# Can Unionid mussels manipulate host behavior? Early evidence of extended phenotype from the *Margaritifera margaritifera* – *Salmo trutta* interaction.

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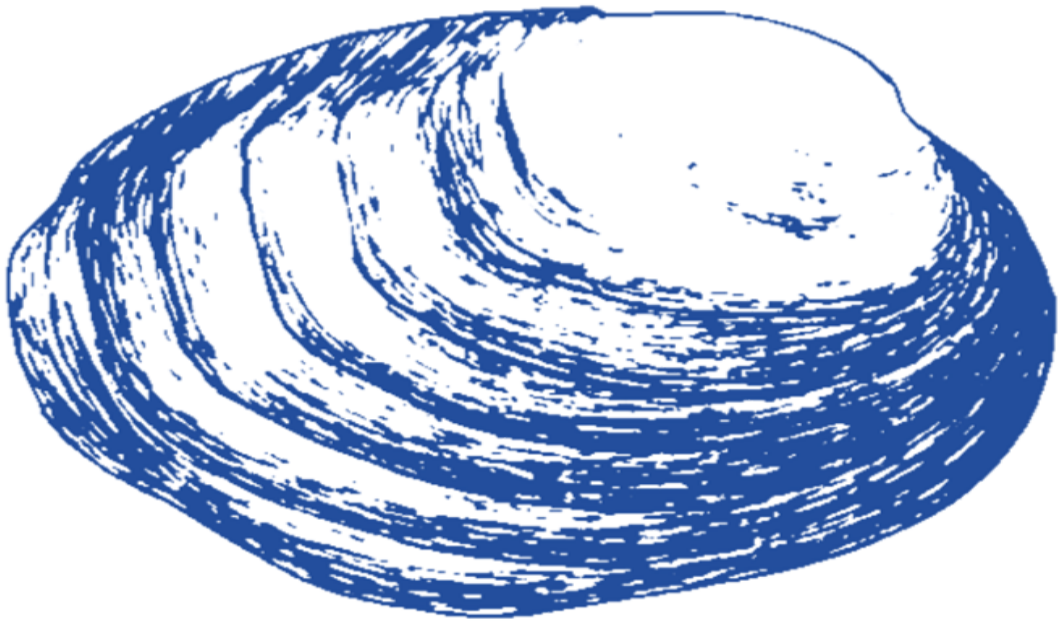


# LIFEConnects

- Improve ecosystem functions and services of rivers in south Sweden to protect endangered species
- Large scale habitat restoration
- Remove migration barriers for fish migration
  - Atlantic Salmon (*Salmo salar*)
  - Brown trout (*Salmo trutta*)
  - European Eel (*Anguilla anguilla*)
- Reintroduce highly endangered parasitic mussels
  - Thick-shelled river mussel (*Unio crassus*)
  - Freshwater pearl mussel (*Margaritifera margaritifera*)

# Freshwater Mussels?

- Important ecosystem engineers

- Natural bio filters
  - Filter feeders
  - Redeposited bio-matter increases sediment nutrients
  - Redeposited inorganic matter increases water clarity
  - Large populations increases this a lot

- Bioturbation increases sediment water flow
  - Improves conditions for sediment fauna
  - Shells provide good habitat for fauna
  - Freshwater reef

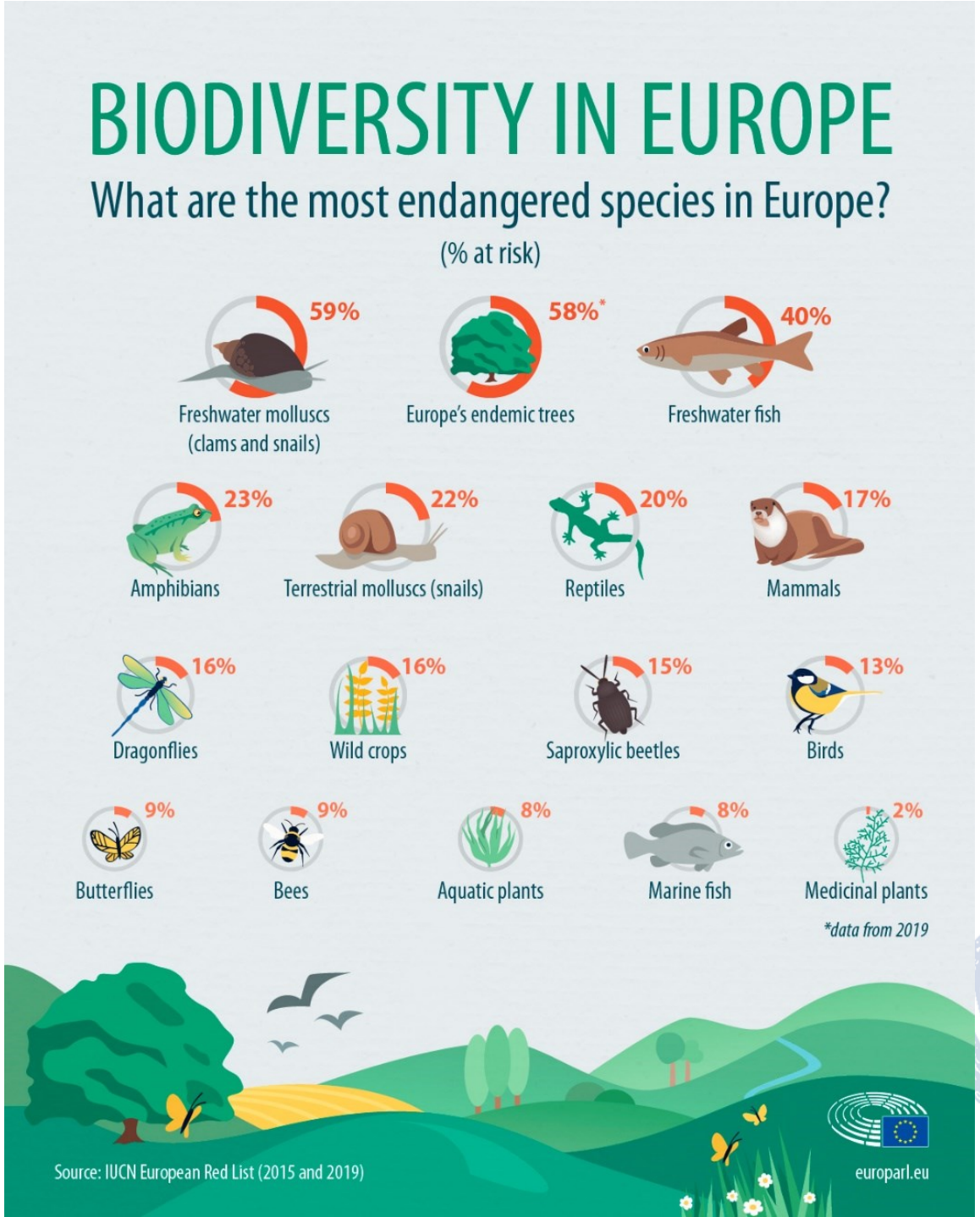
# Freshwater Reef?

# Why should we care about freshwater mussels?

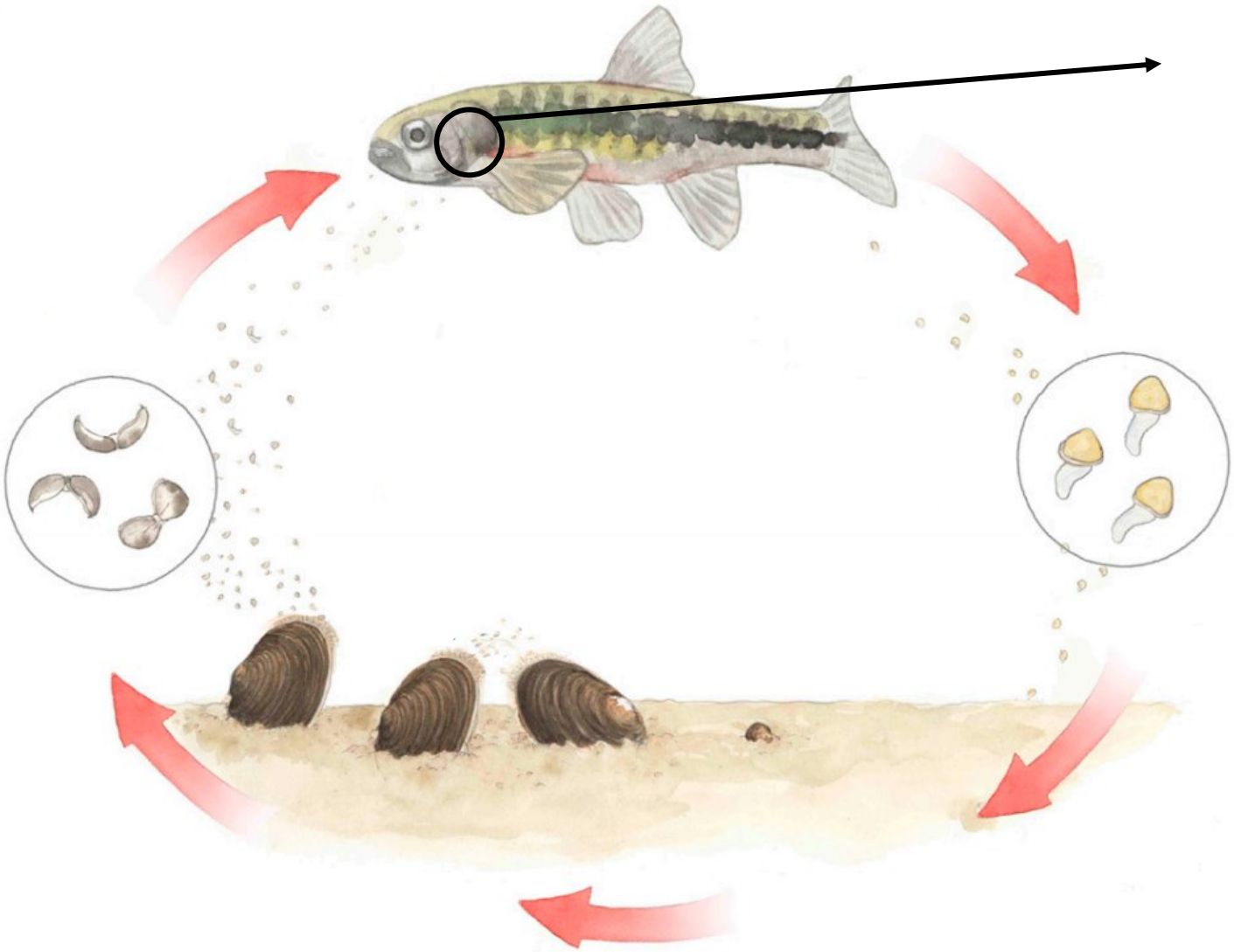
# BIODIVERSITY IN EUROPE

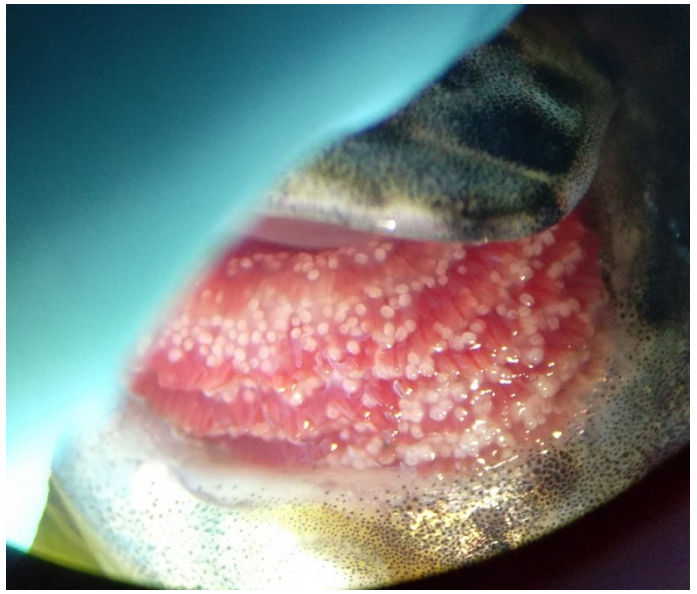
## What are the most endangered species in Europe?

(% at risk)



# Freshwater Mussels?







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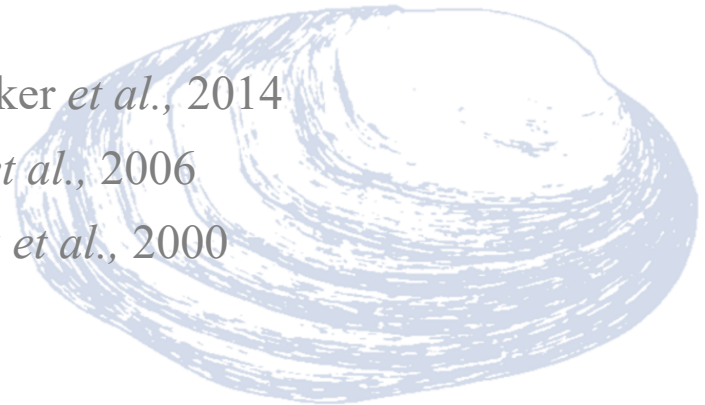
# Extended Phenotype?

- Phenotype can be more than coloration and protein synthesis
  - Can be *extended* to all effects the genotype has beyond the organism

- Animals can manipulate their environment
  - Bever dams — Gurnell, 1998
  - Termite mounds — Bonachela *et al.*, 2015
  - Hydropower dams
  - Skyscrapers

- Parasites can manipulate their hosts
  - Cordycept mushrooms in insects — de Bekker *et al.*, 2014
  - Nematodes cause suecide in crikets — Biron *et al.*, 2006
  - *Toxoplasma gondii* makes rodents find cats — Berdoy *et al.*, 2000

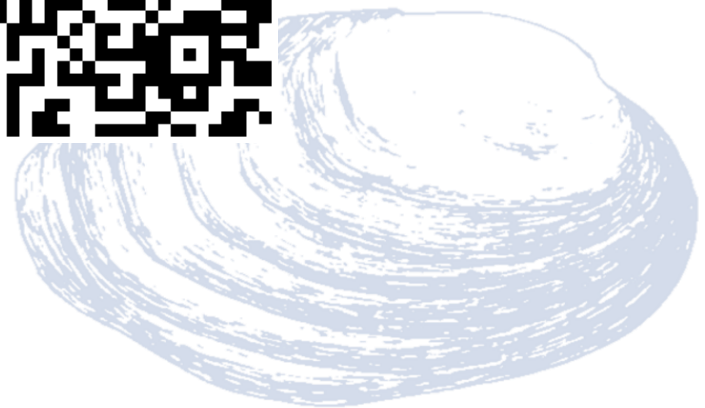


# General experimental set-up

- Year-long mark/recapture study during a reintroduction project
- Background literature
  - Unionids evolved to disperse, not feed
  - Assuming extended phenotype: hosts should go upriver
  - Behavioral thermoregulation has been observed
  - Upriver dispersal has been demonstrated

Rock SL, Watz J, Nilsson PA, Österling M (2022). Effects of parasitic freshwater mussels on their host fishes: a review. *Parasitology* 149, 1958–1975

- Questions:
  1. Does infestation alter host dispersal?
  2. Does infestation alter host growth?
  3. Does infestation alter host habitat usage?



# The location

- Skåne (southern most region of Sweden)

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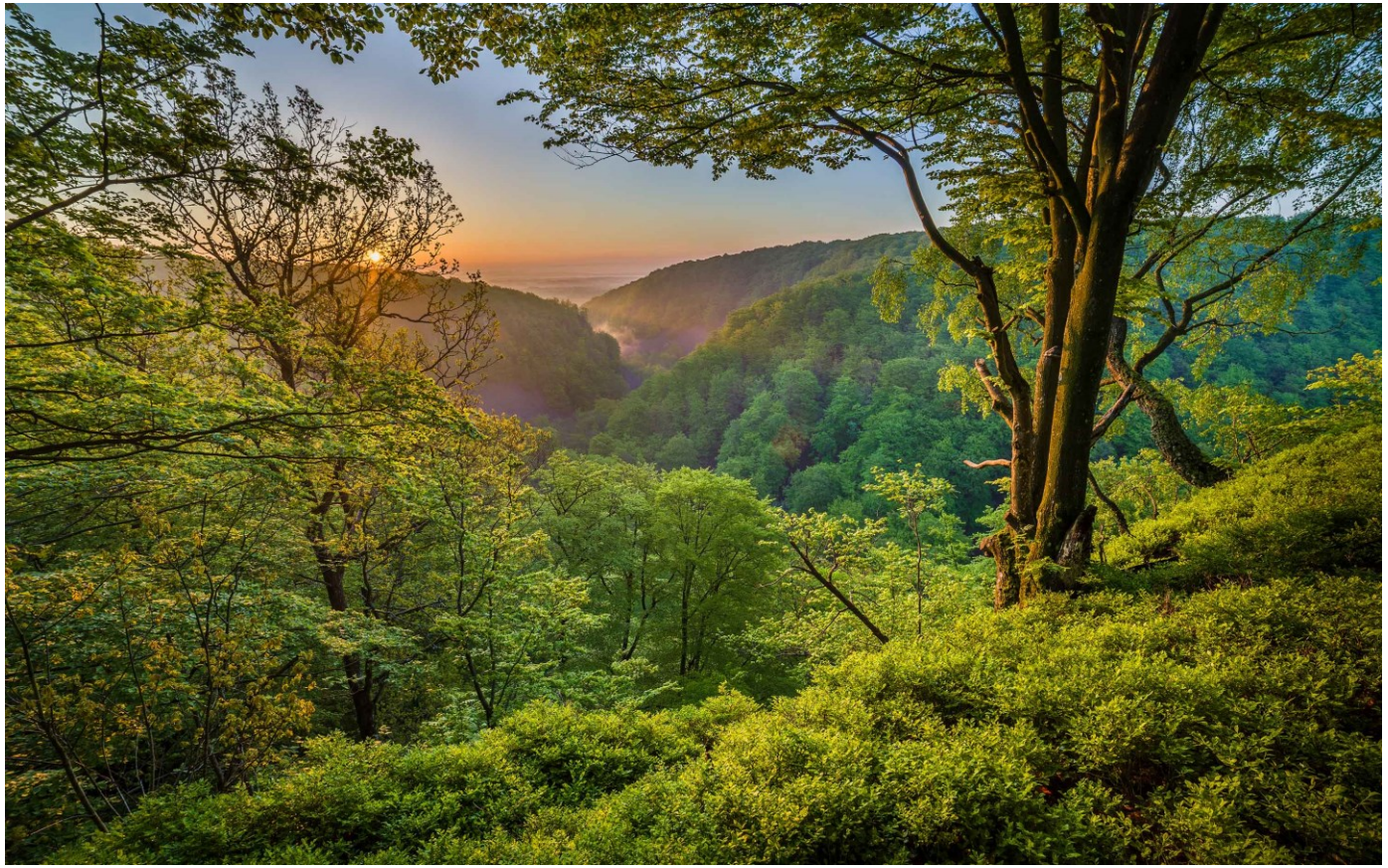


# The location

- Skåne (southern most region of Sweden)
- Rönne å catchment
- Söderåsen nationalpark
- Skärån

# The fish

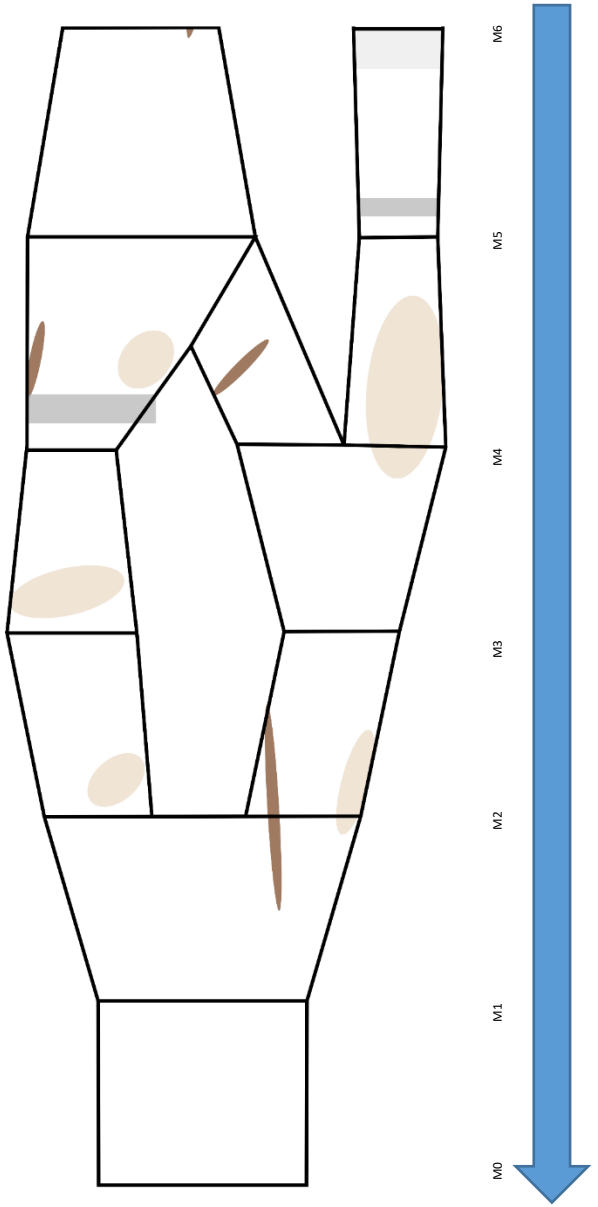
- Mixed age cohort *S. trutta*
- Electrofished in early August

# The fish


# The mussels

# The infestation

# The release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# The study

# Results Q1 (LMM)

## Host growth

Treatment p<0.001

F(1, 34.571)= 20.872

DPI p<0.017

F(2, 18.257)= 5.154

Interaction p<0.347

F(2, 34.571)= 1.122

Treatment p<0.859

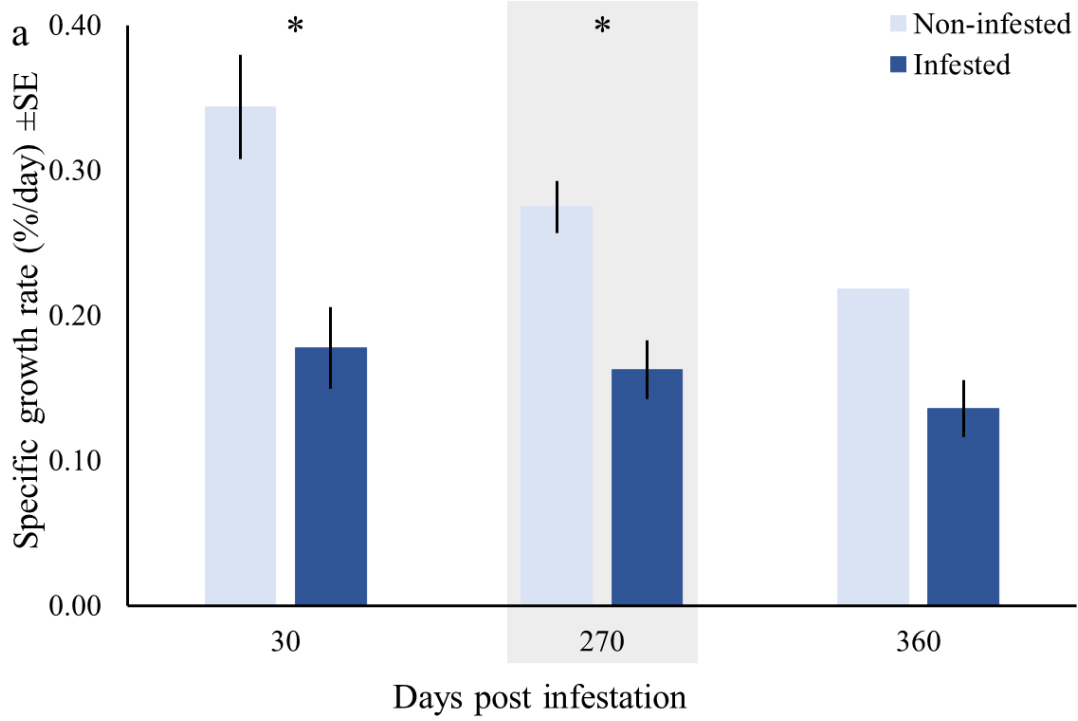
F(1, 9.359)= 0.033

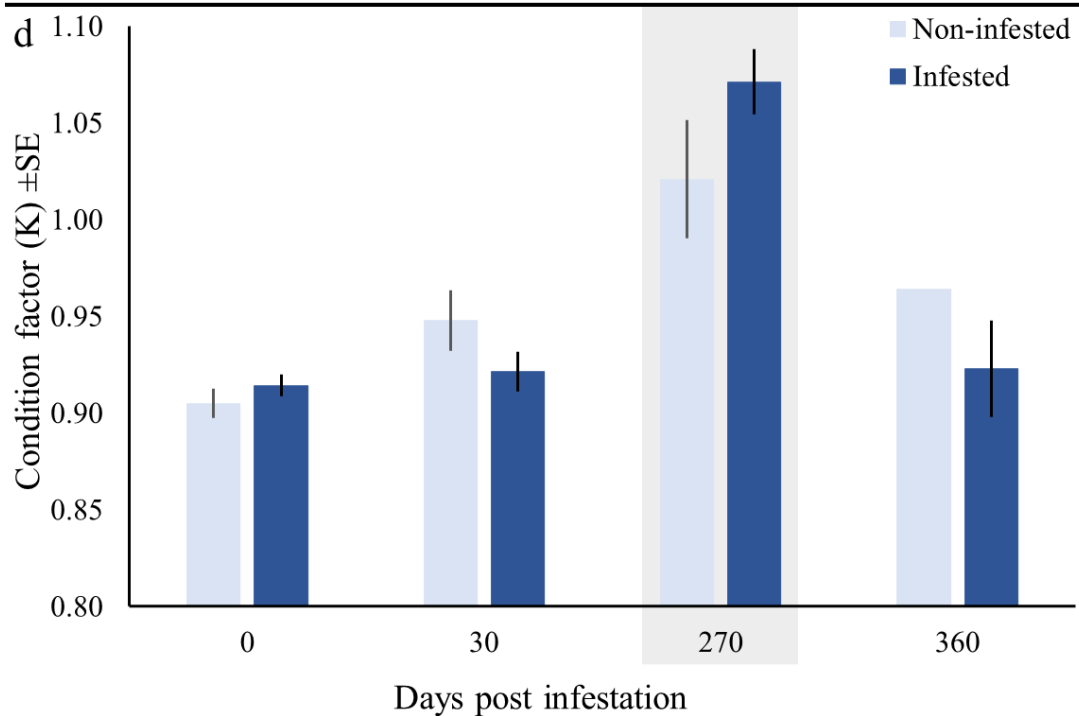
DPI p<0.001

F(3, 11.225)= 17.211

Interaction p<0.366

F(3, 11.225)= 1.165



# Results Q2 (LMM)

## Host dispersal

Treatment $p<0.014$

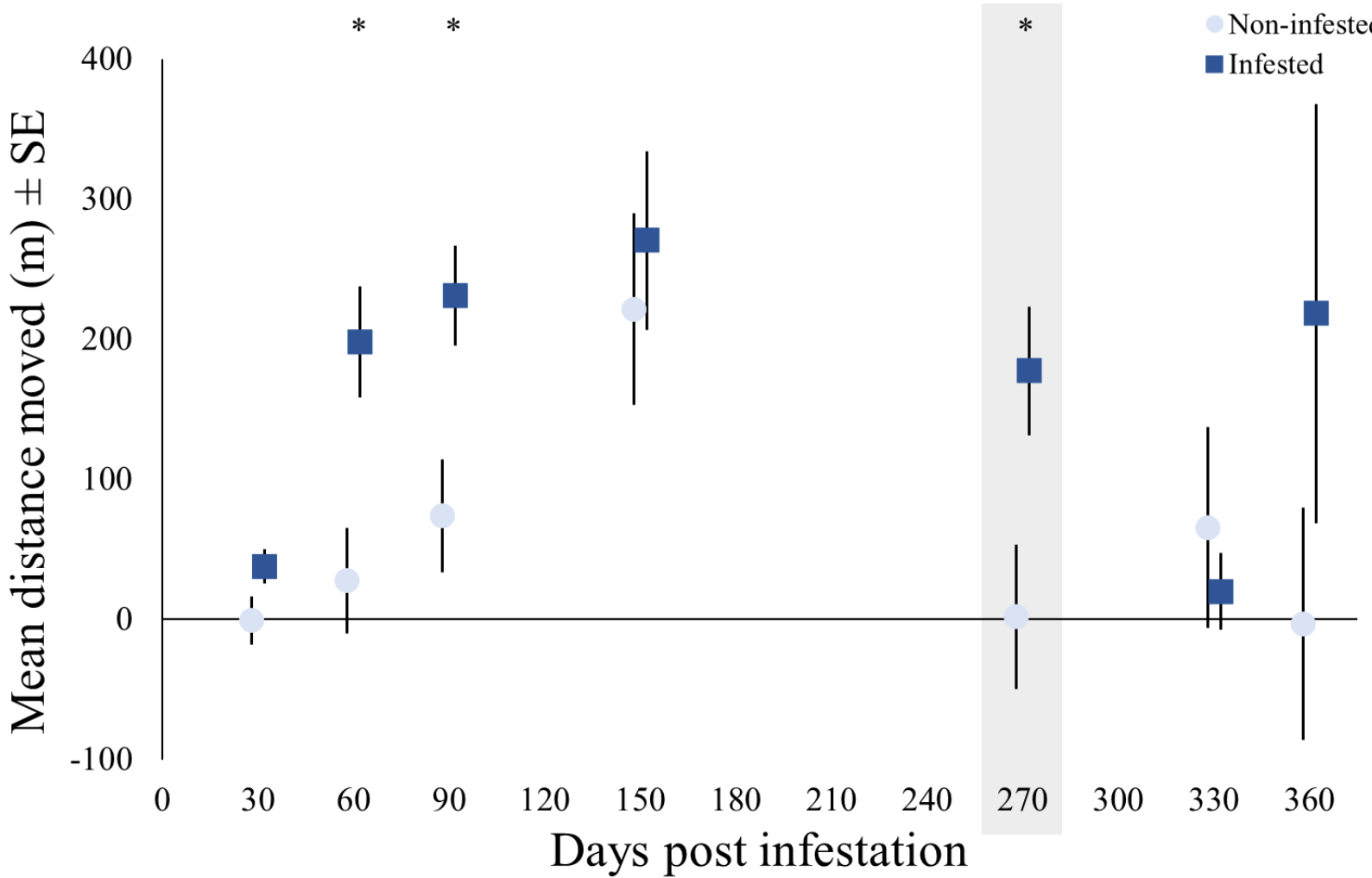
$F(1, 15.677)= 7.566$

DPI $p<0.001$

$F(6, 23.971)= 7.283$

Interaction $p<0.083$

$F(6, 23.971)= 2.161$



# Results Q3 (PCA)

## Habitat usage

- Dominating substrate type
- Secondary substrate type
- Dominating flow condition
- Average depth
- Max depth
- Distance from lake
- River width

Rotated Component 1

Rotated Component 2

Rotated Component 3

# Results Q3 (LMM)

## Habitat usage

### Flow Regime & Substrate type

Treatment p<0.032

F(1, 214.836)= 4.666

DPI p<0.098

F(6, 187.252)= 1.815

Interaction p<0.495

F(6, 187.252)= 0.901

### Water Depth

Treatment p<0.253

F(1, 211.491)= 1.316

DPI p<0.002

F(6, 192.390)= 3.637

Interaction p<0.337

F(6, 192.390)= 1.147

### River Width

Treatment p<0.334

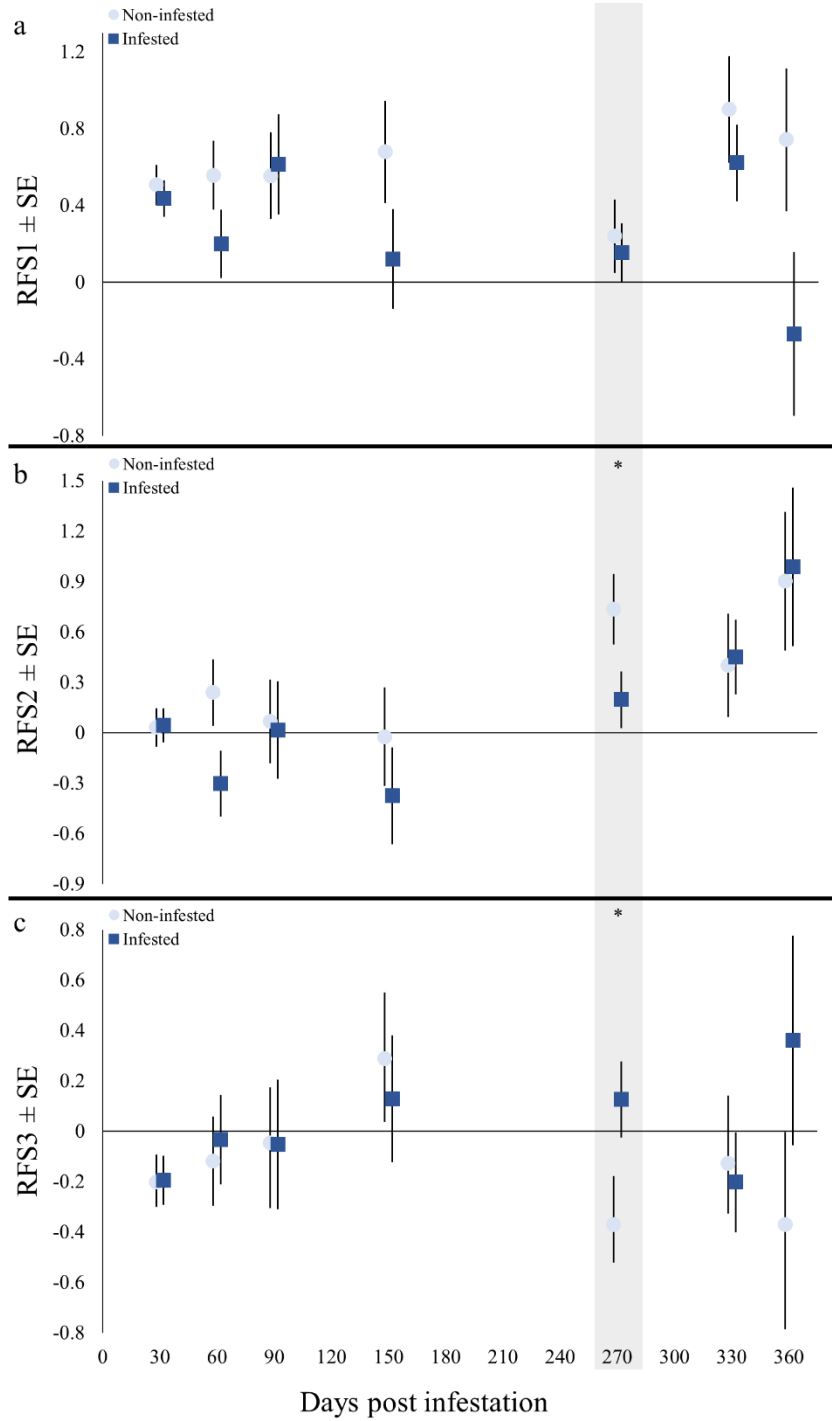
F(1, 225.976)= 0.936

DPI p<0.462

F(6, 172.837)= 0.948

Interaction p<0.394

F(6, 172.837)= 1.051

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# Result interpretation

- Hypothesis 1: False
  - Infested trout are *significantly* smaller than controls
  - Equal condition factor
- Hypothesis 2: True
  - Host fish disperse upriver sooner and further
    - Glochidia disperse ~170m upriver
- Hypothesis 3: True
  - Infested fish use slower moving water (validated in the literature)
  - Infested fish use more shallow water when glochidia excise
- No significant mortality
  - Ratio of Control: Treatment remained consistent

# Discussion

- Very few, arguably no, previous studies like this before
  1. Horký *et al.,* 2014
  2. Irmsher & Vaughn, 2015
  3. Teuri et al., 2017
  4. Horký et al., 2019 – On MM & ST
  5. Wengström, 2022 – On MM & ST

- Further evidence of complex interaction
  - Marwaha *et al.,* 2019 – Higher Condition Factor in infested trout
  - Chowdhury *et al.,* 2021 – Higher immunologic resistance
  - Ziuganov *et al.,* 2005 – Higher resistance to gill trauma

- Serious harm to host is not evolutionarily favorable
  - Parasite *Reduced* Trophic Transmission

# Conclusions

- Host fish are marginally smaller
- Host dispersal follows expected pattern
  - Go further for longer
- Host habitat usage is more similar than different
  - Preference for habitats optimal for excystem
  - Depth only impacted when it matters
- Removing dams helps protect mussels
  - Improves habitat
  - Allows for free host movement

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# Thanks! Any Questions?

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