eDNA Science & Application

Detecting Species Sight Unseen

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for a Sustainable Future
Cornell University

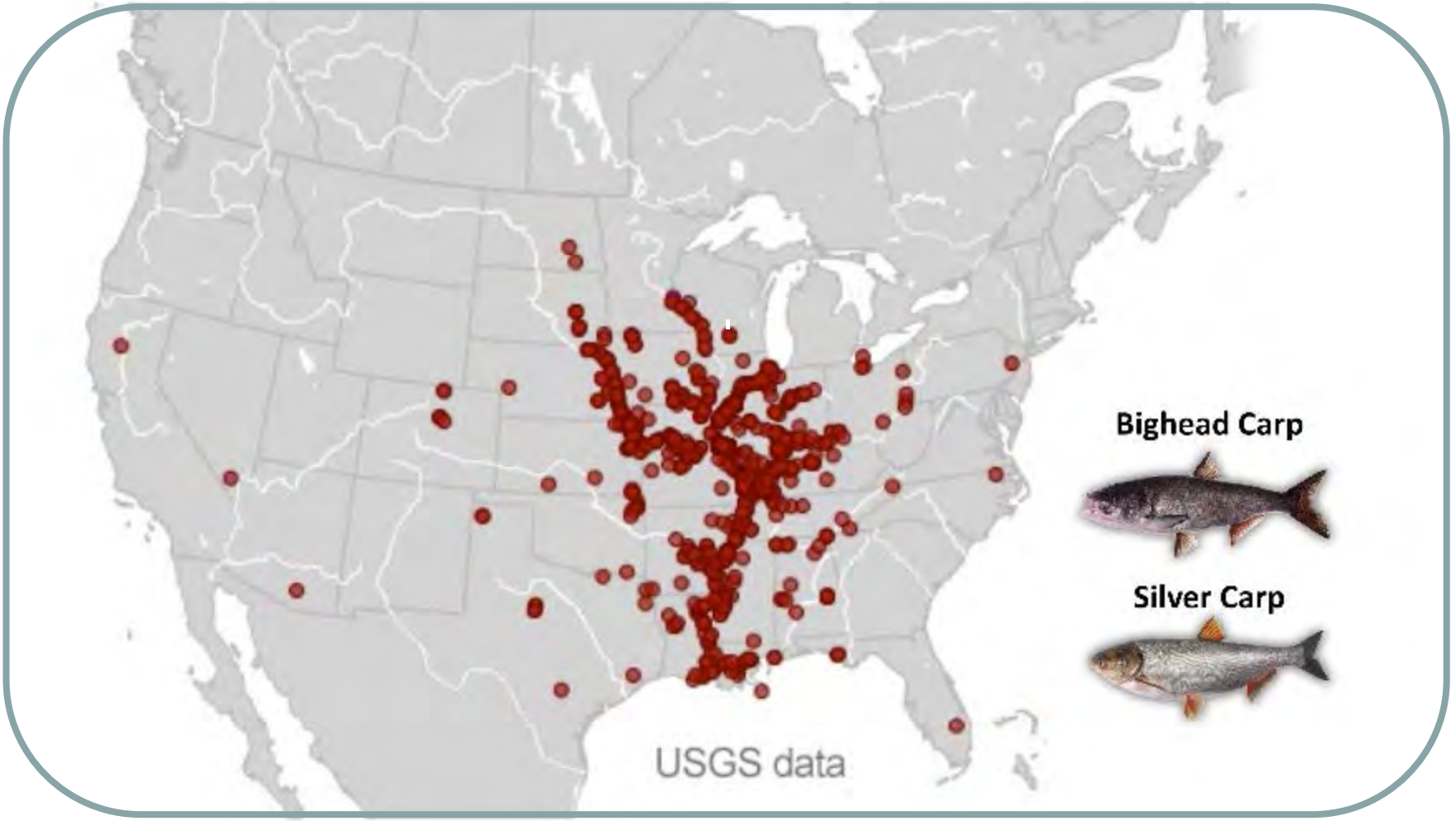
Indirect, DNA-based Species Detection

Asian Carps: Imminent Threat to Great Lakes

1975

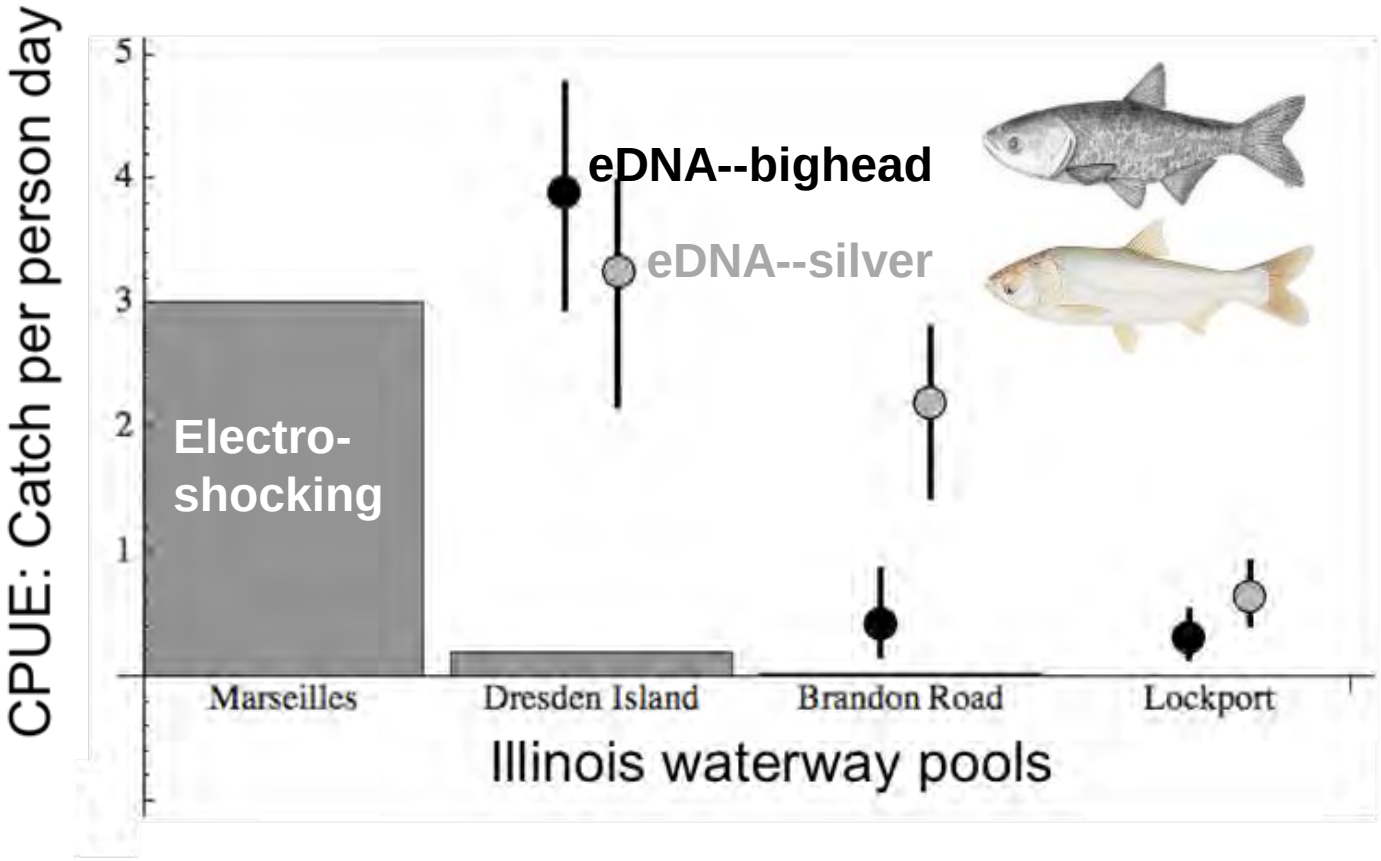
Asian Carps: Imminent Threat to Great Lakes

2013



Chicago Sanitary & Ship Canal

Silver and bighead carps CPUE: Electroshocking vs. eDNA



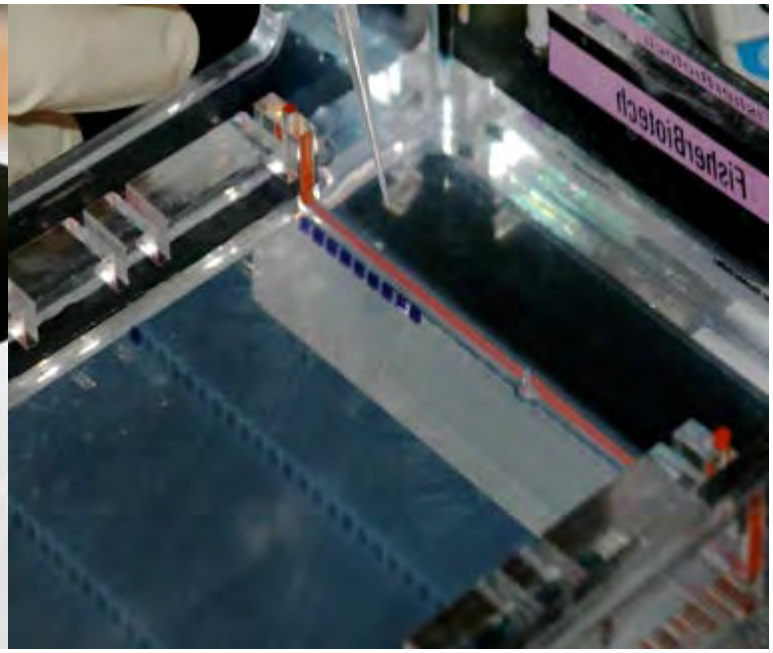
(Jerde et al 2011. Conservation Letters*)*

Potential Applications for eDNA

1. **Species that are rare**
   - Incipient invasions—early detection-rapid response
   - Threatened, endangered species
2. **Species that are difficult to sample with traditional tools**
3. **Species for which handling causes harm**
4. **Habitats in which traditional tools are difficult to deploy**
   - Limited access for boats and sampling gear
   - Strong currents
   - Interference with navigation, fishing, or other uses
5. **Where/when "integrative" samples are cost effective**
   - "contaminant" species in bait trade, fish stocks, imports

Environmental DNA Overview

1. Collect water sample
2. Filter water sample
3. Extract all DNA
4. Amplify target DNA
5. Visualize DNA presence



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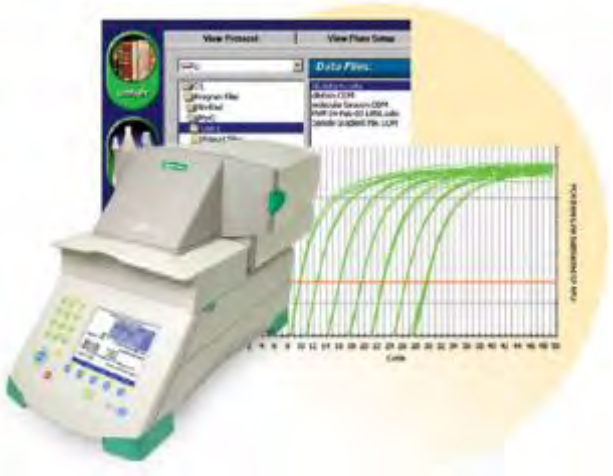
Design primers for target DNA; Polymerase Chain Reaction (PCR)

PCR



Quantitative PCR

Digital droplet PCR

Environmental DNA Overview

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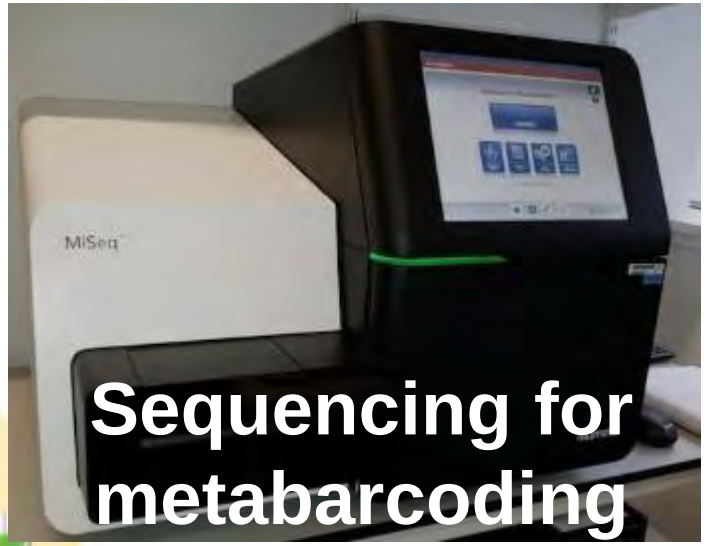


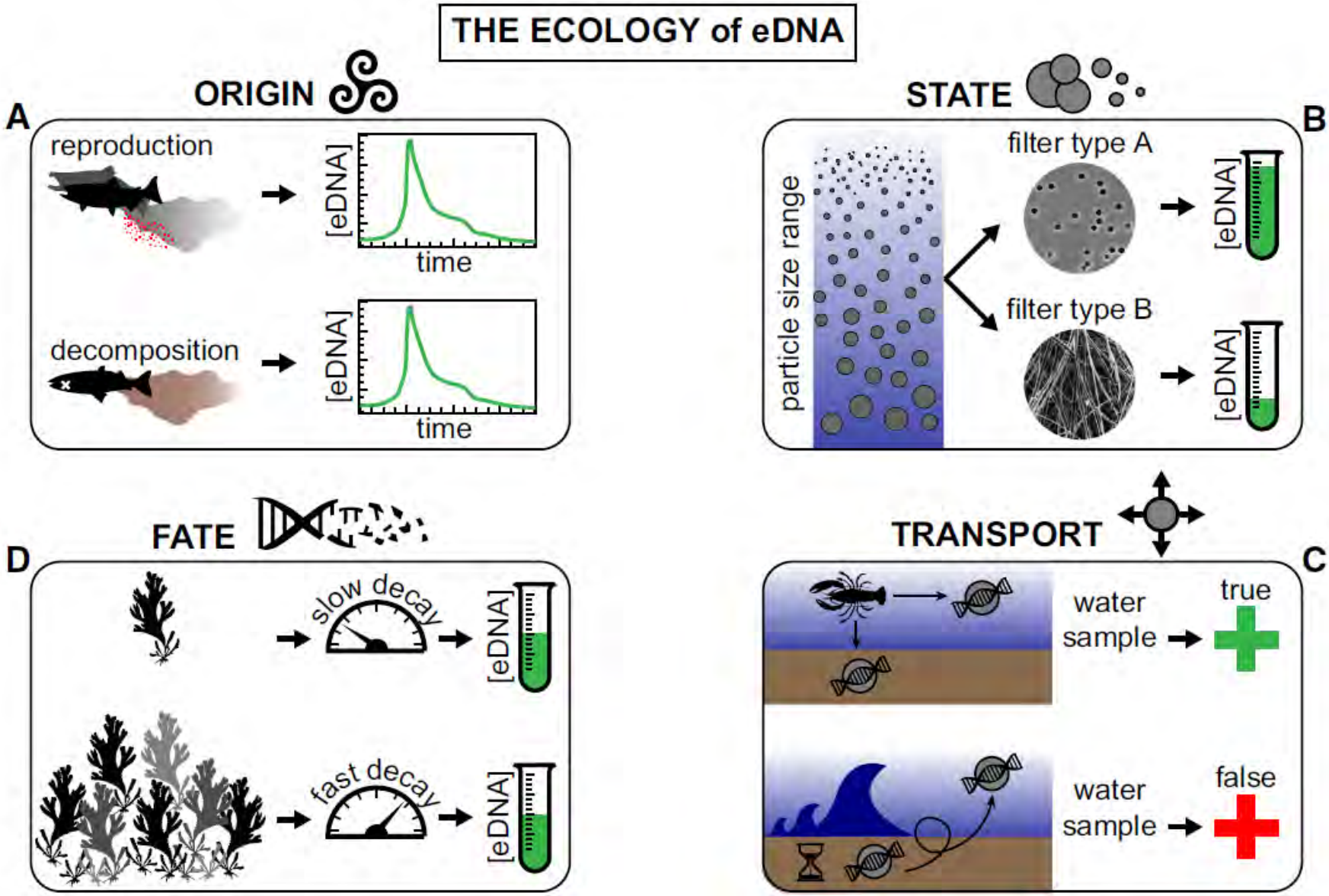
Digital readout for qPCR and ddPCR, Laser Transmission Spectroscopy

Environmental DNA Overview

The more sensitive an assay, the greater the risk for false positives from contamination.

Meticulous care is required to reduce risk of contamination at every step in the field and laboratory.

- **Laboratory design to separate different processes**



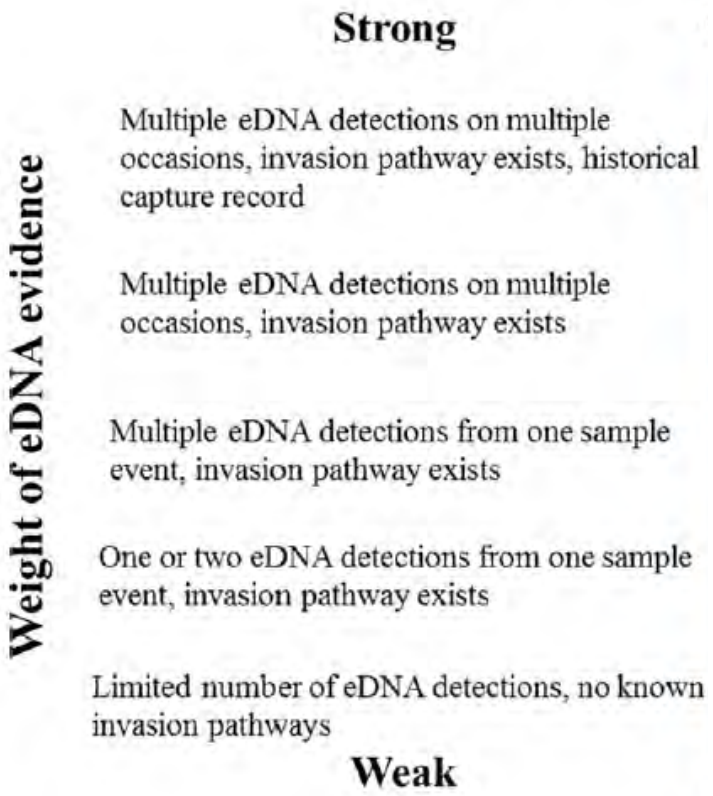
Barnes & Turner 2015

Sources of Asian Carp DNA in Canal (in the absence of live fish)?

- Ballast or bilge water from barges?
- Dead fish kicked off of barges?
- Sewage discharge from carp eating humans?
- Feces from carp eating birds?
- Overflow from Chicago ponds?

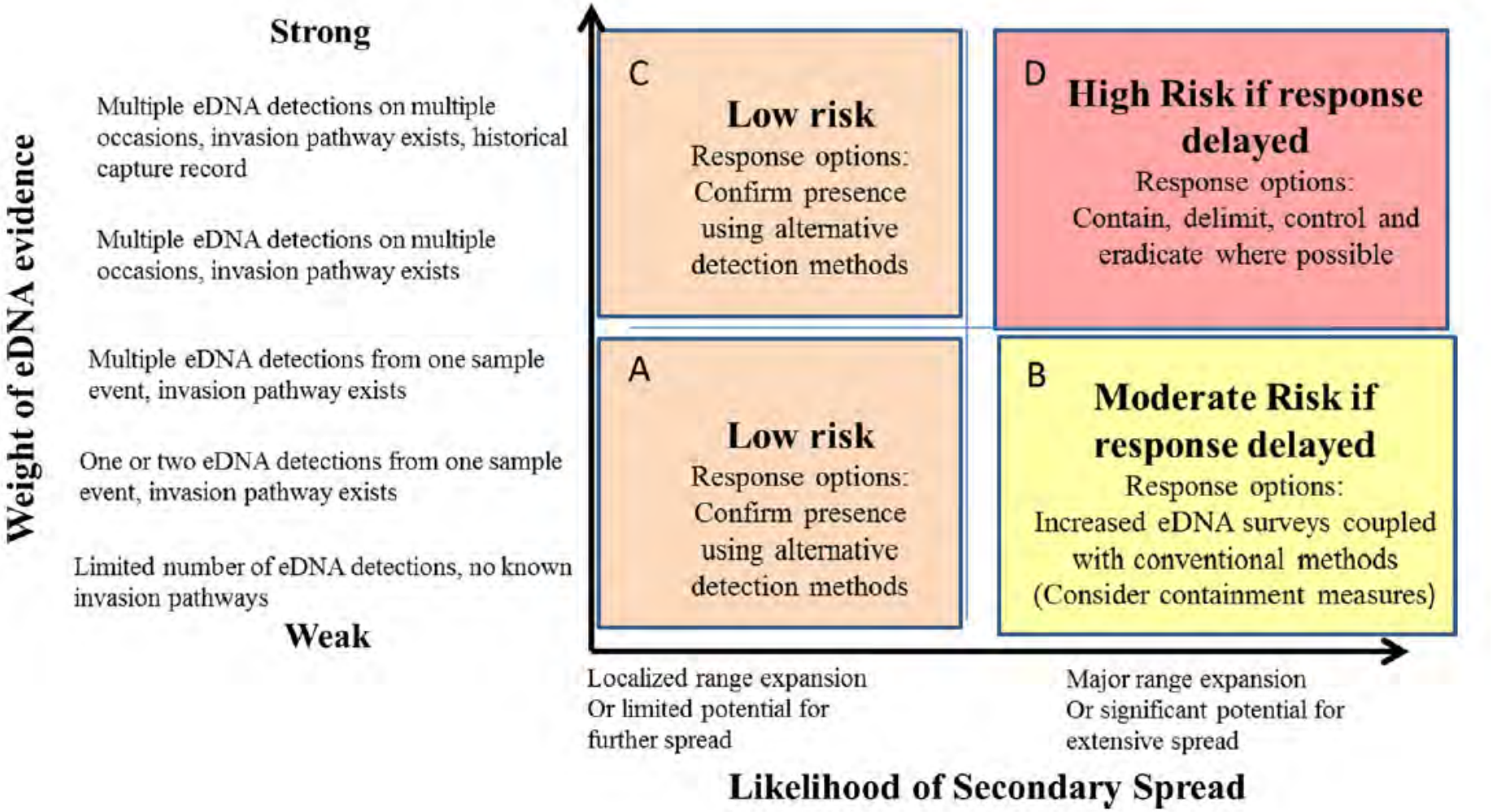
None of these possibilities were plausible explanations for the overall temporal and spatial pattern of eDNA results.

Interpretations of eDNA results and implications for management



Tucker et al. 2016

Interpretations of eDNA results and implications for management



Tucker et al. 2016

Current & Future eDNA R&D

1. Degradation rates of eDNA
2. Assay sensitivity & capture efficiency of eDNA
3. Vertical transport of eDNA
4. Horizontal transport of eDNA
5. Differences among taxa in ecology of eDNA
6. eDNA concentration re population size
7. Intrapopulation variation (population genetics)
7. Metabarcoding for community detection
9. Faster, portable, automated analysis

Automated sampling, detection

BIOFIRE
PCR device

Spyglass
TECHNOLOGIES

S. Howard (ND)
Portable PCR


SMITH-ROOT
Technology For Fisheries Conservation


eDNA
DETECTION
CREATES
OPPORTUNITY
TO MANAGE
MOTIVATES

END

Future general directions for eDNA R&D

1. Degradation rates of eDNA
2. Assay sensitivity & capture efficiency of eDNA
3. Vertical transport of eDNA
4. Horizontal transport of eDNA
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Current/future management applications?

1. Statewide fisheries surveys (e.g., more efficient, cheaper than electrofishing & nets?) to prioritize systems for follow up.
2. Statewide invasive or imperiled species surveillance (e.g., pathway hotspots like ports).
3. Post management monitoring program for invasive (e.g. hydrilla) or imperiled species (e.g. hellbender, cisco).

Tension points at research-management interface

1. More humility often needed from academics.
   - Be open to questions from management;
   - Be sensitive to limited resources, political context, rapidly changing priorities;
   - Communicate clearly about uncertainty.

2. More understanding of academic environment often needed from managers.
   - Creativity and cheap labor come with slower, episodic progress;
   - Interest in novelty in addition to problem solving.

3. Data management, sharing protocols essential.

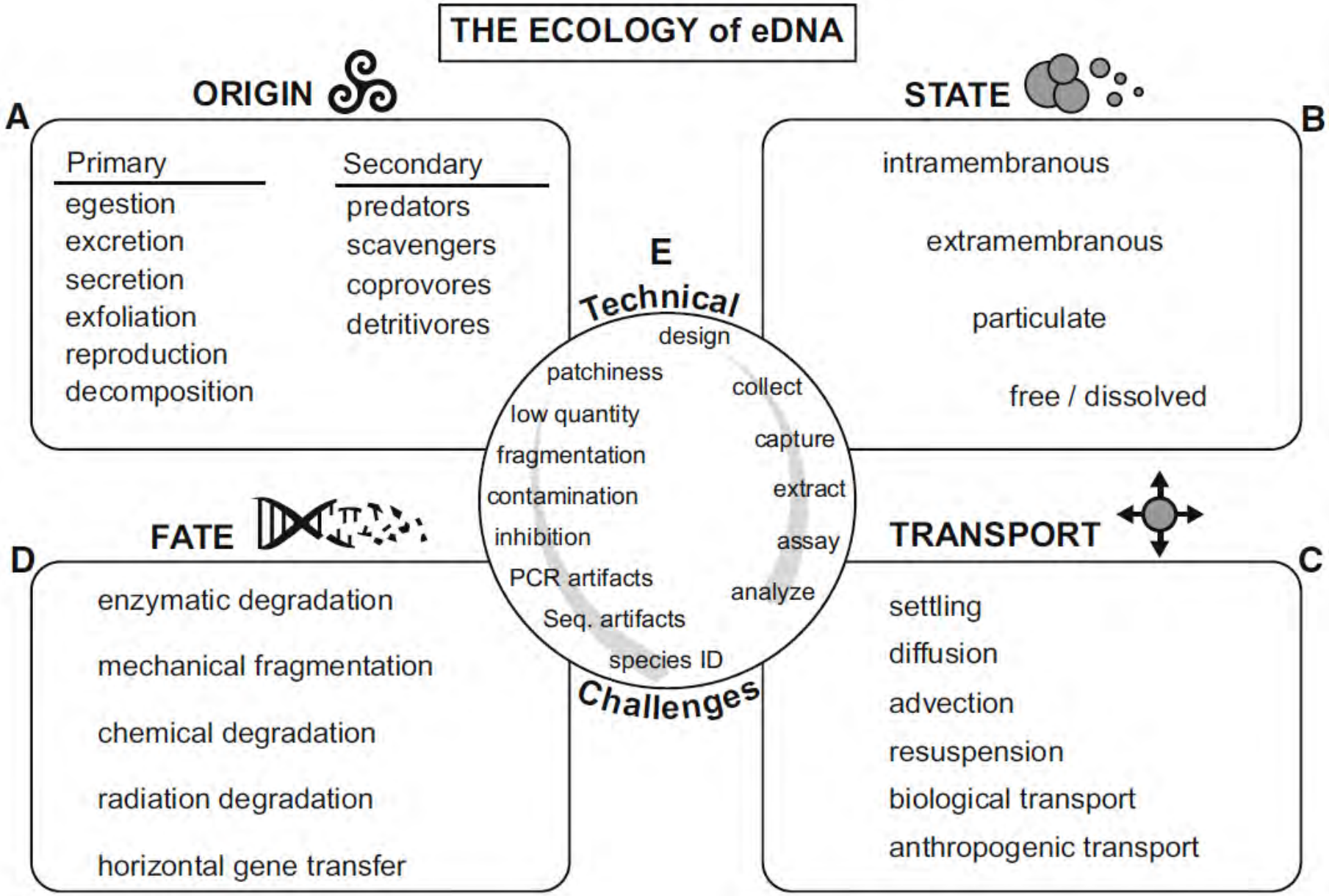
4. Communications protocols are essential.

END

Arroyo Toad

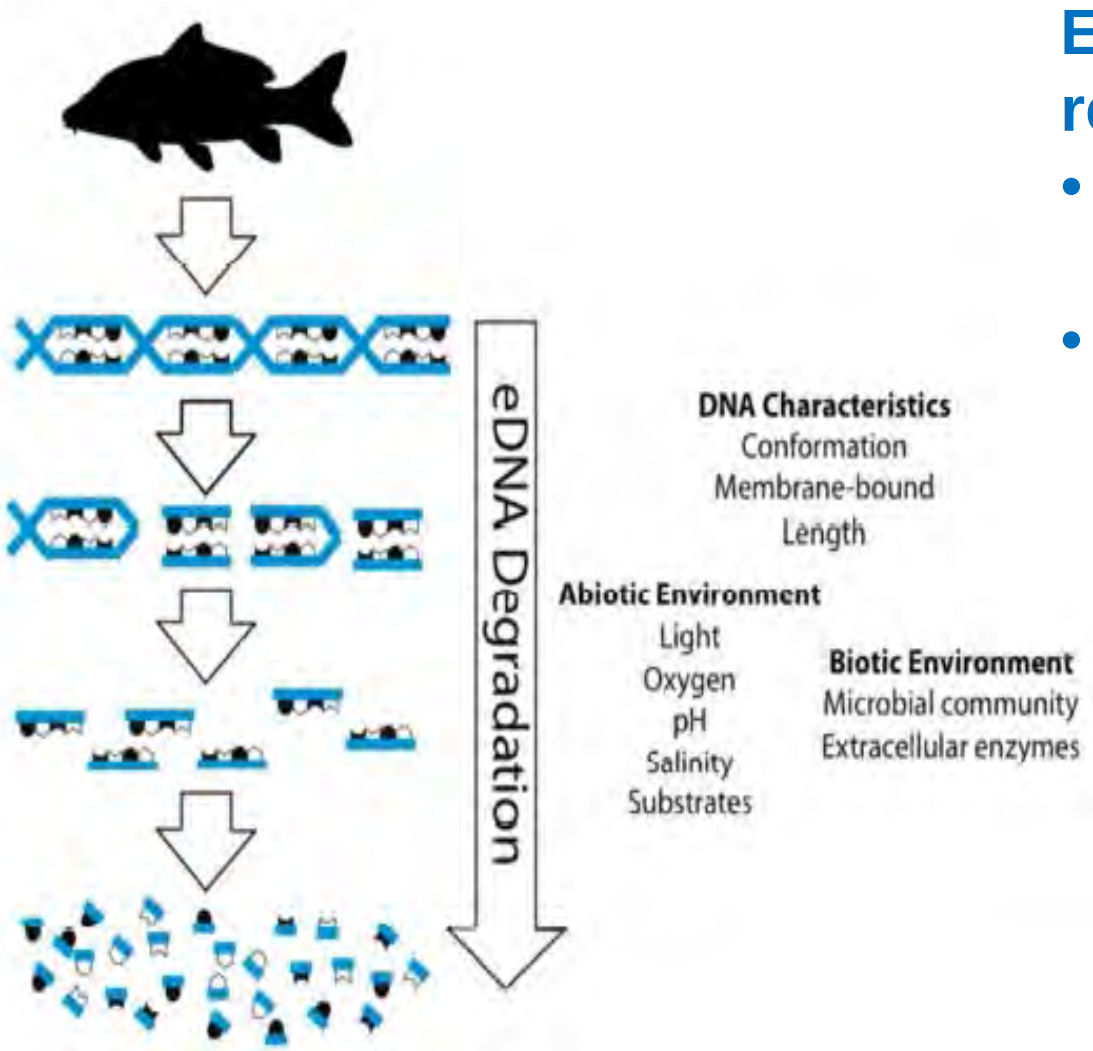
Bull Trout

Hellbender



Barnes & Turner 2015

Degradation of eDNA: How long ago was the animal present?

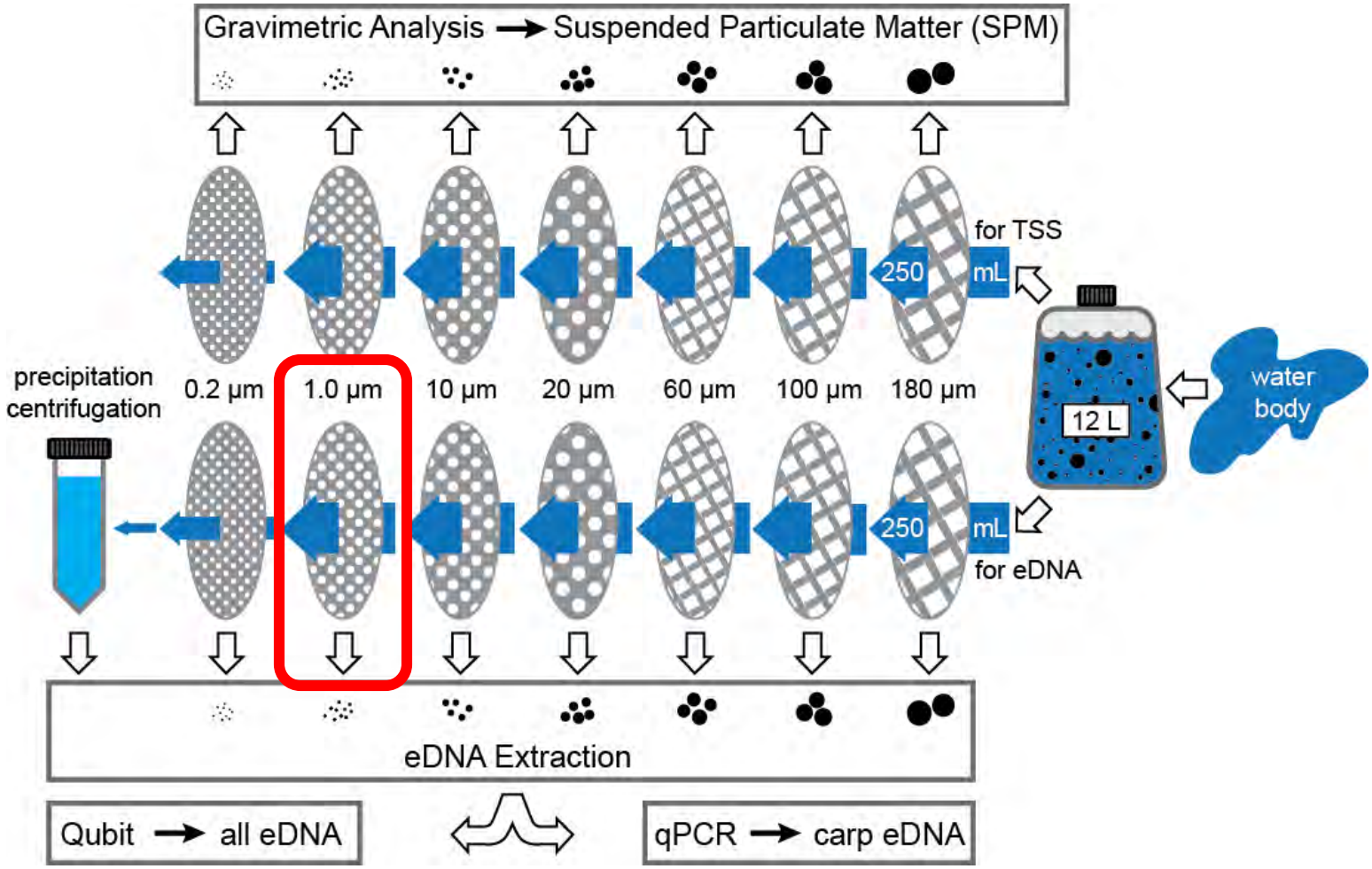


Experimental results:

- eDNA undetectable after hours-days
- Degradation affected by biological activity

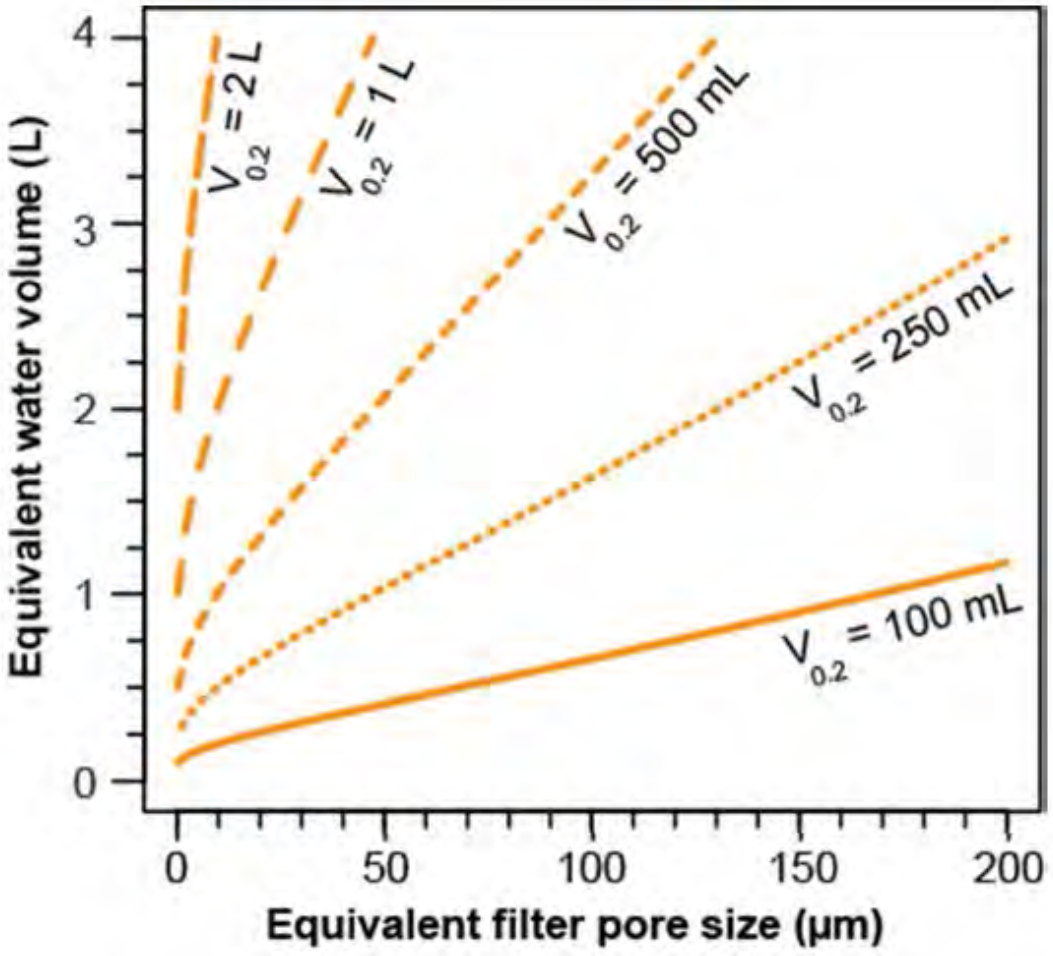
(Barnes et al 2014. Environmental Science & Technology*)*

eDNA collection:
sequential filtration of field water samples



(Turner et al. 2014 *Methods in Ecology & Evolution*)

Common carp eDNA collection: sequential filtration of field water samples



For optimal eDNA capture:

- 0.2 um filtration *or*
- a combination of larger pore size and larger water volume that captures the same amount of eDNA (i.e., exceeds the 0.2 um isocline)

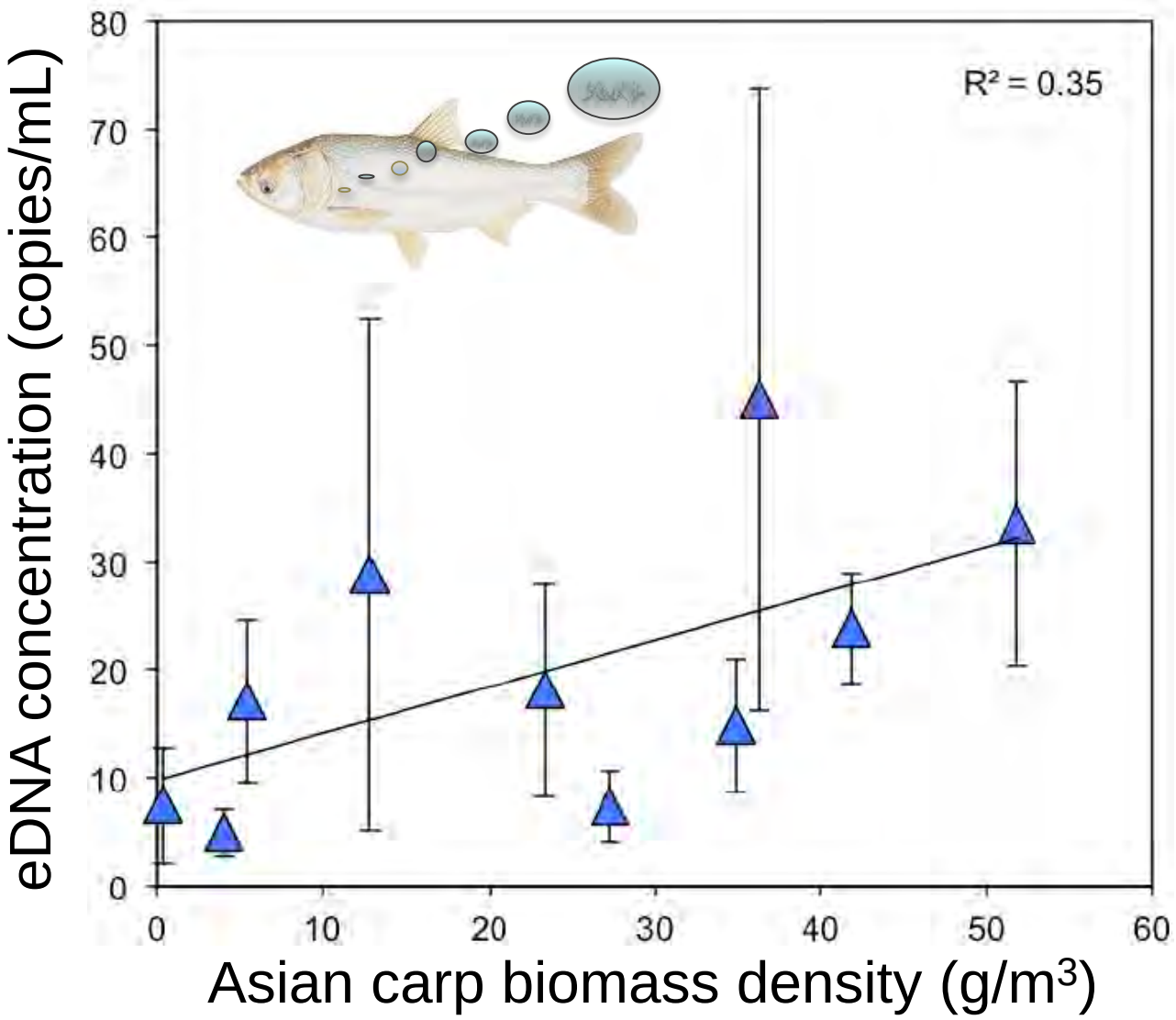
(Turner et al. 2014 *Methods in Ecology & Evolution*)

Differences among taxa?

Differences among taxa in:

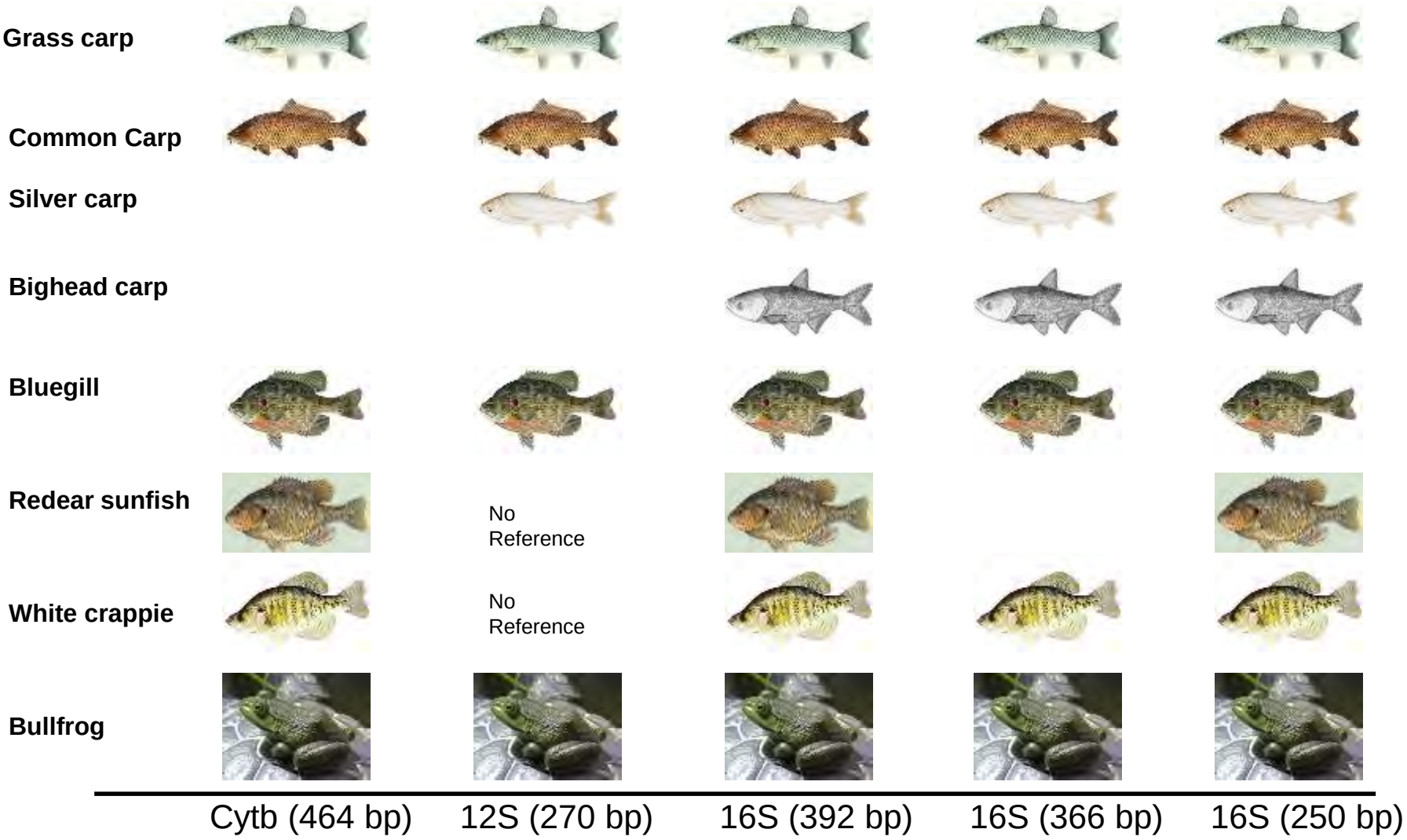
- Production rate?
- Degradation rate?
- Particle size?
- Location in water column?
  - Vertical transport?
  - Horizontal transport?

eDNA concentration correlates to pop size



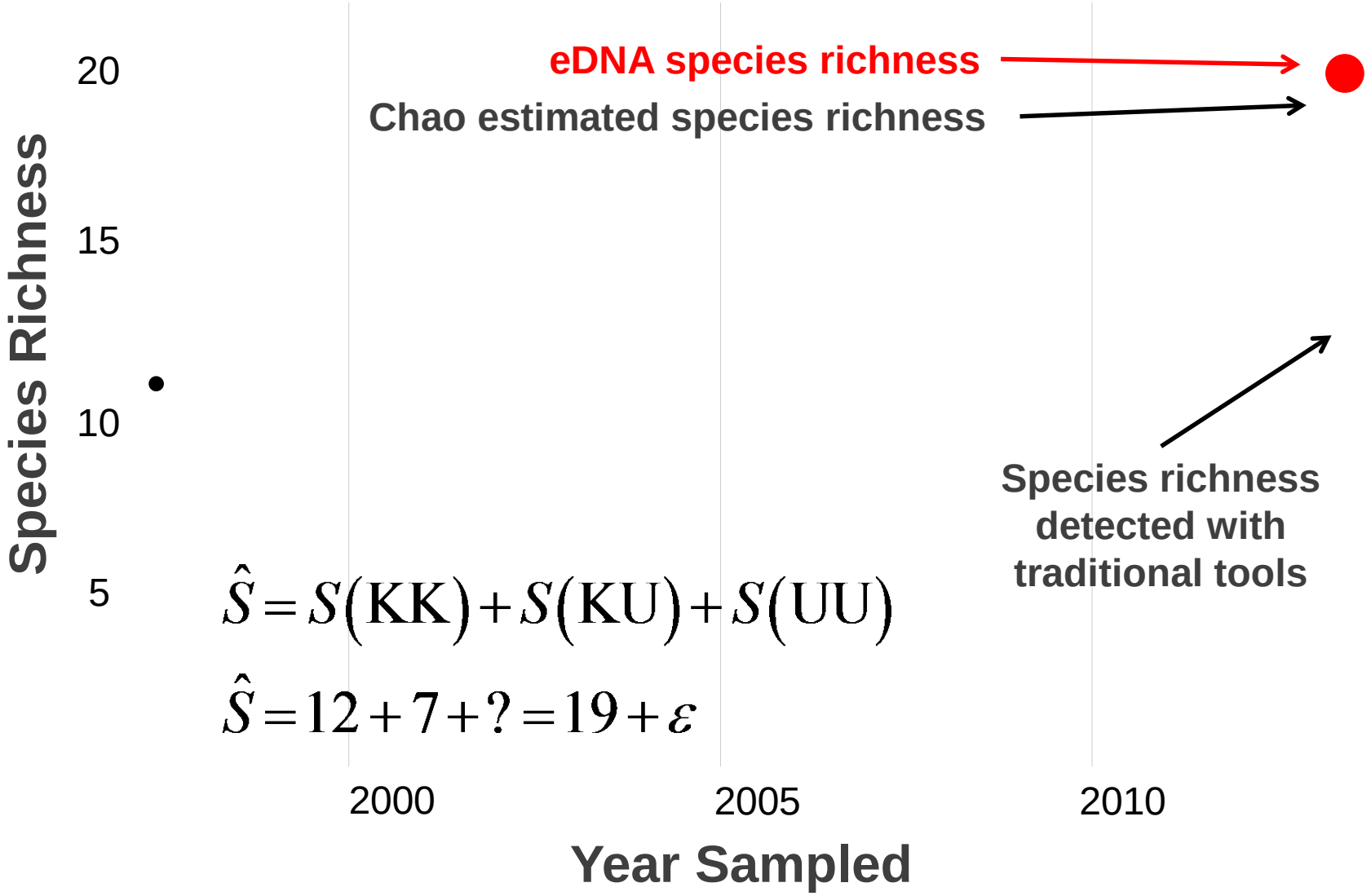
(Turner et al. *unpublished*)

Metagenetic Analysis (Ultrasequencing): Kansas ponds



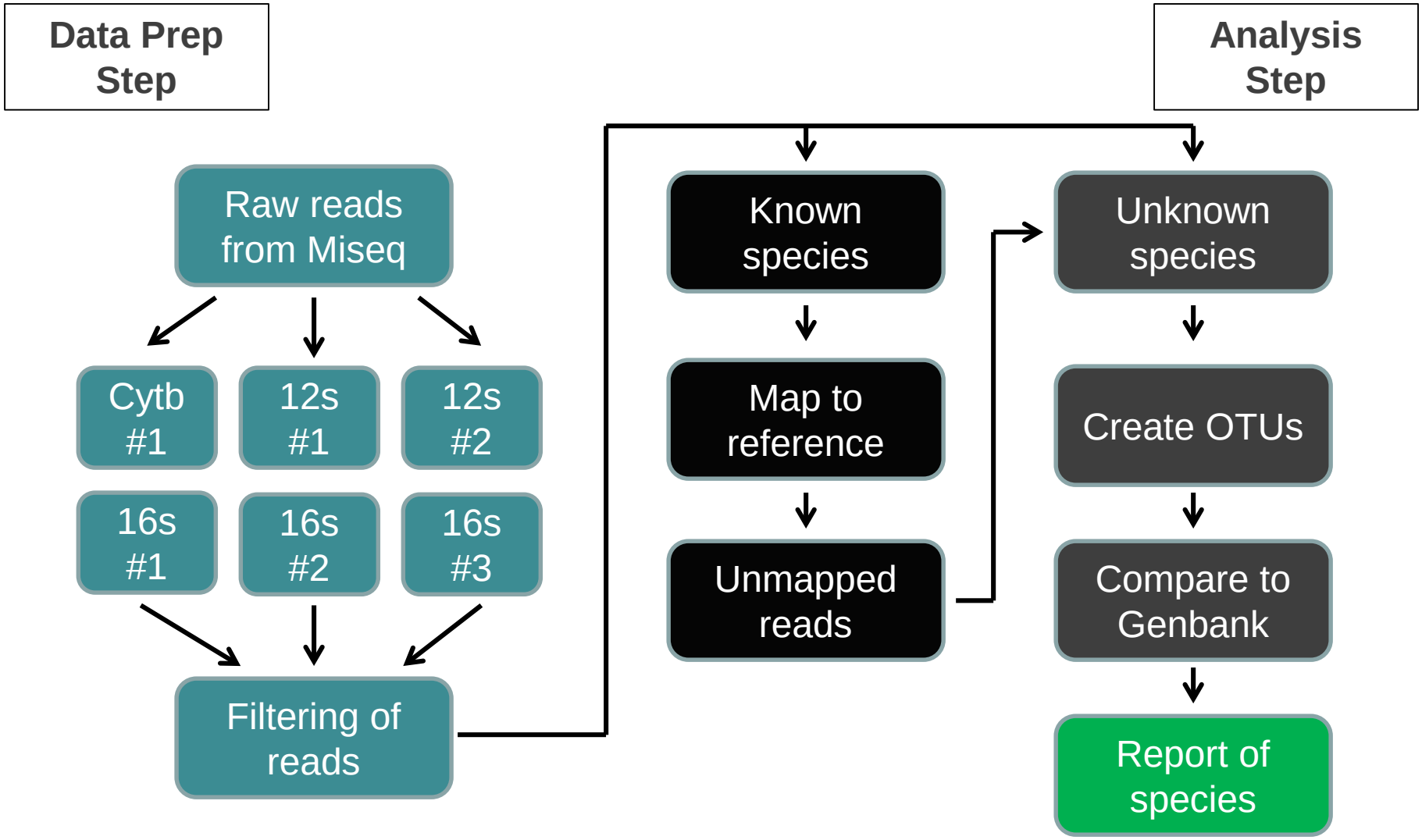
(Olds et al. unpublished)

Metagenetic Analysis (Ultrasequencing): Juday Creek, Notre Dame

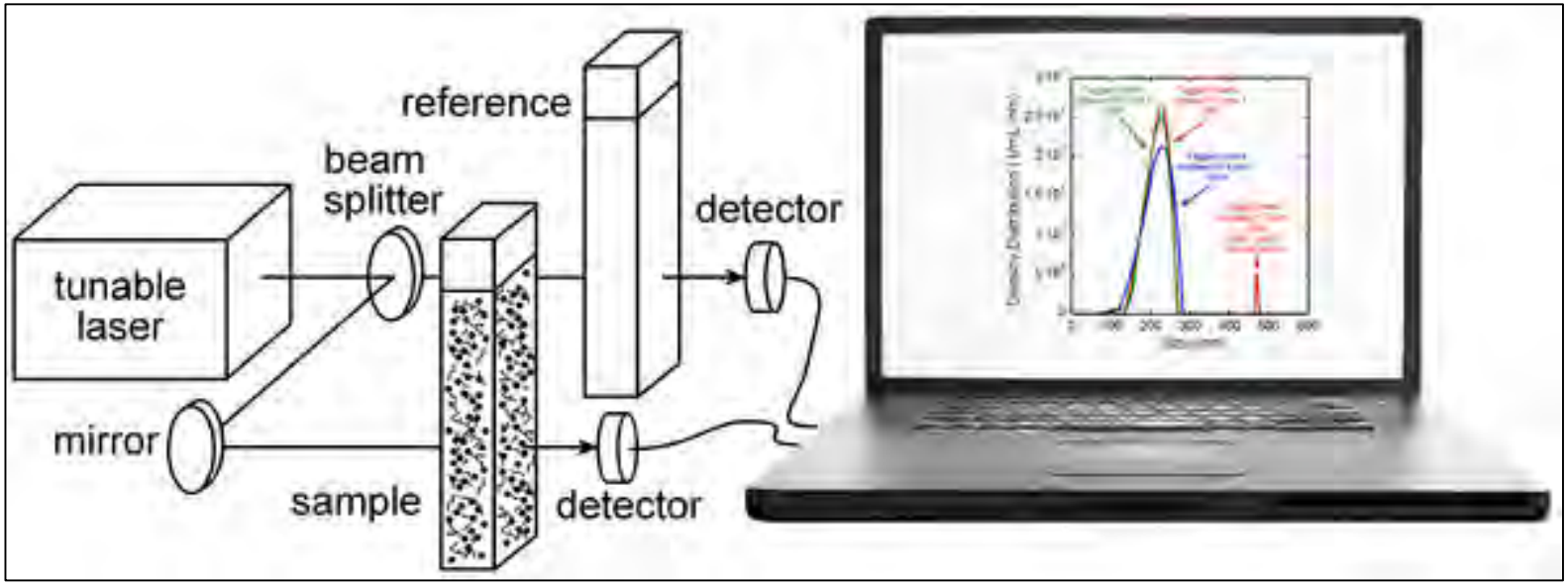


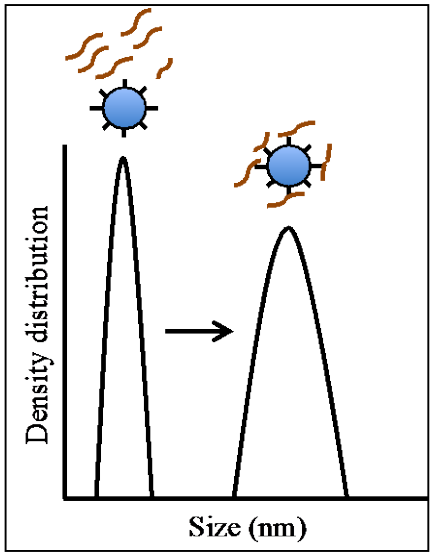
(Jerde et al. unpublished)

Example of bioinformatics workflow



eDNA detection using Laser Transmission Spectroscopy (LTS)





Recent LTS results:

- Very high sensitivity (picomolar range)
- Detects invertebrate species in “ballast” water with 100% accuracy, and no false positives
  (Egan et al. 2013. *Conservation Letters*; Mahon et al. 2013. *Proc. Roy. Soc. Interface*)

LightSprite (http://www.m3dev.com/)