An Overview of Everglades Mercury Issues:
Critical Questions Remain

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Greater Everglades Ecosystem Restoration Conference
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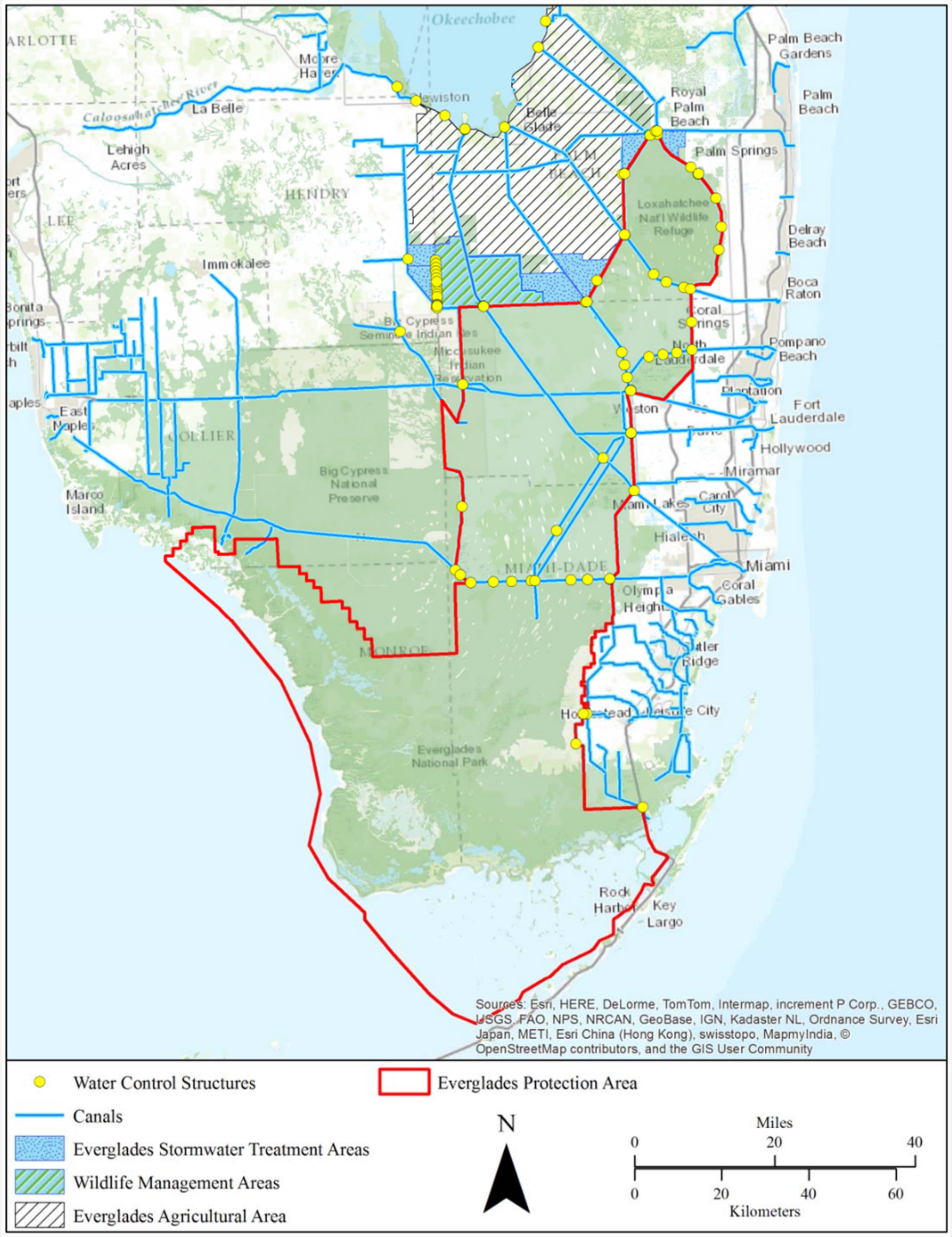
Mercury Science Program

State and Federal Agencies Collaborated with Universities, Consultants and Governmental Researchers in a Mercury Science Program

During two decades, experts from multiple disciplines rewrote much of the science on mercury in wetlands, yet areas of uncertainty remain. -

Everglades Protection Area



Mercury - Back to Basics

- **Mercury (Hg)**
  - **Naturally occurring element**
    - **Minerals (i.e. cinnabar ore)**
  - **Sources**
    - **Anthropogenic Sources (Past and Current)**
      - **Municipal Incinerator**
      - **Fossil Fuel (i.e. Coal)**
      - **Precious metal mining (i.e. Gold)**
    - **Natural**
      - **Geologic Activity**
      - **Volatilization of Hg in marine environments**
      - **Emissions from terrestrial environments**

Bergman (1775)

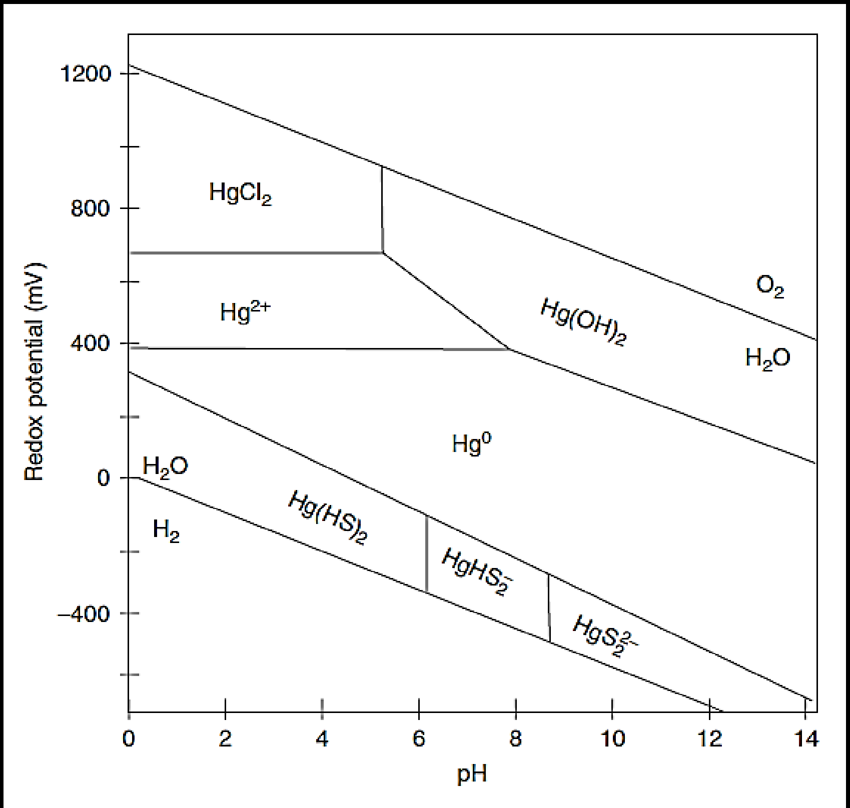
Courtesy of Bureau of Land Management

Courtesy of Alaska Volcano Observatory

Bergman, T.O. 1775. *Disquisitio de Attractionibus Electivis*

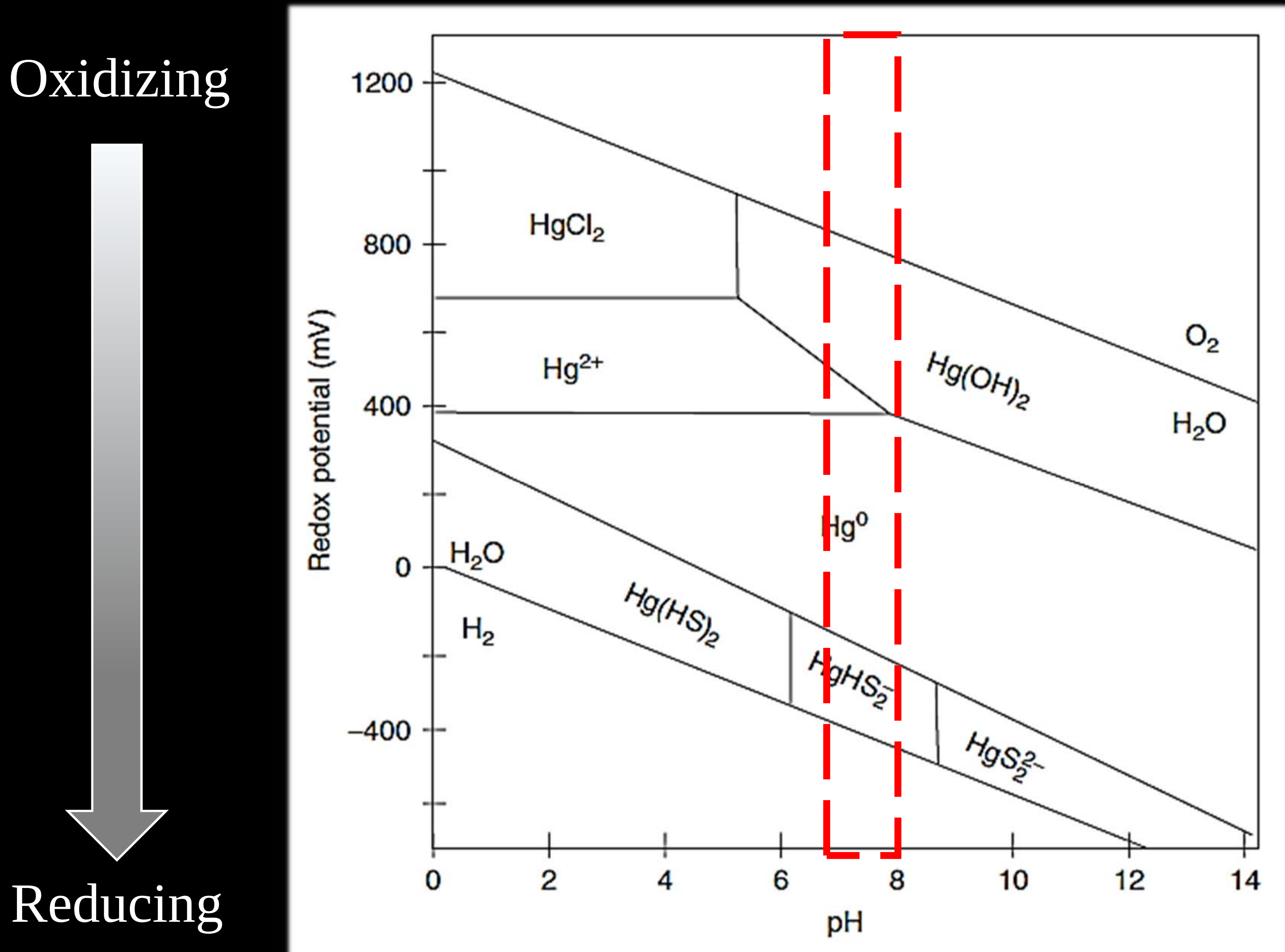
Mercury Forms - Many and Varied

- Oxidation states
  - Hg(0) – metallic
  - Hg(I) – mercurous
  - Hg(II) – mercuric
- Inorganic
- Organic
  - Methyl Mercury (MeHg)
  - Dimethyl Mercury (DMeHg)
  - Ethyl Mercury (EtHg)



Redox Potential (Eh) – pH diagram
(Reddy and DeLaune 2008)

Mercury Forms - Many and Varied



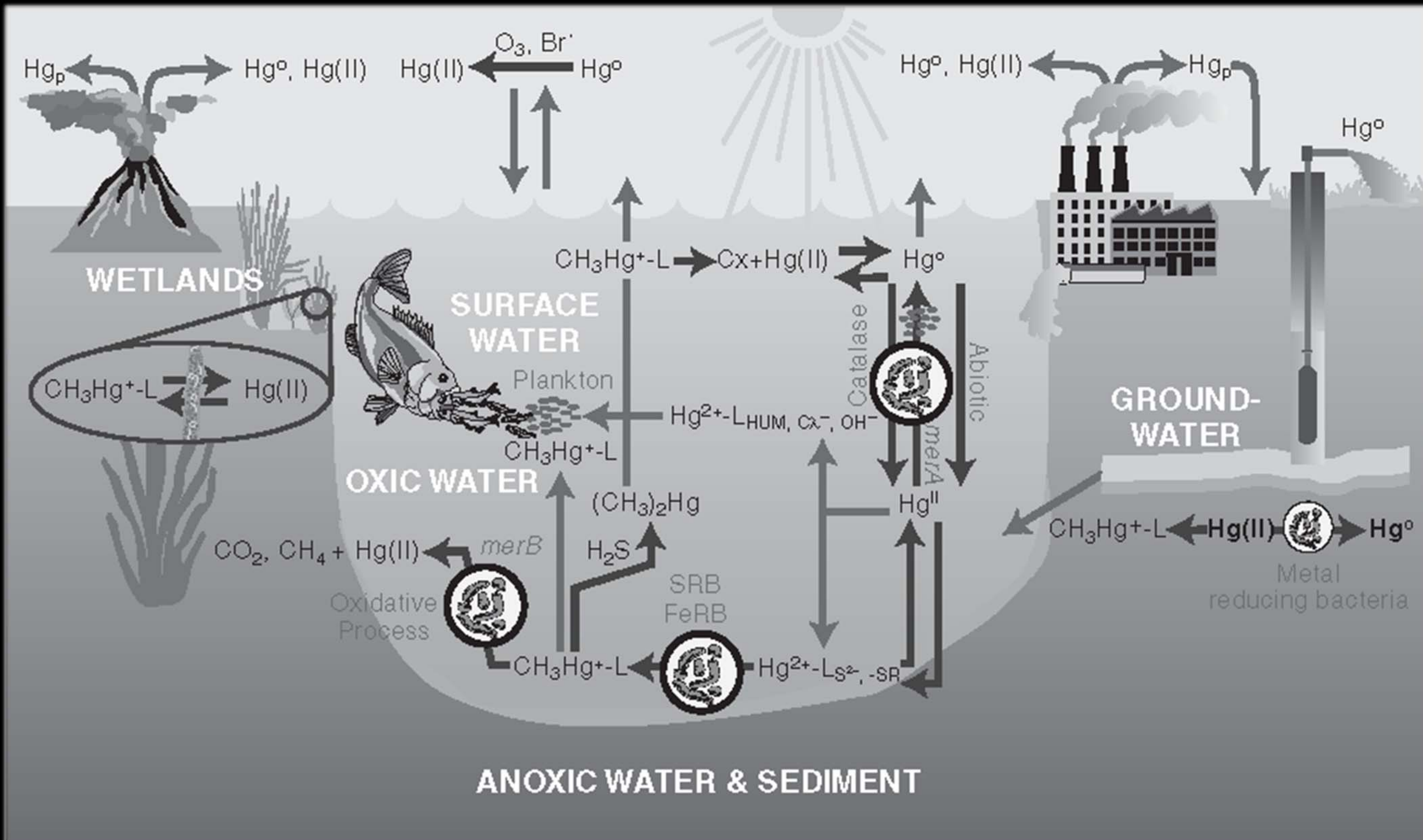
Redox Potential (Eh) – pH diagram adapted from Reddy and DeLaune (2008)

Reddy, K.R. and R.D. DeLaune. 2008. Biogeochemistry of wetlands: science and applications. CRC Press, Boca Raton, FL.

Mercury Accumulation

- Recognized as a global contaminant
- All forms of mercury are toxic to both humans and wildlife
  - Humans
    - Mad-Hatter Syndrome
    - Chisso-Minamata Disease
  - Wildlife
    - Neurotoxicity
    - Influences behavior and reproduction
- Mercury is an environmentally persistent toxin
- Long-range transport in the atmosphere

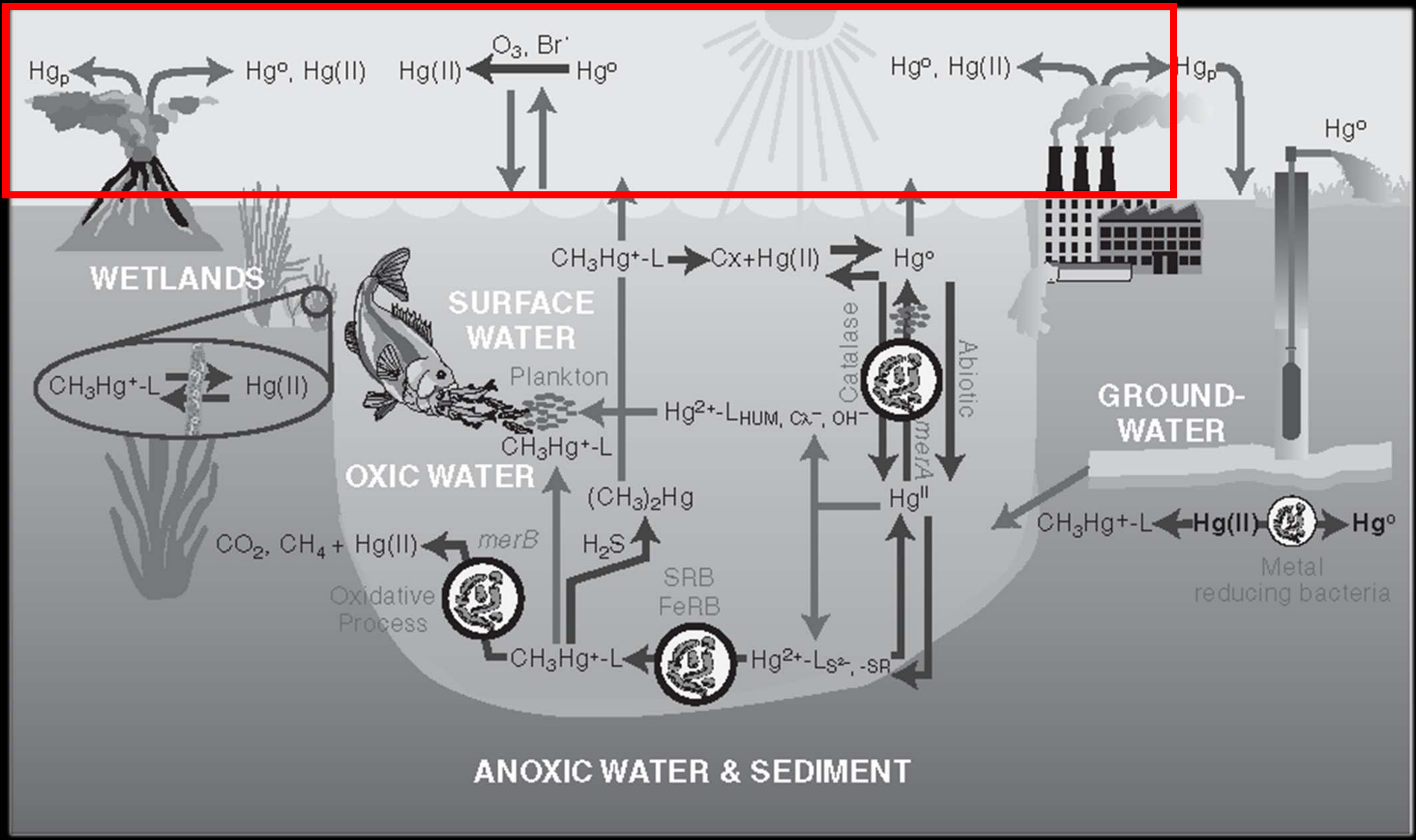
The Mercury Cycle



Lin, C., N. Yee and T. Barkay. 2012. Microbial transformation in the mercury cycle. In: Liu, G., Cai, Y., O'Driscoll, NJ (Eds.), *Advances in Environmental Chemistry and Toxicology of Mercury*. John Wiley & Sons, Hoboken, NJ.

How is mercury distributed?

Atmospheric Deposition



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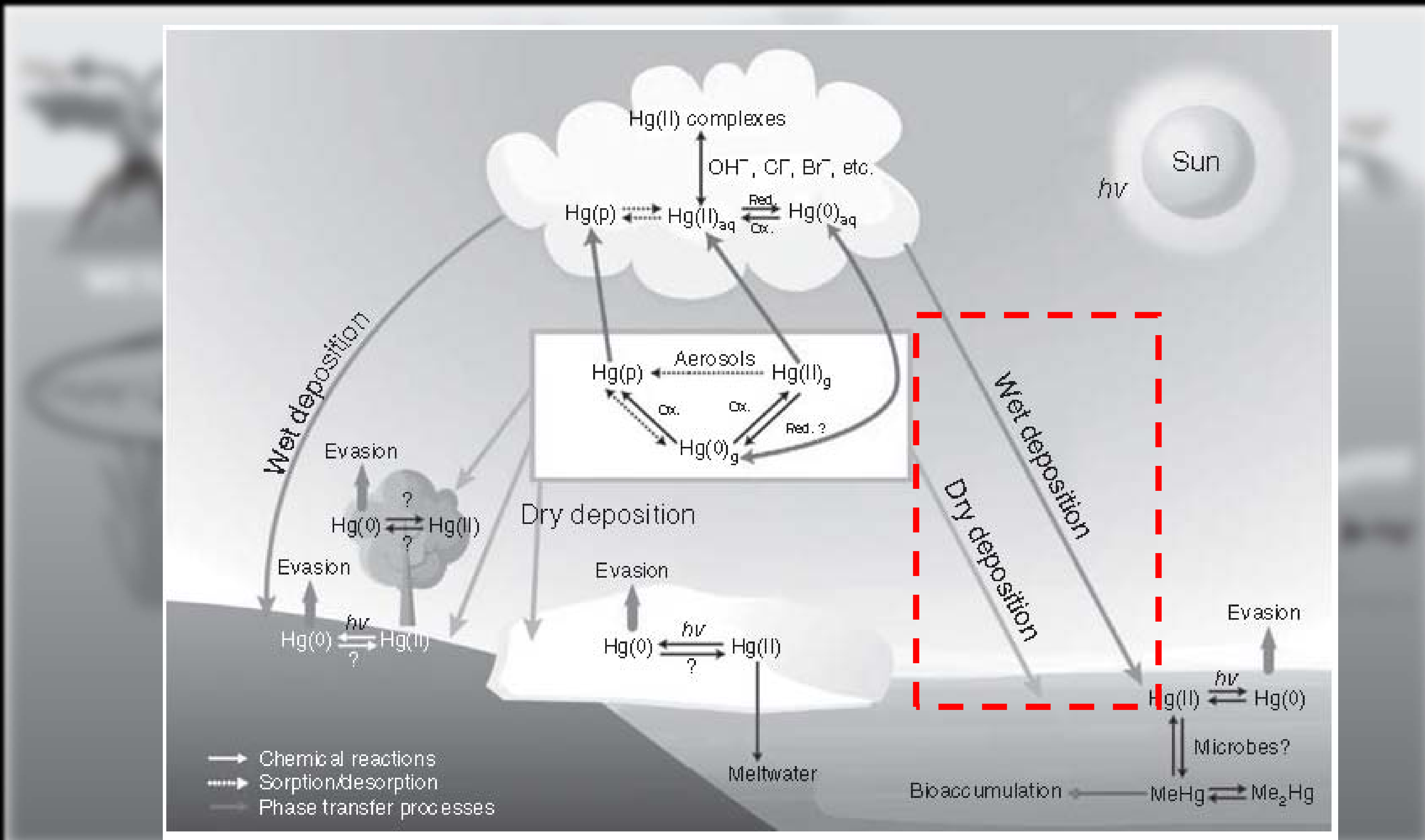
Atmospheric Deposition



Lin, C., P. Singhasuk and S.O. Pehkonen. 2012. Atmospheric Chemistry of Mercury. In: Liu, G., Cai, Y., O'Driscoll, NJ (Eds.), *Advances in Environmental Chemistry and Toxicology of Mercury*. John Wiley & Sons, Hoboken, NJ.

How is mercury distributed?
Atmospheric Deposition

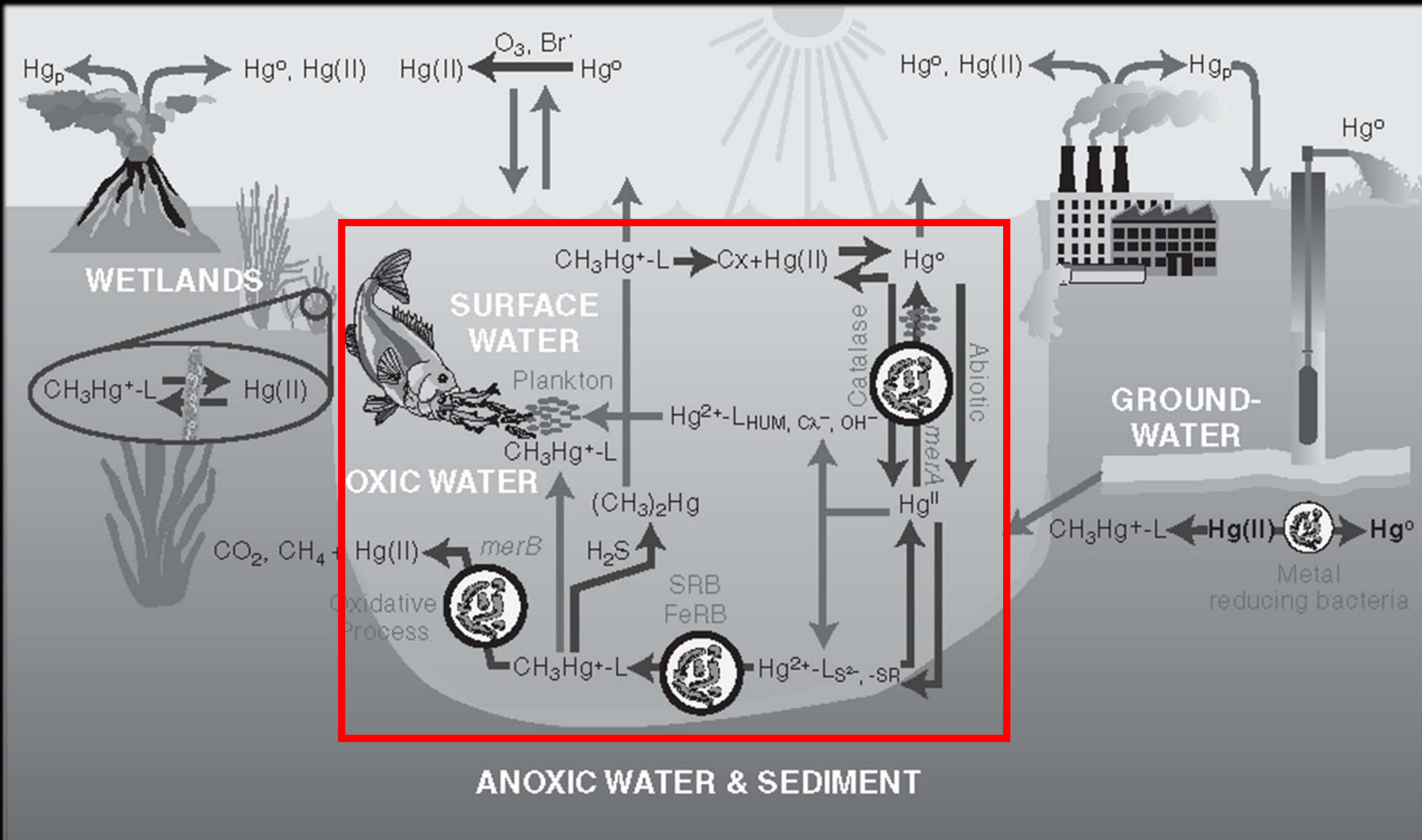
Mercury Amount (kg)	Mercury Concentration (ng/L)	Region	Reference
137 (Total)	---	Everglades	Liu et al. 2008
121.7 ± 3.8 (Wet)	13.5 ± 0.3 *	Everglades	Julian et al. 2015**
810 (Total)	9.0	Lake Superior	Hoff et al. 1996
327 (Total)	12.0 ± 8.5 *	Lake Champlain Basin	Rea et al. 1996

* Volume-weighted concentration

**17 year period (Florida WY1998 – 2014; May 1, 1997 – April 30, 2014)

How is mercury distributed?

Atmospheric Deposition



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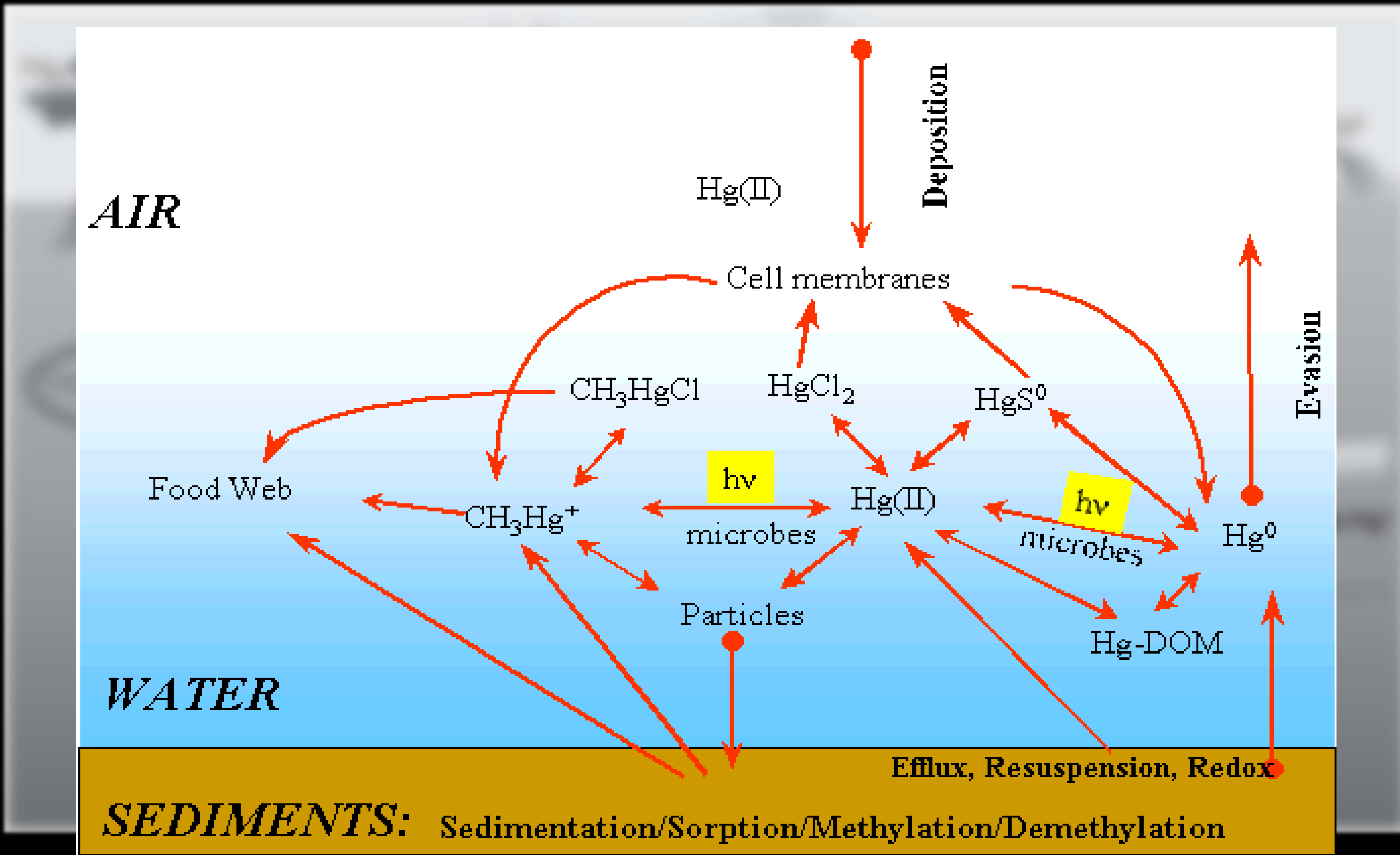
How is mercury distributed?
Water Column



Krabbenhoft et al. 2000. Aquatic Cycling of Mercury in the Everglades (ACME) project: Synopsis of Phase I studies and plans for Phase II studies. *Presentations Made at the Greater Everglades Ecosystem Restoration (GEER) Conference.*

How is mercury distributed?
Water Column

Total Mercury (ng/L)	Methyl-Mercury (ng/L)	Region	Reference
2.6 ± 0.1 (0.6 - 41.4)	0.5 ± 0.02 (0.02 - 5.5)	Everglades (Marsh)	Stober et al. 2001 Schedit and Kalla 2007
0.05 - 5.4	0.01 - 3.6	Everglades (STA2 Discharge)	Zheng et al. 2013
2.73 ± 0.27 (0.44 - 7.23)	0.7 ± 0.3 (0.04 - 9.7)	Canada (Lakes and Wetlands)	Clayden et al. 2014
10.6 ± 2.0 (4.1 - 22.6)	0.8 ± 0.1 (0.2 - 1.3)	Minnesota (Forest Pools)	Brooks et al. 2012

Mean ± Standard Error ;Minimum – Maximum

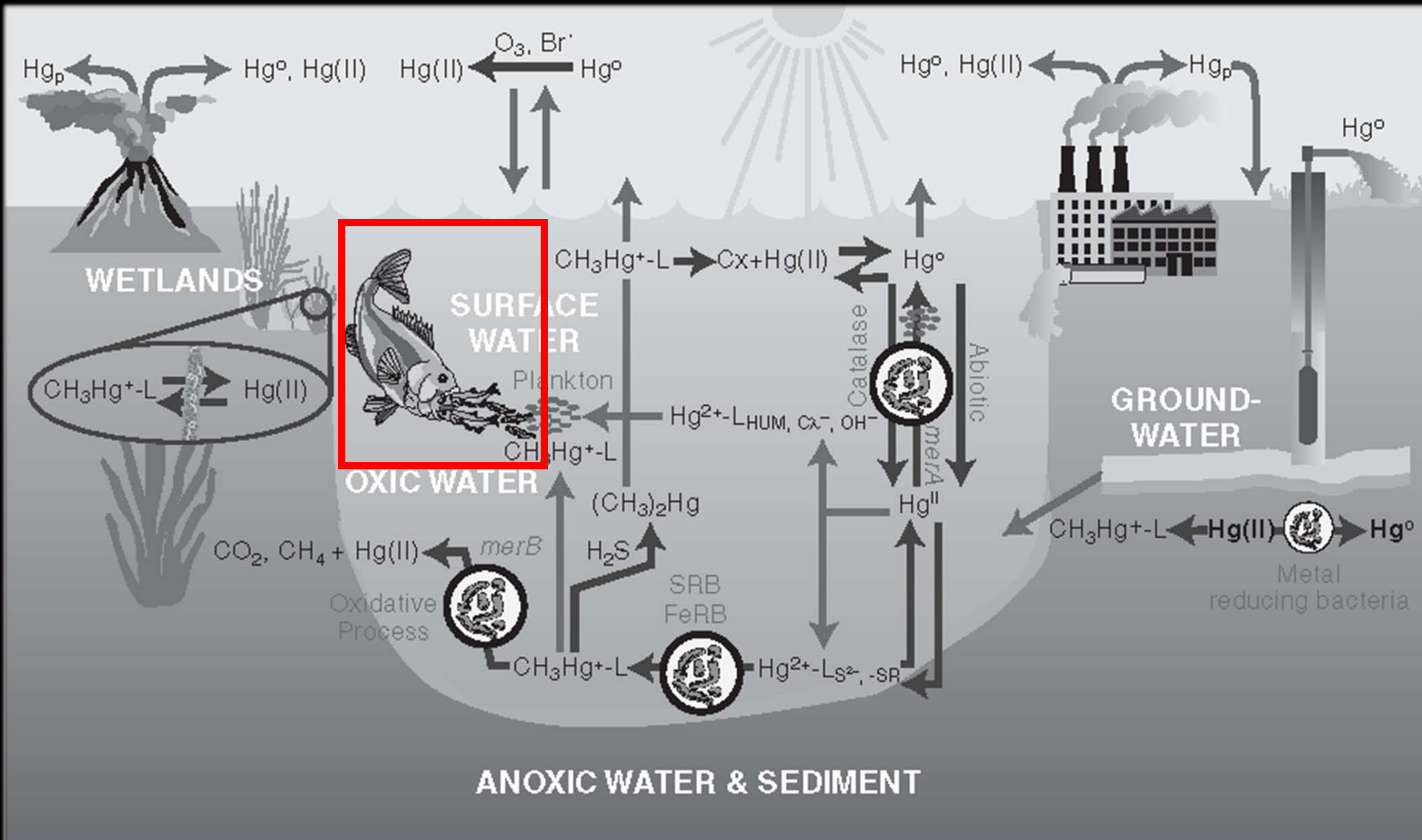
How is mercury distributed?
Atmosphere versus Water Column

Atmospheric load of total mercury (THg) to each region of the EPA

Region	Atmospheric Load (kilograms)	WY2001–WY2008 Surface Water Inflow Load* (kilograms)	Percent Atmospheric Contribution
Refuge	12.1	0.27 ± 0.03	98
WCA-2	11.5	0.51 ± 0.06	96
WCA-3	36.0	1.89 ± 0.18	95
ENP	68.2	1.12 ± 0.21	98

Julian et al. 2015. Chapter 3B: Mercury and Sulfur Environmental Assessment for the Everglades. In: *2015 South Florida Environmental Report*. South Florida Water Management District, West Palm Beach, FL.

How is mercury distributed?
Consumers (i.e. fish)



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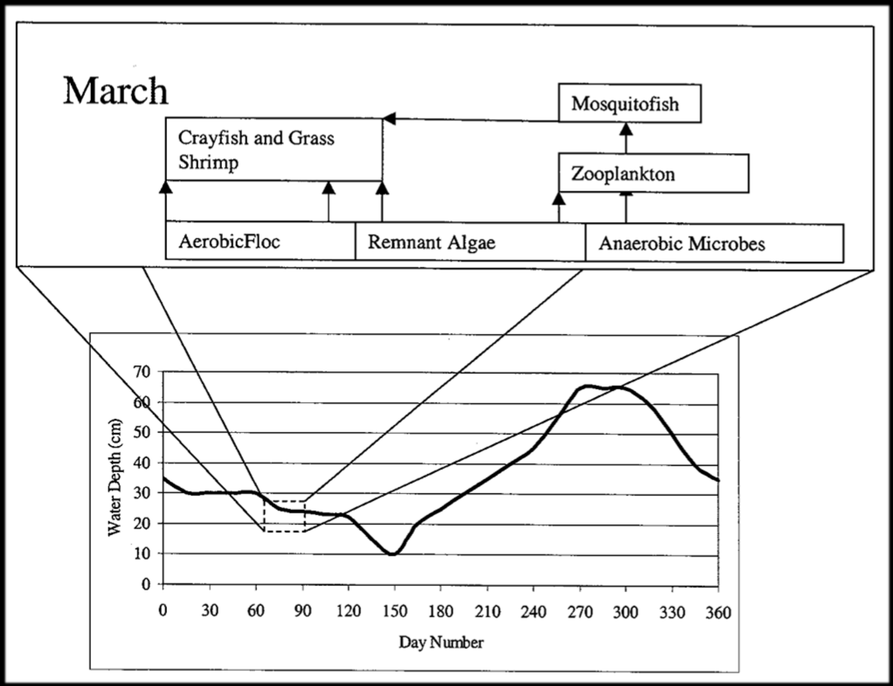
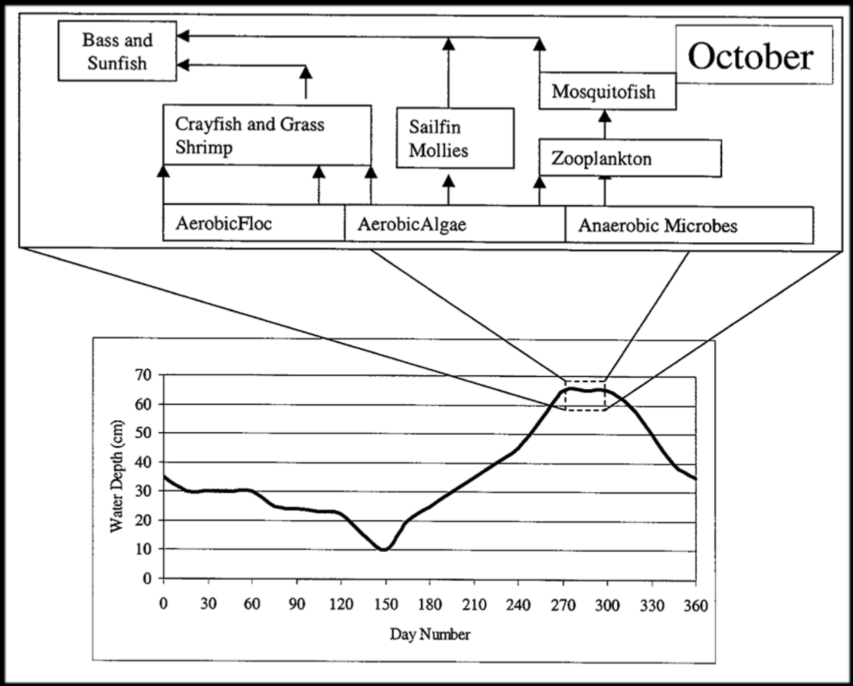
How is mercury distributed?
Consumers (i.e. fish)

- Everglades food webs
  - Vary spatially and temporally
  - May explain huge variation on mercury levels

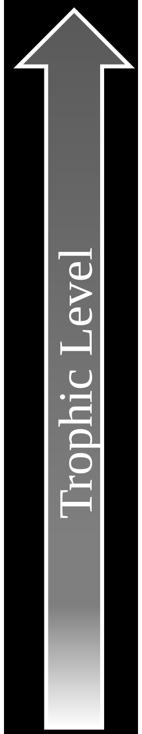


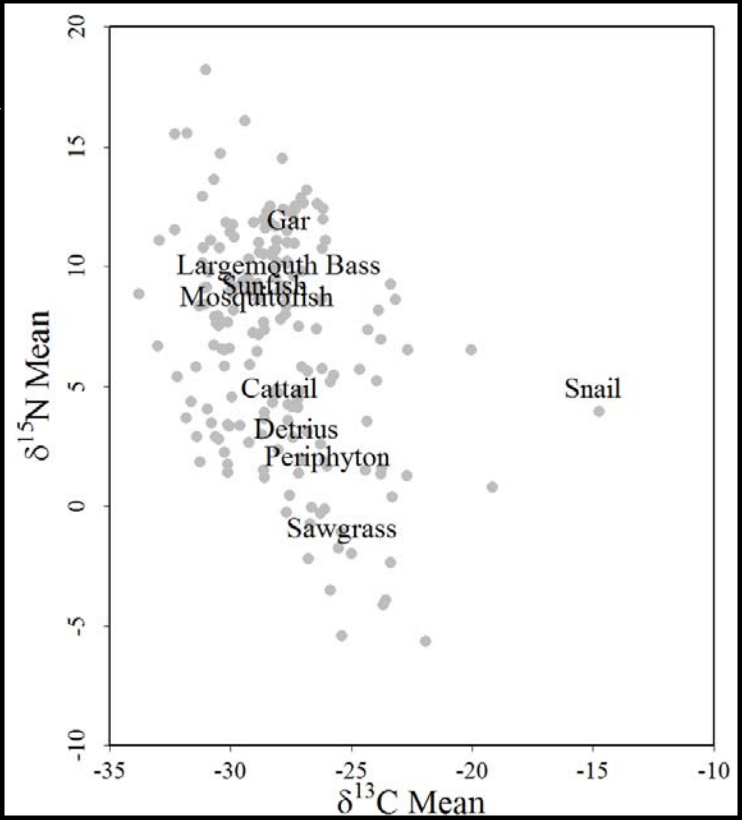


Rawlik et al. 2002. A conceptual model for seasonal changes in foodwebs in the Everglades: implications for mercury bioaccumulation. South Florida Water Management District, West Palm Beach, FL.

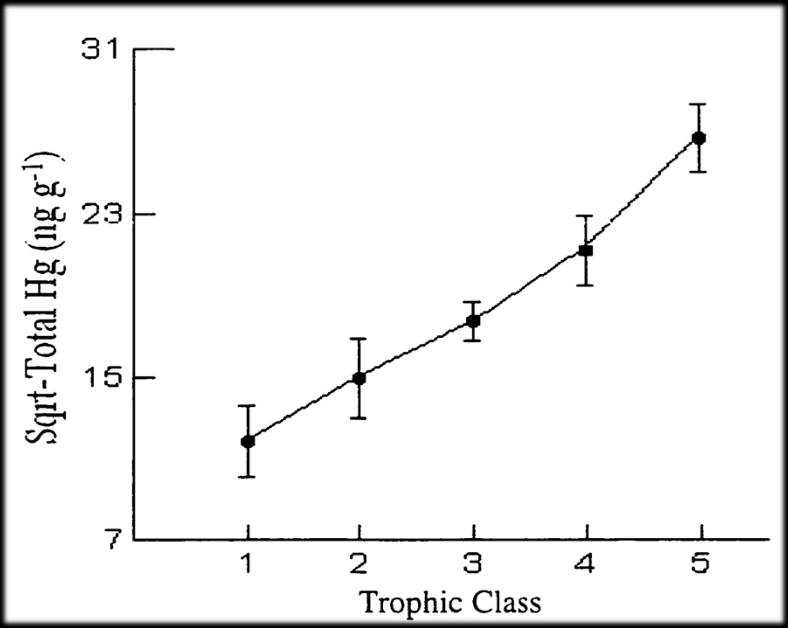
How is mercury distributed?

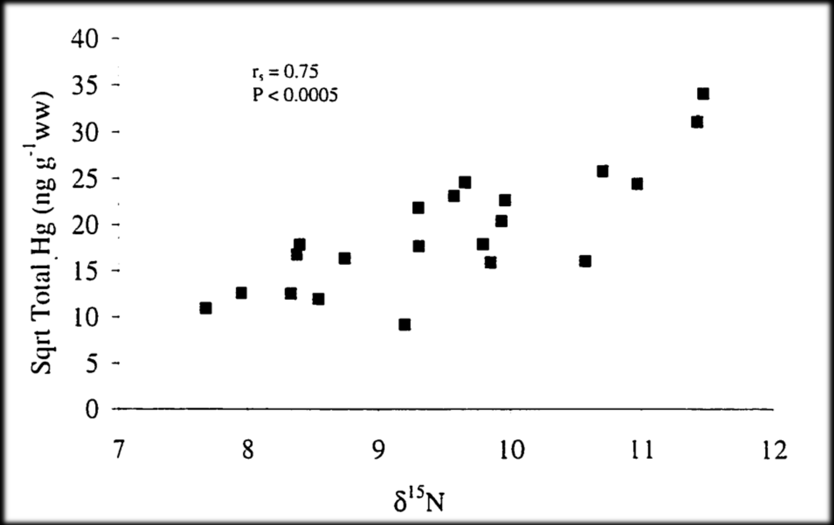
Consumers (i.e. fish)





Isotope data presented in Loftus (2000)





Loftus. 2000. Accumulation and fate of mercury in an Everglades aquatic food web. Florida International University, Miami, Florida.

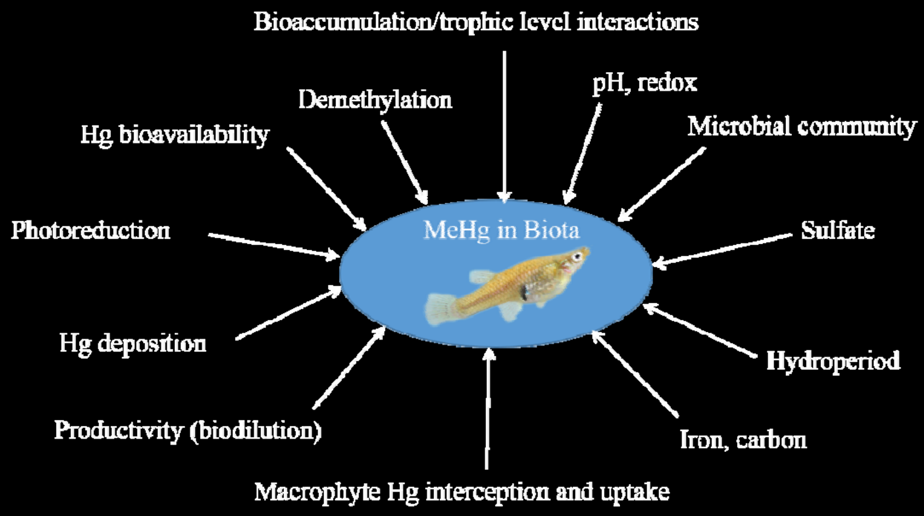
How is mercury distributed?

Consumers (i.e. fish)

Mercury Concentration (mg/kg)	Species	Trophic Position	Region	Reference
0.63 ± 0.02	Largemouth Bass	Carnivore	Everglades (Marsh)	Julian et al. 2015
1.16 ± 0.10	Florida Gar			Loftus 2000
0.14 ± 0.004 (0.003 – 0.93)	Mosquitofish	Ominvore		Stober et al. (2001), Schedit and Kalla (2007)
0.08 ± 0.005	Flagfish	Herbivores		Loftus 2000
0.11 ± 0.01	Sailfin Molly			Loftus 2000
0.04 - 2.04	Largemouth Bass	Carnivore	Florida (Lakes)	Lange et al. 1993
0.09 - 0.37	Pike		Iran (Wetlands)	Zamani et al. 2014
0.04 - 0.14	Trout		Wisconsin	Riva-Murray et al. 2013
0.39 - 0.70	Largemouth Bass		South Carolina	

Mean ± Standard Error; Minimum - Maximum

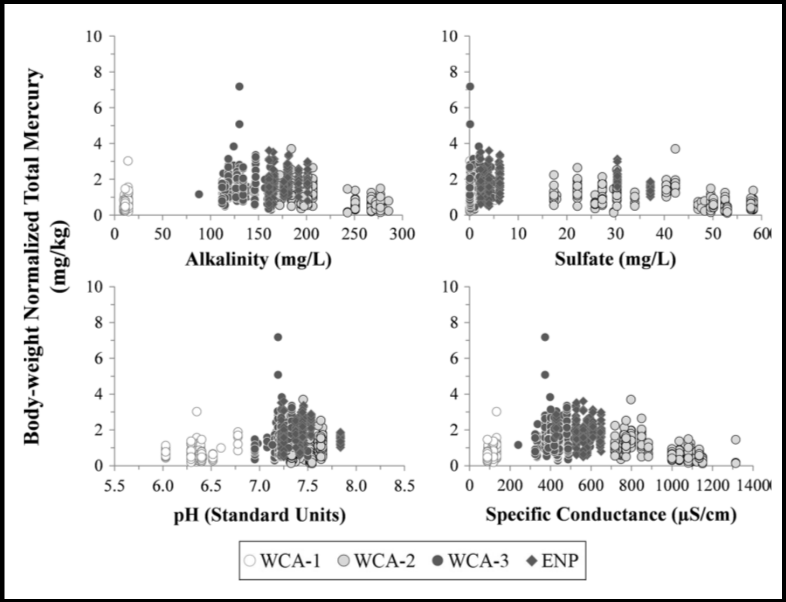
Future Directions



Adapted from DB Environmental (2015).

- Trophic level effects of mercury accumulation

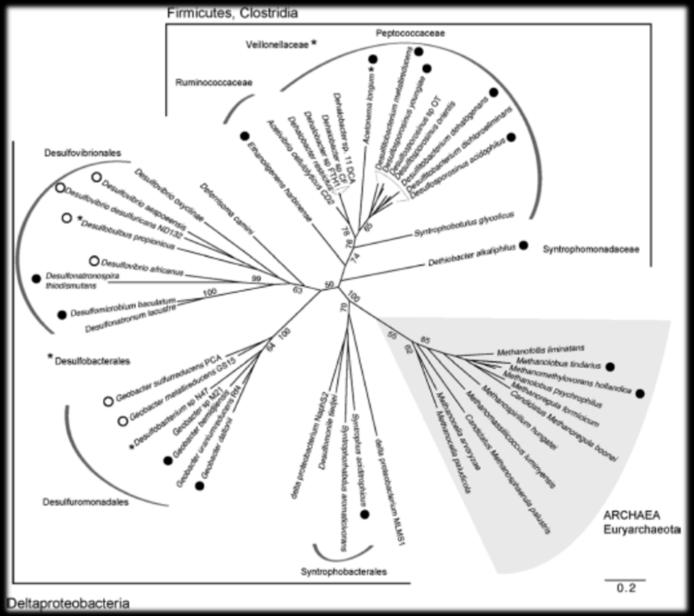
- Identifying factors that influence mercury accumulation in biota



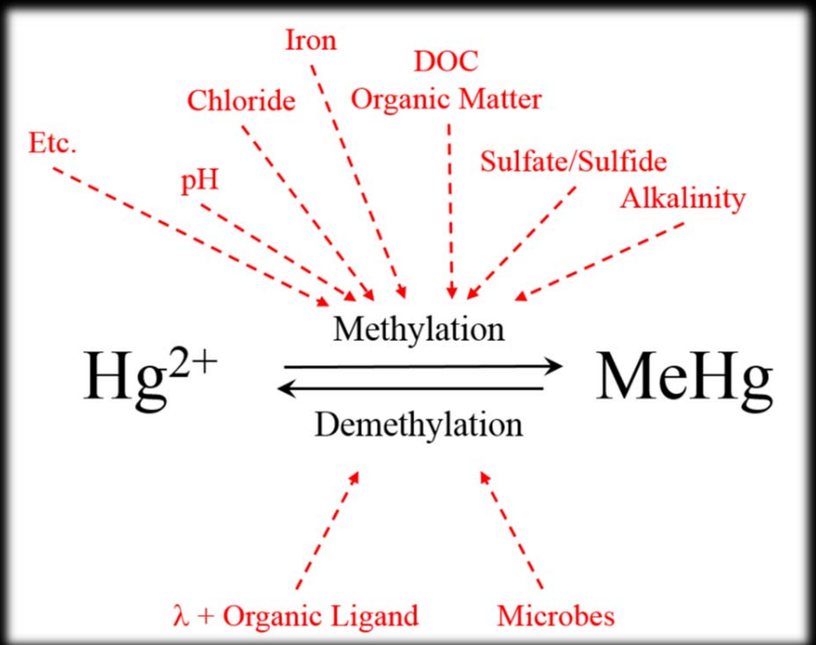
Julian and Gu (2015)

Future Directions

- Microbial dynamics of mercury methylating bacteria



Gilmour et al., (2013)



- Mercury methylation and de-methylation dynamics
- Further clarifying role of sulfur and other constituents

Photo courtesy of Kara Tyler-Julian