapor – but allowed to operate with no restrictions since the founding of the city.

Several studies of Hg levels in gold shops were done.

After Hg studies were communicated directly + by the press, a group of 10 mothers in the downtown area self-organized to force the city to shut the gold shops down for the safety of their children – they asked for our data. We gave it to them.



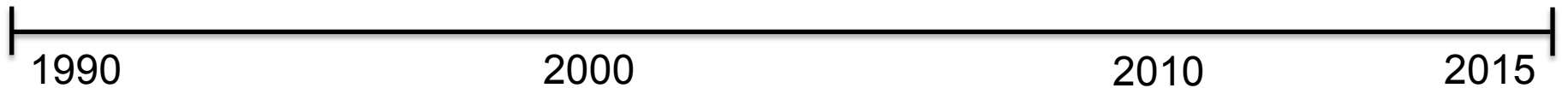
CAMEP worked with MINAM, Defensoria del Publico and the grassroots community group to figure out, craft and execute a “innovative“ strategy to force the issue with the municipal government and close the shops.

Within 3 months, all the gold shops in Puerto Maldonado closed.

**Mercury exposure and the nervous systems damage to tens of thousands of people living and working in the downtown zone was eliminated.**

# Science about mercury in ASGM in MDD

(.....very few studies)

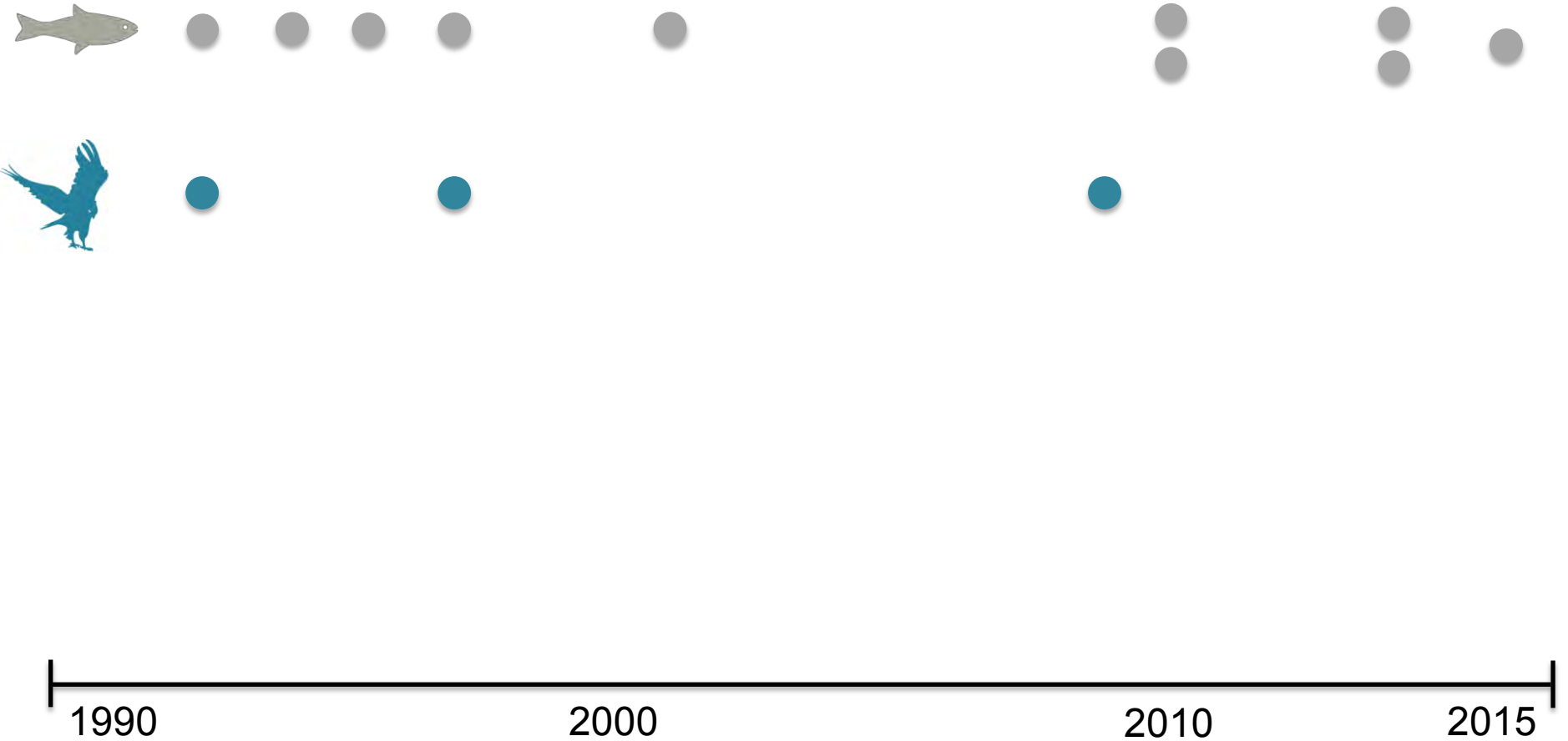


# Science about mercury in ASGM in MDD

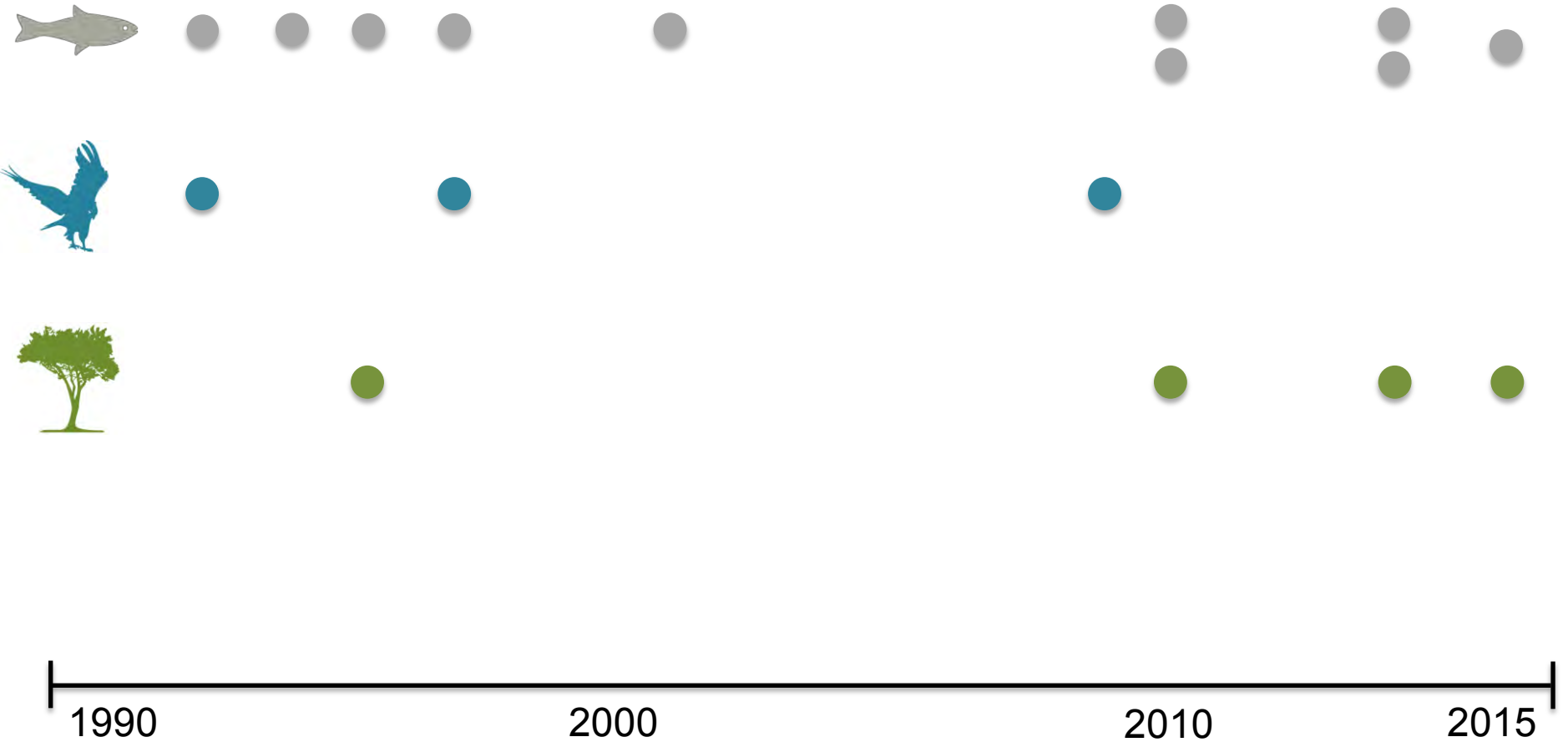




# Science about mercury in ASGM in MDD



# Science about mercury in ASGM in MDD



# Science about mercury in ASGM in MDD

