Putting aquatic species on the map: The eDNAAtlas and Archive for aquatic taxa in western North America

Michael Young and Dan Isaak
U.S. Forest Service, Rocky Mountain Research Station
Evolution of an idea

- **Origin:** concern about a focal species
  - Juvenile bull trout

- **Understanding its distribution**
  - SDM: Climate Shield
  - Uncertainty

- **eDNA sampling**
  - What is it
  - Why use it

- **Bull trout + eDNA**
  - Where to look
  - Early results

- **All species + eDNA**
  - eDNAtlas
  - eDNArchive

Detection
No detection
Why choose juvenile bull trout?

- ESA-listed as threatened
- Presence dictates land & water management & planning
- Widespread in PNW
- Often rare
- Difficult to detect
- Juveniles constrained by water temperature, vulnerable to nonnative spp.
- = candidate for occupancy modeling to identify suitable habitat
Identifying climate refugia for native trout – the Climate Shield

- Climate to cold-water habitat
- Predictions
  - Accurate & sufficient
  - Address invasive species
  - Empirical
  - Precise
  - Range-wide
- Projections
  - Address climate change
- Validation

https://www.fs.fed.us/rm/boise/AWAE/projects/ClimateShield.html or Google “cold-water climate shield”

~3700 potentially occupied cold-water habitats: which ones are?
Conventional sampling issues

- Harmful
- Expensive & time-consuming
- Ineffective
  - Rare native species
  - Invasion fronts & removal survivors
- Is there an alternative?
What is eDNA sampling?

- Environmental = “free”

- Mitochondrial (usually)
  - Durable
  - Abundant

- Nuclear options
  - Dolly Varden & coastal bull trout

*could be RNA
Why use eDNA sampling: efficiency

- Fast
- Portable
- Stable
- Cost: pennies on the dollar, minutes on the hour
- Rapid, broad-scale surveys are feasible
Why use eDNA sampling: accuracy

- Reliably* species-specific
- Sensitivity: high & quantified
  - Release rate: ~500 copies/sec
  - Detection threshold: 1 copy
- Very good at detecting rare species
- Occupancy estimates are robust

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Robust Detection of Rare Species Using Environmental DNA: The Importance of Primer Specificity

Taylor M. Wilcox\textsuperscript{1,2}, Kevin S. McKelvey\textsuperscript{1}, Michael K. Young\textsuperscript{1}, Stephen F. Jane\textsuperscript{2}, Winsor H. Lowe\textsuperscript{3}, Andrew R. Whiteley\textsuperscript{4}, Michael K. Schwartz\textsuperscript{1}

Understanding environmental DNA detection probabilities: A case study using a stream-dwelling char *Salvelinus fontinalis*

Taylor M. Wilcox\textsuperscript{1,2}, Kevin S. McKelvey\textsuperscript{1}, Michael K. Young\textsuperscript{1}, Adam J. Sepulveda\textsuperscript{2}, Bradley J. Shepard\textsuperscript{2,3}, Stephen F. Jane\textsuperscript{4}, Andrew R. Whiteley\textsuperscript{4}, Winsor H. Lowe\textsuperscript{5}, Michael K. Schwartz\textsuperscript{1}
Why use eDNA sampling: revolutionary

- Apply a consistent approach
- Craft a sampling design
- Engage the stakeholder community

- Defensible, precise, broad-scale occupancy estimates for priority species in real time for reasonable cost
eDNA: many applications

- Trout: rainbow, westslope cutthroat, Yellowstone cutthroat, brown
- Charr: bull, brook, Dolly Varden, lake, Arctic
- Salmon: Chinook, chum, coho, pink, sockeye
- Arctic grayling
- Any salmonid
- Pacific & brook lamprey
- Game fish/invaders: northern pike, sauger, walleye, smallmouth bass
- Non-game fish: sculpin (several), northern leatherside chub, loach minnow, spikedace
- Amphibians: Rocky Mountain tailed frog, western toad
- Mussels: western pearlshell, California floater
- Invertebrates: opossum shrimp, Snake River Physa
- North American river otter
- Harlequin duck
- Your species here...

NGC sample sites
n ~ 7,000
Using eDNA sampling to detect bull trout

- ESA listed as threatened
- Dictates land & water management & planning
- Widespread - rare
- Difficult to detect
- Juveniles constrained by environment/community
- = ideal candidate for eDNA sampling

- Test: Montana 2014
- Confirmed known habitats
- Discovered new ones

McKelvey et al. 2016
The range-wide, eDNA-based inventory of bull trout: Coordinators

Michael Young, Dan Isaak, Kevin McKelvey, Michael Schwartz, Tommy Franklin, Kellie Carim, Taylor Wilcox, Wade Fredenberg, Matt Groce, Dave Nagel, Dona Horan, Sherry Wollrab

<table>
<thead>
<tr>
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Institutional Support

![Great Northern Landscape Conservation Cooperative](image)

![U.S. Forest Service](image)

![USDA Forest Service, National Genomics Center for Wildlife and Fish Conservation](image)
Project framework

- **Target: natal bull trout habitats**
  - Cold-water habitats that are part of the Climate Shield
  - USFWS-designated critical habitat for bull trout spawning & rearing
  - Habitats about which recent occupancy is unknown

- **Grain:** sites at 1-km intervals

- **Scope:** all 8-digit U.S. HUs

- **Timing**
  - 2015: 500+ samples
  - 2016: 3,000+ samples
  - 2018: the rest of the range

- **Cost**
  - N. ID/W. MT: FREE!
  - S. ID/E. OR/WA: ½ price
  - W. OR/WA: full price

Detection

No detection
7-9 July 2015
Mean daily temperature 22 °C

23 October 2015
Mean daily temperature 9 °C
Crowd-sourced
Confirmed expectations
Rediscovery
Rapid corroboration

Detection
No detection

Little Blackfoot River
8-digit HU:
Upper Clark Fork
(Little Blackfoot River)

- Sampled ~1 September
- Sampled ~10 October

Detection
No detection
Upper Clark Fork (Little Blackfoot River)

- Sampled ~1 September
- Sampled ~10 October

8-digit HU:

- Detection
- No detection
The Rangewide Bull Trout eDNA Project: want to help?

- Visit our website: www.fs.fed.us/rm/boise/AWAE/projects/BullTrout_eDNA.html
- Google “rangewide bull trout eDNA project”
- Contact us to get your “library card”
- Follow the simple instructions

A Protocol for Collecting Environmental DNA Samples From Streams

Kellie J. Carim, Kevin S. McKelvey, Michael K. Young, Taylor M. Wilcox, and Michael K. Schwartz
Website: Get bull trout hunting directions

A protocol that explains how to collect eDNA samples.
2) Additional guidelines specific to the bull trout eDNA survey project.
3) A map and spreadsheet of eDNA points to guide your sampling.
4) The loan of a pump set with a battery & charger. We operate a “tool library” i.e., you can reserve a pump set for use during a particular time. The number of pump sets is limited and demand is high, so it’s important to reserve one. It’s also critical to return it when you are done to permit others to start their sampling.
5) Field kits for the collection and storage of eDNA samples. To ensure consistency in sampling and guarantee sterility of the supplies, we prefer to provide the field kits to you.

Once sampling is complete, return the pump set, field kits, and collected samples. In a few weeks, we’ll share with you whether and where bull trout were present. And at the end of each year, we’ll post an interactive map of the results of sampling across the range of bull trout on our website page.
Go sample & mail everything back
eDNA is the Ultimate...

One Person can Rapidly Sample Many Sites

Bull trout eDNA survey
St. Joe River (266 sites)
- Detection
- No detection

Redundancy & Inefficiency Lurk Dead Ahead!!!
No Database: Result = Expensive Chaos

>200,000,000 hourly records
>20,000 unique stream sites
>$10 - $15 million US$ to collect
Database: Result = Order & Efficiency

Temperature Scenarios

Interagency coordination

Stream temperature models

Species distribution & niche models
Database Teams Work on Data
Steps in eDNAAtlas Database Development

Data collected with standard protocol

A Protocol for Collecting Environmental DNA Samples From Streams

Kellie J. Carim, Kevin S. McElvee, Michael K. Young, Taylor M. Wilcox, and Michael K. Schwartz
General Technical Report RMRS-GTR-355

Metadata documentation & website delivery in user-friendly formats

QA/QC procedures (laboratory & data)

Steps in eDNA Atlas Database Development

Database entry (relational & geospatial)
A Microcosm of the eDNA Atlas:
Rangewide eDNA Bull Trout Project

Website: Many Resources

Supporting Science
Protocols
Sampling maps
Results
Year 1 Results…

Partners sampled…

2016: 3,000 stream sites
2017: 4,000 more site surveys planned
2018: 3,000 final site surveys

Sample sites are already organized in a database!

Funded by:
Great Northern Landscape Conservation Cooperative
Dynamic Web-data portal Delivers Results at Website

Query & download data by site, stream, HUC, DSP, species range
Dynamic Web-data portal Delivers Results at Website
~10,000 Samples in eDNAAtlas Database: Online in Late 2017

Collaborating Partners

BLM
Bureau of Reclamation
Chehalis Tribe
Clark Fork Coalition
Coeur d'Alene Tribes
Great Northern LCC
Idaho Conservation League
Idaho DEQ
Idaho Fish and Game
Idaho Power Company
Kalispel Tribes
Montana Dept. Natural Resources Conservation
Montana Fish, Wildlife & Parks
National Fish & Wildlife Foundation
The Nature Conservancy
National Park Service
Oregon Dept. Fish & Wildlife
Shoshone-Bannock Tribes
Trout Unlimited
University of Washington
U.S. Fish and Wildlife Service
USFS National Forests:
USFS Regions 1, 4, and 6
Washington Dept. Fish & Wildlife
Yakama Nation

& YOU
eDNAAtlas & Archive Advantages

1) Efficiencies of scale (i.e., you become part of a massive biological sensing network)
2) System gains efficiency as database size increases each year
3) System coevolves & improves from close collaborations between researchers & managers
4) Consistent data format & metadata documentation facilitates communication within & among agencies
5) Samples archived at NGC can be reused in the future
6) No reinventing of technical wheels (i.e., website/database design, geospatial stuff, etc.)
Goal: Big Databases & Good Information for All Species

High-resolution landscape models

I’m going to invest here...

...instead of here
If Interested, Contact the eDNA Team at NGC

Contact: Tommy Franklin (thomasfranklin@fs.fed.us; 406-542-4171)
Website: https://www.fs.fed.us/research/genomics-center/
Other options

- eDNA assay development
  - $7.5K/taxon
  - 2–3 months*

- Sample analysis
  - $85, 1st species
  - $35, all other species
  - 56-hour turnaround
  - All gear provided*

- Beyond presence
  - Abundance
  - Co-occupancy
  - Multi-species assessments

Questions?
Live Demo of Bull trout eDNA AGOL data tool:
https://usfs.maps.arcgis.com/apps/webappviewer/index.html?id=6d5597b2755c4c00a35613b7a1849760