Temperature Effects on Exploratory Behaviour and Learning Ability of Invasive Mosquitofish

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Behavioural Flexibility

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- Enhances invasion success
  - Exploit novel resources

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  - Rapid adjustment

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  - Exploit novel resources
- Ideal first response to change
  - Rapid adjustment
- Many behaviours
  - e.g. aggression, competition, foraging, reproductive, parental care

Behavioural Flexibility

- Learning

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- Learning
  - Fine tune existing behaviours
  - New behaviours - Innovation

Behavioural Flexibility

- Learning
  - Fine tune existing behaviours
  - New behaviours - Innovation

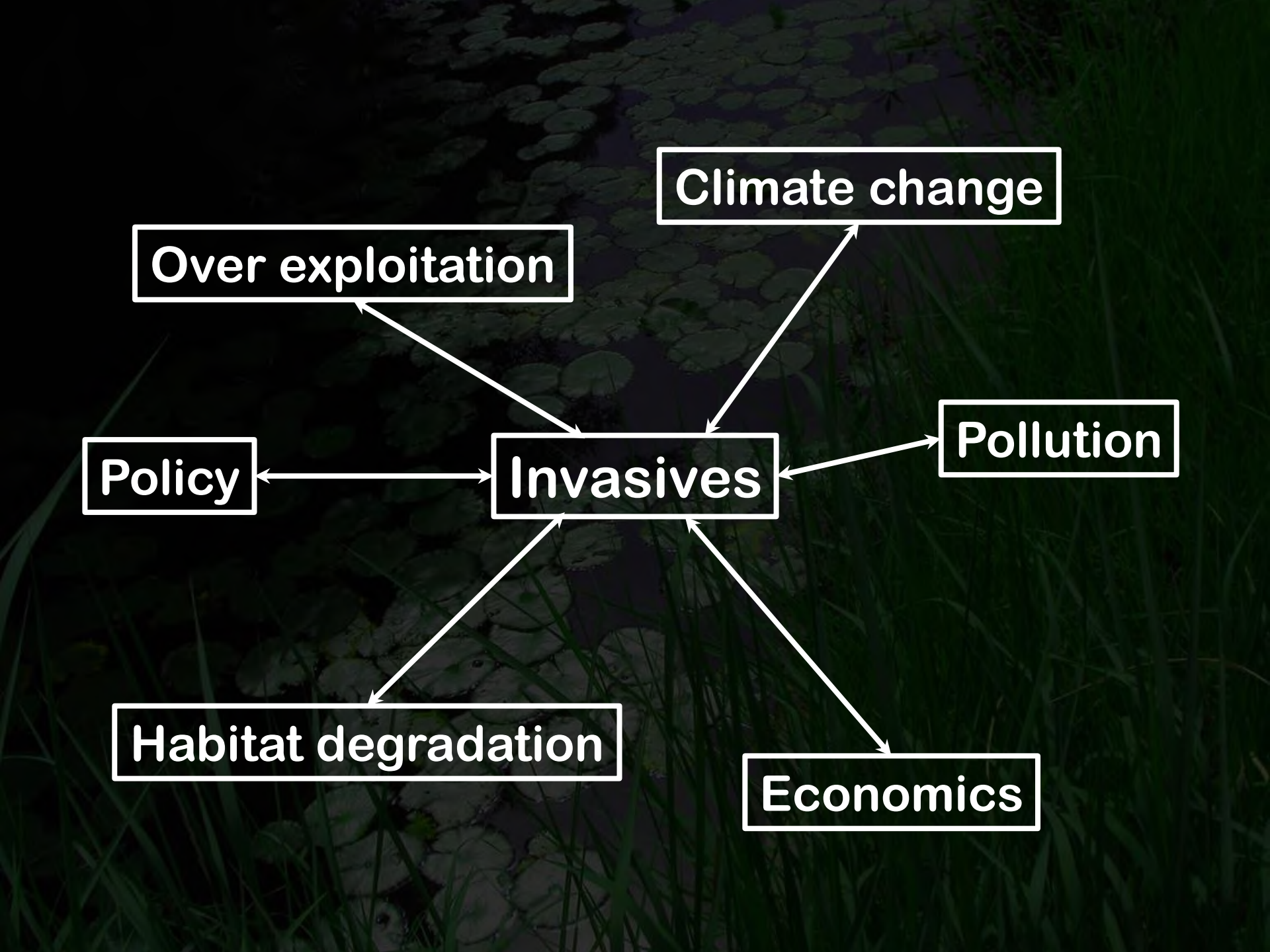
Carcinus maenas

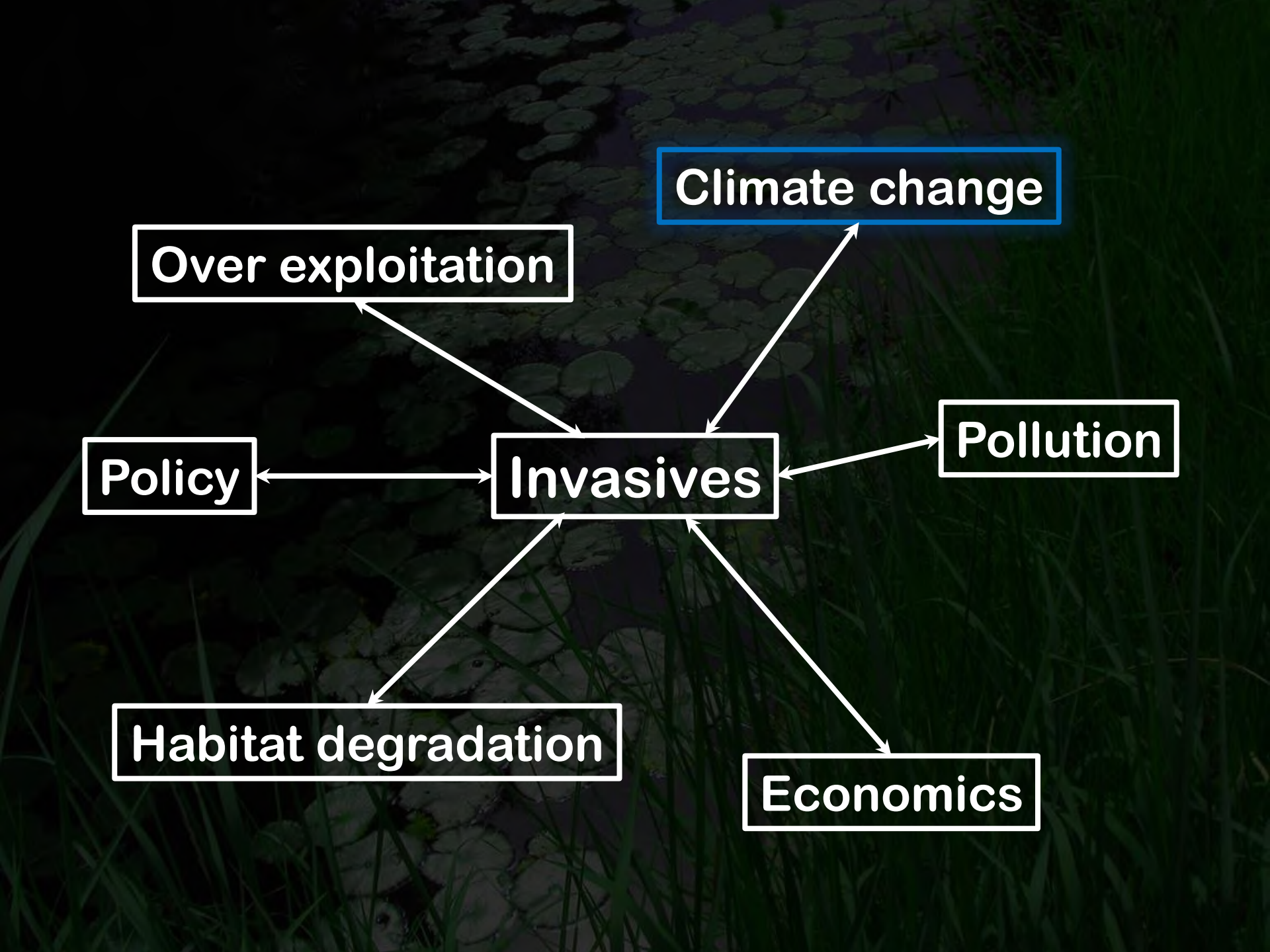
Cherax albidus

Corvus frugilegus

Wikipedia

Invasives


Climate change
Over exploitation
Policy
Invasives
Pollution
Habitat degradation
Economics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Temperature

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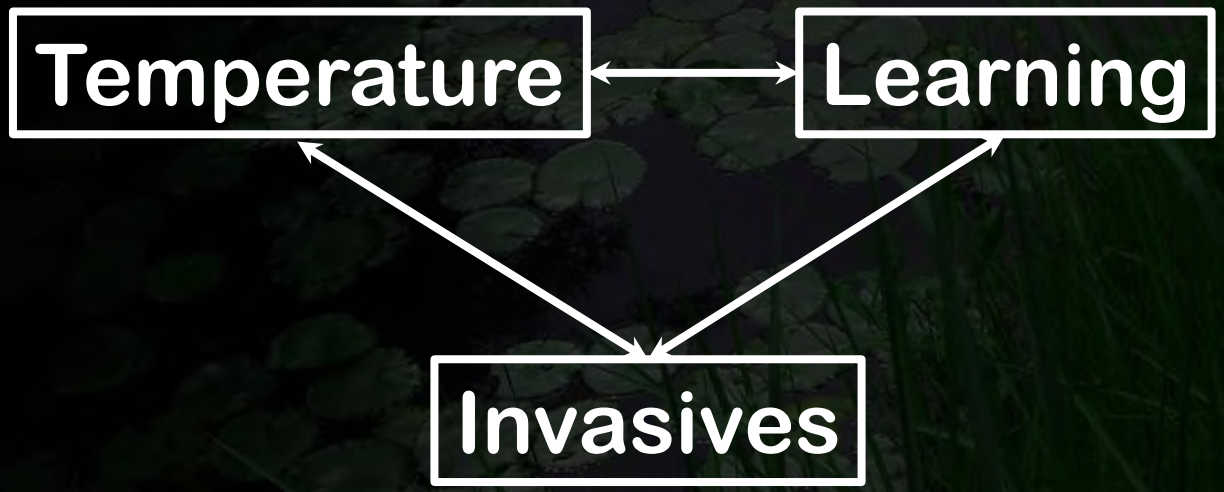
Temperature
Learning
Invasives

Mosquitofish: *Gambusia affinis*

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100 worst invasive species

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Tolerant and generalist

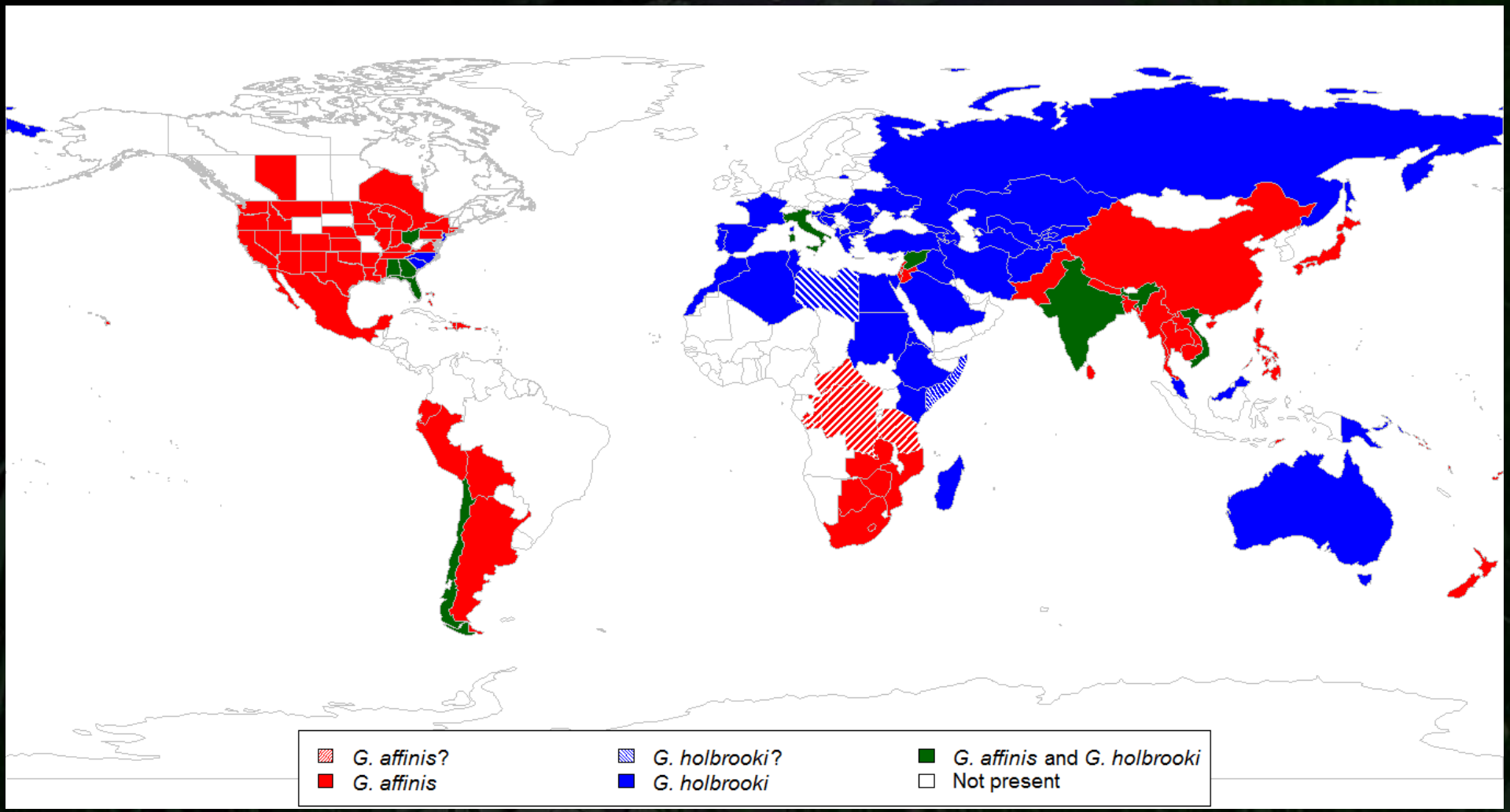
Mosquitofish: *Gambusia affinis*

100 worst invasive species

Tolerant and generalist

Internal fertilization, live birth, sperm storage

Mosquitofish: *Gambusia affinis*



Pao Srean (2015) PhD Thesis

Experiment

Experiment

Outside pond at University of Hong Kong

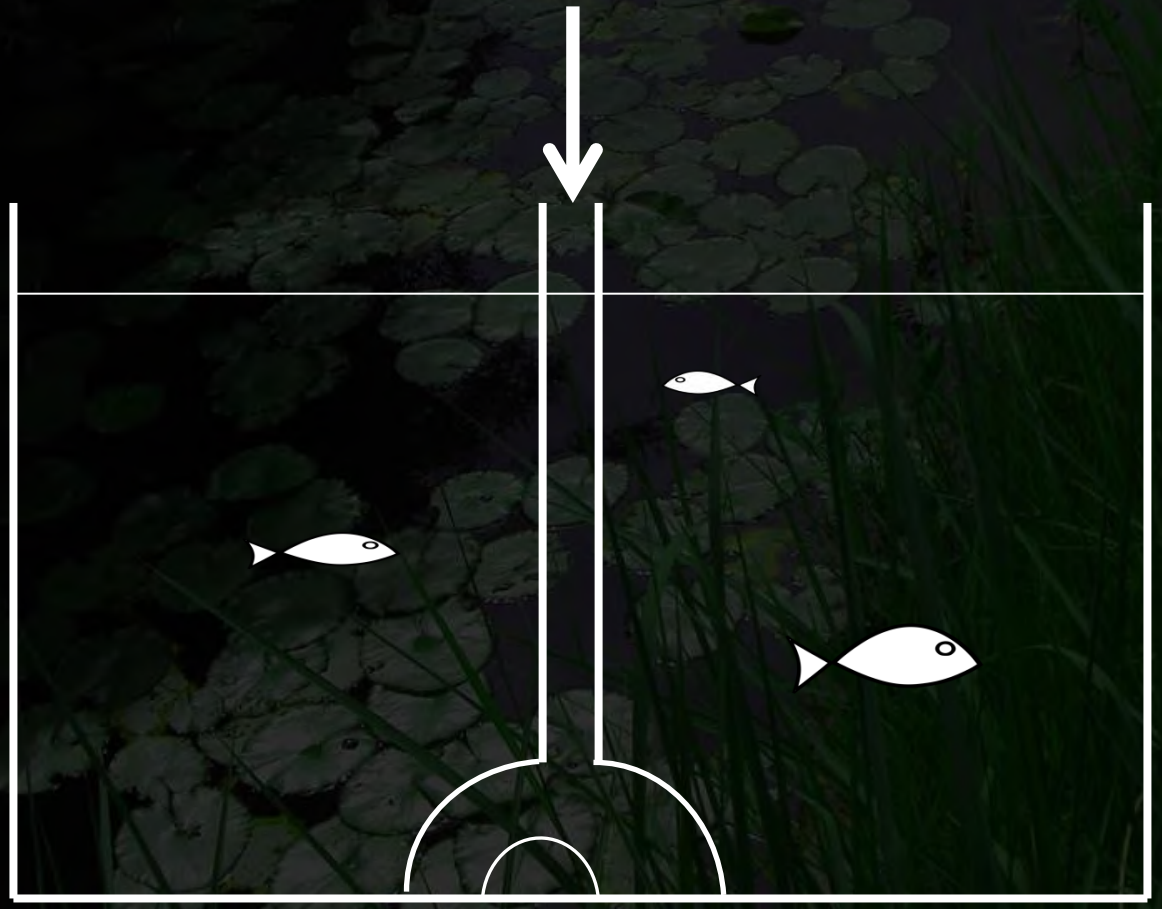
Acclimated fish to:

- lab conditions – 6 weeks
- temperature – 6 weeks

Three temperatures:

- Warm - 31°C
- Medium - 27°C
- Cool - 23°C

Experiment



Experiment

Add fish the evening before

Phase 1: Add novel object (feeding tube)
5 mins observation

Phase 2: Add food (defrosted bloodworms)
5 mins observation

Leave for 30 minutes

Three consecutive days

Measured total length

Experiment

Variables:

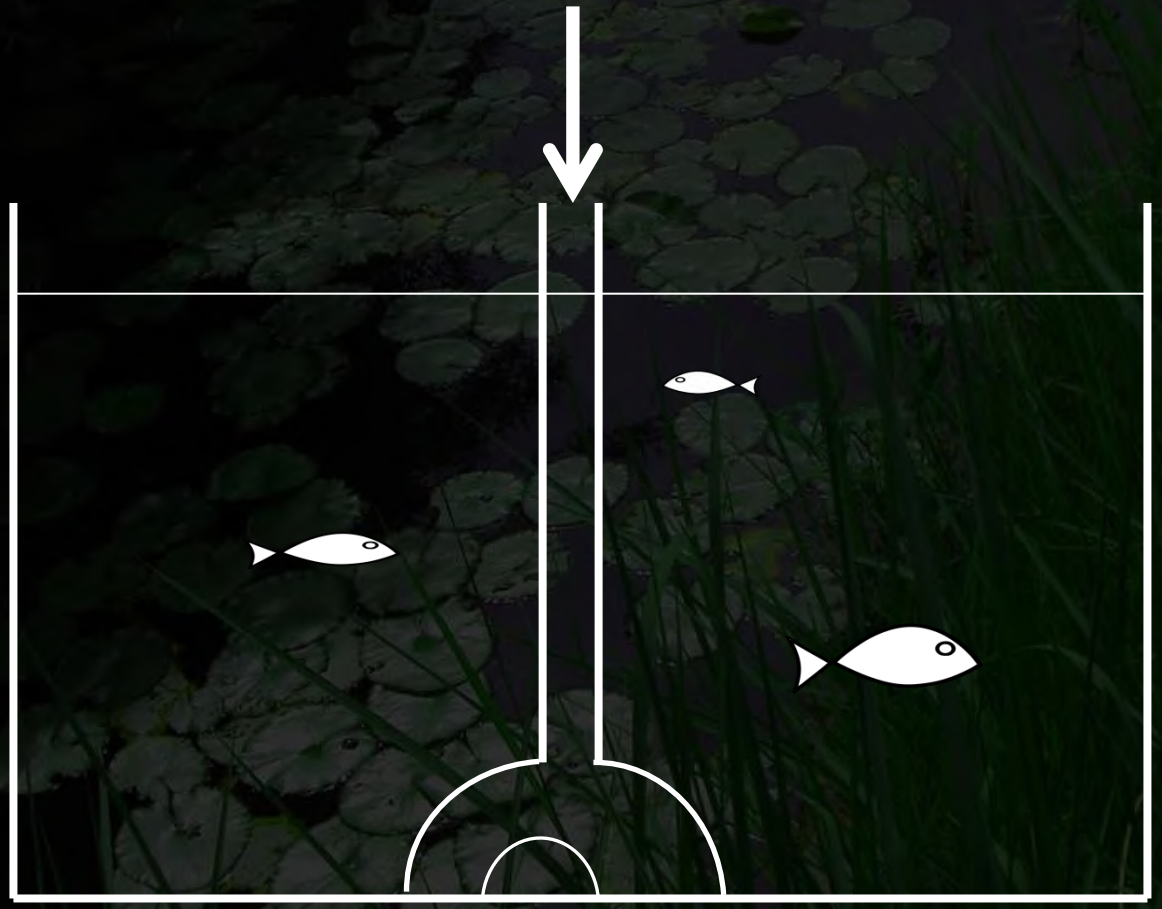
Phase 1: Time to 1st approach

Phase 2: Time to 1st approach
and time to 1st entry

Fish sex and size

Analyses: Generalized Linear Models
Generalized Estimating Equations

General Results



General Results

Phase 1 – Novel
Approached: 64%

Day 1: 34%
Day 2: 72%
Day 3: 86%

Warm: 57%
Medium: 71%
Cool: 63%

Phase 2 – Food
App & Entered: 37%

Day 1: 25%
Day 2: 39%
Day 3: 48%

Warm: 39%
Medium: 38%
Cool: 35%

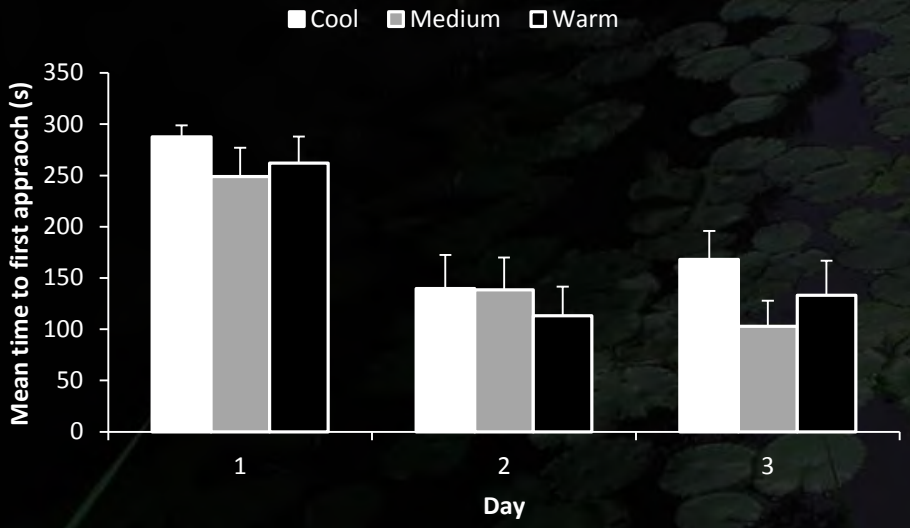
Predictions

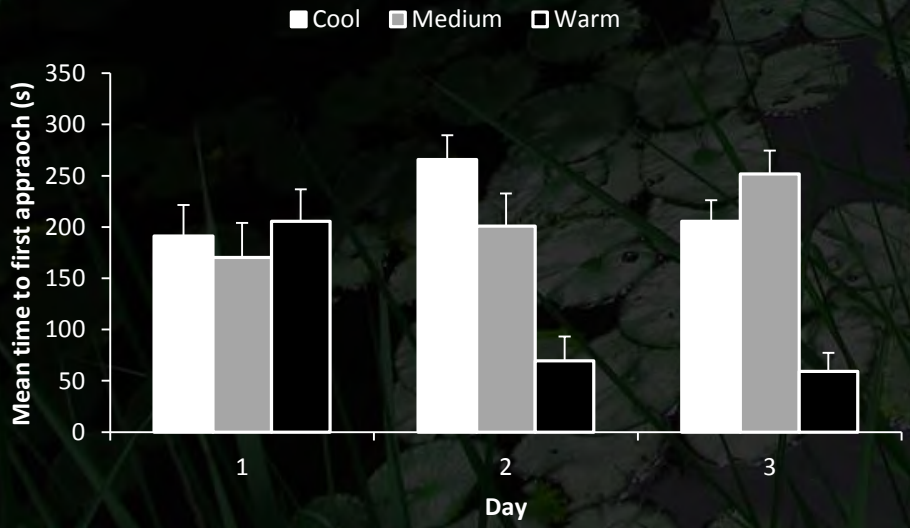
Prediction 1

Warm-acclimated mosquitofish

- Approach a novel object faster
- Adjust to a novel object faster
- learning

Phase 1 data



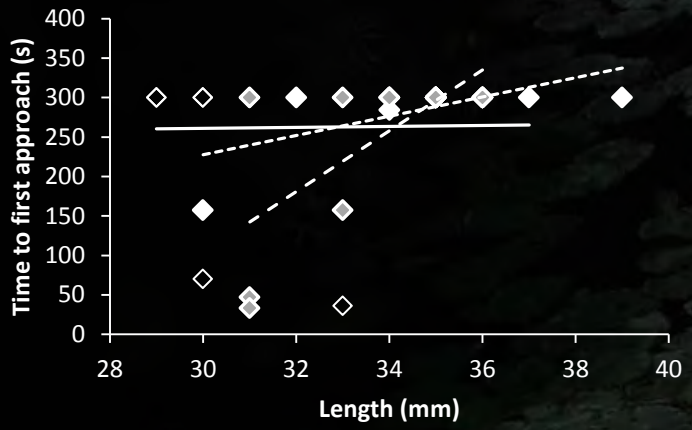


Effect	Wald χ^2	df	p
Temp	1.616	2	0.446
Day	65.688	2	<0.001
Sex	17.540	1	<0.001
Temp × Day	2.577	4	0.631
Temp × Sex	1.008	2	0.604
Day × Sex	9.497	2	0.009
Temp × Day × Sex	2.354	4	0.671

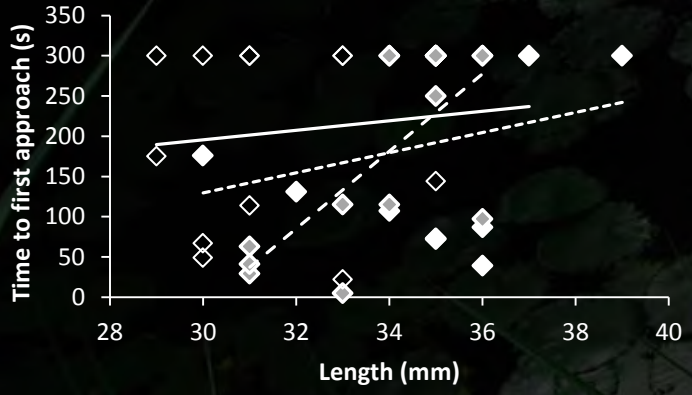
- Females
  - Approach faster over time
  - No difference with temperature

- Males
  - Warm-acclimated
    - approach faster over time
  - Medium & cool acclimated
    - approach slower over time

	df	Sex			
		Females		Males	
		Wald χ^2	p	Wald χ^2	p
Temp	2	16.309	<0.001	7.181	0.028
Day	2	6.098	0.047	2.928	0.231
Size	1	29.986	<0.001	0.030	0.862
Temp × Day	4	12.213	0.016	11.555	0.021
Temp × Size	2	16.261	<0.001	5.798	0.055
Day × Size	2	4.736	0.094	2.480	0.289
Temp × Day × Size	4	11.094	0.026	11.619	0.020


Time to first approach (s)
400
350
300
250
200
150
100
50
0
28
30
32
34
36
38
40
Length (mm)

Time to first approach (s)
350
300
250
200
150
100
50
0
24
26
28
30
32
Length (mm)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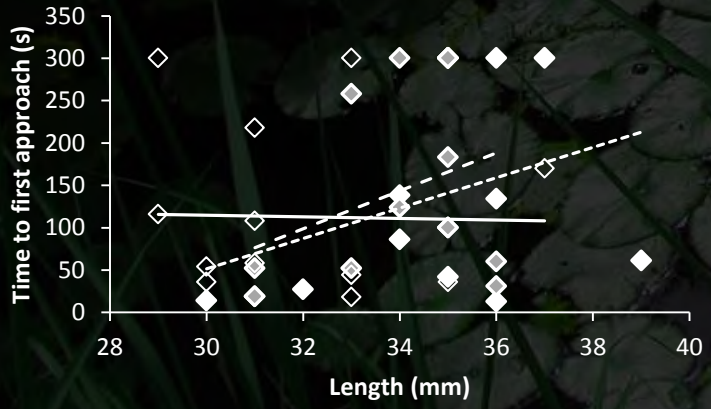
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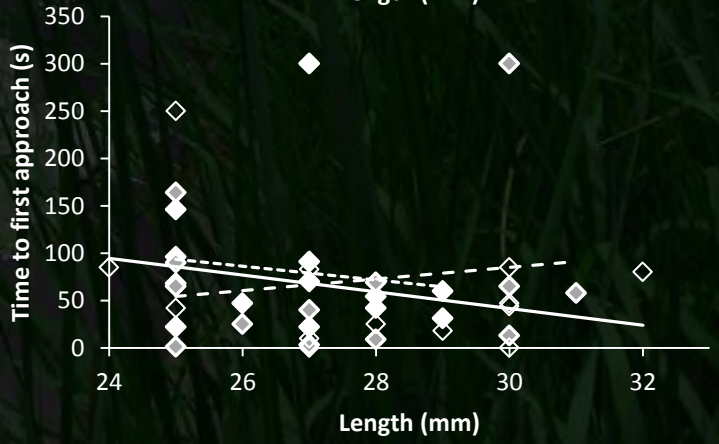
Time to first approach (s)
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26
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Length (mm)

- Females
  - Generally approach faster over time
  - Medium & cool acclimated
    - approach faster with increasing size
  - Warm acclimated
    - no effect of size

- Males
  - Generally approach faster over time
  - Warm-acclimated
    - approach faster with increasing size
  - Medium & cool acclimated
    - No effect or approach slower over time

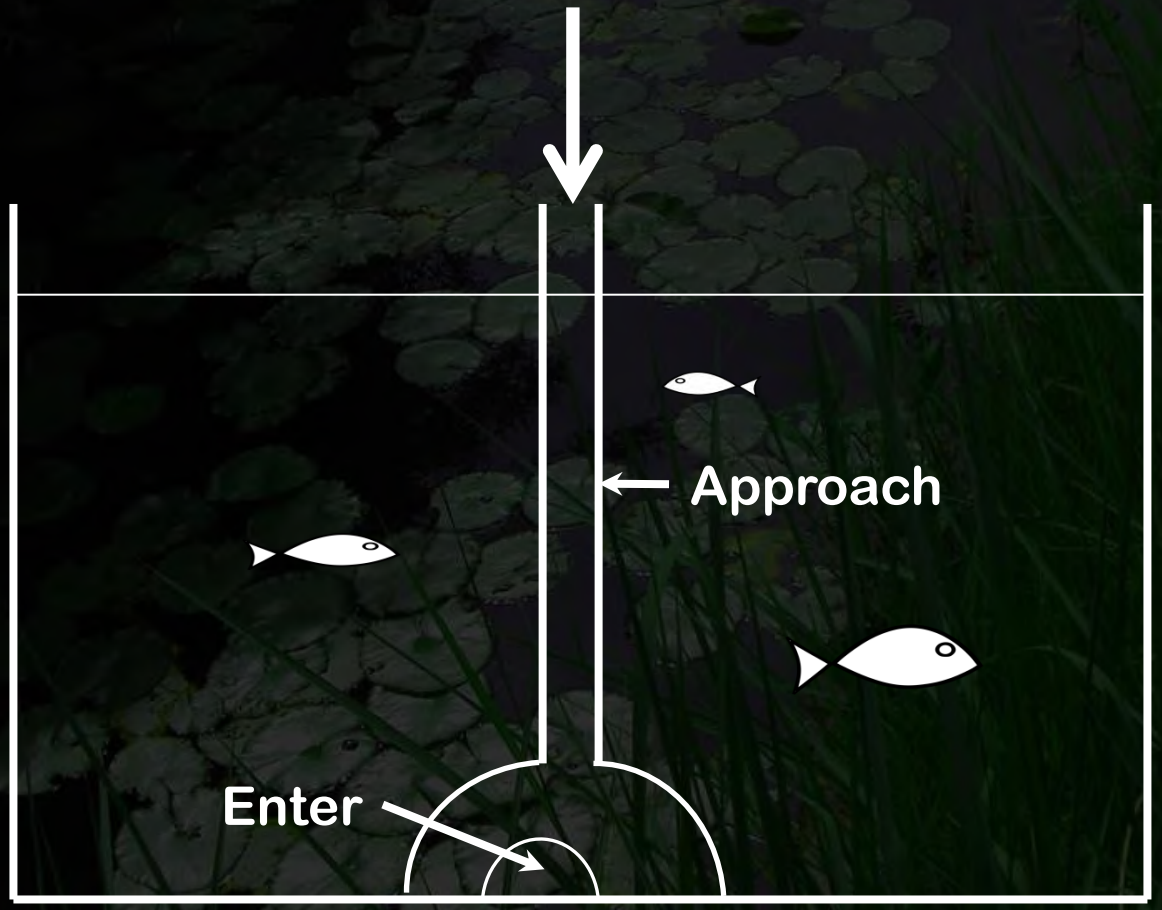
Prediction 2

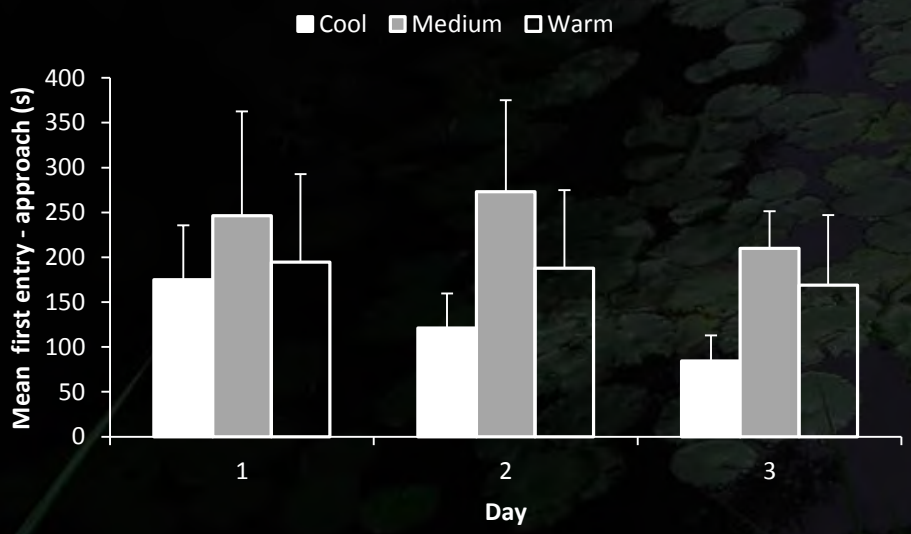
Warm-acclimated mosquitofish

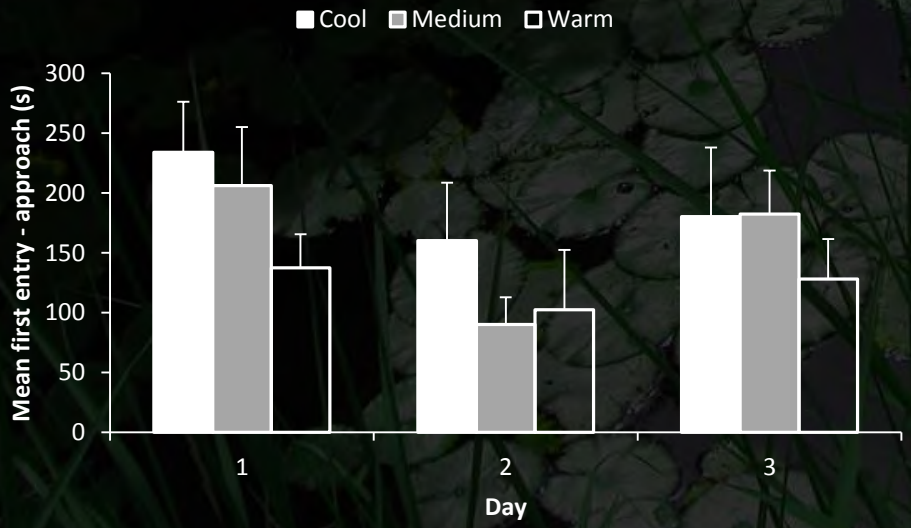
- **Learn to find food faster**

Phase 2 data

Variable = (Enter – Approach)

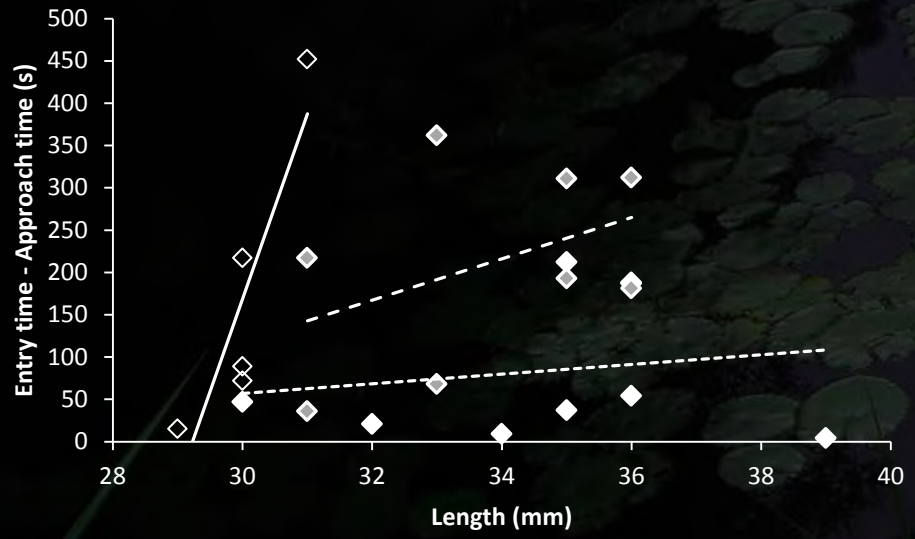


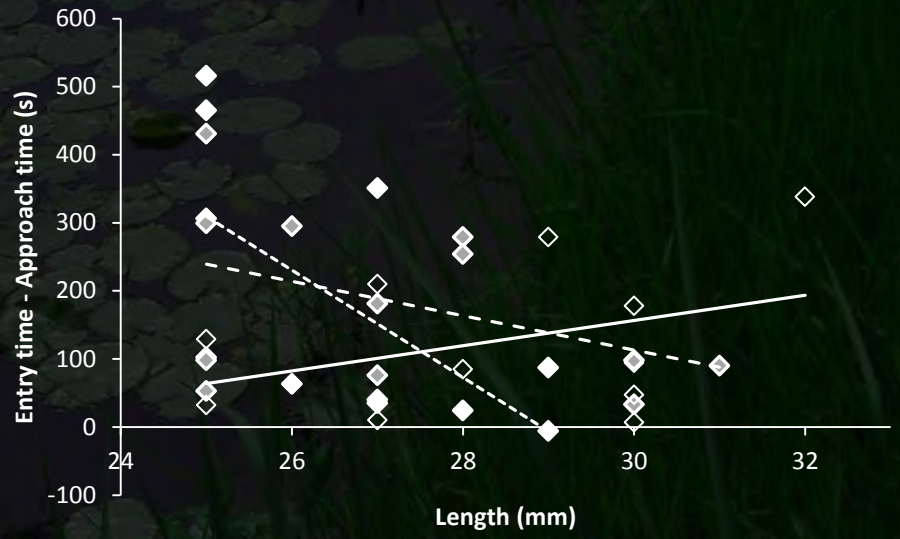




Effect	df	Wald χ^2	p
Temp	2	2.193	0.334
Day	2	3.122	0.210
Sex	1	1.585	0.208
Temp × Day	4	0.321	0.988
Temp × Sex	2	10.755	0.005
Day × Sex	2	3.936	0.140
Temp × Day × Sex	4	2.446	0.654

- Overall decrease over time
  - More apparent for males than females
  - Females
    - Cool acclimated showed greatest response
  - Males
    - Warm acclimated found food faster
    - Not much improvement over time





Effect	df	Females		Males	
		Wald χ^2	p	Wald χ^2	p
Temp	2	11.478	0.003	11.974	0.003
Size	1	15.323	<0.001	6.737	0.009
Temp × Size	2	12.275	0.002	11.819	0.003

- Females
  - Larger females took longer to find food
    - Especially at warmer temps
- Males
  - Larger males faster in cool & medium temps
  - Smaller males faster in warm temps

Conclusions

Overall warm acclimated fish performed better

But patterns influenced by sex and size

Remarkably rapid learning

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Research Article

Temperature effects on exploratory behaviour and learning ability of invasive mosquitofish

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**Corresponding author*

https://www.reabic.net/aquaticinvasions/2019/AI_2019_Magellan_etal.pdf

Questions

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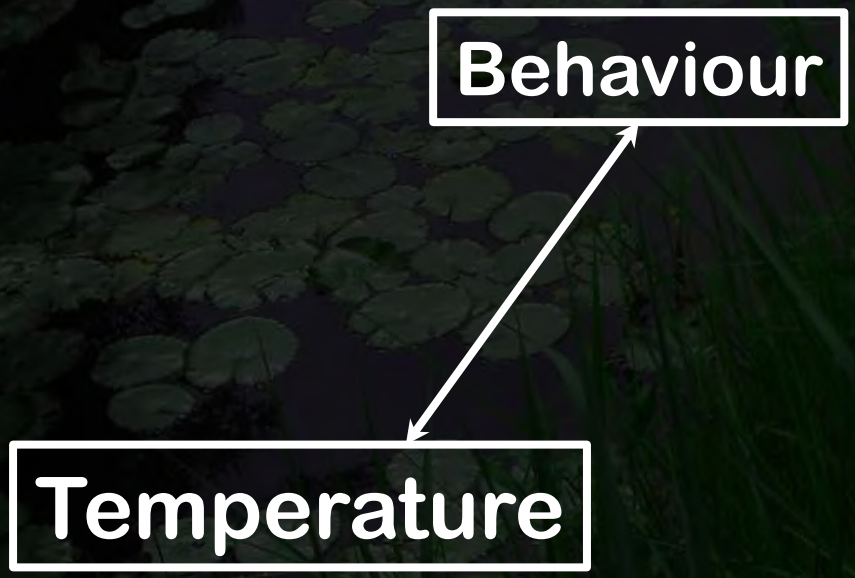

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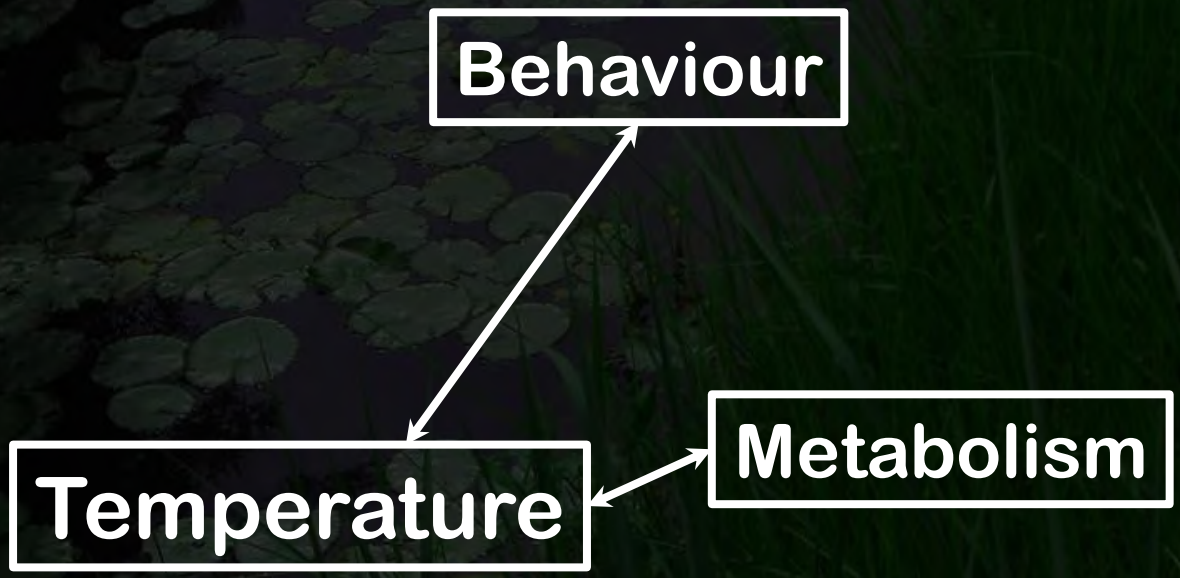

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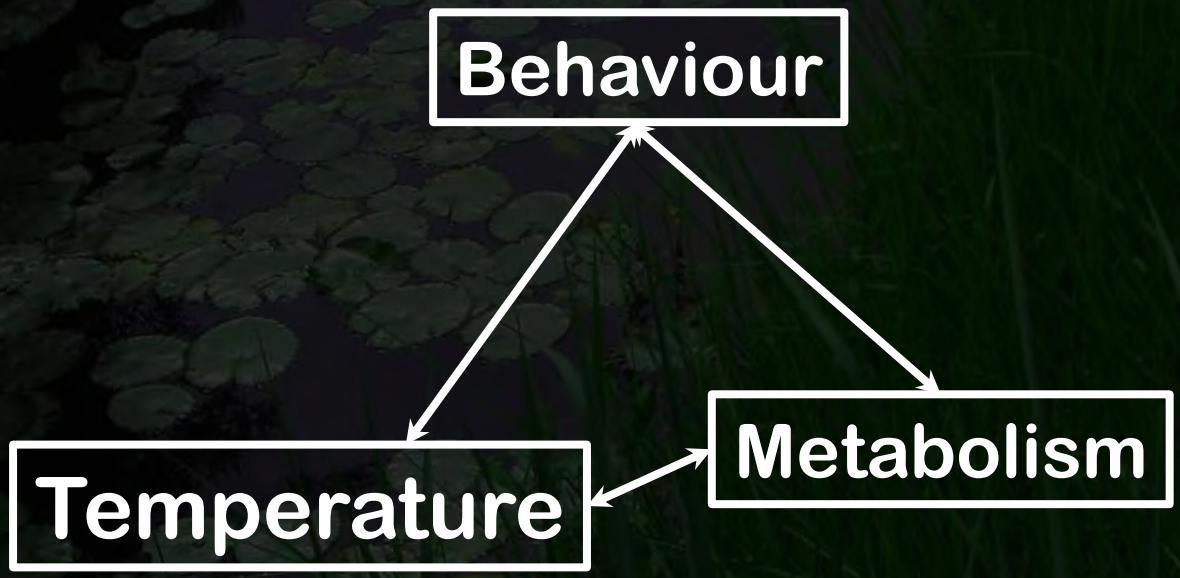

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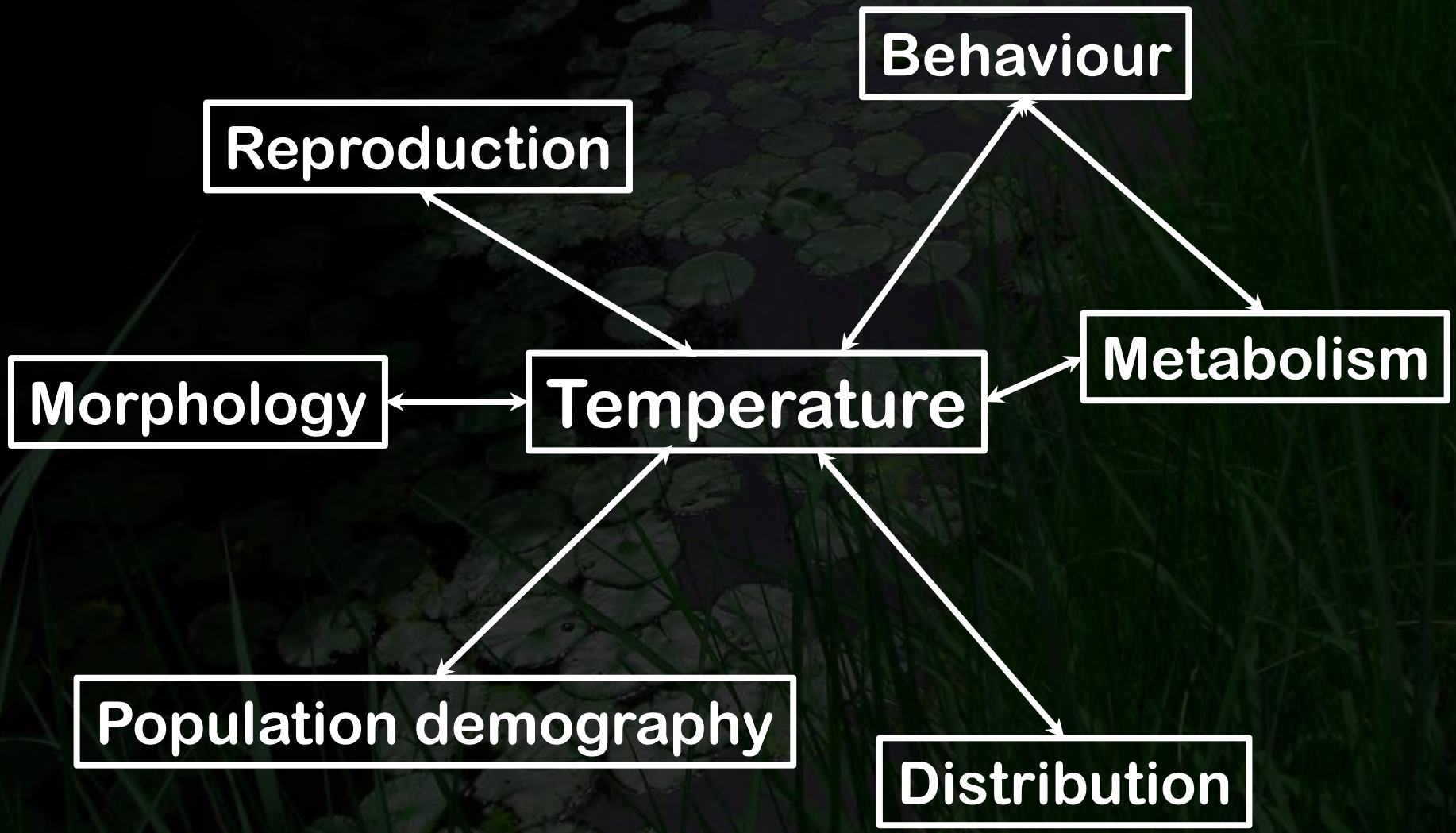
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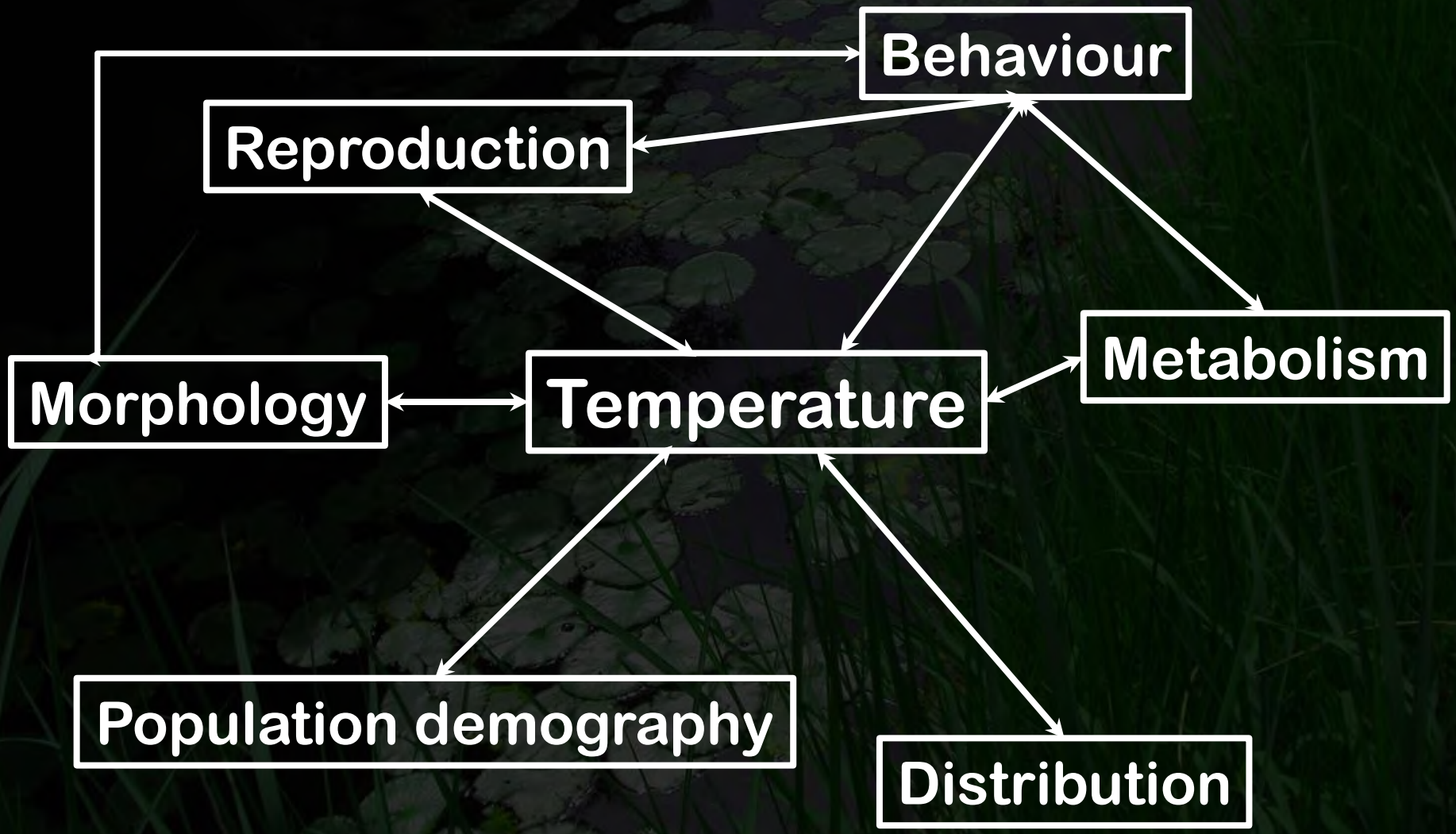
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Questions

Levels of Effect

Questions

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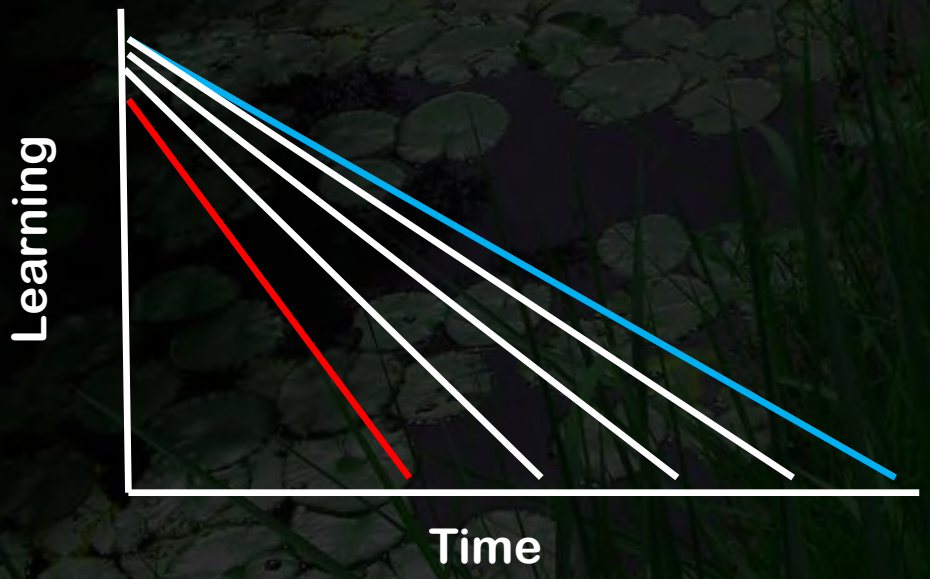
- Plasticity

Questions

Levels of Effect

- Plasticity
- Developmental
- Evolutionary

Questions Developmental

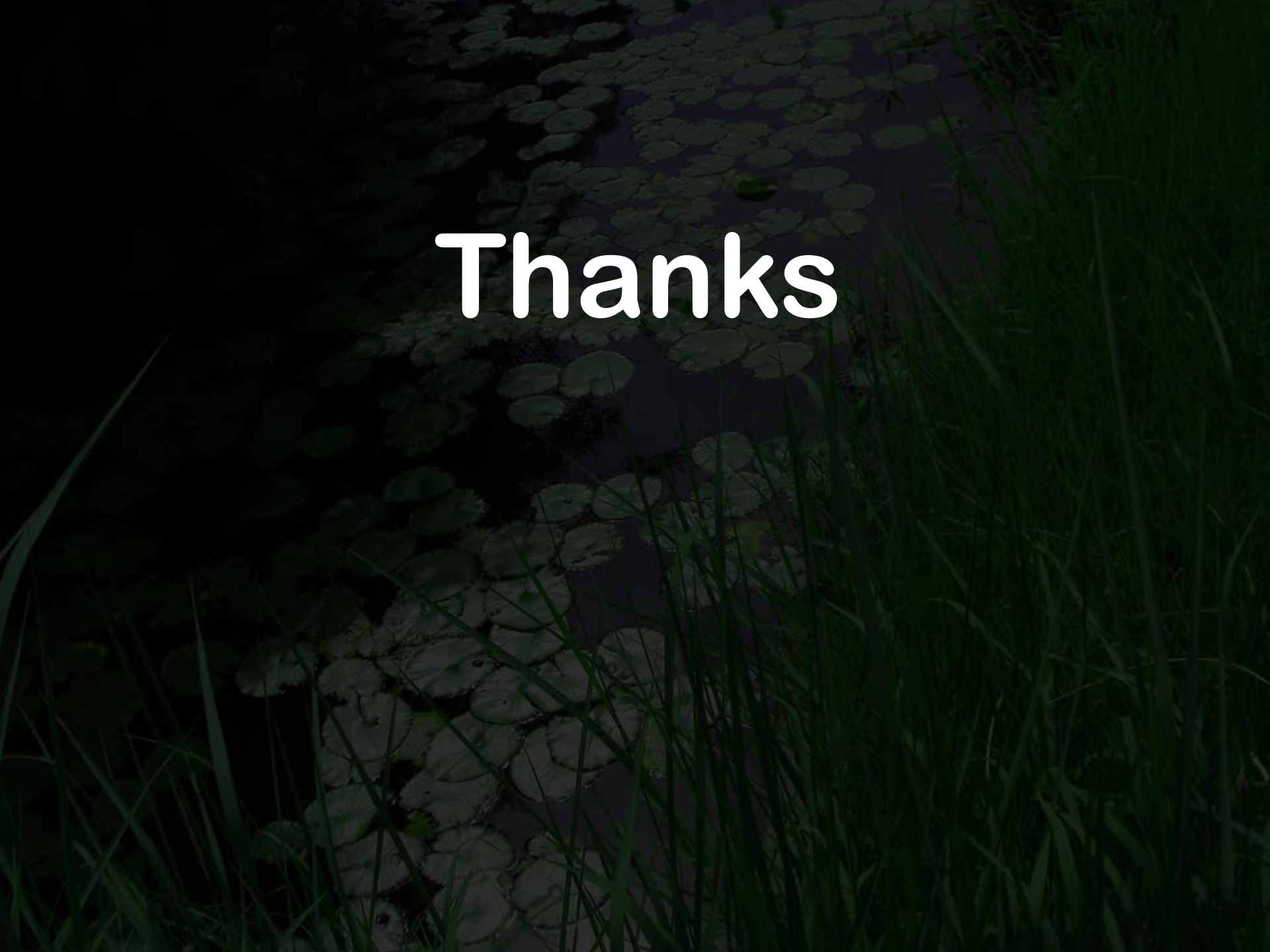


Questions

Central Nervous System Regeneration

Questions

Will increased learning ability enhance invasive success or impacts?


Thanks