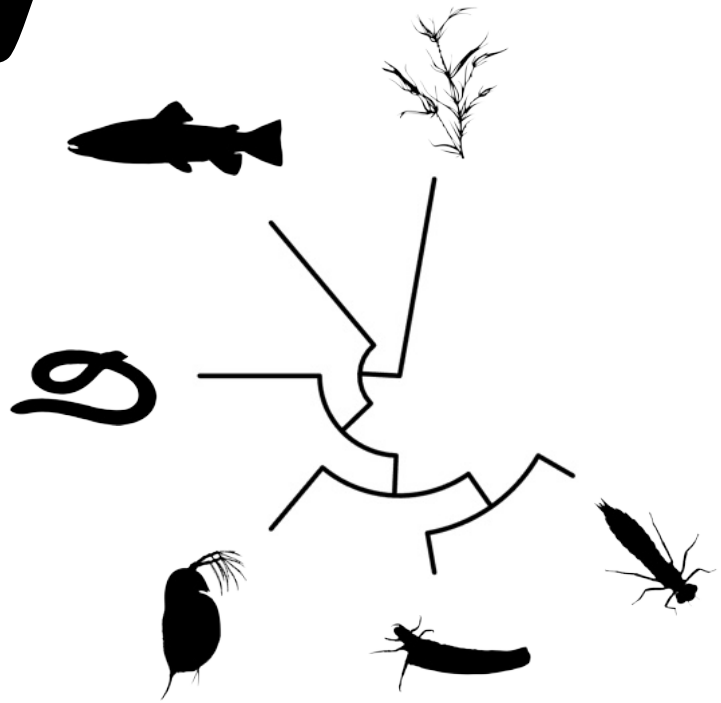
Branching out into Ecotoxicology

Evolutionary perspectives on species' responses to toxicants

Iain R. Moodie

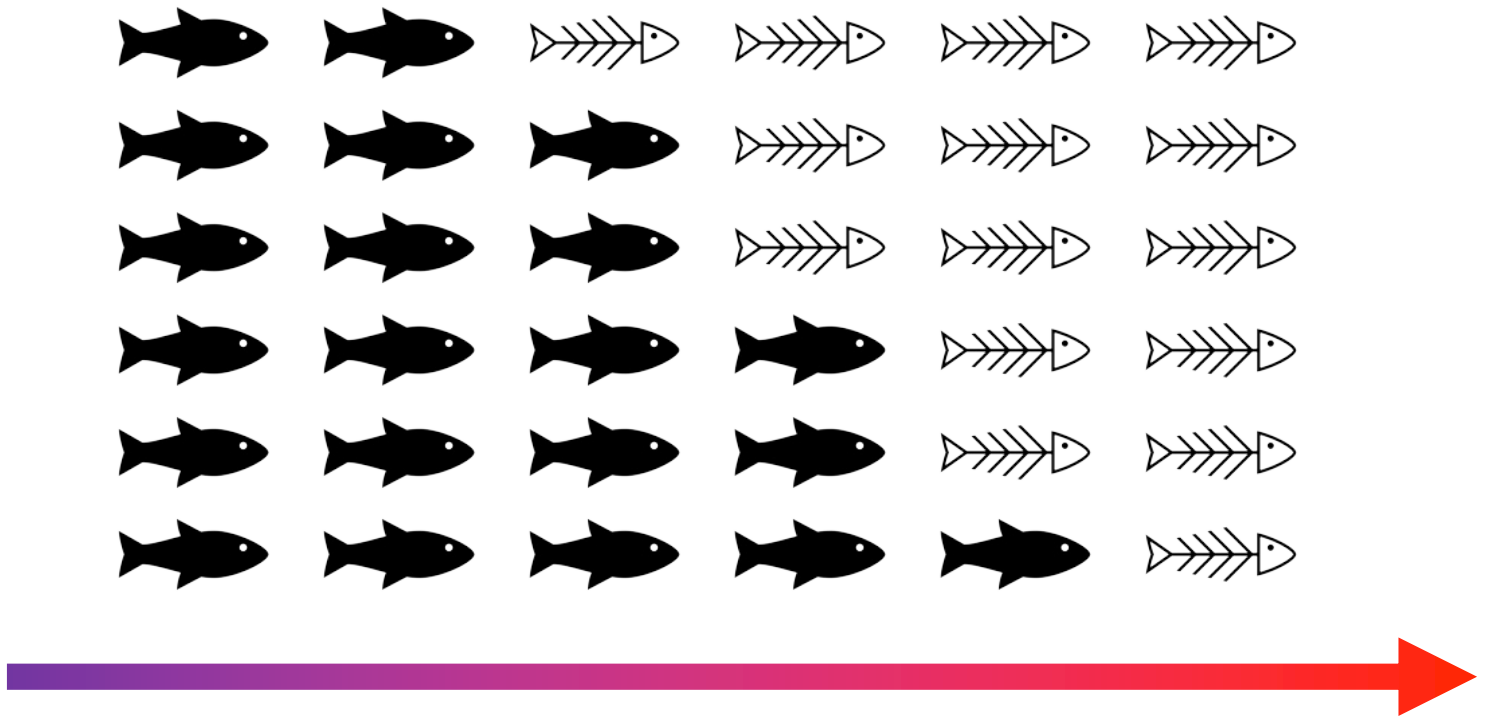
Supervisor: Stephen De Lisle
Co-supervisor: Erik Svensson

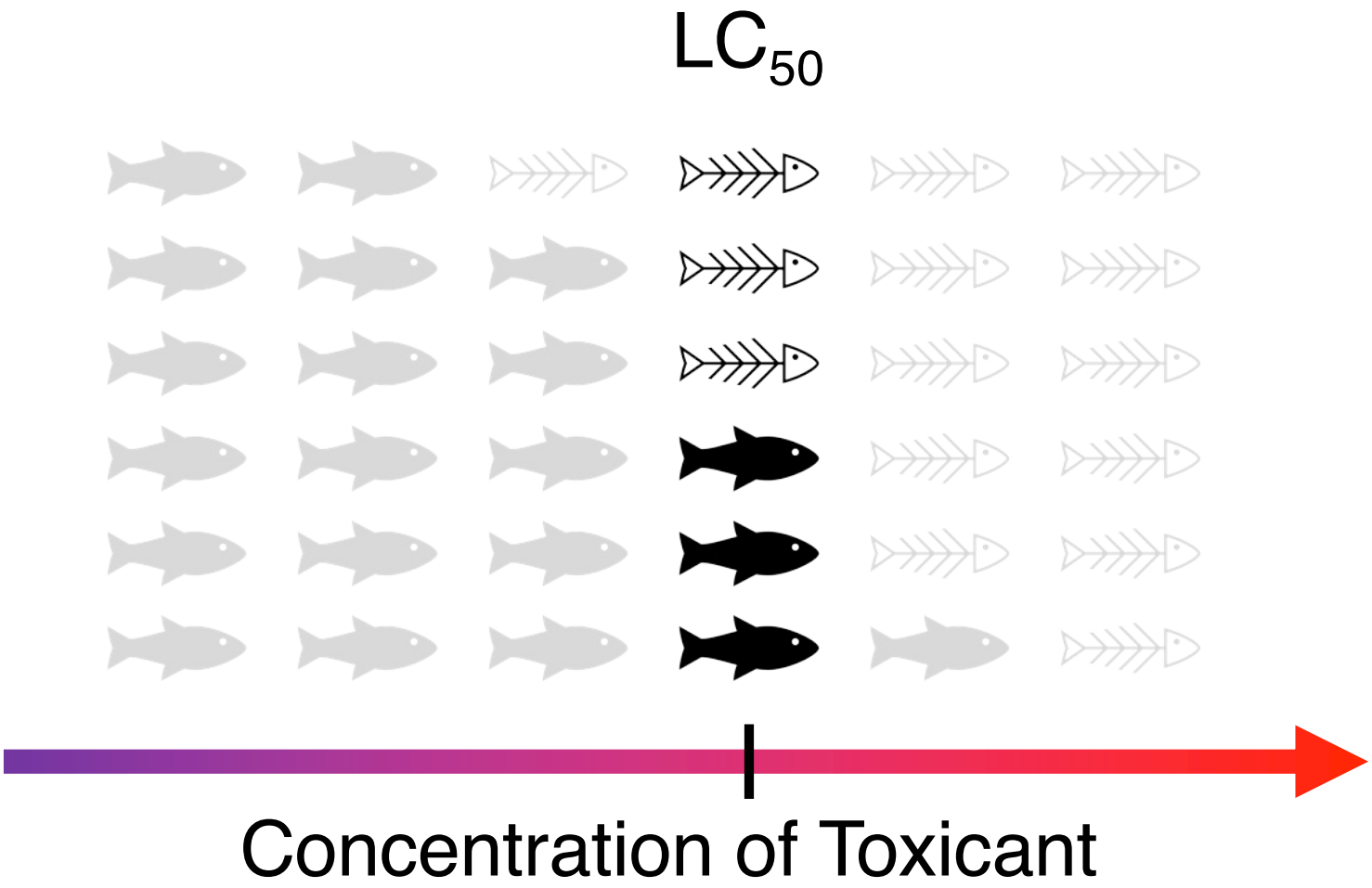


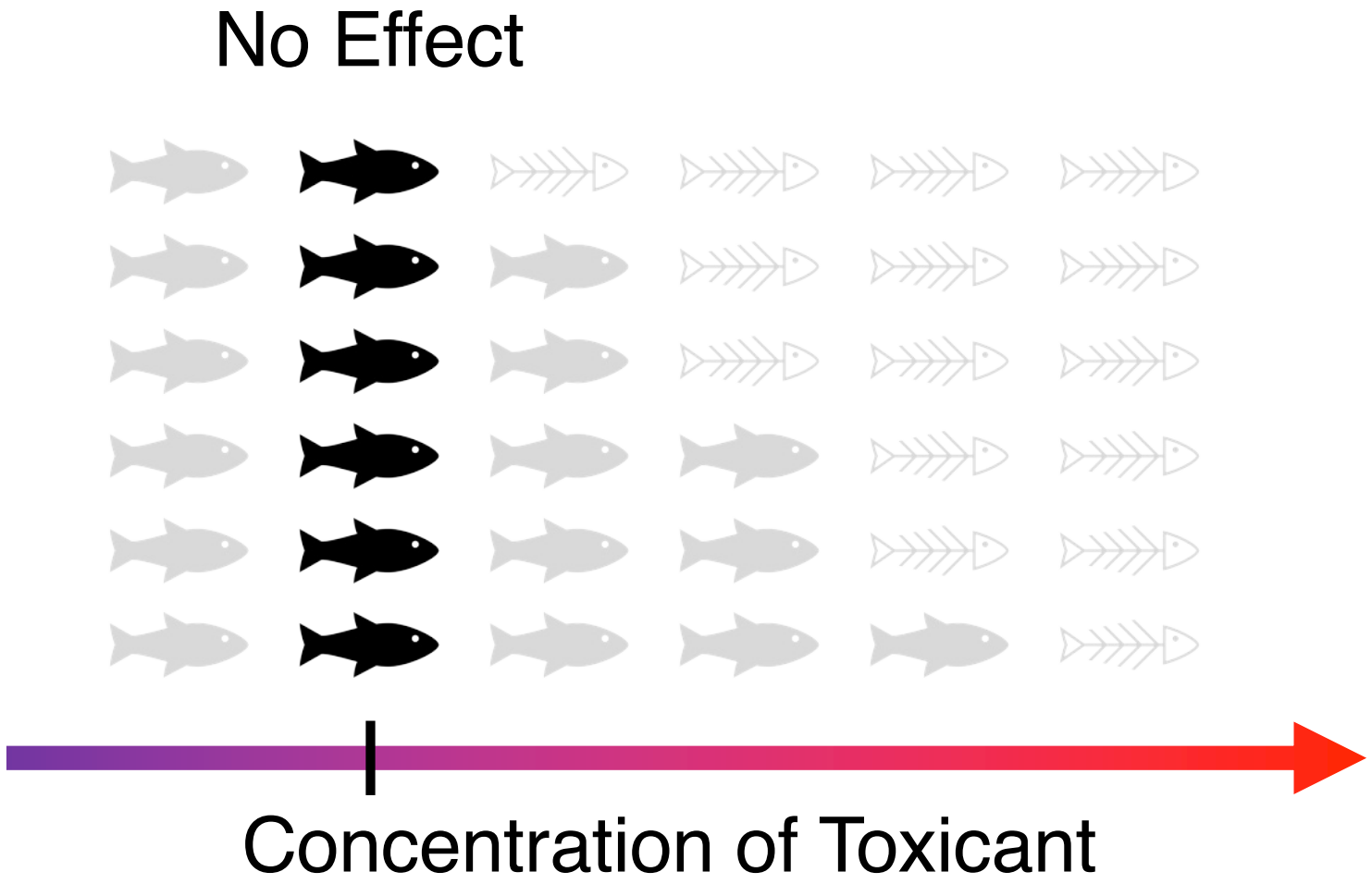
How sensitive to a toxicant are different **species**?

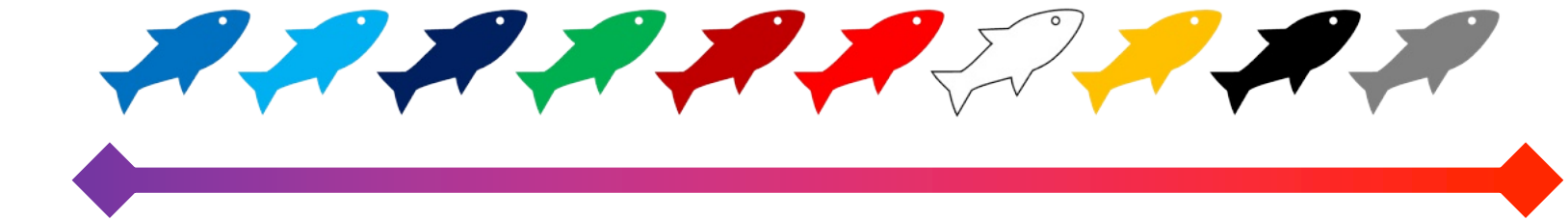
How sensitive to a toxicant is an **ecosystem**?

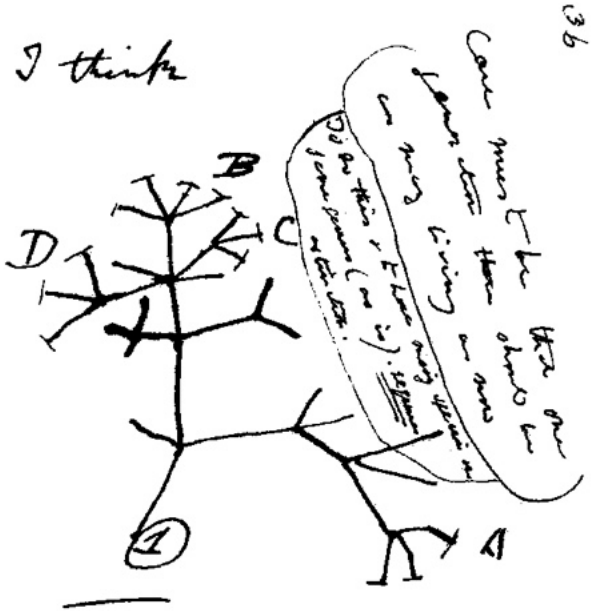
What is the **safe** amount of a toxicant in the environment?


Concentration of Toxicant

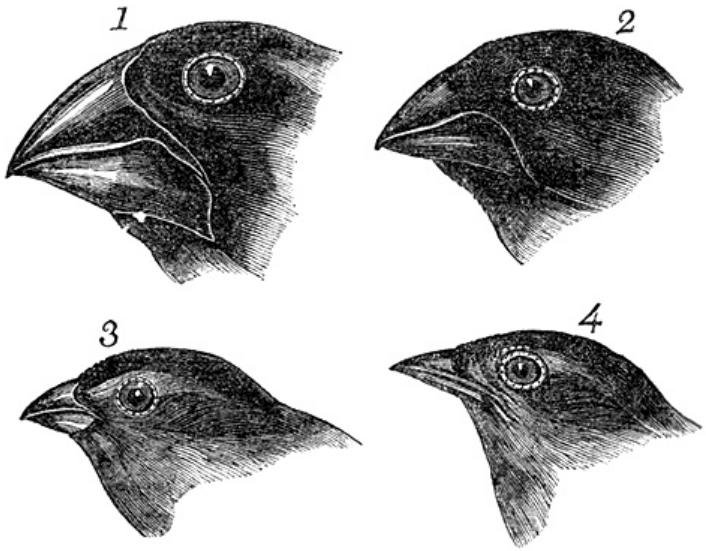

LC_{50}
Concentration of Toxicant


No Effect
Concentration of Toxicant

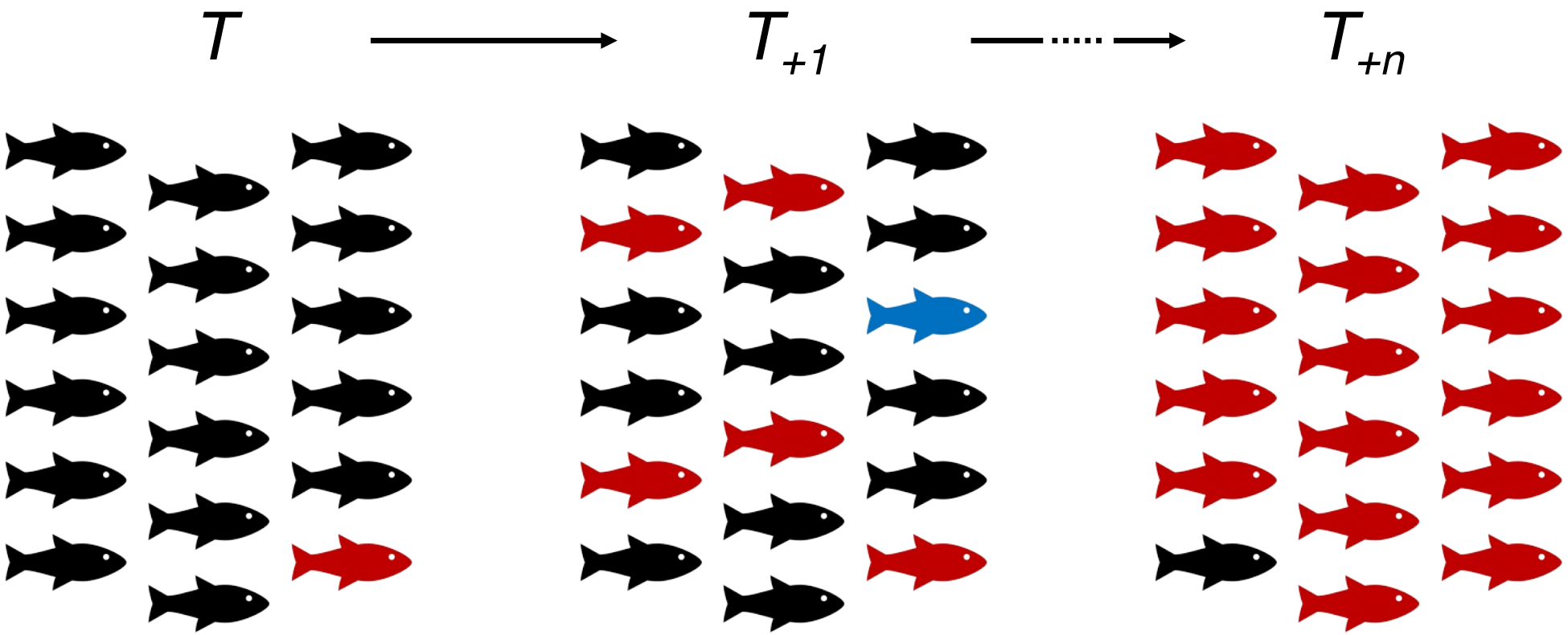

Sensitive
Tolerant



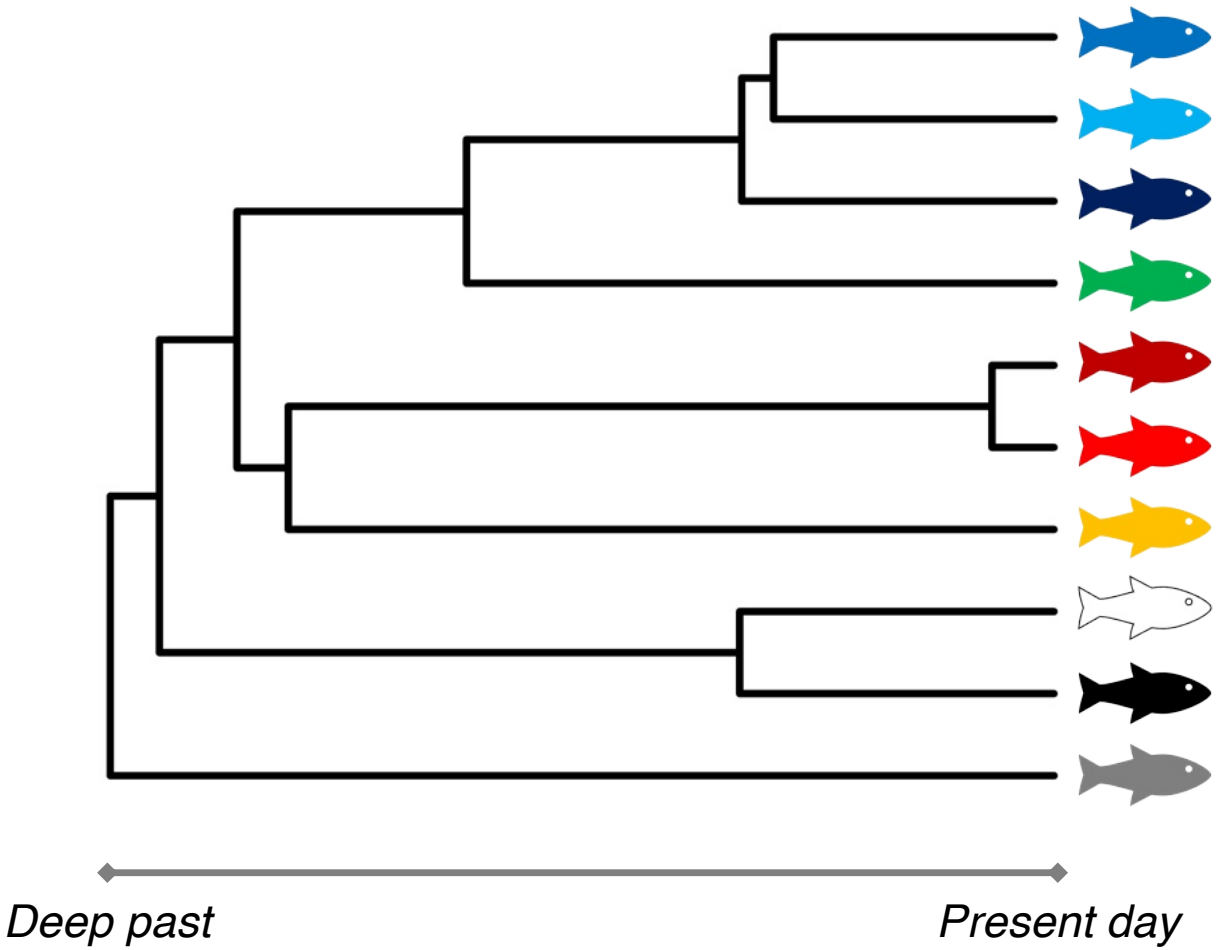
Then between A & B. causing
beg of relation. C & B. the
first gradation, B & D
rather greater distinction
Then genera would be
formed. - Bearing relation



Microevolutionary change



Macroevolutionary change



Outline

- What shapes the contemporary distribution of species sensitivities?
- How have species sensitivities evolved?
- Understanding species sensitivities in context.

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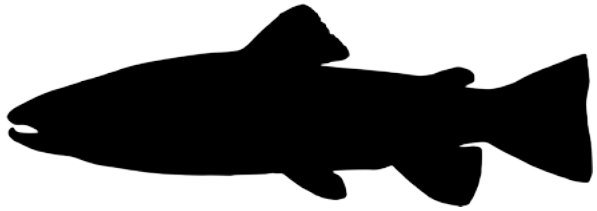
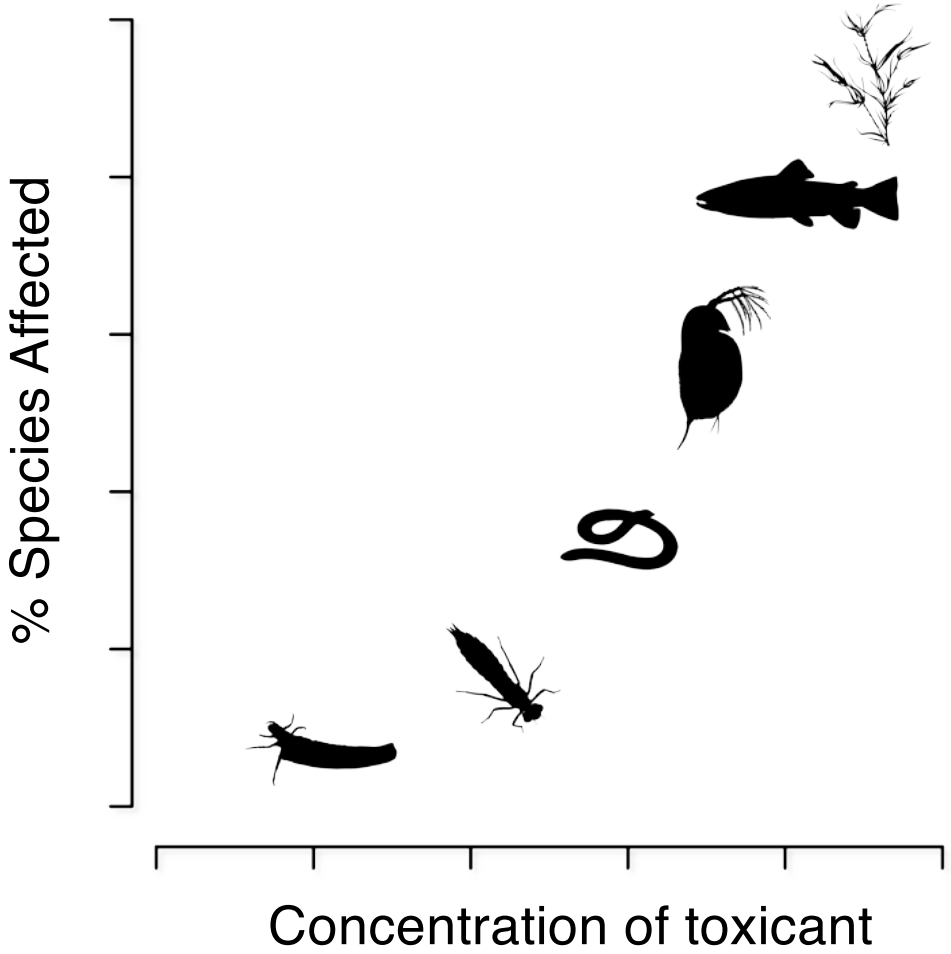


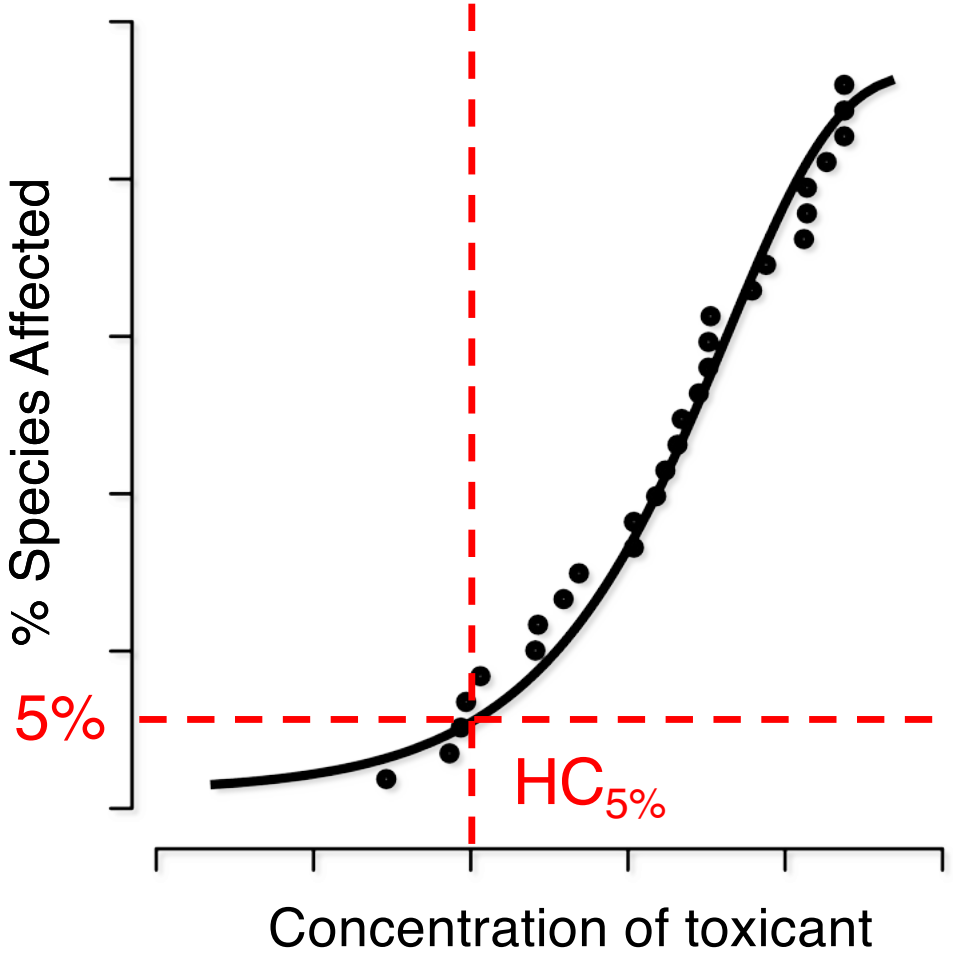
Sensitive

Tolerant

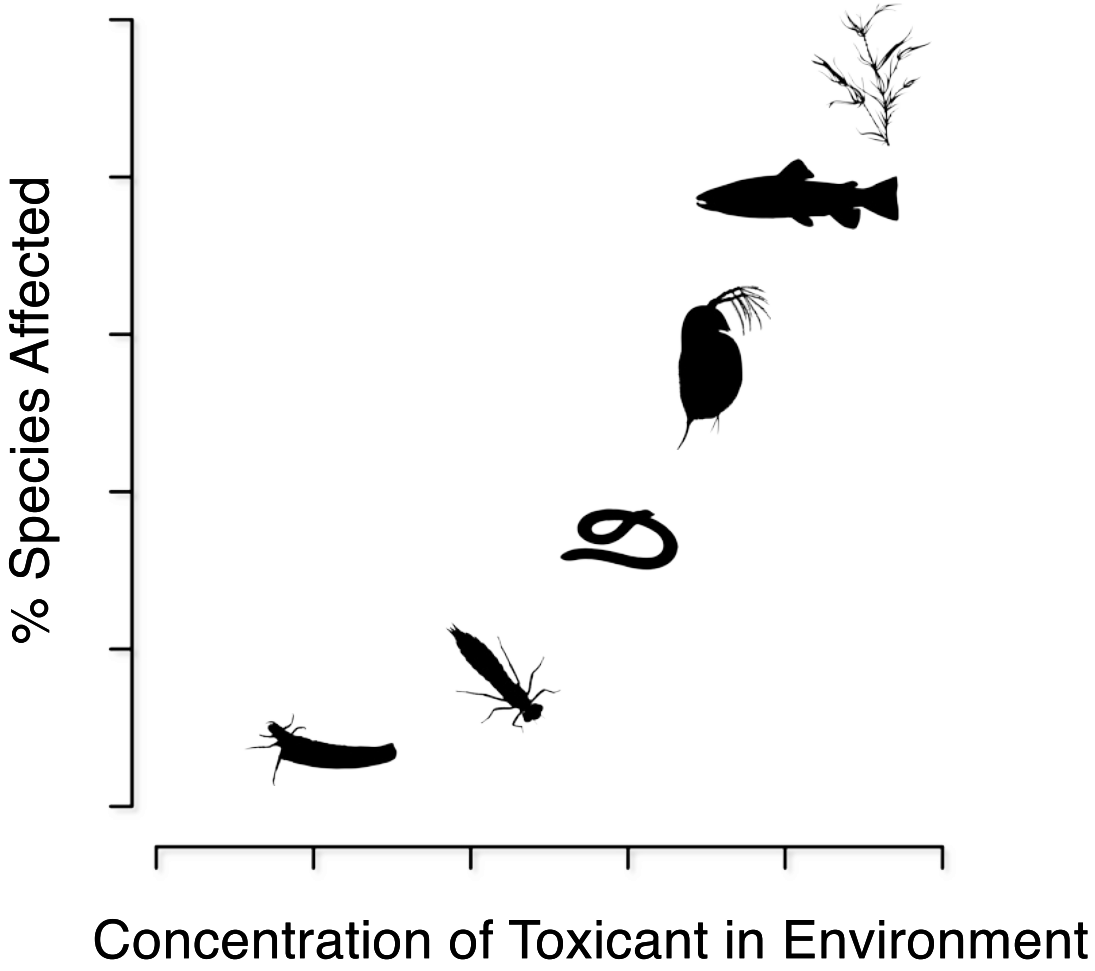
Species Sensitivity Distribution

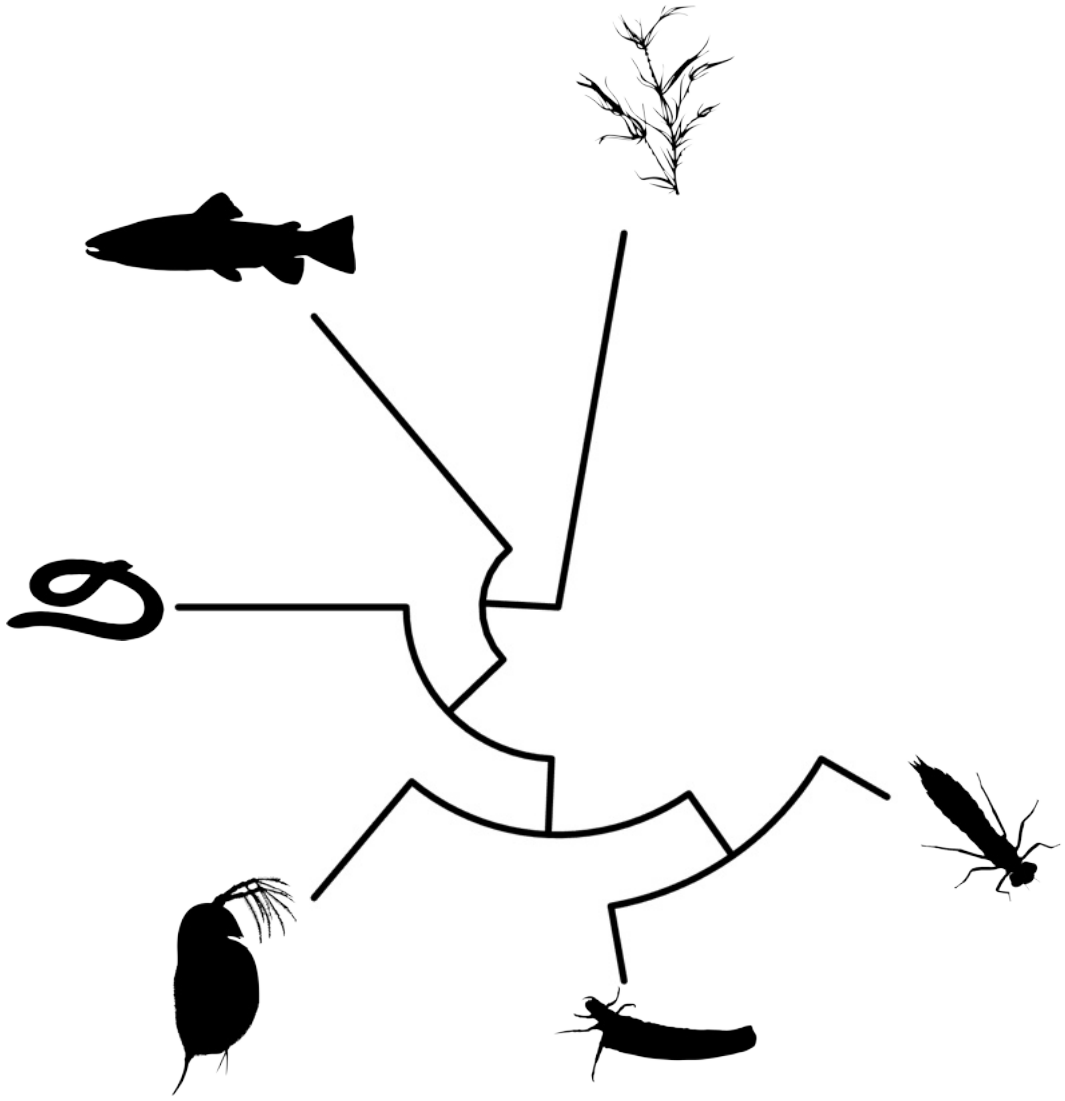


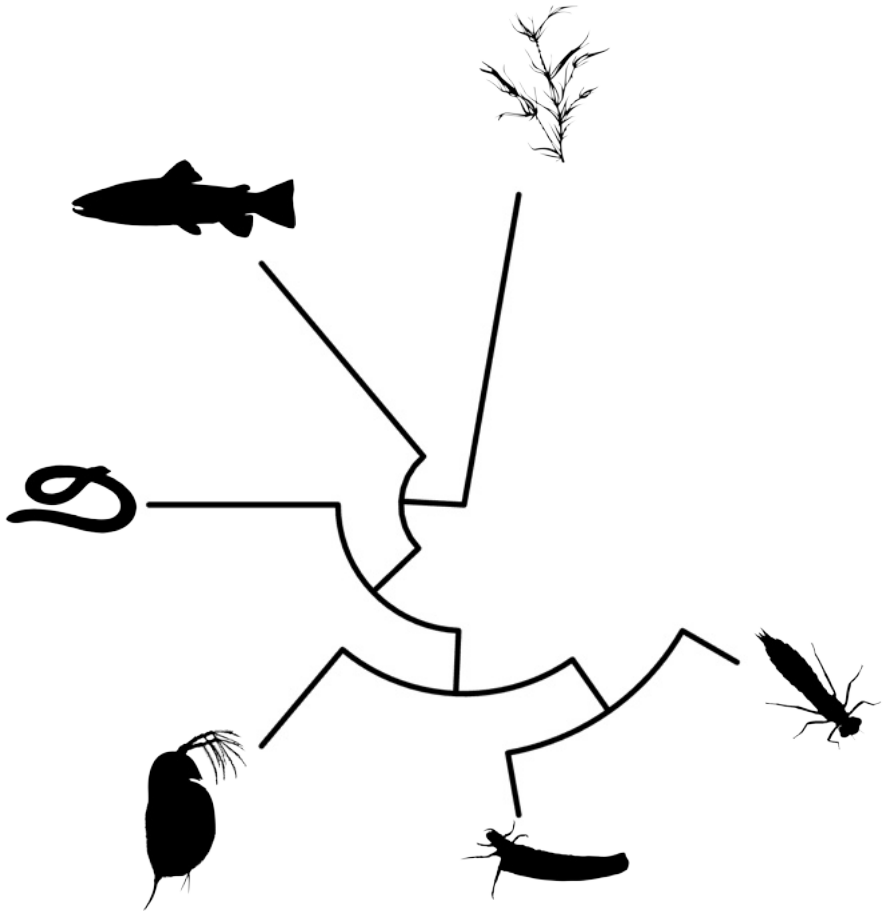
Species Sensitivity Distribution

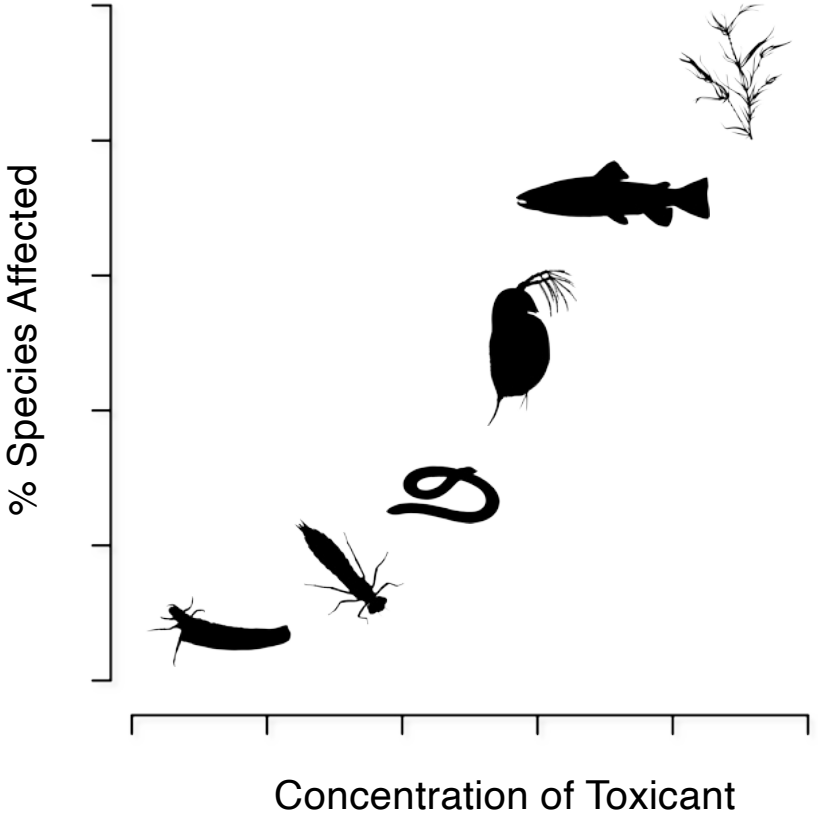


Species Sensitivity Distribution

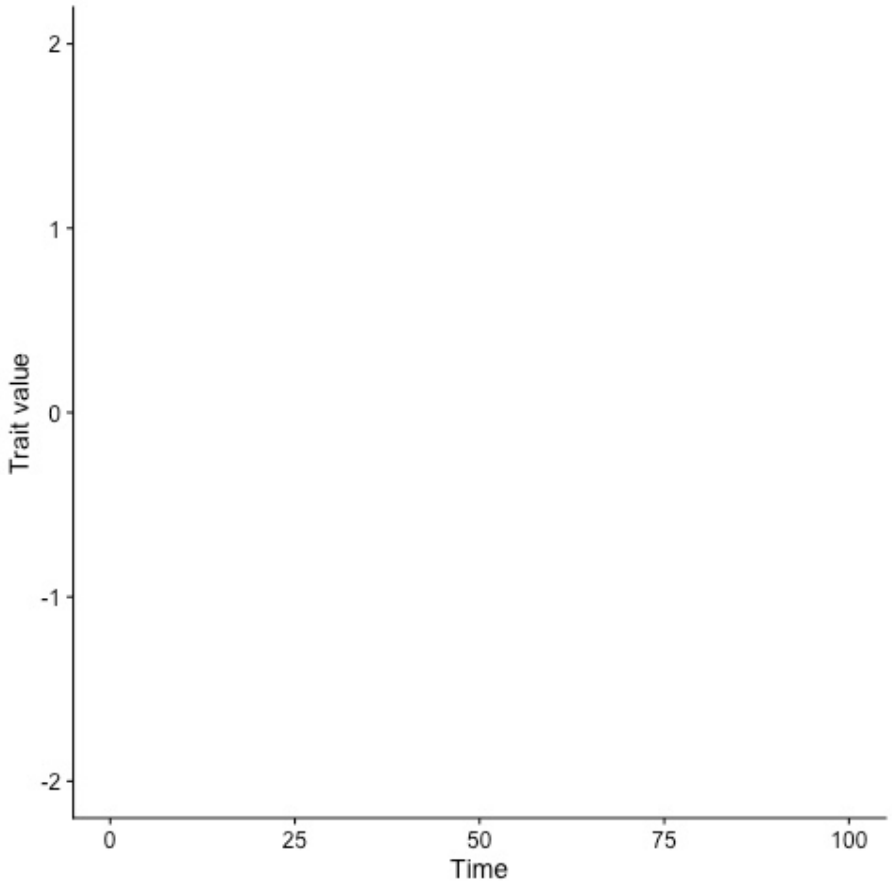






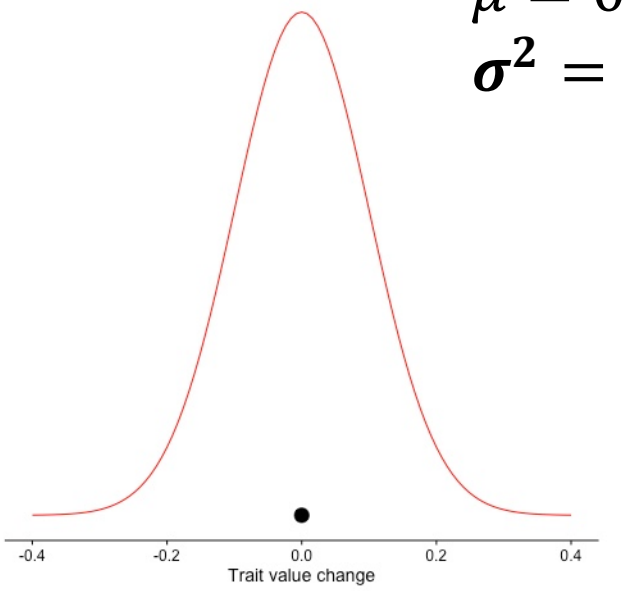

% Species Affected
Concentration of Toxicant

Brownian motion model of trait evolution



$\mu = 0$

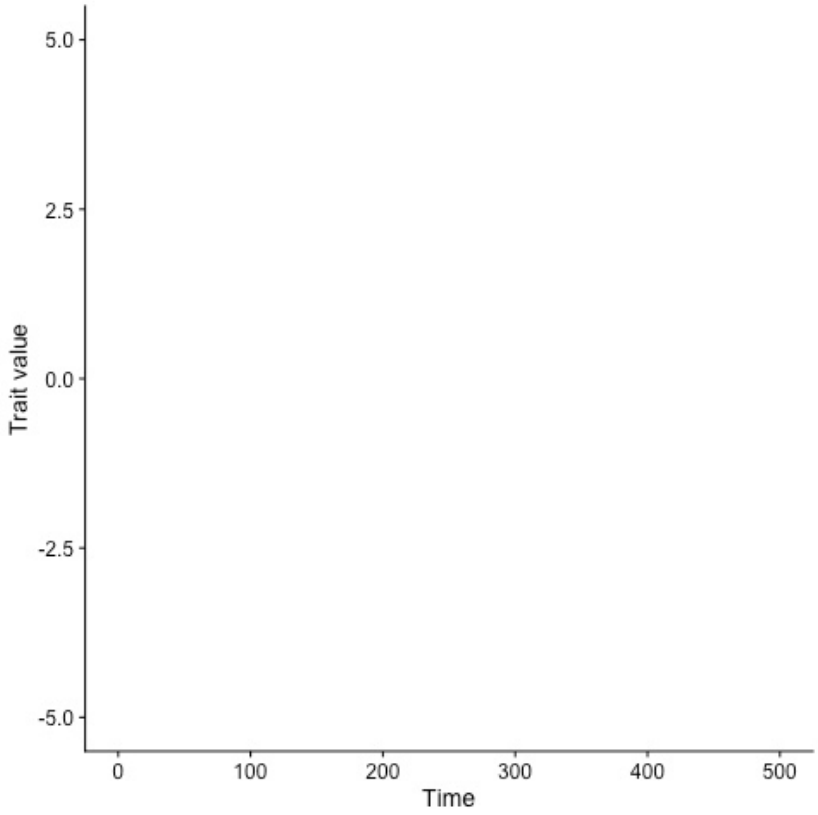
$\boldsymbol{\sigma^2 = 0.01}$



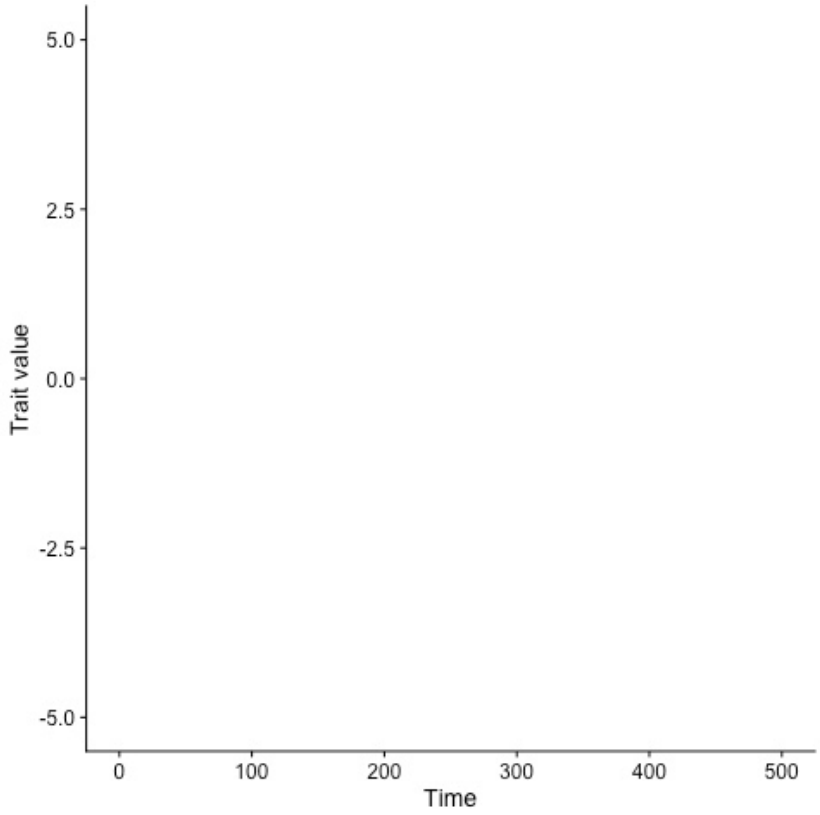
Felsenstein 1973

Brownian motion model of trait evolution

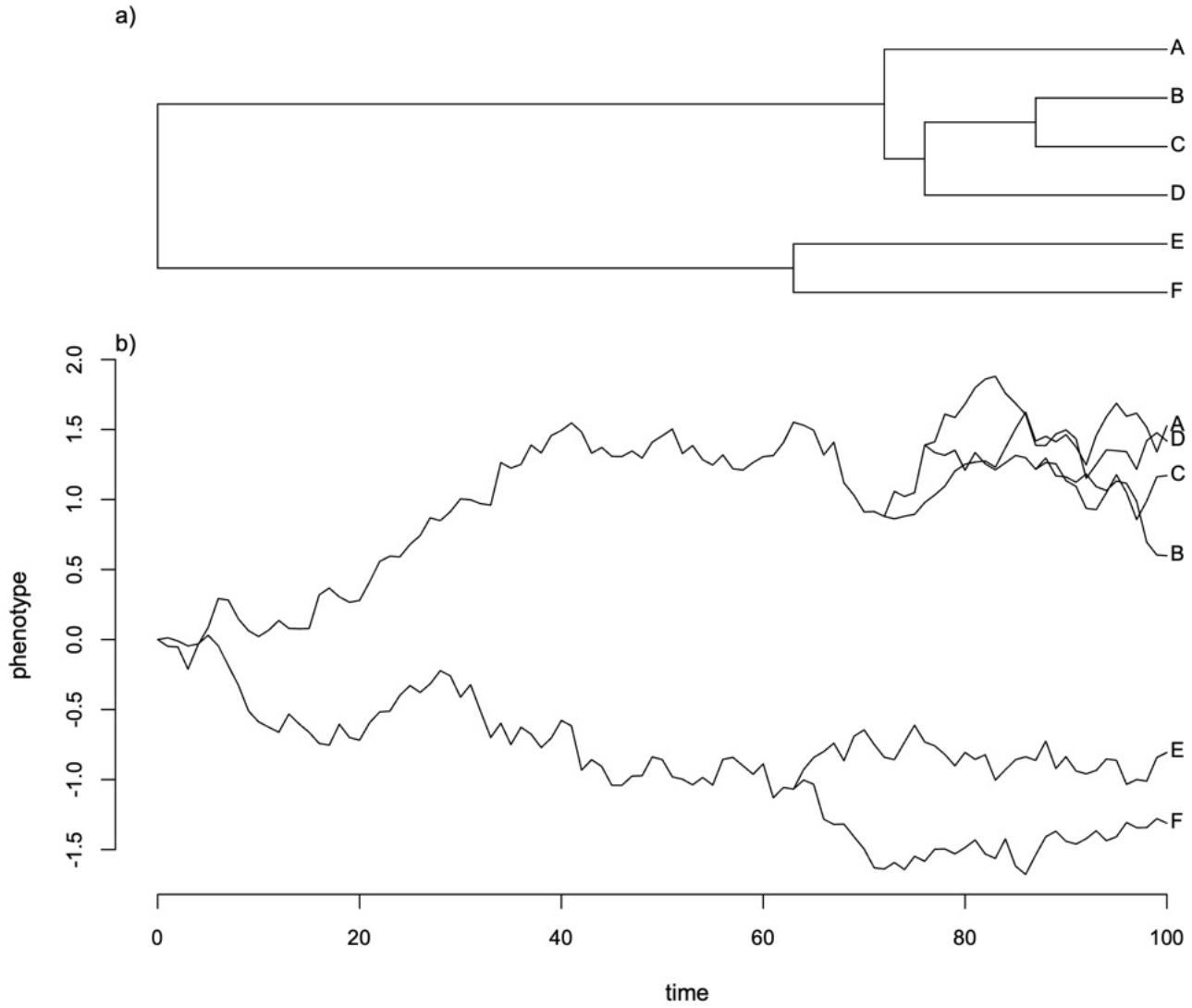
$\boldsymbol{\sigma^2 = 0.01}$



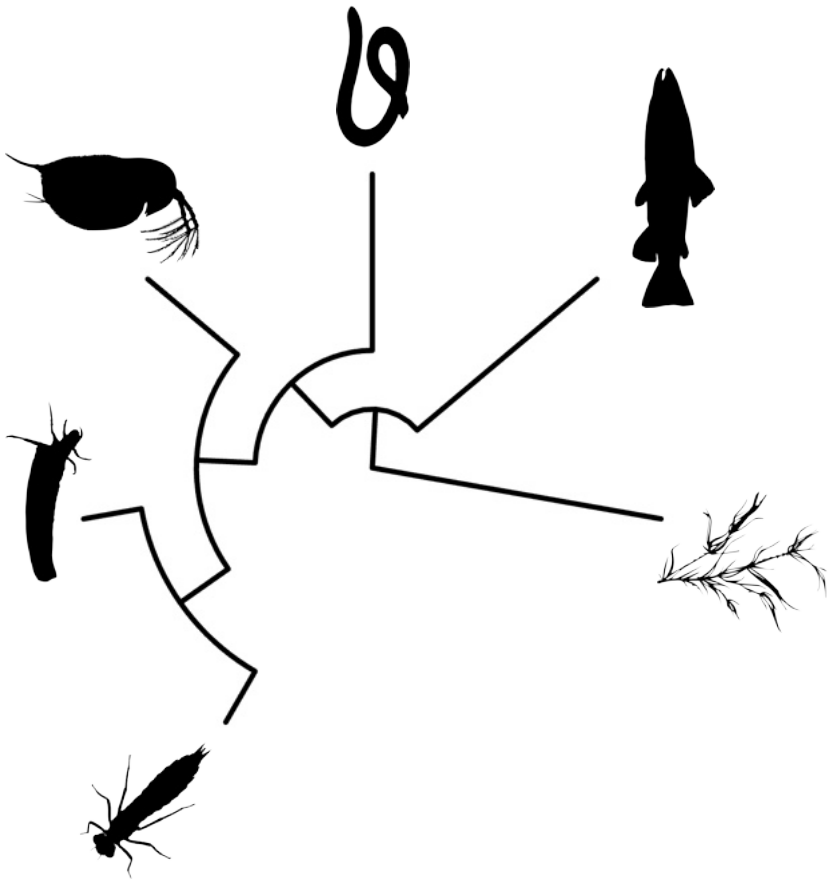
$\boldsymbol{\sigma^2 = 0.001}$

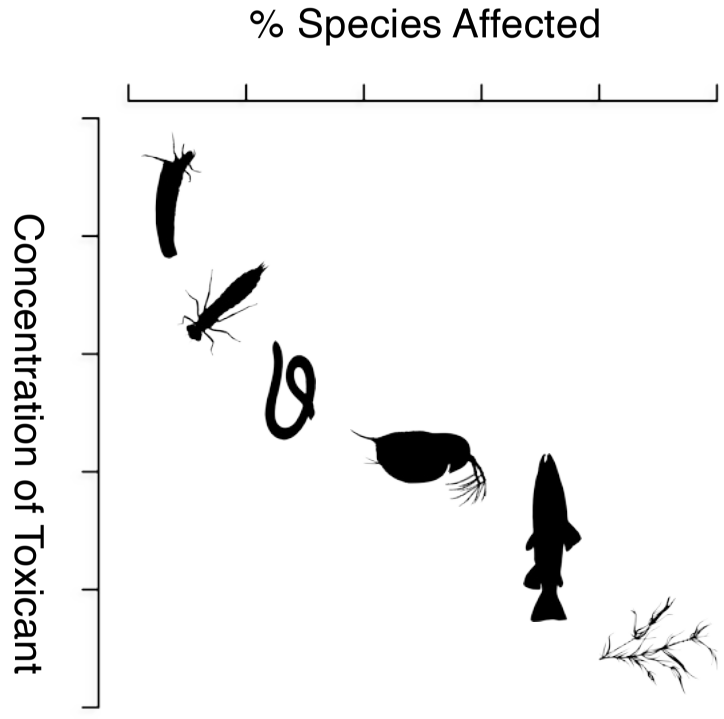


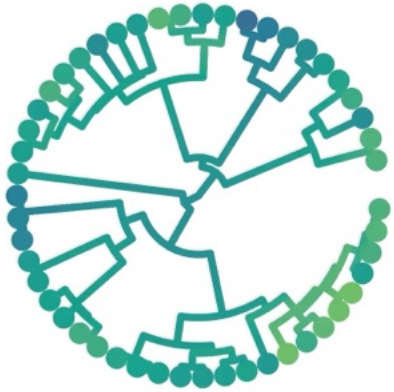
Felsenstein 1973

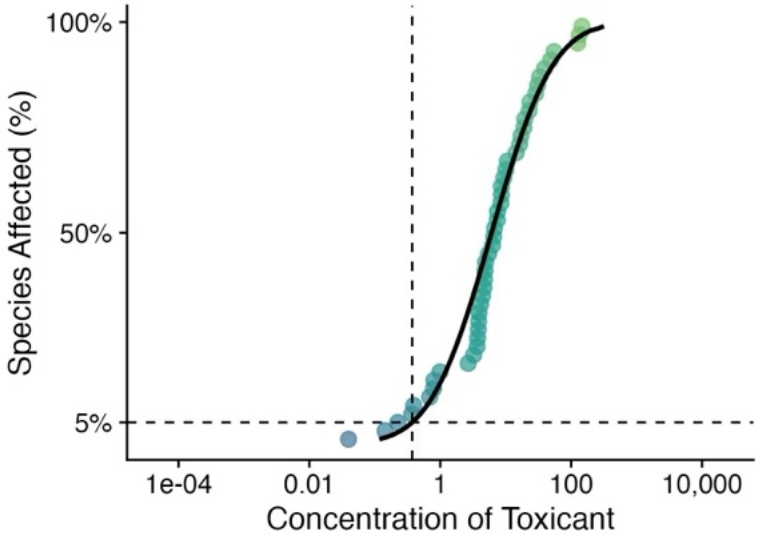


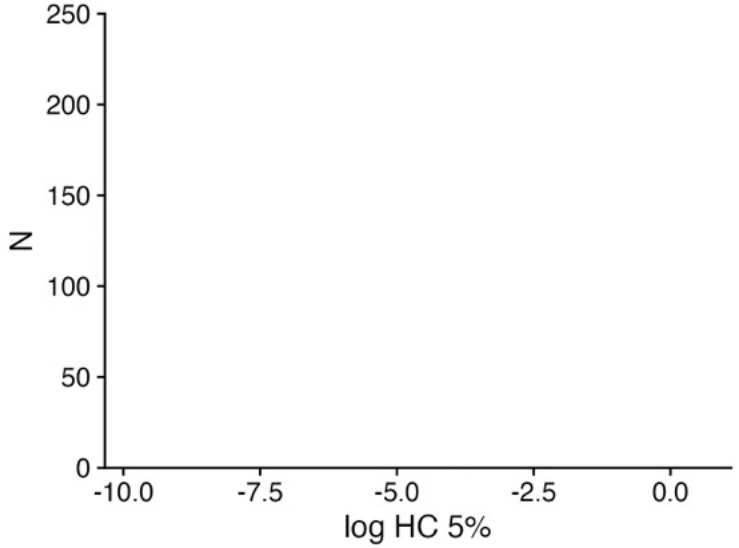
Felsenstein 1973

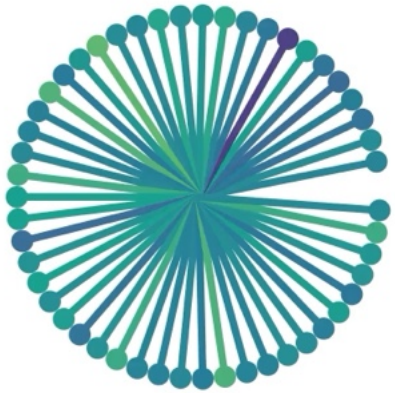


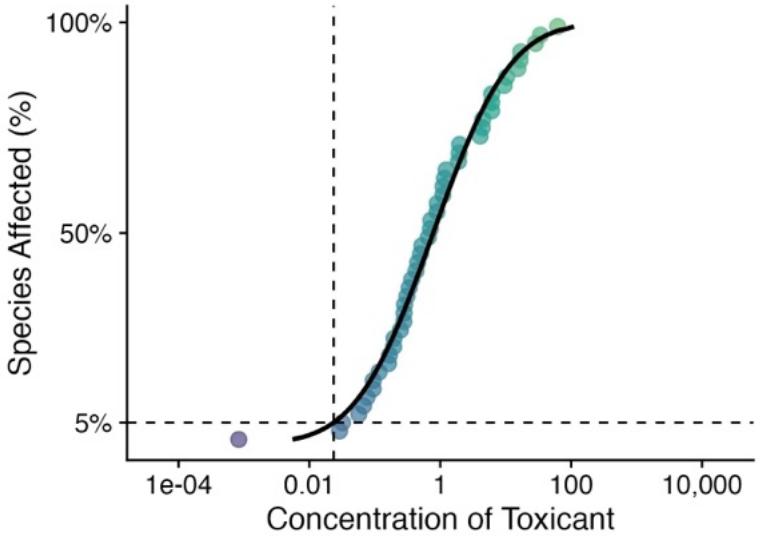

% Species Affected
Concentration of Toxicant

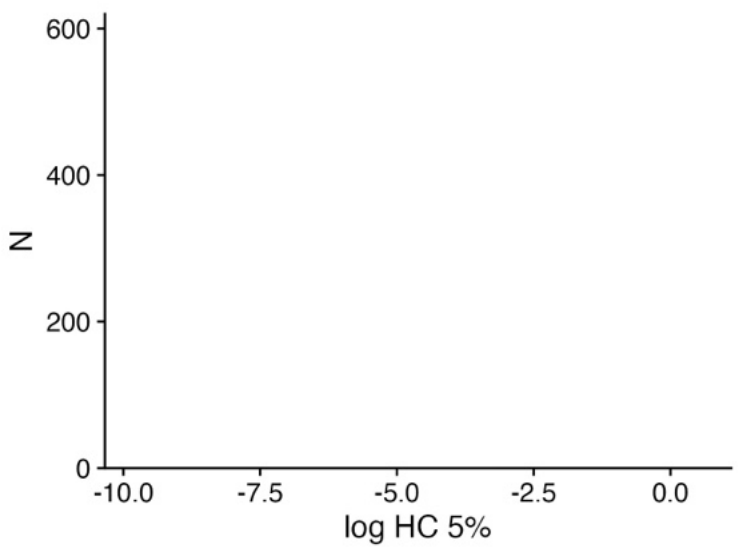


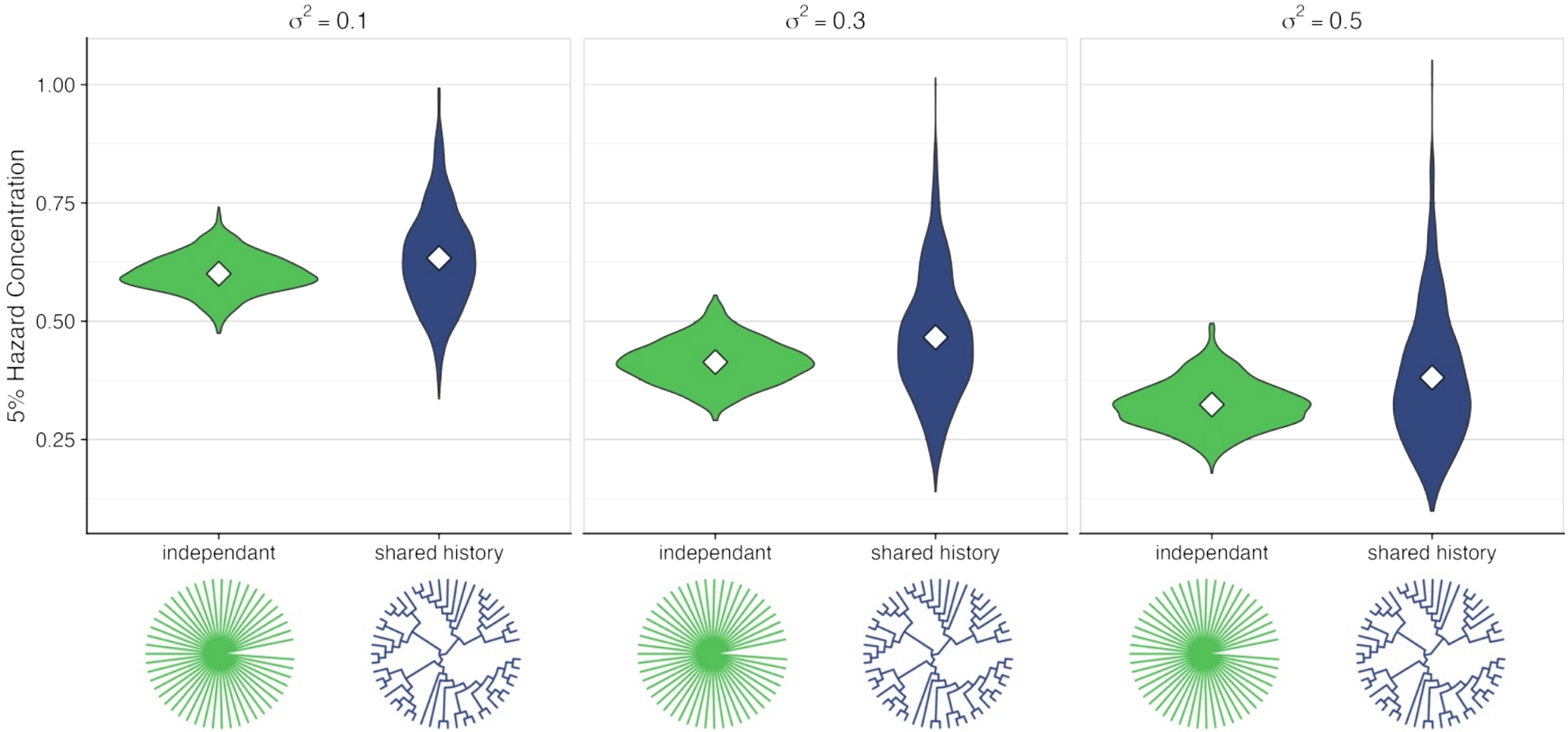

100%
50%
5%
Species Affected (%)
1e-04
0.01
1
100
10,000
Concentration of Toxicant

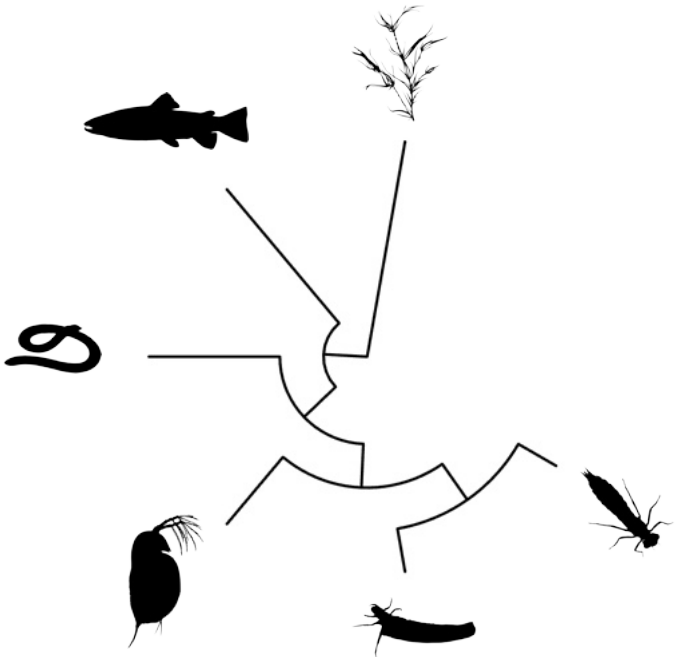

250
200
150
100
50
0
N
-10.0
-7.5
-5.0
-2.5
0.0
log HC 5%

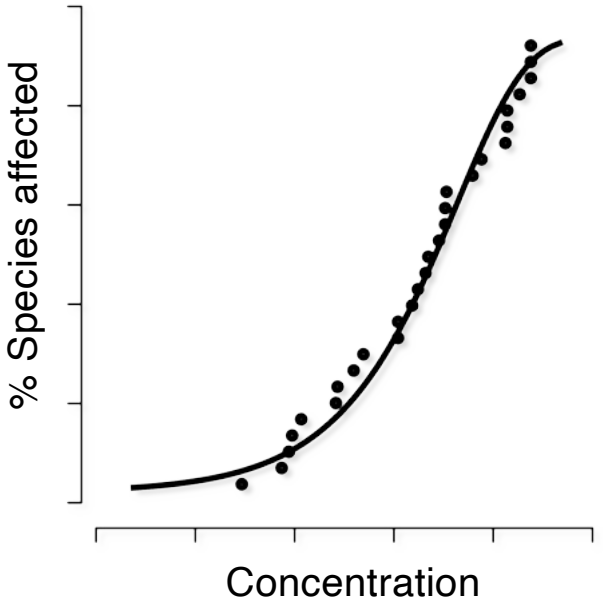



100%
50%
5%
Species Affected (%)
1e-04
0.01
1
100
10,000
Concentration of Toxicant


600
400
200
0
N
-10.0
-7.5
-5.0
-2.5
0.0
log HC 5%


$\sigma^2 = 0.1$
$\sigma^2 = 0.3$
$\sigma^2 = 0.5$
5% Hazard Concentration
1.00
0.75
0.50
0.25
independant
shared history
independant
shared history
independant
shared history




% Species affected
Concentration

Outline

- What shapes the contemporary distribution of species sensitivities?
- How have species sensitivities evolved?
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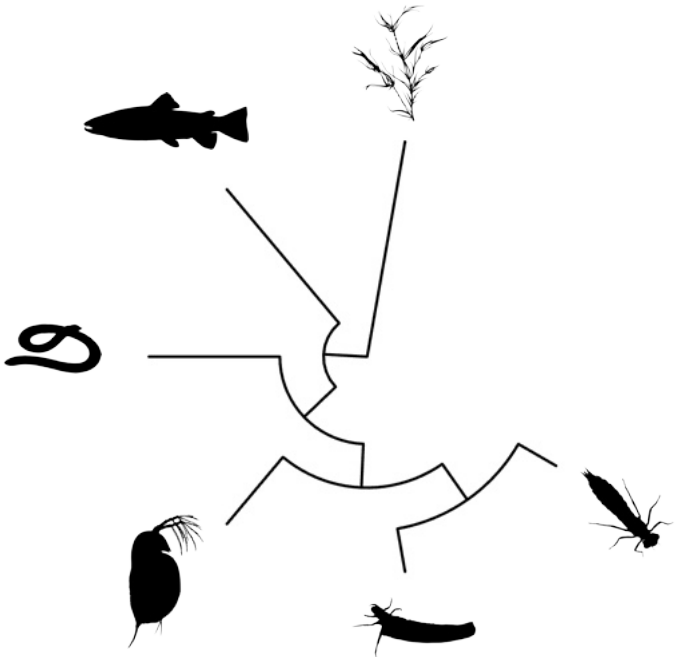
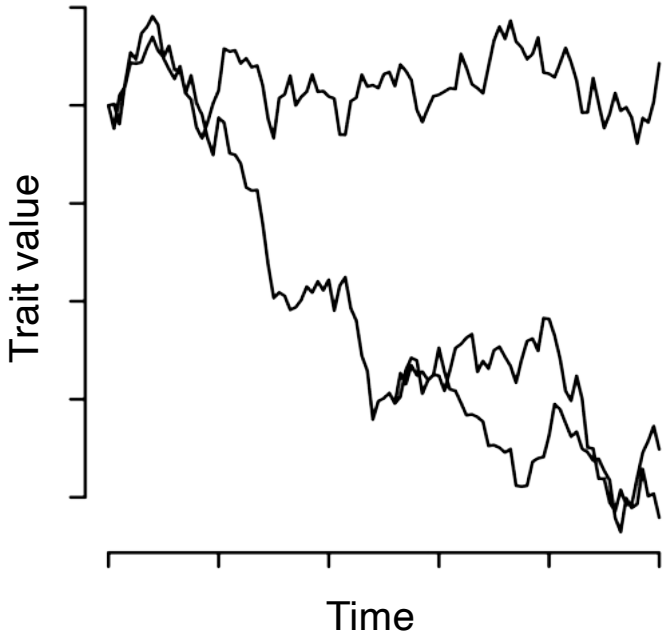
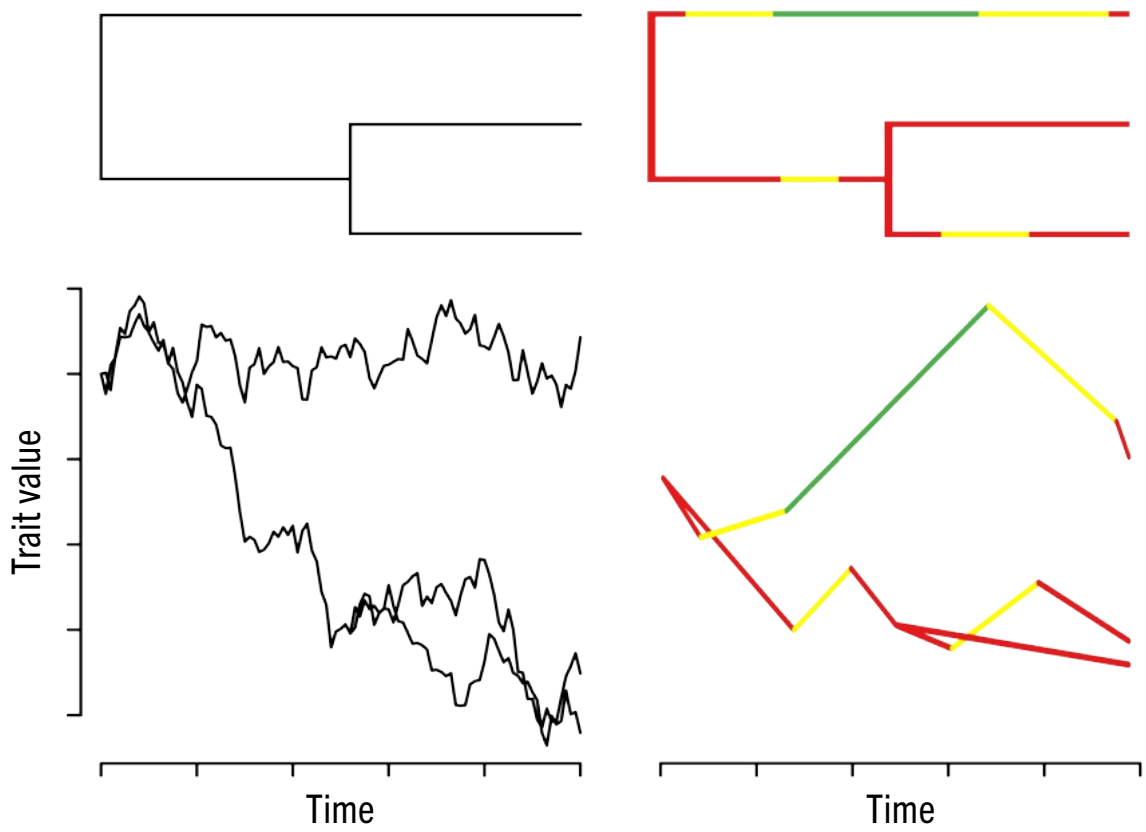


$$dX(t) = \sigma dW(t)$$

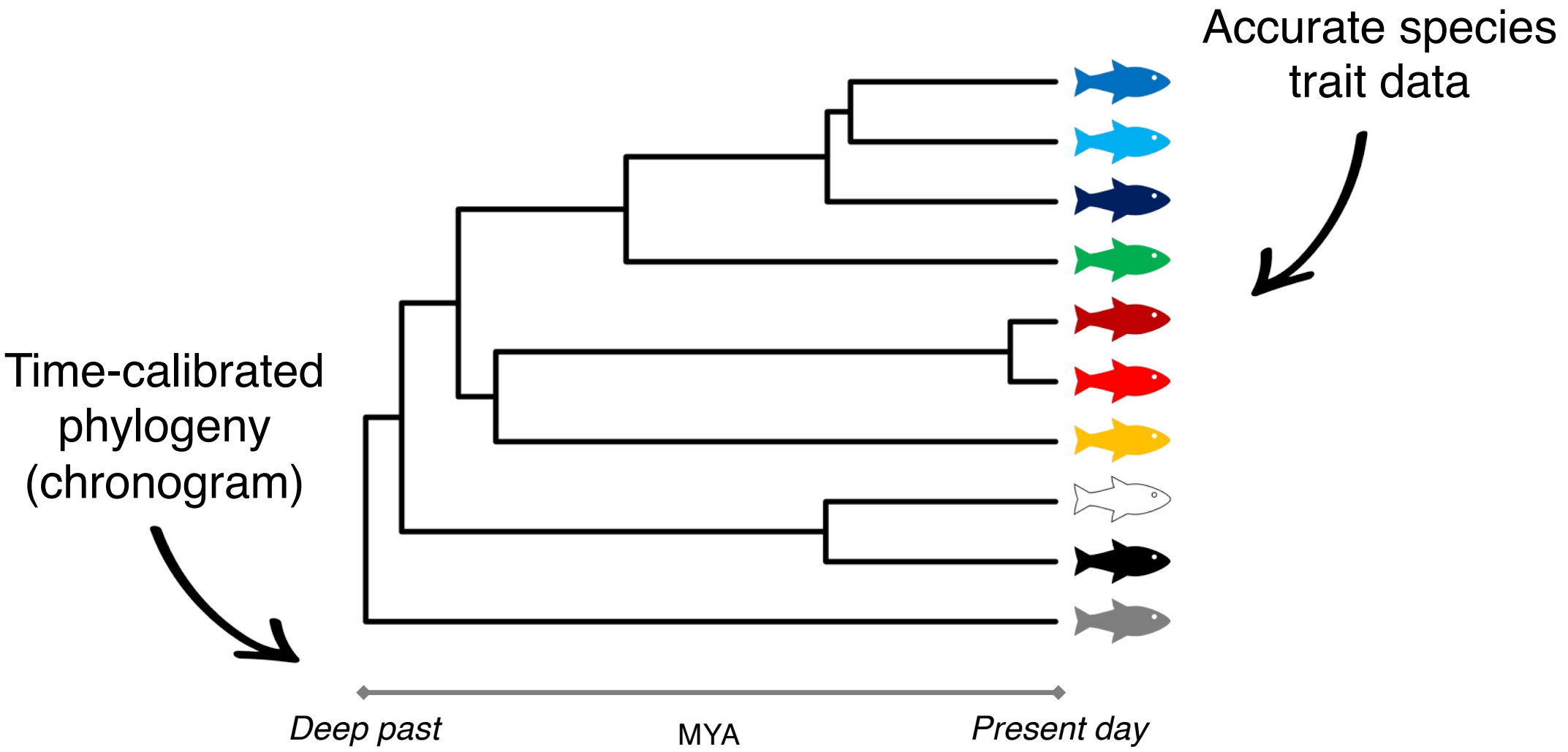


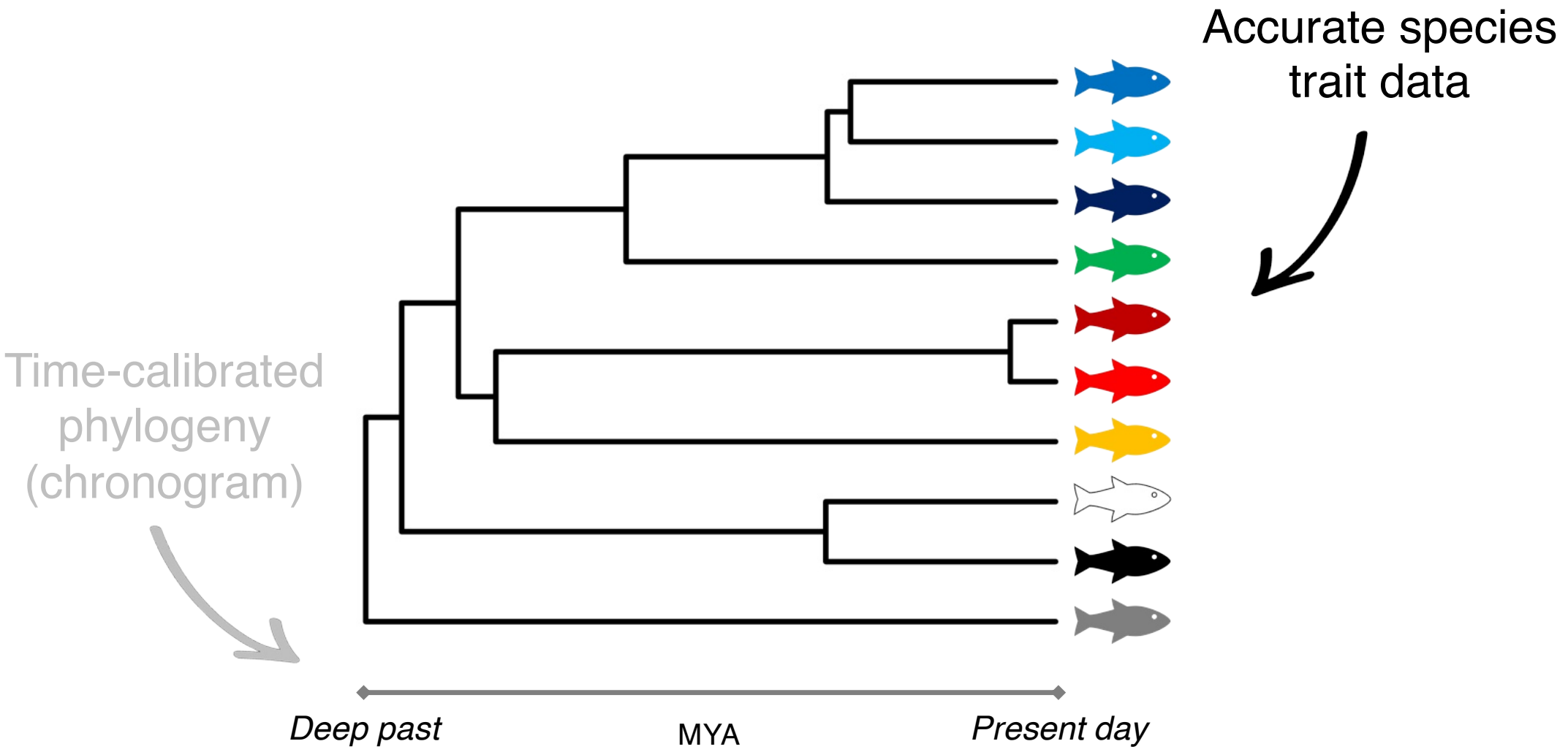
Tempo and Mode of Toxicant Sensitivity Evolution



$dX(t) = \sigma dW(t)$

$dX(t) = -\alpha(X(t) - \mu) + \sigma dW(t)$


Accurate species trait data
Time-calibrated phylogeny (chronogram)
Deep past
MYA
Present day

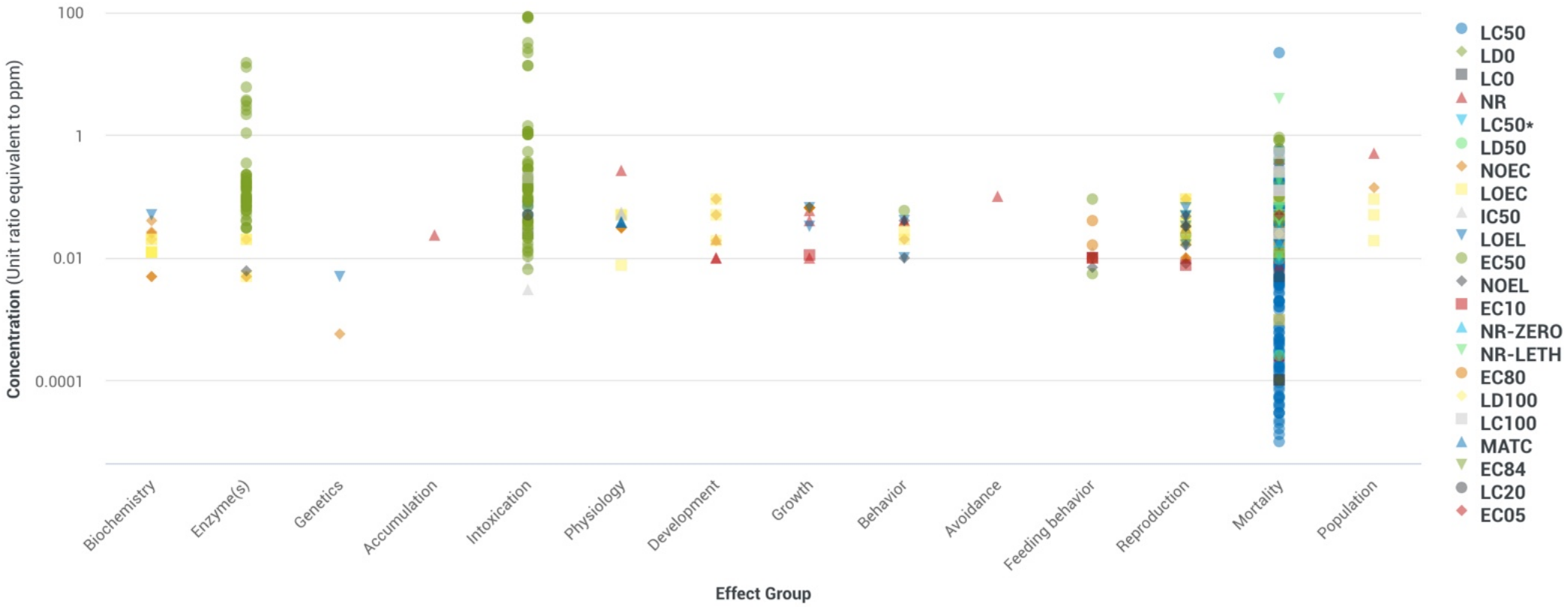

Accurate species trait data
Time-calibrated phylogeny (chronogram)
Deep past
MYA
Present day

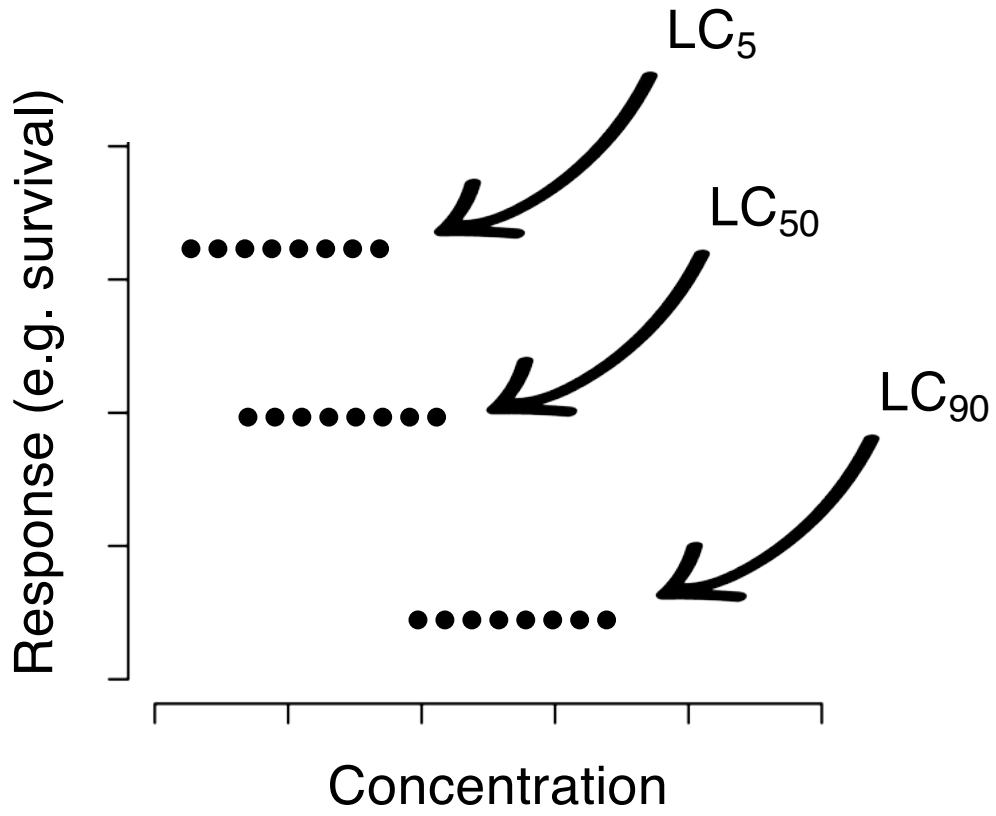
Accurate trait data

Results > 1.1 million
Species > 28,000
Chemicals > 17,000

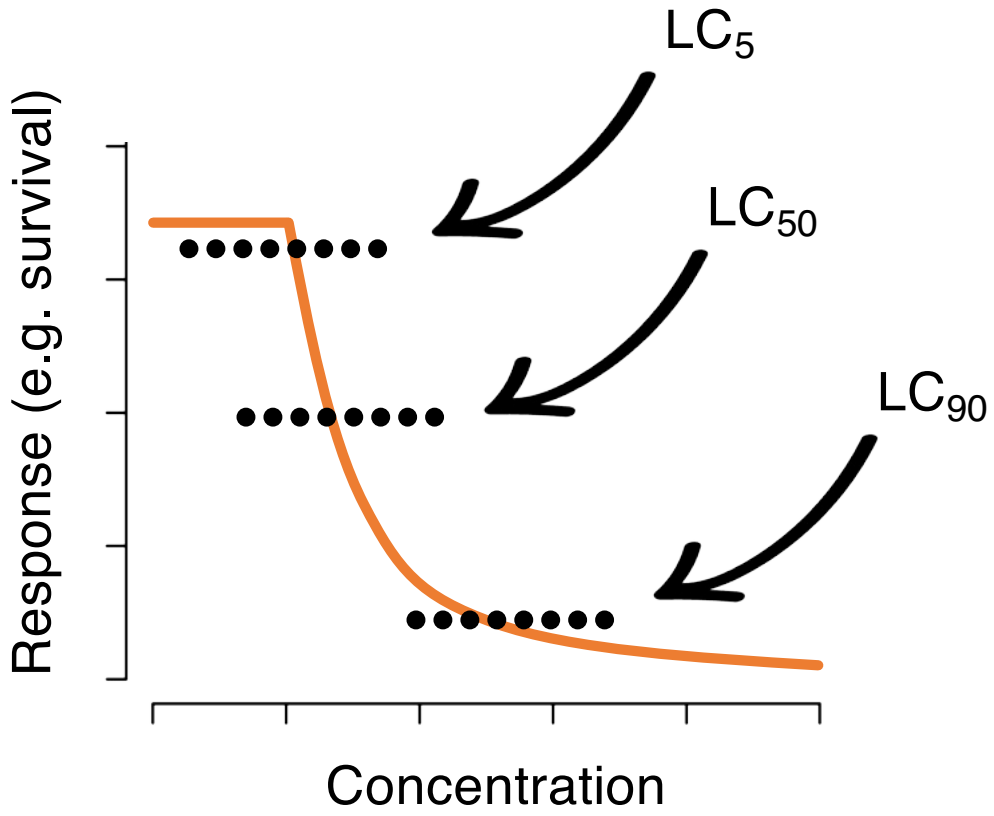
Olker et al. 2022

Only reported endpoints

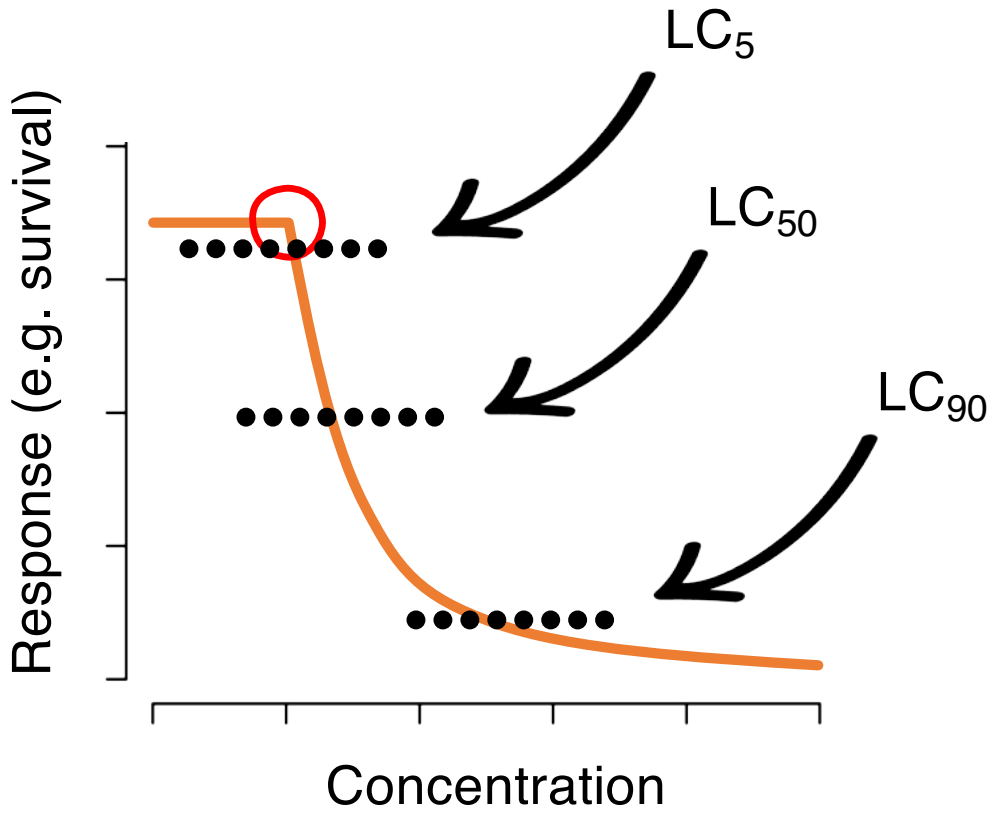




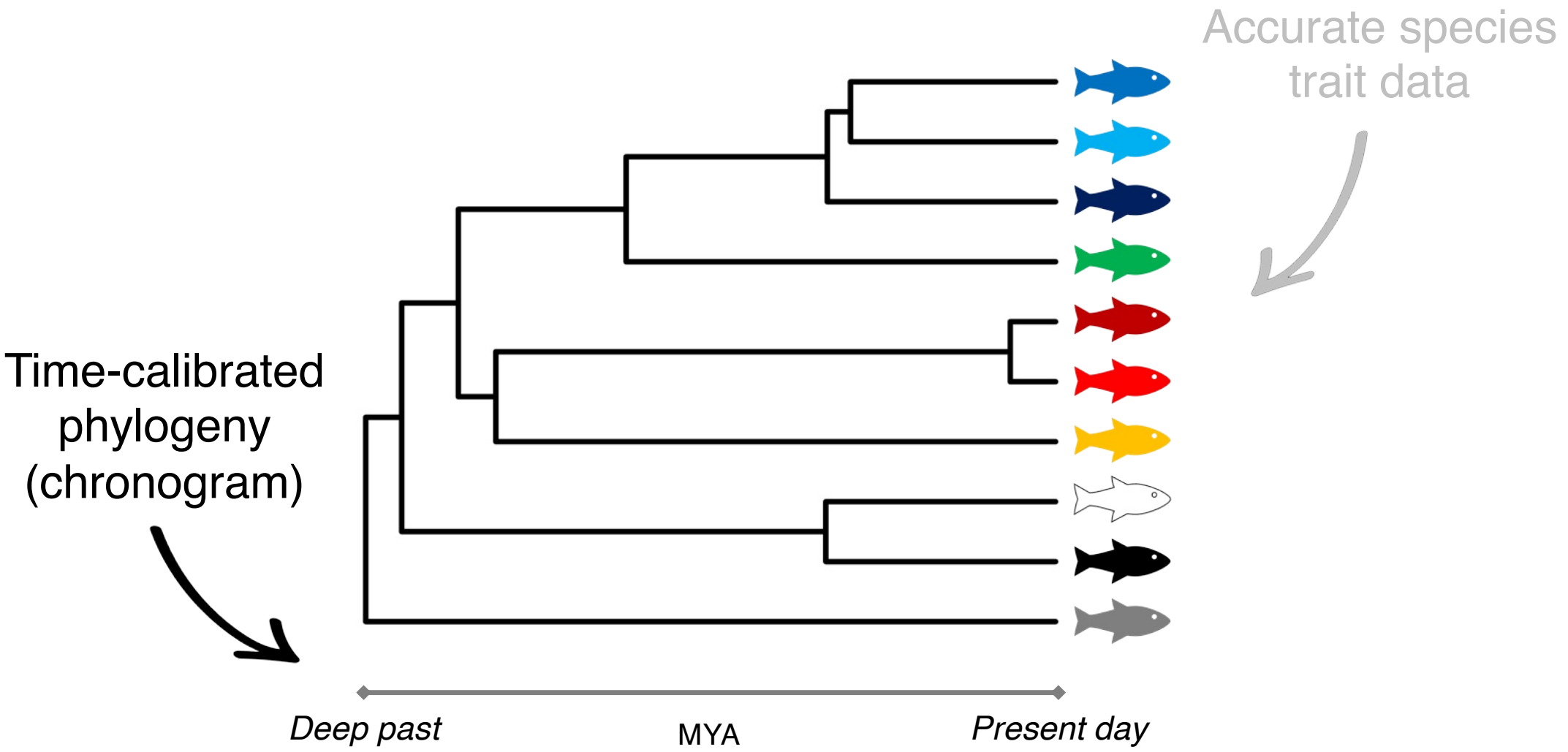
Fisher, Barneche & Fox 2024



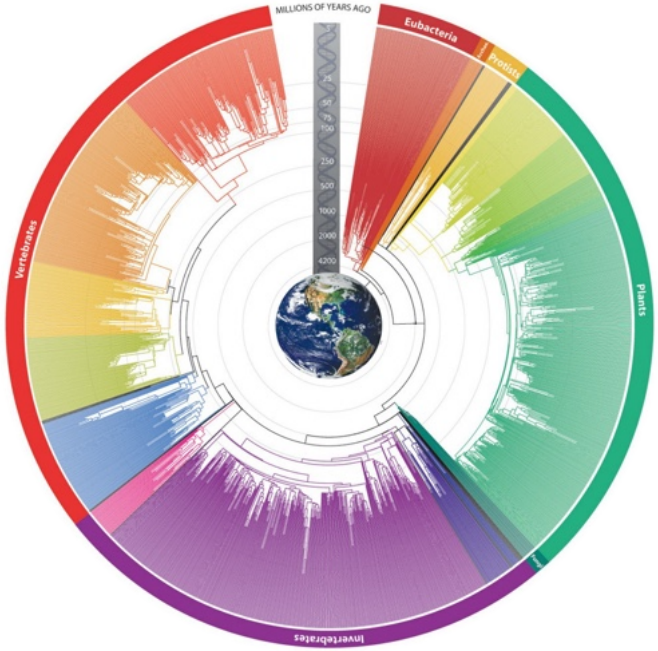
Fisher, Barneche & Fox 2024



Fisher, Barneche & Fox 2024

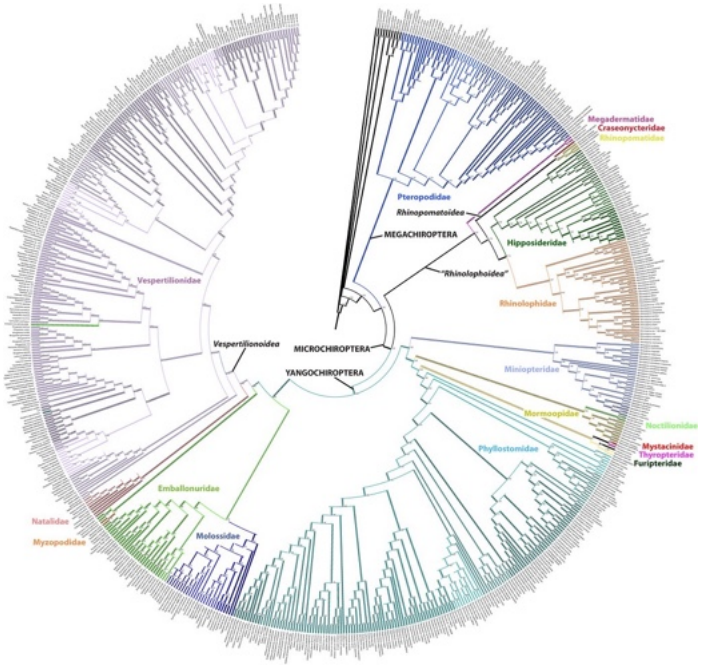

Accurate species trait data
Time-calibrated phylogeny (chronogram)
Deep past
MYA
Present day

TimeTree5



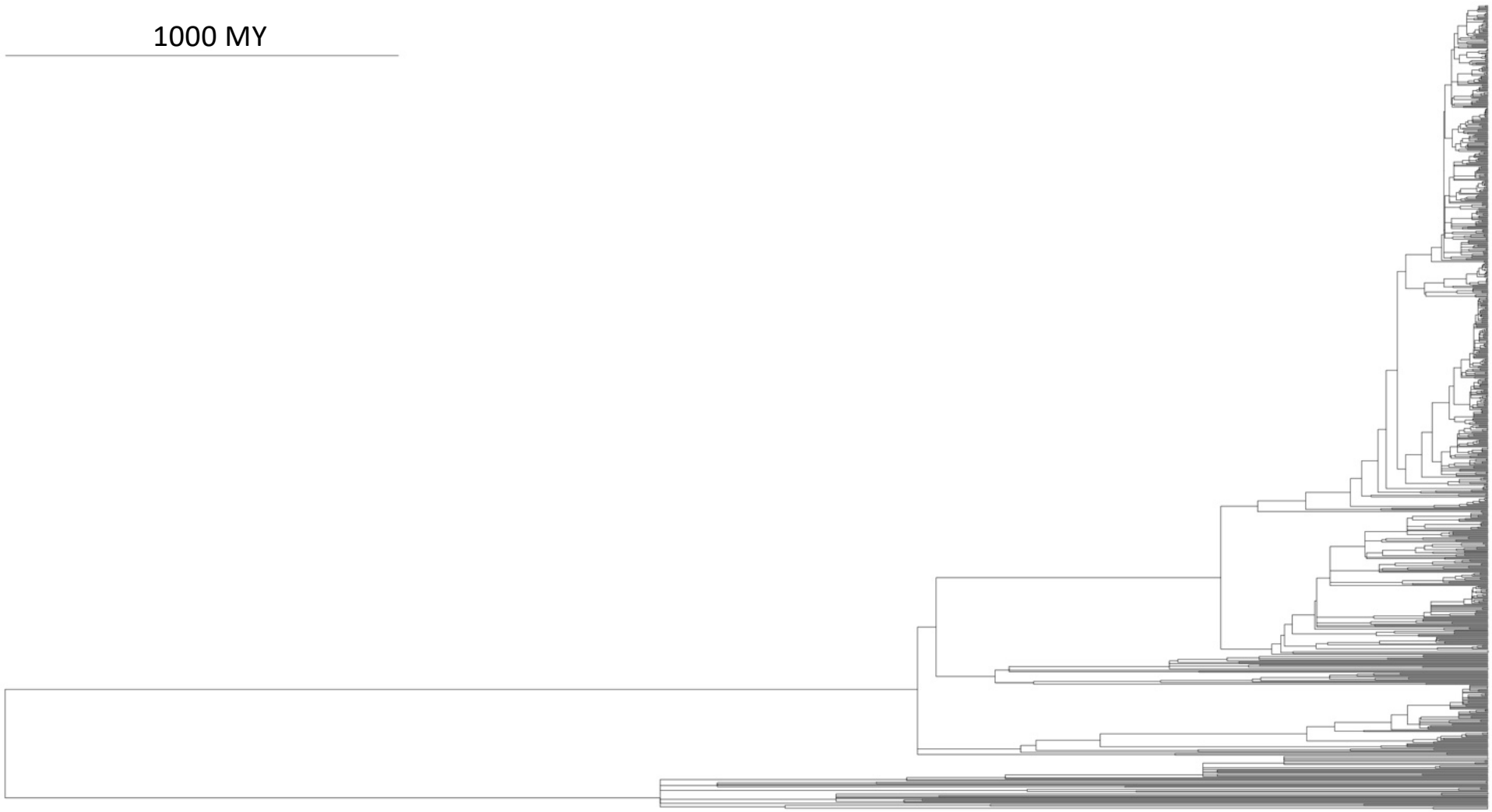
Divergence times for
>148,000 taxa

Open Tree of Life Project



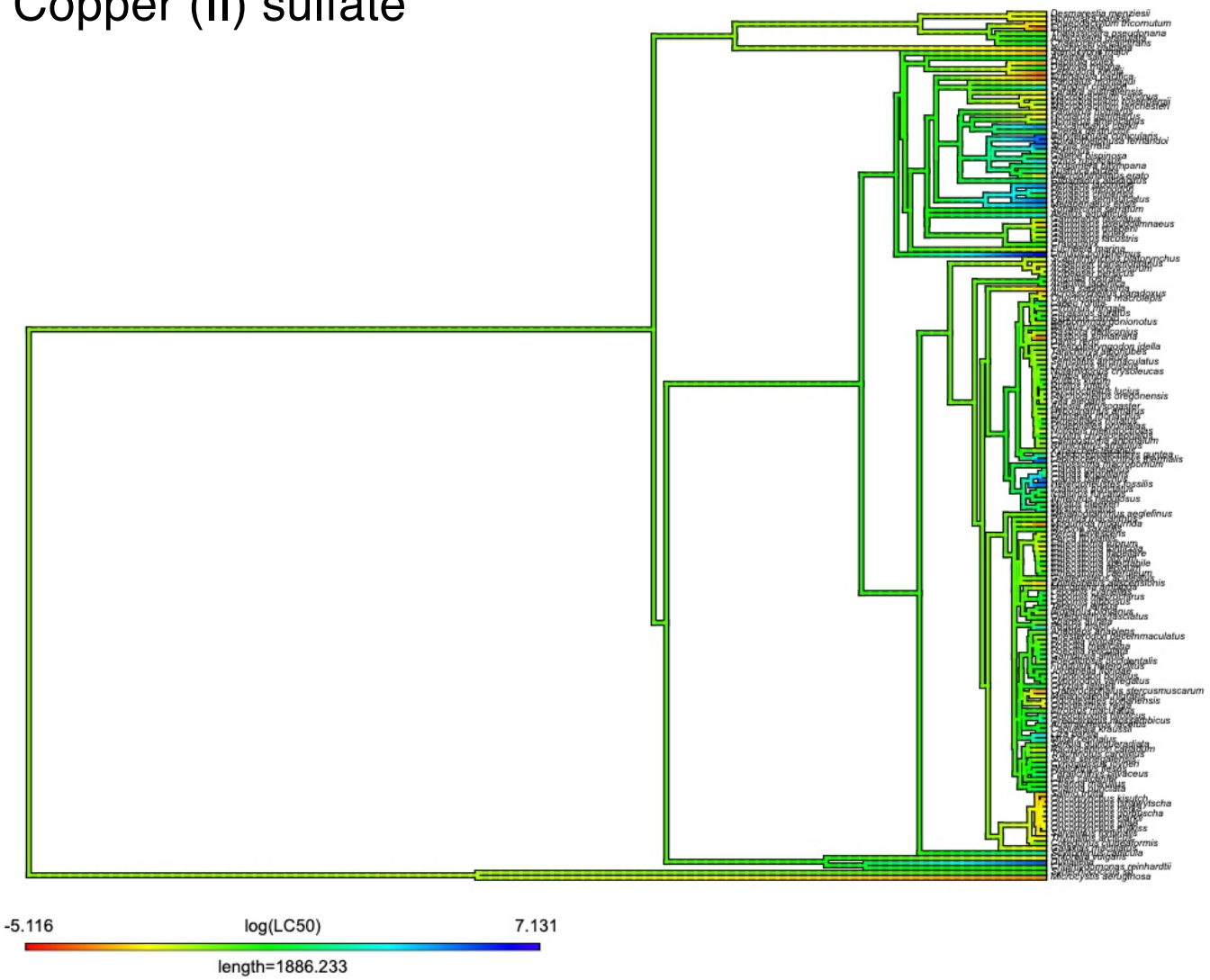
Synthesis tree with
> 2.3 million tips

Kumar et al. 2022, OpenTree et al 2024



Kumar et al. 2022, OpenTree et al 2024

Copper (II) sulfate



- Mode of Evolution
- Rate of Evolution
- Predict unknown tips

Outline

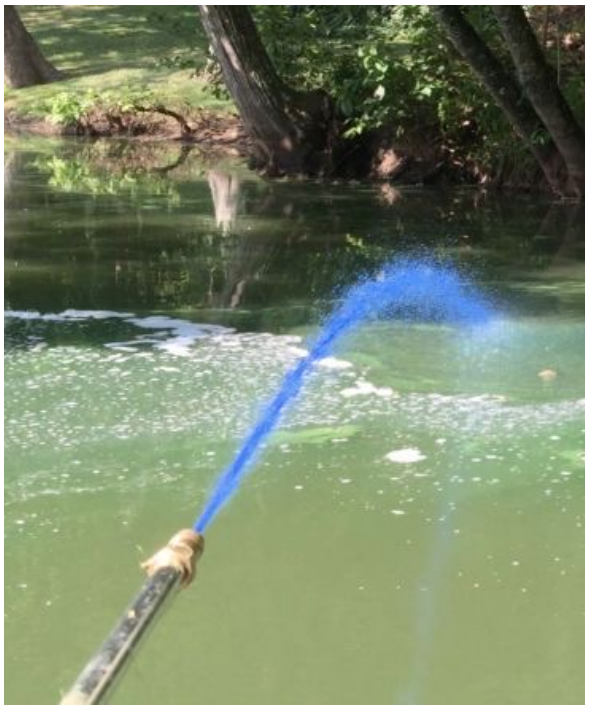
- What shapes the contemporary distribution of species sensitivities?
- How have species sensitivities evolved?
- Understanding species sensitivities in context.

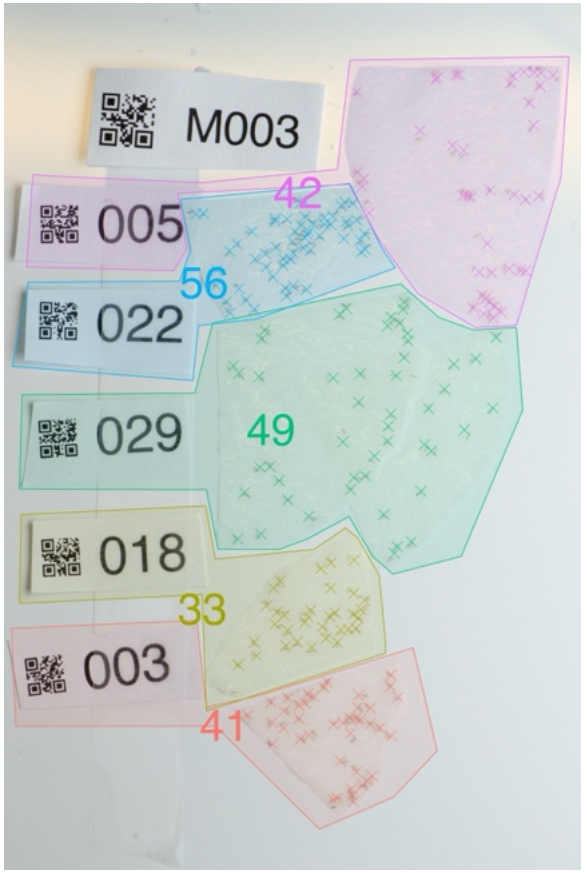
Ischnura elegans (Större kustflickslända)

Aims

1. Effect of a toxicant on a population across the entire life-cycle
   a. Non-lethal effects (morphology, growth)
   b. Population level effects (emergence rates)
2. Test predictive ability of phylogenetic models
   a. Acute toxicity testing

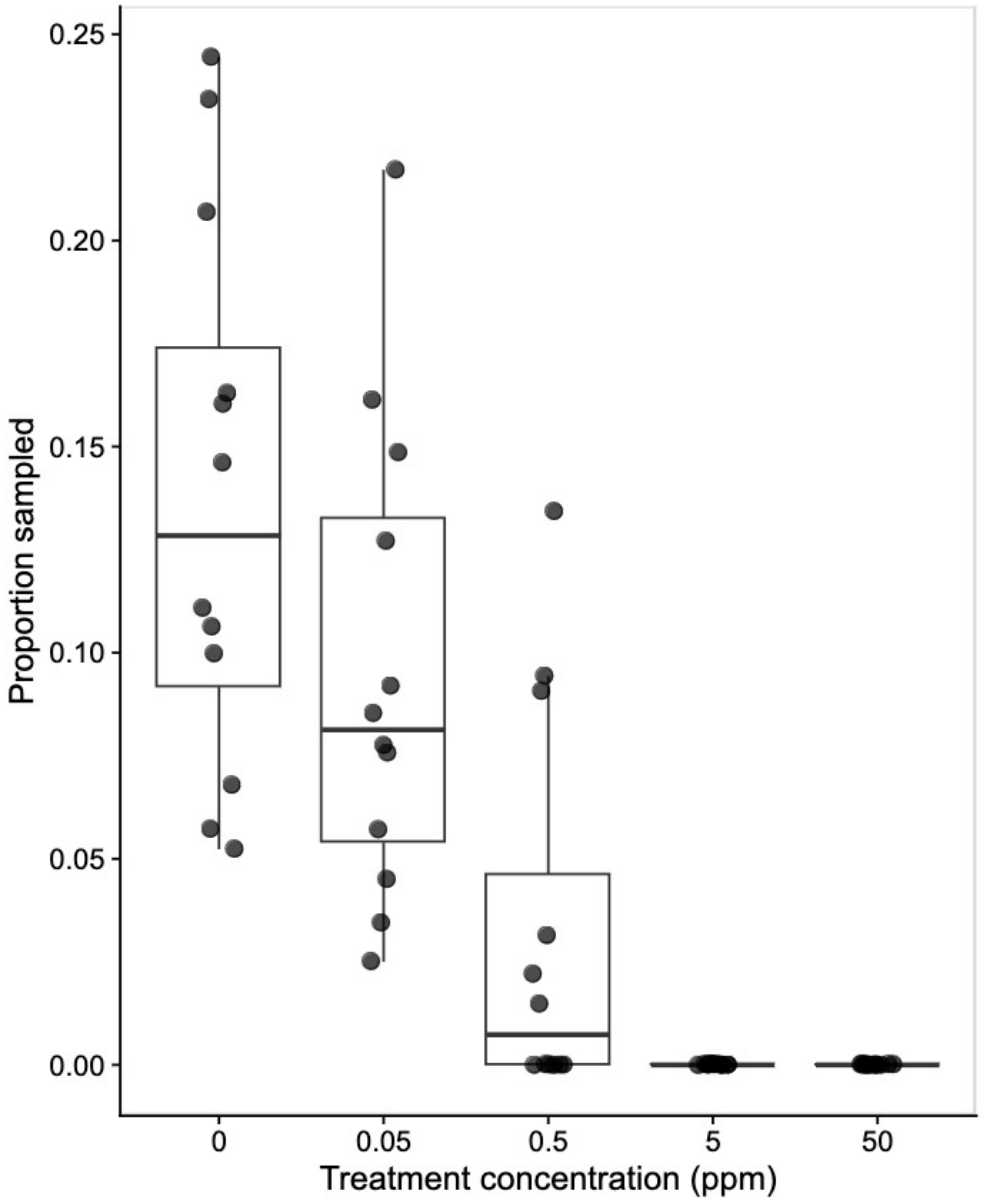
Copper (II) sulfate

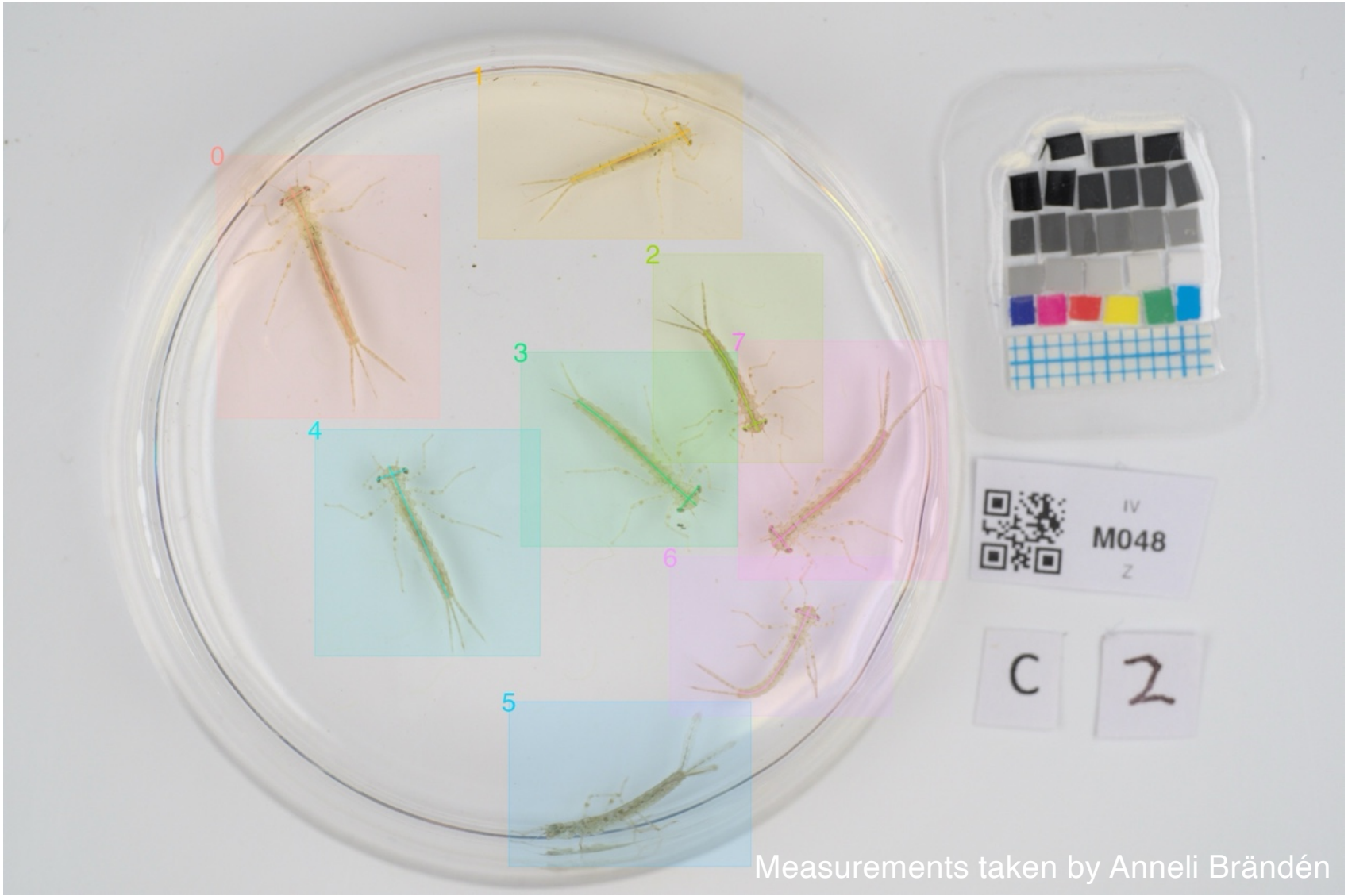


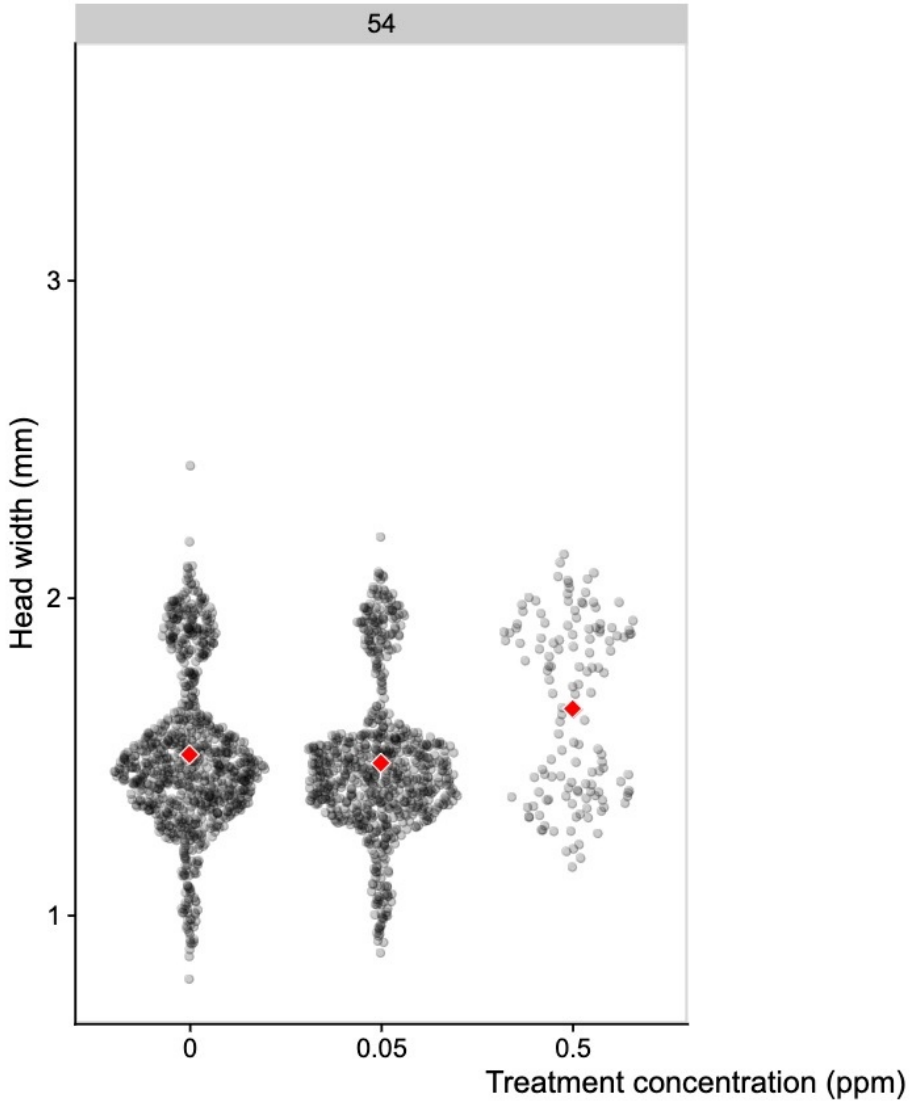

M003
005
42
56
022
029
49
018
33
003
41

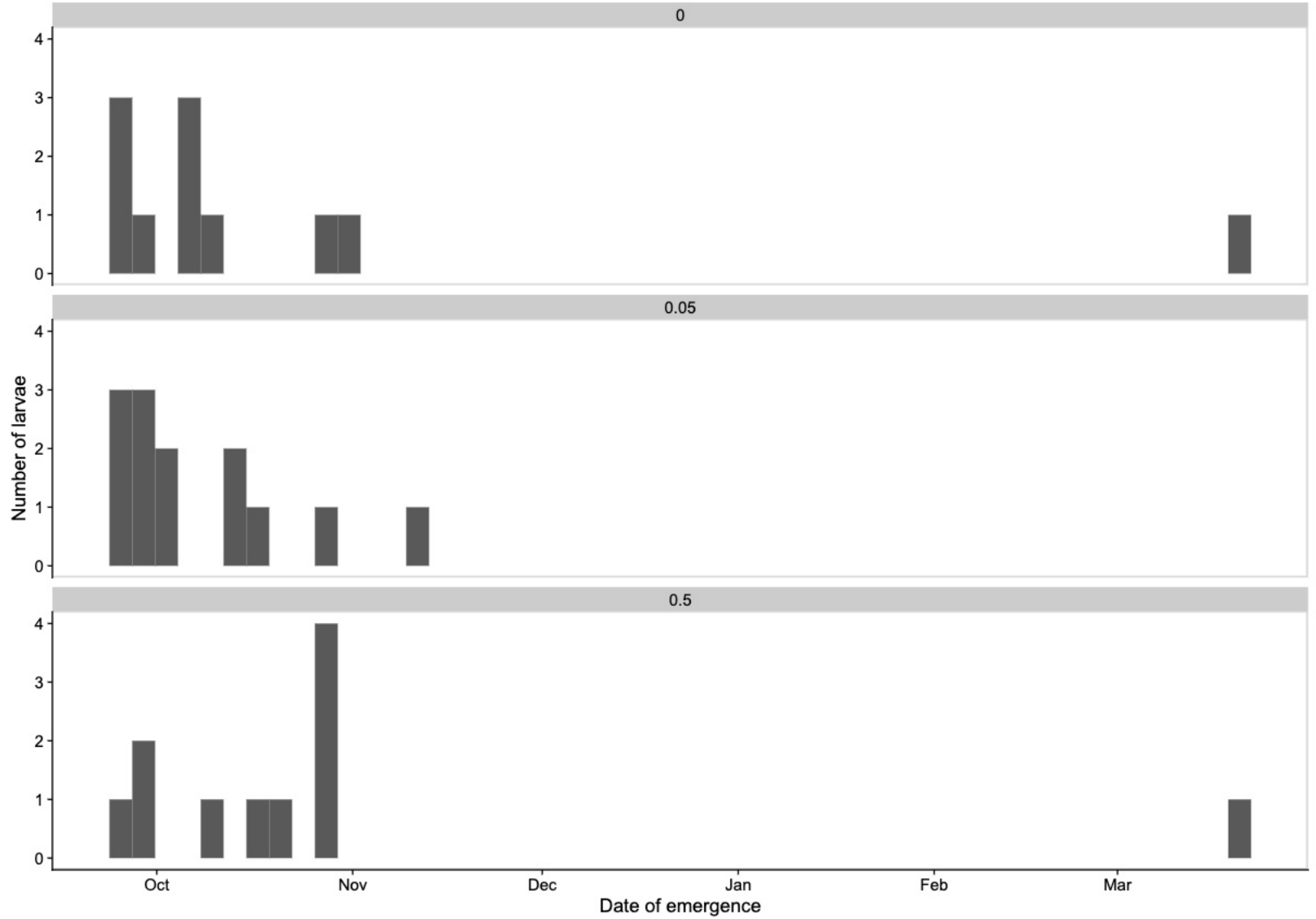
BILTEMA
VÄLKOMMEN TILL BILTEMA MALMÖ

IKEA

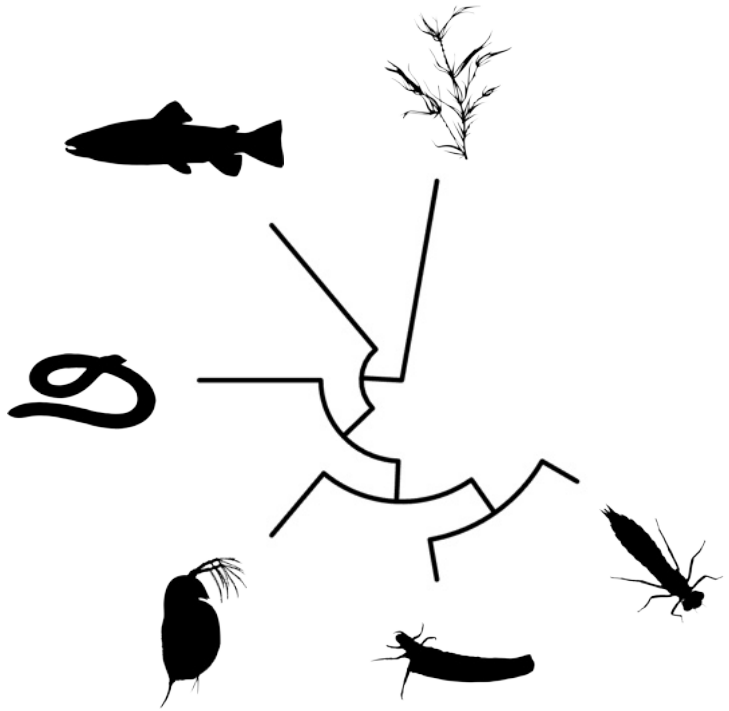

0.25
0.20
0.15
0.10
0.05
0.00
Proportion sampled
0
0.05
0.5
5
50
Treatment concentration (ppm)


0
1
2
3
4
5
6
7
IV
M048
Z
C
2
Measurements taken by Anneli Brändén


54
Head width (mm)
3
2
1
0
0.05
0.5
Treatment concentration (ppm)


0
0.05
0.5
Number of larvae
0
1
2
3
4
Oct
Nov
Dec
Jan
Feb
Mar
Date of emergence

Thank you for listening



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