Designing monitoring programs for aquatic species using environmental DNA

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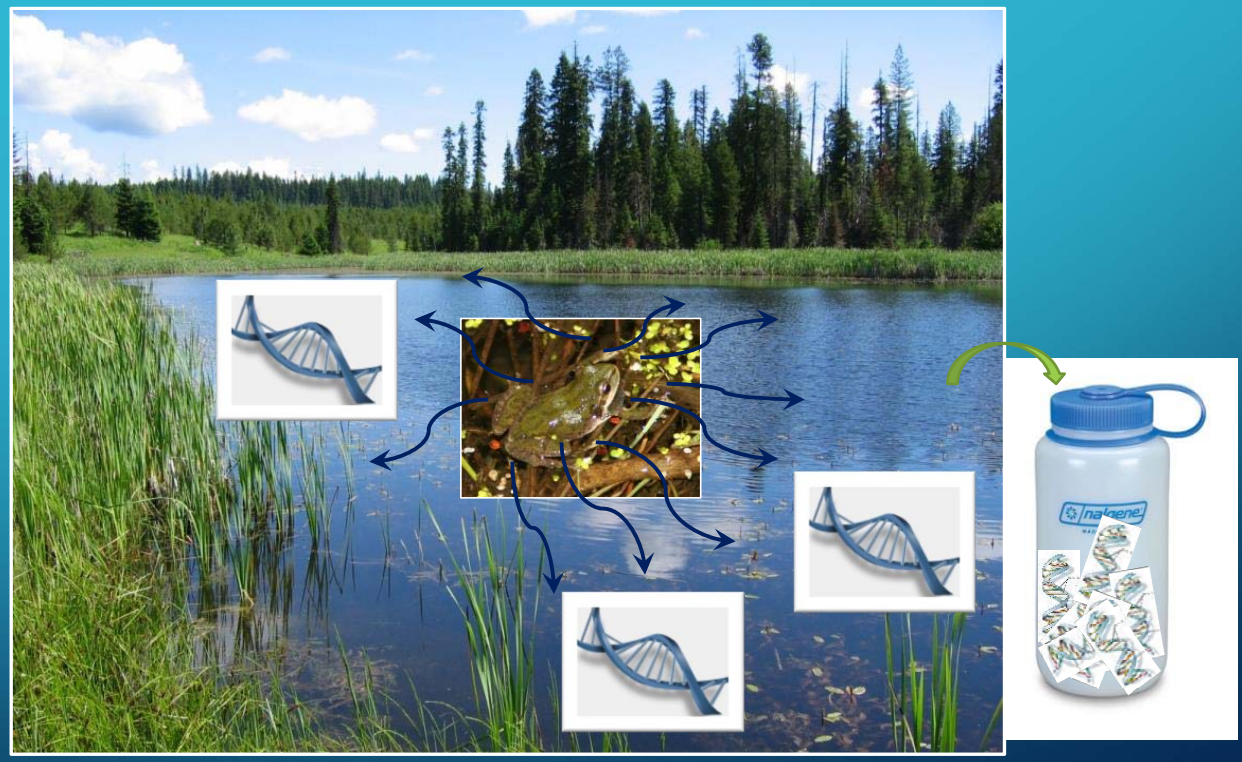
Challenges of monitoring aquatic species

Surveys can be:

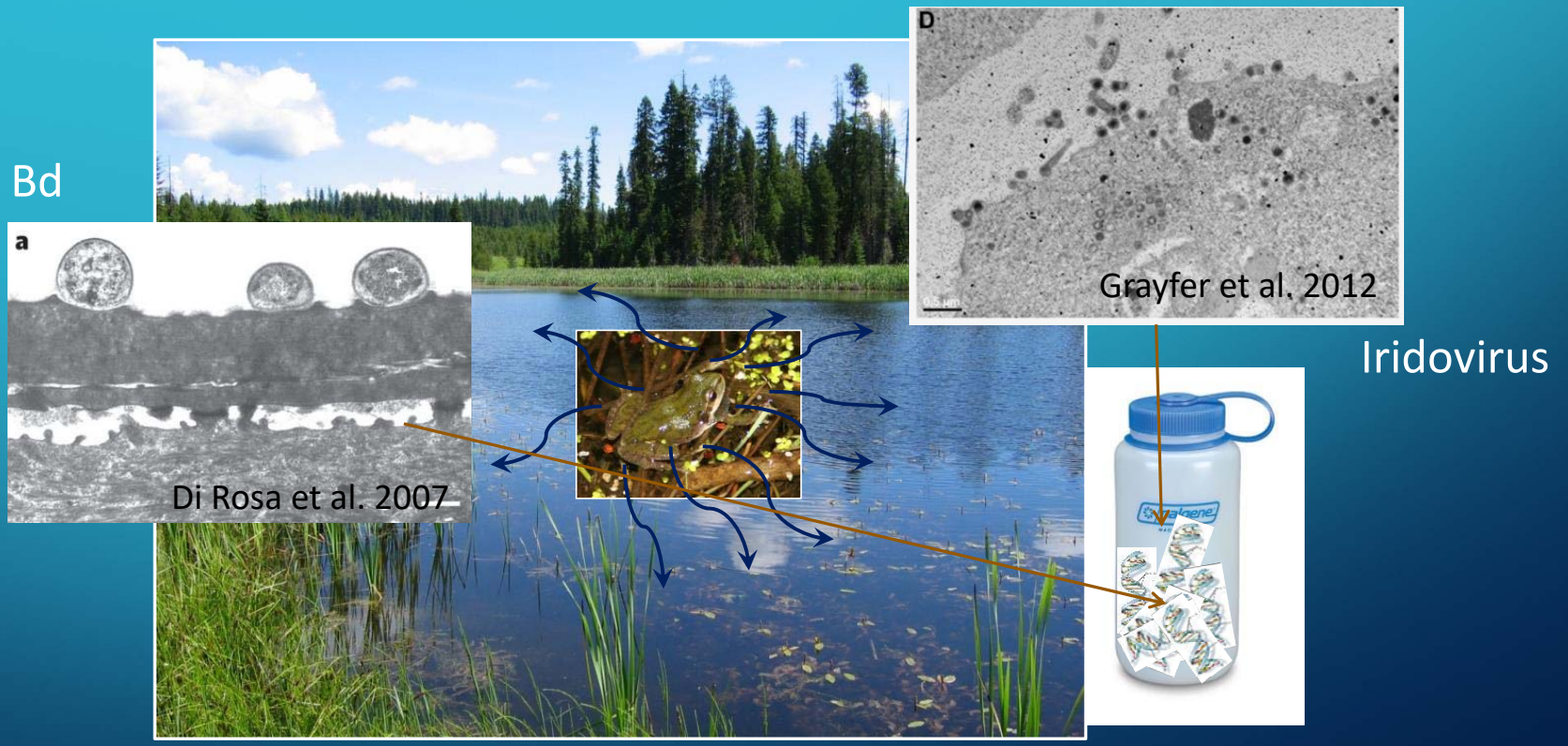
- difficult
- destructive
- time-consuming

And still may miss species that are present

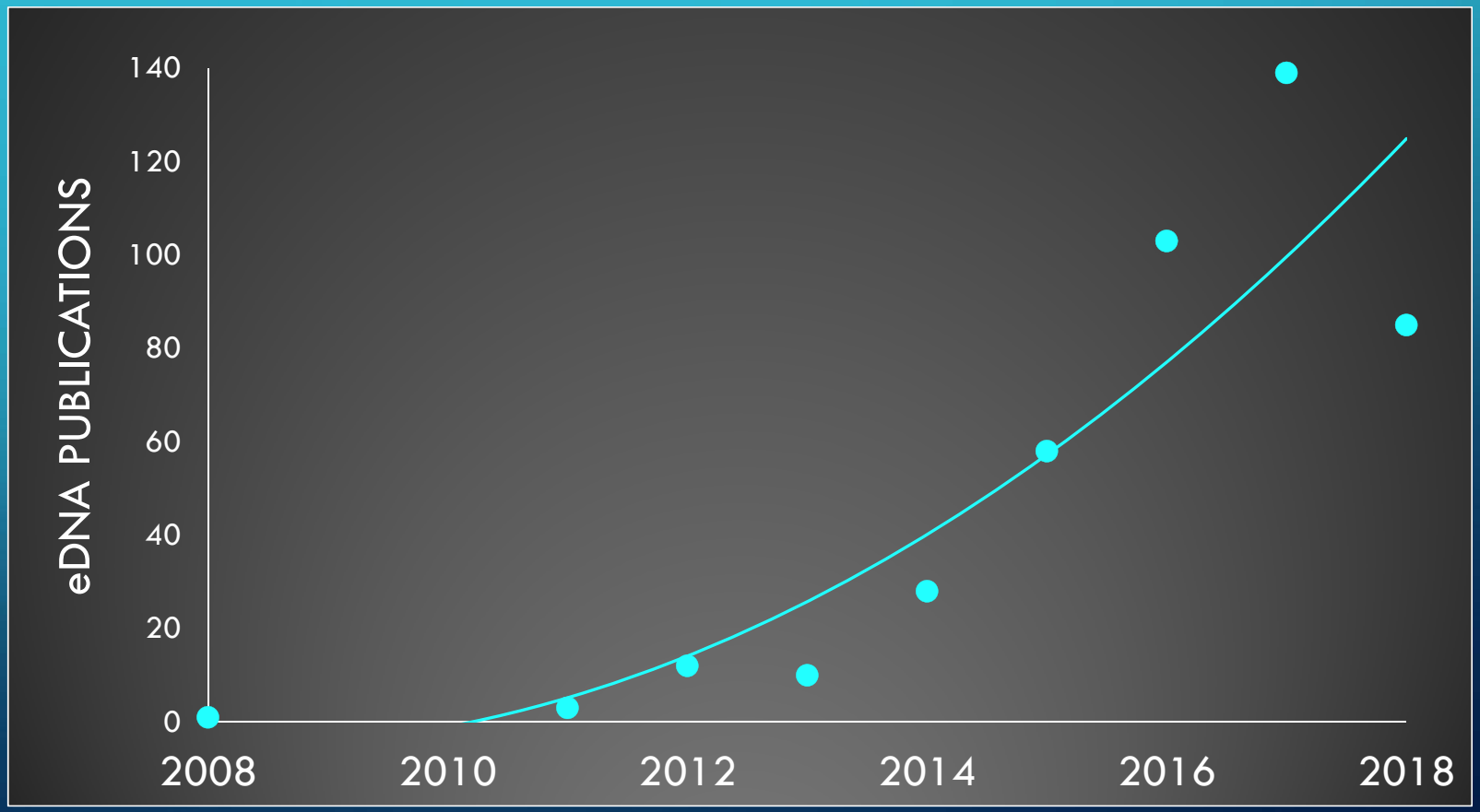
Environmental DNA (eDNA)



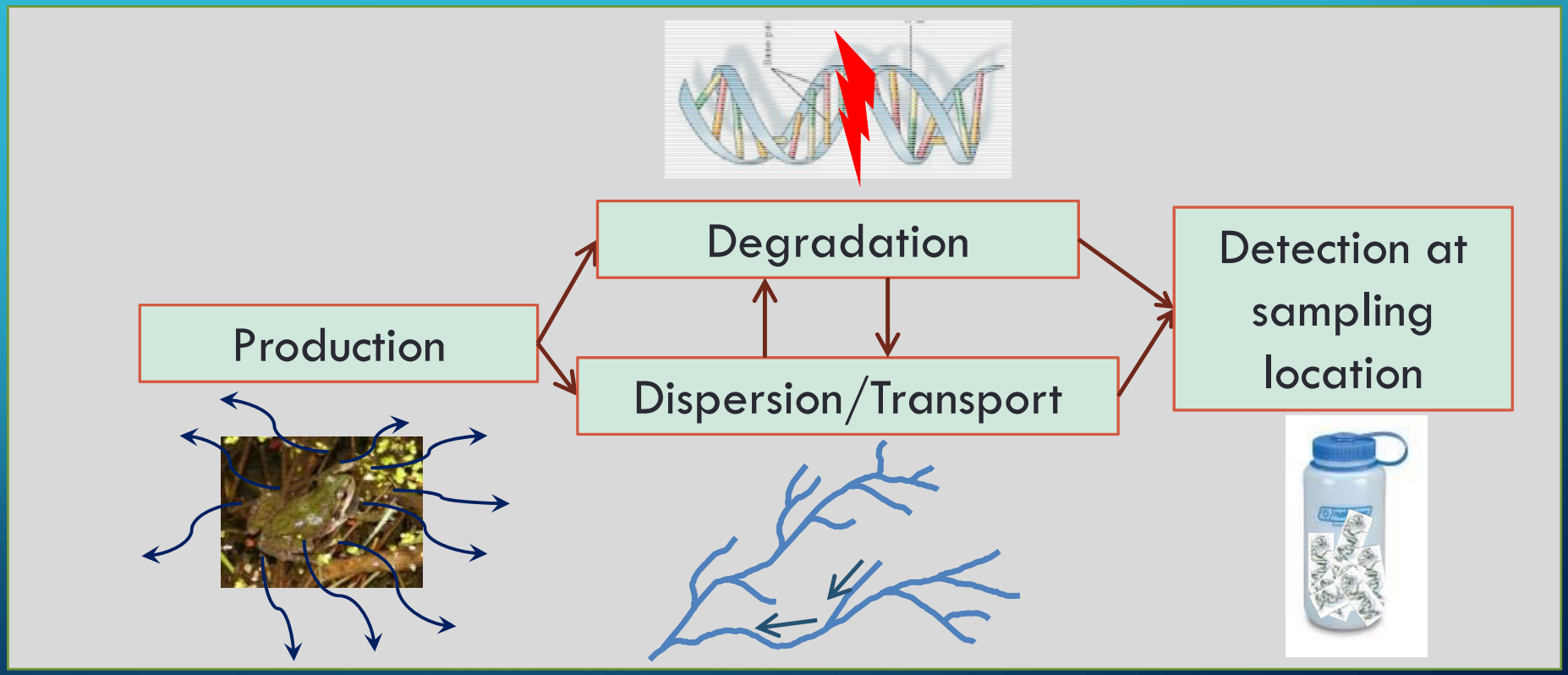
Environmental DNA (eDNA)



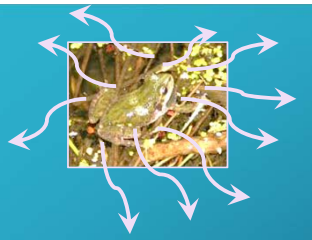
eDNA detection of macro-organisms



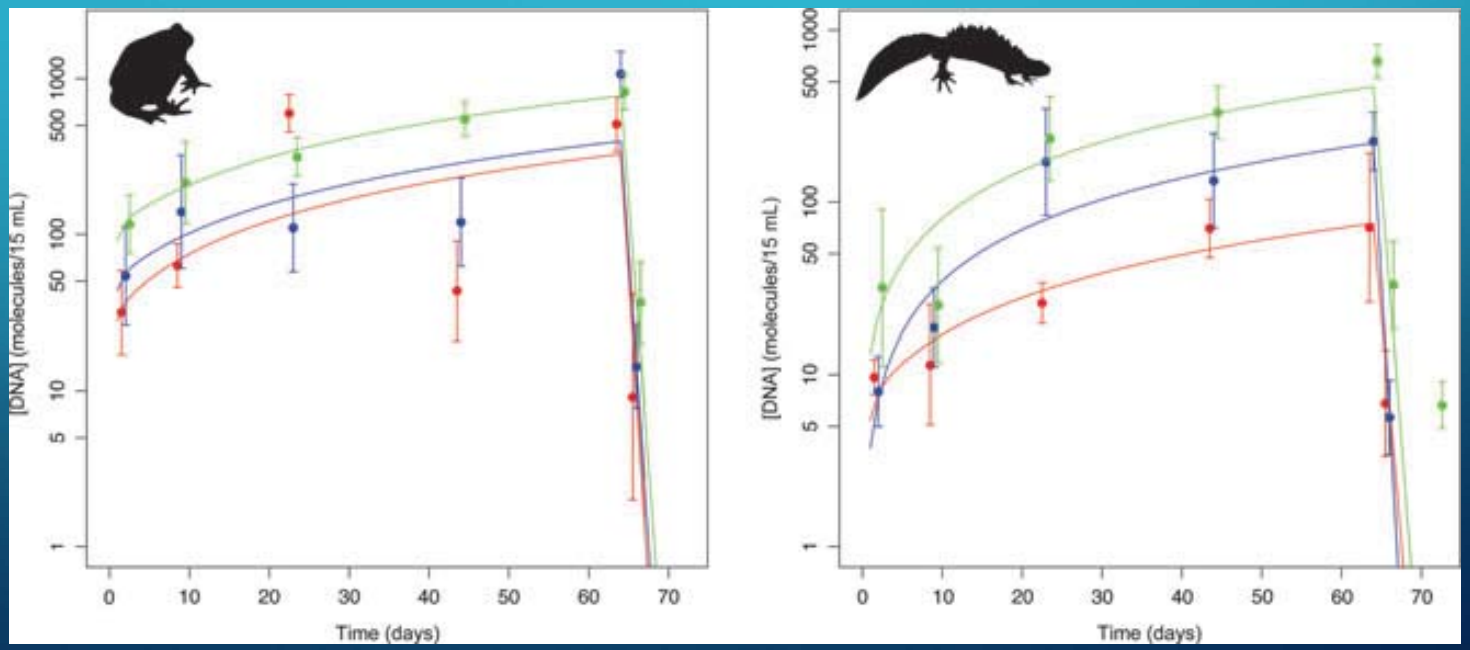
What limits eDNA detection?



eDNA production

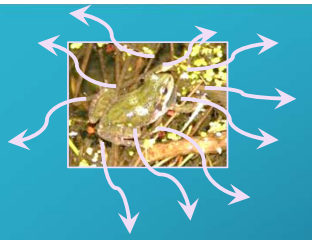


- Could be affected by:
  - Metabolism, stress, water chemistry, population density…

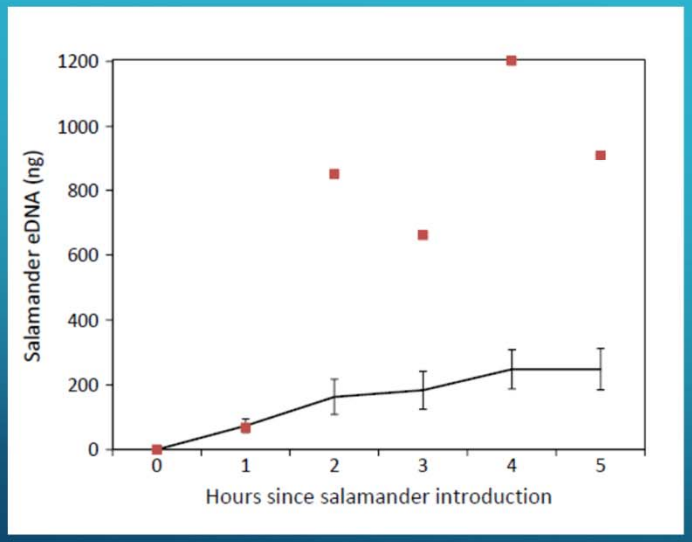


Thomsen et al. 2012

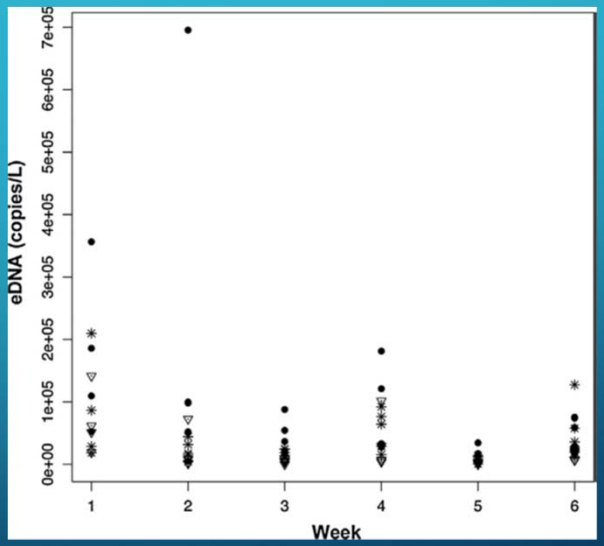
eDNA production



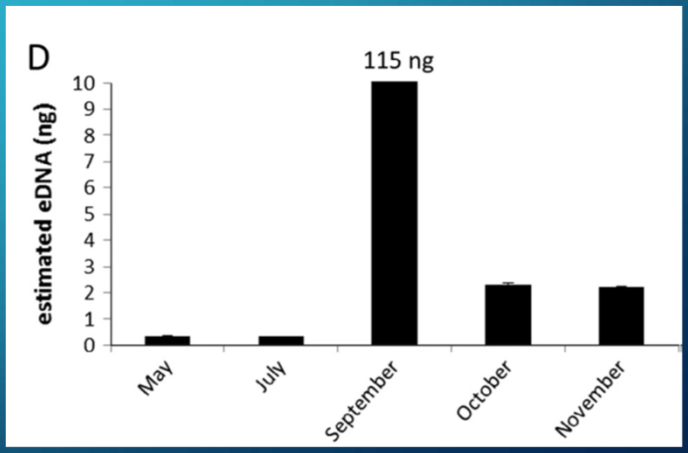
- Varies widely across individuals and within individuals across time



Pilliod et al. 2014

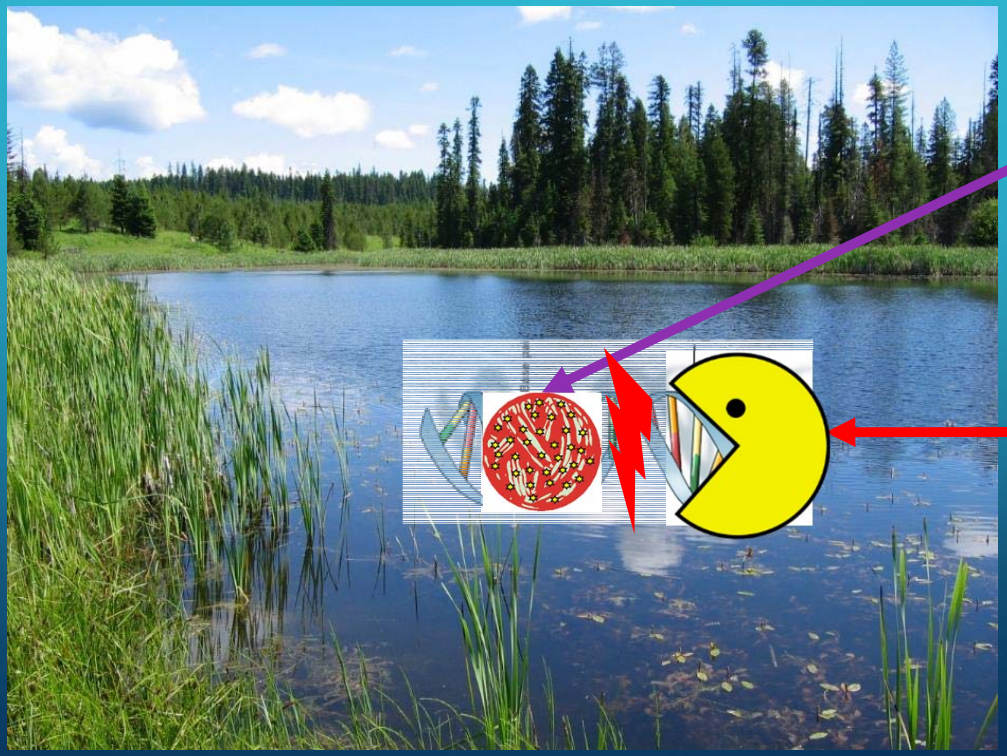


Klymus et al. 2015



Spear et al. 2015

eDNA degradation

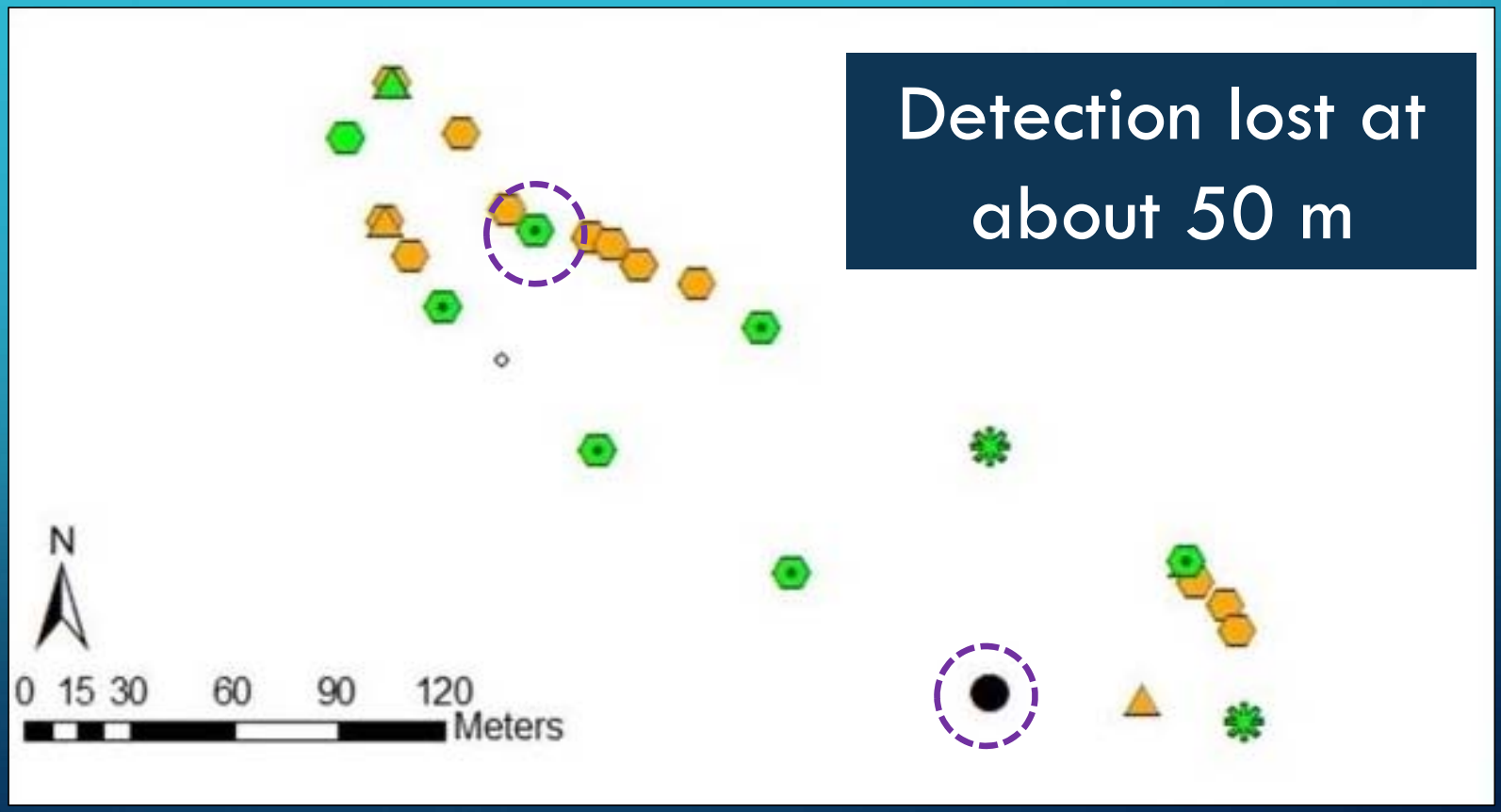


UV

Increased activity

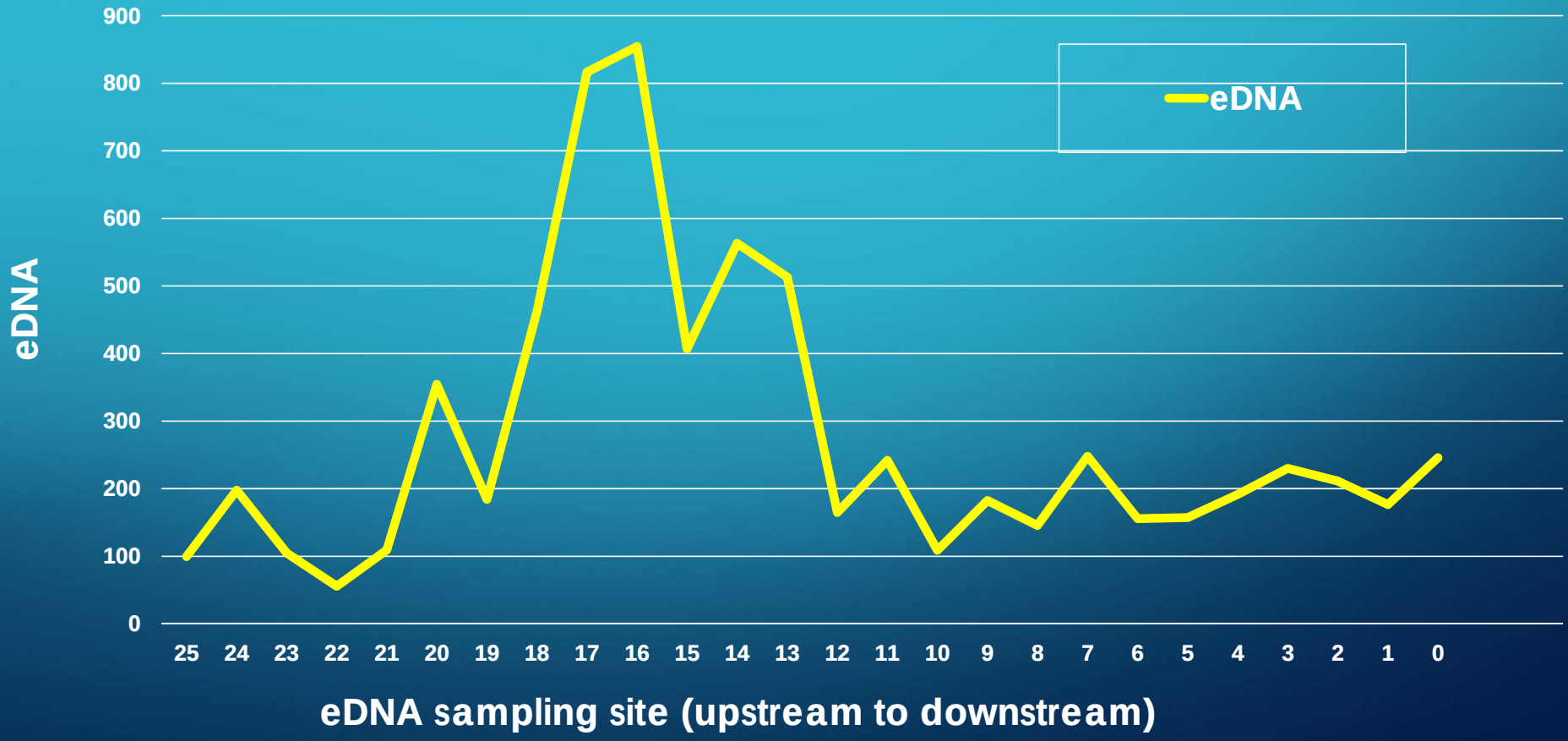
endonucleases/
exonucleases

Limits of eDNA dispersion

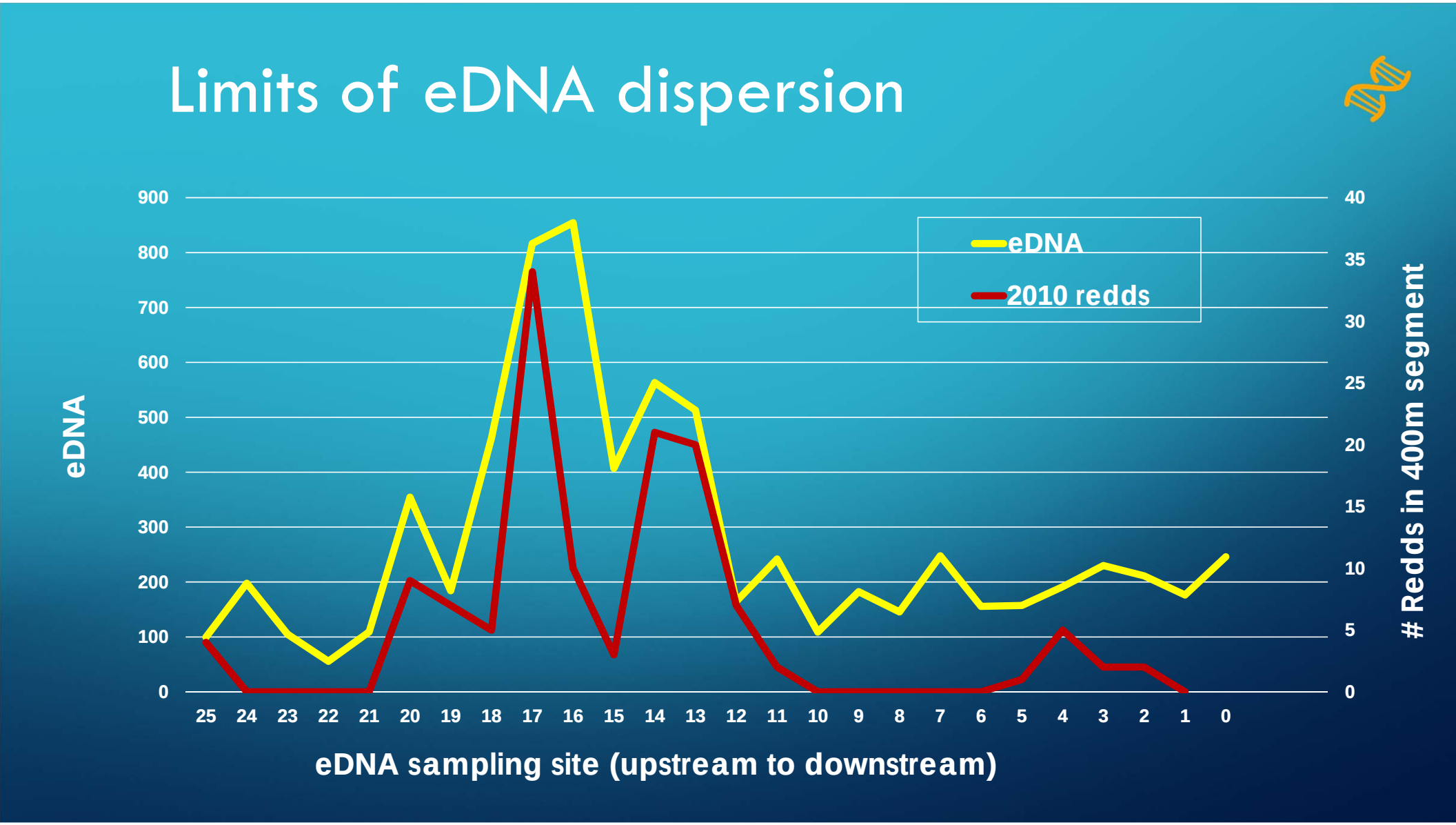


Lucid et al. in prep

Limits of eDNA dispersion



Limits of eDNA dispersion



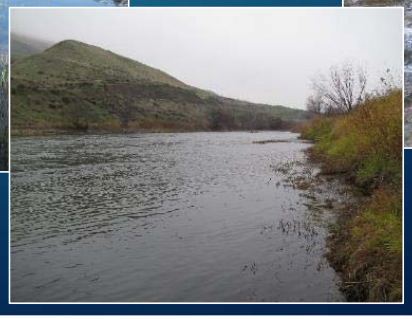
eDNA in Practice

- Very sensitive, accurate tool for species detection
- Works better for some species and systems than others

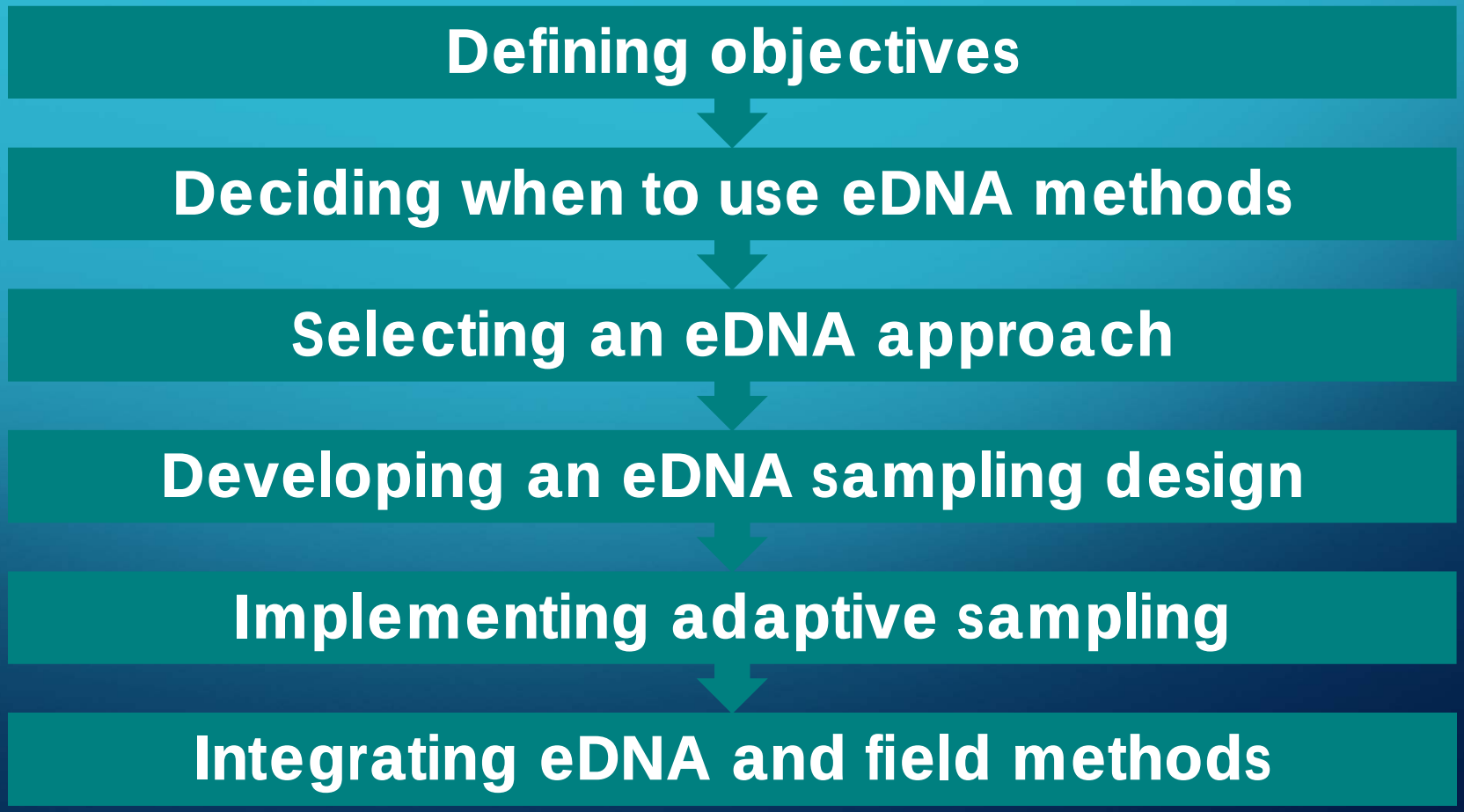
► Need for systematic implementation of eDNA methods








Framework for applying eDNA methods



Defining objectives

- Occupancy (species presence)
- Population estimation
- Disease status/physiological condition
- Single species or multispecies detection
- Temporal and spatial scales

Defining objectives

eDNA inference

- eDNA *can* tell us:
  - Recent target species presence
  - Amount of eDNA in a sample
  - Pathogen presence
  - Presence of potential hybridizing non-native species
- eDNA *can't* tell us:
  - Age structure
  - Reproductive status
  - Population size
  - Disease status
  - Presence of hybrid individuals
  - Presence of non-target species (qPCR)

U.S. Air Force Photo
Heide Couch

Deciding when to use eDNA methods

When is eDNA is most useful?

Target species are difficult to detect

- elusive
- rare/low density
- difficult to identify

Conventional survey methods are problematic

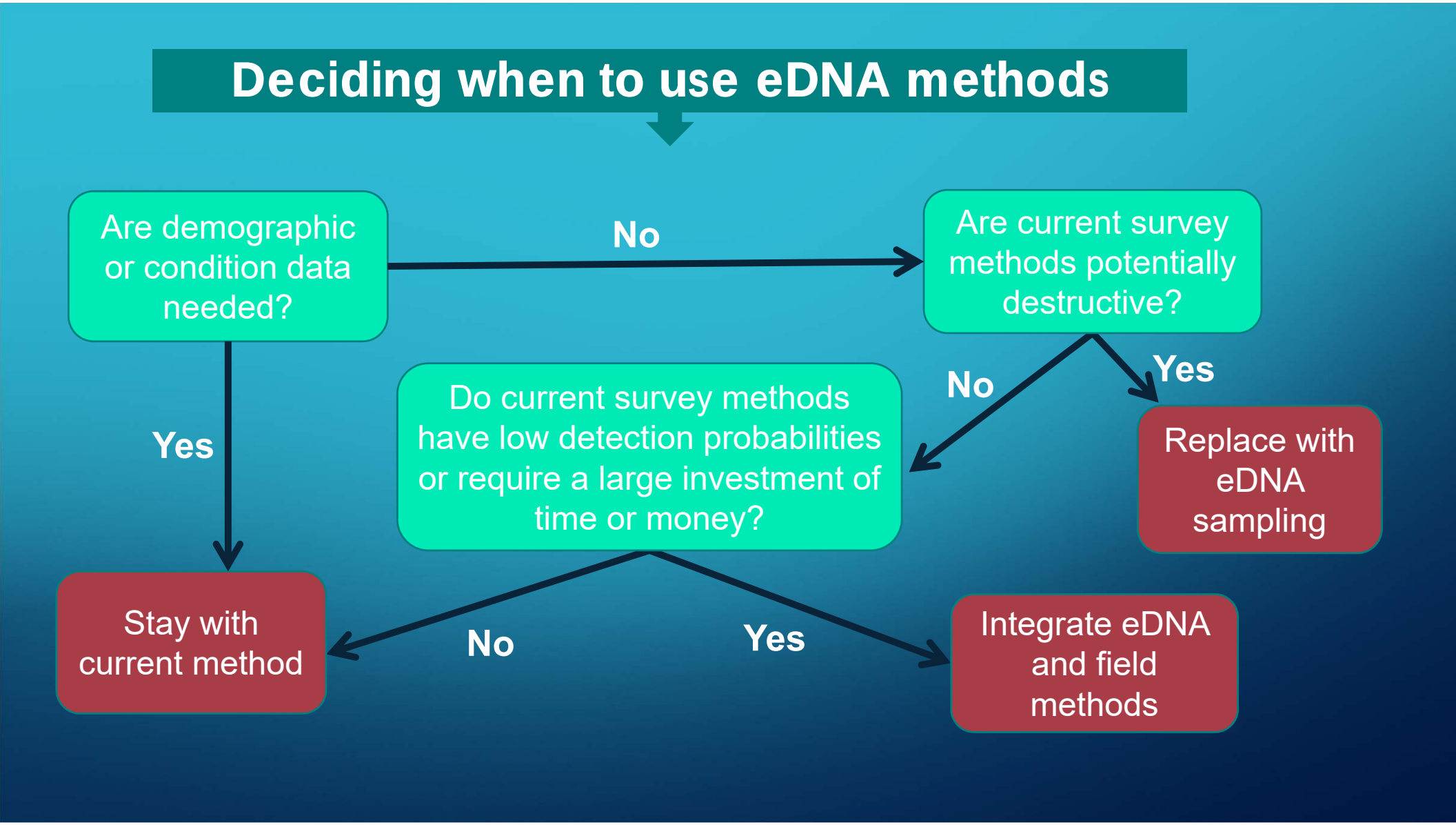
- low detection rates
- expensive
- require extensive training
- destructive

Deciding when to use eDNA methods

When is eDNA is most useful?

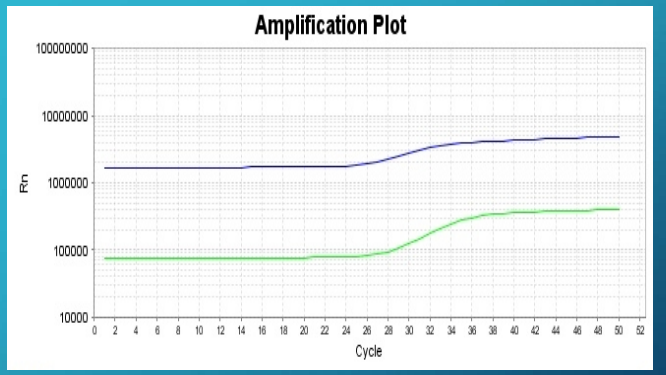
Community-level or system-level information is needed

- multispecies monitoring / bioassessment
- when conventional surveys:
  - target individual species or species groups
  - are biased toward individual species or groups of species
  - require many types of surveys to detect multiple species


Deciding when to use eDNA methods
Are demographic or condition data needed?
No
Are current survey methods potentially destructive?
Yes
No
Yes
Do current survey methods have low detection probabilities or require a large investment of time or money?
Replace with eDNA sampling
Stay with current method
No
Yes
Integrate eDNA and field methods

Selecting an eDNA approach

1. Target species
   - One or a few species at a time
   - Species-specific primers and probes



2. Metabarcoding
   - Many species at a time
   - Generic primers

Selecting an eDNA approach

Target species eDNA? **OR** eDNA metabarcoding?

Management concern is targeted toward one or several species

- Threatened, Endangered, or at-risk species
- Target invasive species

Management goal is biodiversity monitoring

- Clean Water Act - 303(d)
- Long list of target species

Developing an eDNA sampling design

Design a pilot sampling strategy that considers:

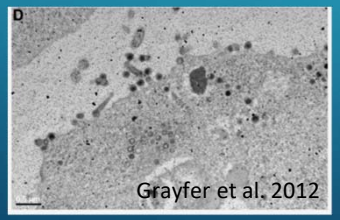
- Seasonal timing
- Spatial sampling design
- Number of samples
- Sample volume
- Filter type
- Preservation method
- Environmental covariates

Developing an eDNA sampling design

Conduct a pilot study:

1. Implement pilot sampling protocol
2. Record environmental and sampling covariates when collecting eDNA water samples
3. Analyze covariates to identify important factors for species detection
4. Adapt sampling strategy to improve detection

Pilot study example: Tiger salamander/ATV system

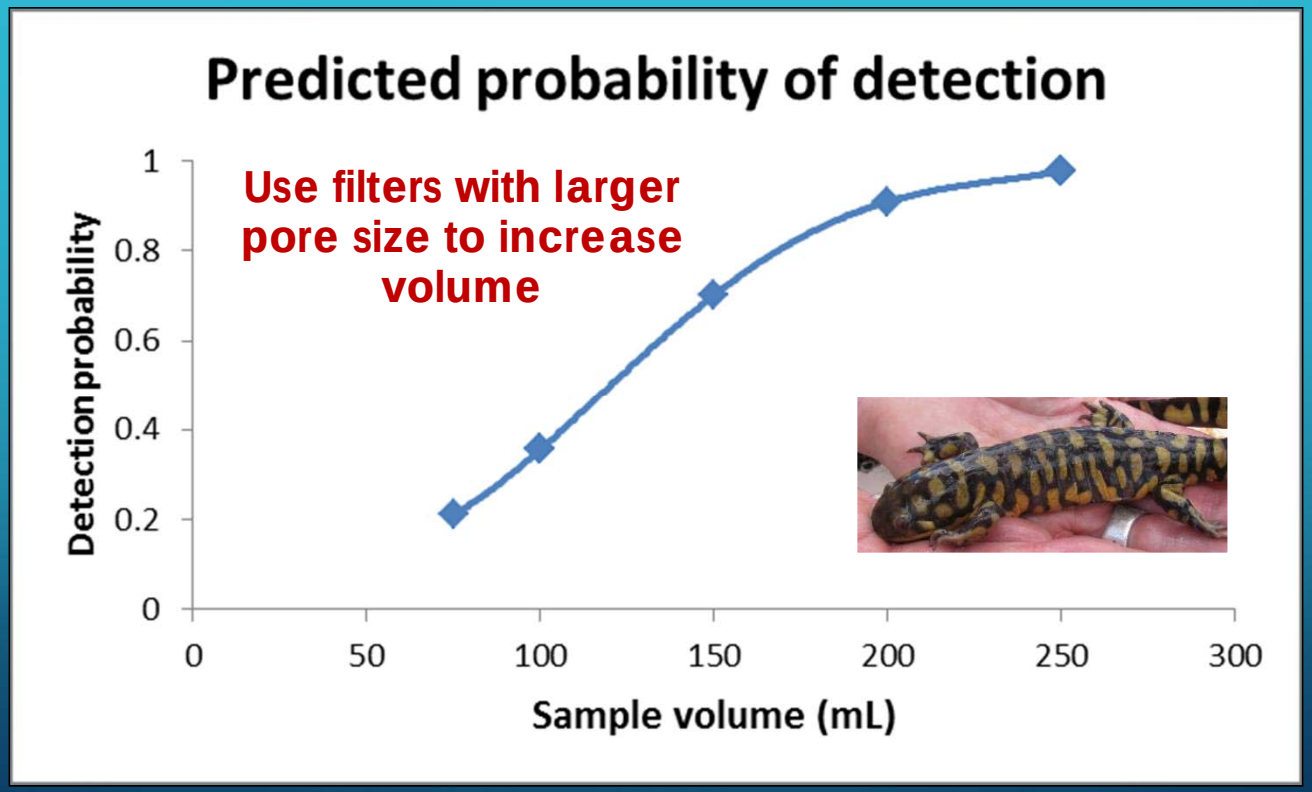


iridovirus

Sonora tiger salamander - Year 1

eDNA Detection \ Field Detection	Y	N
Y	8	1
N	3	11

Implementing adaptive sampling



Sonora tiger salamander - Year 2

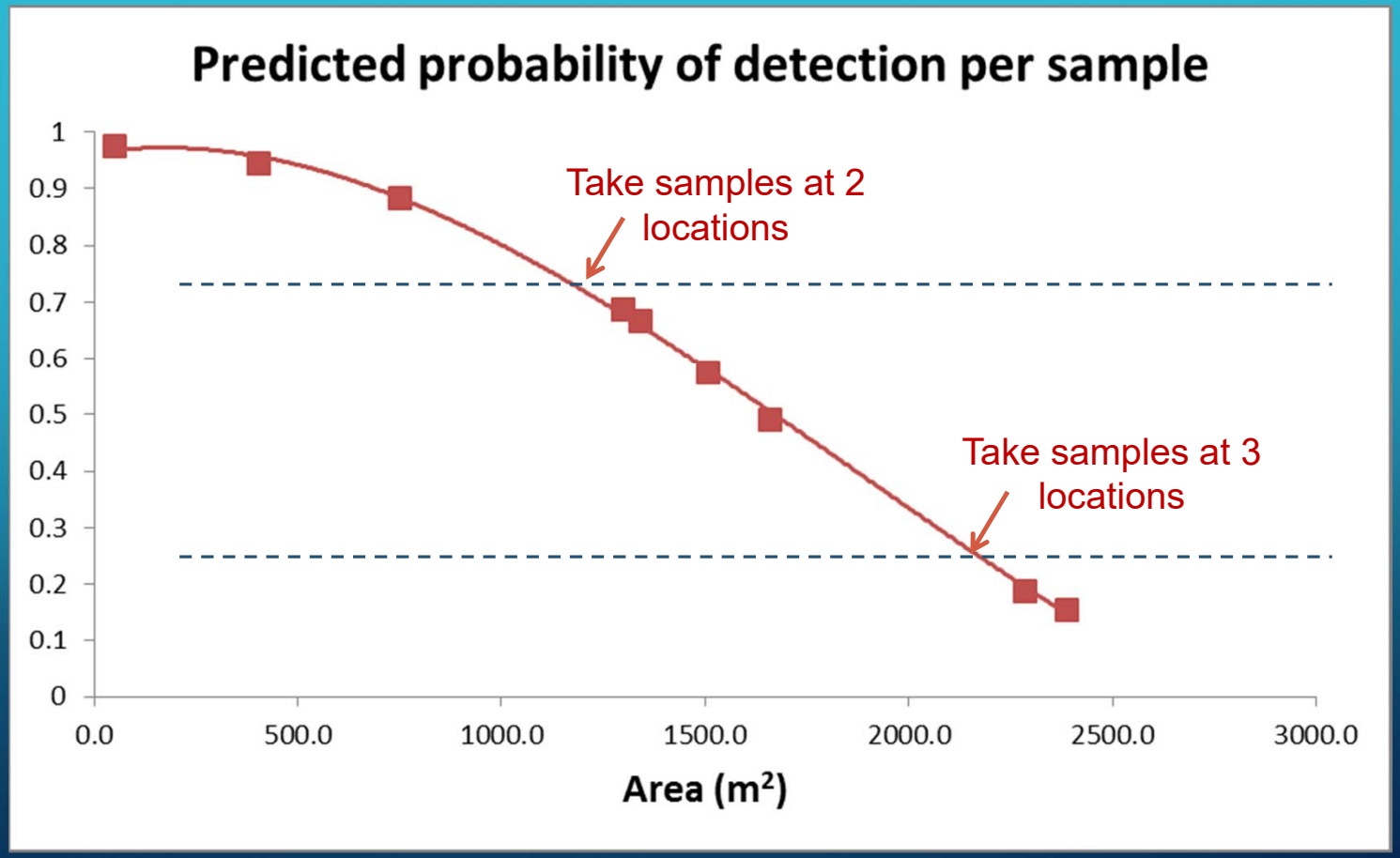
- Switched from 0.45 CN to 6 µm cellulose filter

Field Detection

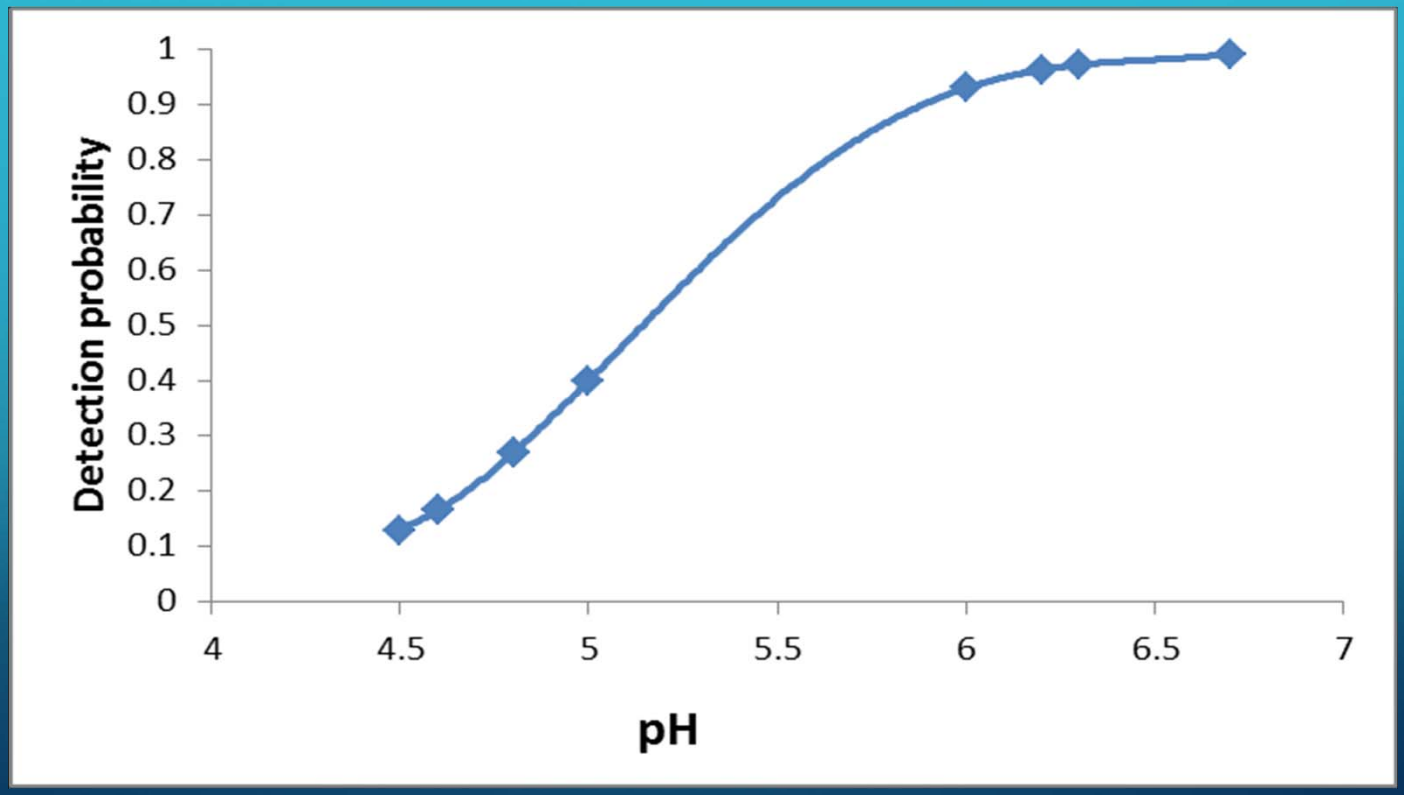
eDNA Detection	Yes	No
Yes	10	3
No	0	6

(per sample detection probability = 0.77)

Chiricahua leopard frog



Reticulated flatwoods salamander



Integrating eDNA and field methods

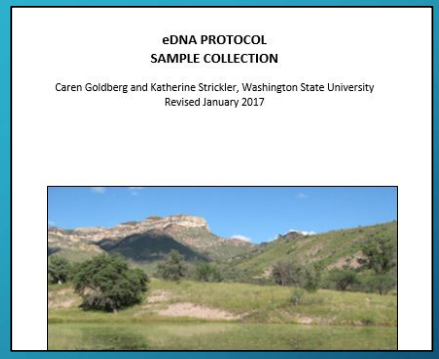
eDNA field sampling protocols - published

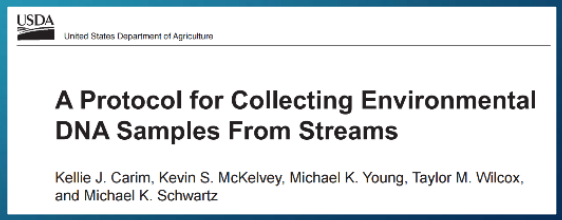
Published sampling protocols

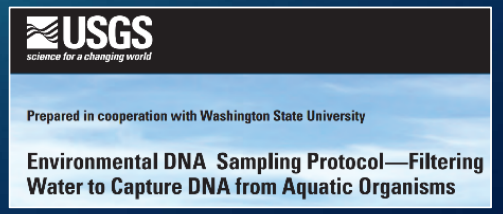
WSU: https://labs.wsu.edu/edna/edna_protocols/

USGS: https://pubs.usgs.gov/tm/02/a13/tm2a13.pdf

USFS: http://www.fs.fed.us/rm/pubs/rmrs_gtr355.pdf





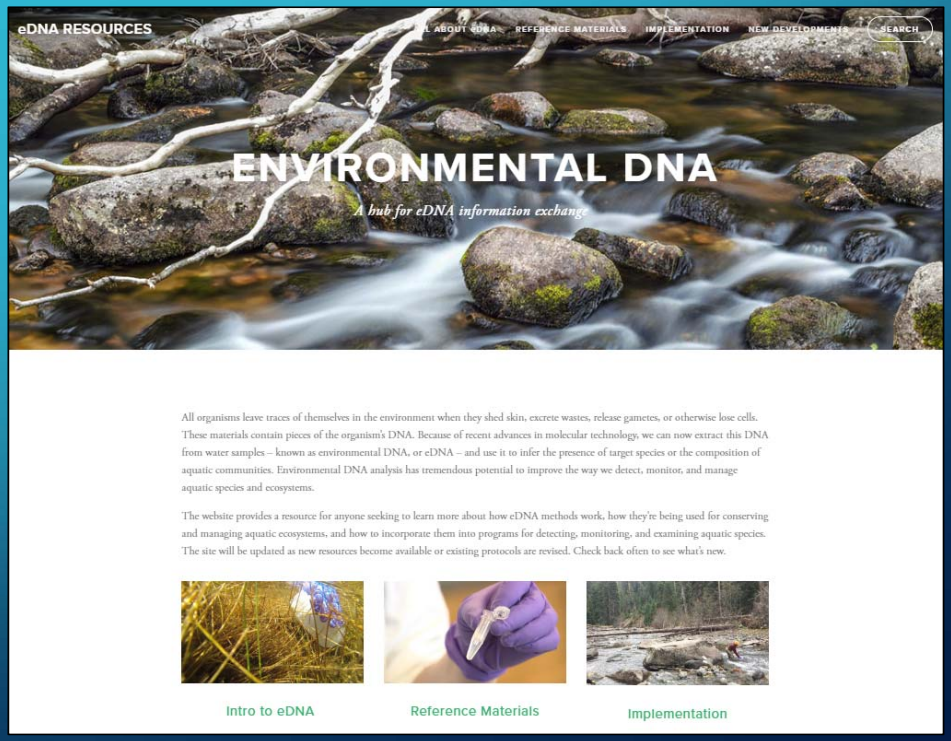


- Every sampling situation is unique
  - Protocols may need small tweaks to work in your system
  (but be careful!)

eDNA online resource center

- Knowledge base
  - Intro to eDNA
  - Project profiles
  - Lessons learned
  - Links to research and commercial labs
- Guidance
  - Protocols
  - Technical details
- Community hub
  - Information exchange
  - Emerging technology

www.ednaresources.com



Thank You