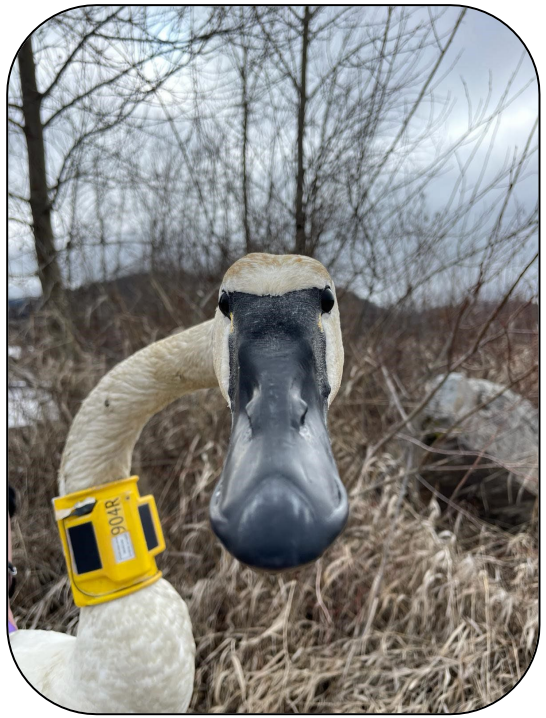
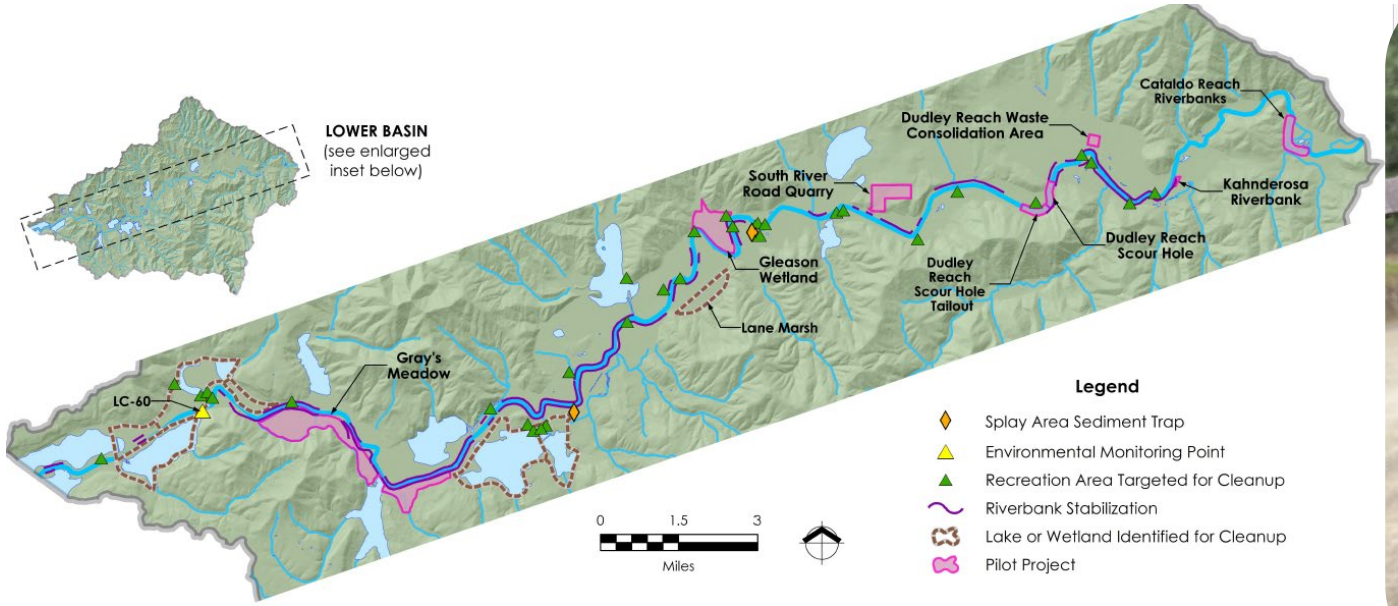
Development of Biomonitoring Tools for the Bunker Hill SF Site, Lower Basin BEMP

Tundra swan feces

Wood duck eggshells





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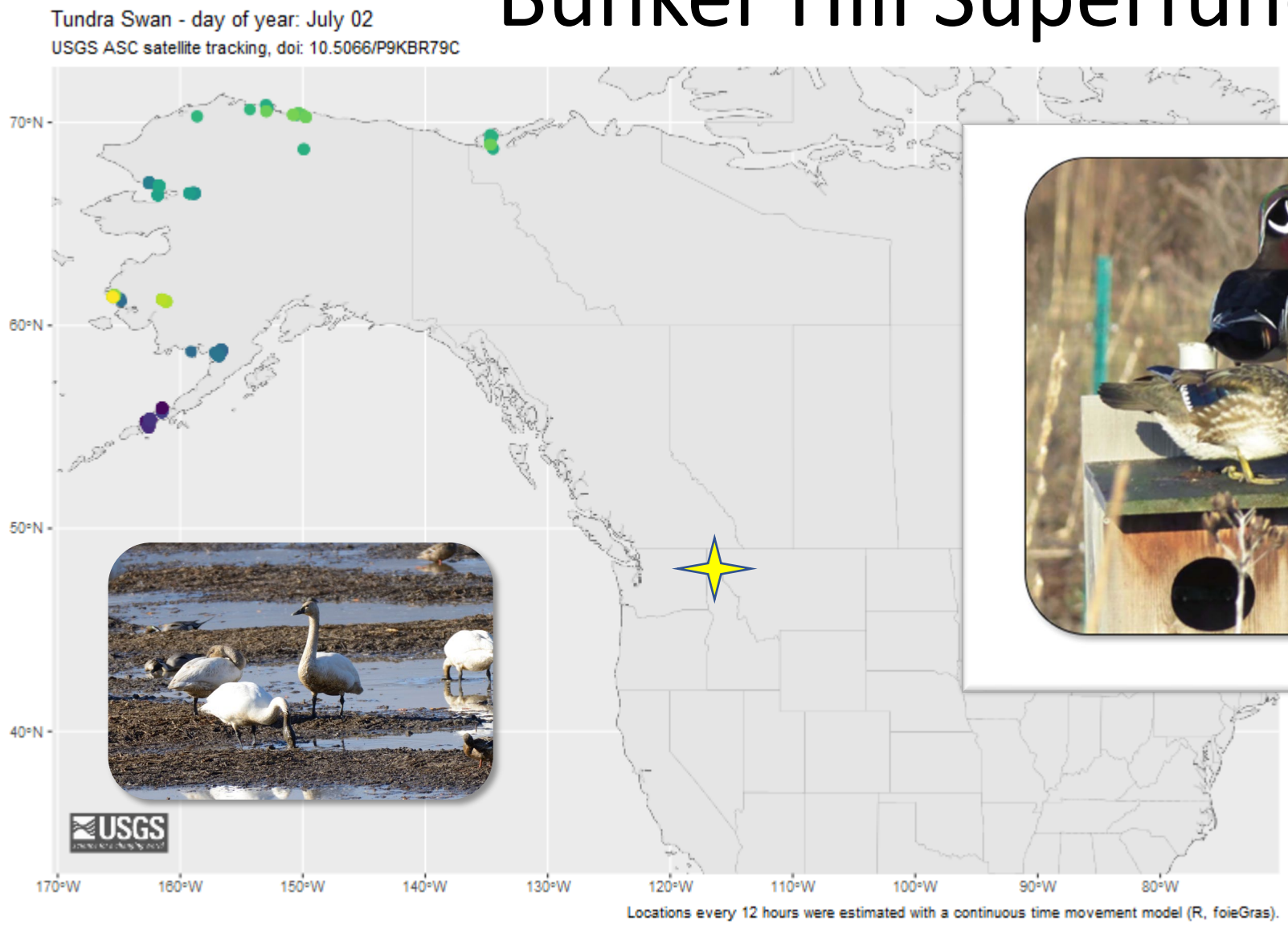
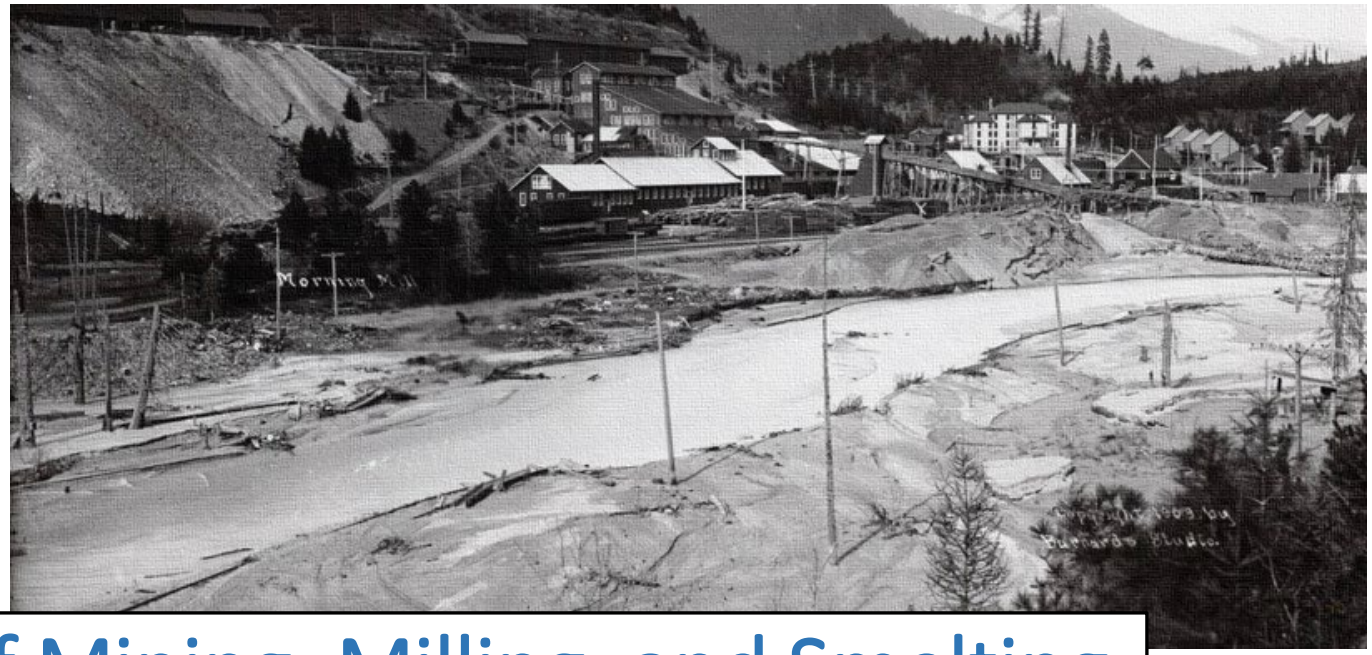
Tundra Swans Migrate Through the Bunker Hill Superfund Site

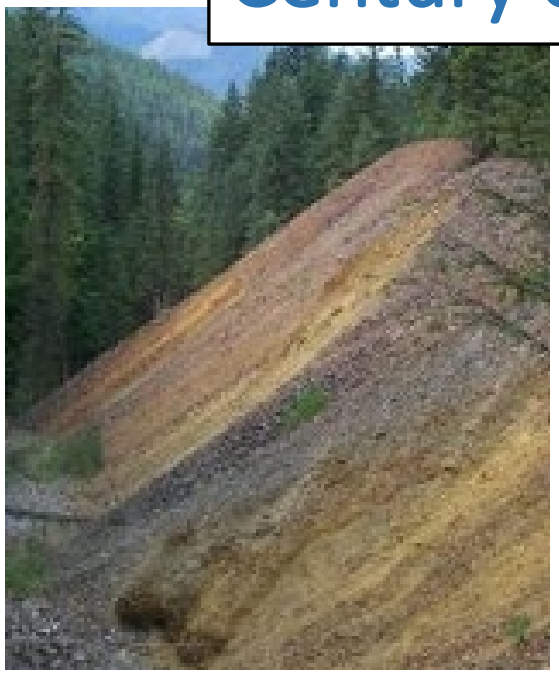


Many other susceptible waterfowl - i.e. wood ducks - also migrate through and reproduce in the Basin.

Every February to April, approximately 10,000 tundra swans feed in the Lower Basin



Century of Mining, Milling, and Smelting



…and flooding!

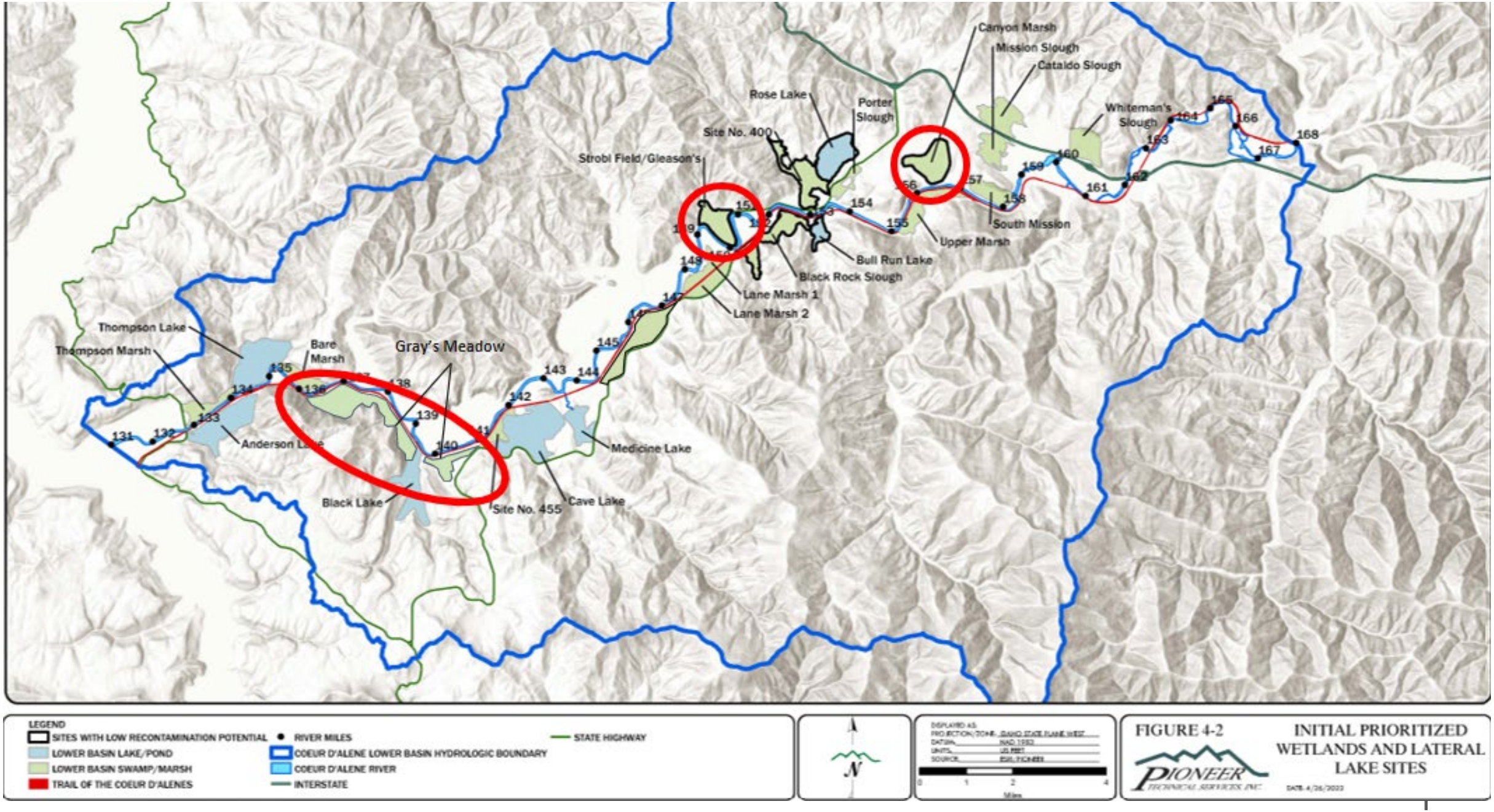


FIGURE 4-2

INITIAL PRIORITIZED WETLANDS AND LATERAL LAKE SITES

PIONEER TECHNICAL SERVICES, INC.

DATE: 4/26/2022

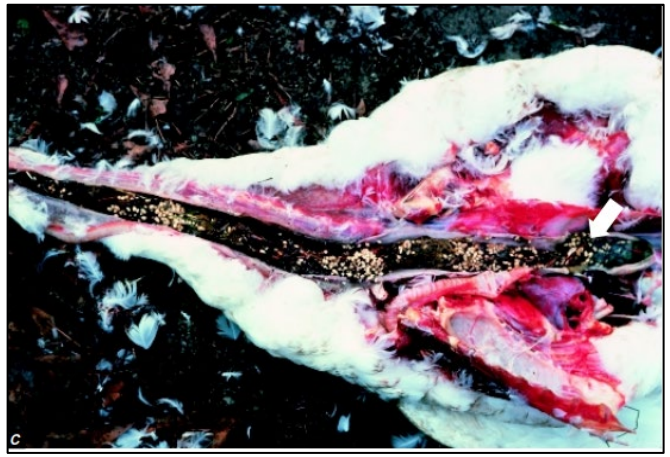
Tundra swans forage in the mud for water potato and other aquatic vegetation, which exposes them to Pb in sediments

Clinical signs of a lead (Pb) poisoned bird

Neurological Signs

Wing droop

Inability to fly



Gut impaction

Emaciation from starvation

Bile-stained feces

Lead poisoning without Pb pellets in 93% of TUSW and 92% of all cases

Sileo et al. 2001, Arch. Environ. Contam. Toxicol. 41, 364–368

Table 1. Ultimate causes of death of waterfowl found sick or dead in the Couer d'Alene River basin

Cause of Death	Tundra Swans	Canada Geese	Other[a]	Total
Nonartifactual lead poisoning with or without other secondary or contributing factors	172	33	14[b]	219
Lead poisoning accompanied by ingested lead pellets	13	6	1	20
Infectious disease (aspergillosis, avian cholera, tuberculosis)	4	3	0	7
Trauma, liver lead not elevated[c]	1	2	4	7
Trauma with elevated liver lead	8	0	4	12
Other (eggbound, renal gout, ruptured ova)	0	3	2	5
Multiple conditions	0	1[d]	0	1
Undetermined, liver lead not elevated	3	1	1	5
Undetermined with elevated lead	2	3	1	6
Emaciation, liver lead not elevated	0	1	1	2
Emaciation with elevated liver lead	1	0	0	1
Total	204	53	28	285

[a] 13 *Anas platyrhynchos*, 6 *Aix sponsa*, 3 *Anas americana*, 1 *Cygnus buccinator*, 1 *Anas crecca*, 1 *Anas acuta*, 1 *Aythya valisineria*, 1 *Aythya americana*, 1 *Bucephala clangula*.

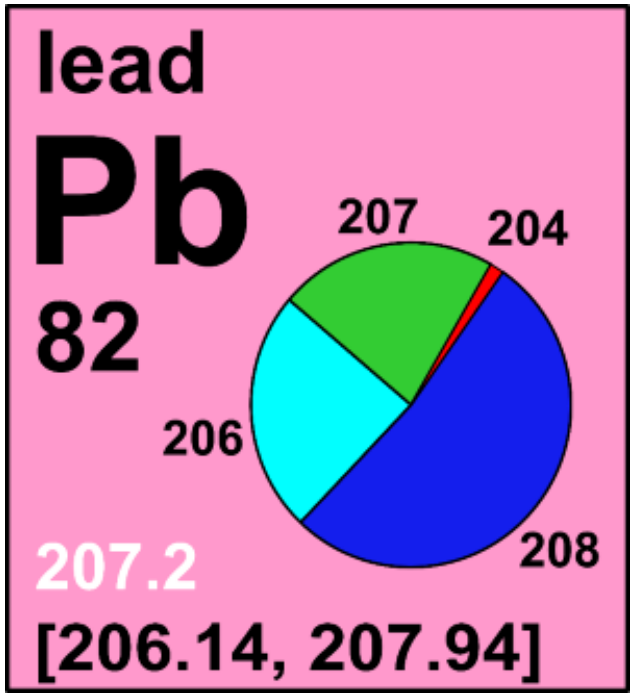
[b] 6 *Anas platyrhynchos*, 3 *Aix sponsa*, 1 *Anas americana*, 1 *Anas acuta*, 1 *Aythya valisineria*, 1 *Aythya americana*, 1 *Bucephala clangula*.

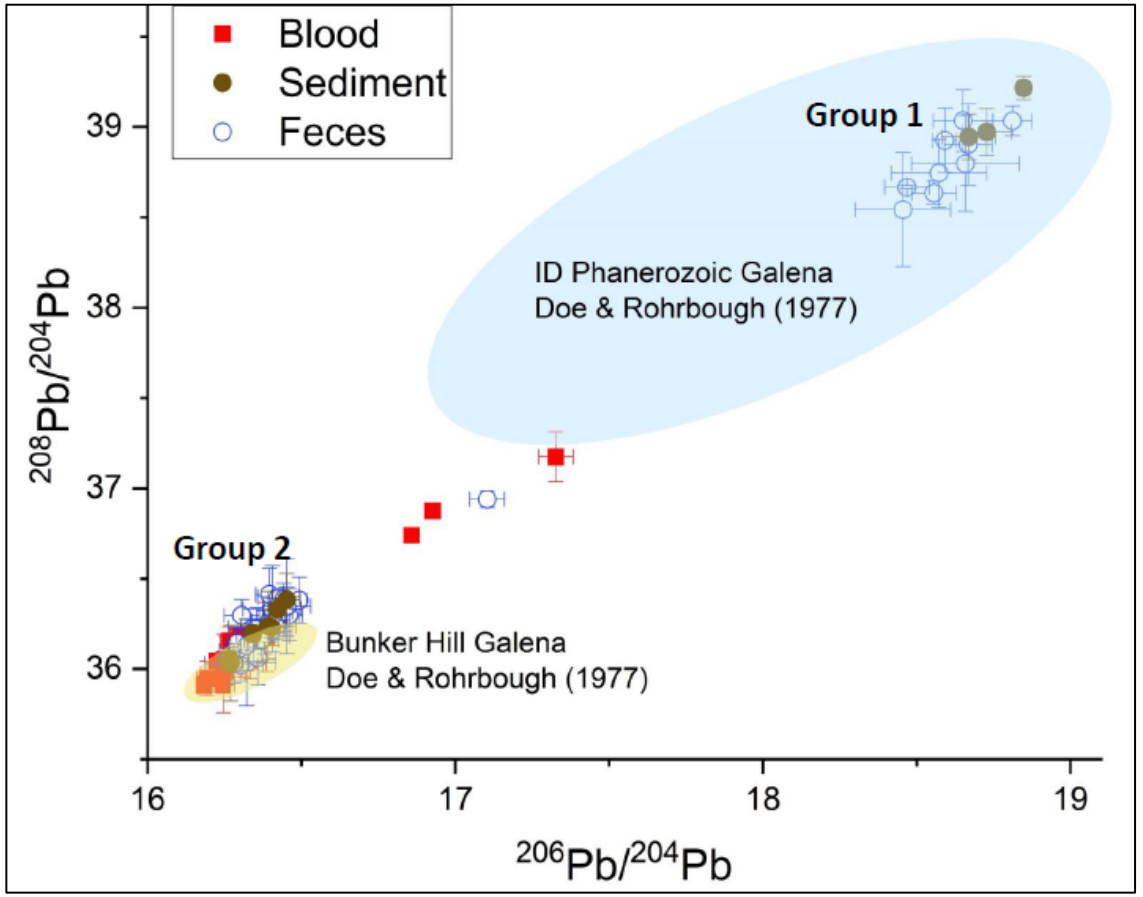
[c] Concentrations of lead in liver below 6 ppm wet weight.

[d] Damaged feet, emaciation, and renal gout.

Further Evidence for Local Exposures and Effects in Tundra Swans

- Clinical signs observed at Bunker would likely stop affected birds from migrating to Bunker; acute signs generally occur rapidly (days of high exposure)
- Pb stable isotope data indicate that over 90% of Pb detected in swans from 2022 captures was of Bunker Hill origin





The Challenge

- Contaminated Wetland Scale
  - Nearly 20,000 acres
  - Pb is several feet deep into sediments
- Need to demonstrate progress towards remedial action objectives:
  - reduced Pb exposure to waterfowl
- Tundra swans of highest public interest and are considered a sensitive indicator species: but difficult to capture!
- Alternative biomonitoring approaches are sought:
  - **efficient, cost effective & sustainable**

Current BEMP Biomonitoring:
Waterfowl Surveys


3/11 – 005R (Black), Dead in Thompson Lake


3/11 – 004R (Black), ill along shore in Thompson Lake
3/15 – 004R (Black), dead and scavenged in same location

Tundra Swan Mortality

2008-19, 2021-22[2]	Total Count	Total dead swans	Ratio Dead:Total swan obs.
Average	11930	83	1:140
Median	11581	58	1:200
Max (2022)	24515	388	1:63

	# Tundra Swan observations	# Wood Duck observations
Wetland Surveyed	USFWS 5yr total 2018-2022	USFWS 5yr total 2018-2022
Anderson Lake	5754	84
Bare Marsh	1812	33
Black Rock Slough	1782	414
Bull Run Lake	35	218
Canyon Marsh	640	46
Cataldo Slough	274	247
Cave Lake	6883	92
Gleason's Field	2626	533
Gray's Meadow East	612	12
Harrison Marsh	2100	11
Harrison Slough	8188	28
Killarney Lake	5209	138
Lane Marsh	13895	253
Medicine Lake	563	110
Orling Slough	414	389
Robinson Creek	83	35
Schlepp's East Field	1983	24
Schlepp's West Field	1413	9
Strobl Marsh	11833	220
Thompson Lake	2072	122
Thompson Marsh	686	389
Whiteman's Slough	245	119
Grand Total	**69102**	**3526**
% surveyed in ROD priority wetlands	46%	31%
% surveyed in currently planned/completed wetlands	11%	18%
	Tundra Swan	Wood Duck

Why are biological samples needed for long-term monitoring?

BIRDS:

- Sample the sediment that matters to THEM
- Indicate remedy progress that directly relates to public concerns and cleanup criteria
- Identify which remedy strategies yield results
- Differences in bioavailability are accounted for specifically
- Provide data on exposure differences due to vegetation food sources
- Leave behind non-invasive samples (i.e. feces & shells) for easy, low-cost biomonitoring tools

Candidate Biomonitoring Approaches

Photos from Birds of the World

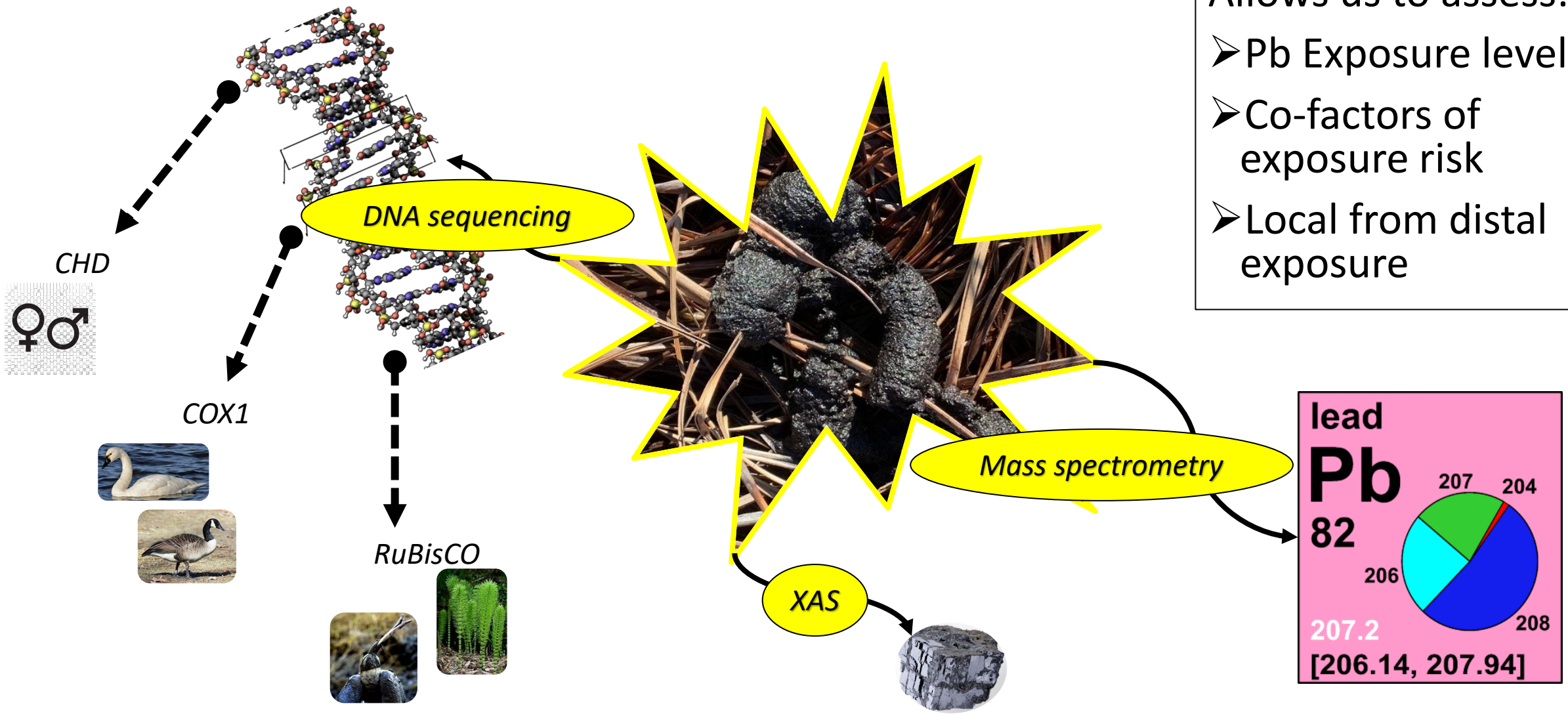
- What is the spatial resolution (wetland, wetlands, lower basin) for each approach?
- How responsive to changing sediment Pb concentrations is each approach?
- Is each approach reasonably representative of bird health?
- What is the level of complexity to execute each approach?
- Do results from one approach represent the other? Different media consumed?

Learning about Swan Exposures from their Fecal Samples

A More Efficient Assessment of Swan Exposure Than Sediment

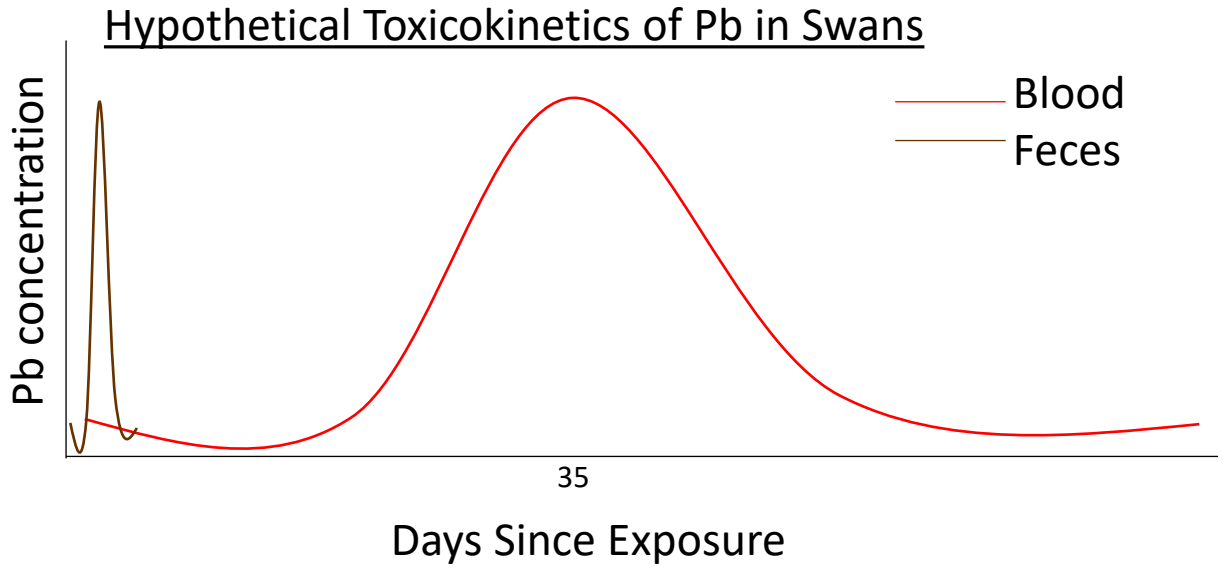
Allows us to assess:

- Pb Exposure level
- Co-factors of exposure risk
- Local from distal exposure



Fecal samples versus blood samples: space, time, & logistics

- Integration period and thus exposure window is different for each media
  - Blood reflects a turnover rate of 35 days
  - Feces reflects a gut transit time of 3-6 hours
- Sampling logistics
  - Blood sampling requires capture



Four Phases for the Swan Research

1. 2021: **Pilot** season to work through sampling and analytical method challenges. Sediment and fecal samples collected. No birds trapped.
2. 2022 – 2024: **Empirical**: Swan trapping, sampling, and tracking
3. 2024 – 2025: **Transition to Modeling**: Swan trapping, sampling, tracking, and model development
4. 2025 onward: **Integration** of findings into monitoring recommendations

Phase 2 Research Questions

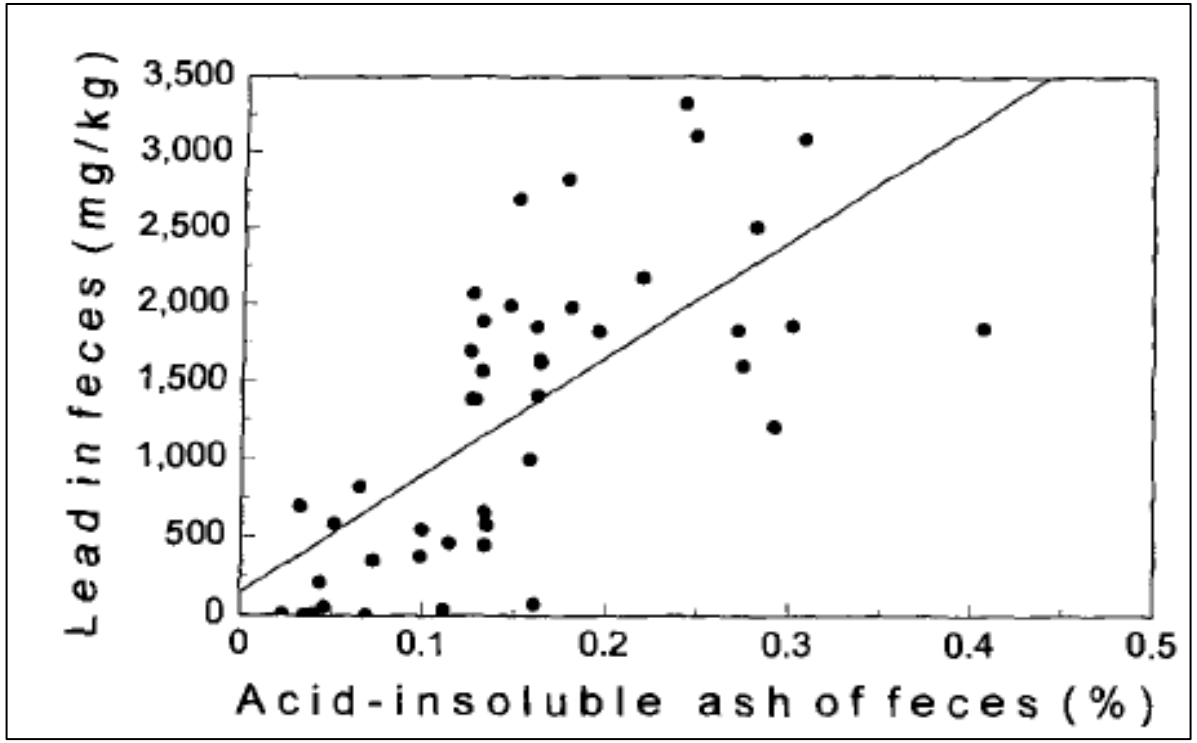
- Sampling conducted every March since 2022
- Primary Question
  - What is the environmental and biological meaning of a given Pb concentration in feces?
- Approaches
  - Environmental meaning of fecal Pb concentrations
    - Sediment Use: Relationships between sediment and fecal sample chemistry
    - Vegetation Use: Relationship between vegetation consumed and Pb in fecal samples
    - Site Use: GPS tracking of locations and behavioral activity
  - Biological meaning of fecal Pb concentrations
    - Relationships between fecal and blood Pb levels
    - Future: modeling impacts of Pb on life cycle
    - Future: determination of a fecal Pb monitoring benchmark

Environmental

Sediment Ingestion Correlated with Pb in Feces

- TUSW consume plants at Bunker Hill
- Pb in feces correlates with sediment ingestion, which is variable
- At Bunker Hill, ~20% of diet is incidental sediment uptake (Beyer et al. 1998 and current study)
  - Range 2.6-41% via acid insoluble ash in feces

Concentration of Pb in feces correlated with sediment ingestion rate



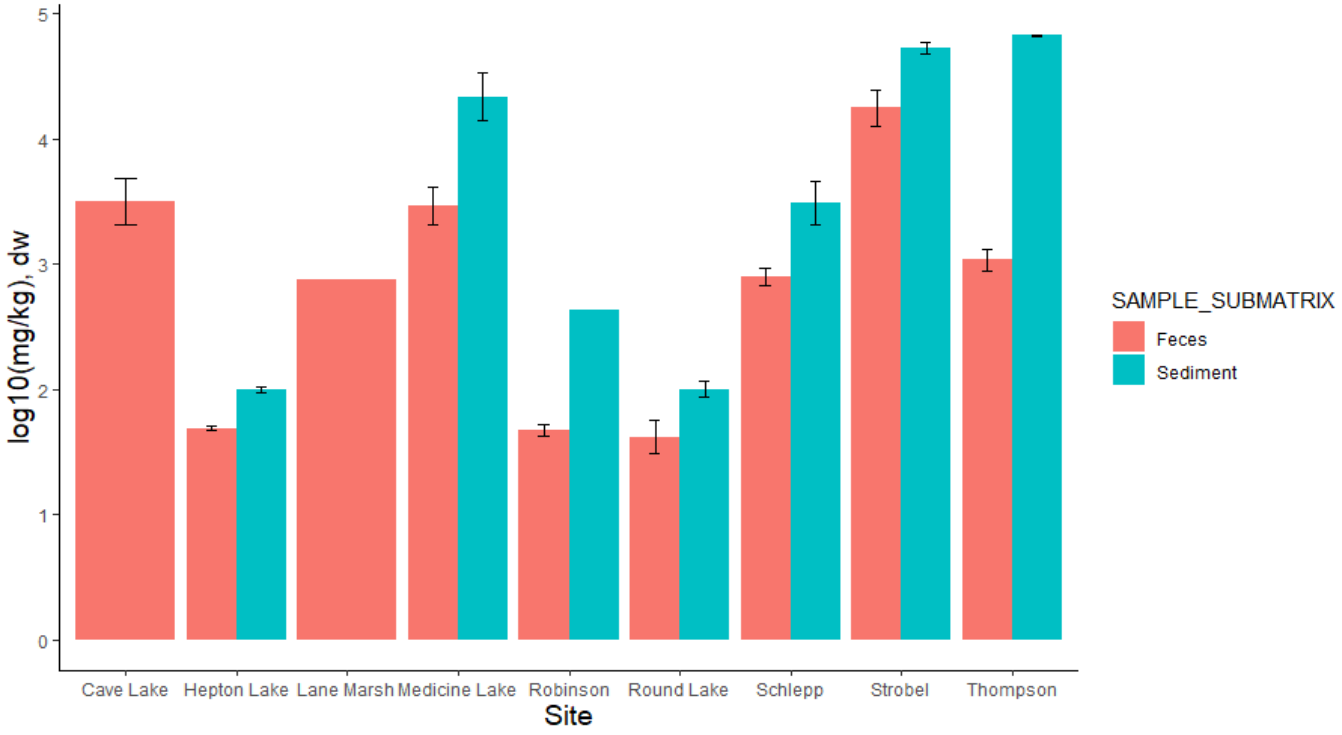
Tundra Swan Data
Beyer et al. 1998

Environmental

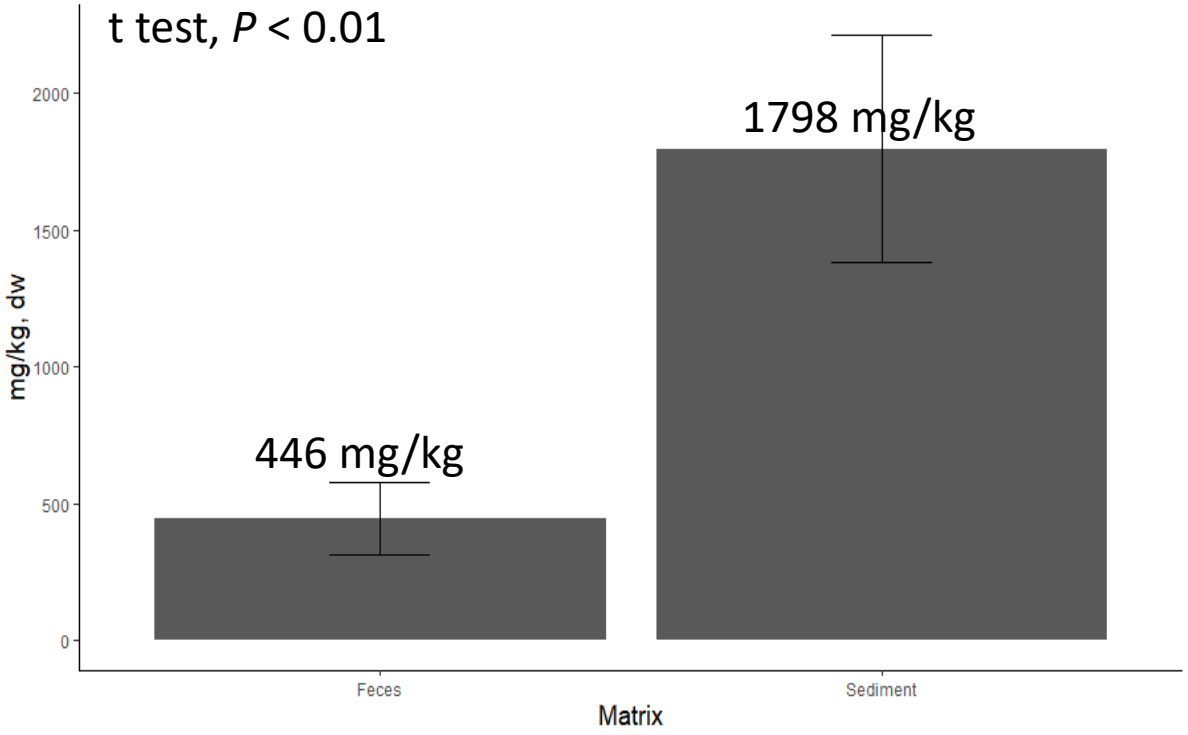
Consistent Relationship Between Pb in Sediment and Feces

Potentially useful for a fecal Pb monitoring benchmark derivation

Sediment Had Consistently Higher Pb levels than Feces



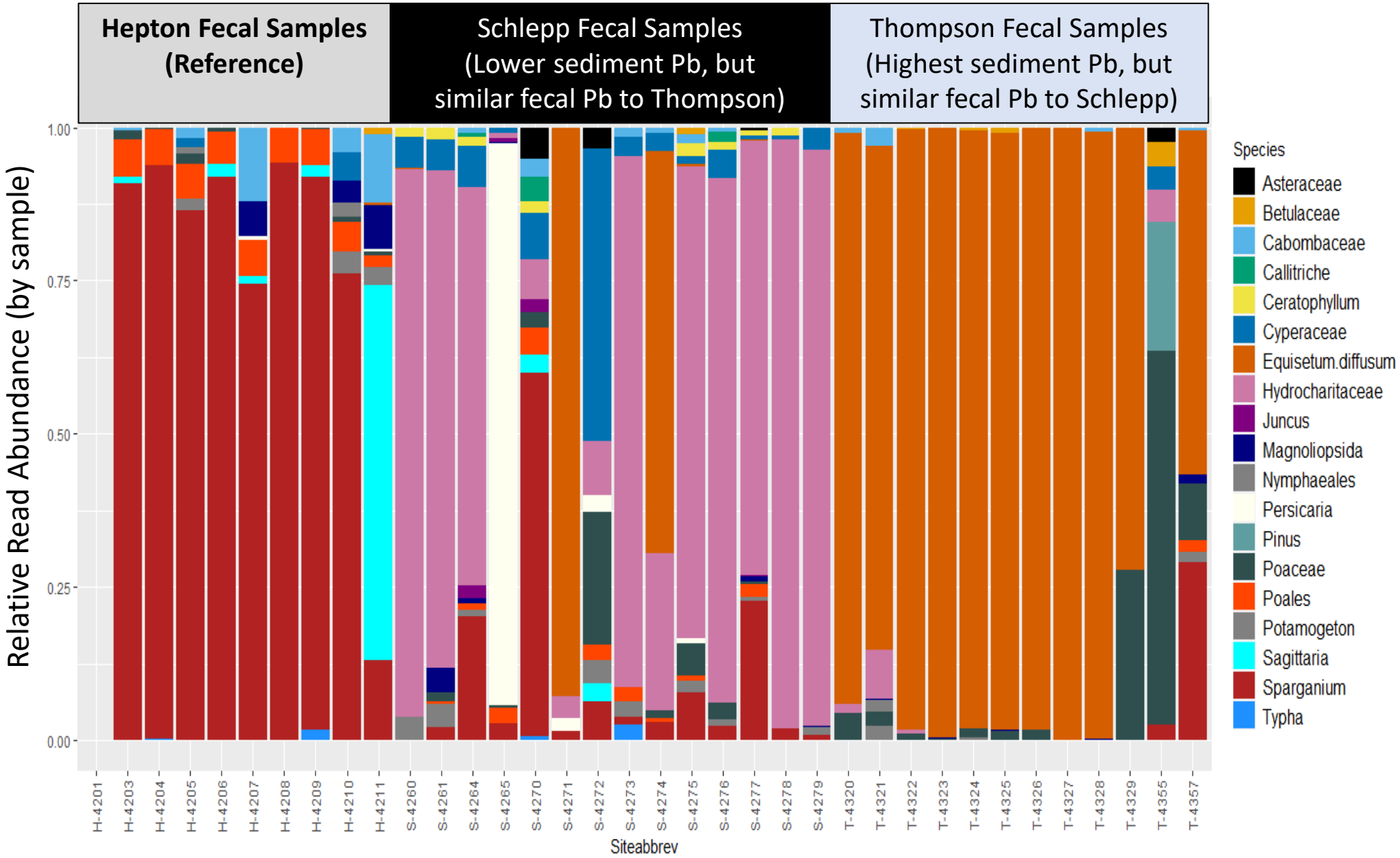
Sediment Pb was 4.03 times higher than fecal Pb



Environmental

Significant Diet (DNA) Differences Between Wetlands

- Hepton dominated by *Sparganium* (**bur-reed**)
- Schlepp more diverse, but dominated by *Hydrocharitaceae* (**Elodea**)
- Thompson dominated by *Equisetum diffusum* (**Himalayan horsetail**)
- *Sagittaria* (water potato) was <1% of detected DNA, **but correlated with higher Pb in feces**



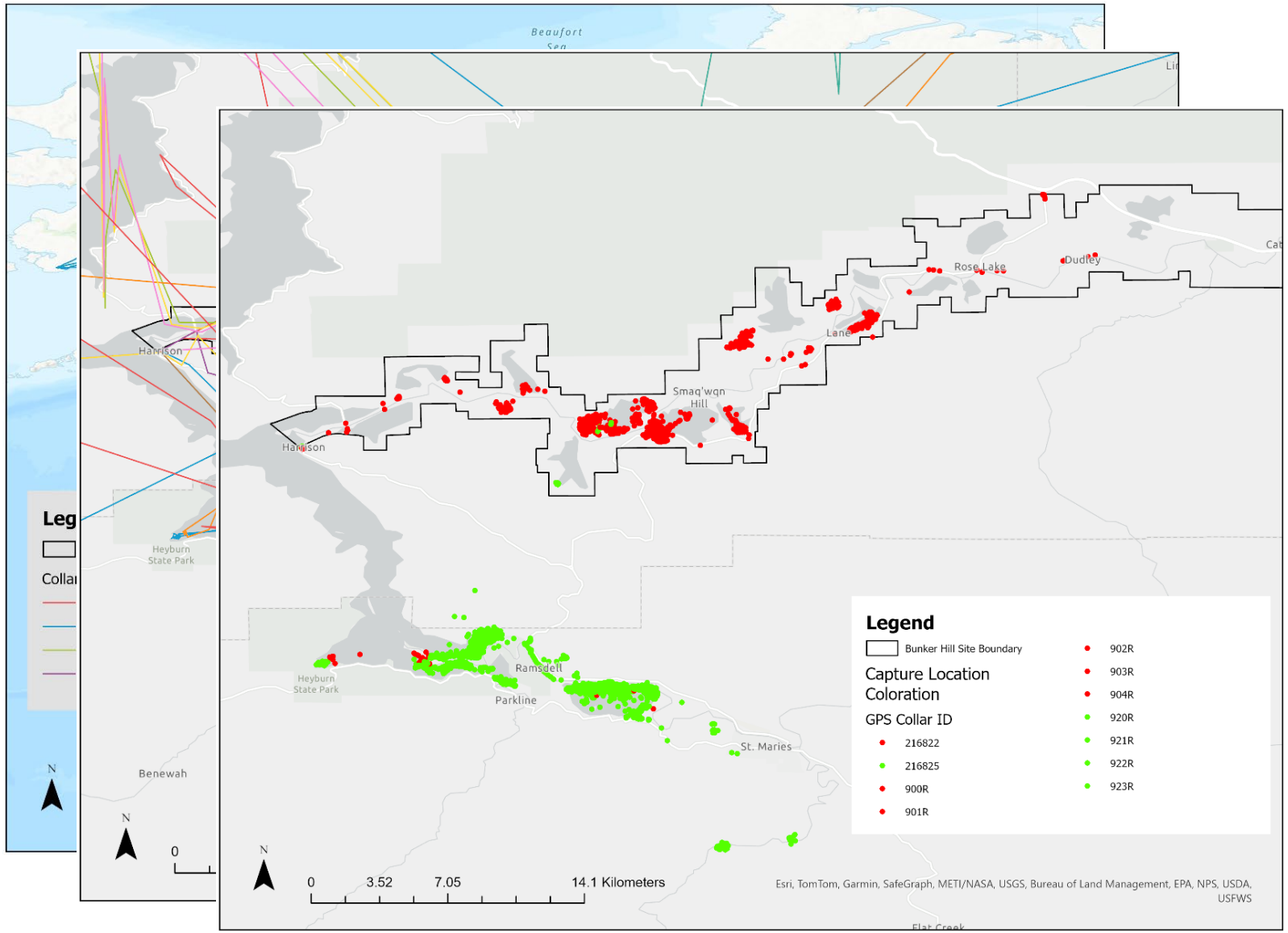
Environmental

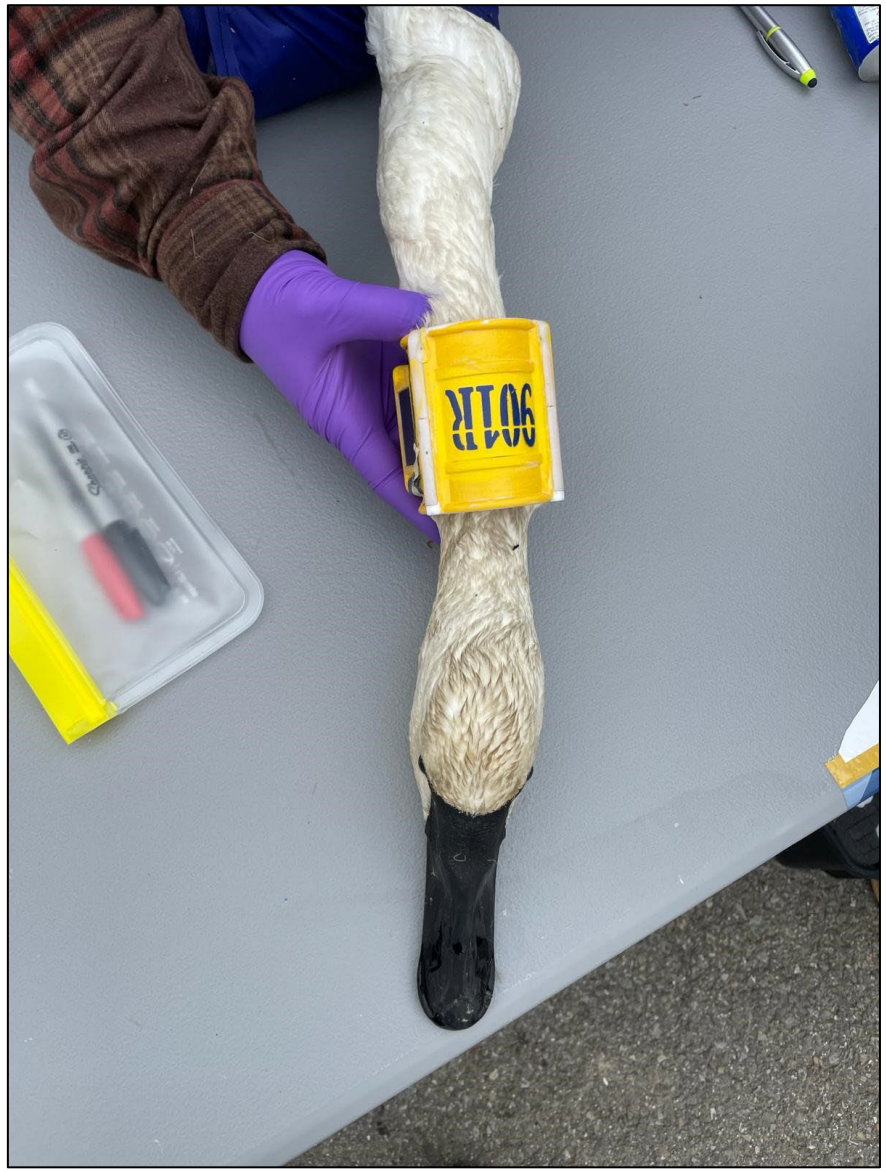
Summary of Vegetation Analyses

- Plant consumption similar within, but different across wetlands
- The five most common plants consumed by swans were *Equisetum* (horsetail), *Hydrocharitaceae* (elodea), *Sparganium* (bur-reed), *Persicaria* (knot weed), and *Poaceae* (rice).
- Based on 33 fecal samples from two wetlands, DNA read counts for *Sagittaria* negatively (-0.35, *P*=0.09) and *Equisetum* positively (0.34, *P*=0.11) correlated with Pb concentration.
- Pb not detected inside plant tissues (Luxton et al.)

Environmental

Site Use Monitoring by GPS Collars





Biological

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    - Relationships between fecal and blood Pb levels
    - Future: modeling impacts of Pb on life cycle
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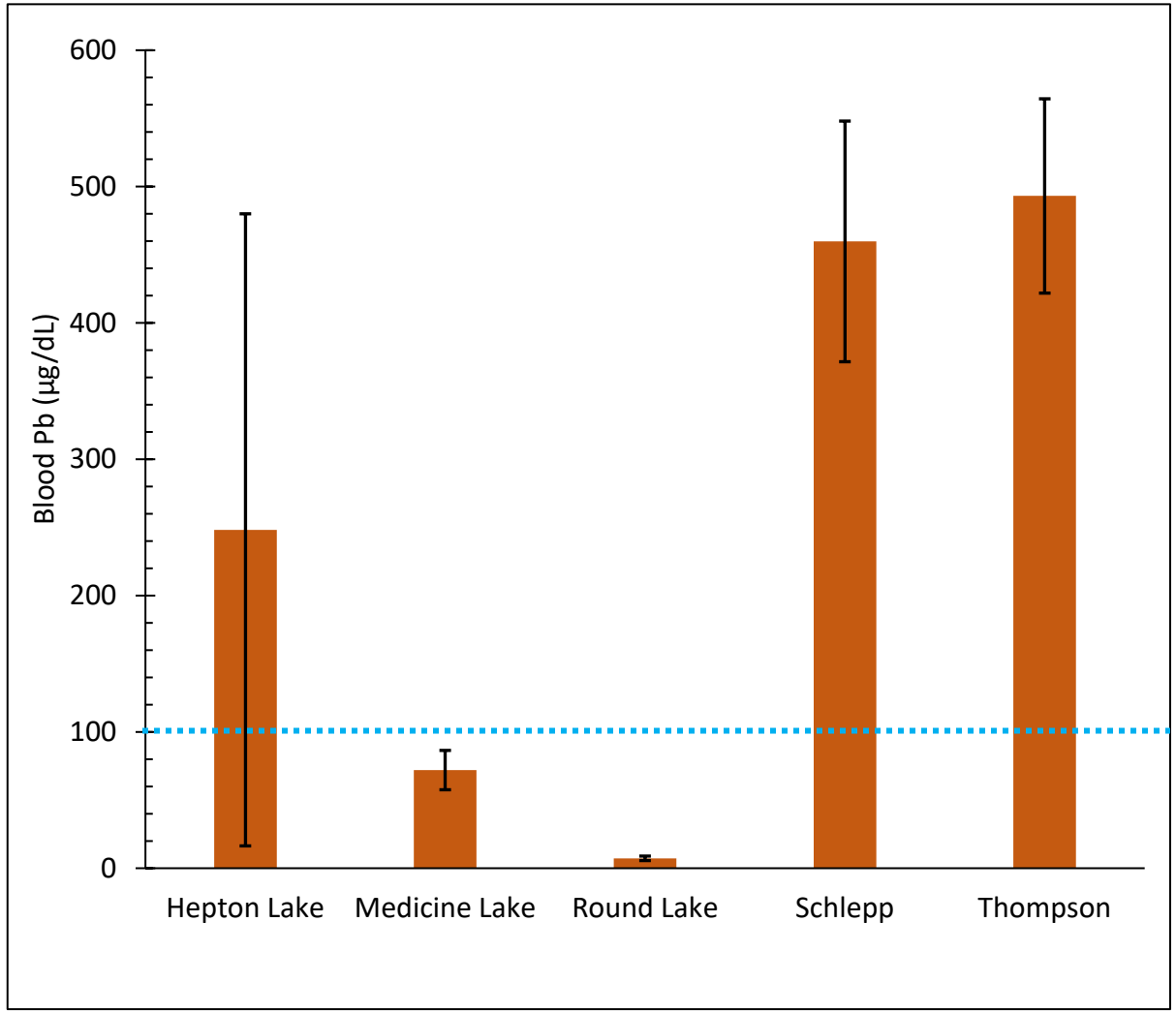
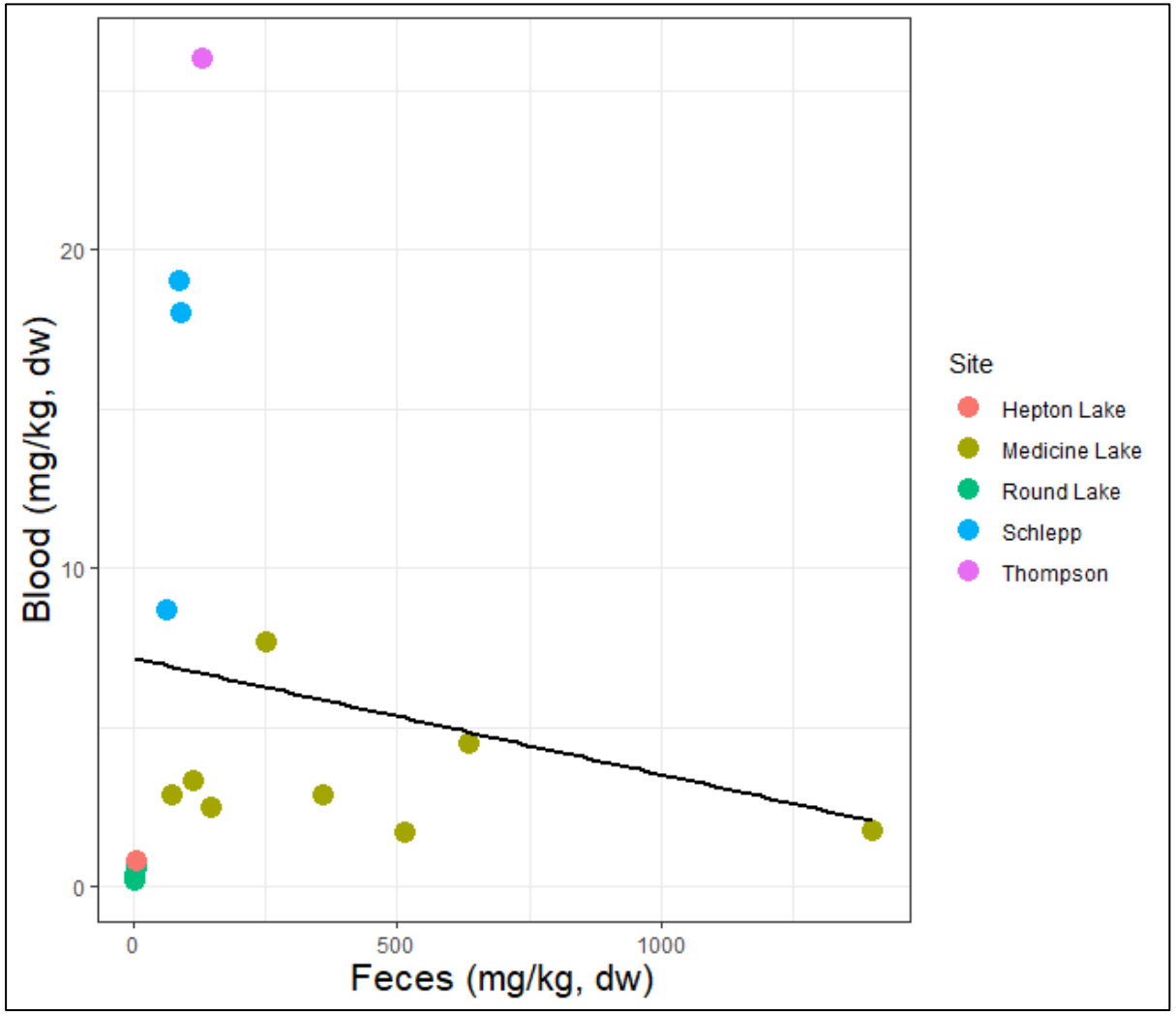
Biological

Relationship between fecal and blood Pb concentrations



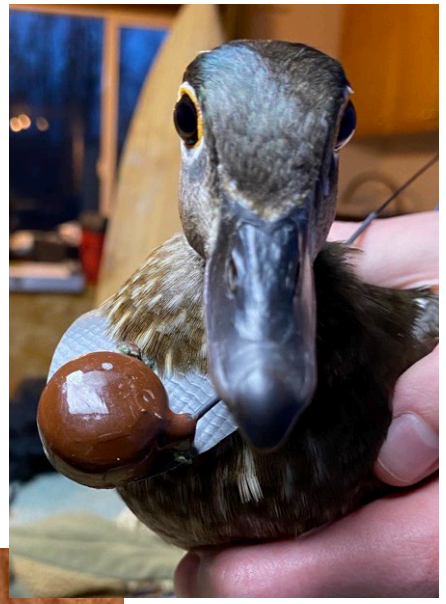


Severe clinical threshold Pb level

Next Steps to Integrate Effectiveness Monitoring Program and Guide Remedy Implementation

- Fecal deposition platforms
  - Looking into it for some wetlands soon
- Activity budget analysis
  - How long do birds feed at each location?
- Modeling
  - Simulate how remedy implementation strategies affect swan behaviors at the site (and vice versa), and thus Pb exposure potential
  - Couple with a model to estimate fitness costs of elevated Pb in feces
- Integrate into long-term monitoring strategy after next year?

Next Project: Wood Duck Eggshells



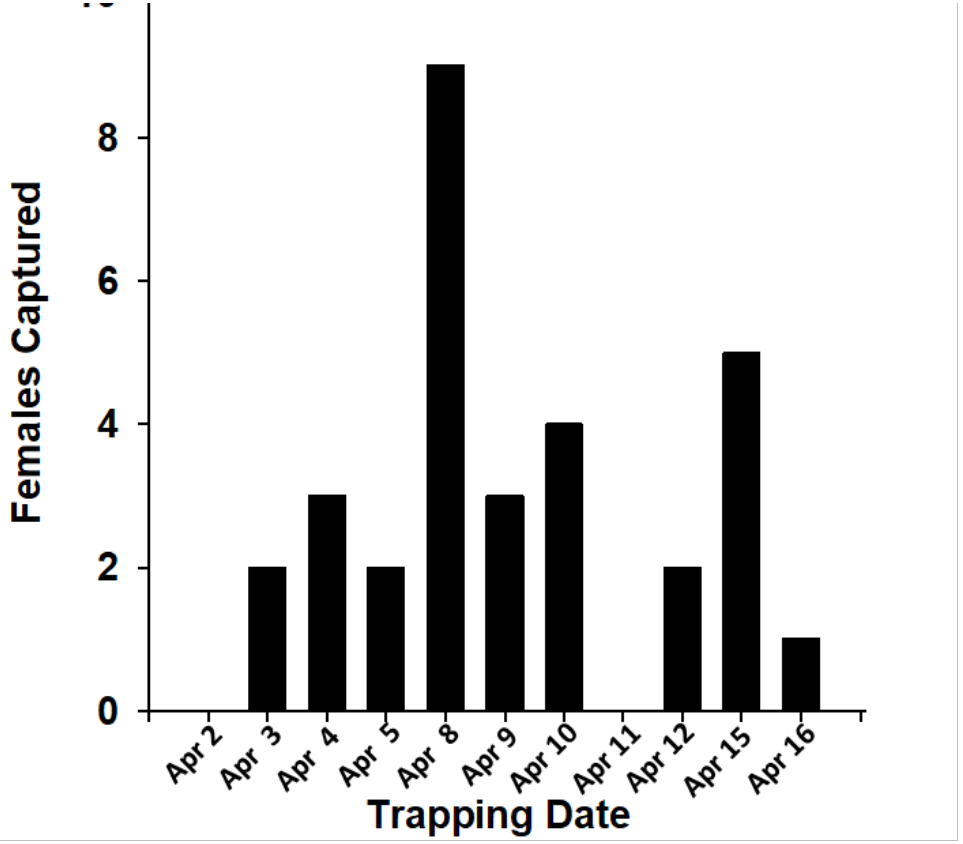
- Why Wood Ducks?
  - Wood ducks consume shallow benthic invertebrates during nesting season; swans forage deep into sediments
  - Likely wetland specific use during pre-laying (TBD)
  - Eggshells are easy to find and collect in nest boxes; part of IDFG's regular work to clean WODU boxes
  - Nesting success and other attributes could be monitored at nests

Goal: Determine if wood ducks are a reliable ecological receptor for remediation efforts

1) Radio telemetry – wetland spatial use
2) Nest ecology – egg Pb conc
3) Invertebrates – Pb in diet
4) Sediment/Porewater/Surface water – connects to biological exposure
5) Plant sampling – Pb in potential diet

USGS
science for a changing world

Wood Duck Capture

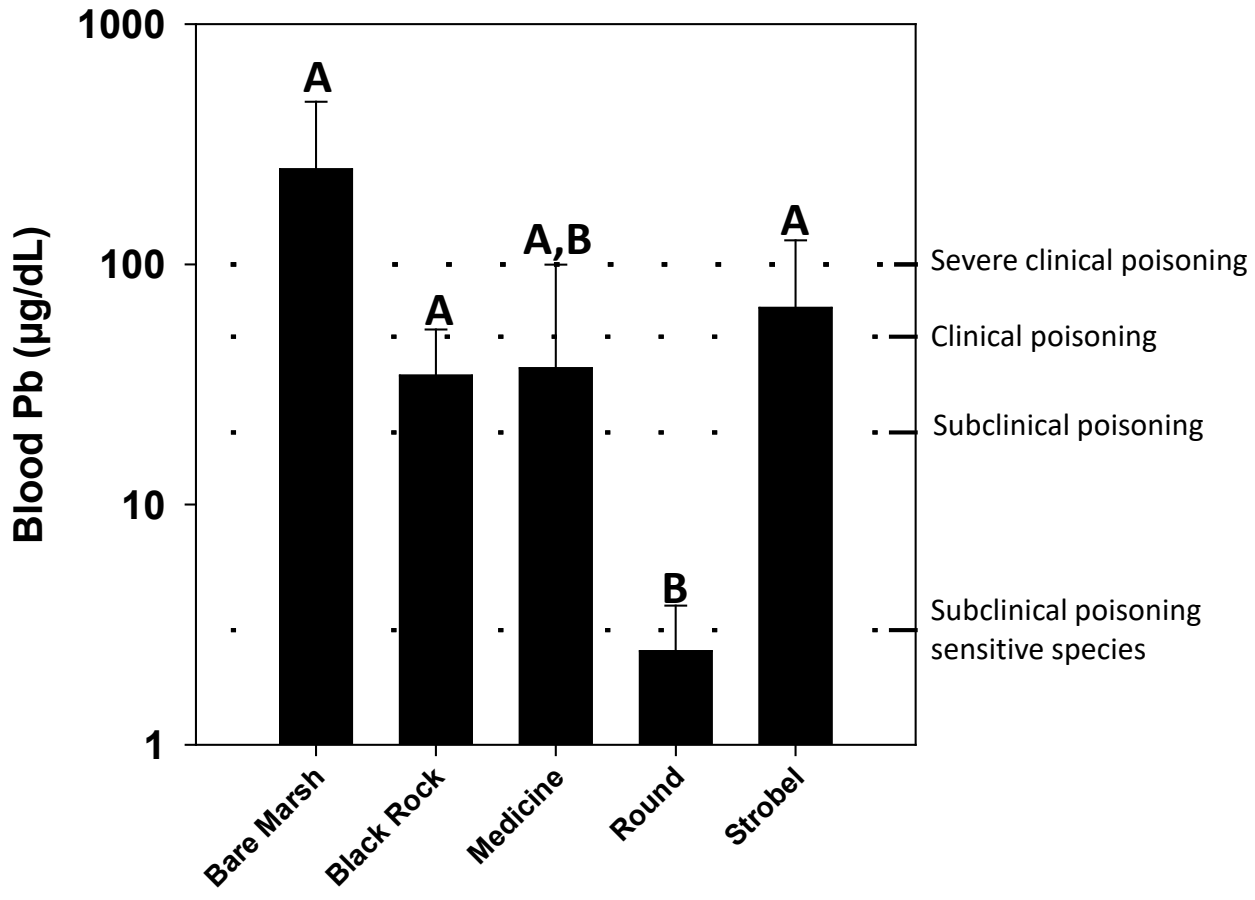


- Trapped April 2 - 16
- Captured & processed 37 wood ducks (31 females, 6 males)
- 11 days trapped, 2.8/d

USGS
science for a changing world

Wood Duck Pb

- Pb ranged from 1 – 604 µg/dL
- Geometric mean = 18 g/dL
- 65 % exceeded subclinical poisoning for sensitive species
- 46% exceeded subclinical poisoning
- 38% exceeded clinal poisoning
- 34% exceeded severe clinical poisoning

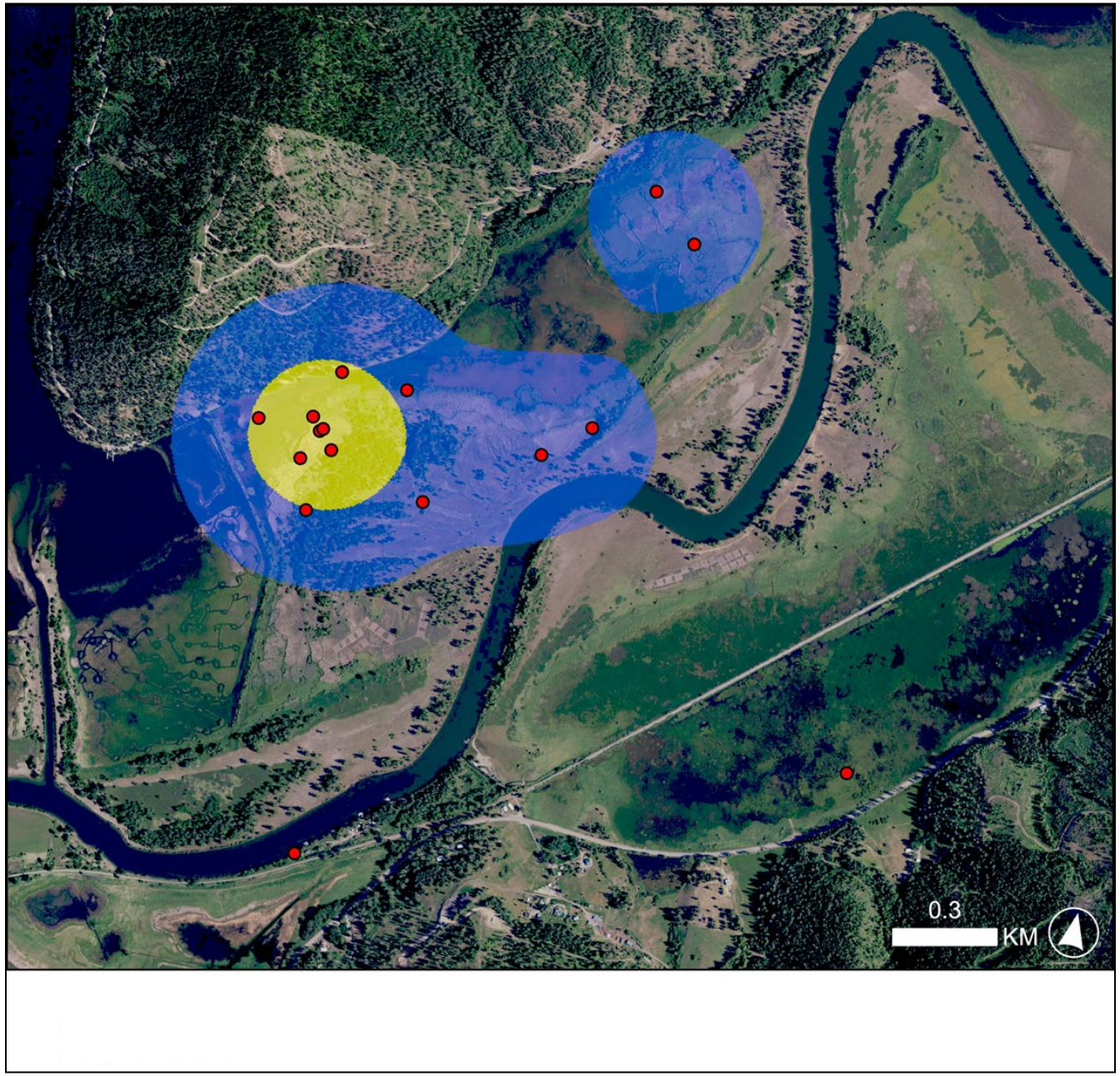


Wood Duck Telemetry

- 31 transmitters deployed on female wood ducks
- 494 total relocations across 31 marked females
- Average 16 locations/bird
  - (range 3 – 35)
  - Home ranges – 24 females

Example Range Map During Pre-laying Period, April-May 2024

- Preliminary Map by USGS of female wood duck locations
- Yellow, 50% use area guides pore water, water, sediment, and invertebrate collections



Conclusions & Next Steps

- TUSW
  - Rocket netting where swans normally go is path forward for capture
  - Most Pb is of Bunker Hill origin in blood and feces
  - Sediment Pb was generally higher than fecal Pb (~4x)
  - Pb in feces and blood don’t necessarily correlate
  - More work on vegetation and activity budgets to come followed by model development and implementation
- WODU
  - 32 telemetered birds at locations ranging from low to high sediment Pb
  - Water, sediment, invertebrates, and egg components being analyzed now
  - One more year of work to determine best matrix for monitoring
- Both
  - Likely: Feces and eggshells are wetland specific metrics that can be pooled for broader trends
  - Likely: Represent different but complementary environmental exposure pathways

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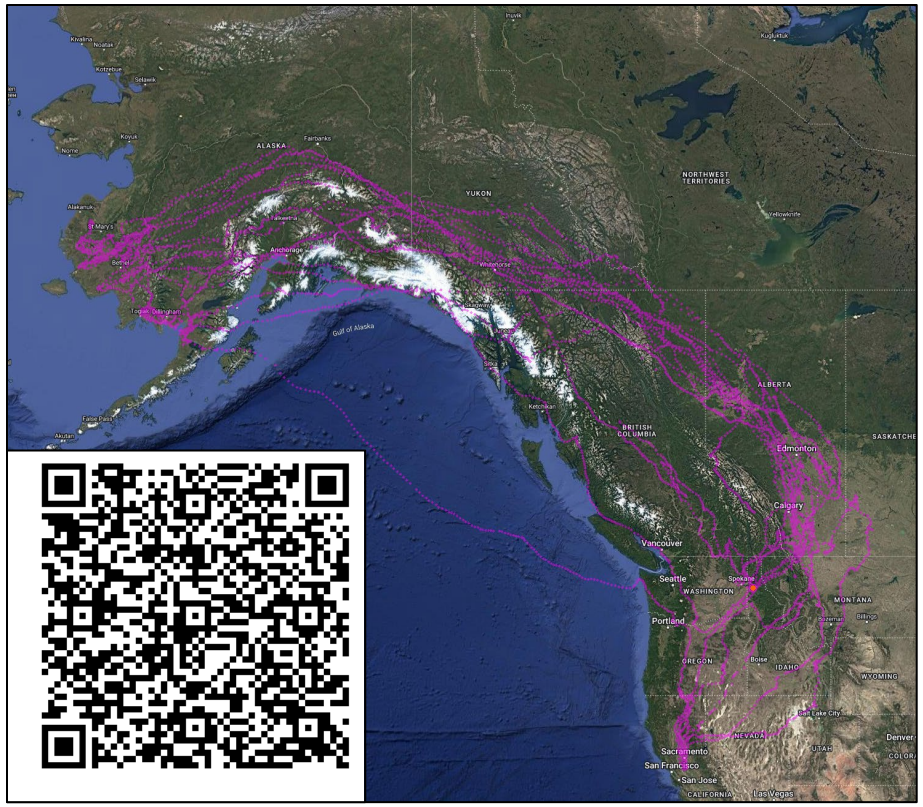
Questions?



QR Code to See the Swan Tracks

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Thank you!

Photo courtesy of
Cam Heusser, CDA Tribe