Can Mosquitofish kairomones stimulate morphological and behavioral plasticity of the fire-Salamander larvae?

Avi Koplovich, Ori Segev, Leon Blaustein

Background

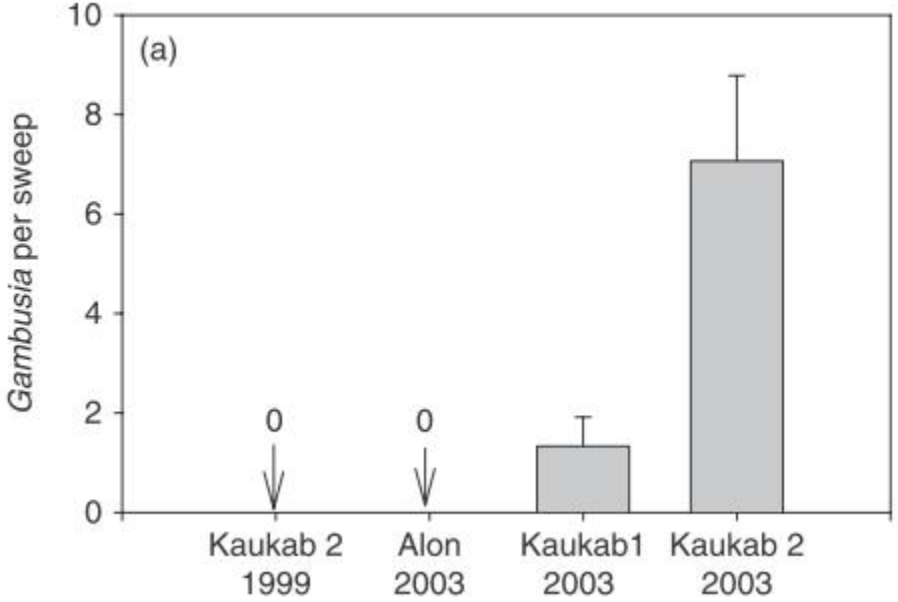
The Mosquitofish (Gambusia) is an introduced species in Israel used to control mosquitoes.

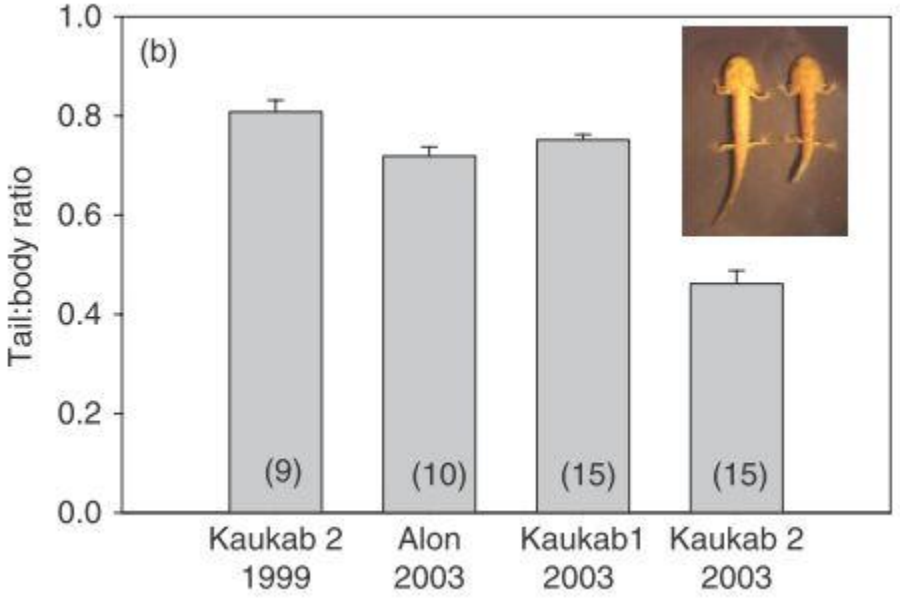
The Gambusia is a predator.

Although both Gambusia and Salamander larvae could have been found together, they don’t co-exist in Israel.

Background

Gambusia were shown to harm Salamander larvae and consequently to reduce their numbers.

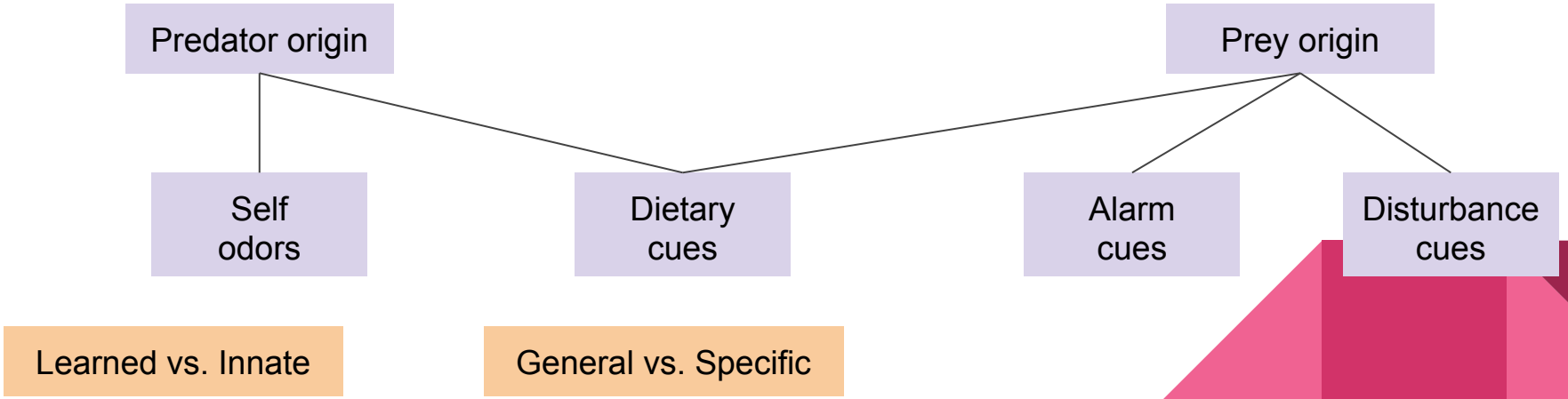




Background: Kairomones

"A kairomone is a chemical released by one species (predator), received by a second species (prey), that is adaptively favorable to the second species but not to the first"

Ferrari *et. al.* 2010, Canadian Journal of Zoology



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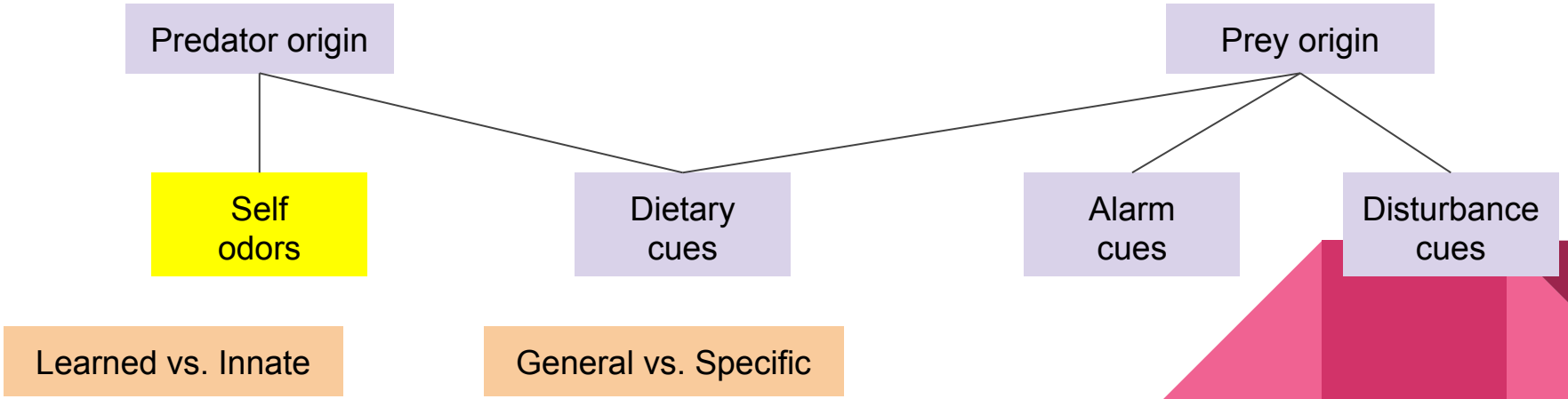
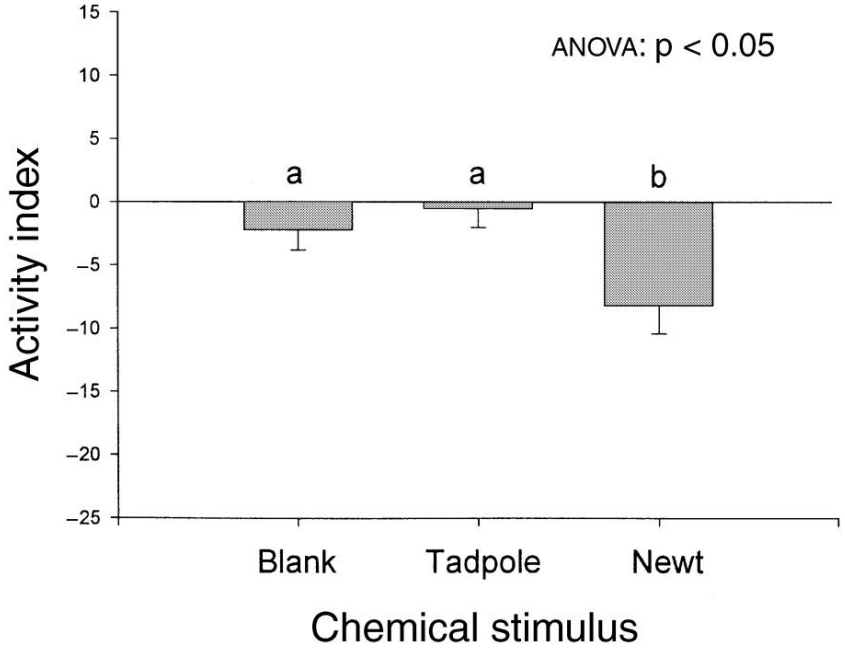
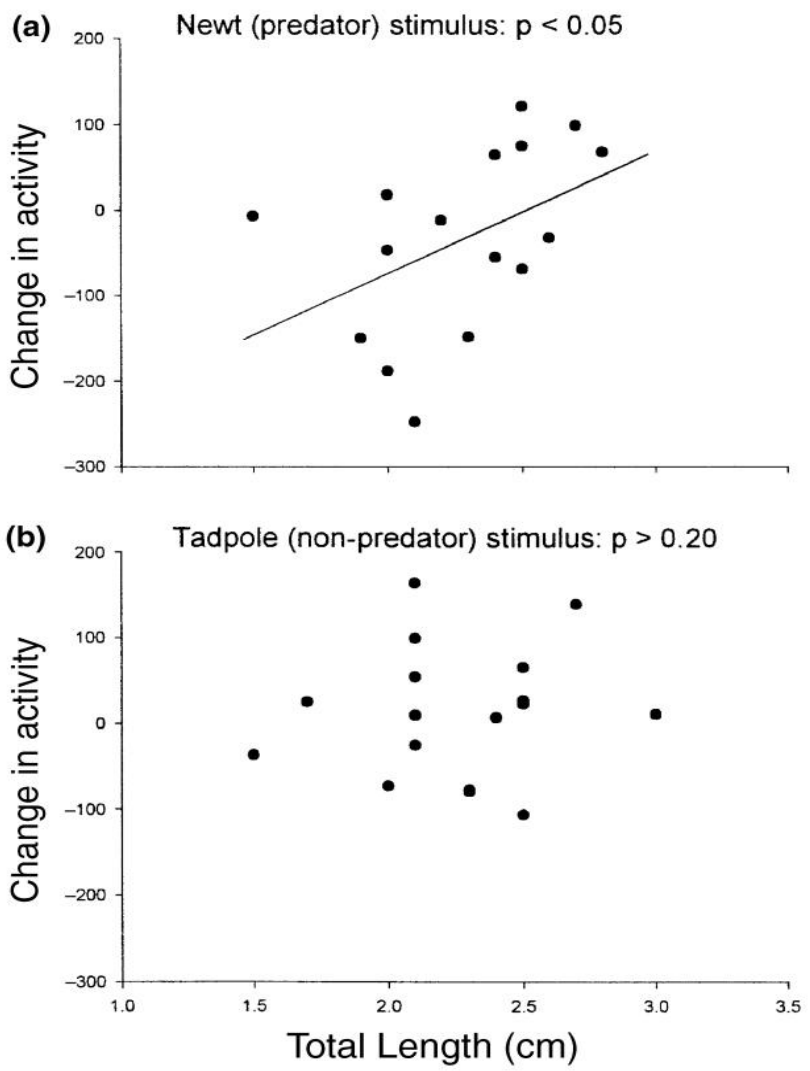


Background

Predator self odors and dietary cues can modify Salamander larvae behavior

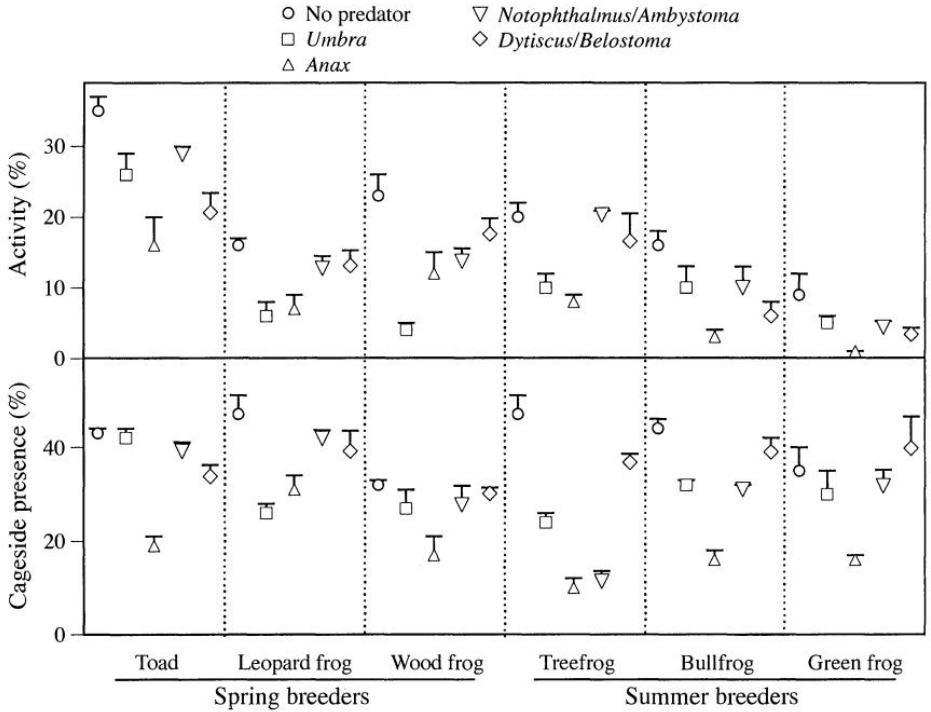


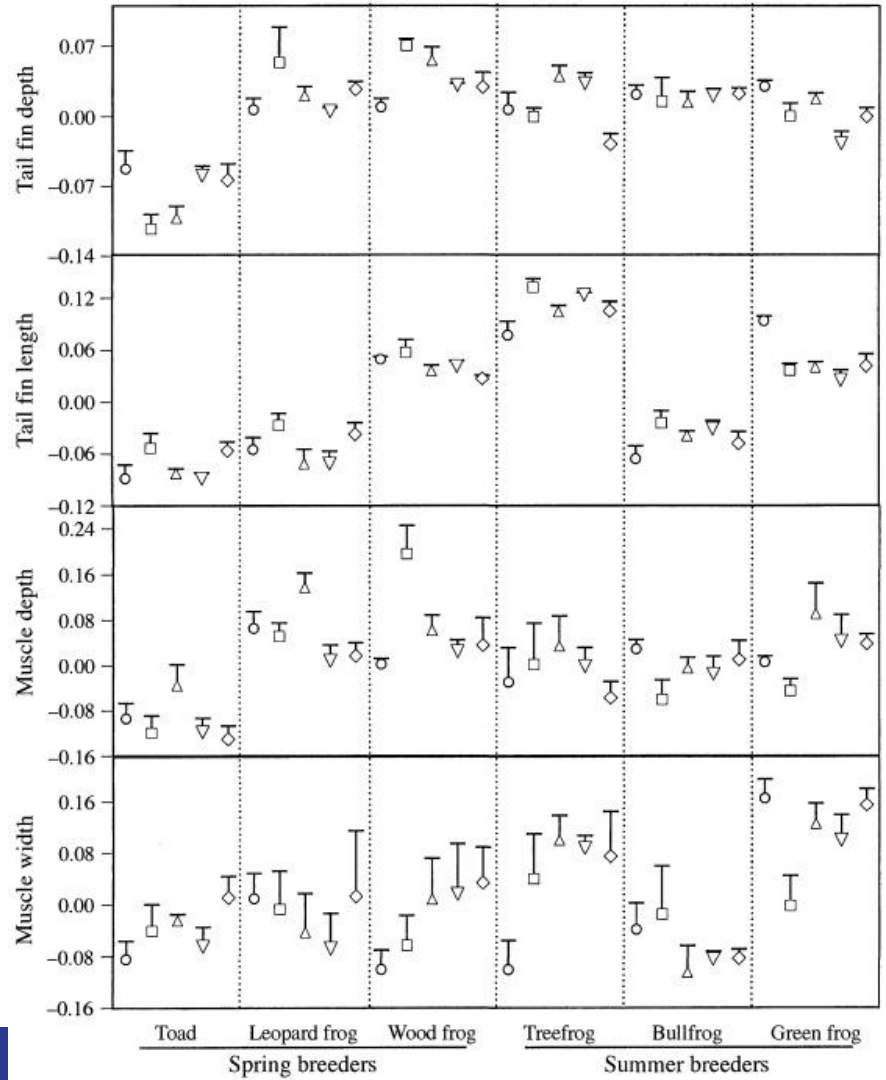


Mathis *et. al.*, 2003, Ethology

Background

Alarm cues can modify morphological and behavioral traits of Anurans





Relyea, 2001, Ecology

Hypothesis

Gambusia self odors are perceived as kairomones by salamander larvae and cause the latter to change behavior and/or morphology during their development.

Questions

1. Can self-odors of an introduced predatory-fish affect the morphology and/or behavior of salamander larvae?
2. If yes,
    a. Do Kairomones have different effect in different phases of the development?
    b. Do Gambusia Kairomones effect on salamander larvae is concentration-dependent or binary?
    c. How fast do larvae react to kairomones both behaviorally and morphologically? Is the rate steady?
    d. Do sites/females interact with the effect of the kairomones?

Methods

Six Salamander females were collected from three sites - all permanent lentic.

Gambusia were collected from a stream near Zipori and divided to males and females.

Dozen Larvae from each female (lab spawned) were designated to 3 treatments: no fish, 3 (1M+2F) fish, 6 (1M+5F) fish. - Each tub contains 4 larvae.

In each tub fish were constrained in a plastic jar with a fabric mesh allowing water diffusion but no visual nor vibration signals.

Methods

Larvae are being filmed for 30 min (each tub) once a week to track behavior.

Filming takes place in a separate white coated tubs, while the same number of Gambusia, as in their rearing tubs, are in adjacent partition (fabric mesh).

Larvae are being weighed and photographed for geometric morphometrics analysis every other week.

Experimental design

Permanent - Lentic

Sites	Ein Balad		Ein Alon		Kaukab	
Females	F1	F2	F1	F2	F1	F2
Treatments	0 fish: 4 larvae	0 fish: 4 larvae	0 fish: 4 larvae	0 fish: 4 larvae	0 fish: 4 larvae	0 fish: 4 larvae
	3 fish: 4 larvae	3 fish: 4 larvae	3 fish: 4 larvae	3 fish: 4 larvae	3 fish: 4 larvae	3 fish: 4 larvae
	6 fish: 4 larvae	6 fish: 4 larvae	6 fish: 4 larvae	6 fish: 4 larvae	6 fish: 4 larvae	6 fish: 4 larvae

Methods: Behavior (video tracking)

Anti-predatory behavior is analyzed using Toxtrac software

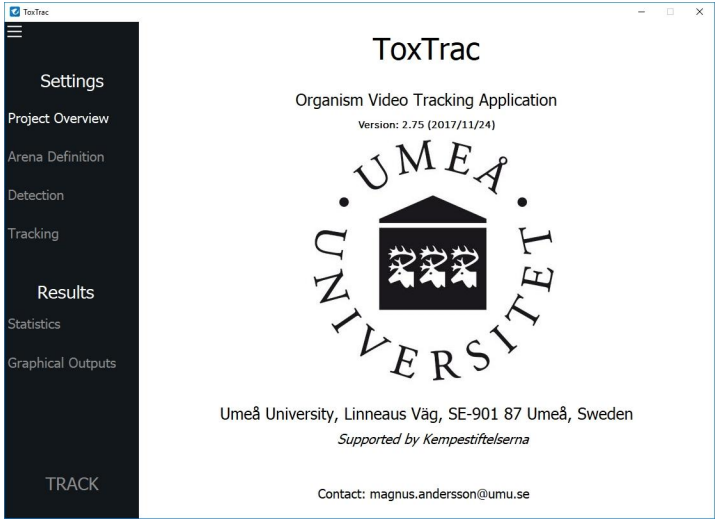
Manuscript version

ToxTrac: a fast and robust software for tracking organisms

Alvaro Rodriquez[1], Hanqing Zhang[1], Jonatan Klaminder[2], Tomas Brodin[2], Patrik L. Andersson[3], Magnus Andersson[1]

[1]Department of Physics, Umeå University, 901 87 Umeå, Sweden, [2]Department of Ecology and Environmental Science, Umeå University, 901 87 Umeå, Sweden, [3]Department of Chemistry, Umeå University, 901 87 Umeå, Sweden

Keywords: animal behavior; guppy; salmon; zebrafish; tadpole; cockroach; Kalman filter; ecotoxicology; ecology; tracking software;



Methods: Behavior (video tracking)

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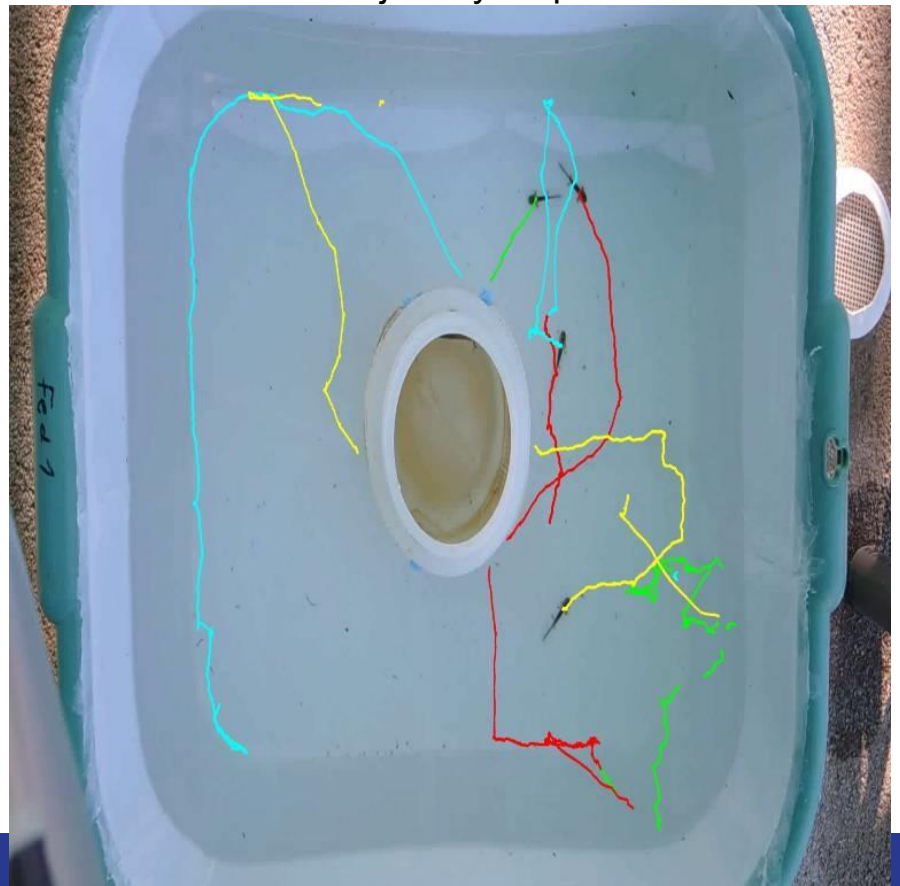
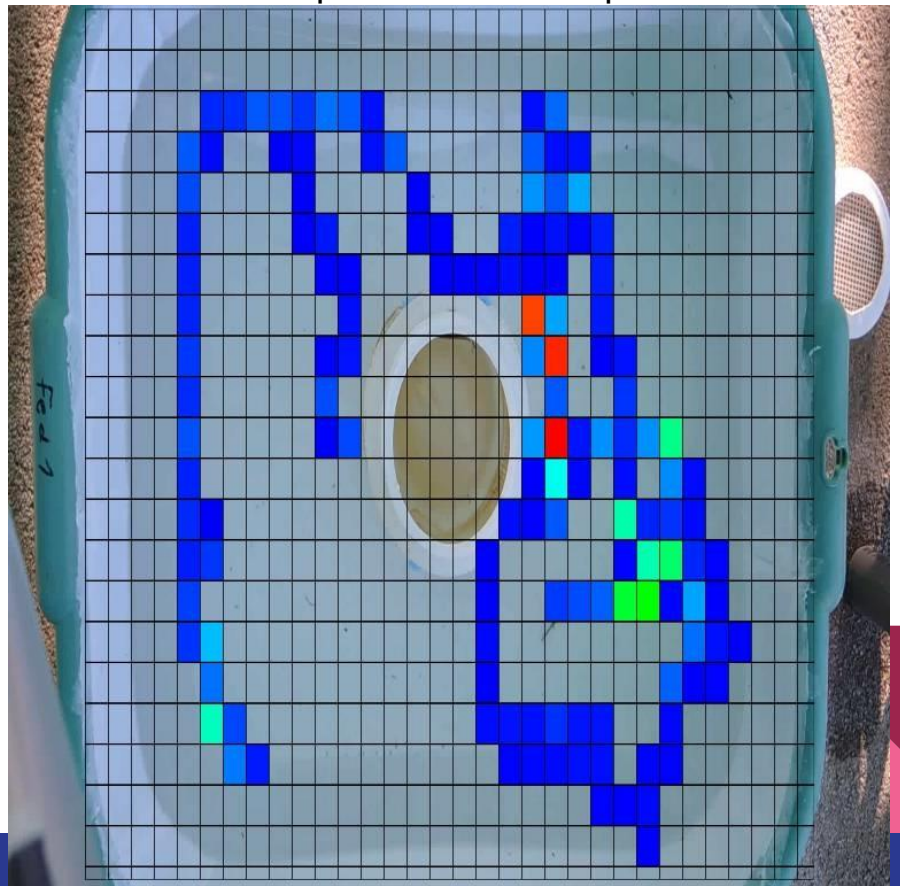
Trajectory map



Exploration heat map



Methods: Behavior (video tracking)

TRACKING STATS

	Mean	Std. Dev
Av. Speed (mm/s)	2.28	0.00
Mob. Av. Speed (mm/s)	4.28	0.00
Av. Accel (mm/s^2)	9.80	0.00
Mobility Rate (%)	42.33%	0.00%
Visible Frames	34353	0
Visible Time (m:s)	19:06.2	0:00.0
Invisible Frames	17800	0
Invisible Time (m:s)	9:53.9	0:00.0
First Visible Frame	0	0
Last Visible Frame	52151	0
Visibility Rate (%)	65.87%	0.00%
Invisibility Rate (%)	34.13%	0.00%
Explored Areas	138	0
Number of Areas	704	0
Exploration Rate (%)	19.60%	0.00%
Total Distance (mm)	4848.7	0.0
Transitions In	0	0
Transitions Out	1	0
Frozen Events	200	0
Tot. Time Frozen (m:s)	40:40.6	0:00.0
Avg. Time Frozen (m:s)	0:12.2	0:00.0

Time Count (m:s)	50mm	100mm	150mm	200mm	250mm	300mm	350mm	400mm	450mm	500mm	550mm	600mm	650mm	700mm	750mm	800mm	850mm	900mm	950mm	1000mm	1050mm	1100mm	1150mm	1200mm
50mm	0:10.7	0:11.7	0:37.5	0:44.1	0:19.2	0:19.6	1:08.2	0:08.3	0:05.7	0:00.0	0:00.0	0:00.0	0:00.0	0:00.0	0:00.0	0:39.5	0:09.9	0:00.0	0:00.0	0:00.0	0:00.0	0:00.0	0:00.0	0:00.0
100mm	0:49.5	0:00.0	0:00.0	0:00.0	0:03.4	0:00.0	0:00.0	0:02.2	0:13.4	0:28.6	0:00.0	0:00.0	0:00.0	0:00.0	0:00.0	0:42.0	0:12.2	0:00.0	0:00.0	0:00.0	0:00.0	0:00.0	0:00.0	0:00.0
150mm	0:19.4	0:00.0	0:00.0	0:00.0	0:00.1	0:00.2	0:00.0	0:00.0	0:00.0	0:00.2	0:00.1	0:00.0	0:00.0	0:00.0	0:00.1	1:25.3	1:16.5	0:01.3	0:00.0	0:00.0	0:00.0	0:00.0	0:00.0	0:00.0
200mm	0:11.8	0:00.0	0:00.0	0:00.0	0:00.0	0:03.4	0:06.1	0:00.0	0:00.0	0:00.0	0:00.1	0:00.0	0:00.0	0:00.6	0:11.9	0:06.1	0:00.5	0:13.0	0:00.2	0:00.0	0:00.0	0:00.0	0:00.0	0:00.0
250mm	0:12.0	0:00.0	0:00.0	0:00.0	0:00.0	0:00.0	0:00.5	0:00.0	0:00.0	0:00.0	0:00.0	0:00.1	0:00.0	0:05.8	0:00.0	0:00.4	0:00.0	0:00.0	0:12.0	0:00.0	0:00.0	0:00.0	0:00.0	0:00.0
300mm	0:14.1	0:00.0	0:00.0	0:00.0	0:00.0	0:00.0	0:05.0	0:00.0	0:00.0	0:00.0	0:00.0	0:00.0	0:00.0	0:00.0	1:30.6	7:01.8	0:00.9	0:00.0	0:09.8	0:00.0	0:00.0	0:00.0	0:00.0	0:00.0
350mm	0:30.0	0:00.0	0:00.0	0:00.0	0:00.0	0:00.0	0:08.9	0:00.0	0:00.0	0:00.0	0:00.0	0:00.0	0:00.0	0:00.0	0:09.5	4:56.2	1:49.3	0:00.0	0:07.6	0:00.0	0:00.0	0:00.0	0:00.0	0:00.0
400mm	0:10.7	0:00.0	0:00.0	0:00.0	0:00.0	0:30.9	0:00.5	0:00.0	0:00.0	0:00.0	0:00.0	0:00.0	0:00.0	0:00.0	0:00.0	0:36.1	0:00.0	0:00.0	0:21.4	0:00.0	0:00.0	0:00.0	0:00.0	0:00.0
450mm	0:33.4	0:00.0	0:00.0	0:00.0	0:00.0	0:00.0	0:07.6	0:21.1	0:00.0	0:00.0	0:00.0	0:00.0	0:00.0	0:00.0	0:00.0	7:30.6	0:41.6	0:36.8	0:29.8	0:24.7	3:23.9	0:00.0	0:00.0	0:00.0
500mm	0:14.8	0:00.0	0:00.0	0:00.0	0:00.0	0:00.0	0:00.0	0:00.0	0:00.0	0:00.0	0:00.0	0:00.0	0:00.0	0:00.0	0:00.0	0:08.8	1:45.1	0:00.1	0:00.0	0:05.8	0:30.2	0:34.7	0:00.0	0:00.0
550mm	0:16.7	0:00.0	0:00.0	0:00.0	0:00.0	0:00.0	0:00.0	0:00.0	0:00.0	0:00.0	0:00.0	0:00.0	0:00.0	0:01.7	0:04.2	0:35.6	0:00.0	0:00.0	2:11.8	0:22.9	0:00.0	0:31.6	0:00.0	0:00.0
600mm	0:33.5	0:00.0	0:00.0	0:00.0	0:00.0	0:00.0	0:00.0	0:00.0	0:00.0	0:00.0	0:00.0	0:00.0	0:00.0	0:00.1	0:00.0	0:00.0	0:00.0	0:00.0	0:01.3	0:40.0	3:57.9	0:54.3	0:02.4	0:00.1
650mm	0:30.8	0:00.0	0:00.0	0:00.0	0:00.0	0:00.0	0:00.0	0:00.0	0:00.0	0:00.0	0:00.0	0:00.0	0:00.0	0:00.4	0:00.0	0:00.0	0:36.4	0:25.6	0:37.9	4:09.4	2:07.4	1:13.6	0:02.5	0:00.3
700mm	1:32.5	0:02.7	0:00.0	0:00.0	0:00.0	0:00.0	0:00.0	0:00.0	0:00.0	0:00.0	0:00.0	0:00.0	0:00.0	0:03.1	0:00.0	0:00.0	0:00.0	0:00.0	0:00.0	0:00.0	0:00.0	0:38.8	0:03.9	0:02.9
750mm	0:45.5	0:16.3	0:00.0	0:00.0	0:00.0	0:00.0	0:00.0	0:00.0	0:00.0	0:00.0	0:00.0	0:00.0	0:00.0	0:00.2	0:00.0	0:00.0	0:00.0	0:00.0	0:00.0	0:00.0	0:32.7	0:07.7	0:01.2	0:00.0
800mm	0:00.0	2:25.3	0:15.7	0:00.0	0:00.0	0:00.0	0:00.0	0:00.0	0:00.0	0:00.0	0:00.0	0:00.0	0:00.0	0:07.5	0:07.1	0:26.0	0:10.1	0:20.2	0:00.0	0:00.0	0:02.7	0:00.0	0:00.0	0:00.0
850mm	0:00.0	0:03.6	0:42.1	0:00.0	0:00.0	0:00.0	0:00.0	0:00.0	0:00.0	0:00.0	0:00.0	0:00.0	0:00.0	0:00.0	0:00.0	0:00.0	0:01.9	0:02.3	0:01.3	0:00.0	0:02.7	0:00.0	0:00.0	0:00.0
900mm	0:00.0	0:00.0	0:00.0	0:00.0	0:00.0	0:00.0	0:00.0	0:00.0	0:00.0	0:00.0	0:00.0	0:00.0	0:00.0	0:00.0	0:00.0	0:00.0	0:00.0	0:00.0	0:00.8	0:00.1	0:03.2	0:00.0	0:00.0	0:00.0
950mm	0:00.0	0:00.0	0:00.0	0:00.0	0:00.0	0:00.0	0:00.0	0:00.0	0:00.0	0:00.0	0:00.0	0:00.0	0:00.0	0:00.0	0:00.0	0:00.0	0:00.0	0:00.0	0:00.0	0:00.0	0:00.1	0:00.0	0:00.0	0:00.0

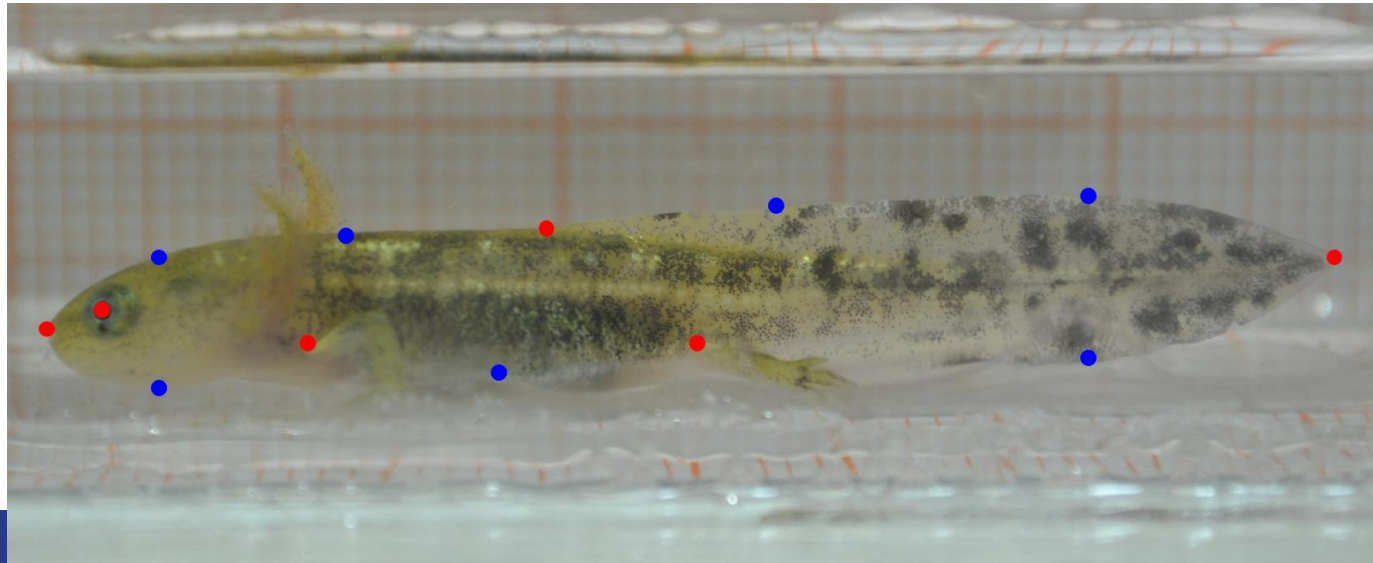
Methods: Geometric Morphometrics

GMM analysis will include six fix-landmarks and seven semi-landmarks.

GMM analysis (MANOVA, PCA) will be done using the Geomorph package within R.

Fixed-Landmark

Semi-Landmark



Predictions

Behavior:

Variable \ Treatment	Predator absent	Predator present
Movement velocity in active times	fast	slow
Mobility rate	high	low
Total distance	long	short
Exploratory	high	low

Predictions

Morphology:

Variable \ Treatment	Predator absent	Predator present
Tail shape	Short and tall	Long and shallow
Body shape	Long	Densed

Thanks for your Attention!

Any questions?