Lichen bioindicators for mercury contamination

Rotary Kiln,
New Almaden Quicksilver County Park

DTMC Meeting – May 19, 2021

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Outline

- Utility of lichen as a bioindicator of atmospheric mercury deposition.
- Need for monitoring with lichen to identify deposition hotspots.
- Recent results in Hg-mine impacted areas.
- Calibrating lichen Hg with direct measurements of Hg dry deposition.
- Application of method to the Carson River Superfund site.

Flavopunctelia sp.

Ramalina farinaceae

Ramalina menziesii

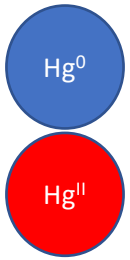
Evernia prunastri

Usnea sp.

5 Principal Species of Lichen in California Coast Range

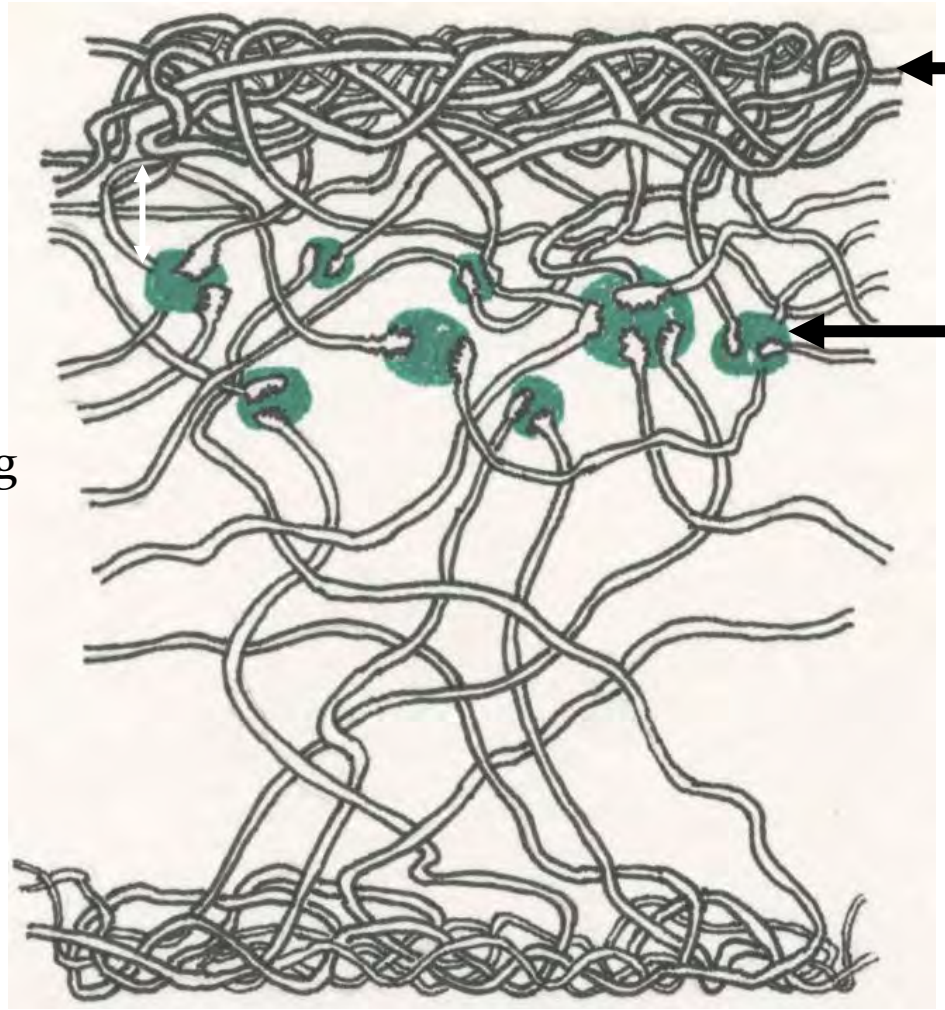
How lichen interacts with mercury in air

Dry deposition of Hg



Bi-directional exchange of Hg^0

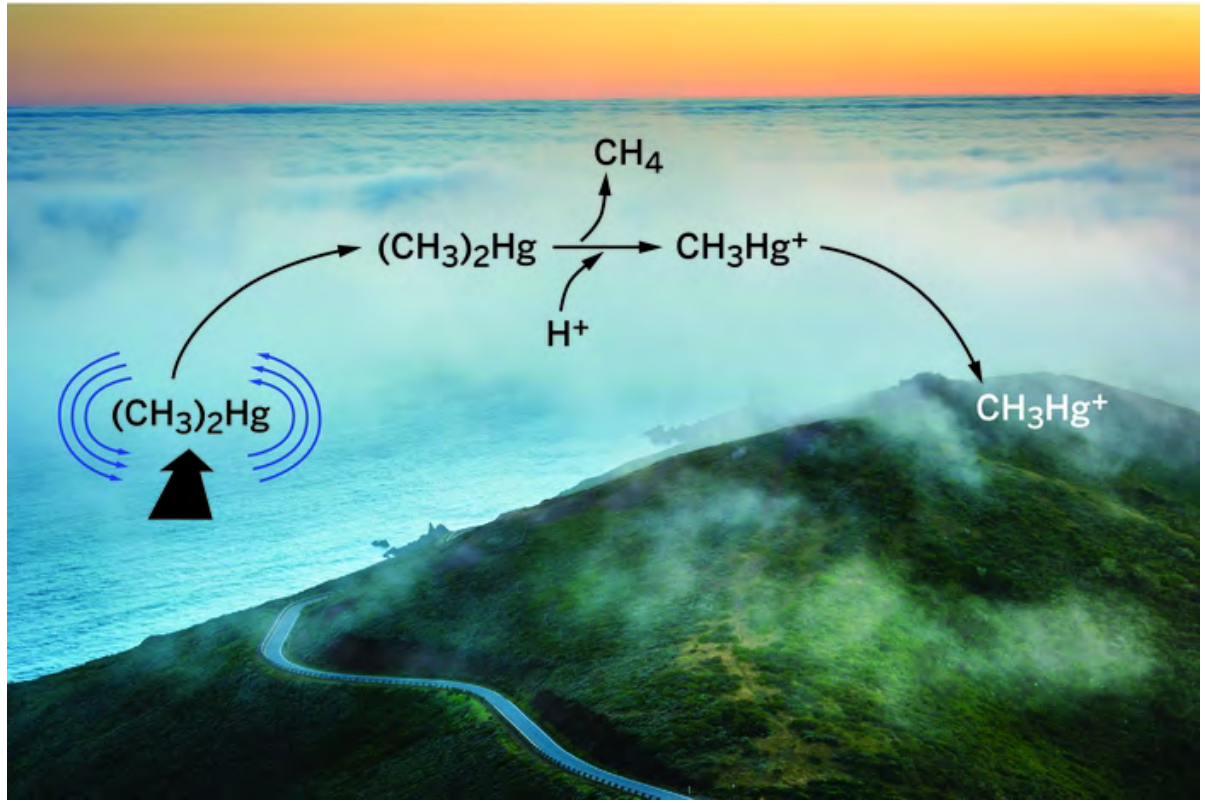
Wet deposition of MMHg



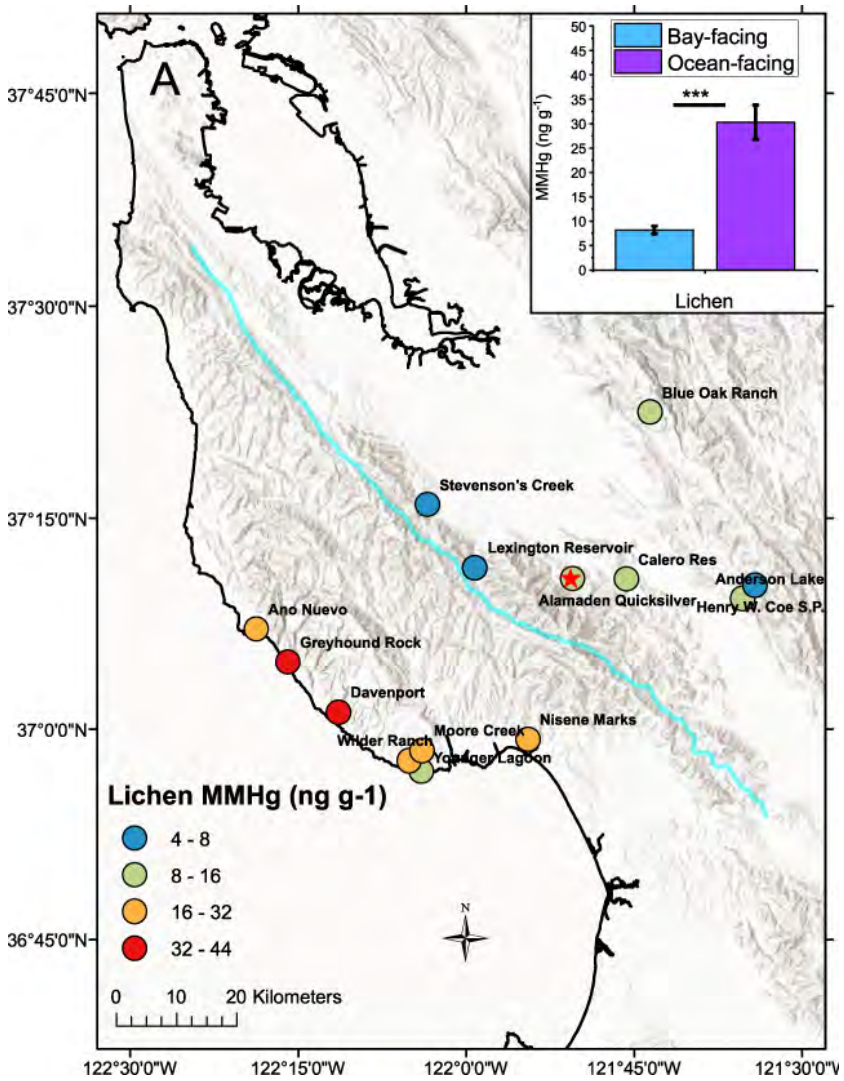
Fun Facts about Lichen and Hg

- Rapid uptake of Hg, especially Hg^{II}
- Residence time of Hg of ~5 years (Nieboer and Richardson, 1981)
- Time-integrated Hg accumulation rate reflects temporal variations in atmospheric Hg loads (Wittig, 1993)

Previous Work:
Methylmercury in Ramalina menziesii along a coastal fog gradient



C&EN, 2016



Weiss-Penzias et al., 2019

Pros and Cons of Using Lichens as a Bioindicator of Atmospheric Deposition

Pros

- Less expensive than using instrumentation.
- Better measure of the net supply of the metal to terrestrial ecosystems than data from wet deposition measurements or model calculation.
- Hg contamination around point sources or “hot spots” can be easily depicted.
- Allows for the tracing of large-scale maps of Hg deposition and to locate “hot spots”.
- Validates the effectiveness of adopted environmental recovery procedures.

Cons

- The metal uptake and bioaccumulation depend on its bioavailability, the amount of deposition, pH, species, metabolic growth rate and surface area, which are all affected by climatic and environmental stress factors.
- Potential for poor distribution of lichen habitat across a broad landscape.
- Current need for standardization and optimization of biomonitoring procedures and for a more in-depth knowledge of the mechanisms and factors affecting Hg uptake and bioaccumulation.

-From Bargagli, 2016

Monitoring Need

- There is developing interest in the regulating communities in the West to limit public exposure to high levels of toxic methylmercury in fish.
- The California Water Board and Washington State Department of Ecology are developing TMDLs to limit mercury inputs to and accumulation within reservoirs.
- One of the principal, and unstudied, sources of mercury to reservoirs is atmospheric deposition (both to the reservoir and watershed).
- The mercury amounts in lichen can help to constrain atmospheric deposition, helping managers manage mercury inputs in an informed manner.

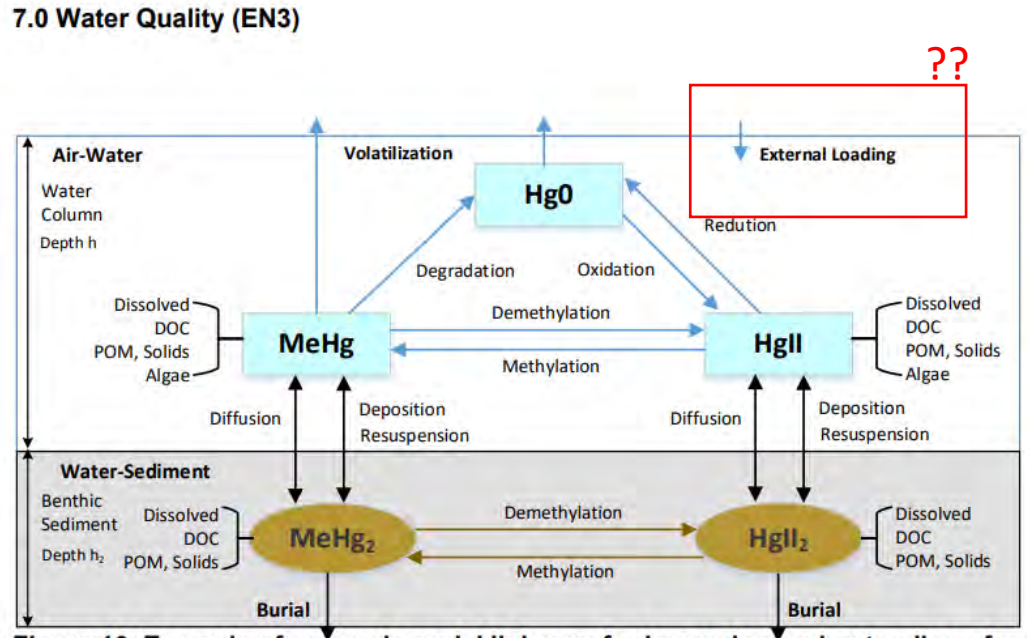
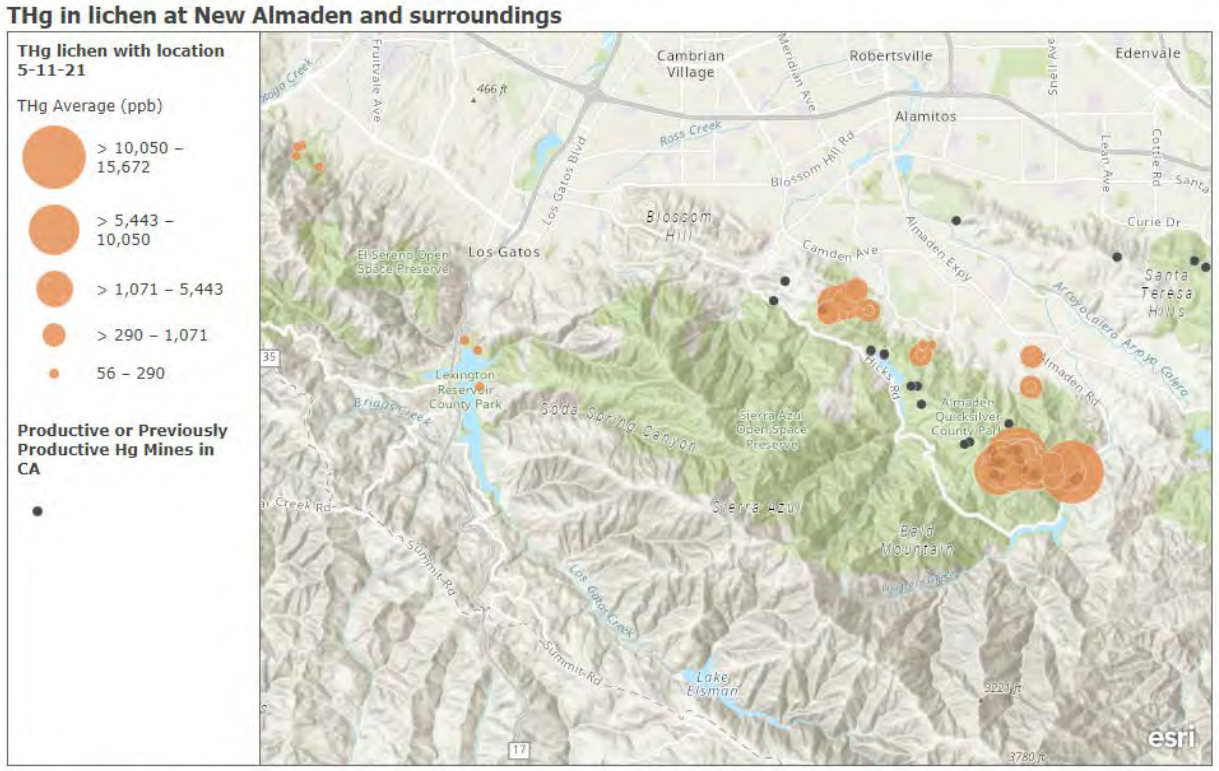
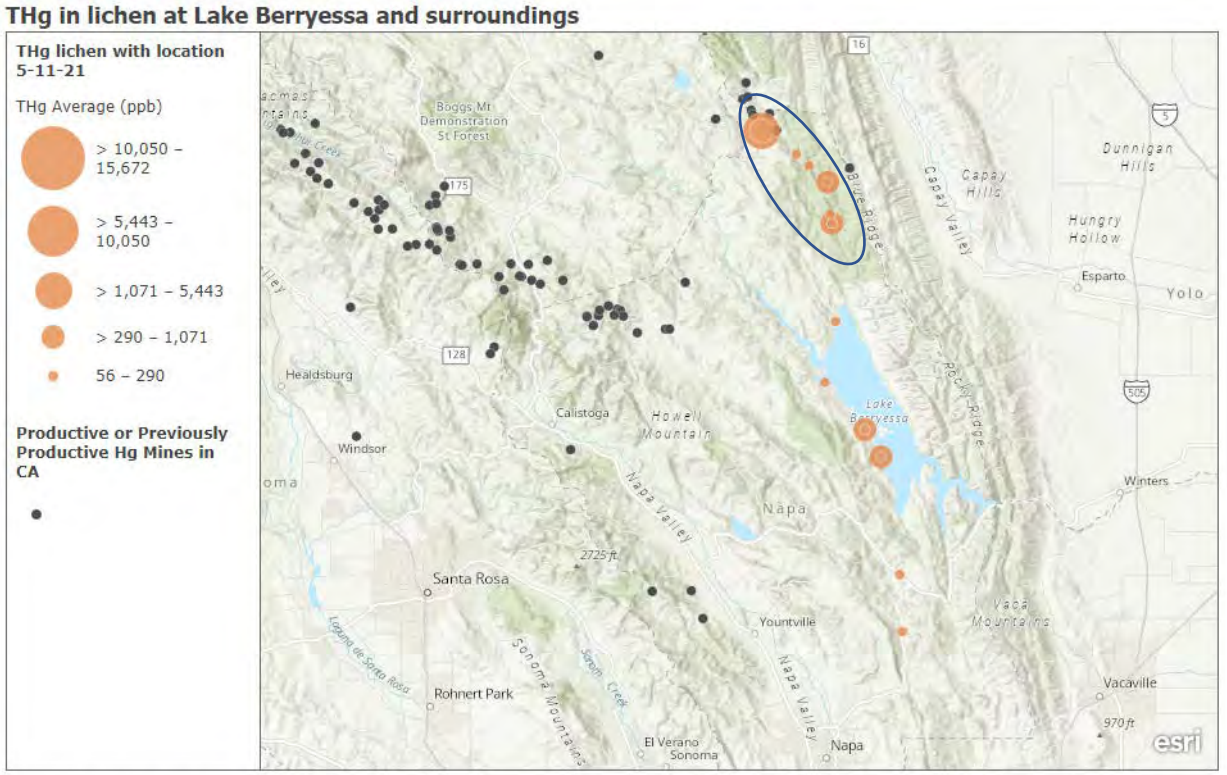


Figure 10. Example of research model linkages for improving understanding of mercury mobilization and transport in reservoirs. Image provided by Yong Lai, Reclamation.

Mercury in Lichen at New Almaden and Lake Berryessa, 2020/2021



Esri, NASA, NGA, USGS | County of Santa Clara, Esri, HERE, Garmin, SafeGraph, METI/NASA, USGS, Bureau of Land Management, EPA, NPS, USDA

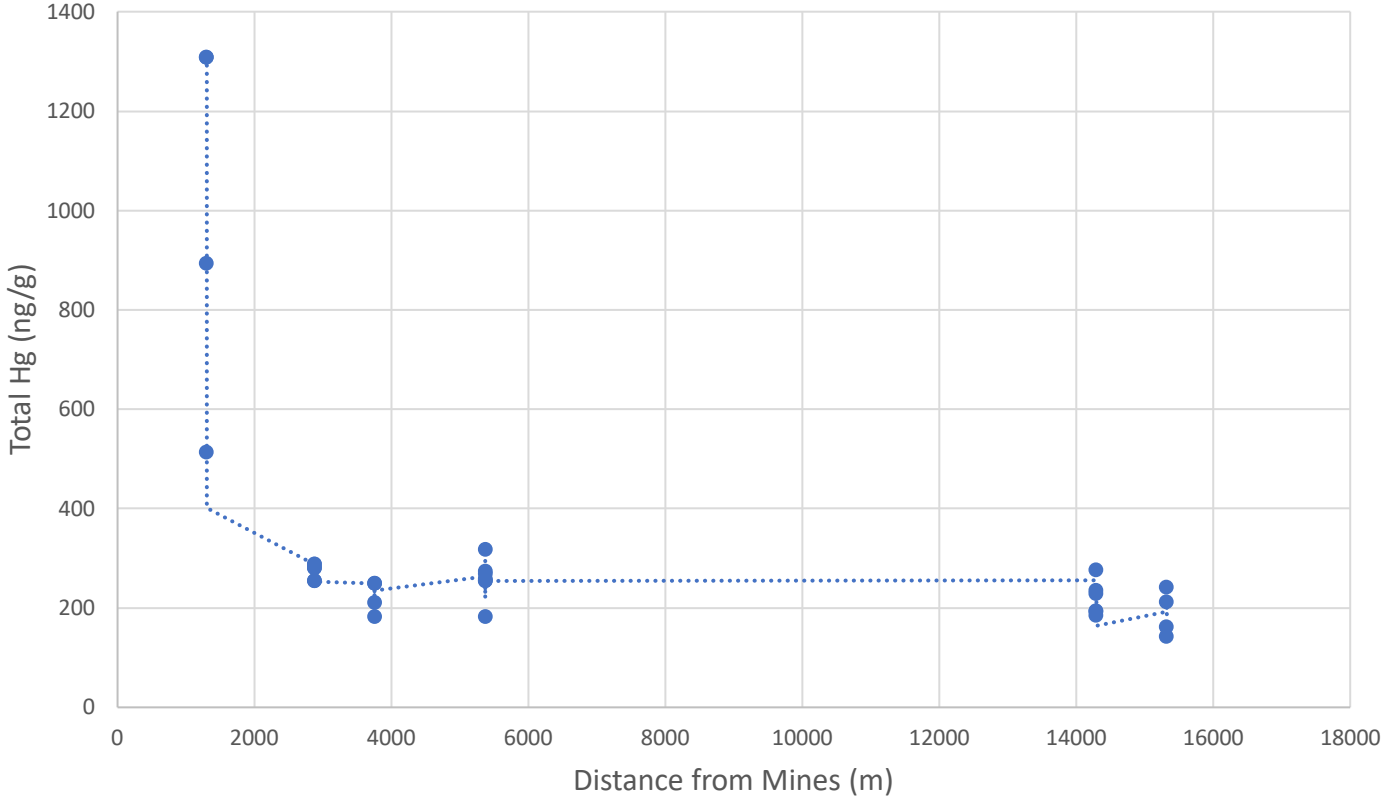


Esri, CGIAR, USGS | County of Napa, Yolo County, Esri, HERE, Garmin, SafeGraph, METI/NASA, USGS, Bureau of Land Management, EPA, NPS, USDA

Unpublished data

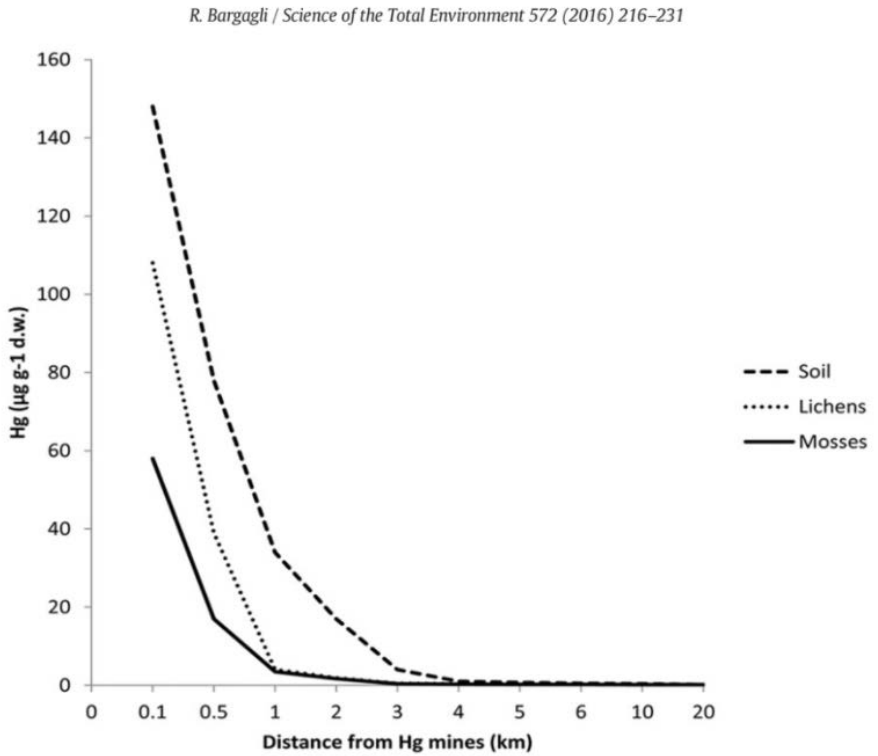
Total Hg in Lichen as a Function of Distance from Hg Mines

Knoxville to Lake Berryessa

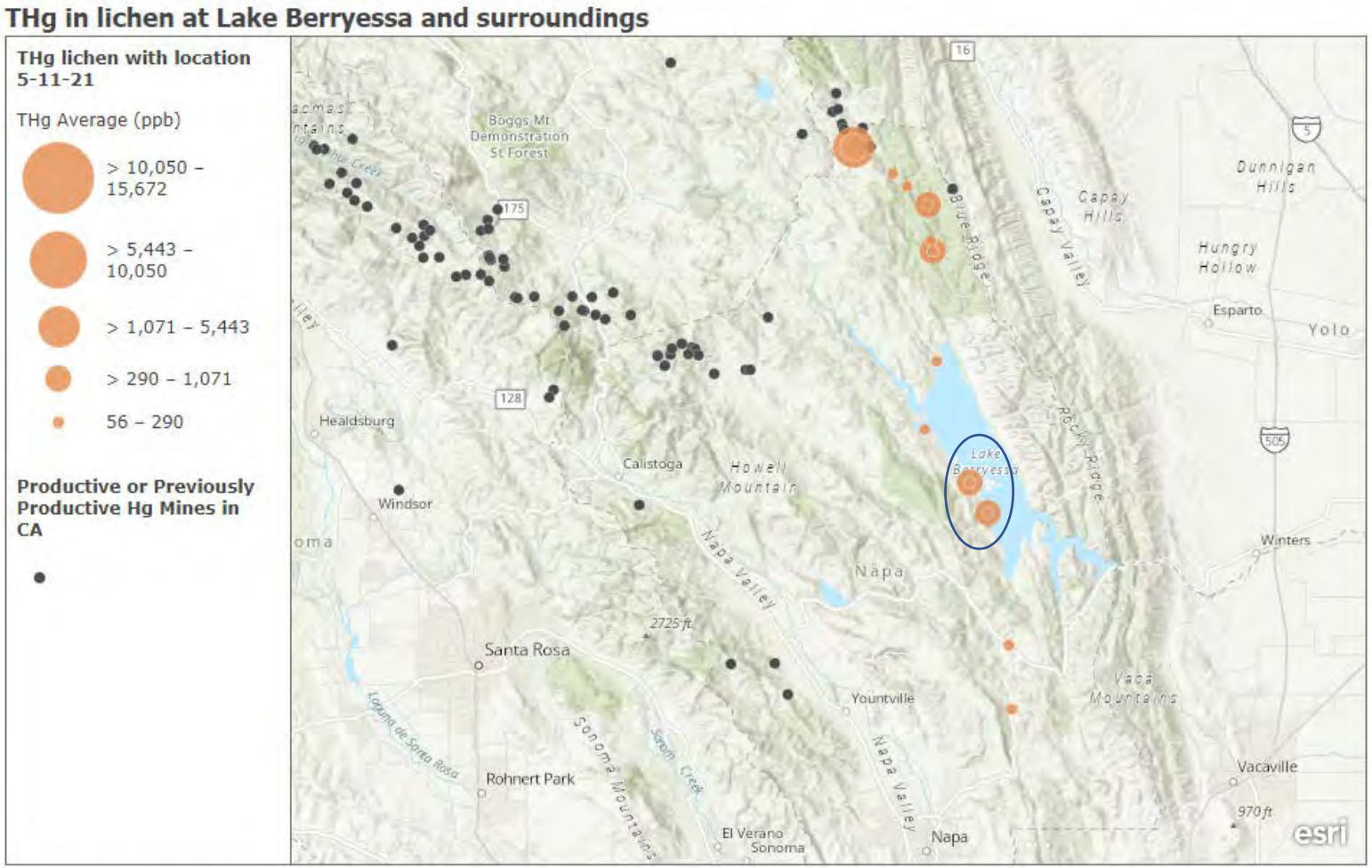


Unpublished data

Tuscany, Italy



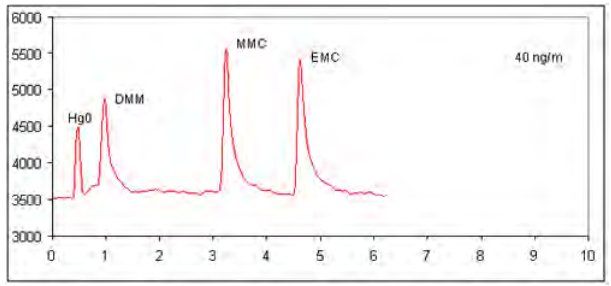
Elevated Lichen Hg at the Shore of Reservoir

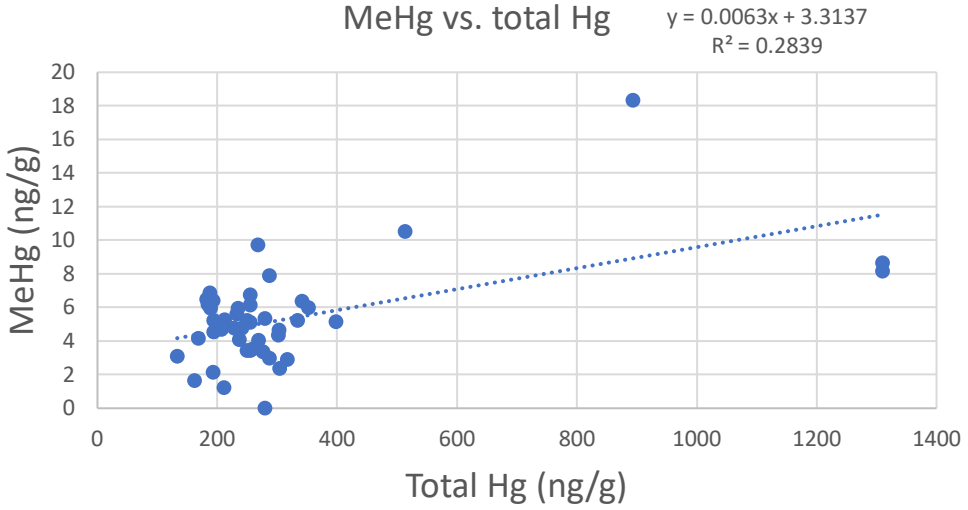


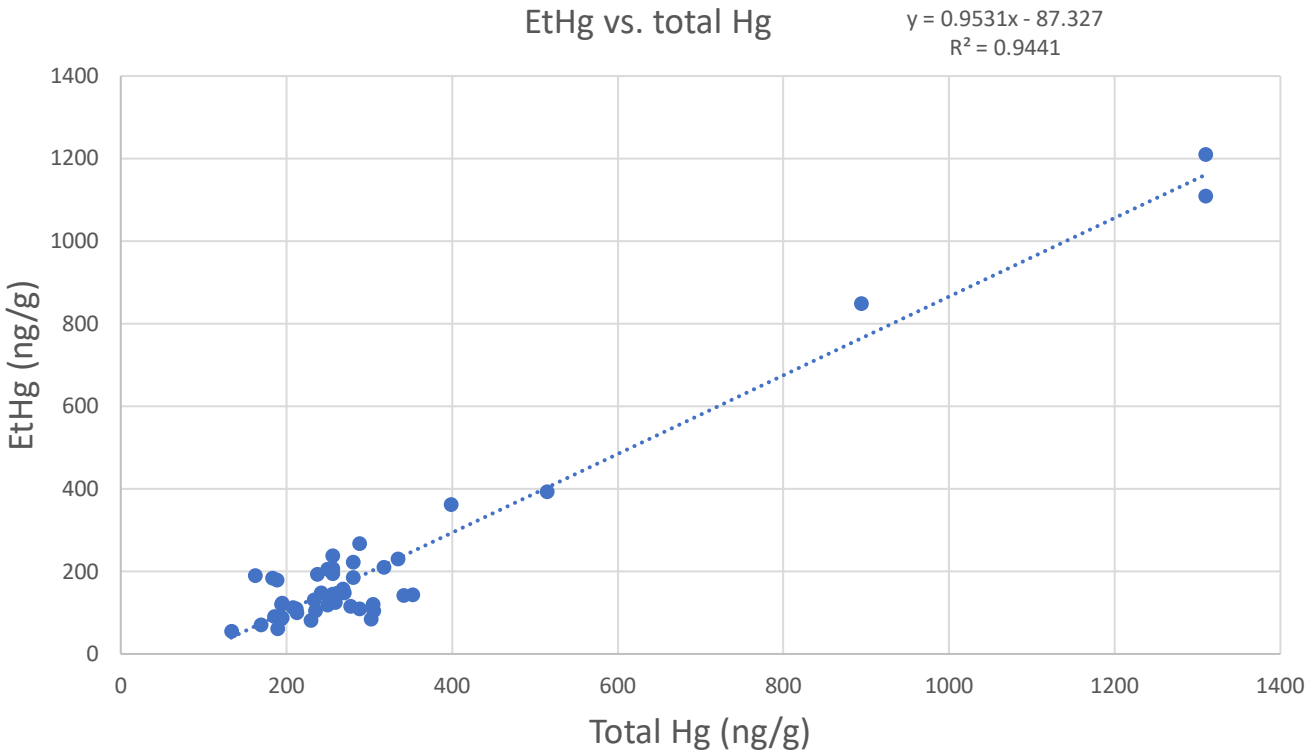
- Fires?
- Mines?
- Free troposphere?

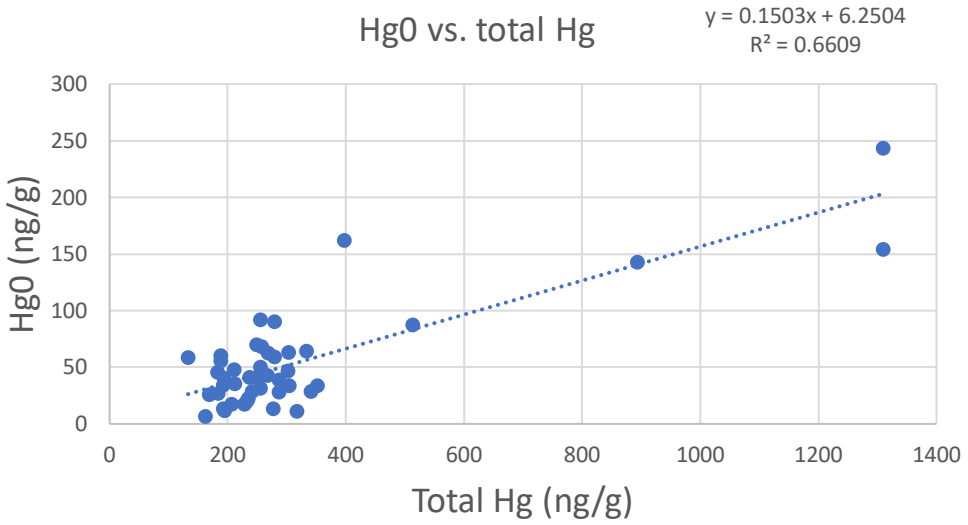
Speciated Hg vs. Total Hg in Lichen at Lake Berryessa

EPA Method 1630 quantifies 4 Hg species

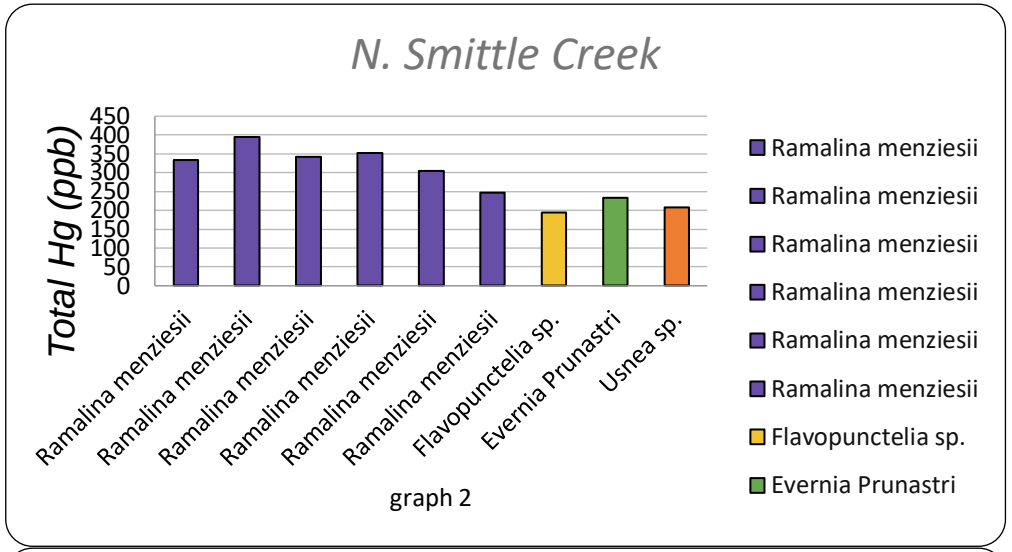




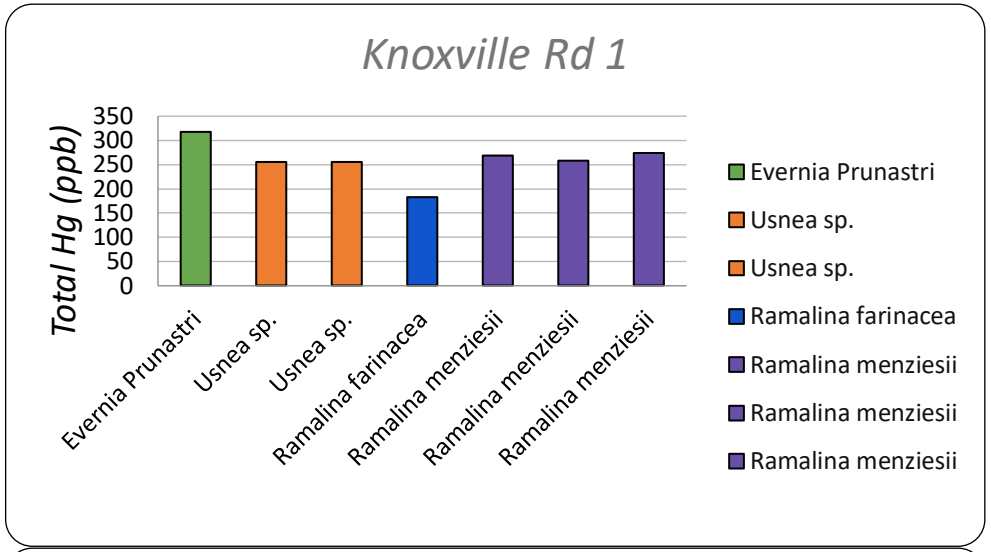


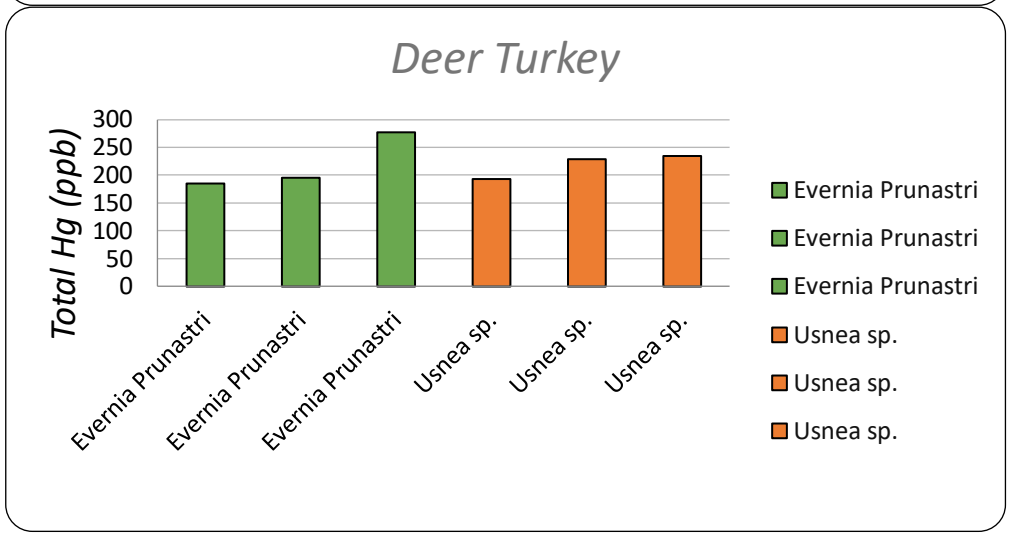


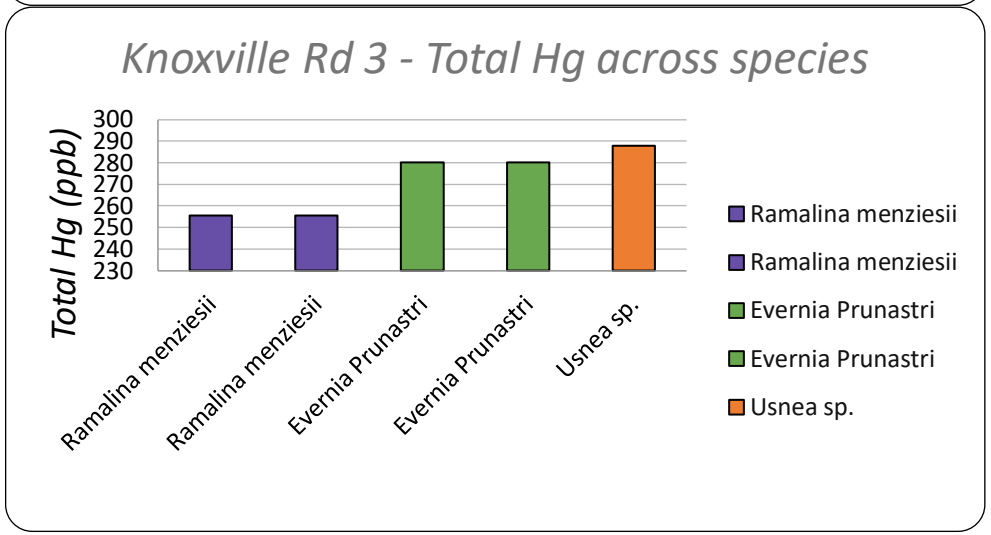
Total Hg as a Function of Species at Four Sites at Lake Berryessa



graph 2

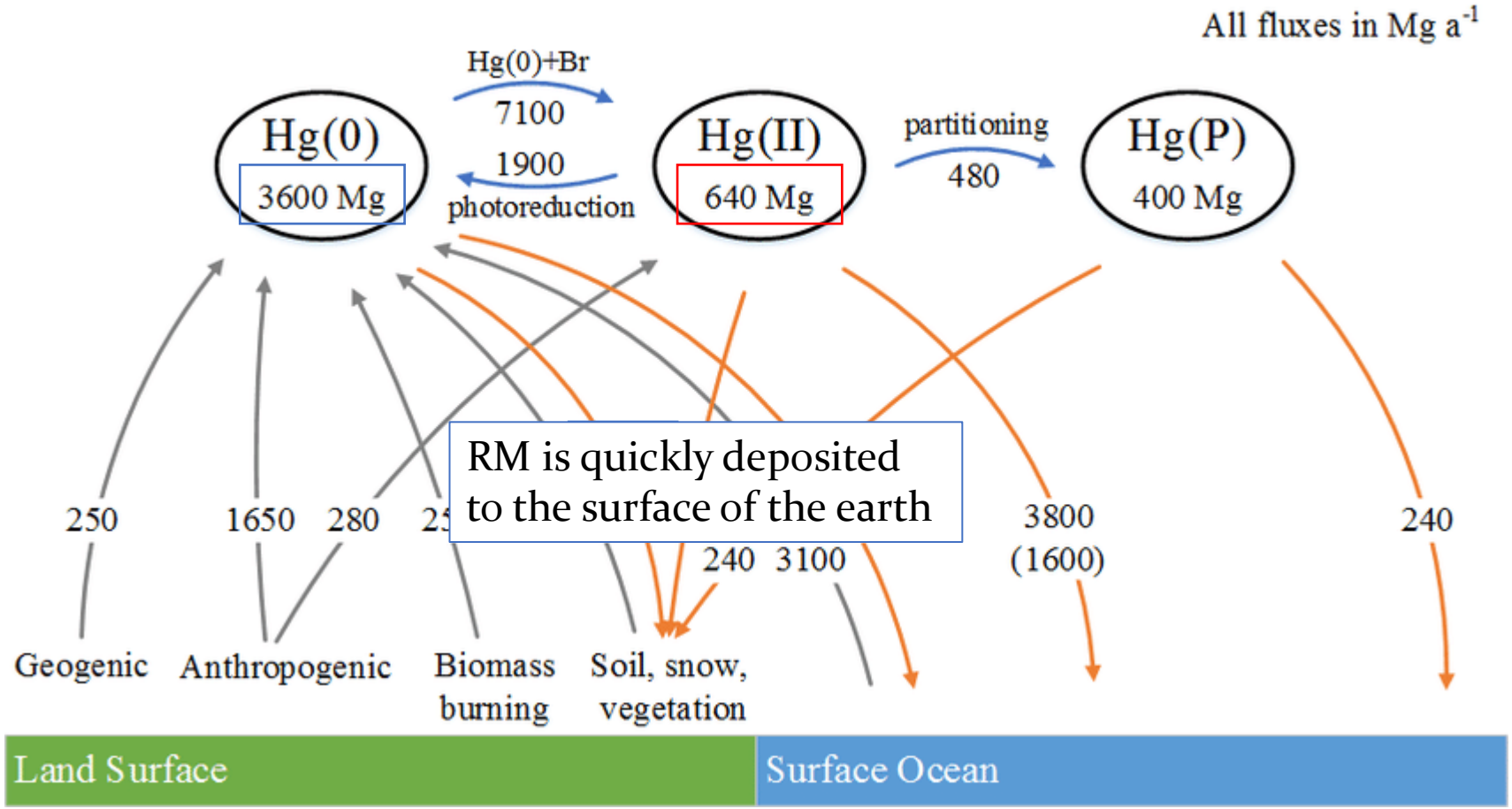






The Importance of Reactive Mercury in Atmospheric Deposition

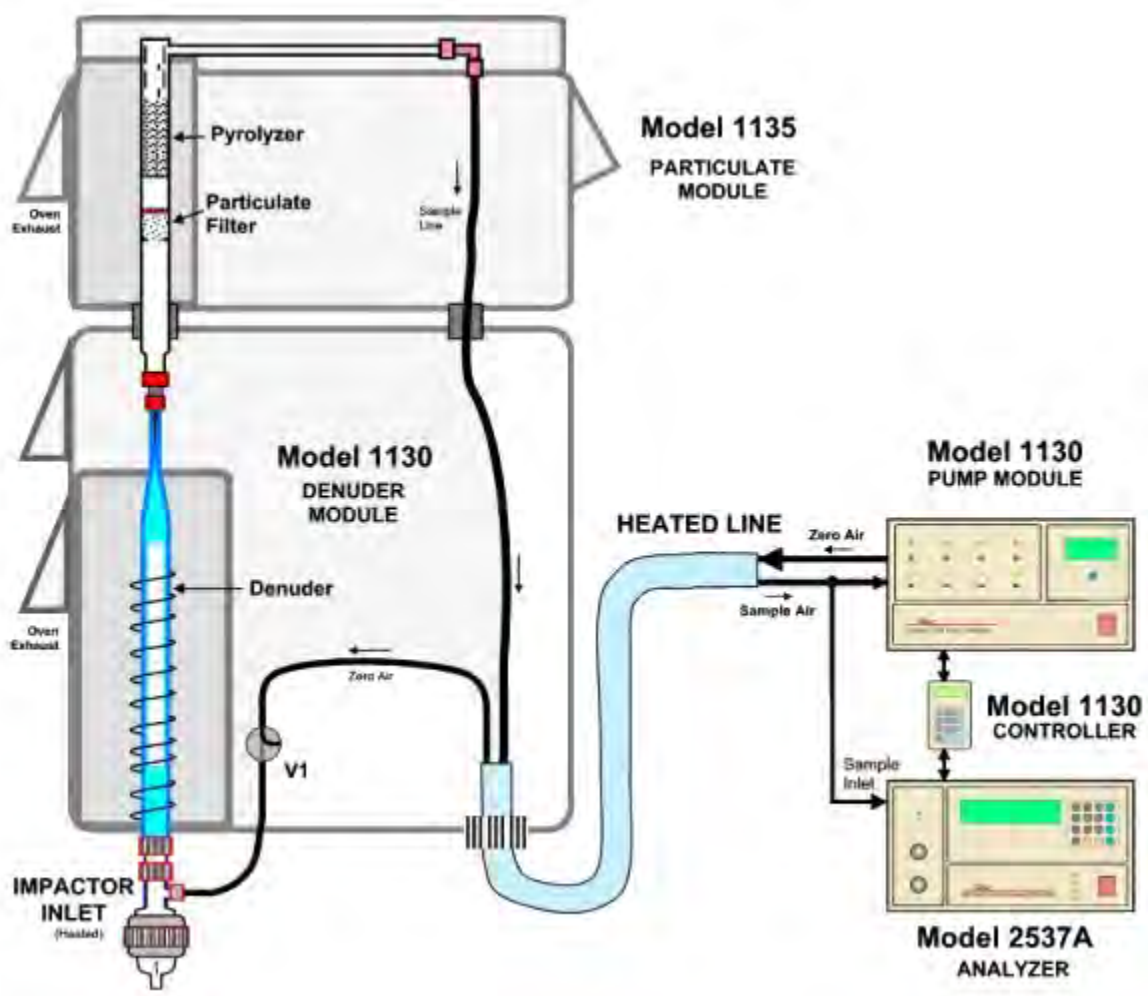
Reactive Mercury (RM) = gaseous Hg(II) + Hg(P)



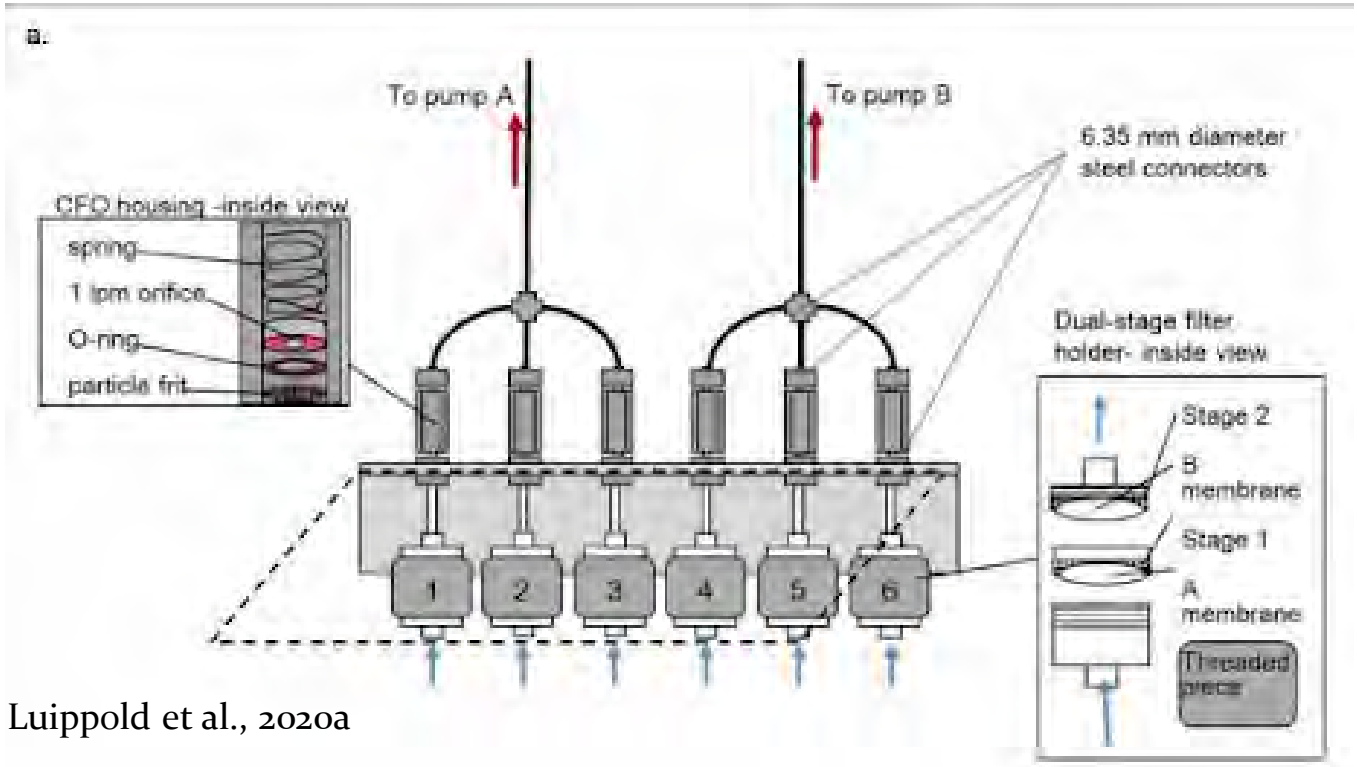
Chen et al., 2014

Traditional Instrumental Analysis of Reactive Mercury (Tekran 1130/1135/2537)

- Artefacts and biases due to water vapor and ozone
- Expensive system (~$100k)
- Difficult to operate
- One instrument per site



New Instrumental Analysis: UNR-RMAS 2.0



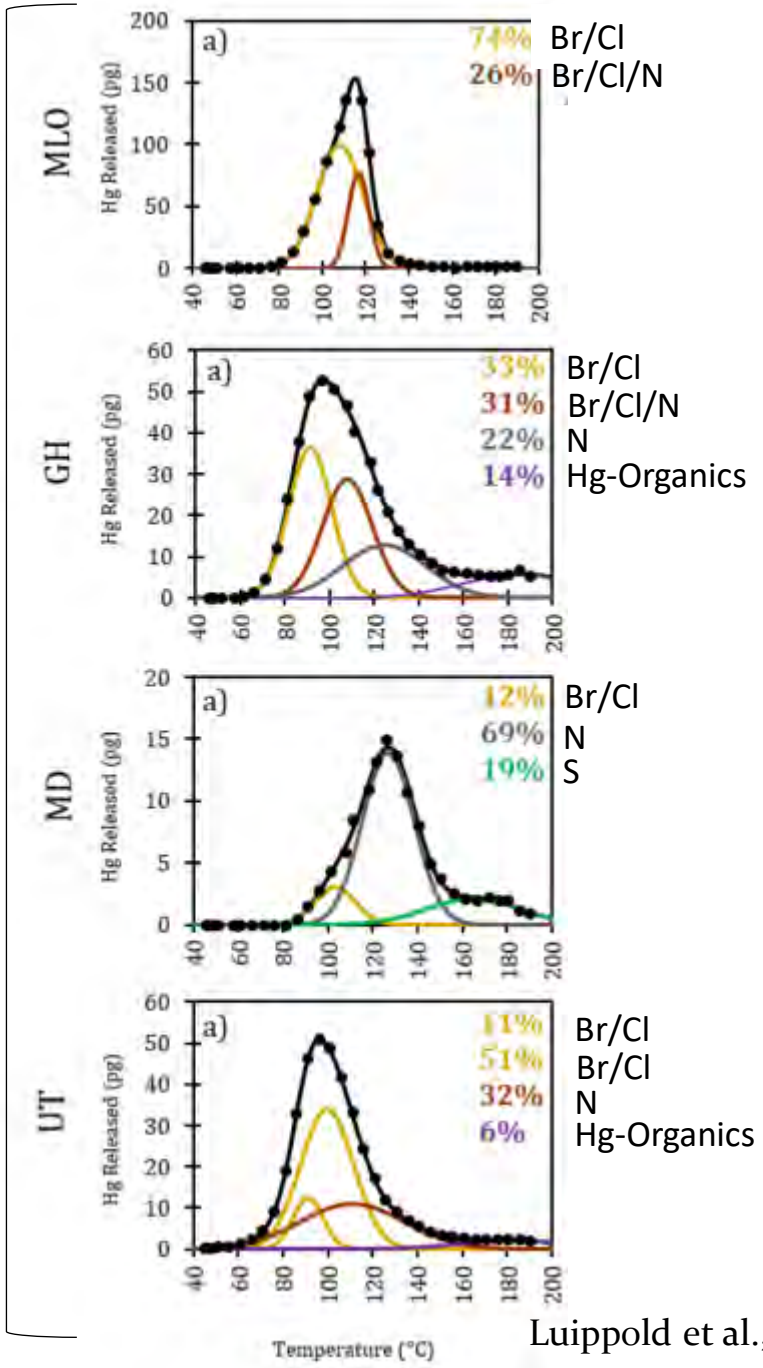
Luippold et al., 2020a

RM Concentration

Nylon and cation-exchange membranes are collected bi-weekly and analyzed for total Hg in the lab.

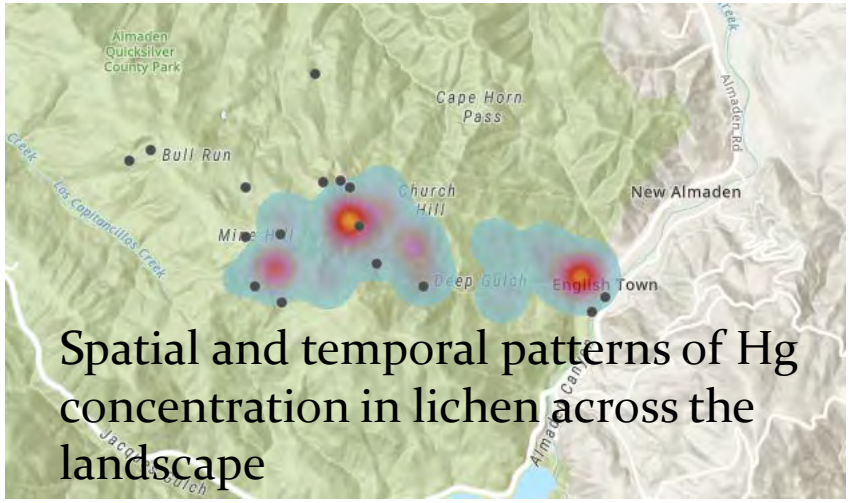
RM Speciation

Different RM compounds are desorbed at different temperatures.



Luippold et al., 2020b

New Idea #1: Calibrate Hg in lichen concentration maps, with atmospheric RM measurements and dry deposition modeling



Spatial and temporal patterns of Hg concentration in lichen across the landscape

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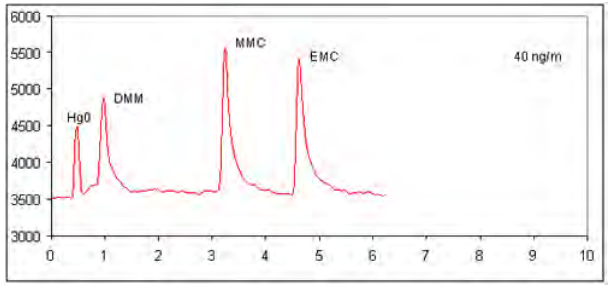
RM concentration measurements at multiple locations + resistance modeling

Landscape scale Hg deposition estimates

New Idea #2: Compare speciated Hg in lichen with atmospheric RM speciation to determine potential sources of Hg deposition



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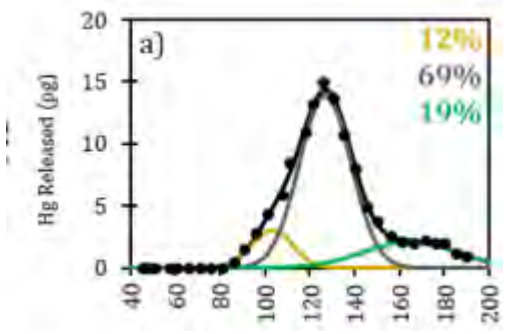
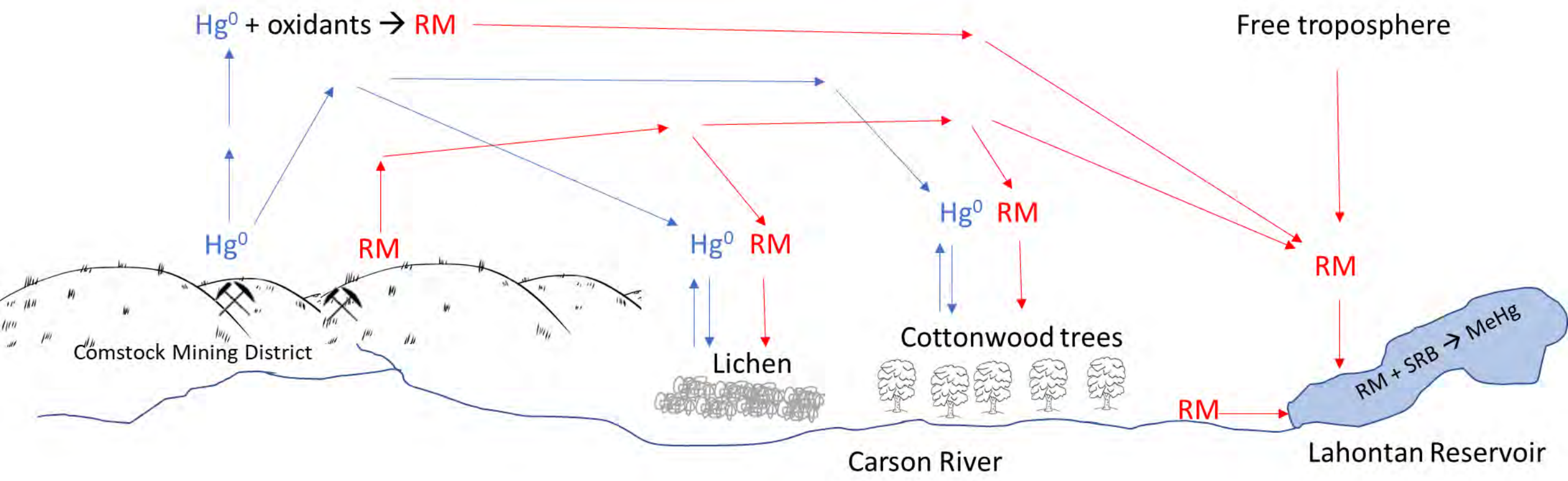


Semi-quantitative assessment of sources of Hg deposition

UCSC/UNR/USBR Collaboration: Assessing the Susceptibility of Reservoirs and Watersheds to Pollution from Historical Mining Sites via the Atmosphere



1) Sample bioindicators in the watershed. 2) Make RM measurements and model dry deposition at two locations.
3) Combine RM and bioindicator Hg data to constrain atmospheric inputs to the reservoir.

Acknowledgements

- Daniel Deeds, Branch Chief, Environmental Monitoring and Assessment, US Bureau of Reclamation
- Mae Gustin, Professor, University of Nevada, Reno
- Belle Zheng, Masters Student, UC Santa Cruz
- Tarabryn Grismer, Undergraduate Student, UC Santa Cruz

Tarabryn with the lichen picker at Lake Berryessa