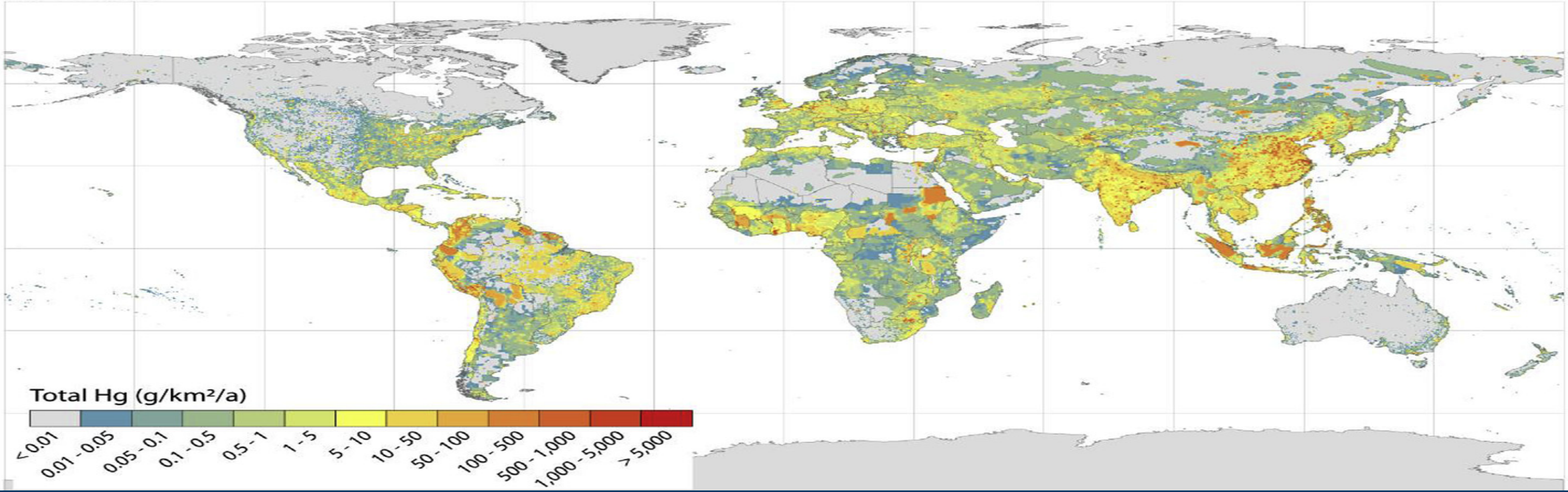


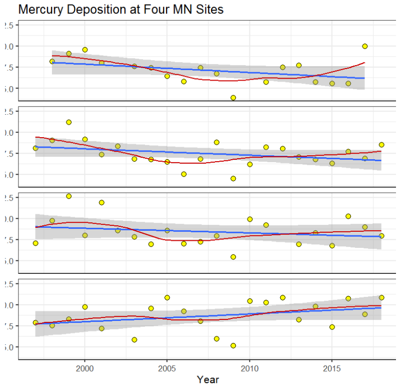
2019 STATE OF THE KNOWLEDGE ON MERCURY

Bruce Monson | Research Scientist

1 October 2019

MINNESOTA POLLUTION
CONTROL AGENCY

Topics



Wet Deposition & Fish Trends in Minnesota

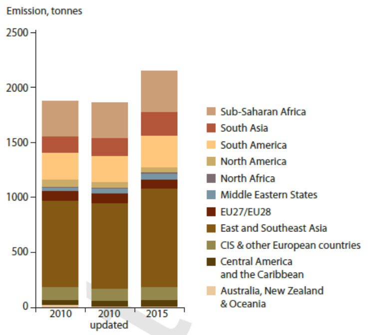
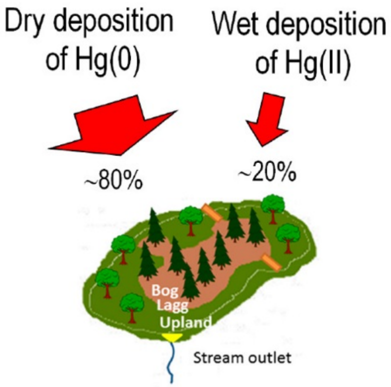
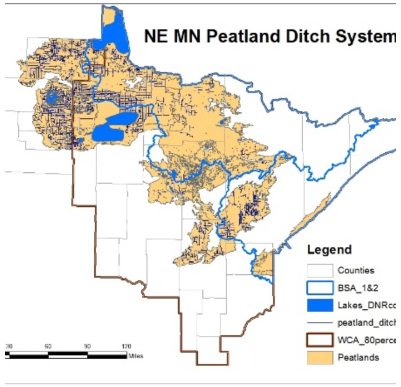


Figure 3.6 Regional breakdown of global emissions of Hg to air from

Minamata Convention & Global Mercury Assessment 2018

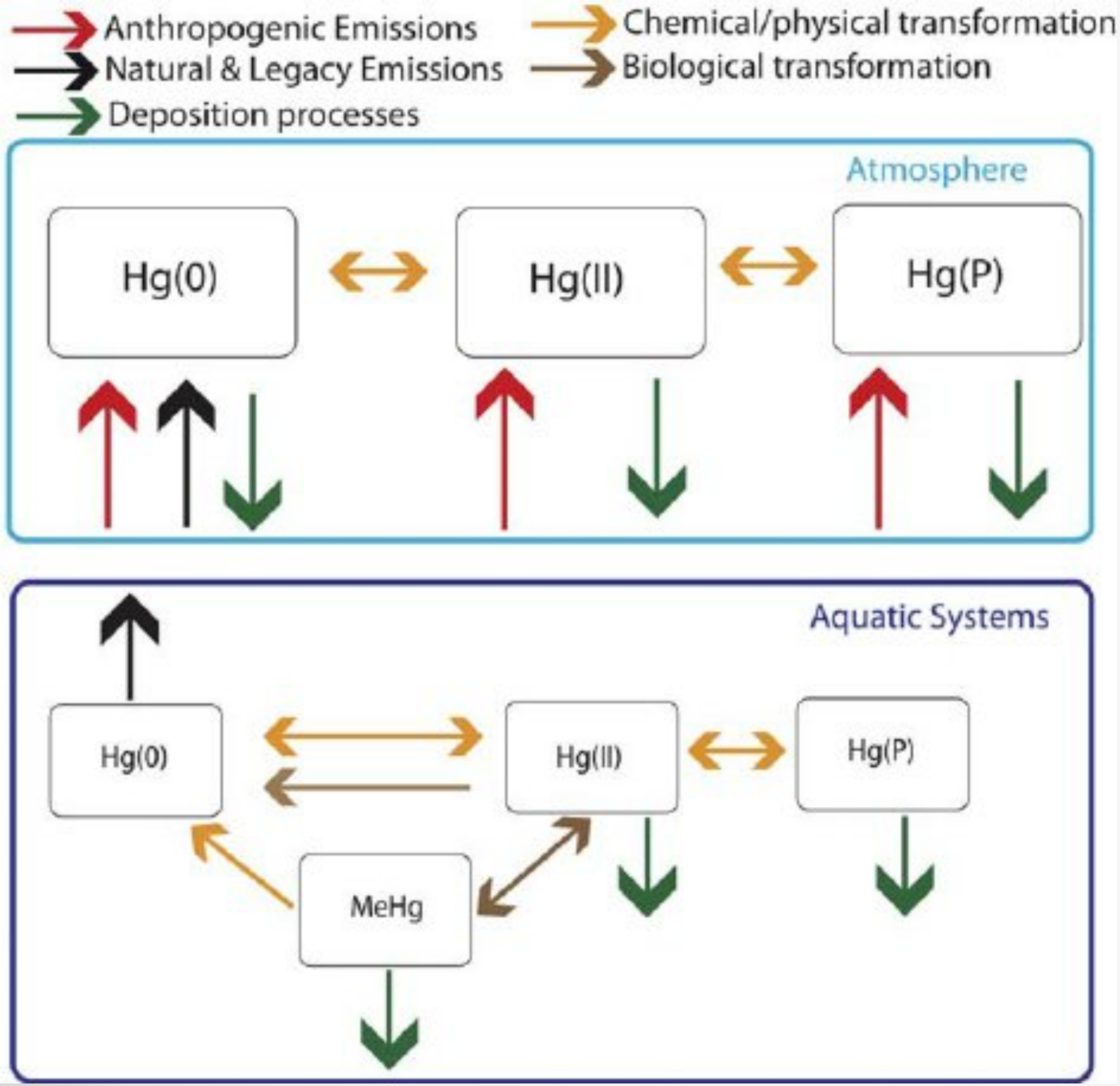


New Research Publications



New Project in Minnesota

Mercury Species



Hg(0): elemental

Hg(II): divalent / ionic / oxidized

Hg(P): particulate

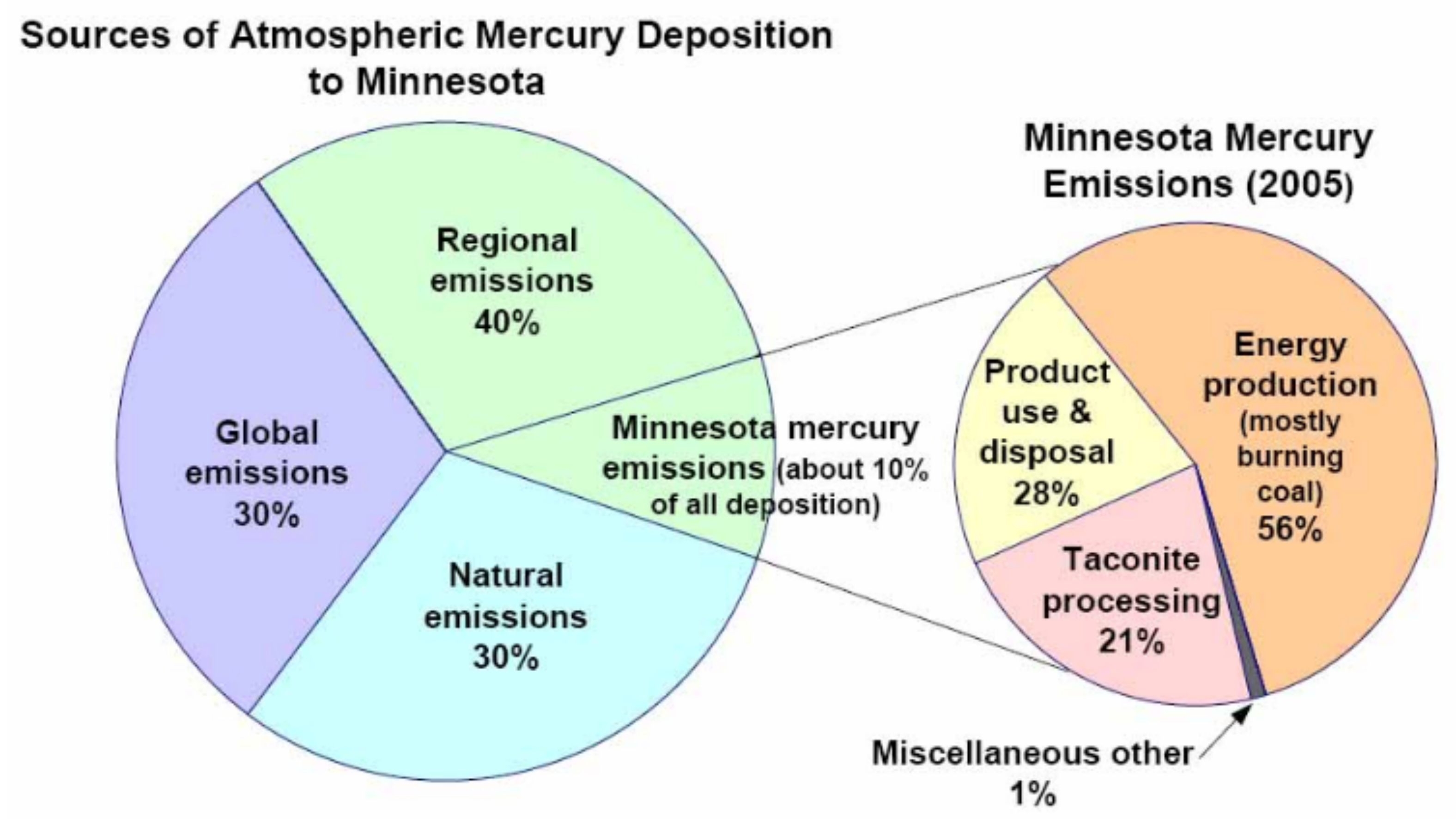
MeHg: methylmercury

Selin 2011 Science and strategies to reduce mercury risks: A critical review. J. Environmental Monitoring 13(9):2389-99

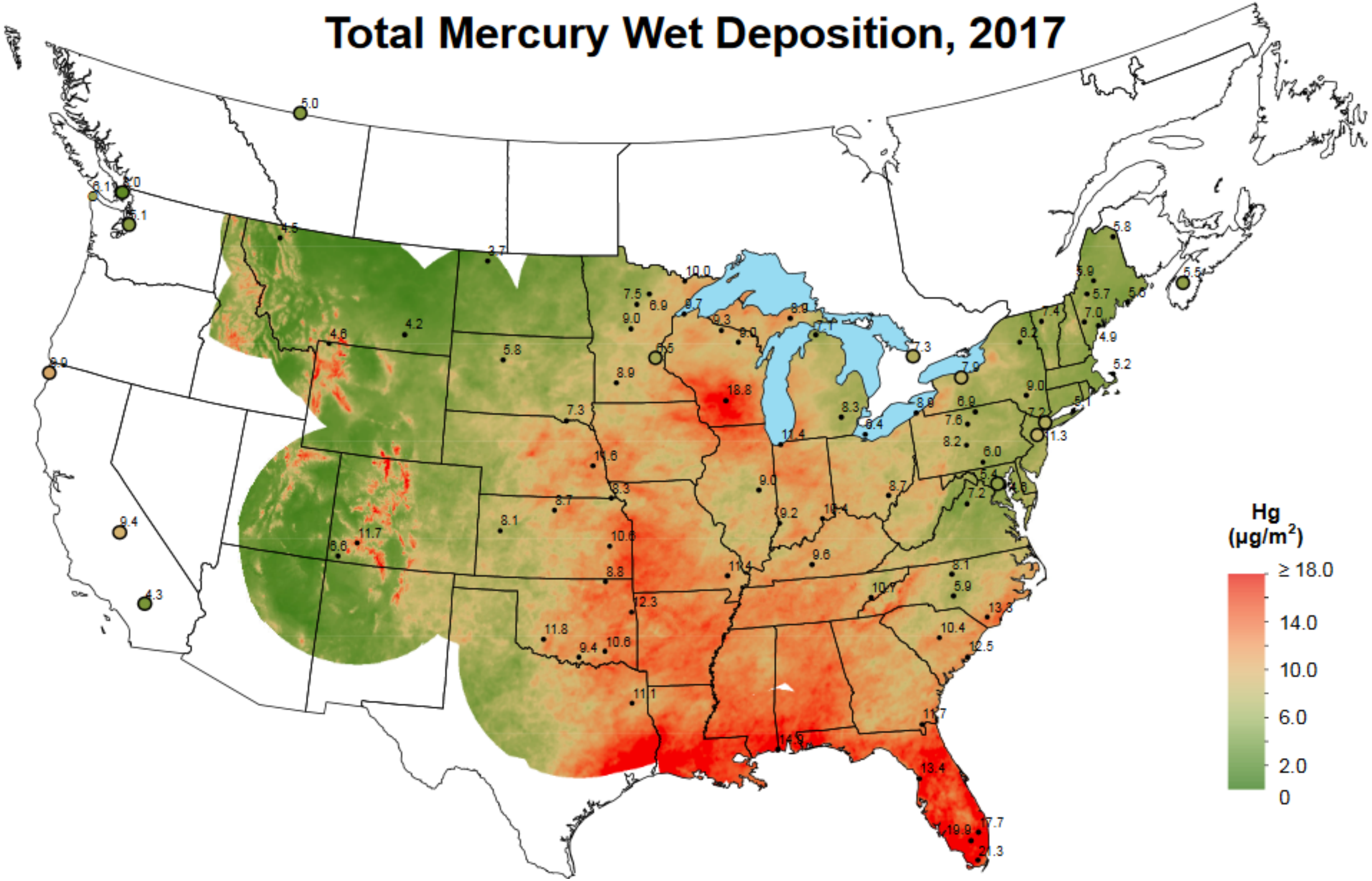
2009 Mercury TMDL Implementation Plan

Under "Other Recommended Actions":

Support for Regional, National and International Mercury-reduction Policies and Initiatives

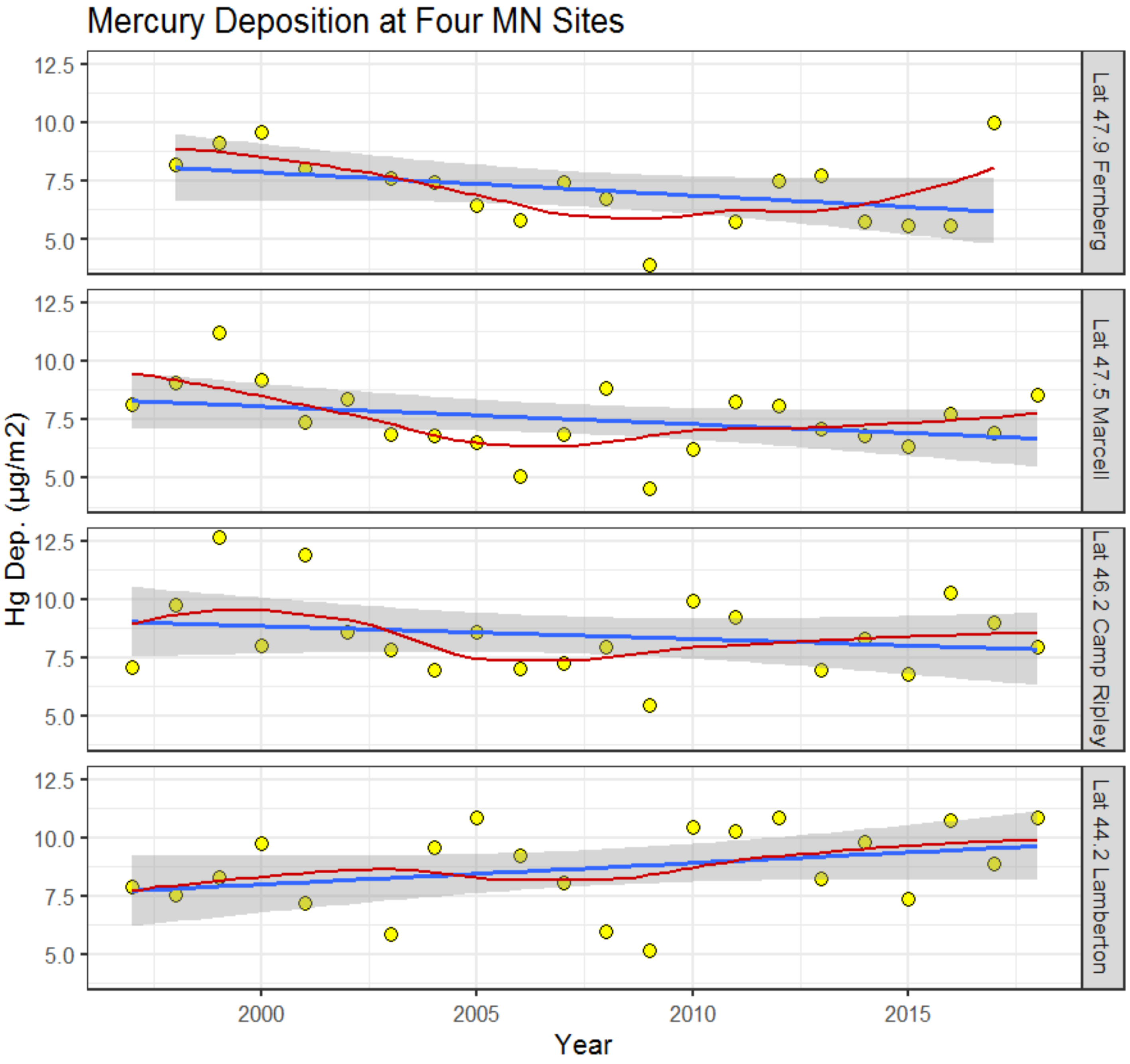


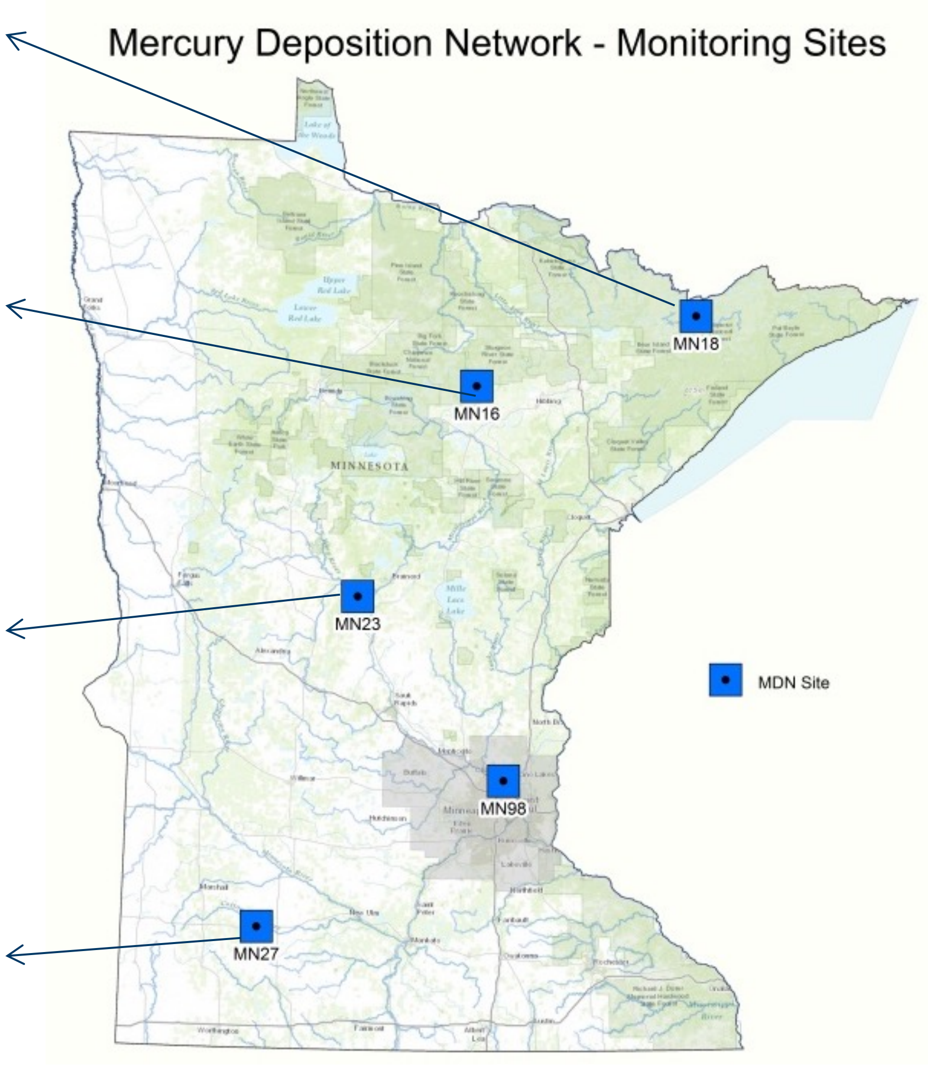
Total Mercury Wet Deposition, 2017



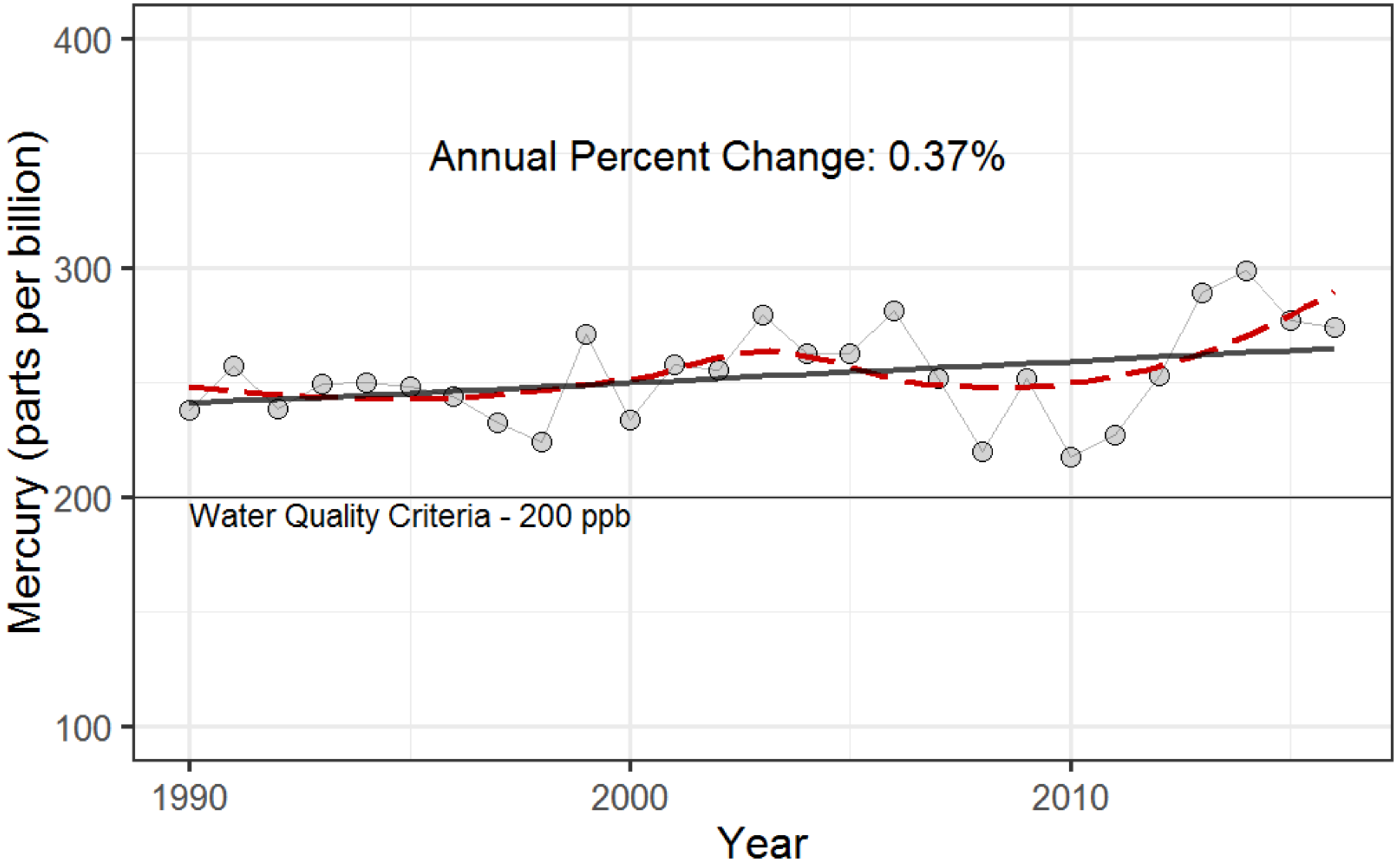
http://nadp.slh.wisc.edu/MDN/annualmdnmaps.aspx

Wet Deposition: 1997 – 2018
No significant trends ($p < 0.05$)





Mercury Trend in Northern Pike and Walleye



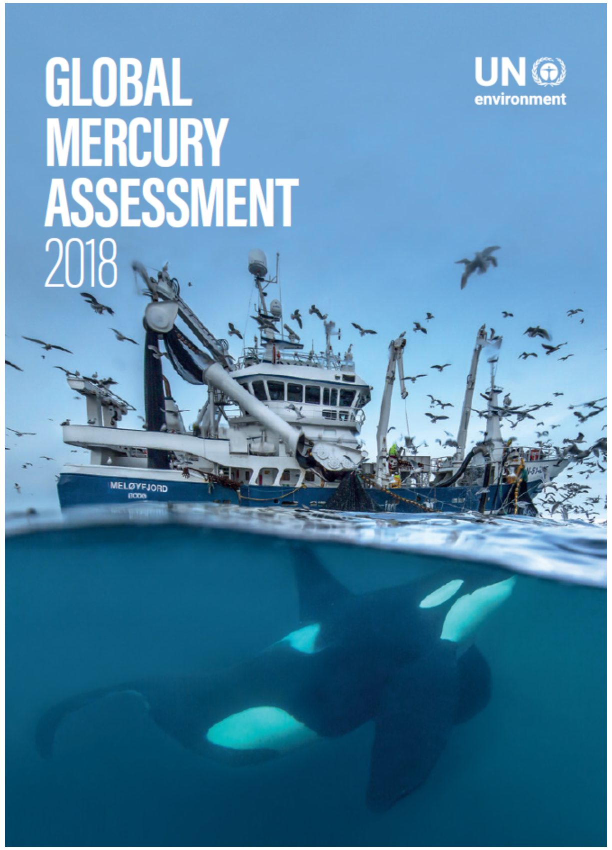
black trend line and red-dashed smooth curve

Minamata Convention on Mercury

- Adopted in 2013 and “entered in to force” August 2017
- 128 Countries; 113 ratifications (74 in 2017)
- Conference of the Parties (COP) 3rd meeting: November 2019
- COP3 Topics:
  - Guidance for inventories and contaminated sites
  - Effectiveness evaluations
  - Technical support and technology transfer
  - Review excluded products and manufacturing
  - Waste thresholds
- www.mercuryconvention.org

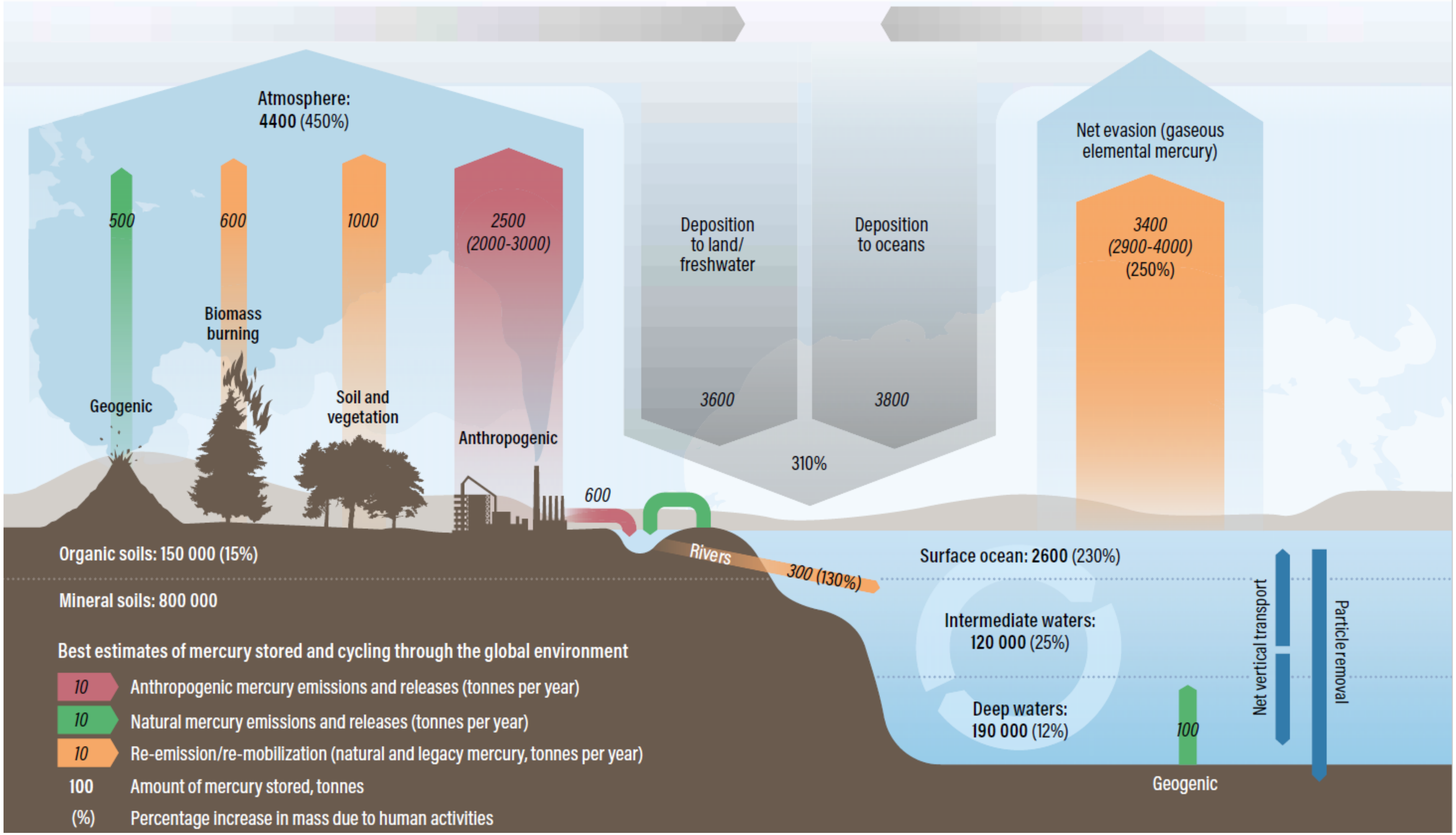
Global Mercury Assessment 2018

- Released March 2019
- Mercury emissions inventory for 2015
- Total global primary anthropogenic emissions: 2,200 tonnes (4.85 million pounds)
- New to inventory: biomass combustion for energy, secondary steel production, and emissions from vinyl chloride monomer production
- New chapters: mercury in biota and trends in humans
- GMA: 62 pages; Key Findings: 6 p; Technical Background Report: 430 p; Methodology Annex: 226 p.



(https://www.unenvironment.org/resources/publication/global-mercury-assessment-2018)

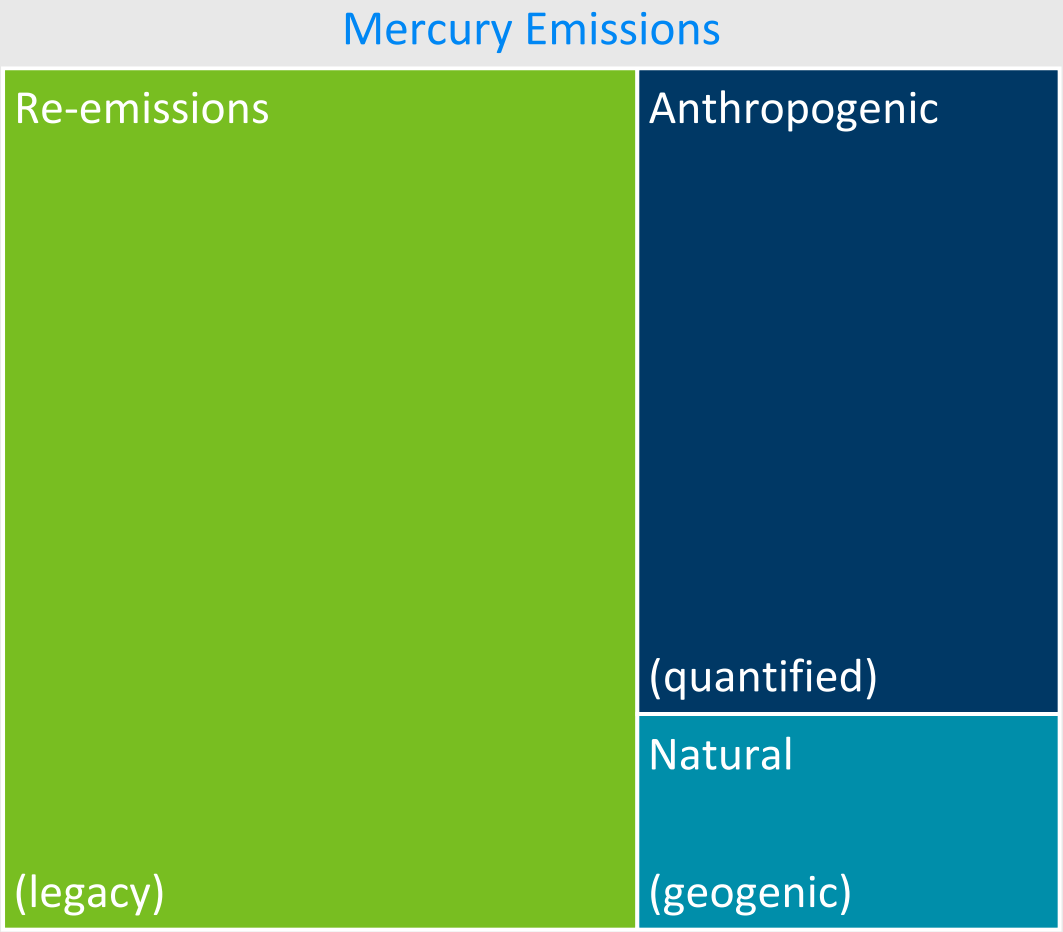
2015 Global Mercury Budget



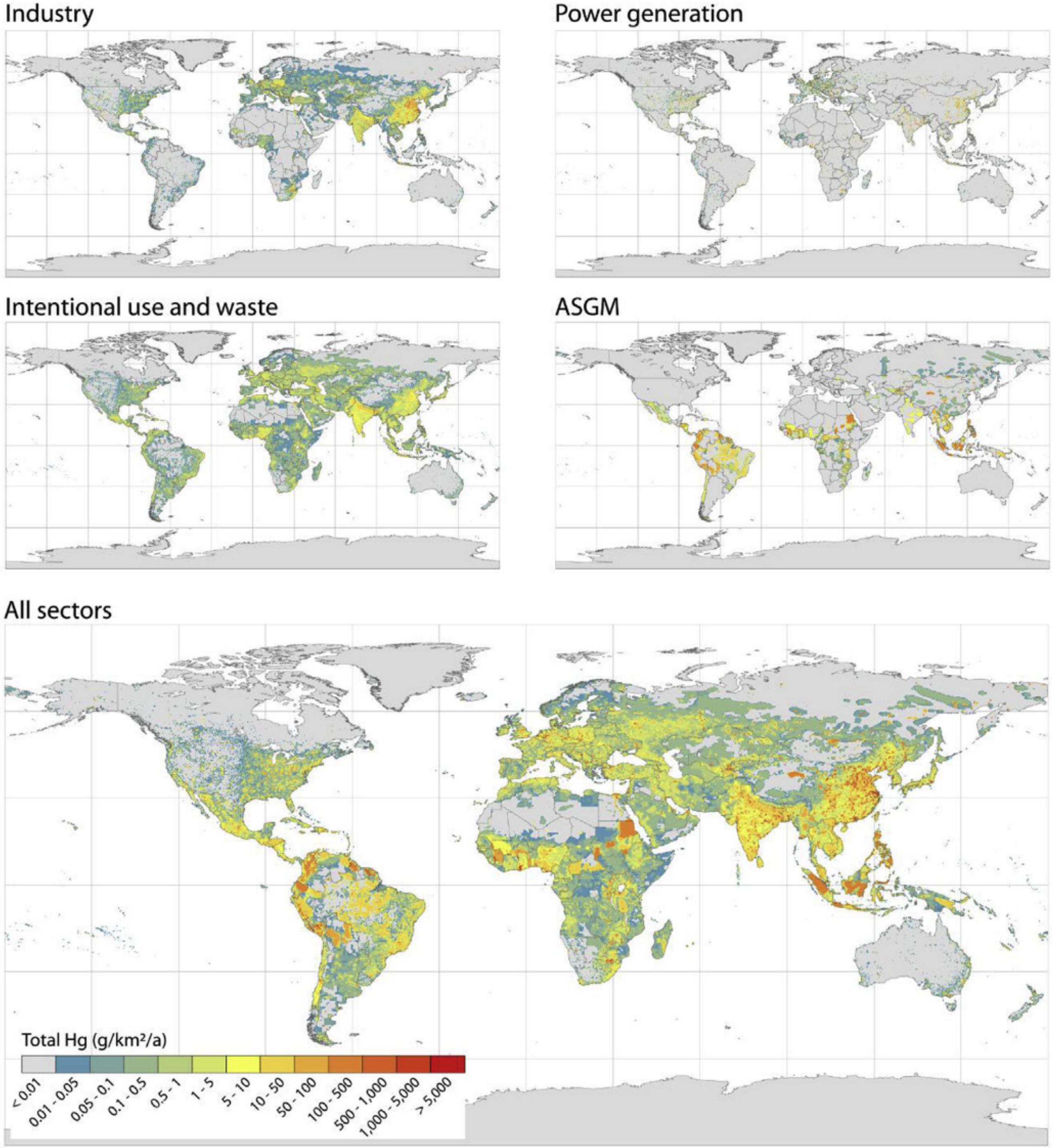
1 tonne = 1 Mg = 1000 kilograms = 2204.6 lb

Budget Summarized in GMA 2018

- Total Annual Hg Emissions
    - 30% anthropogenic
    - 60% re-emissions (gas evasion, biomass burning, soil & vegetation)
    - 10% natural sources (geogenic)
- Sectors not yet quantified may add 10 – 100s tonnes
- = 2,500 ± 500 t



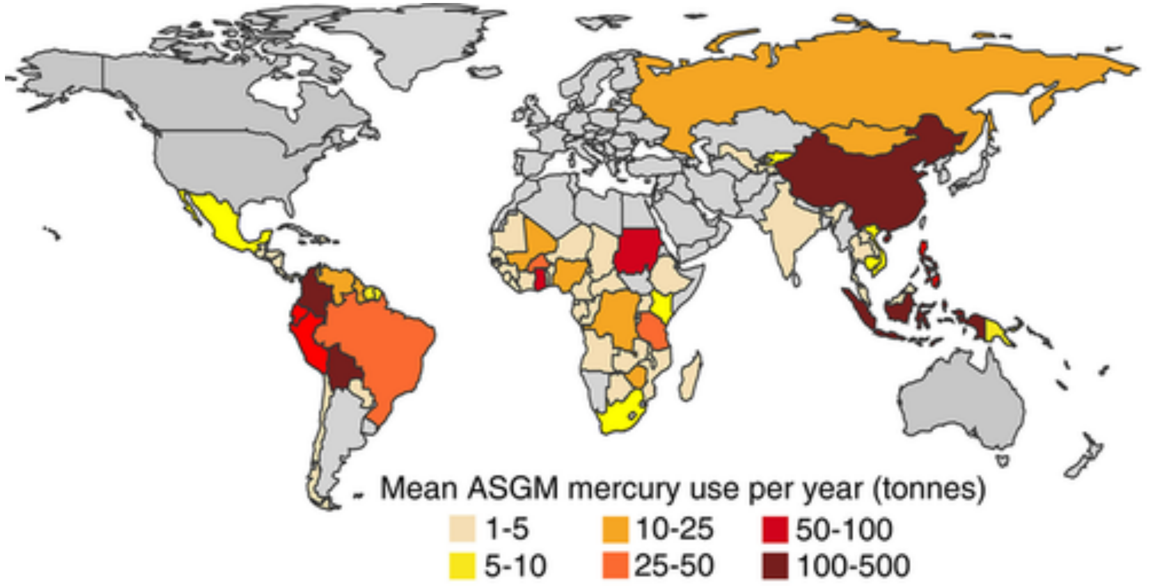
Global Anthropogenic Emission Distribution



Steenhuisen and Wilson 2019 Atmos Environ 211: 138-150

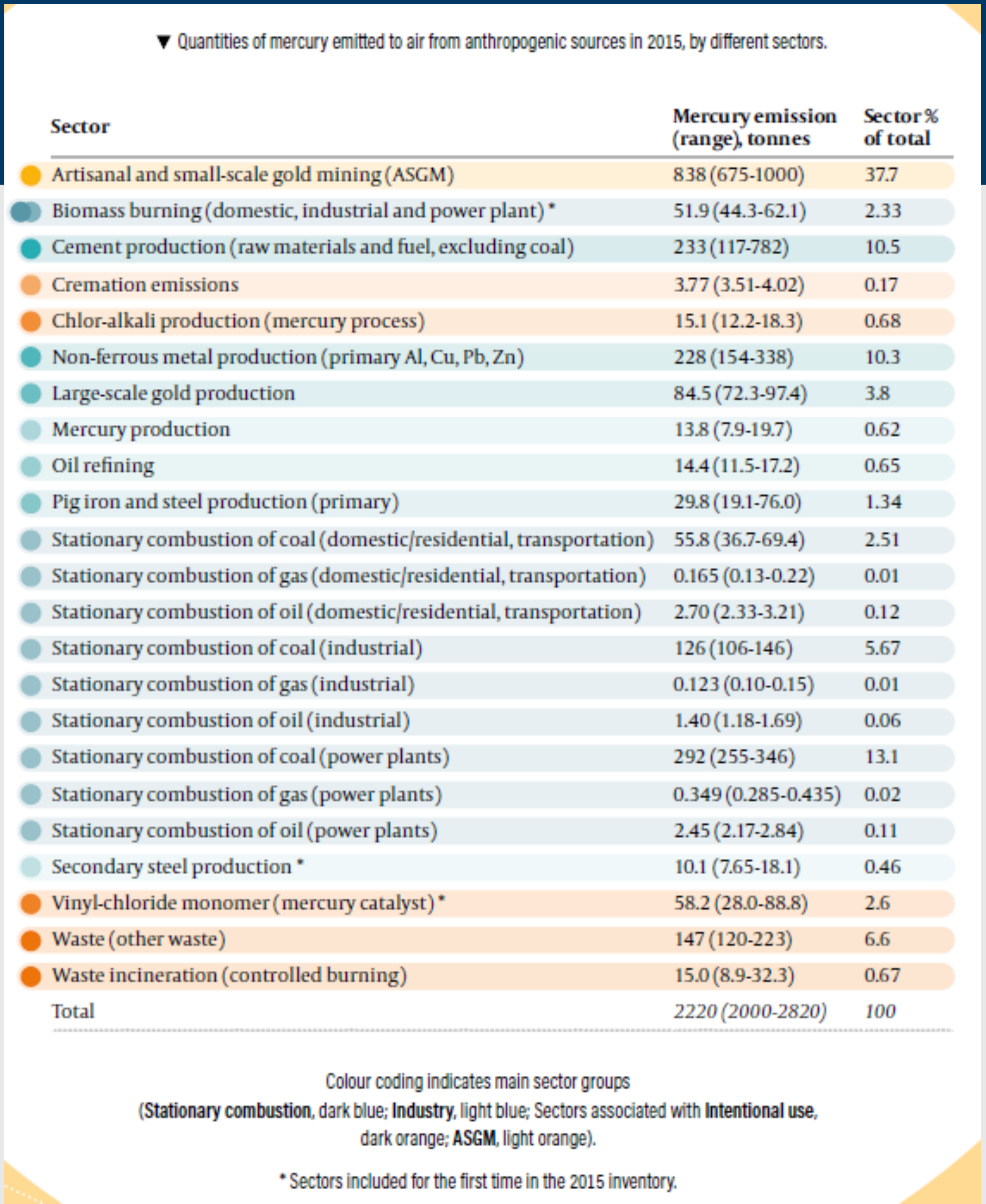
The Mercury Problem in Artisanal and Small-Scale Gold Mining (ASGM)

- Individual miners or small enterprises with limited capital investment and production
- 10-19 million people in 70 countries



Up to 1400 tonnes Hg emissions annually from >70 countries	15-25% of global gold production	37% of global mercury pollution	10-19 million miners including 4-5 million women & children

Chemistry – A European Journal, Volume: 24, Issue: 27, Pages: 6905-6916, First published: 03 January 2018, DOI: (10.1002/chem.201704840)

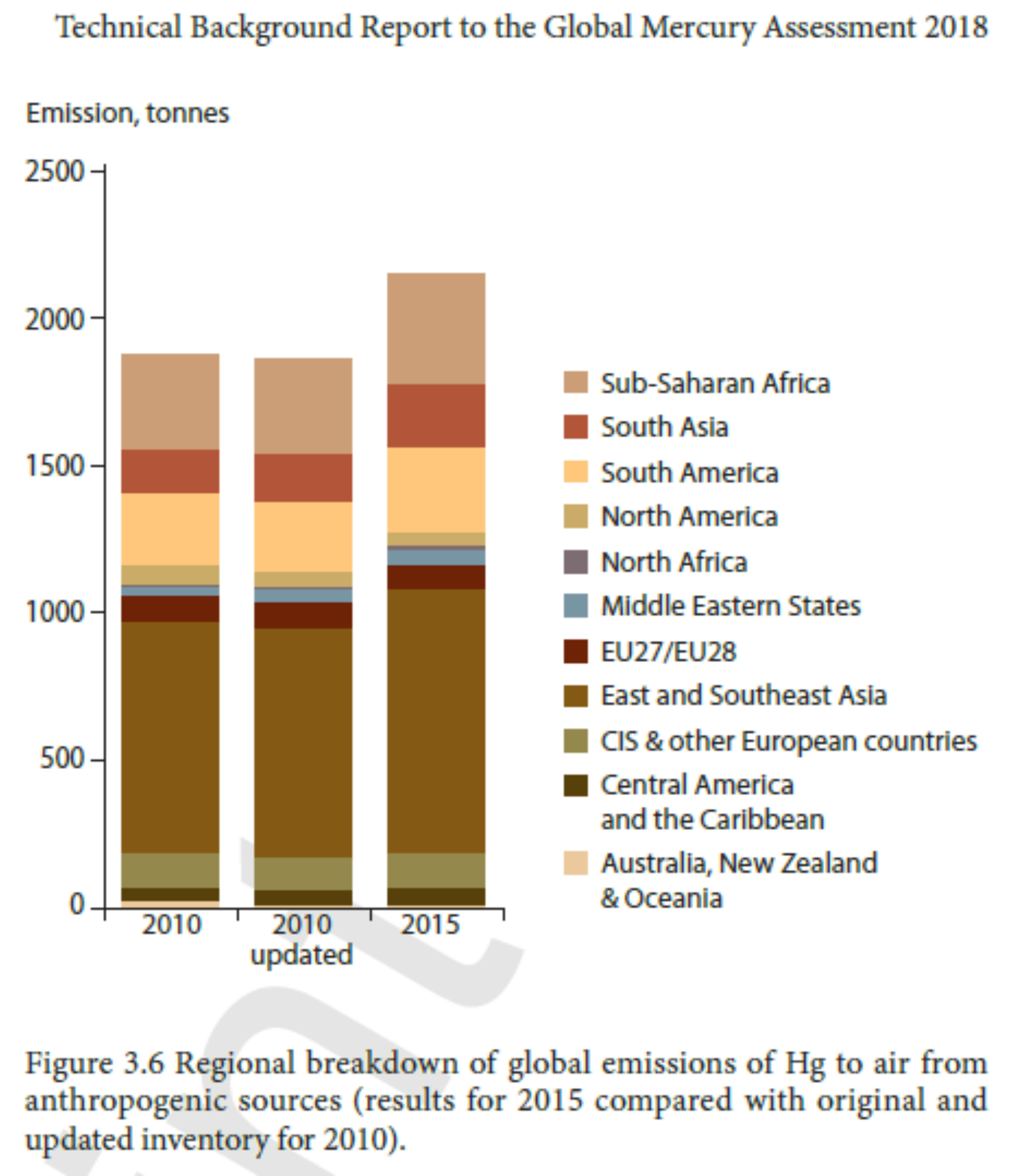


▼ Quantities of mercury emitted to air from anthropogenic sources in 2015, by different sectors.

Sector	Mercury emission (range), tonnes	Sector % of total
● Artisanal and small-scale gold mining (ASGM)	838 (675-1000)	37.7
●● Biomass burning (domestic, industrial and power plant) *	51.9 (44.3-62.1)	2.33
● Cement production (raw materials and fuel, excluding coal)	233 (117-782)	10.5
● Cremation emissions	3.77 (3.51-4.02)	0.17
● Chlor-alkali production (mercury process)	15.1 (12.2-18.3)	0.68
● Non-ferrous metal production (primary Al, Cu, Pb, Zn)	228 (154-338)	10.3
● Large-scale gold production	84.5 (72.3-97.4)	3.8
● Mercury production	13.8 (7.9-19.7)	0.62
● Oil refining	14.4 (11.5-17.2)	0.65
● Pig iron and steel production (primary)	29.8 (19.1-76.0)	1.34
● Stationary combustion of coal (domestic/residential, transportation)	55.8 (36.7-69.4)	2.51
● Stationary combustion of gas (domestic/residential, transportation)	0.165 (0.13-0.22)	0.01
● Stationary combustion of oil (domestic/residential, transportation)	2.70 (2.33-3.21)	0.12
● Stationary combustion of coal (industrial)	126 (106-146)	5.67
● Stationary combustion of gas (industrial)	0.123 (0.10-0.15)	0.01
● Stationary combustion of oil (industrial)	1.40 (1.18-1.69)	0.06
● Stationary combustion of coal (power plants)	292 (255-346)	13.1
● Stationary combustion of gas (power plants)	0.349 (0.285-0.435)	0.02
● Stationary combustion of oil (power plants)	2.45 (2.17-2.84)	0.11
● Secondary steel production *	10.1 (7.65-18.1)	0.46
● Vinyl-chloride monomer (mercury catalyst) *	58.2 (28.0-88.8)	2.6
● Waste (other waste)	147 (120-223)	6.6
● Waste incineration (controlled burning)	15.0 (8.9-32.3)	0.67
Total	*2220 (2000-2820)*	*100*

Colour coding indicates main sector groups
(**Stationary combustion**, dark blue; **Industry**, light blue; Sectors associated with **Intentional use**, dark orange; **ASGM**, light orange).

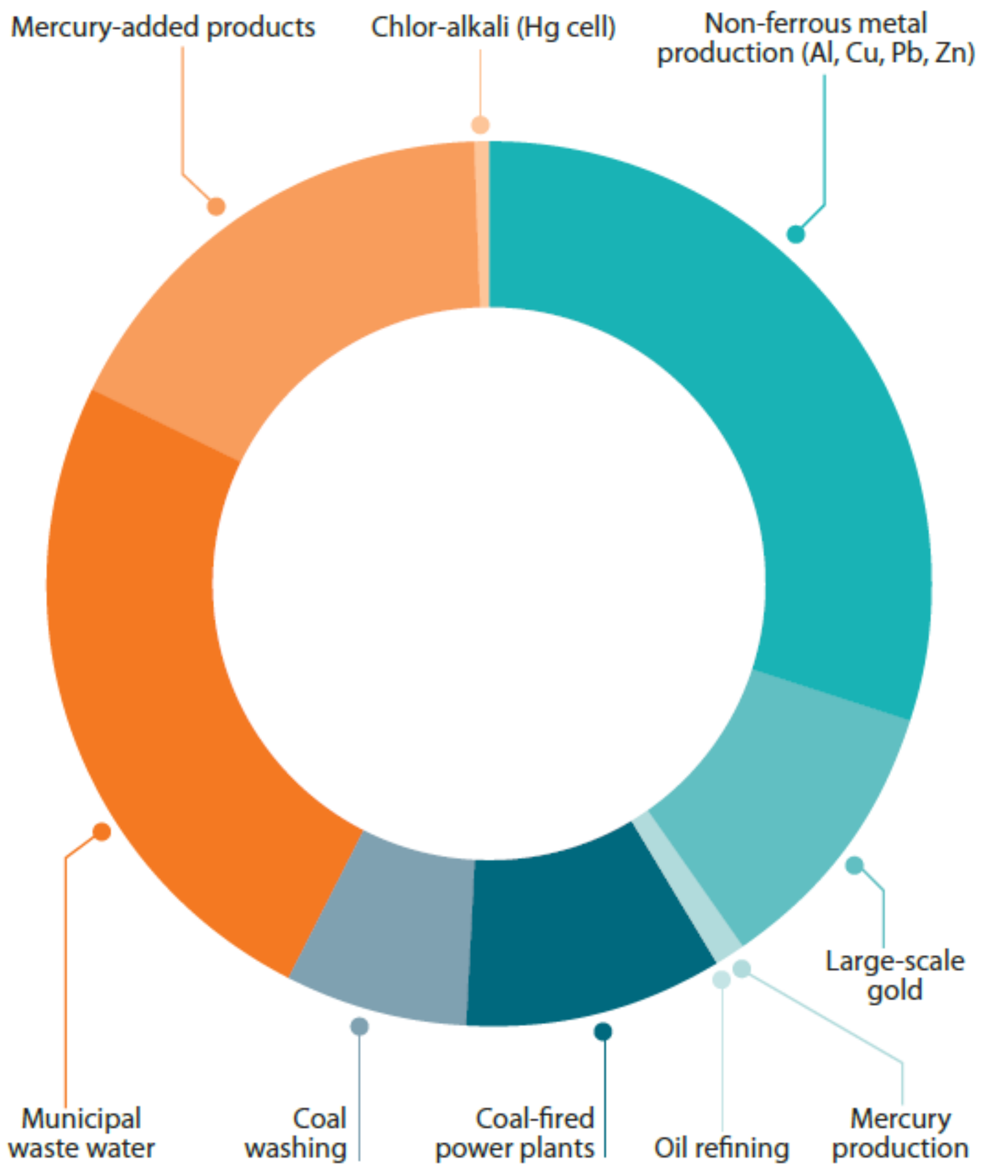
* Sectors included for the first time in the 2015 inventory.



Technical Background Report to the Global Mercury Assessment 2018

Figure 3.6 Regional breakdown of global emissions of Hg to air from anthropogenic sources (results for 2015 compared with original and updated inventory for 2010).

2015 Global Mercury Releases to Water, excluding ASGM



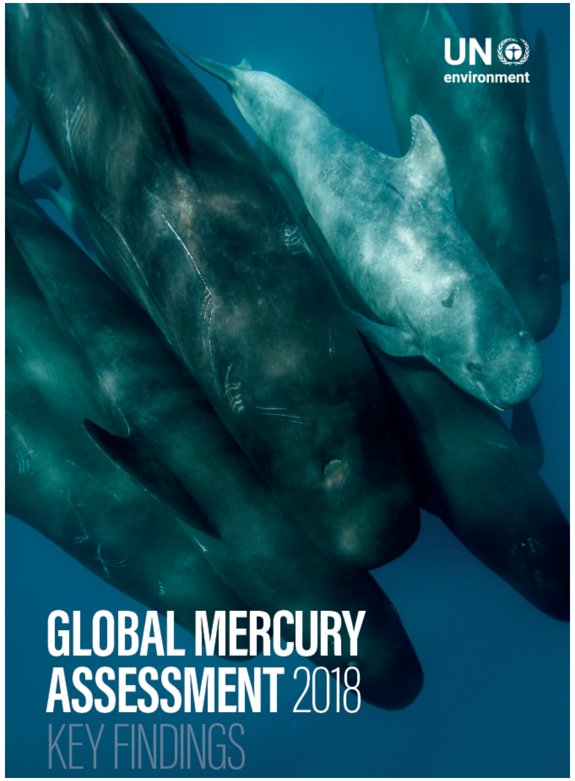
Wastewater Treatment: 42%

Ore mining & processing: 41%

Energy sectors: 16%

Global Mercury Assessment 2018: Key Findings

1. Global Hg emission inventory for **2015** from 17 sectors: ~ **2,200 tonnes**
2. ~ **20% higher than in 2010**
3. Pattern similar to 2010 - 49% from Asia, 18% from South America, and 16% from Africa
4. Burning fossil fuels and biomass ~ 24% of global emissions, primarily coal (21%)
5. Human activities have increased total atmospheric Hg **concentrations** by ~450% above natural levels
6. Gold mining (ASGM*) ~ 1,220 tonnes of Hg into terrestrial and freshwater environments in 2015
7. Natural production of methylmercury is no longer limited by input of inorganic mercury
8. Reductions in Hg emissions and resulting declines in atmospheric concentrations may take time to show up as reductions of mercury concentrations in biota
9. Mercury loads in some aquatic food webs are at levels of concern for ecological and human health
10. All people are exposed to some amount of mercury



*ASGM: artisanal and small-scale gold mining

Mercury Emissions in China

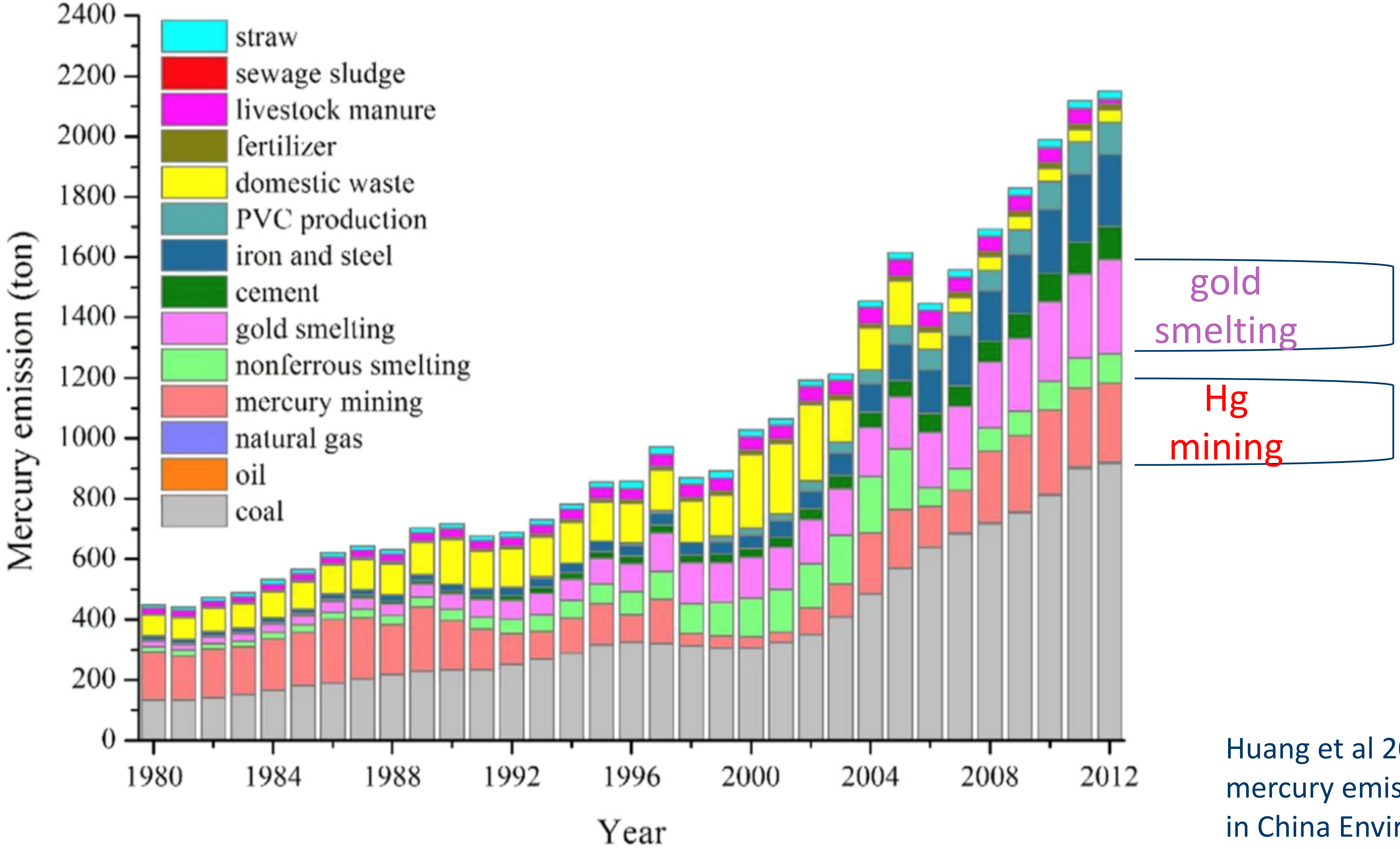
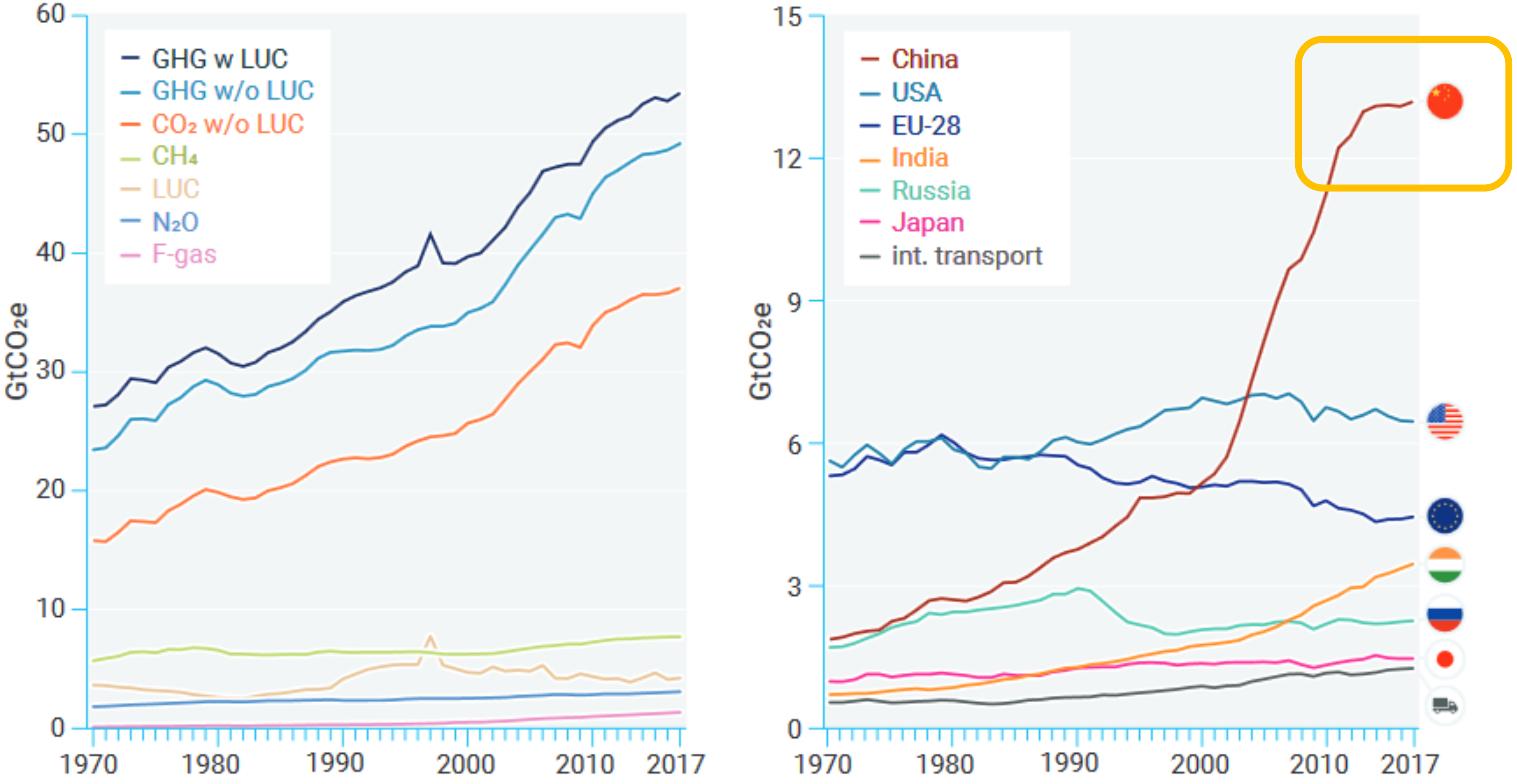


Fig. 1. National mercury emission from anthropogenic sources to the environment in China from 1980 to 2012.

Huang et al 2017 Anthropogenic mercury emissions from 1980 to 2012 in China Environ. Pollution 226

Hg & GHG connected by emissions

Figure 2.3: Global greenhouse gas emissions per type of gas (left) and top greenhouse gas emitters excluding land-use change emissions due to lack of reliable data (right).



Source: EDGAR v5.0/v4.3.2 FT2017 CO_2 (Olivier *et al.*, 2018) and Global Carbon Project (Le Quéré *et al.*, 2018).

http://www.unenvironment.org/emissionsgap
UNEP Emissions Gap Report 2018

Observed decrease in atmospheric mercury explained by global decline in anthropogenic emissions

Yanxu Zhang[a,1], Daniel J. Jacob[a,b], Hannah M. Horowitz[a], Long Chen[a,c], Helen M. Amos[a], David P. Krabbenhoft[d], Franz Slemr[e], Vincent L. St. Louis[f], and Elsie M. Sunderland[a,g]

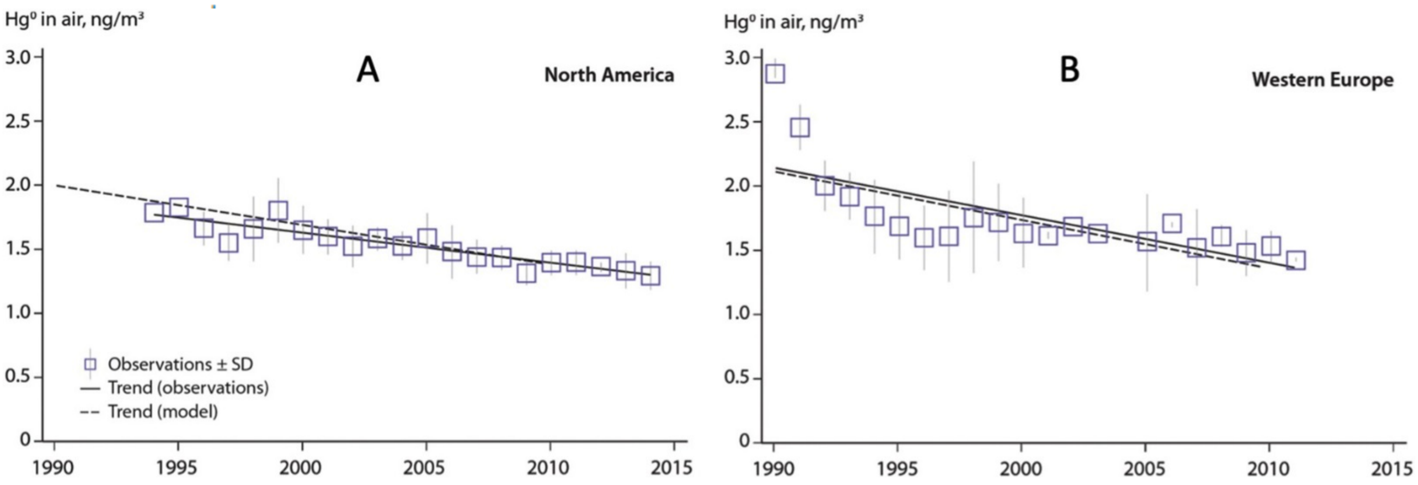
526–531 | PNAS | January 19, 2016 | vol. 113 | no. 3

Elemental Hg decreased 30% from 1990 to 2010

Global emission inventories have “three major flaws”:

1. Didn’t account for decrease from commercial products
2. Estimate for ASGM emissions too high
3. Didn’t properly account for change in Hg speciation of emissions from coal-fired PP after SO2 and NOX controls

Revised global emissions inventory: 20% decrease in total Hg and 30% decrease in Hg^0



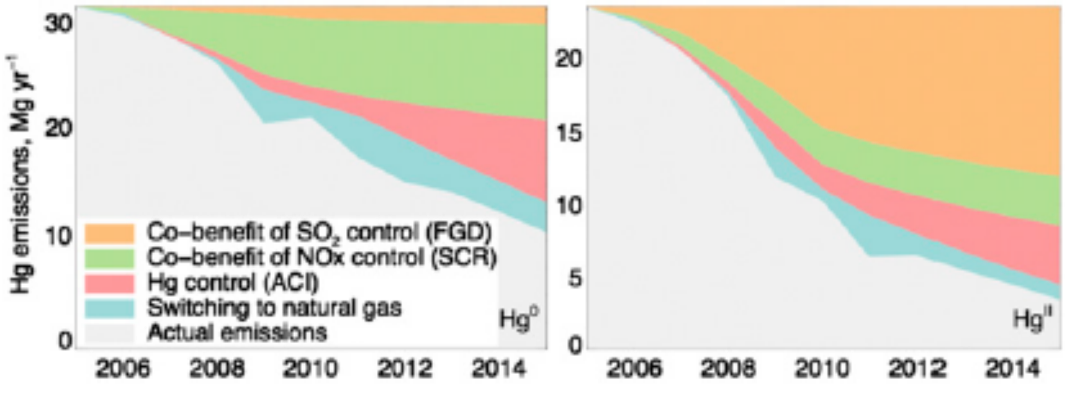
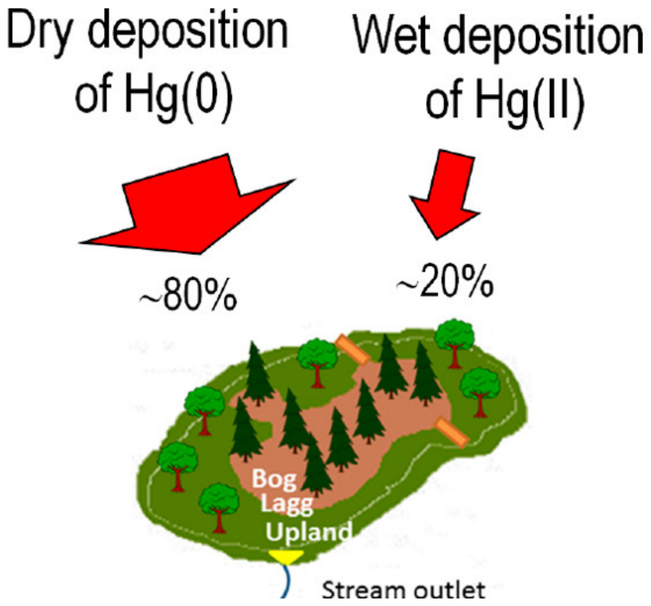
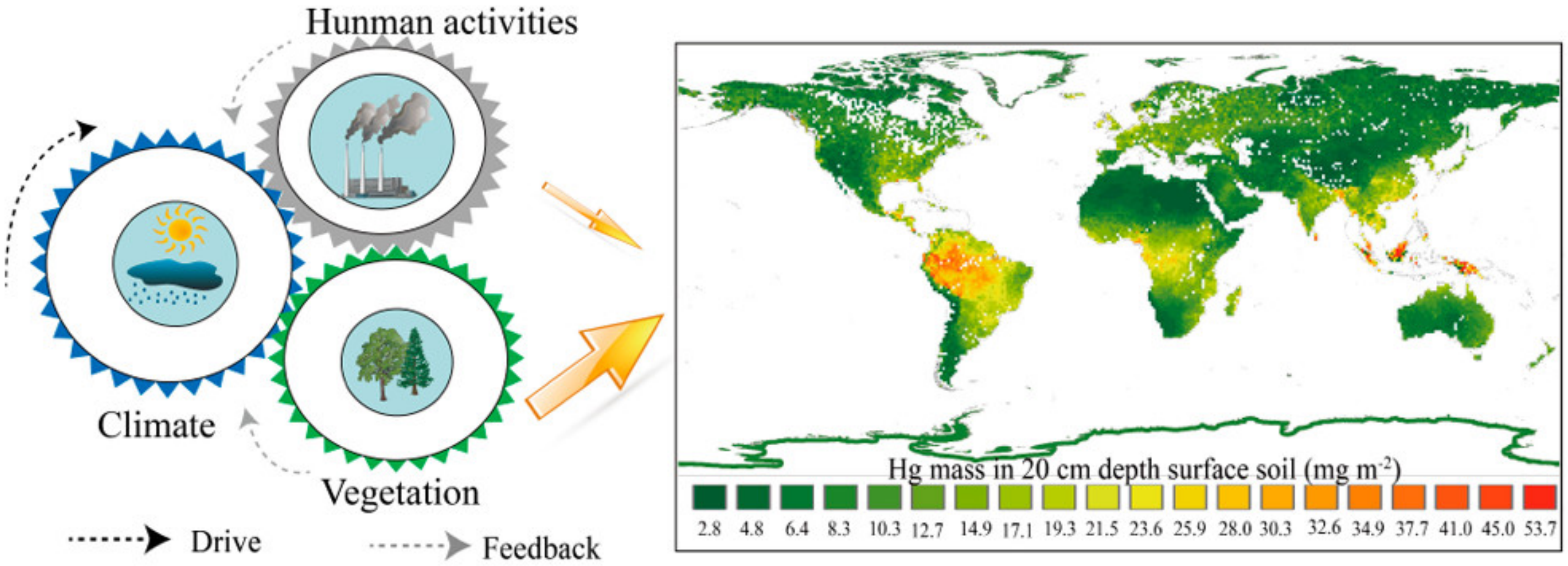


Fig. 1. Major factors driving declines in Hg emission from US coal-fired utilities between 2005 and 2015. Trends were inferred from data on the implementation of different types of emission control technologies.

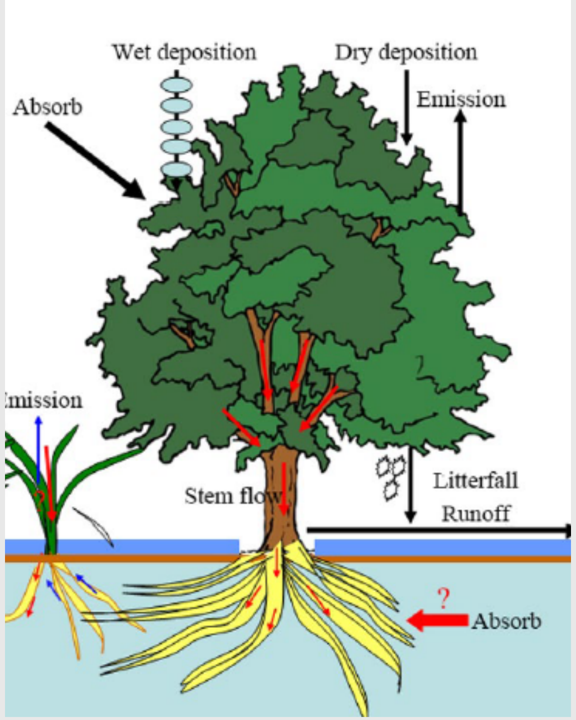
Dry deposition of elemental Hg dominates on vegetated landscapes

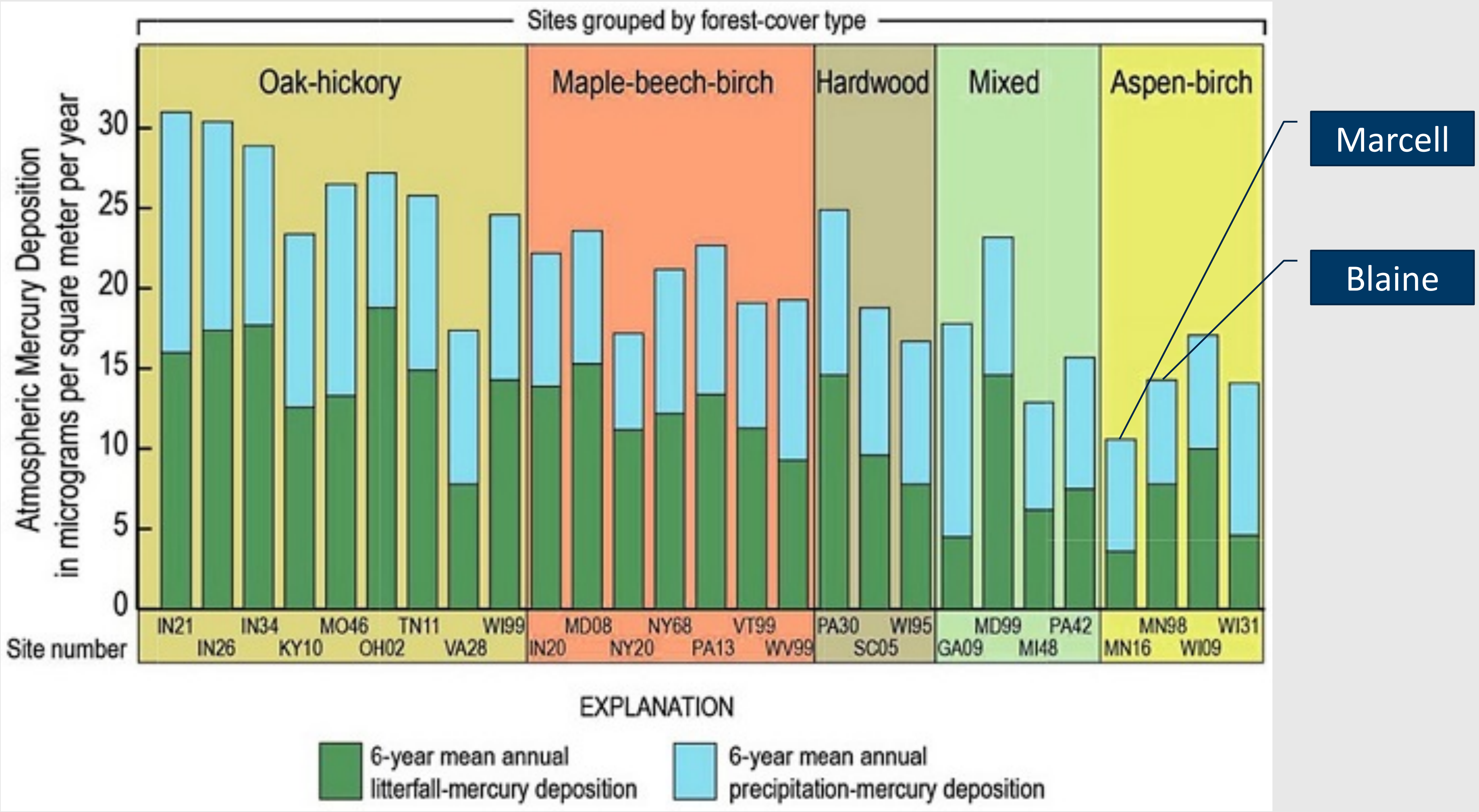
- Zheng et al. 2016. GBC 30, 1475-1492 (U.S. Forests)
- Jiskra et al. 2017. ESPI 19, 1235-1248 (Sweden)
- Obrist et al. 2017. Nature 547, 201-204 (Arctic)
- Woerndle et al. 2018. EST 52 1854-1861 (MN)
- Wang et al. 2019 EST 53, 10665-10675 (Global)





Tree leaves absorb elemental Hg from air





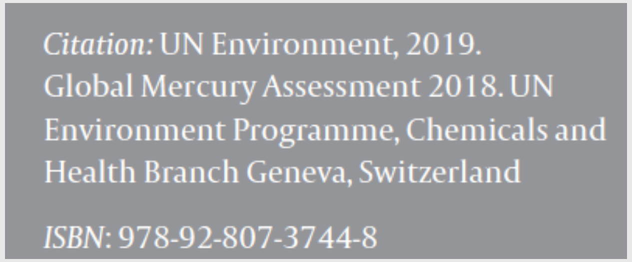
Marcell

Blaine

Ma et al. 2019. BECT 102, 650-656
Risch et al. 2017. Env Polltn 228, 8-18

GMA 2018 Policy-Relevant Findings: Climate Change

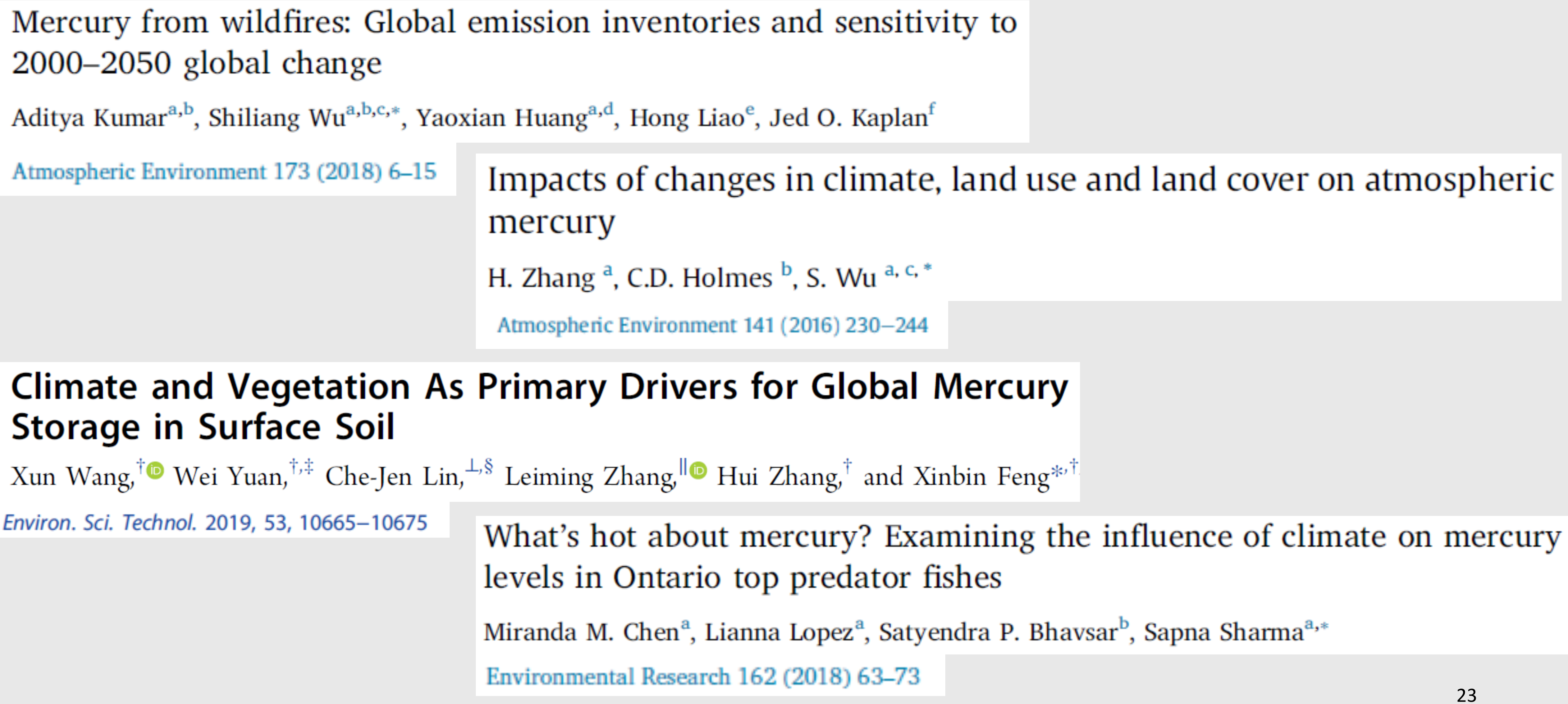
> “Climate change and changes in terrestrial and aquatic ecosystem processes are playing increasingly important roles in the mercury cycle, affecting the distribution, chemical interactions and biological uptake of Hg in the environment.”



Citation: UN Environment, 2019.
Global Mercury Assessment 2018. UN Environment Programme, Chemicals and Health Branch Geneva, Switzerland

ISBN: 978-92-807-3744-8

Big increase in publications on Hg and Climate Change



Mercury from wildfires: Global emission inventories and sensitivity to 2000–2050 global change

Aditya Kumar[a,b], Shiliang Wu[a,b,c,*], Yaoxian Huang[a,d], Hong Liao[e], Jed O. Kaplan[f]

Atmospheric Environment 173 (2018) 6–15

Impacts of changes in climate, land use and land cover on atmospheric mercury

H. Zhang [a], C.D. Holmes [b], S. Wu [a, c, *]

Atmospheric Environment 141 (2016) 230–244

Climate and Vegetation As Primary Drivers for Global Mercury Storage in Surface Soil

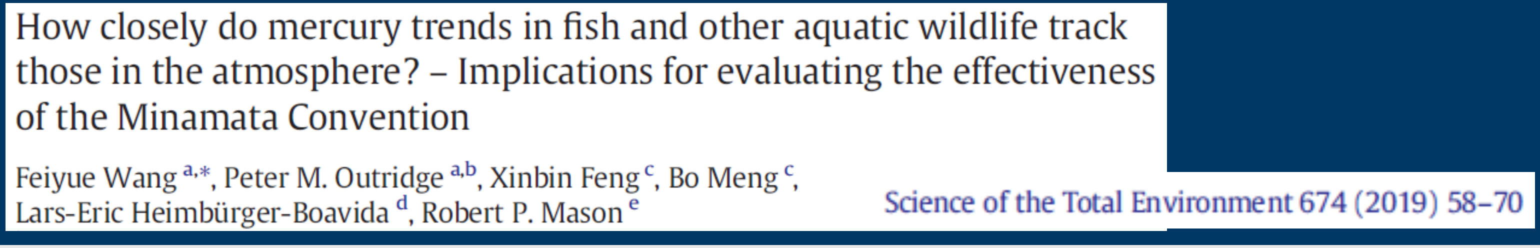
Xun Wang,[†] Wei Yuan,[†,‡] Che-Jen Lin,[⊥,§] Leiming Zhang,[∥] Hui Zhang,[†] and Xinbin Feng[*,†]

Environ. Sci. Technol. 2019, 53, 10665−10675

What's hot about mercury? Examining the influence of climate on mercury levels in Ontario top predator fishes

Miranda M. Chen[a], Lianna Lopez[a], Satyendra P. Bhavsar[b], Sapna Sharma[a,*]

Environmental Research 162 (2018) 63–73

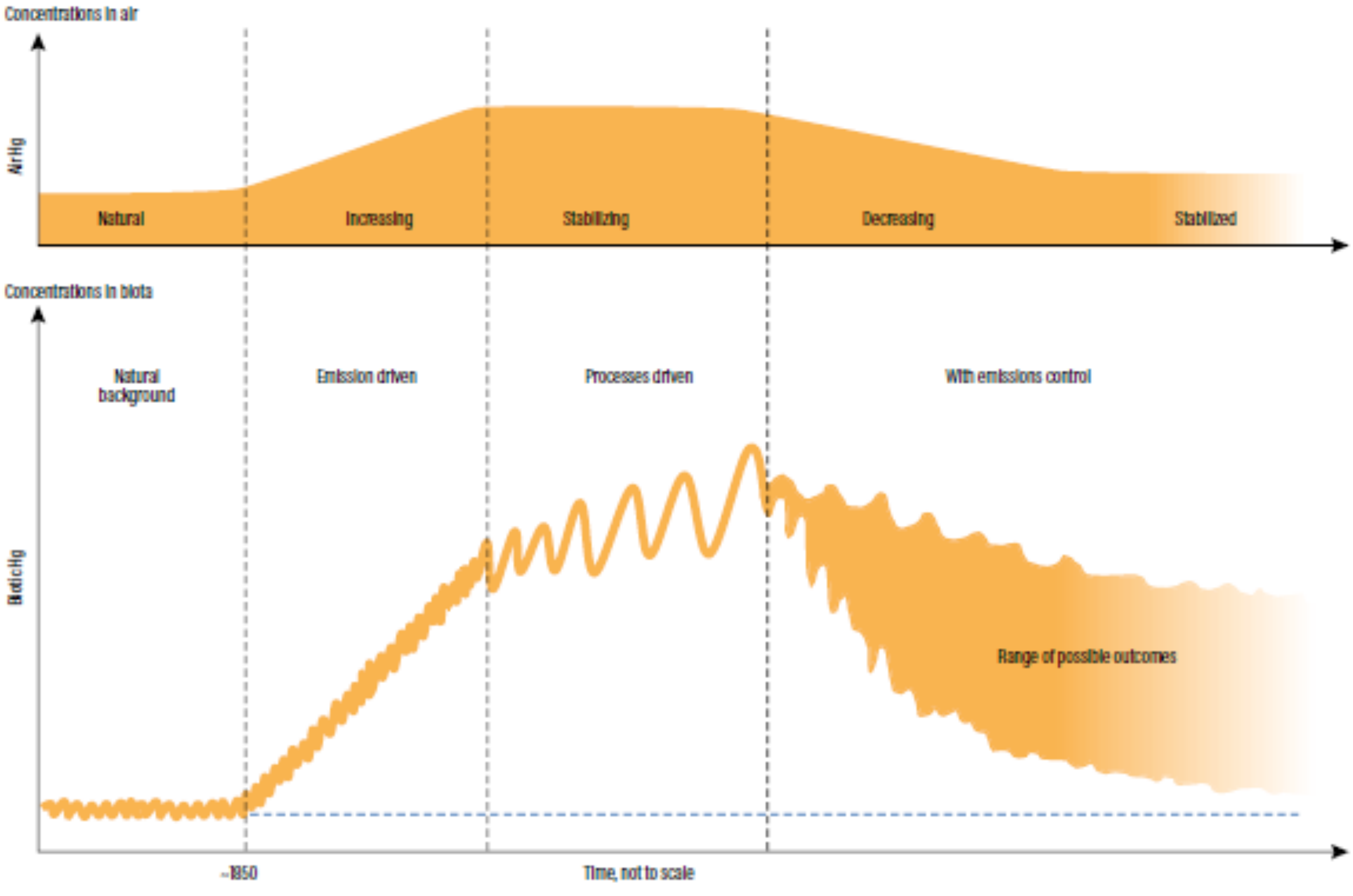


How closely do mercury trends in fish and other aquatic wildlife track those in the atmosphere? – Implications for evaluating the effectiveness of the Minamata Convention

Feiyue Wang [a,*], Peter M. Outridge [a,b], Xinbin Feng [c], Bo Meng [c], Lars-Eric Heimbürger-Boavida [d], Robert P. Mason [e]

Science of the Total Environment 674 (2019) 58–70

The Big Picture



▲ A schematic representation of the response of mercury concentrations in biota to changes in mercury concentrations in air, as the limiting factors in bioaccumulation change.

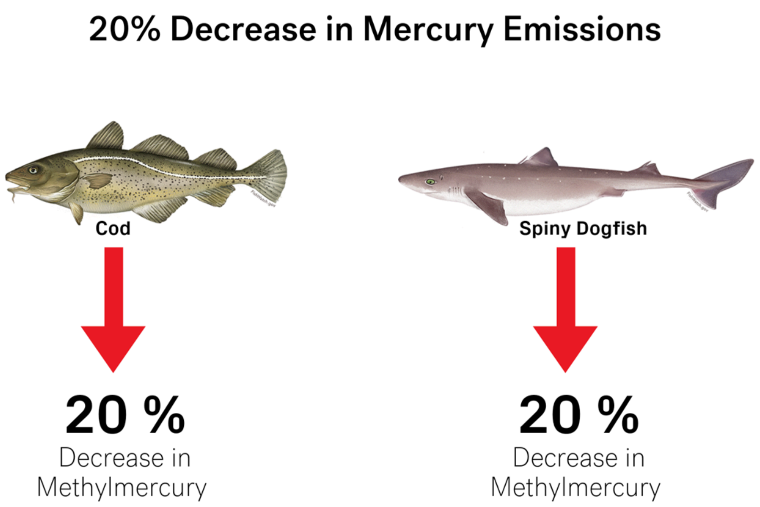
- Divergence between Hg in emissions and fish is due to legacy Hg and changing biogeochemical processes
- Globally climate change has become the most prevalent contributor to the divergence

Climate change and overfishing increase neurotoxicant in marine predators

Amina T. Schartup[1,2]*, Colin P. Thackray[1], Asif Qureshi[3], Clifton Dassuncao[1,2], Kyle Gillespie[4], Alex Hanke[4] & Elsie M. Sunderland[1,2]*

Climate Change Effects

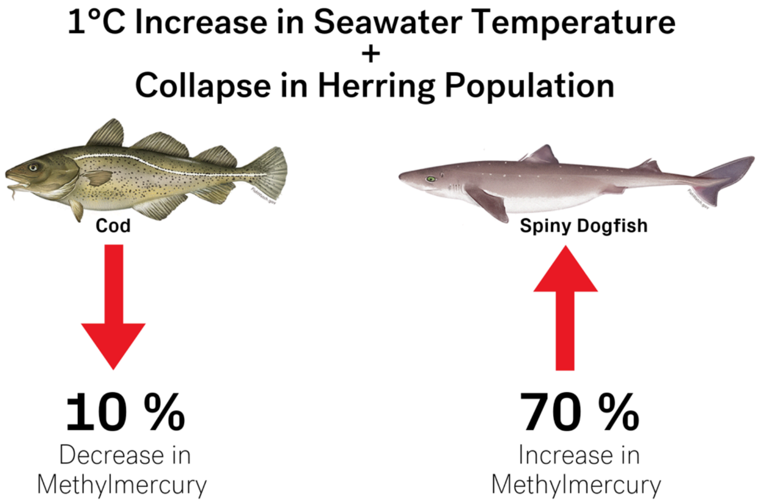
Schartup et al. 2019. Climate change and overfishing increase neurotoxicant in marine predators. NATURE 29 August 2019.



20% Decrease in Mercury Emissions

20 % Decrease in Methylmercury (Cod)

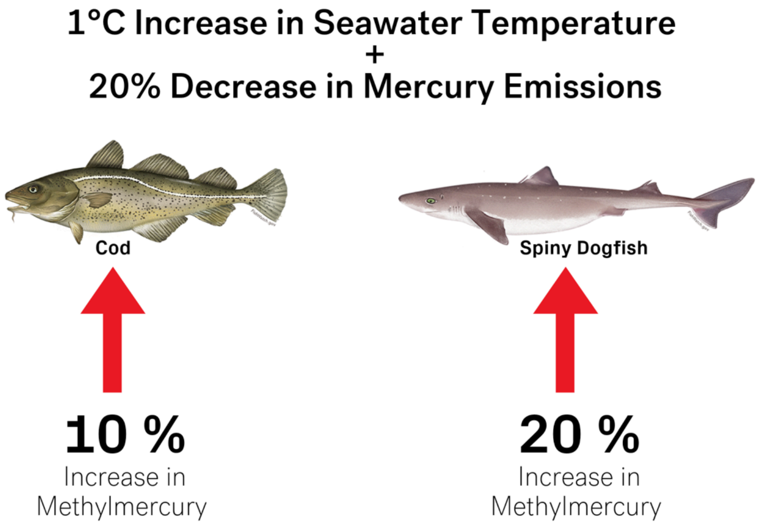
20 % Decrease in Methylmercury (Spiny Dogfish)



1°C Increase in Seawater Temperature + Collapse in Herring Population

10 % Decrease in Methylmercury

70 % Increase in Methylmercury

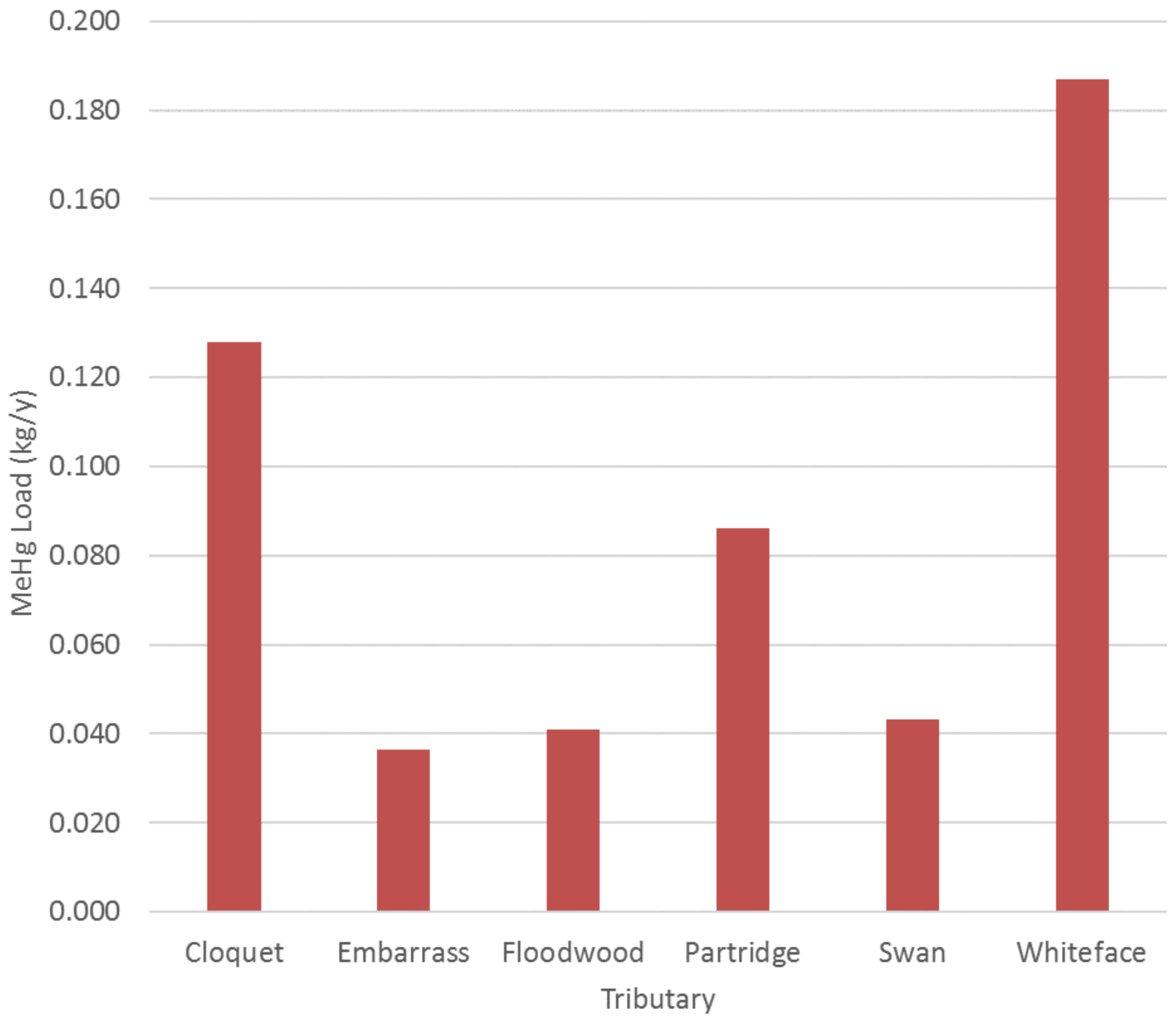


1°C Increase in Seawater Temperature + 20% Decrease in Mercury Emissions

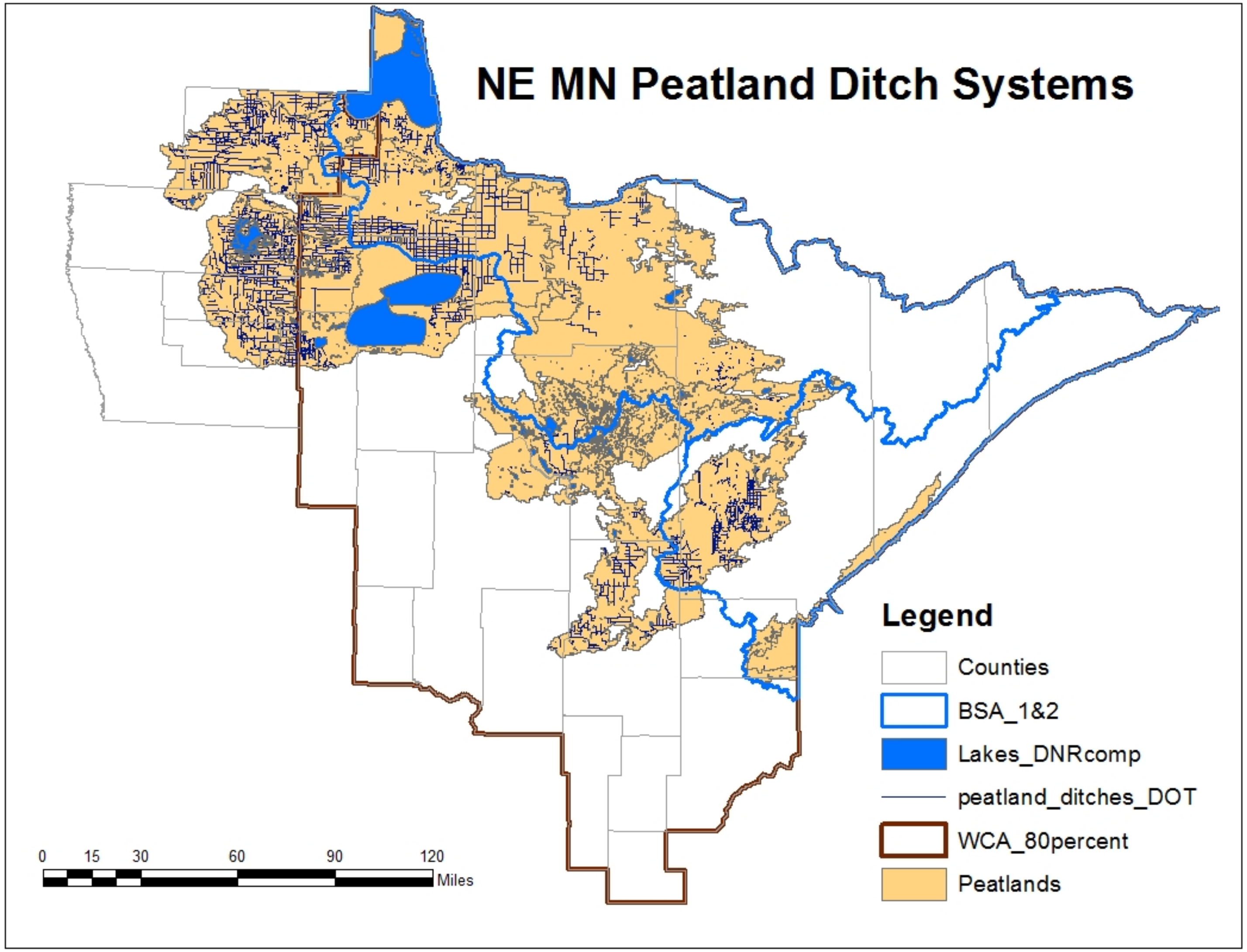
10 % Increase in Methylmercury

20 % Increase in Methylmercury

Methylmercury Load to St. Louis River



Results from MPCA Mercury Loading Study 2013



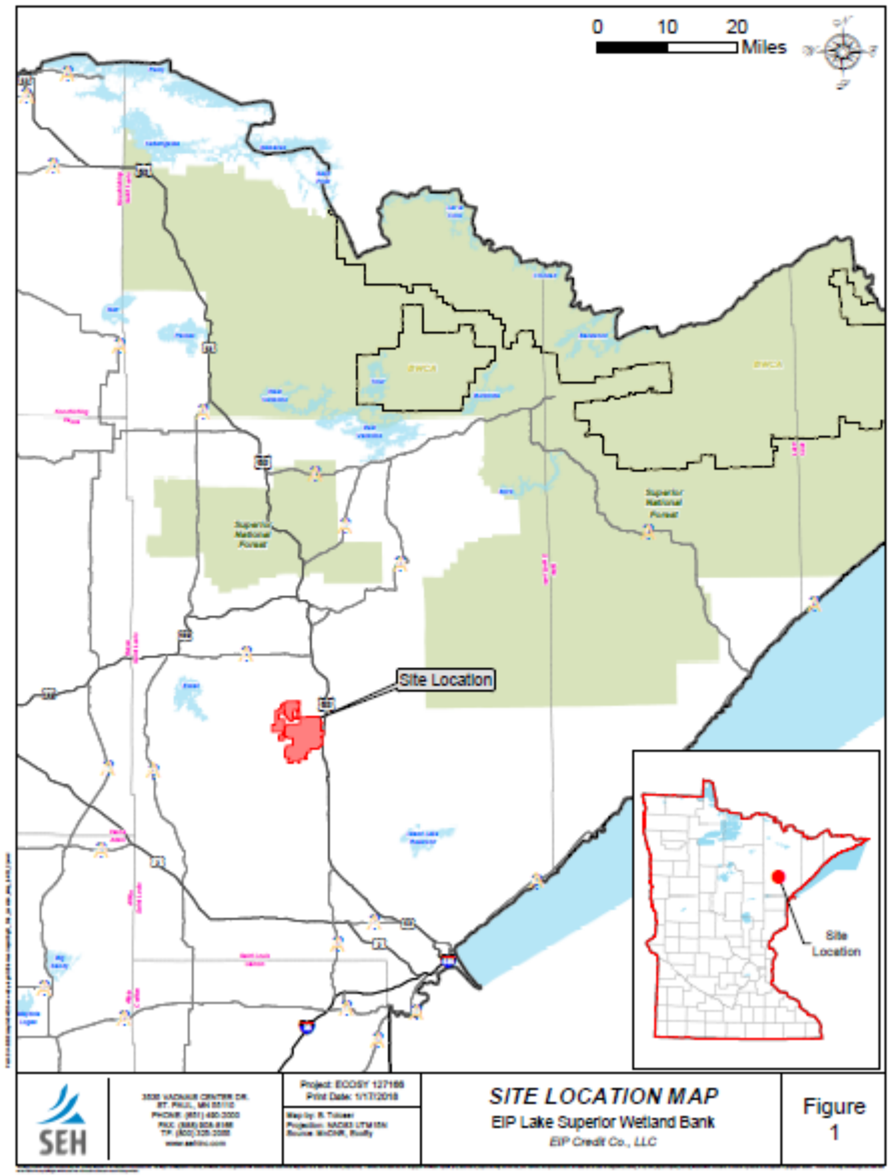
Total ditched peatlands in St. Louis River Watershed: ~ 144,000 ac

Gernes, M. 2013. "Peatland_ditch_decoupling.docx". Figure 1. Approximate coverage of peatland wetland systems in northeastern and north central Minnesota and associated ditches. Peatland extent derived from Agroecoregion GIS coverage for MN developed by D. Mulla at the Univ. of MN. Included are "Peatlands"; "Poorly-drained lake"; "Somewhat poorly drained lake"; "Poorly drained lake sediments"; and Red Lake loams" landforms. The ditch system layer originates from a MNDOT coverage.

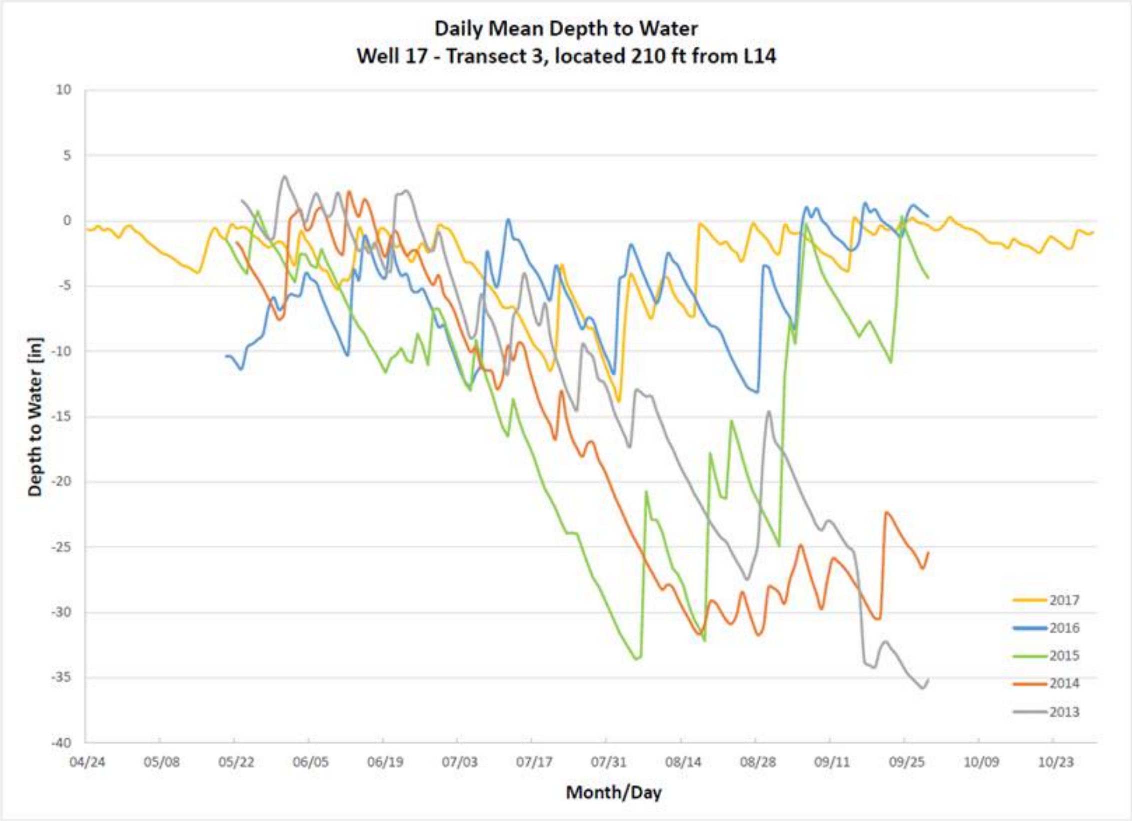
From failed cropland to filled wetland, Sax-Zim bog restoration underway

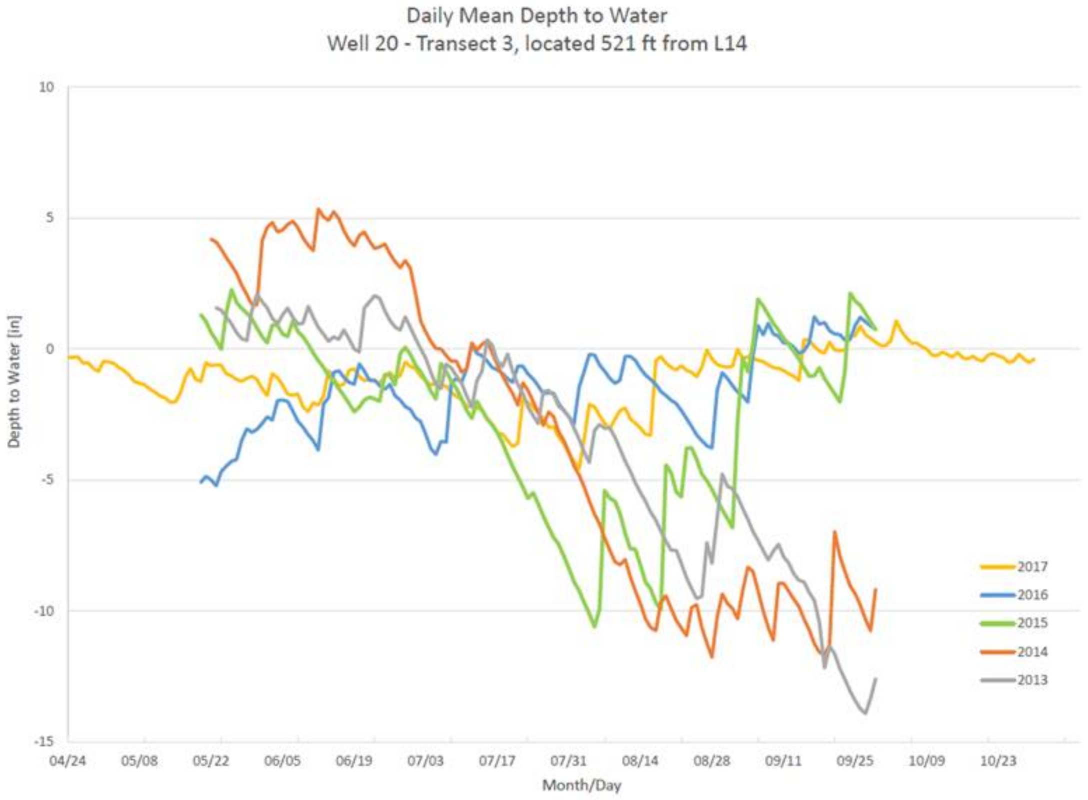
By **John Myers** on Sep 17, 2015 at 2:05 p.m.

“Ecosystem Investment Partners, or EIP, the Baltimore-based for-profit company that has acquired 23,223 acres, 36 square miles of the Sax-Zim bog area to restore as naturally functioning wetlands.”



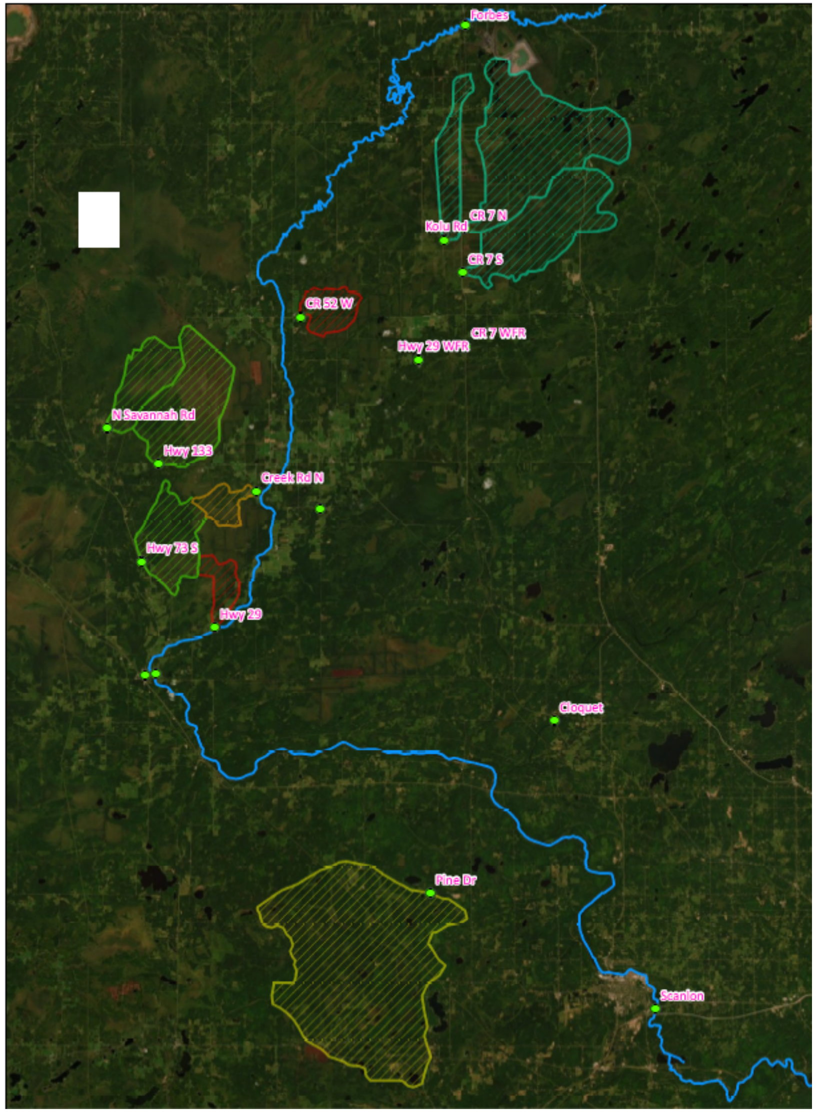
Water Levels in Superior Wetland Bank





Mercury Load Monitoring Study 2019-2020

- Project Manager: Mark Brigham, USGS
- Funded by Great Lakes Restoration Initiative
- Sampling 18 sites for Hg, MeHg, TOC, flow, etc.
  - 4 ditched peatlands
  - 3 natural peatlands
  - 3 restored (plugged) peatlands
  - 8 river/tributary sites
- Technical Advice and Field Support:
  - Fond du Lac (Nancy Schuldt)
  - MPCA (Jesse Martus, Kevin Stroom, Bruce Monson, & Stacia Grayson)
  - MNDNR (Michele Walker)
  - NRRI (Kurt Johnson)



Thank you!

bruce.monson@state.mn.us

651-757-2579

MINNESOTA POLLUTION
CONTROL AGENCY

http://mercuryconvention.org/Portals/11/documents/meetings/COP3/Effectiveness/DraftINF_Doc_FOR_PUBLIC_COMMENT_01Aug2019.pdf

Figure 3.1. Mercury emissions can be transported hundreds and thousands of kilometers from their sources before being deposited on the landscape. Once deposited, the potential impact of mercury on the environment depends largely on ecosystem sensitivity. Understanding which ecosystems are most susceptible and also which organisms can serve as appropriate bioindicators is a critical component of effective mercury monitoring.