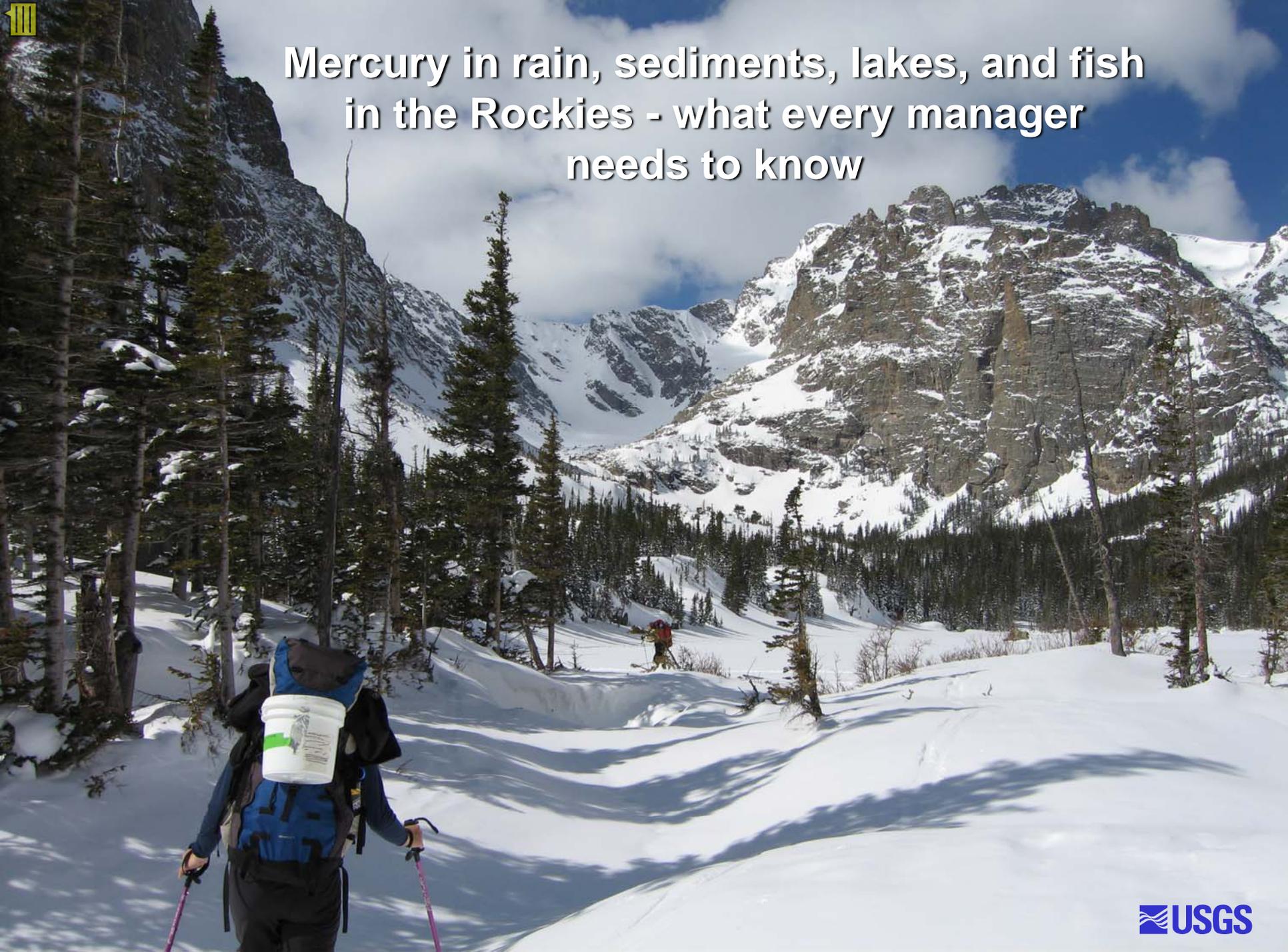




Mercury in rain, sediments, lakes, and fish in the Rockies - what every manager needs to know



Sources of Atmospheric Mercury

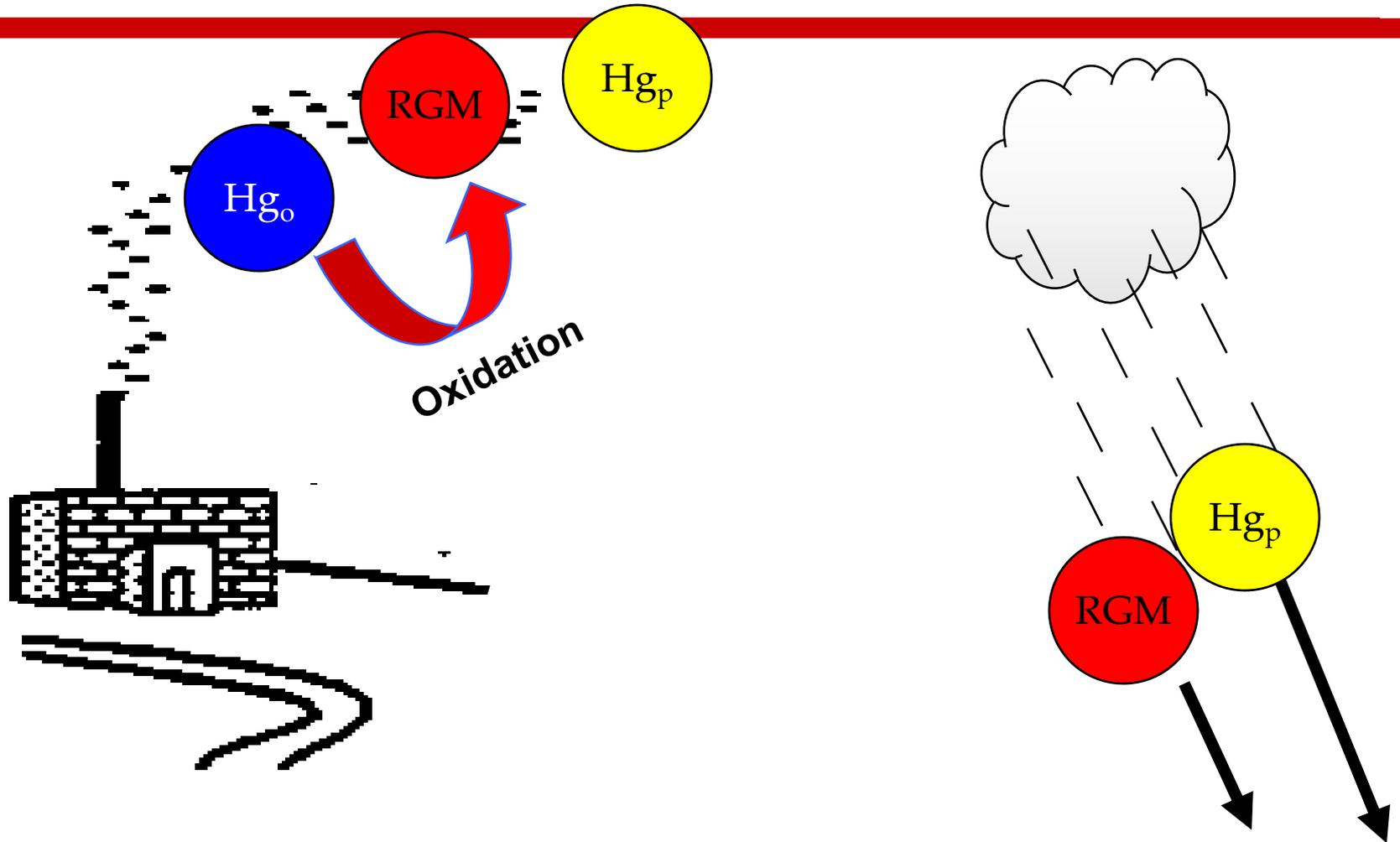
Anthropogenic (60-75%)

- Fossil fuel combustion
(50% from coal-fired power plants)
- Medical and municipal waste incineration
- Chloro-alkali production
- Mining
- Cement production

Natural (25-30%)

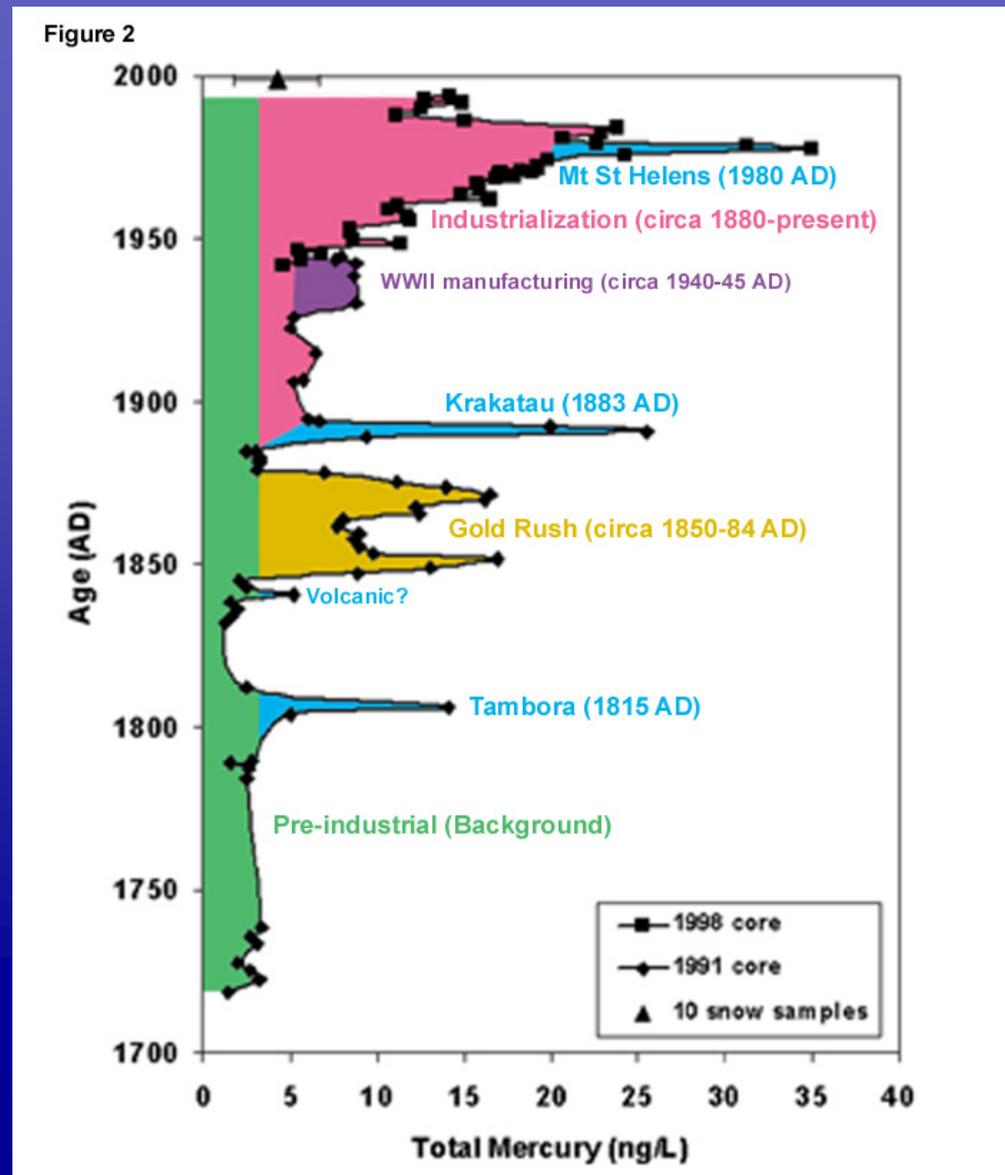
- Volcanoes and geothermal vents
- Emissions from mercury-containing rocks and soils (e.g. HgS)
- Emissions from vegetation and oceans
- Forest fires

How Mercury is Deposited from Atmosphere



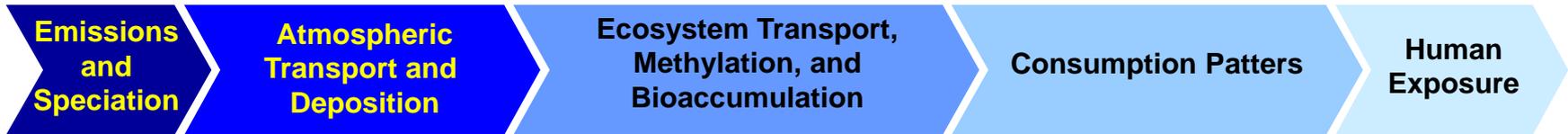
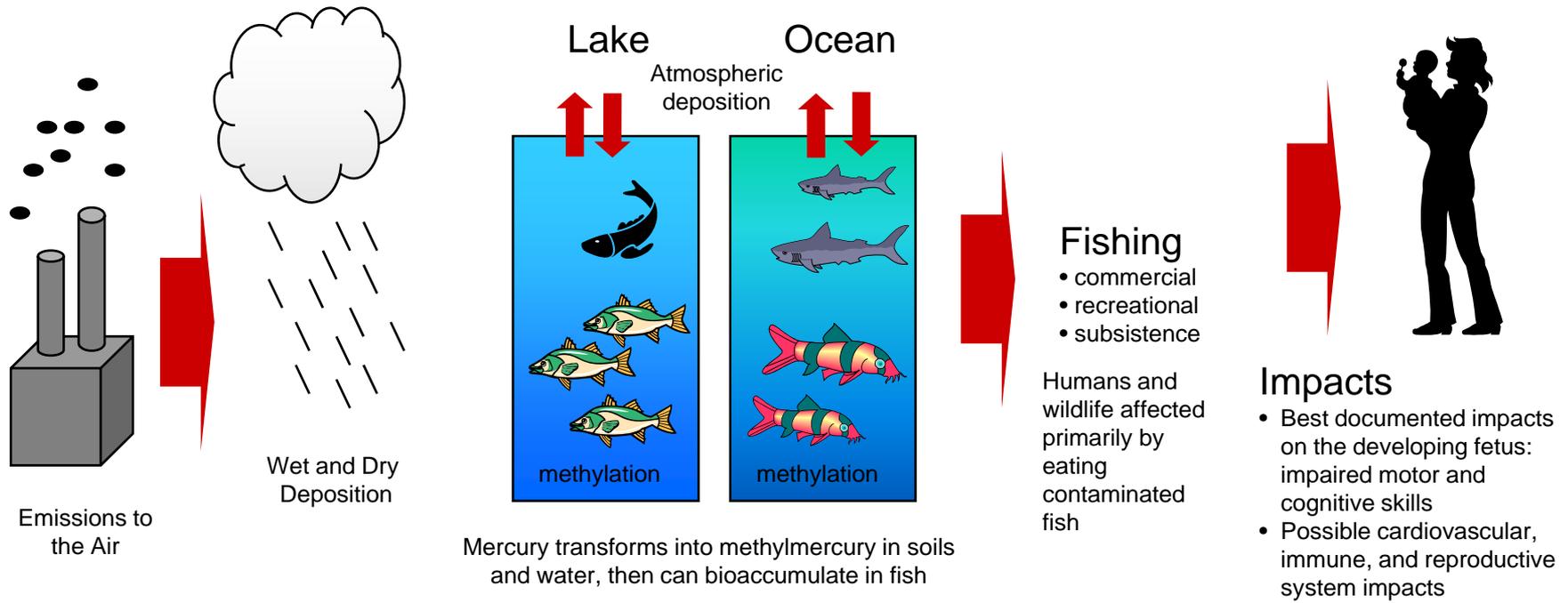
Historical Hg deposition inferred from ice core record

- Fremont Glacier in Wyoming, 4,000 m elevation
- Better temporal resolution than lake-sediment cores
- 70% of Hg-T deposition during last 100 years from anthropogenic sources
- Peak flux (1984) = 20x background



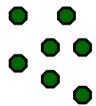
-Schuster and others (ES&T, 2002)

Pathways of mercury exposure to humans

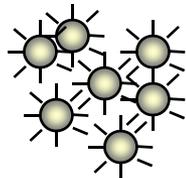


Bioaccumulation

- Methylmercury (CH_3Hg^+) is the most toxic form of Hg and the form that is most easily bioaccumulated in organisms.
- Conversion to MeHg is primarily carried out by sulfate-reducing bacteria that live in anoxic environments (e.g. wetlands and lake-bottom sediments).
- Methylmercury accumulates through aquatic food webs.
 - Highest levels are in large predatory fish and fish-eating (piscivorous) animals.
 - Measured MeHg levels in large fish are 1 – 10 million fold higher than measured levels in water.
- Extent of bioaccumulation depends on many factors including the nature and length of the food chain and water chemistry characteristics.



**Phytoplankton
(algae)**



**Zooplankton
and Shellfish**



**Small
forage
fish**

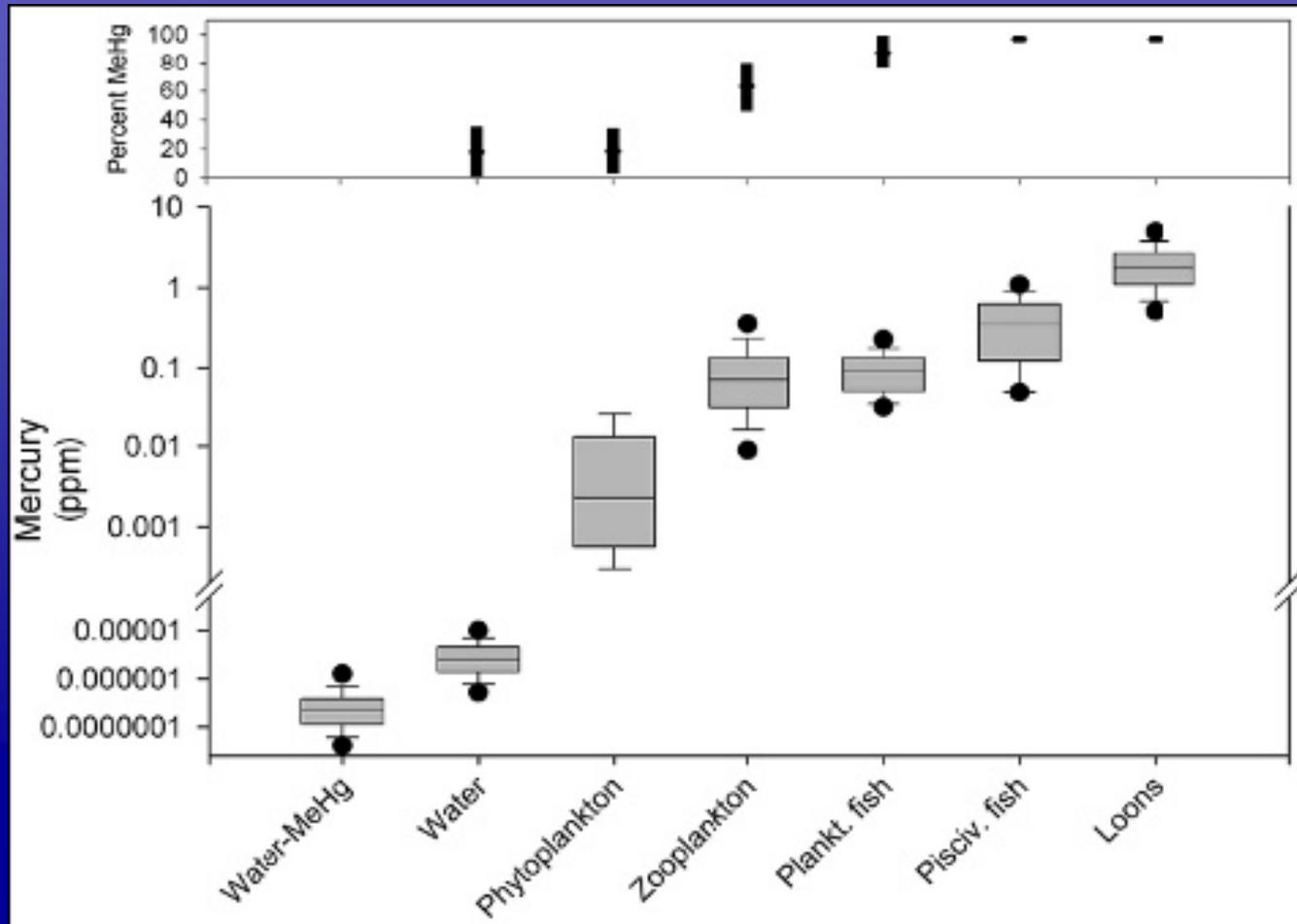


**Predatory
fish**

Less methylmercury

More methylmercury

Mercury in the food chain, northeastern U.S.

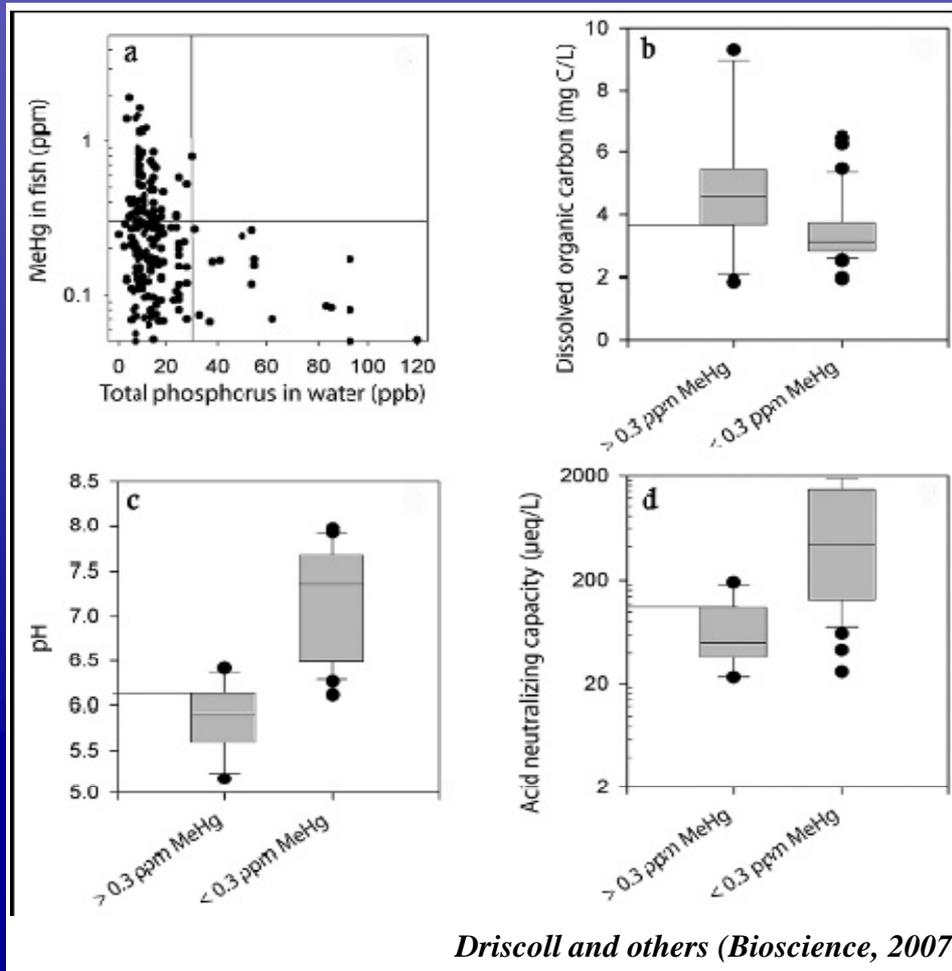


Driscoll and others (Bioscience, 2007)

Indicators of Mercury Sensitivity

- Deposition is only one factor affecting the levels of mercury in fish.
- Water bodies vary substantially in the extent to which inorganic mercury is converted to MeHg.
- Factors that can affect methylation include:
 - Water quality (DOC, pH, ANC, total phosphorus, sulfate)
 - Human land-use patterns
 - Zooplankton density
 - Percent of Wetlands or other hydric soils
 - Wetting and drying of lake sediments (reservoir operations)

Relations between Hg and chemical characteristics of lakes in the northeastern U.S.





Weather Station in Andrews Meadow, Loch Vale Watershed



Mercury Studies

- Atmospheric Deposition
 - Snowpack (RMS and WACAP)
 - Bulk Deposition in Loch Vale Watershed
- Surface Water
 - Loch Vale Watershed
 - Upper Big Thompson Watershed
- Sediment
 - Lake Sediment Cores from ROMO and GLAC
- Fish Tissue
 - Rocky Mountain National Park (NPS & FWS)

Mercury Measurements

Total Mercury (sum of all species)

- majority in streams and precipitation is present as inorganic mercury (Hg^{+2})
- mostly measured in unfiltered samples

Methyl Mercury (CH_3Hg^+)

- dominant form in fish tissue
- more expensive analysis
- mostly measured in unfiltered samples

Mercury Laboratories

- Water (cold vapor atomic fluorescence spectroscopy)
 - USGS Mercury Laboratory, Wisconsin
THg and MeHg (DL=.04ng/L)
 - USGS Research Laboratory, Boulder
THg (DL=0.4 ng/L)
 - Frontier Geosciences
THg and MeHg (DL=.04 ng/L)
- Sediment
USGS Research Laboratory, Boulder
- Fish Tissue
 - Colorado Veterinary Diagnostic Laboratory, CSU
 - USGS Research Laboratory, Boulder

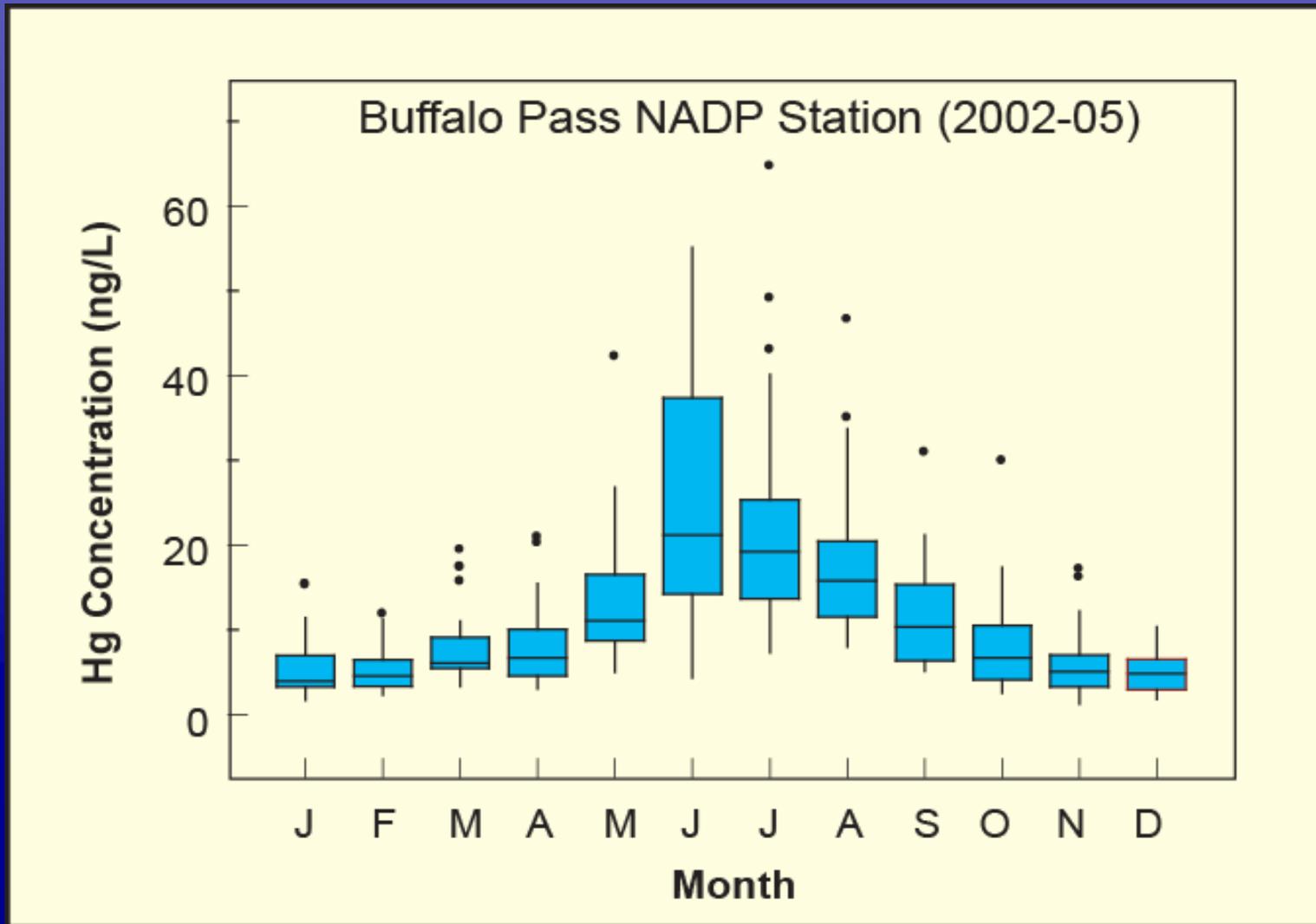
Results

- Concentration in Precipitation
- Deposition Estimates
- Sediment Cores
- Stream-Water Concentrations & Fluxes
- Fish Tissue

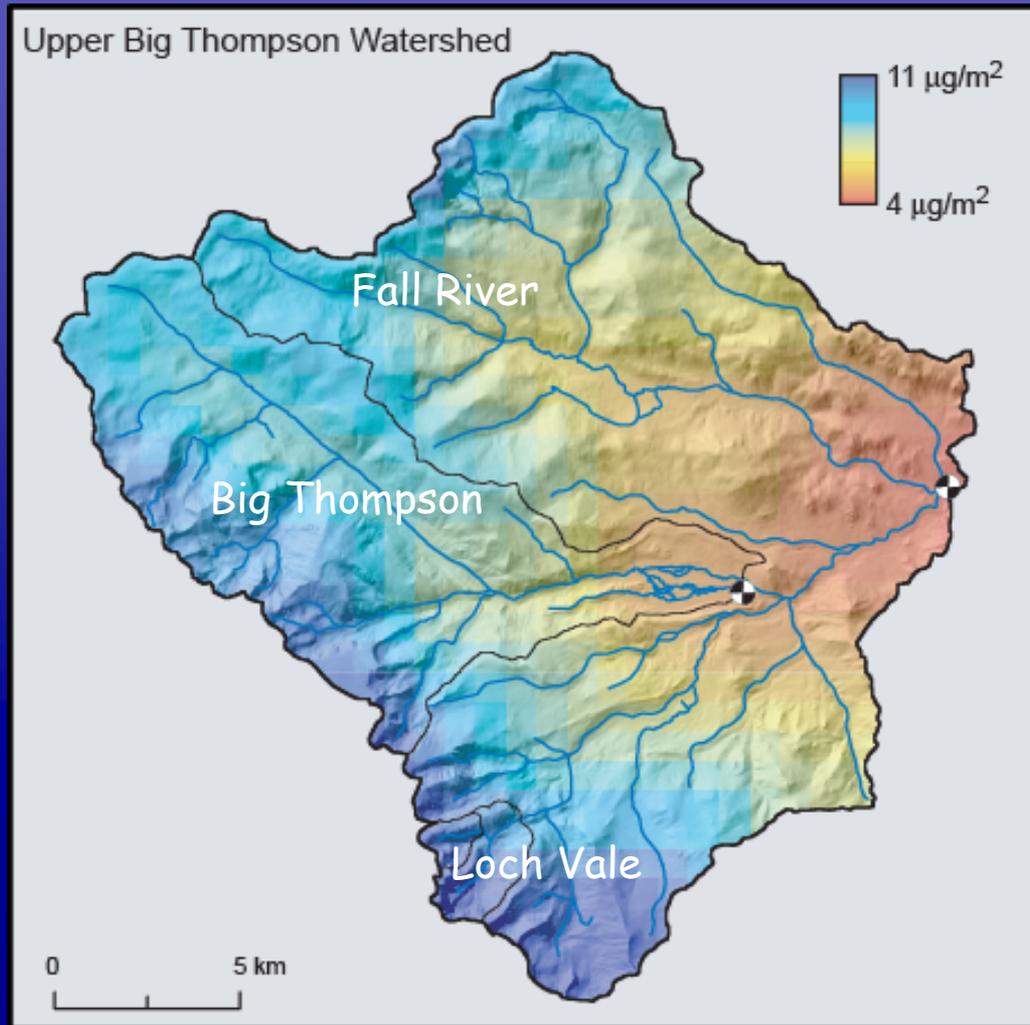


Loch Vale Watershed

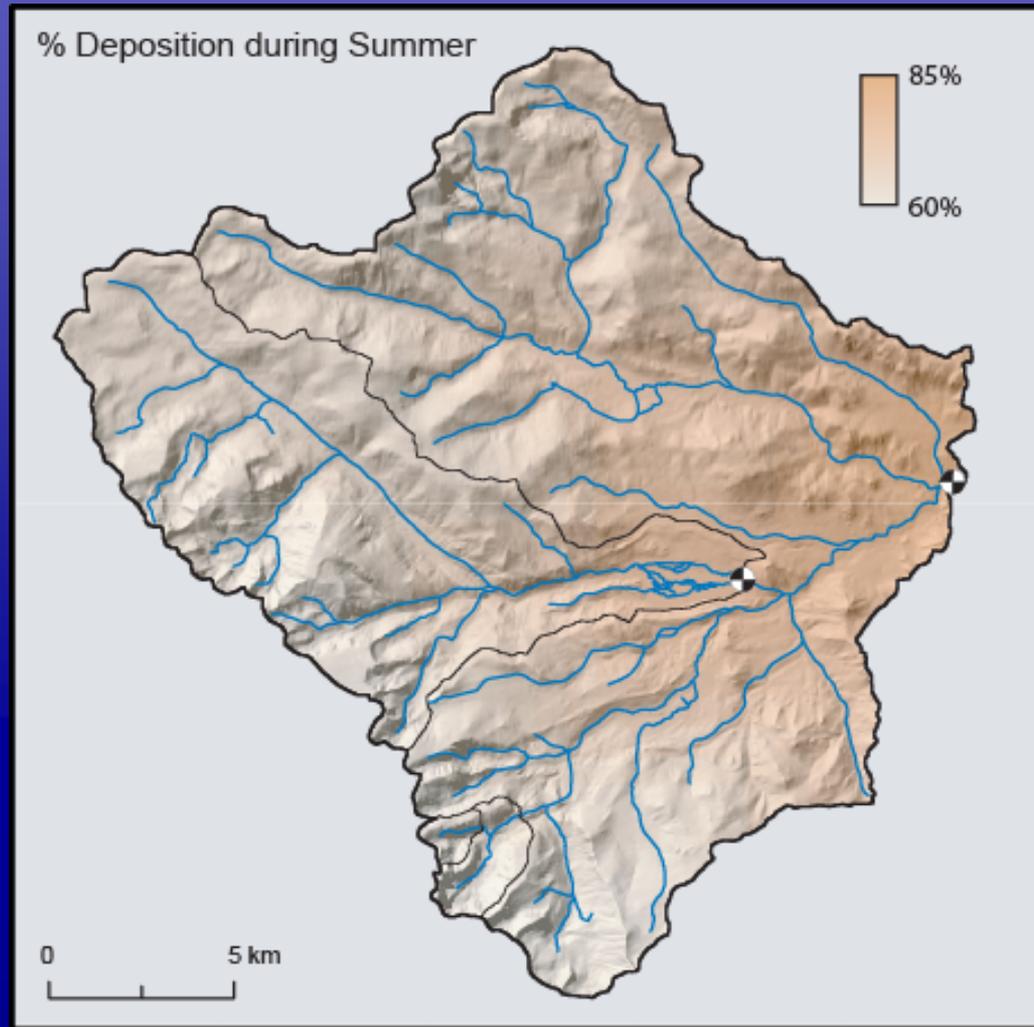
Concentration Range in Precipitation



Annual Deposition for 2005 Upper Big Thompson Watershed

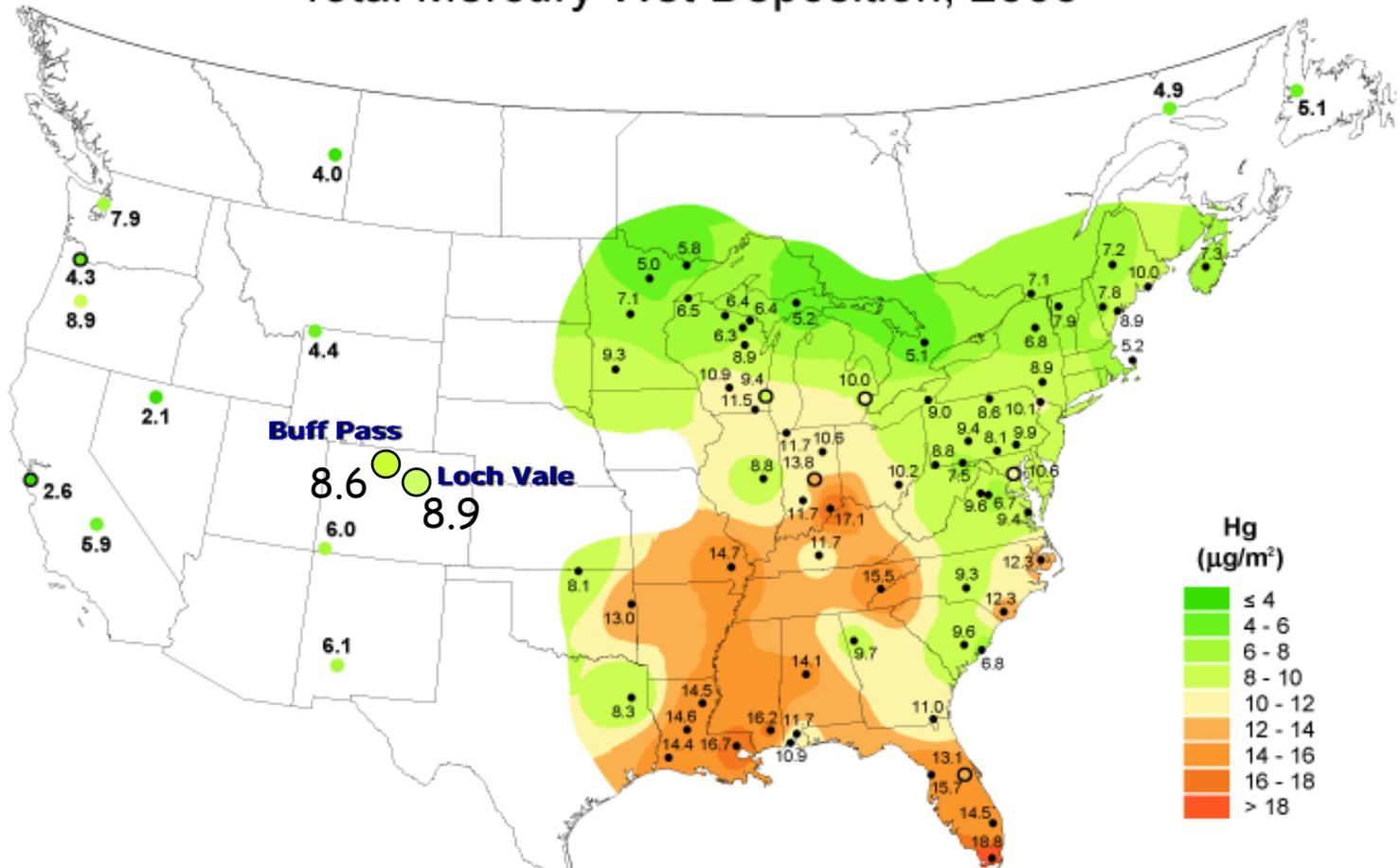


Summer Deposition > Winter Deposition



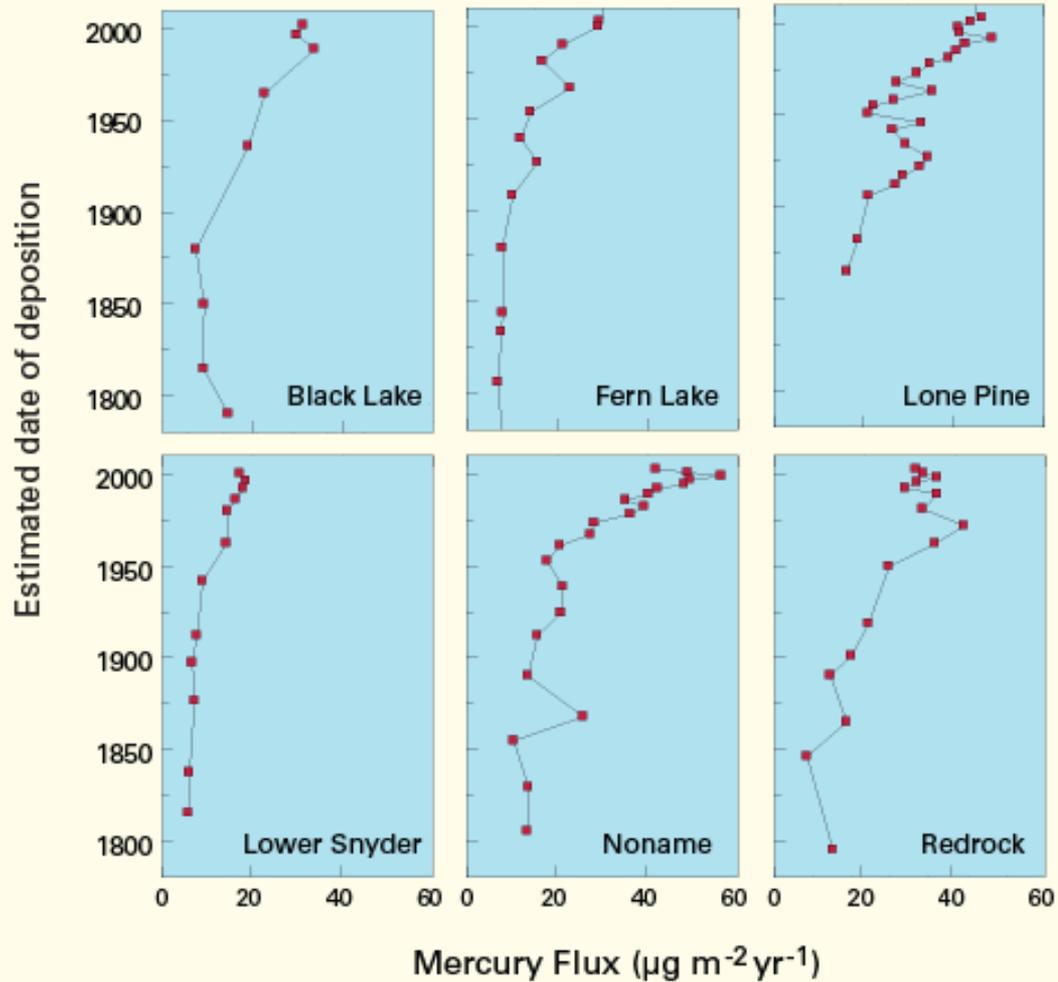
Mercury deposition relative to other sites

Total Mercury Wet Deposition, 2006



National Atmospheric Deposition Program/Mercury Deposition Network

Historical Hg Deposition Inferred from Sediment Cores

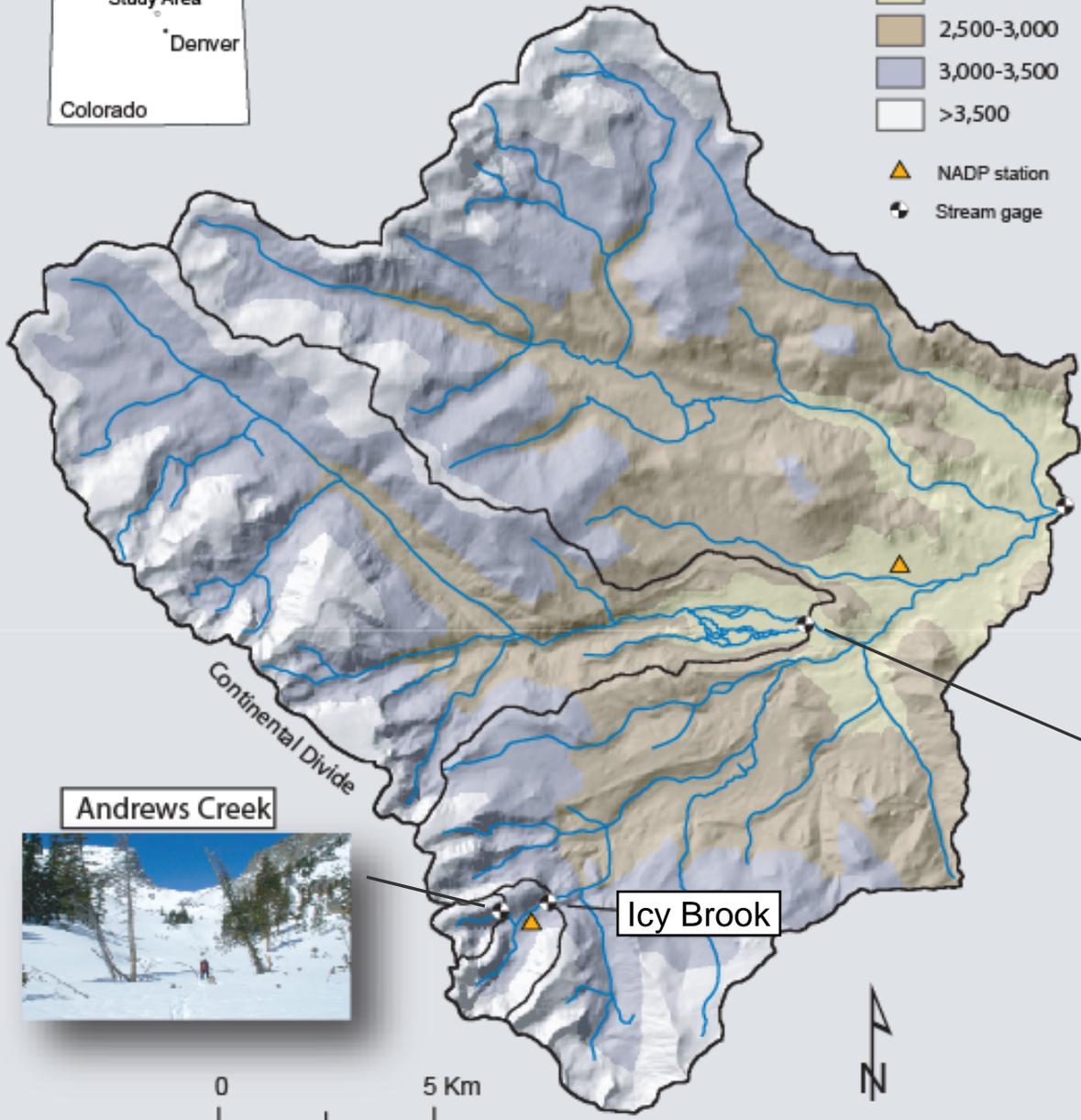
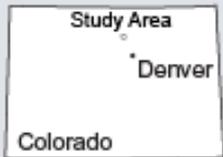


- Flux ratio of 3 (modern/baseline)
- Similar to other remote lakes in US
- Implies source of Hg is regional
- Declines in recent sediments



Upper Big Thompson River

- Elevation (meters)
- <2,500
 - 2,500-3,000
 - 3,000-3,500
 - >3,500
- ▲ NADP station
- ⊙ Stream gage

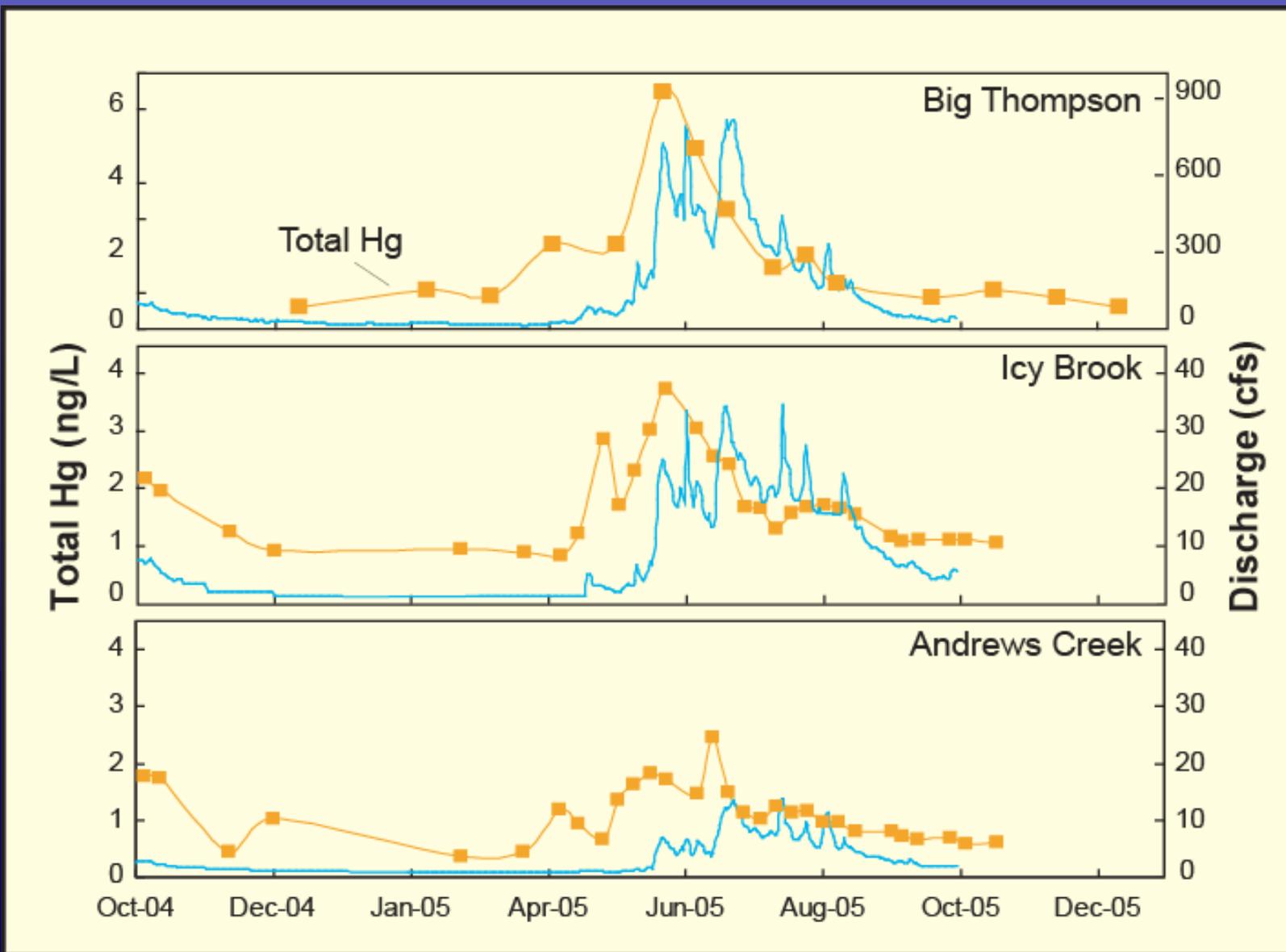


Big Thompson River at Estes Park

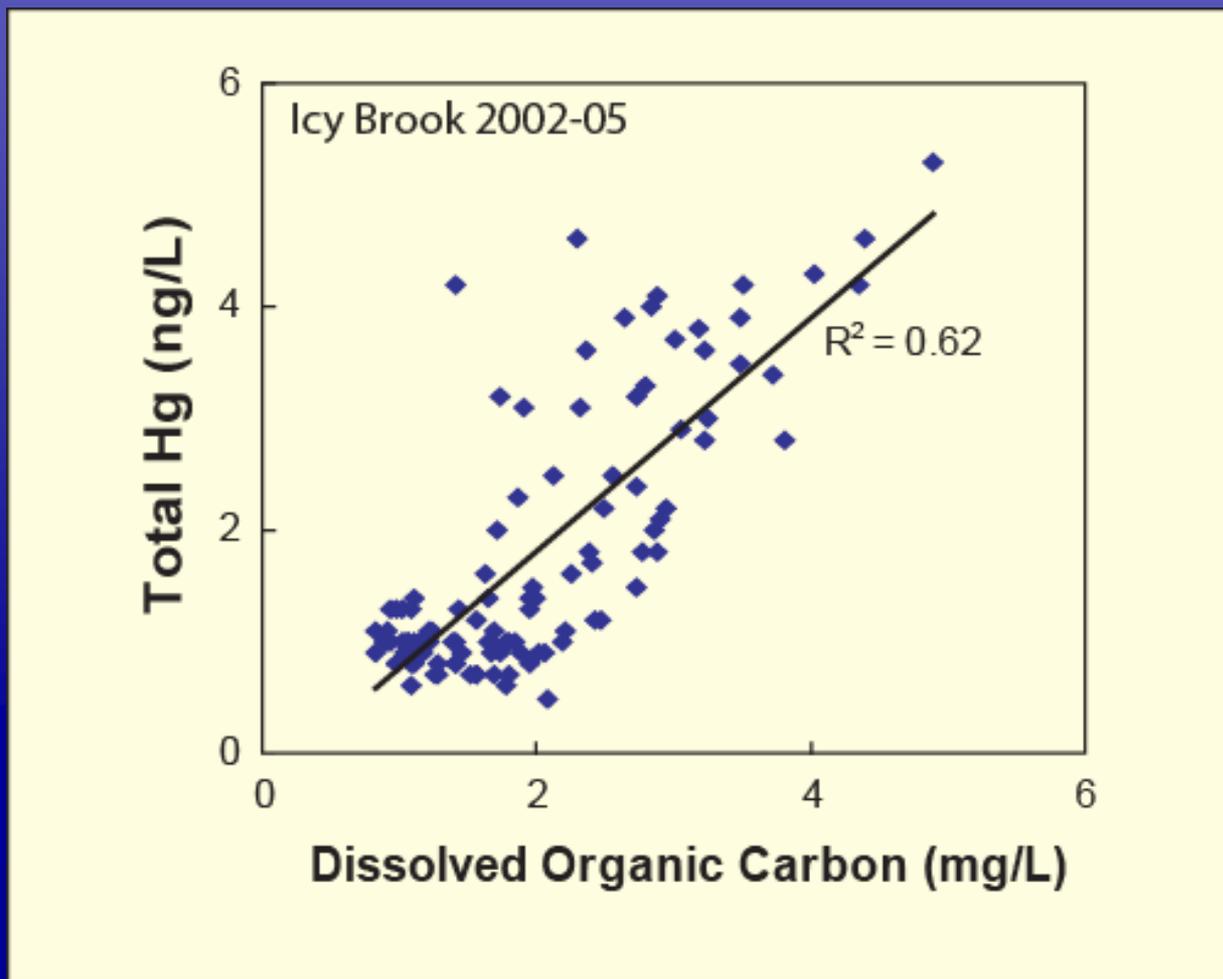


Big Thompson River at Moraine Park

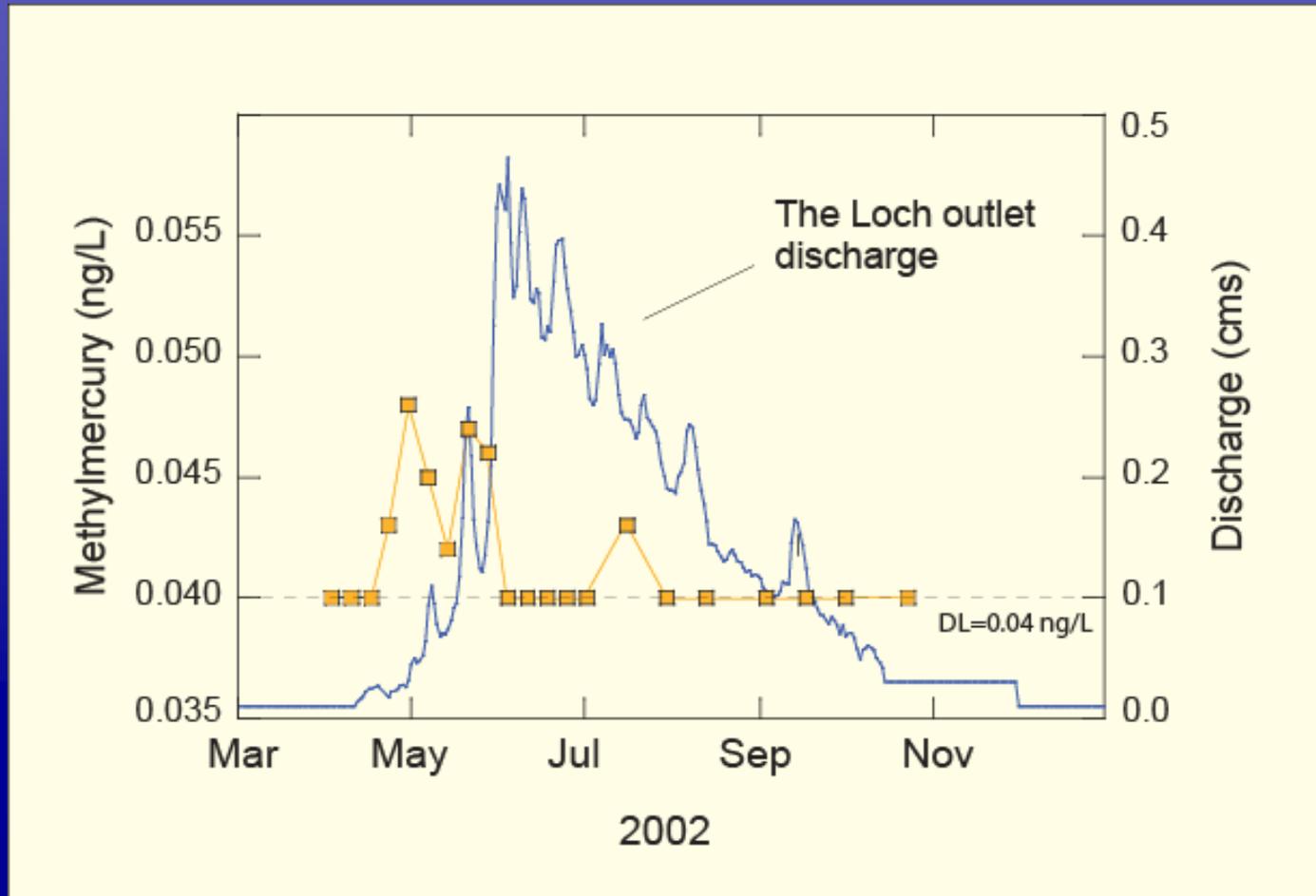
Total Mercury in Streams



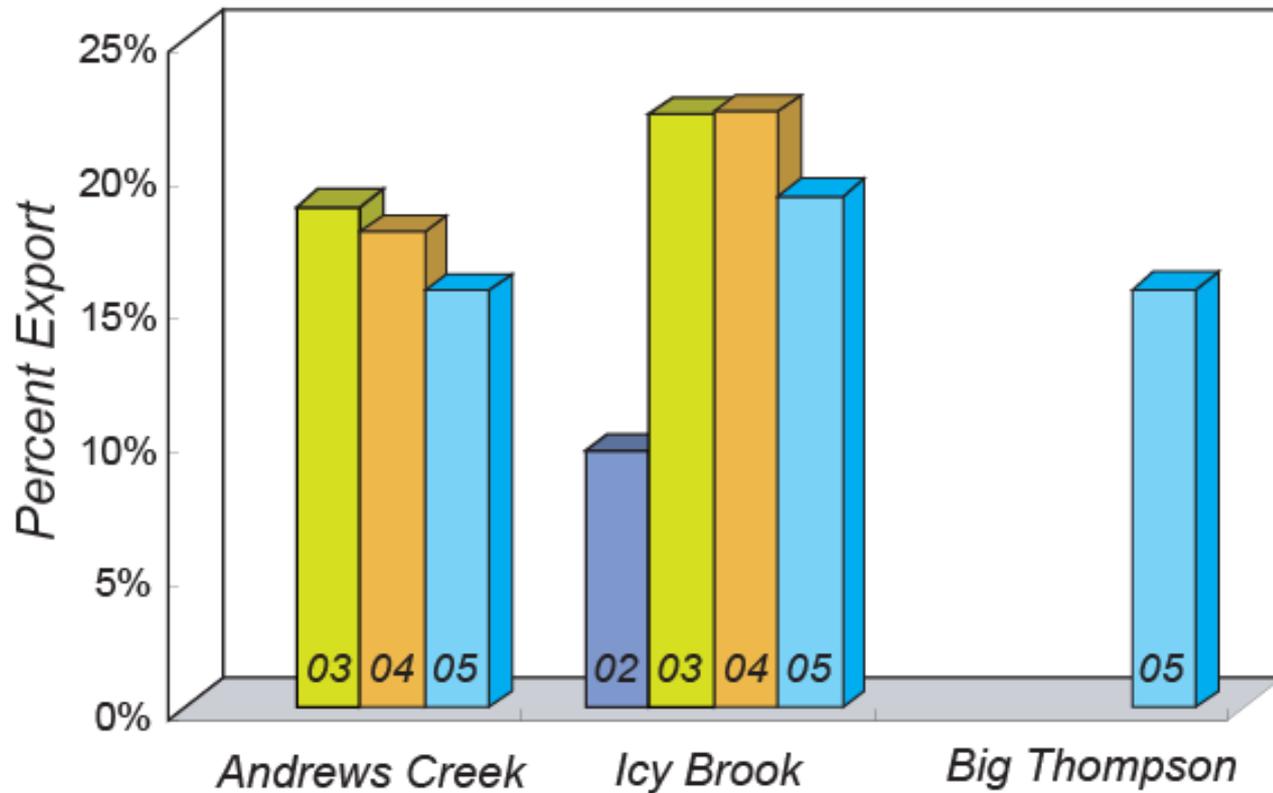
Mercury transport controlled by DOC



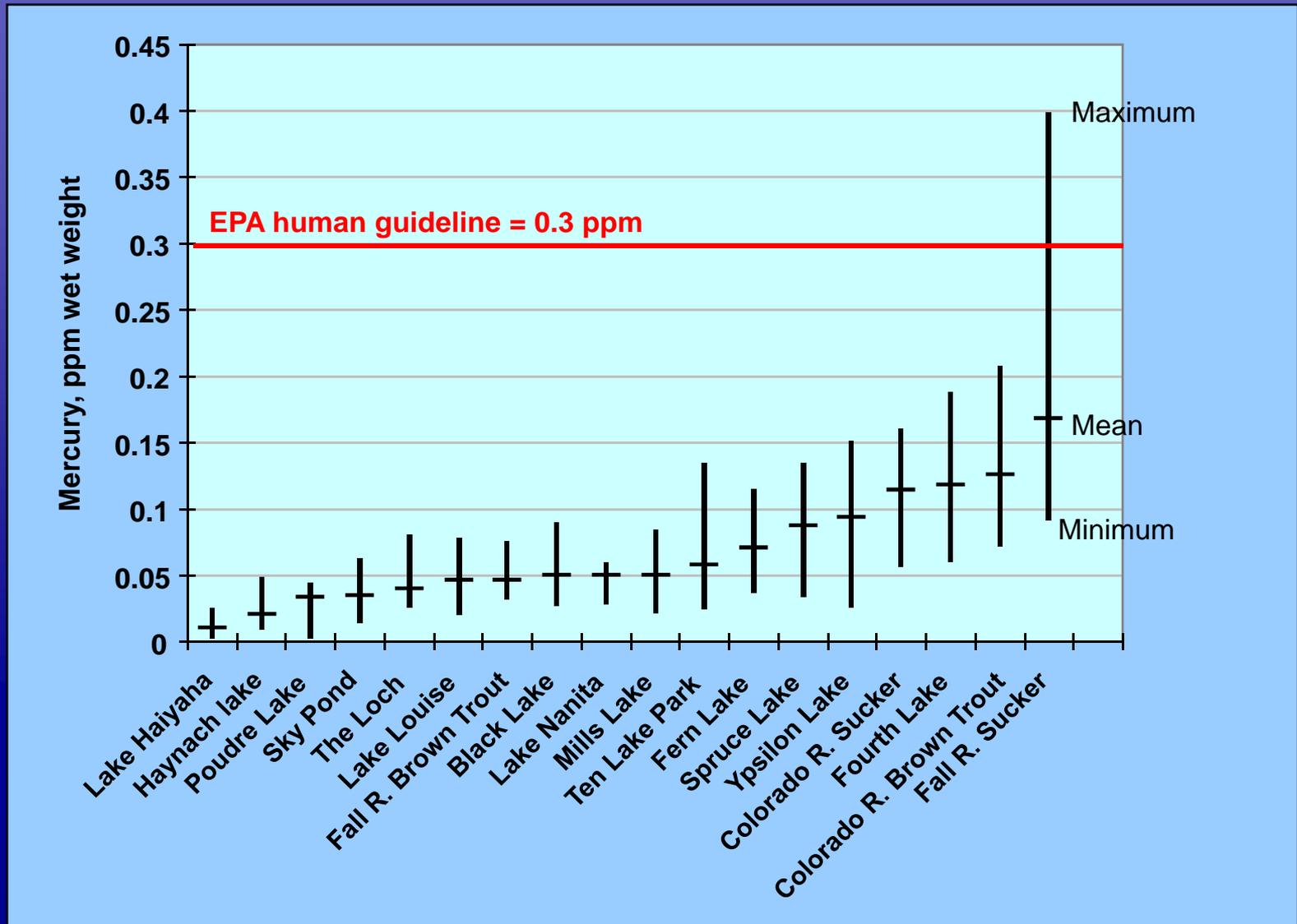
MeHg concentrations low in Loch Vale



Most atmospherically deposited mercury is retained in the watershed



Hg in Fish Tissue, Rocky Mountain National Park



Summary

- Most deposition is occurring in high-elevation areas
- Sediment cores suggest anthropogenic inputs have triples Hg deposition to high-elevation areas
- Less than 20% of atmospherically deposited mercury is exported by streams
- Transport of mercury in snowmelt-dominated streams is controlled by flushing of soils at the onset of snowmelt