Introduction to environmental DNA (eDNA)

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What is environmental DNA (eDNA)?

- All living things have DNA
- eDNA is DNA released from an organism into the environment
- Arises from sloughed cells
  - Skin, hair, scales, etc.
  - Intestinal tract
  - Sperm, eggs
  - Remnants
What is Environmental DNA (eDNA)?

- Potential for nuclear DNA or RNA, but most frequently use mitochondrial DNA
- Mitochondrial DNA is more stable in the environment
- Many copies of mtDNA in each cell
- Mitochondrial genome is short, so sequences are known for most organisms

https://ajweinmann.wordpress.com/organelle/
How do we analyze eDNA?

- Collect
- Concentrate
- Extract
- Amplify
- Detect
How do we detect DNA from one organism and not others?

Quantitative Polymerase Chain Reaction (qPCR)

If the primer sequence matches, the DNA will be copied.
How do we detect DNA from one organism and not others?

Quantitative Polymerase Chain Reaction (qPCR)

If the primer sequence does not match, the DNA will not be copied.

DNA of NON-Target Organism
How do we detect DNA from one organism and not others?

Quantitative Polymerase Chain Reaction (qPCR)

DNA of Target Organism

Primer

Fluorophore

Quenchers

Probe

Fluorophore will be released if probe sequence matches
How do we detect DNA from one organism and not others?

Fluorescent signal will only be detected if Primer sequence matches AND Probe sequence matches.

Quantitative Polymerase Chain Reaction (qPCR)
The History of eDNA

- Microbiologists first used eDNA techniques to identify microbes in soil and water in 1990’s
  - Identify toxic algal blooms
  - Identify fecal contamination in water supplies
  - Identify pathogens in the environment
  - Characterize microbiomes

Photo Credit: Fabling cabin fevers blog
The History of eDNA

Molecular Ecology (2003) 12, 1660–1667
doi: 10.1046/j.1365-294X.2003.01823.x

SHORT COMMUNICATION
Genetic marker investigation of the source and impact of predation on a highly endangered species

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Molecular Ecology Resources (2008) 8, 561–567
doi: 10.1111/j.1755-0998.2007.02344.x

TECHNICAL ADVANCES
Optimizing the use of shed feathers for genetic analysis

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BMC Genetics

Research article
Genetic characterisation of farmed rainbow trout in Norway: intra- and inter-strain variation reveals potential for identification of escapees
Kevin A Glover

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USGS
The History of eDNA

Species detection using environmental DNA from water samples

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“Sight-unseen” detection of rare aquatic species using environmental DNA

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2 Great Lakes Project, The Nature Conservancy

Environmental DNA as a new method for early detection of New Zealand mudsnails (Potamopyrgus antipodarum)

Caren S. Goldberg1,3, Adam Sepulveda2,4, Andrew Ray2,5, Jeremy Baumgardt1,6, and Lisette P. Waits1,7

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Publishing on eDNA

Search Results for Articles Published with (environmental + DNA)
Uses of eDNA analysis

- Detecting rare, cryptic, or elusive species
- Detect migration or spawning behavior
- Monitor species abundance changes in time
- Determine species assemblages
- Evaluate management action
- Archive records
Detecting Rare, Cryptic, or Elusive Species

- Monitoring invasion fronts for early detection to allow rapid response
- Surveying for endangered species
- DNA evidence can’t flee or hide

Partial list of species being studied with eDNA:

- American Bullfrog
- Asian Carp
- Black Warrior Water Dog
- Bluegill
- Brook Trout
- Burmese Python
- Common Carp
- Dreissenid Mussels
- Eastern Hellbender
- Feral Swine
- Flattened Musk Turtle
- Golden Tree Frog
- Great Crested Newt
- Hines Emerald Dragonfly
- Idaho Giant Salamander
- Microcystis
- New Zealand Mudsnaill
- Northern Pike
- Round Goby
- Rudd
- Rusty Crayfish
- Sea Lamprey
- Sturgeon
- Spectaclecase Mussel
- Swollen River Mussel
- Walleye
- Waterfleas
- Water Soldier
- Winged Maple Leaf Mussel
- ... and many more
Even the most Cryptic and Elusive Species

LOCH TEST MONSTER Scientists to test water of Loch Ness for DNA to find out once and for all if Nessie is real

Professor Neil Gemmell will gather water samples and analyse them using the same techniques as police forensic teams

NOTE: The USGS does not acknowledge or deny the existence of the Loch Ness Monster. This is NOT a USGS research project.
A Caveat to eDNA Detection of Rare Species

Persistence of Environmental DNA in Freshwater Ecosystems

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Persistence of DNA in Carcasses, Slime and Avian Feces May Affect Interpretation of Environmental DNA Data

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Early Detection of Invasive Species

Samples collected: 26-March, 2014

Original Infestation Discovered, 2013

New Zealand Mudsnaill in Wisconsin
Early Detection of Invasive Species

New Zealand Mudsnails in Wisconsin

- Tested 46 other sites
- New Zealand Mudsnails were not detected outside BEC
- After this study, WI DNR has also discovered NZMS in Badger Creek

Merkes and others, 2015
Detect Migration or Spawning Behavior

DNA Concentration versus Migrating Bigheaded Carp

Erickson and others, 2016
Detect Migration or Spawning Behavior

- Manage timing for opening and closing barriers
- Disrupt spawning behavior for invasive species
- Limit use during spawning for endangered species
- Trigger control action

Gilbert, 2012
Monitor Abundance Changes Over Time

DNA released into the environment versus bigheaded carp biomass

Klymus and others, 2014
Monitor Abundance Changes Over Time

eDNA Concentration = DNA released – DNA degraded

Some factors that could affect shedding and degradation rates:

- pH
- Temperature
- Food availability
- Season
- Turbidity
- UV exposure
Determine Species Assemblages

DNA barcoding: Species identification from short DNA sequences
Evaluate Management Action

Controlling Invasive Species

Restoring Natural Habitat

In both cases, eDNA can be used to evaluate success.
Archive Records

- eDNA samples can be tested for many species
- Multiple tests can be done on the same samples
- Species of concern today may not be the same in the future
- Samples can be archived frozen or dried
- Archived samples can be reanalyzed years later
Next Steps

Instead of spending countless hours doing this…

Develop molecular methods and computer automation to analyze high throughput sequencing
Next Steps

**eDNA Concentration** = DNA released – DNA degraded

Some factors that could affect shedding and degradation rates:

- pH
- Temperature
- Food availability
- Season
- Turbidity
- UV exposure

Refine the formula for better estimates
Next Steps

More automation for active monitoring and long-term data generation
Next Steps

Enable Citizen Science

#portableDNAamplifire
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Thank You

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