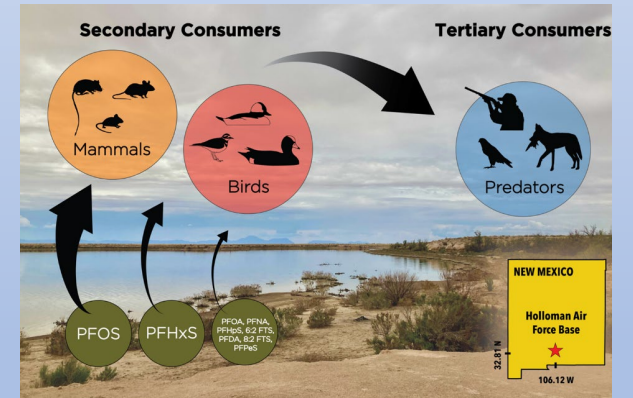


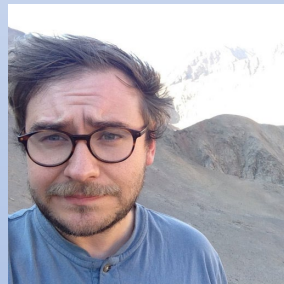
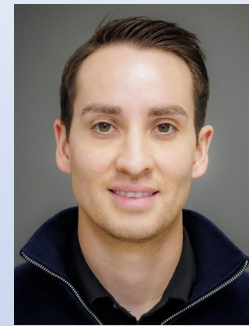
Assessing PFAS contamination levels and toxicity in the wildlife of Holloman Lake, New Mexico: Key Insights from Five Years of Research.

Jean-Luc E. Cartron

Museum of Southwestern Biology and Biology Department, University of New Mexico



UNM Research Team



Above: Jean-Luc E. Cartron, Jonathan L. Dunnum, Mariel Campbell, Andrew B. Johnson, Marcus Garcia, John Ragsdale; below: Joseph A. Cook, Christopher C. Witt, Chauncey Gadek, Danielle J. Parsons, Eve Rowland, Teresa M. Garcia

Museum of Southwestern Biology Division of Mammals

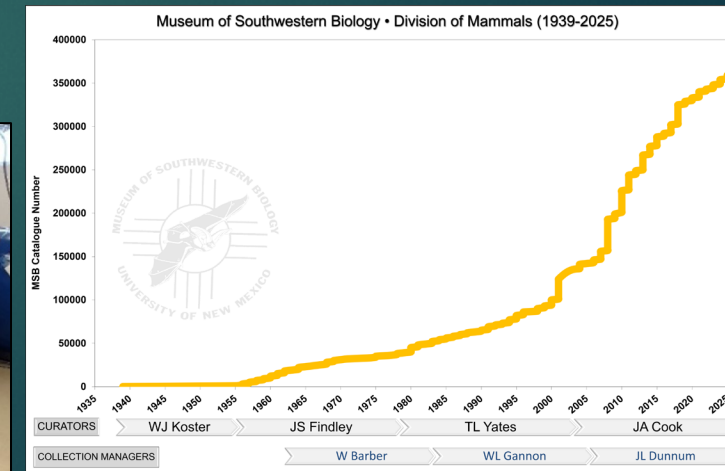
Research Natural History collection/biorepository



- Holdings: 355,000 specimens
- Spatial coverage: Global
- Temporal span: 1880-2026
- Taxonomic coverage: >1,600 species
- 2nd largest in world



- Largest collection of mammalian tissues
 - >250,000 individuals
 - >700,000 cryovials
- Fastest growing
 - Grown by about 250K over past 30 years
 - Large part due to collaborations / archiving for agencies



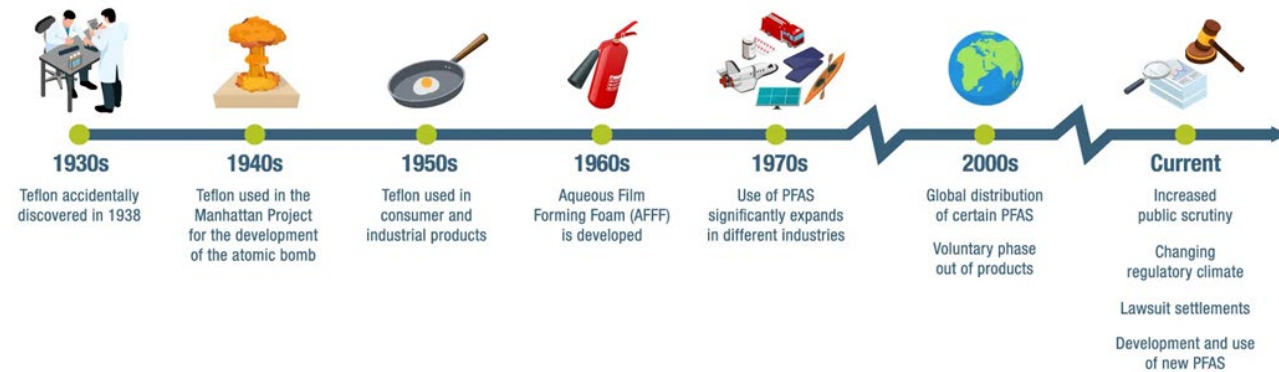
Environmental persistence

Bioaccumulation

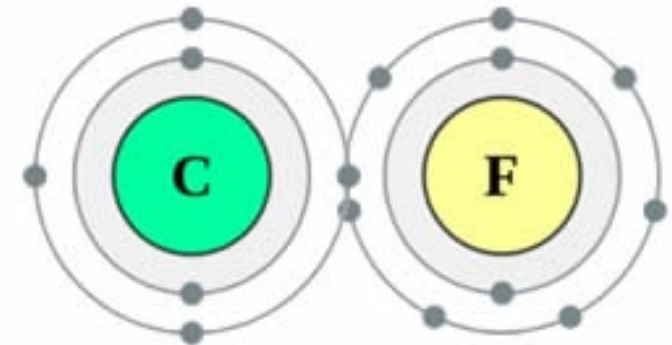
Toxicity



PFAS Development...

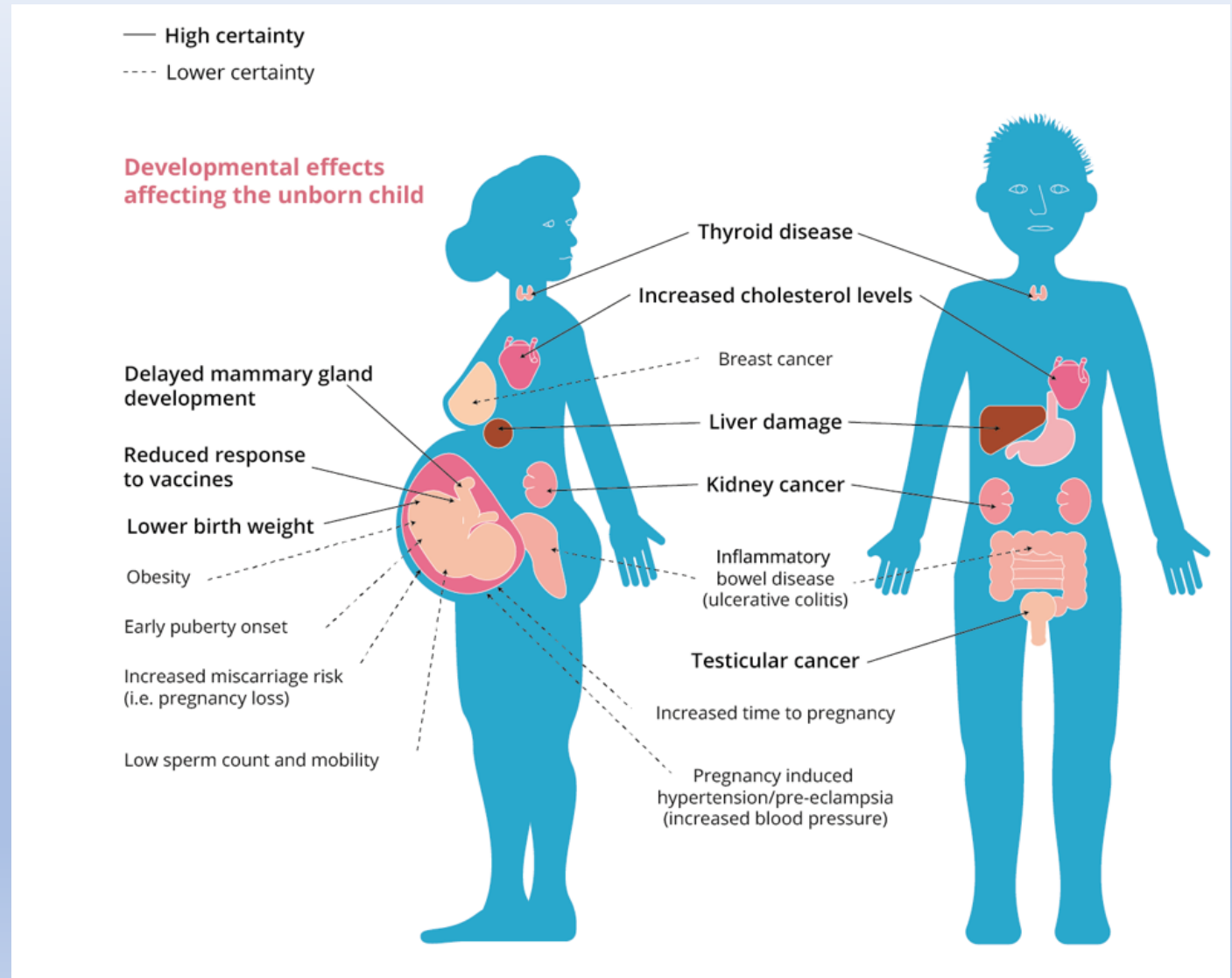


...and Evolution

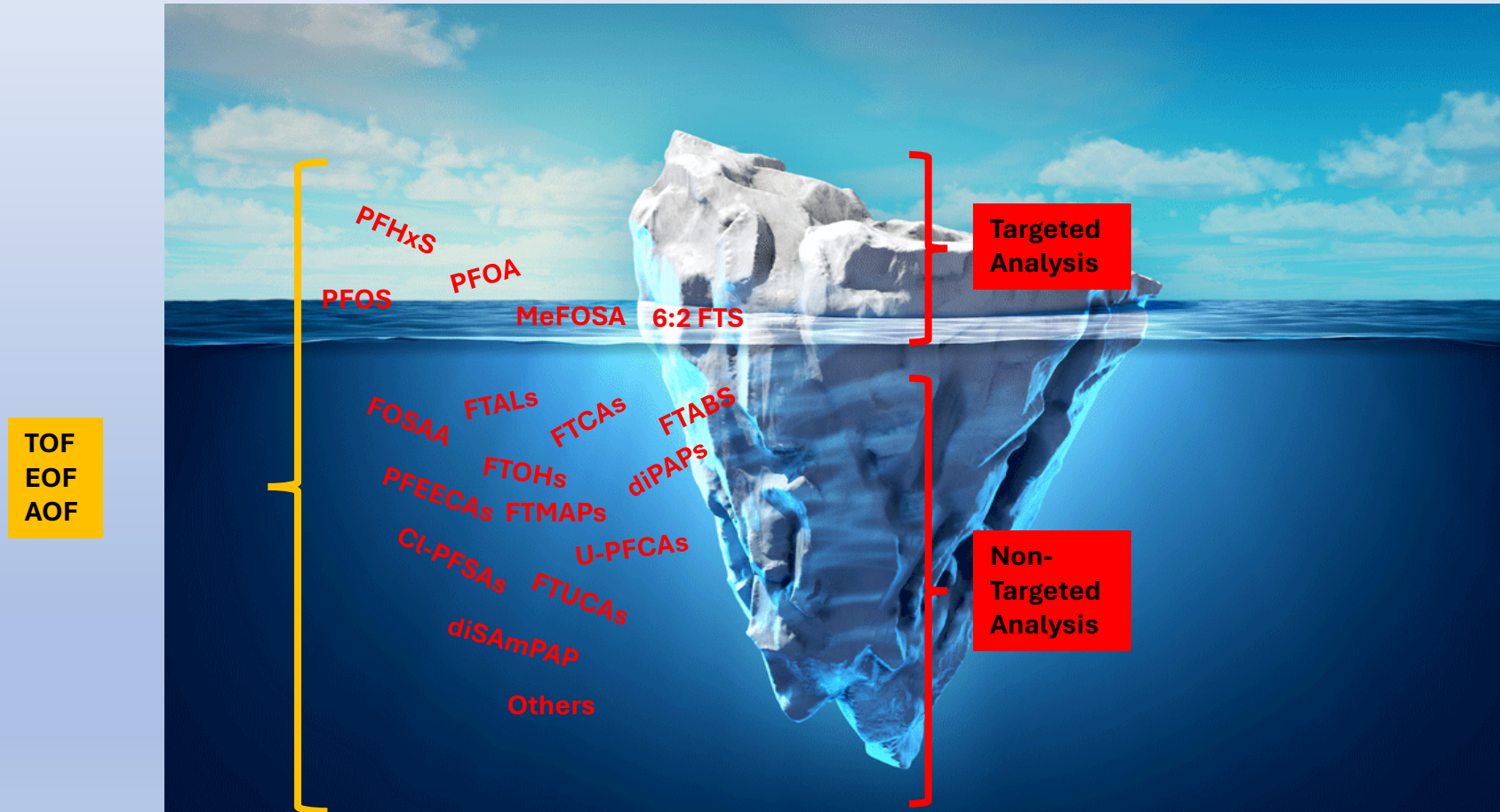


The Reality of Modern PFAS Injury: Cumulative & Chronic

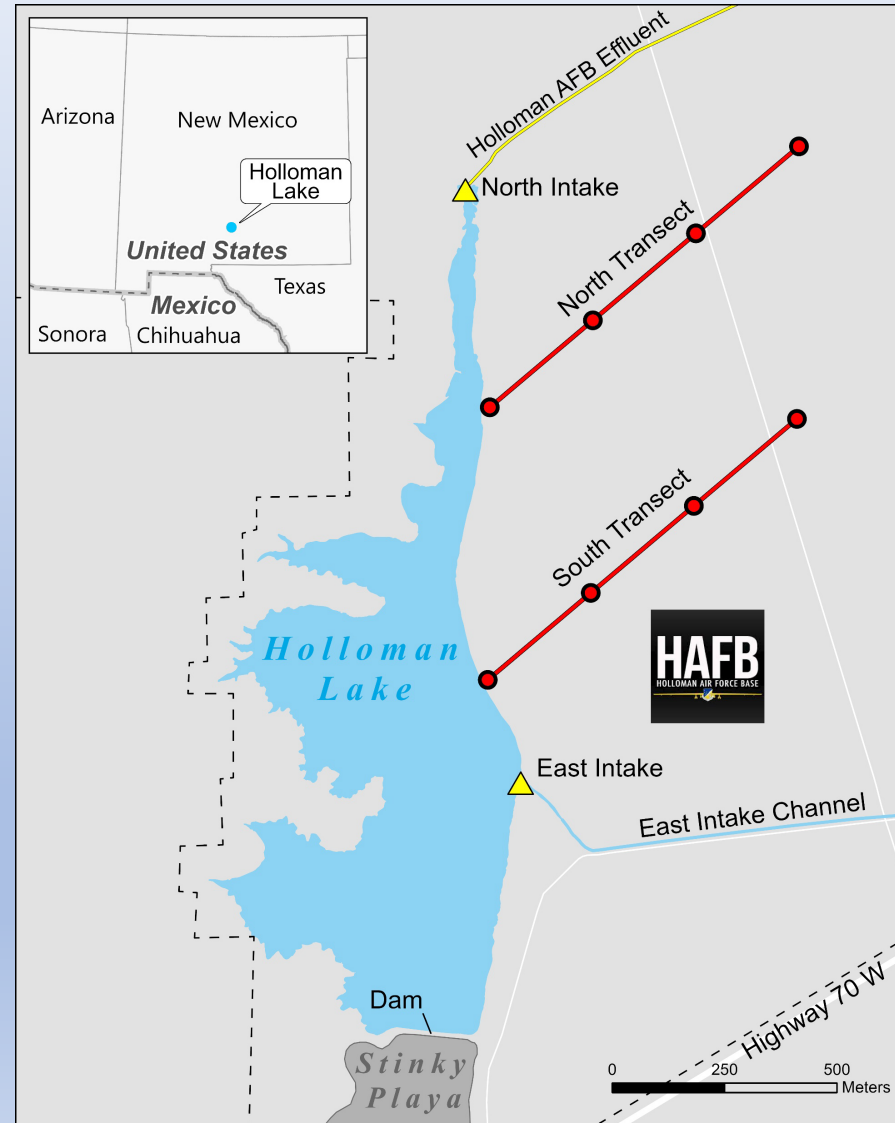
Aside from acute inhalation, the overwhelming majority of documented PFAS "injuries" are chronic.



The Hidden Part of the PFAS Iceberg

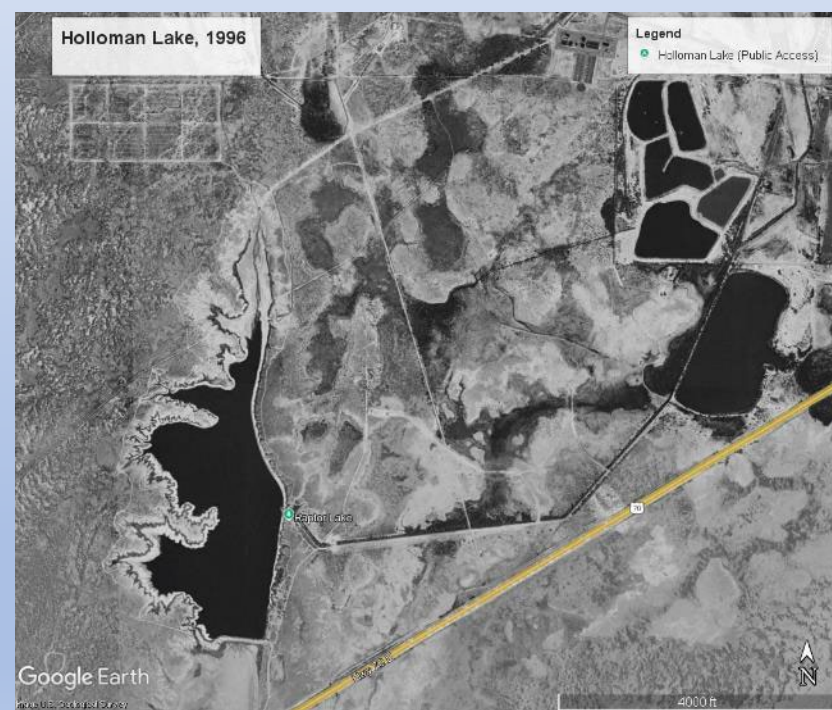
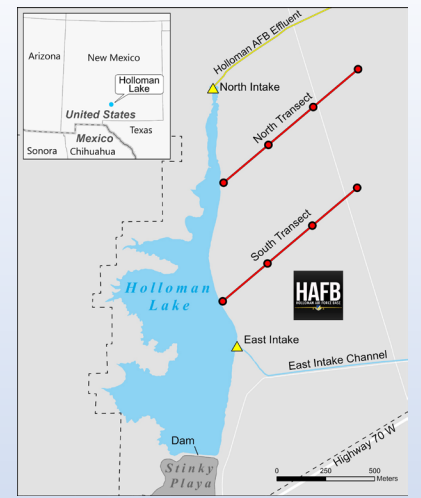


Holloman AFB and Holloman Lake

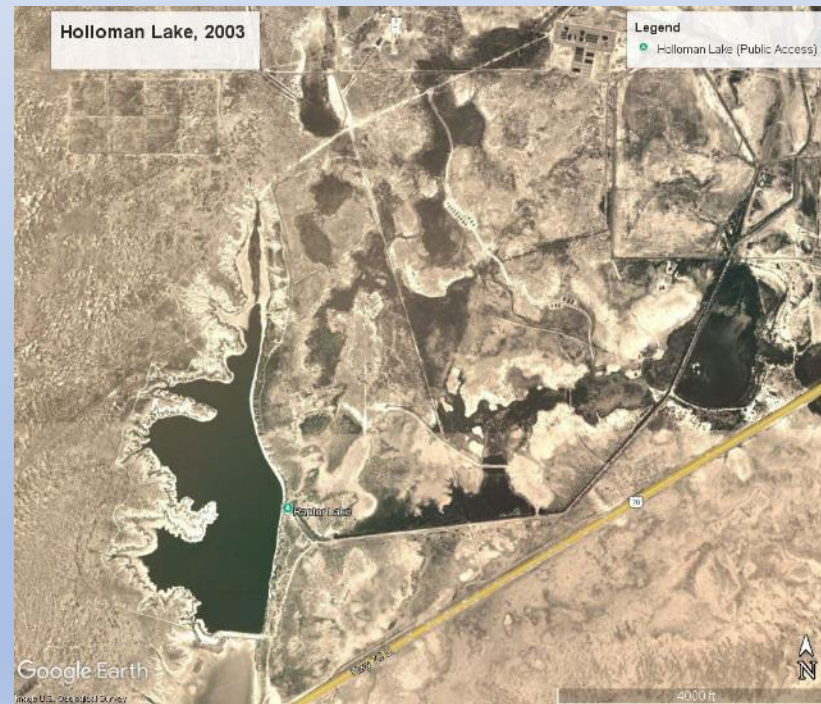


*

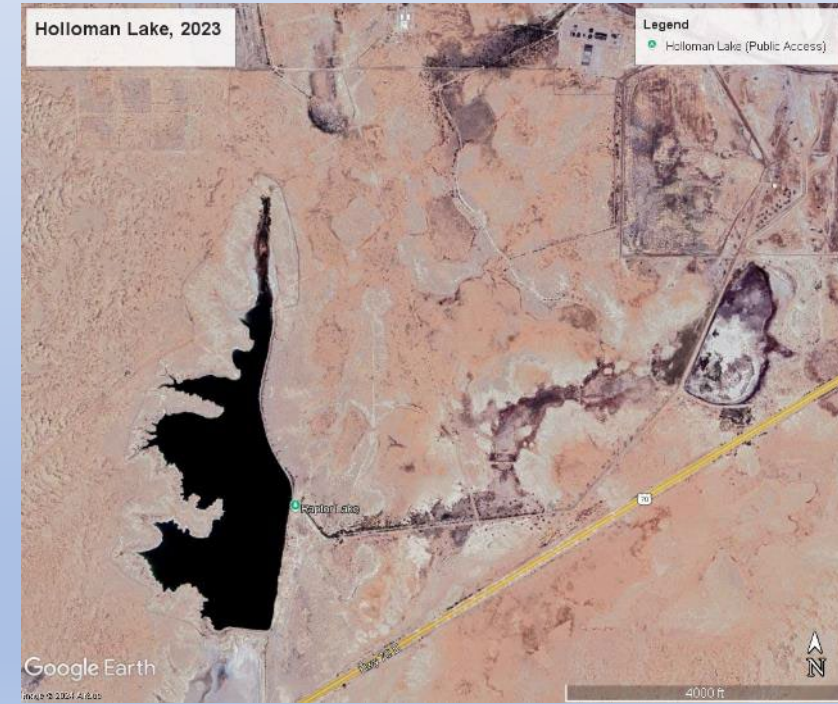
Holloman Lake, 1996-present



1996



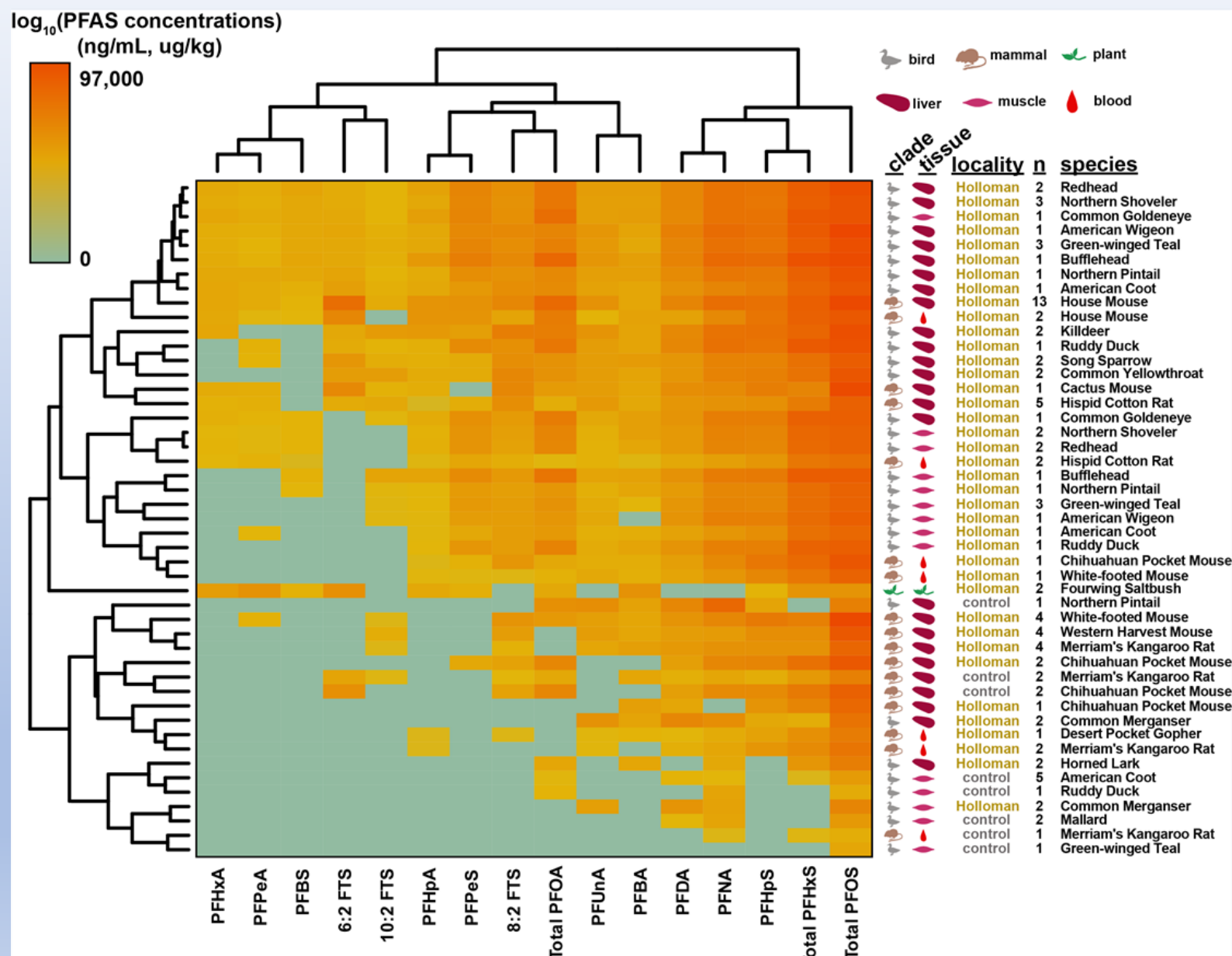
2003



2023

Heatmap of Blood and Tissue Concentrations

Nearly 4,000 assays to measure water/soil/blood/tissue concentrations of 17 PFAS



Highest concentrations recorded in wildlife at Holloman Lake*

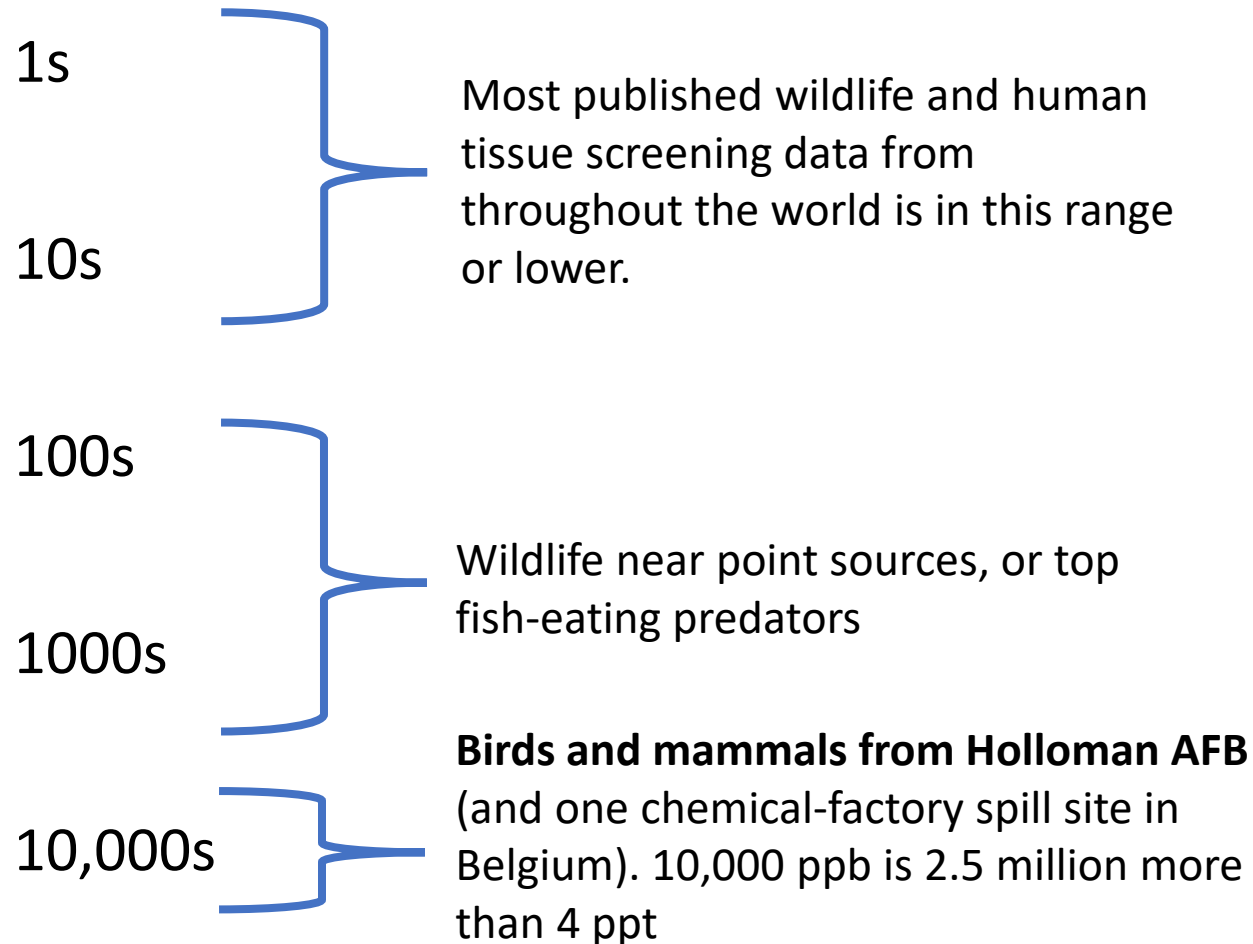


Common Name	Scientific Name	NK Identifier	Concentration (ng/g) ww	Substrate	Collection Site	Collection Date
Merriam's kangaroo rat	<i>Dipodomys merriami</i>	NK 311150	120,000	Liver	Holloman Lake	13 November 2024
Merriam's kangaroo rat	<i>Dipodomys merriami</i>	NK 311152	110,000	Liver	Holloman Lake	13 November 2024
White-footed mouse	<i>Peromyscus leucopus</i>	NK 31806	97,000	Liver	Lagoon G	16 August 1994
Merriam's kangaroo rat	<i>Dipodomys merriami</i>	NK 311147	94,000	Liver	Holloman Lake	13 November 2024
Merriam's kangaroo rat	<i>Dipodomys merriami</i>	NK 311154	66,000	Liver	Holloman Lake	13 November 2024
House mouse	<i>Mus musculus</i>	NK 311422	65,000	Liver	Holloman Lake	30 October 2021
Merriam's kangaroo rat	<i>Dipodomys merriami</i>	NK 311148	65,000	Liver	Holloman Lake	13 November 2024
House mouse	<i>Mus musculus</i>	NK 311426	57,000	Liver	Holloman Lake	30 October 2021
Killdeer	<i>Charadrius vociferus</i>	NK 284439	48,000	Tissue	Holloman Lake	11 July 2024

* The dominance of small mammals among the most contaminated animals indicates they can be used as sentinels of ecosystem health.

How high are these PFAS levels?

Parts per billion (ppb) in tissue



EPA Standards: PFOA and PFOS*

PFAS Compound	Maximum Contaminant Level Goal (MCLG)	Enforceable Maximum Contaminant Level (MCL)
PFOA	0	4.0 parts per trillion (ppt)
PFOS	0	4.0 ppt
PFNA	10	10.0 ppt
PFHxS	10	10.0 ppt
HFPO-DA (GenX Chemicals)	10	10.0 ppt
Mixture of two or more: PFHxS, PFNA, HFPO-DA (GenX), and PFBS	Hazard Index of 1	Hazard Index of 1

* 4.0 ppt = 0.004 ppb

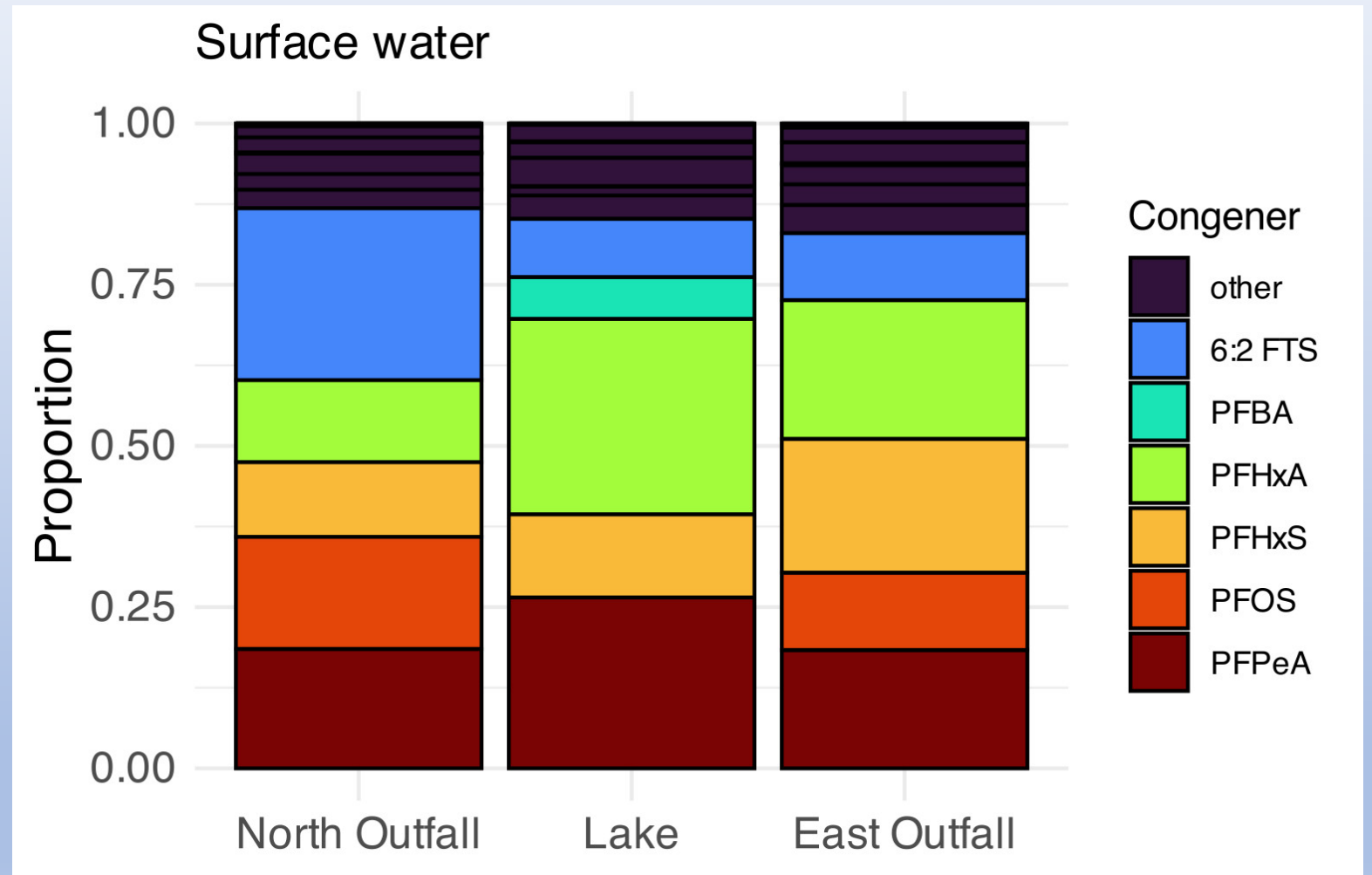
surface water contamination profile

Chemical fingerprints of
three generations of AFFFs,
including:

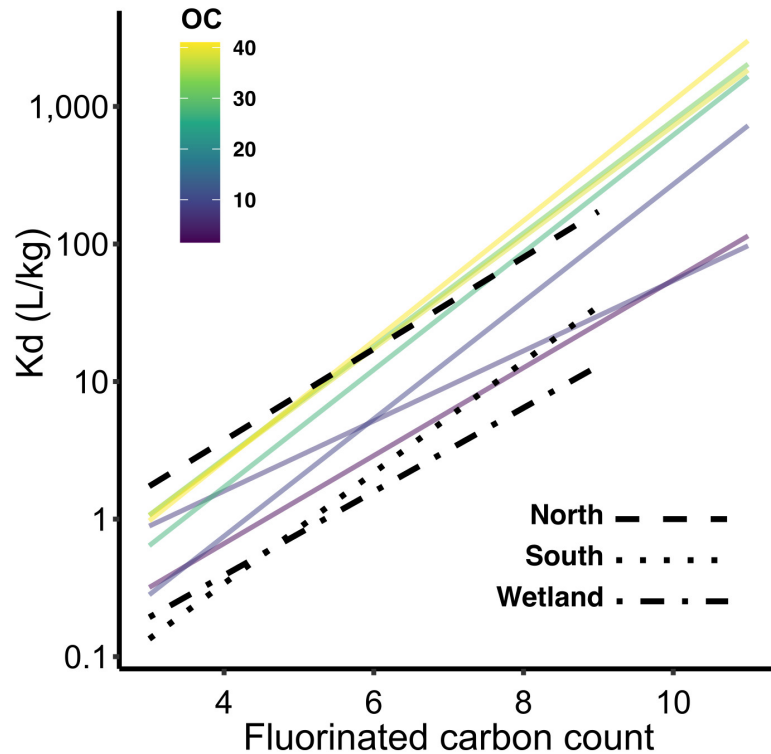
PFOS
PFHxS

PFOA
PFNA

PFPeA
PFHxA



Soil Sorption



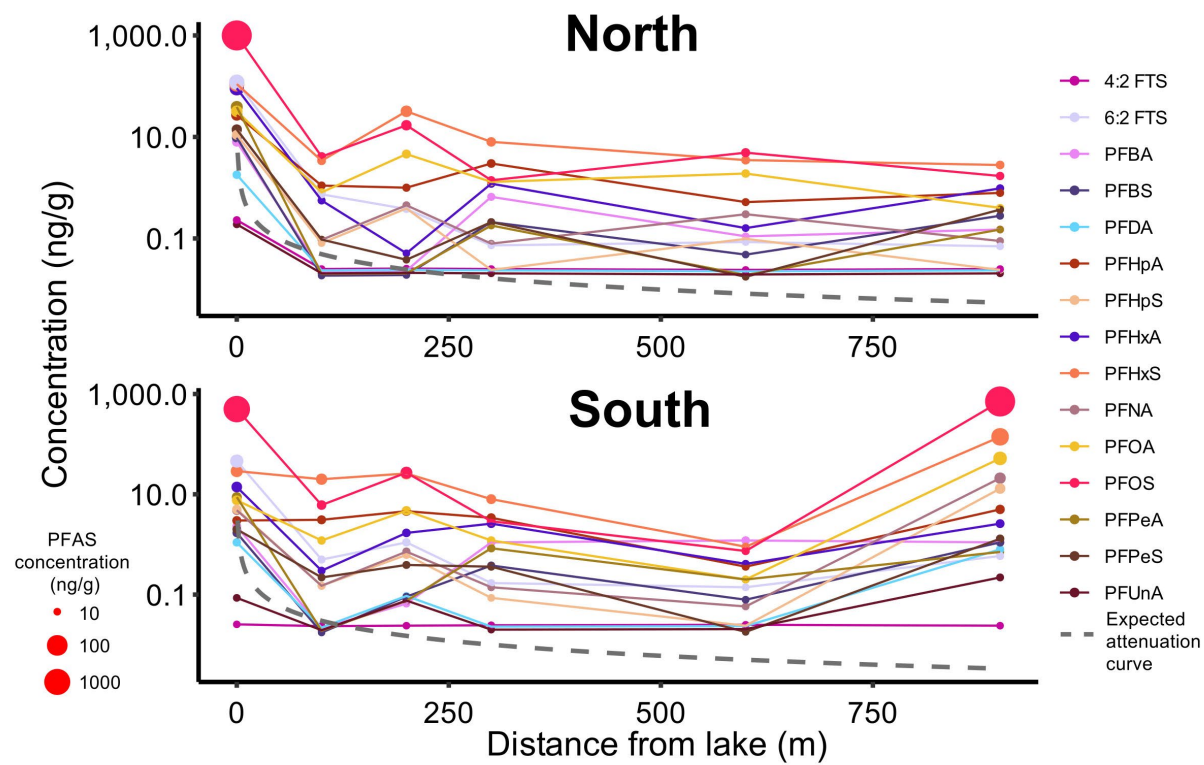
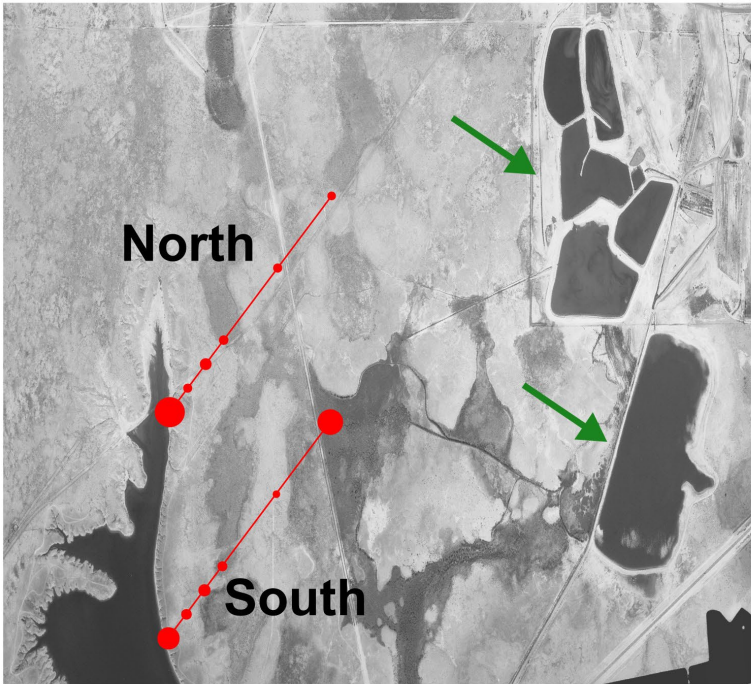
Soil	Adj pH	OC % wt	Ca mg/kg	S mg/kg	CEC meq/100g
North	7.3	1.8	170,000	120,000	170
South	6.5	0.43	190,000	190,000	150
Wetland	7.2	8.0	170,000	70,000	75

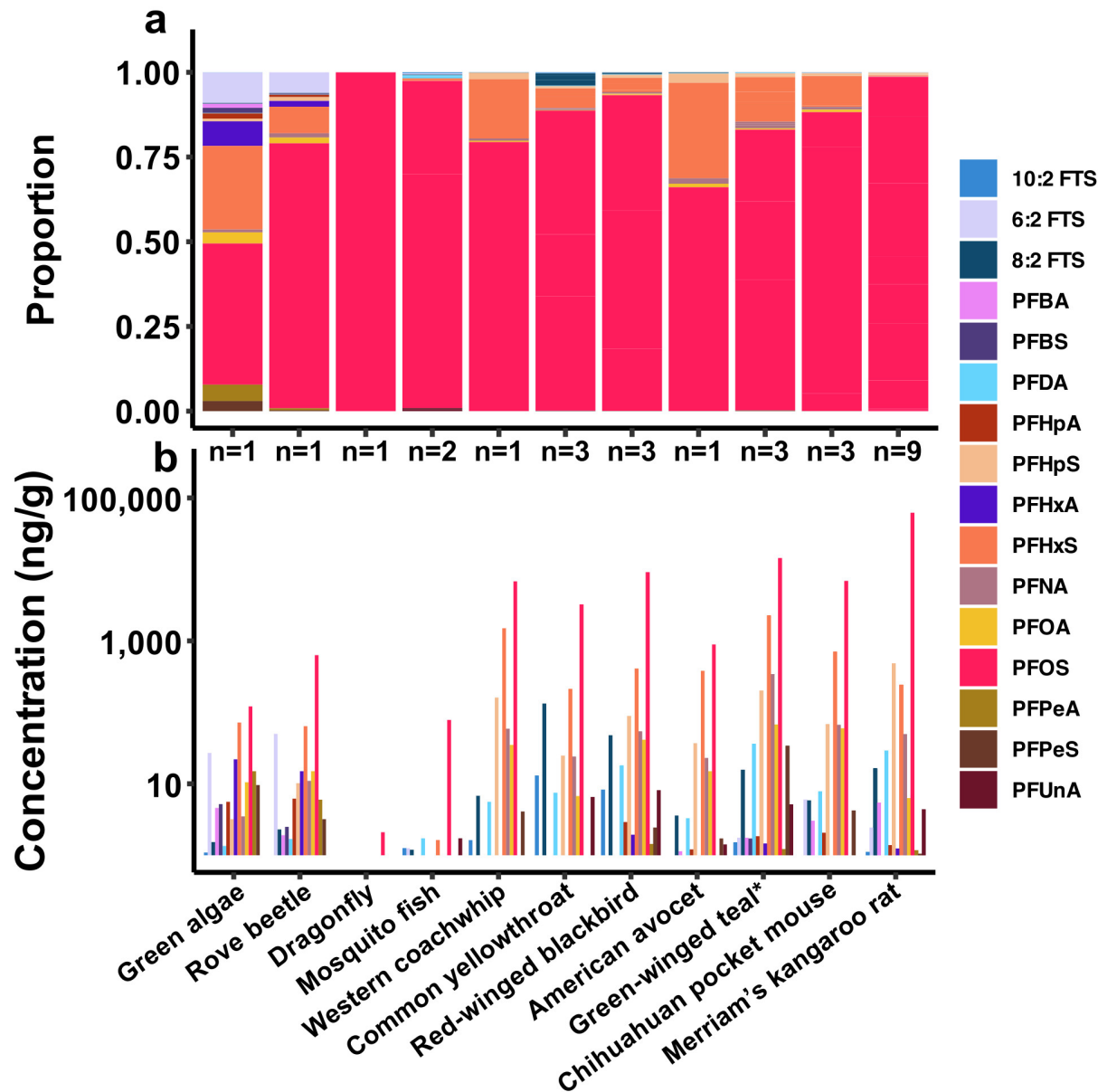
- Longer-chain PFAS migrate from water to soils more than shorter-chain PFAS.

and

- PFAS migration from water to soils increases if the soils have higher organic carbon content and/or they have high concentrations of certain mineral clays

Attenuation





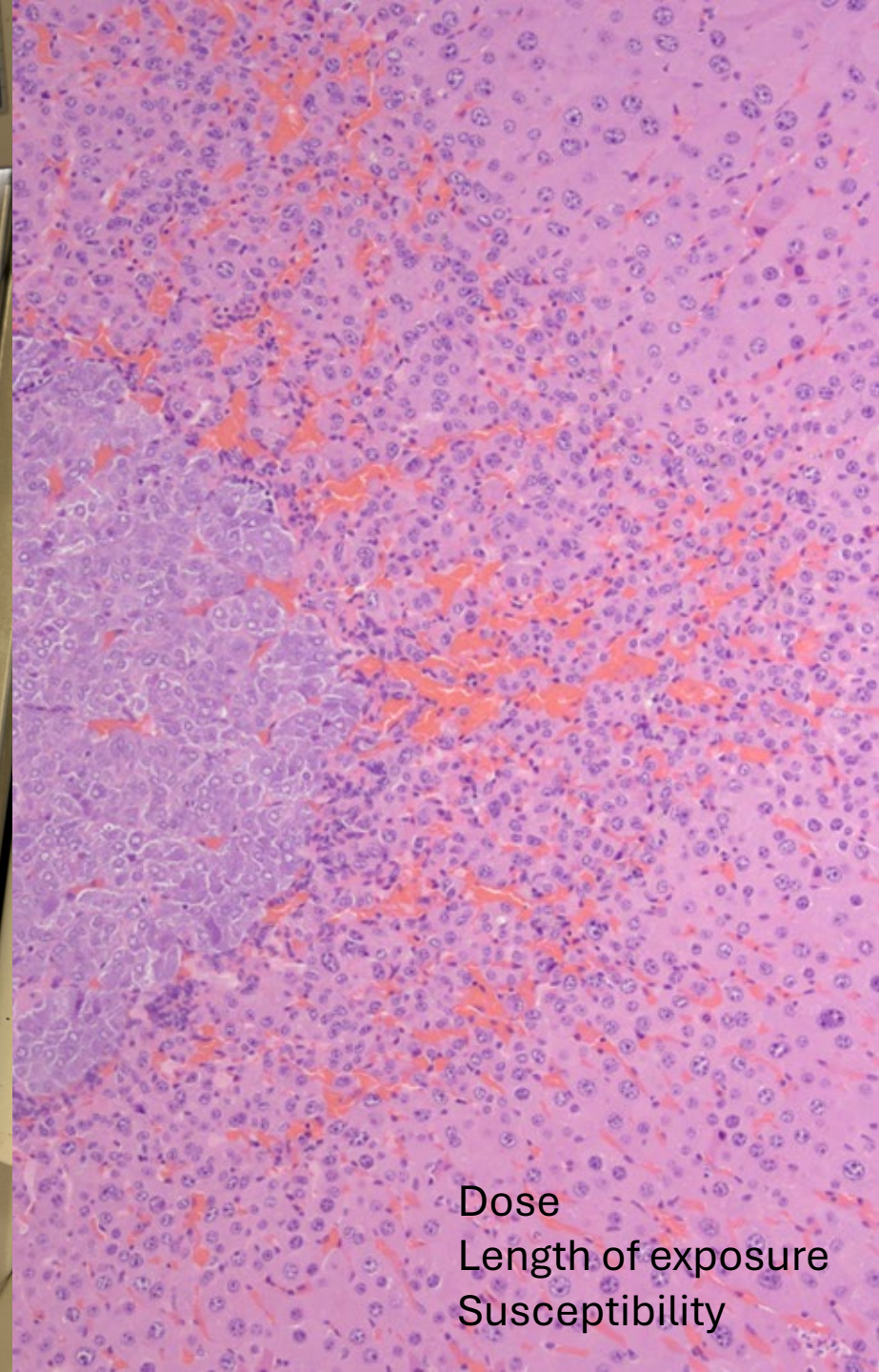
Holloman Lake PFAS Contamination

- High levels of PFAS contamination were detected in water, soils, green algae, plants, flying insects, ground arthropods, fish, lizards, snakes, mammals, and birds.
- The contamination profile of animals is dominated by PFOS, a long-chain PFAS



PFAS toxicity (preliminary results)

In collaboration with NMDA's Veterinary Diagnostic Services
Lipidomic analysis results are pending

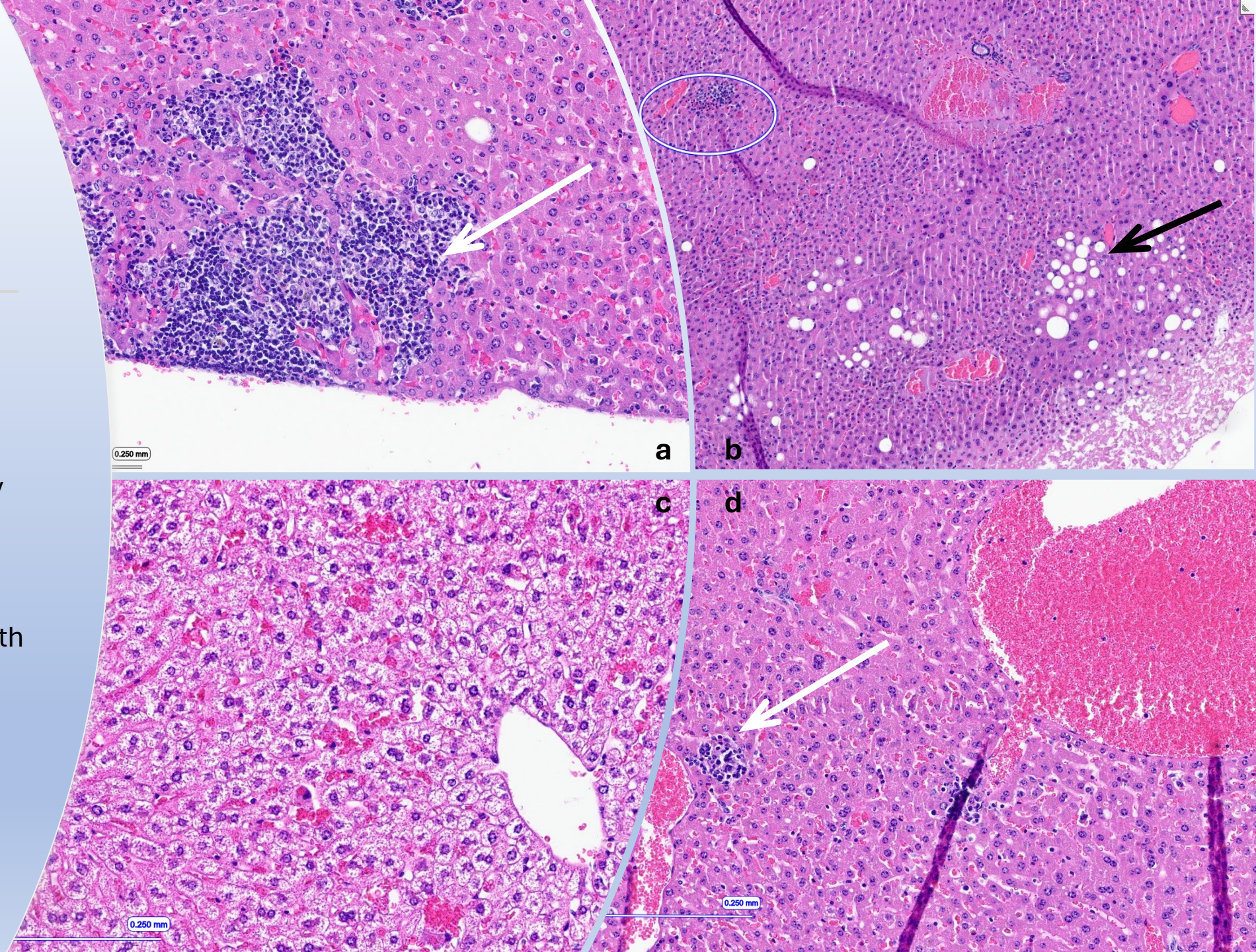


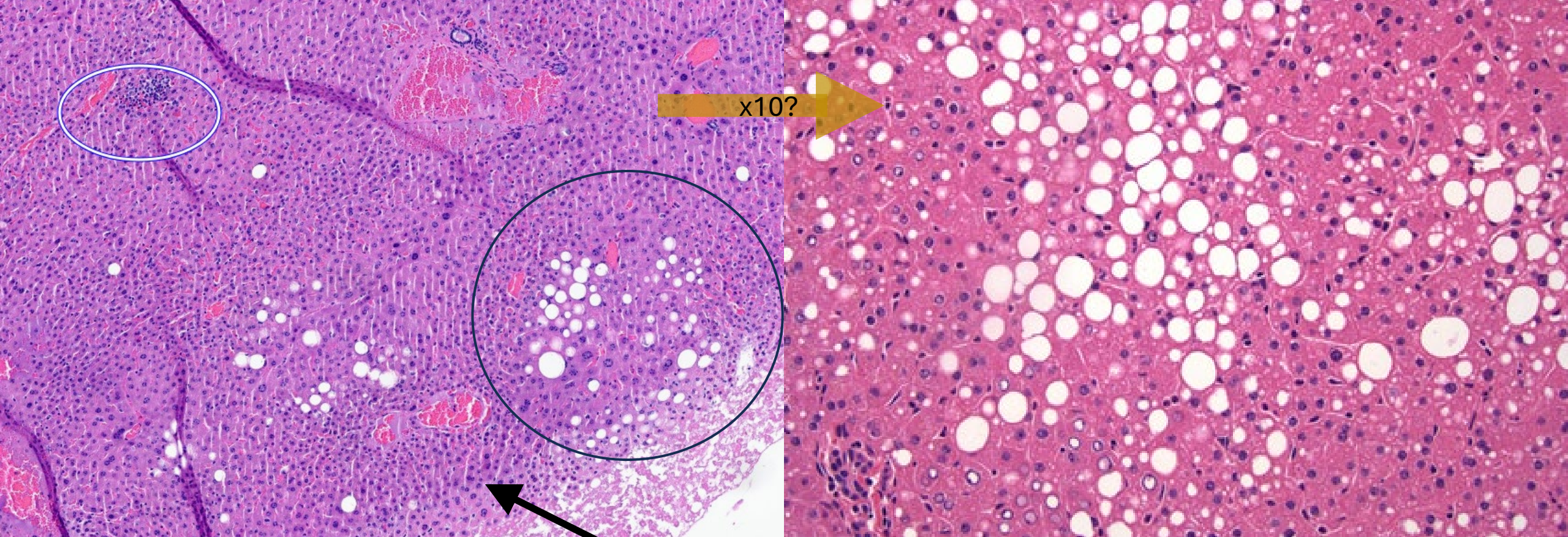
Dose
Length of exposure
Susceptibility

Potential liver toxicity

- Granulomatous hepatitis
- Cytoplasmic vacuolation
- Microgranulomas
- Hepatocyte heterogeneity

Examined by comparison with
two control groups





Liver steatosis (human liver)

72,000 ng/g (ppb) PFOS

Potential liver toxicity (preliminary)

Developmental
or reproductive
toxicity?

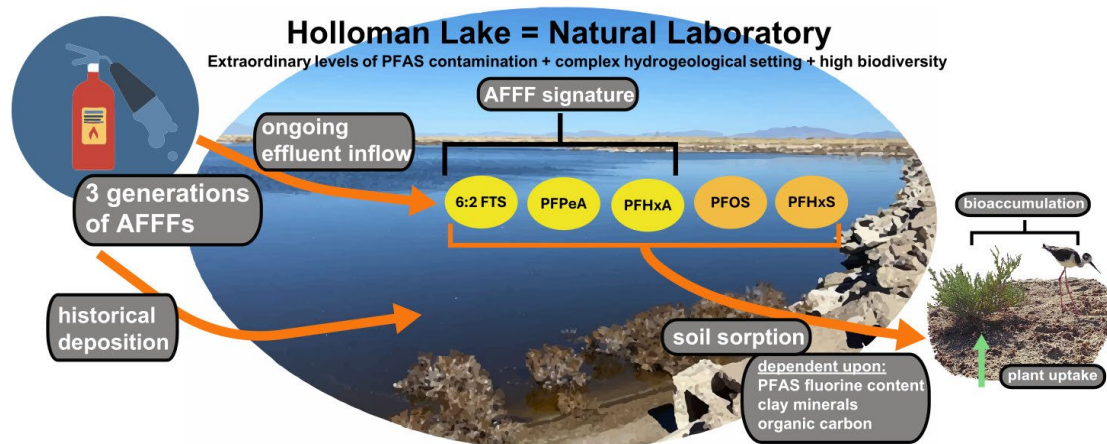


Transovarian contamination: unhatched Says' Phoebe egg: 1,500 ng/g PFOS; Black-necked Stilt eggshell remains: 35,000 ng/g



Conclusions

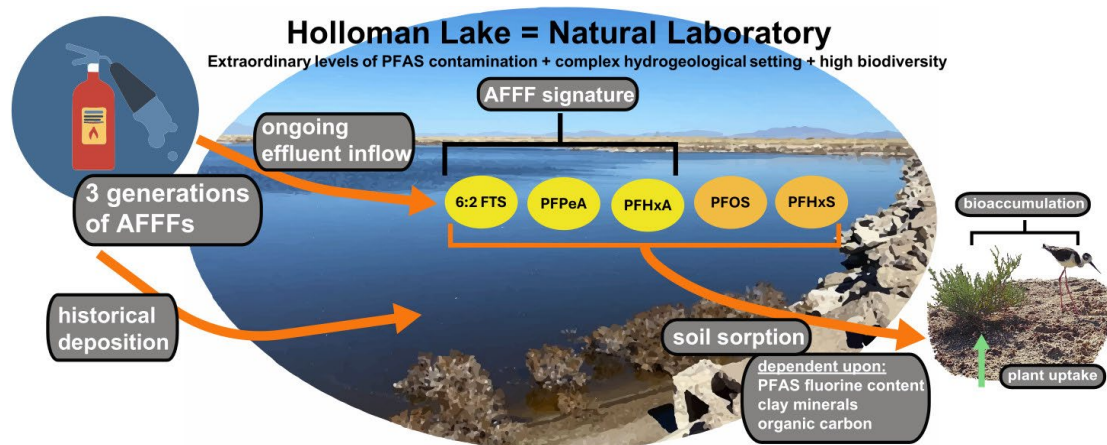
- **Here and Now:** Extreme levels of contamination have been detected from soils and water to plants, algae, and animals
- The footprint of the contamination extends beyond the lake and its shoreline.
- **A 30+-Year History:** The contamination profile of the lake bears the fingerprints of three generations of AFFFs. Specimens collected more than 30 years show record-level contamination levels





Conclusions

- **For the future:** Some results from Holloman Lake and other parts of the state are pending
- Continued monitoring of Holloman Lake will be important even as remediation takes place
- Continued monitoring will also be important at the scale of New Mexico including in the Rio Grande Valley.





Thank you!!

Our Peer-Reviewed Publications

- Witt, C. C., C. R. Gadek, J.-L. E. Cartron, M. J. Andersen, E. F. Gyllenhaal, A. B. Johnson, J. Malaney, K. N. Montoya, A. Patterson, N. Vinciguerra, J. L. Williamson, J. A. Cook, and J. L. Dunnum. 2024. Extraordinary levels of per- and polyfluoroalkyl substances (PFAS) in vertebrate animals at a New Mexico desert oasis: multiple pathways for wildlife and human exposure. *Environmental Research* 249, 118229; <https://doi.org/10.1016/j.envres.2024.118229>.
 - Cartron, J.-L. E., C. R. Gadek, J. L. Dunnum, C. C. Witt, M. L. Campbell, S. J. Romero, A. B. Johnson, J. Kutz, C. Wolf, S. J. Choyke, and J. A. Cook. 2025. Ecosystem-wide PFAS characterization and environmental behavior at a heavily contaminated desert oasis in the southwestern U.S. *Environmental Research* 279, 121872. <https://doi.org/10.1016/j.envres.2025.121872>.
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