Computational approaches to understanding the evolution of sexual signal design

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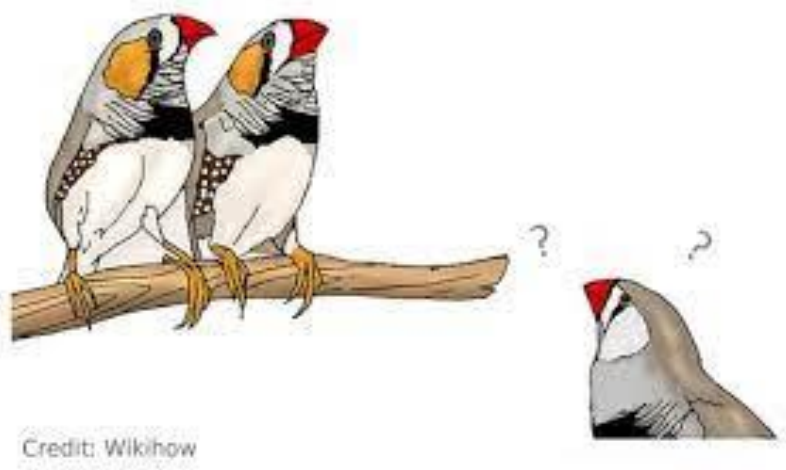
Sexual selection and Assortative mating

Powell et al 2020

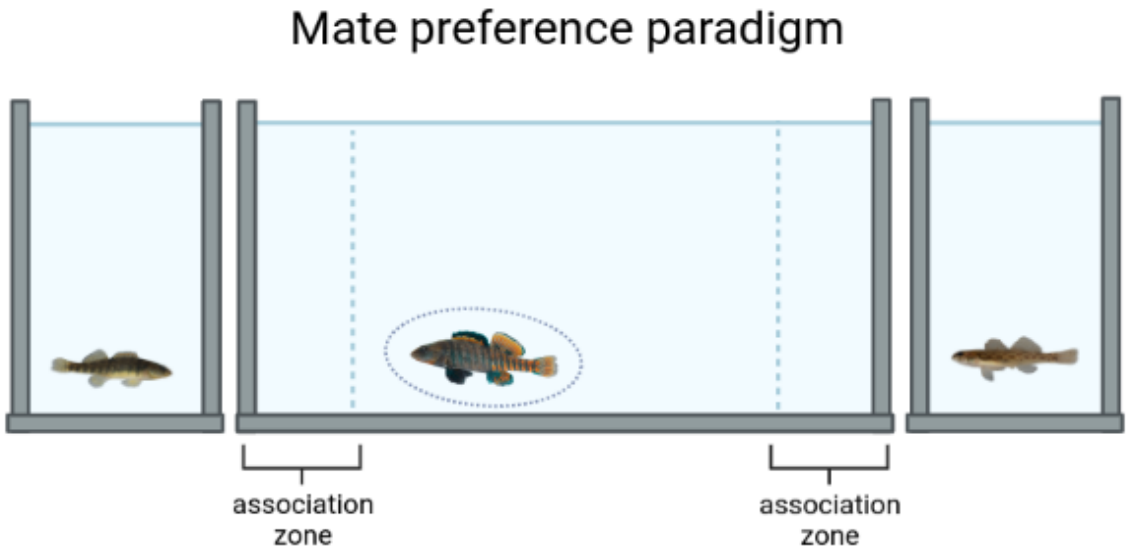
Why do animals choose certain mates?



Can we identify those features?

Darters

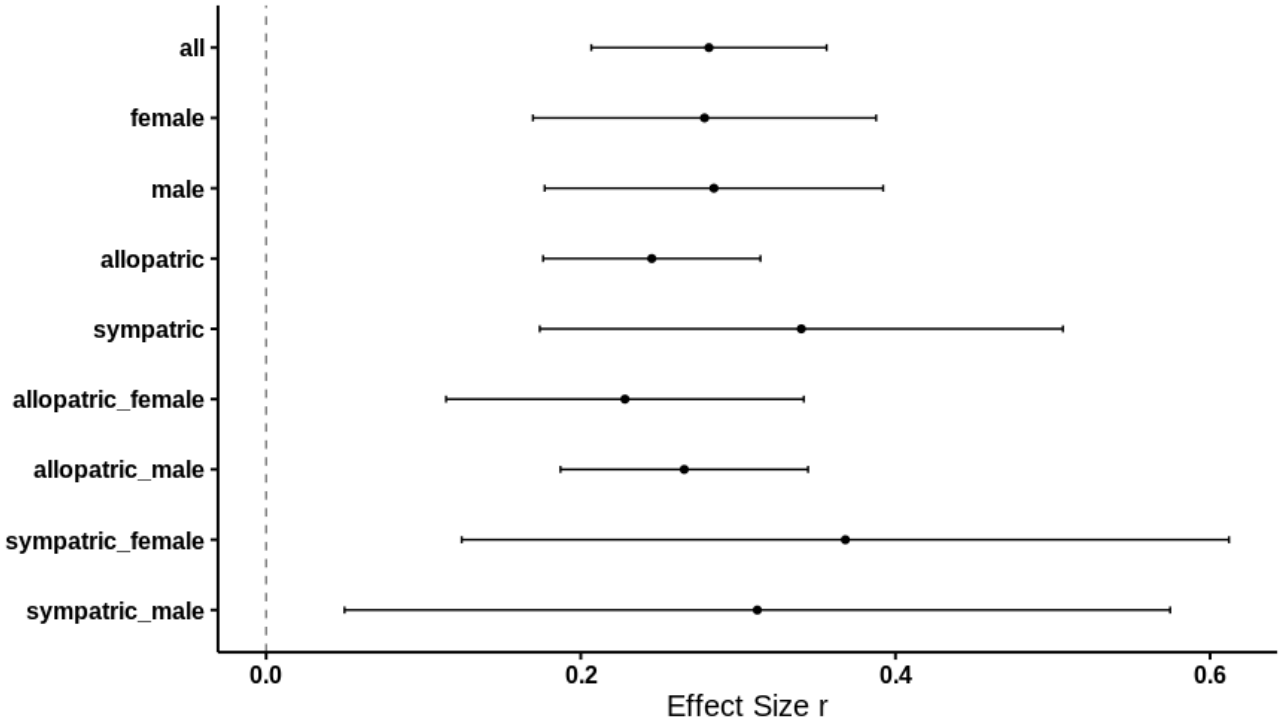
Assortative mating in *Etheostoma*



12 papers + 5 unpublished datasets (2010-2023)
21 species of *Etheostoma*
14 different pairs of species
Allopatric and sympatric populations

Héjja-Brichard, Renoult, Mendelson, in revision, Evolution

Assortative mating in *Etheostoma*



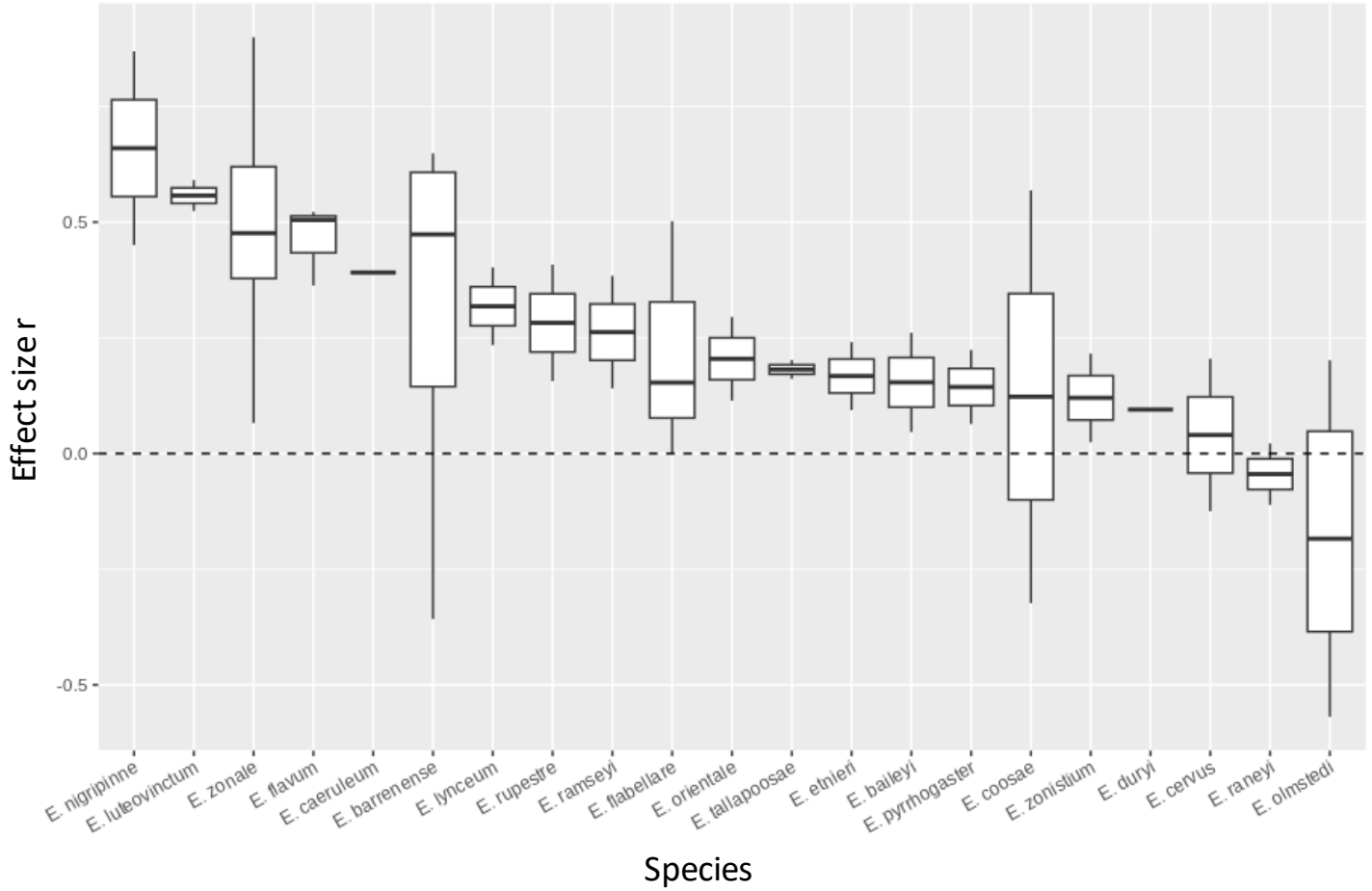
Preference for conspecifics:

- No effect of sex
- No effect of geography

Overall effect size of medium strength (r = 0.3213)

Héjja-Brichard, Renoult, Mendelson, in revision, Evolution

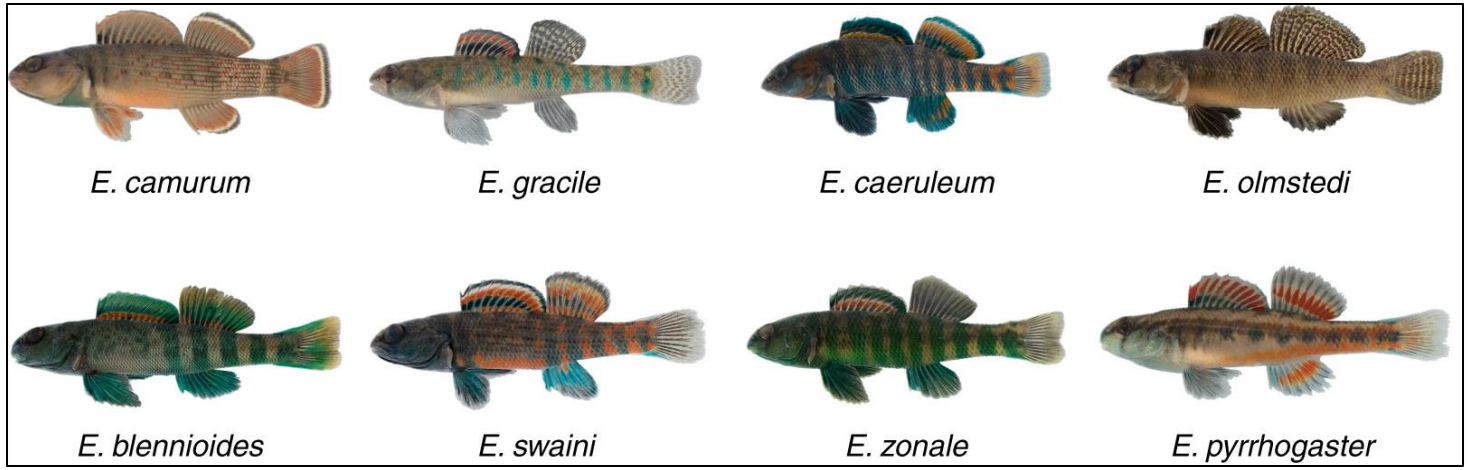
Assortative mating in *Etheostoma*



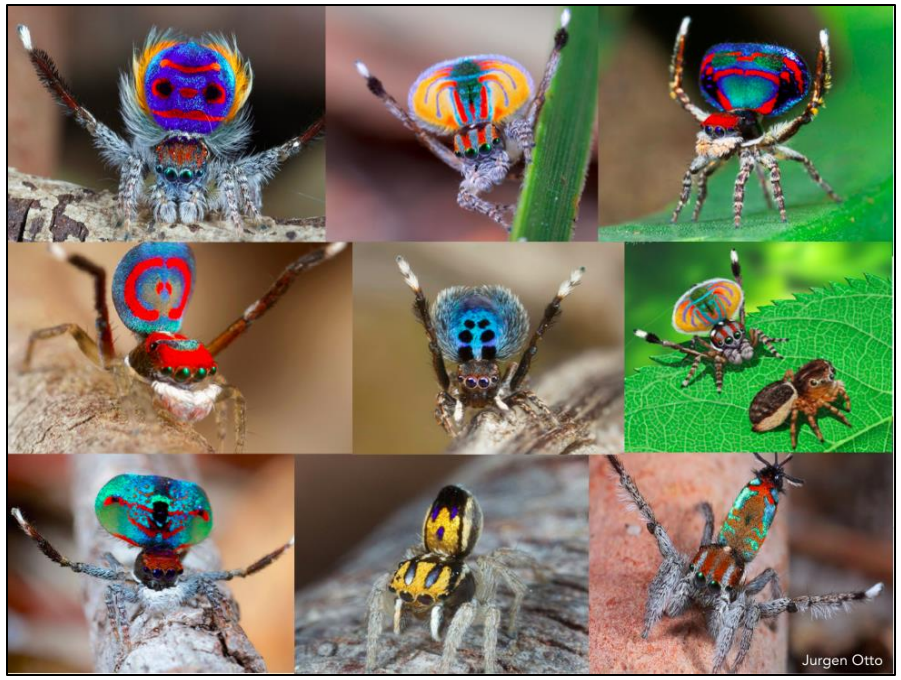
What drives a preference for conspecifics?
What signals matter?
When does geography matter?

Héjja-Brichard, Renoult, Mendelson, in revision, Evolution

Evolution of sexual signals

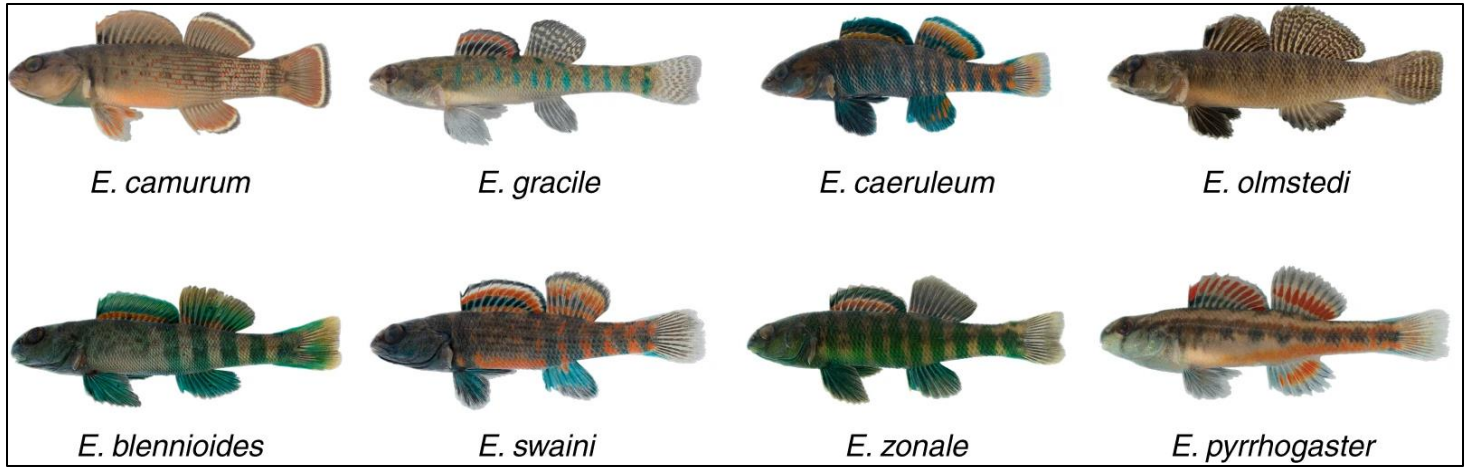


Sam Hulse



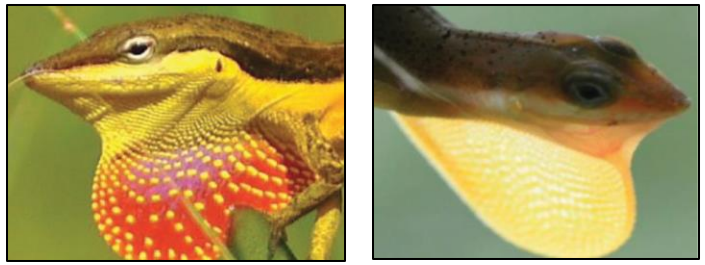
timlaman.com

Evolution of sexual signals



Sam Hulse

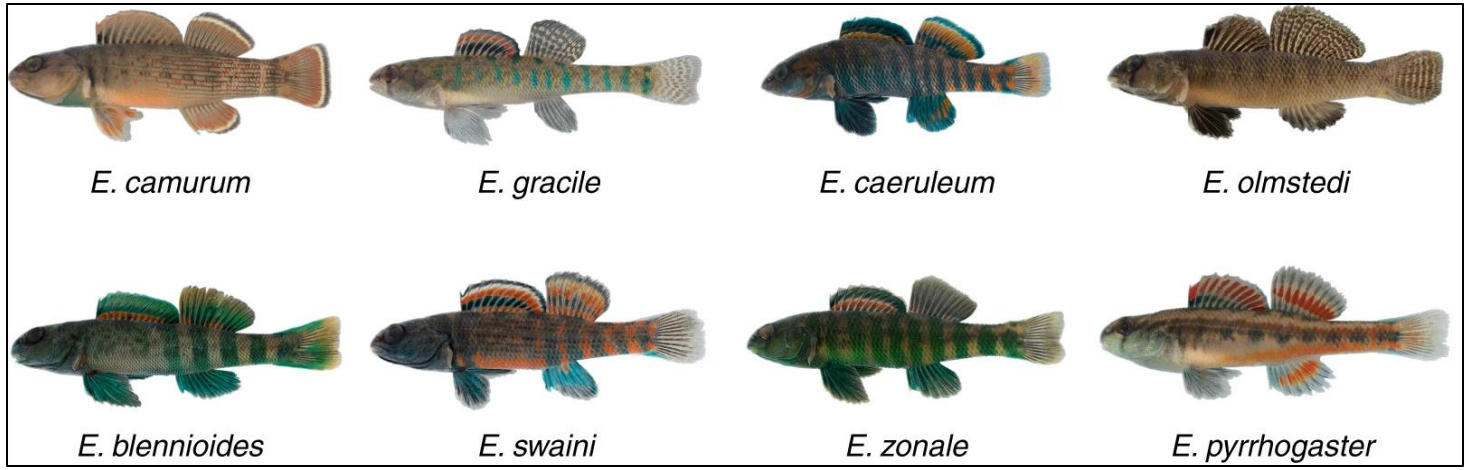
Environmental characteristics → **Signal detection theory** Sensory drive and signal efficacy



Fleishman et al, 2022

Endler & Basolo, 1998

Evolution of sexual signals



Sam Hulse

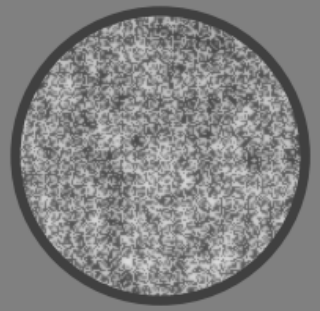
Environmental characteristics

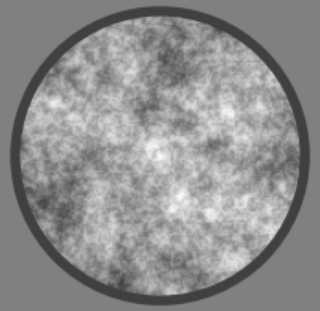
Signal detection theory
Sensory drive and signal efficacy

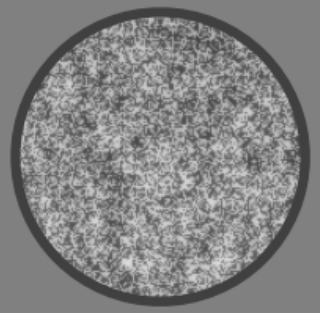
Information theory
Efficient coding

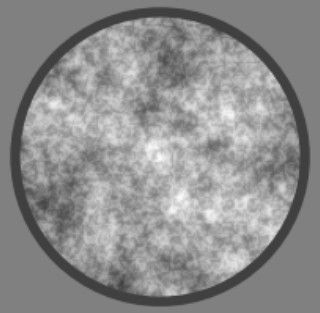
T. Moran, 1907

Endler & Basolo, 1998; Barlow, 1961



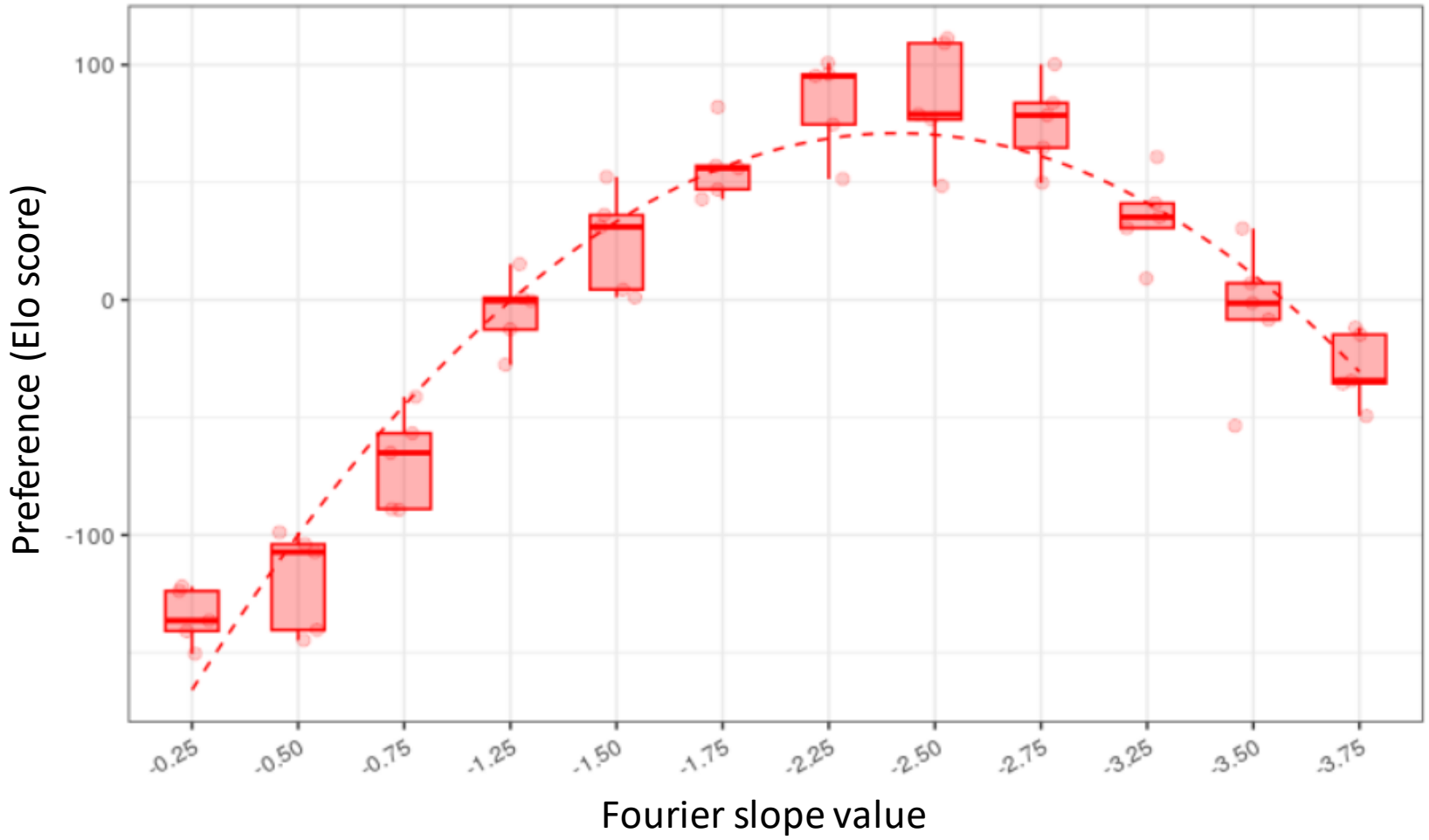






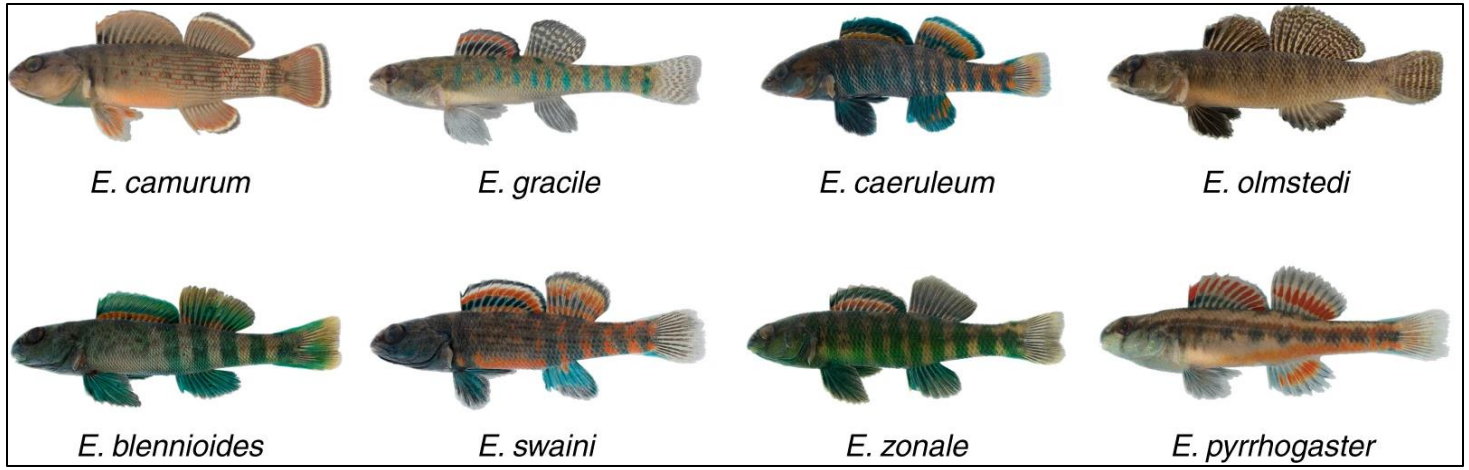
Closer to natural statistics
More efficiently processed

Human pattern preferences are consistent with an information-theoretic hypothesis of signal evolution

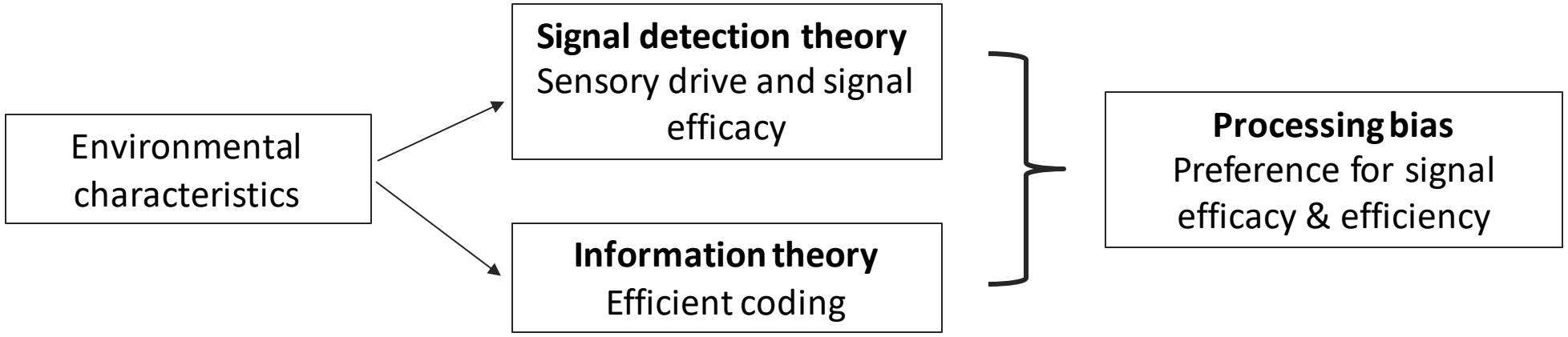


Héjja-Brichard et al., bioRxiv, 2023

Evolution of sexual signals

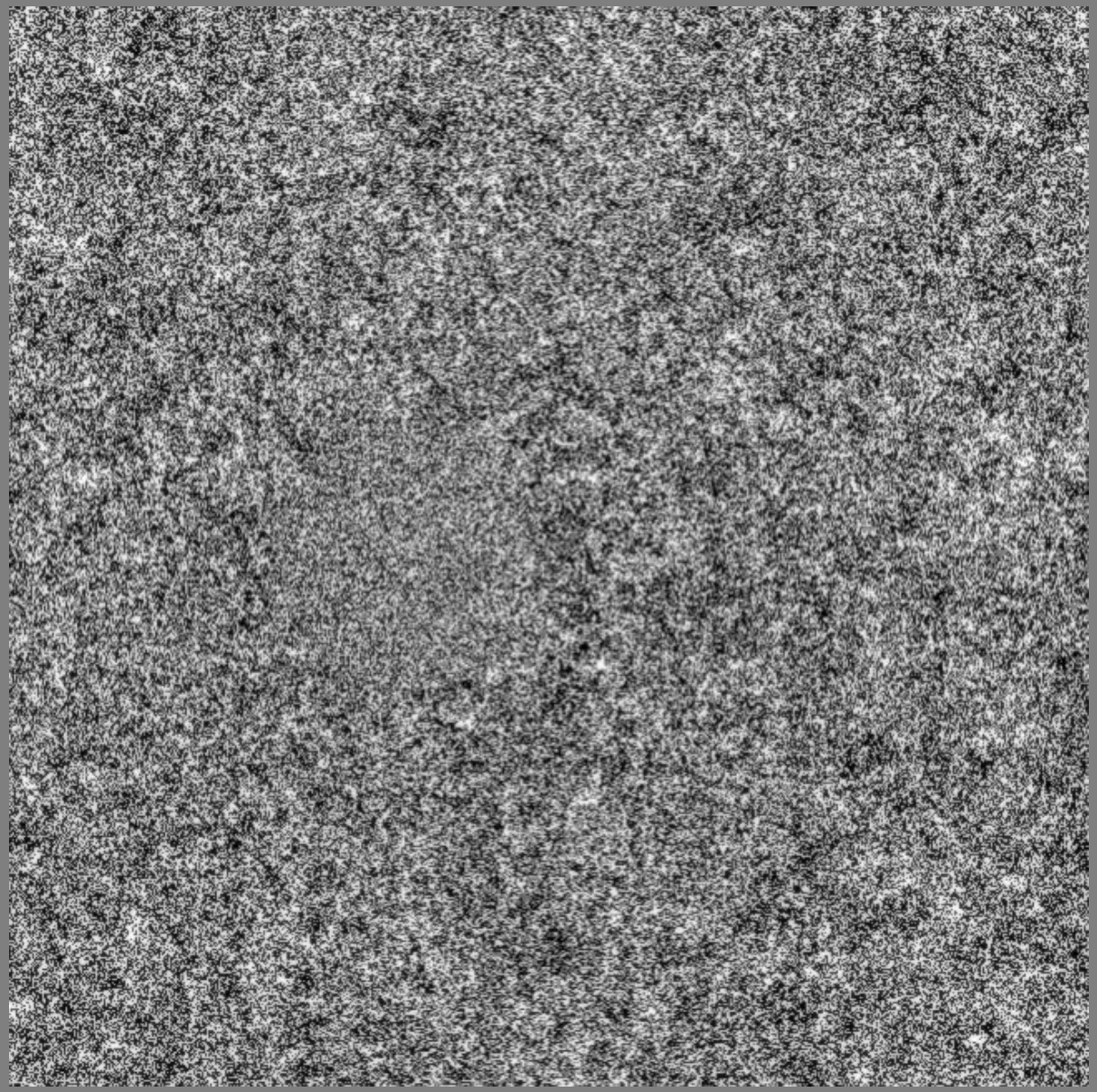


Sam Hulse



Endler & Basolo, 1998; Barlow, 1961; Renoult & Mendelson, 2019

Click on the target as fast as possible



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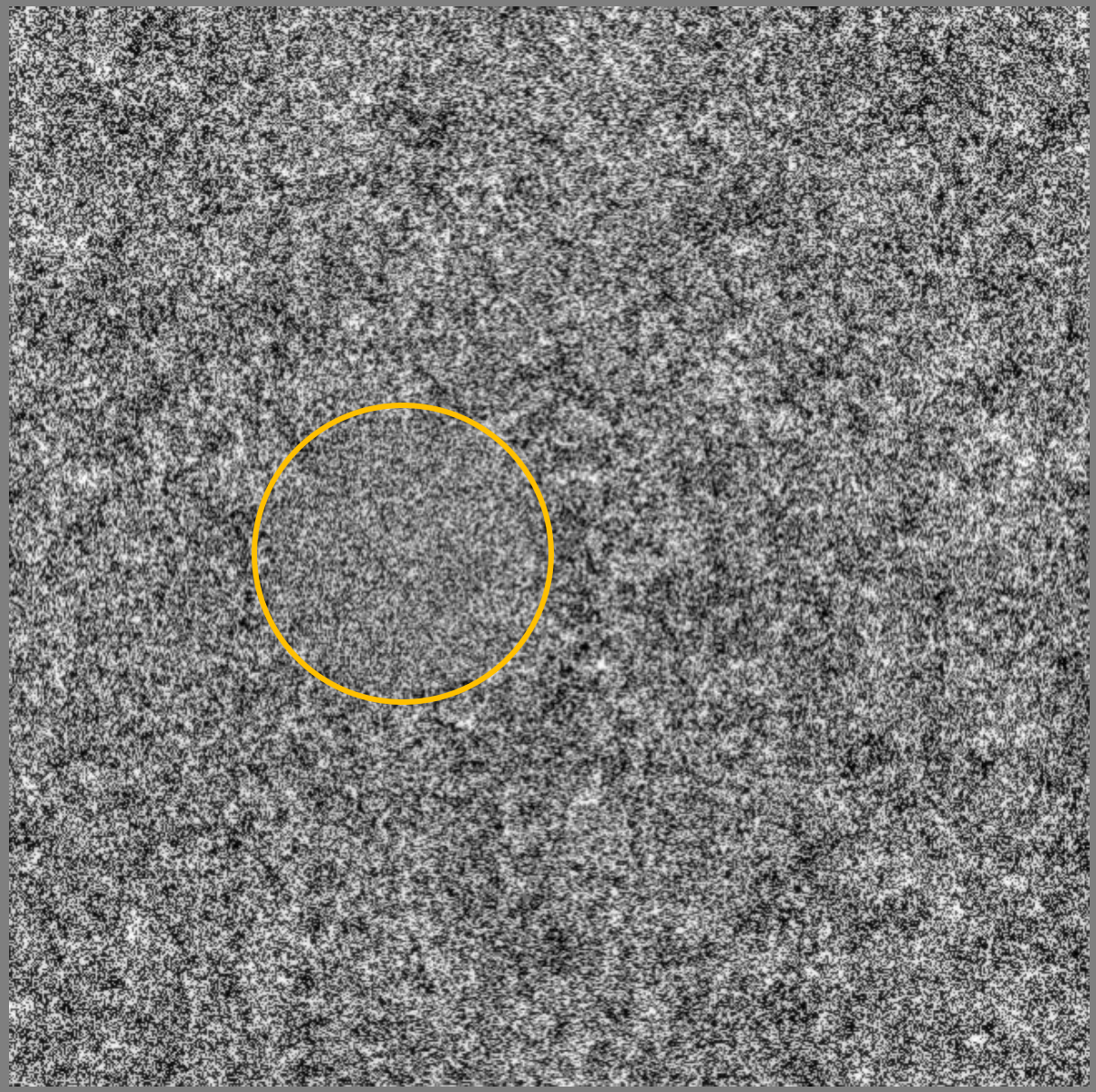
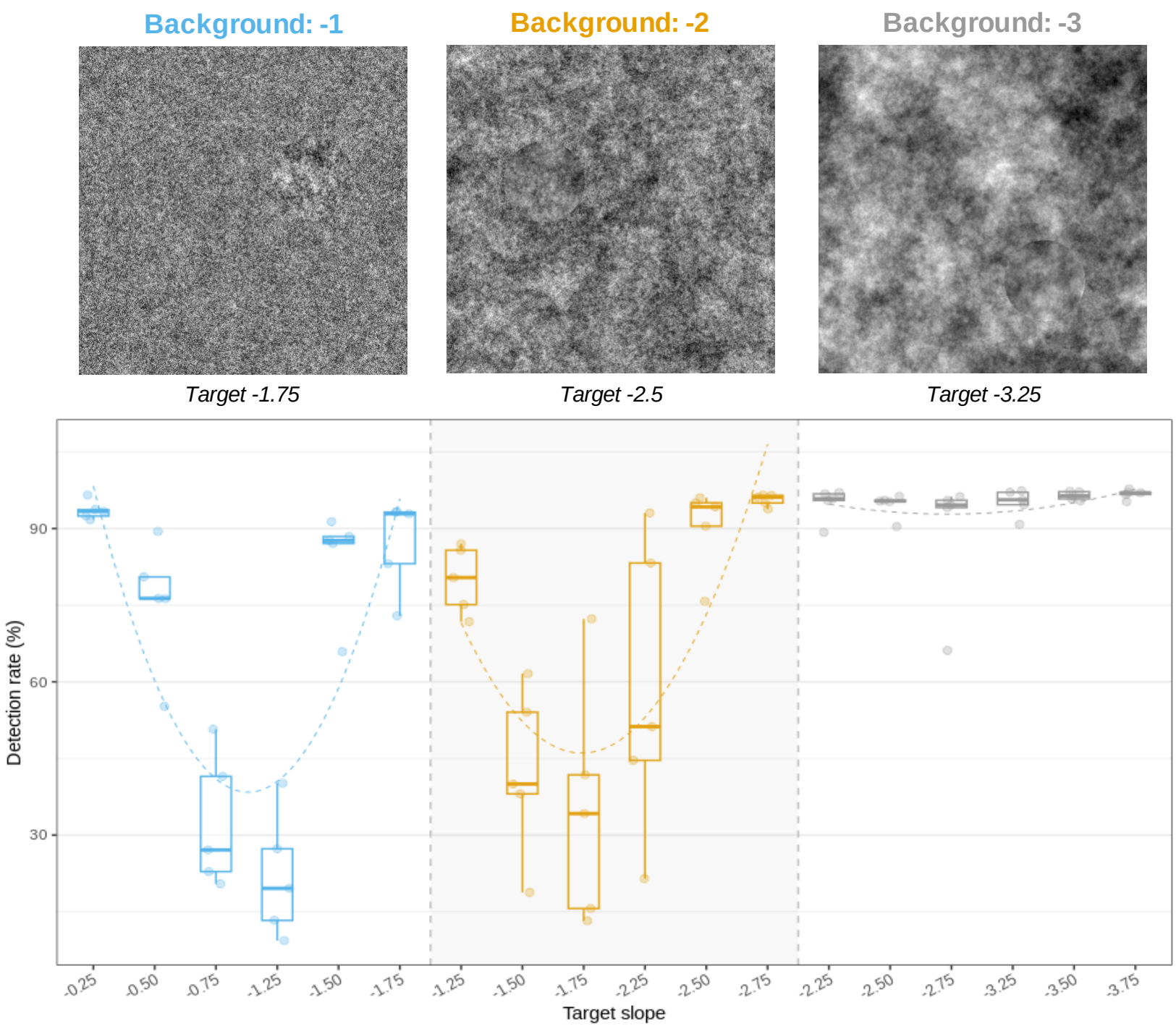
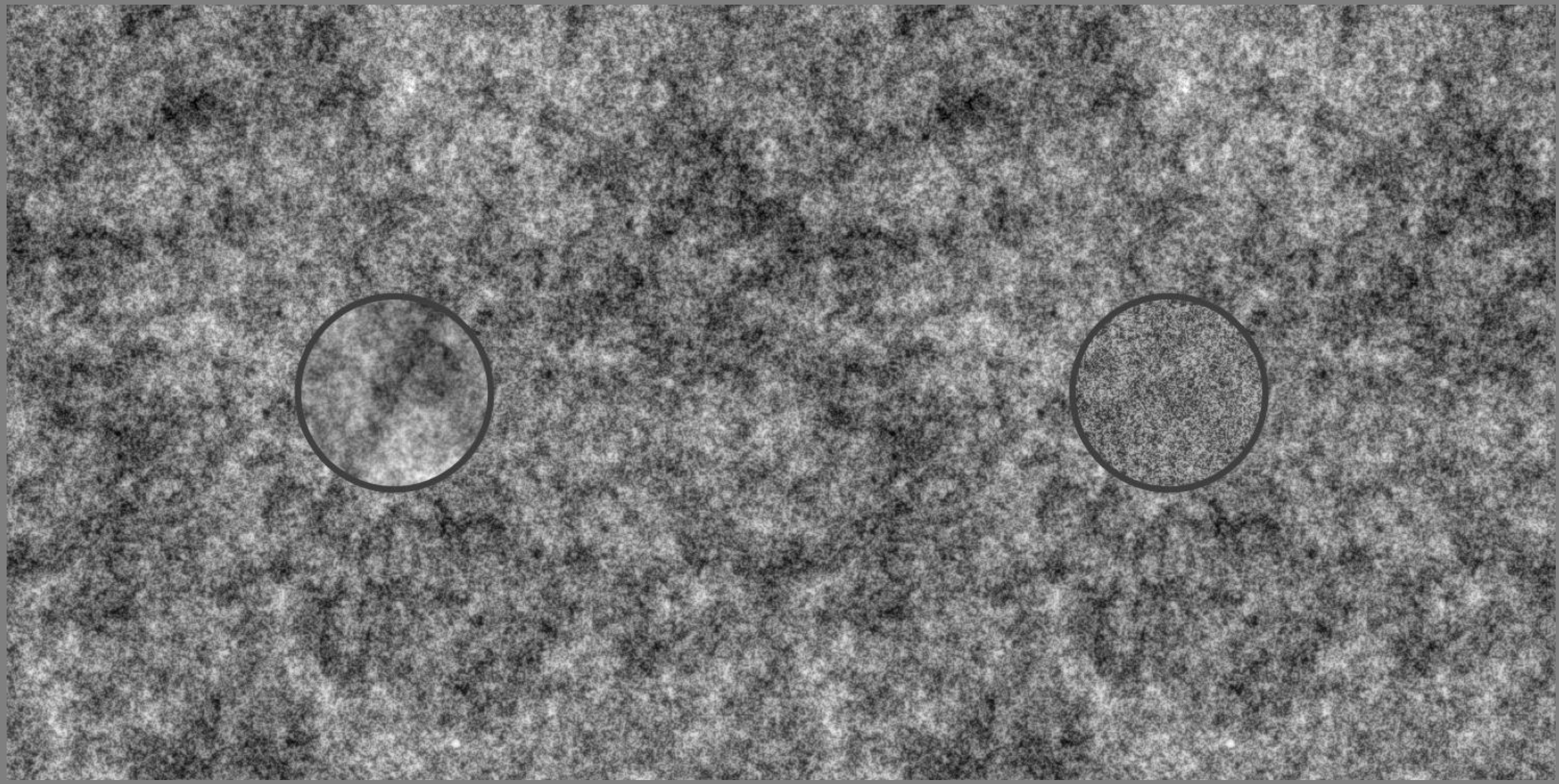
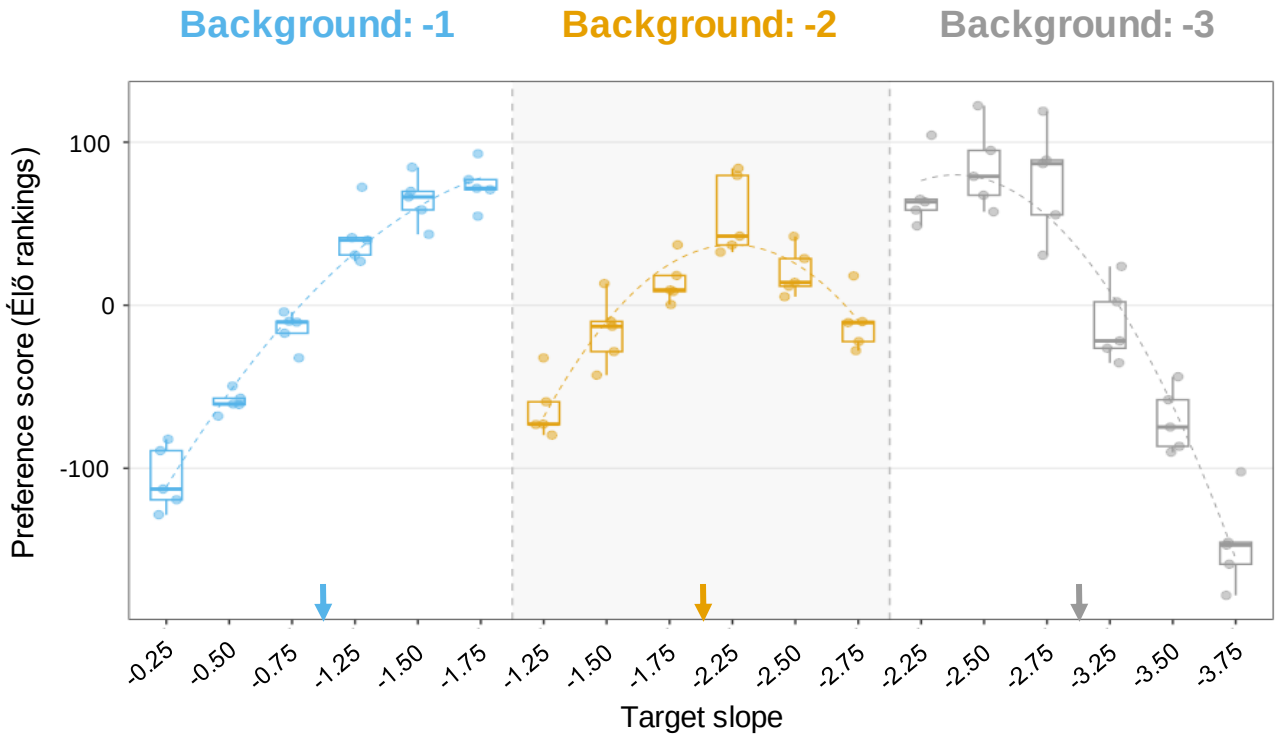




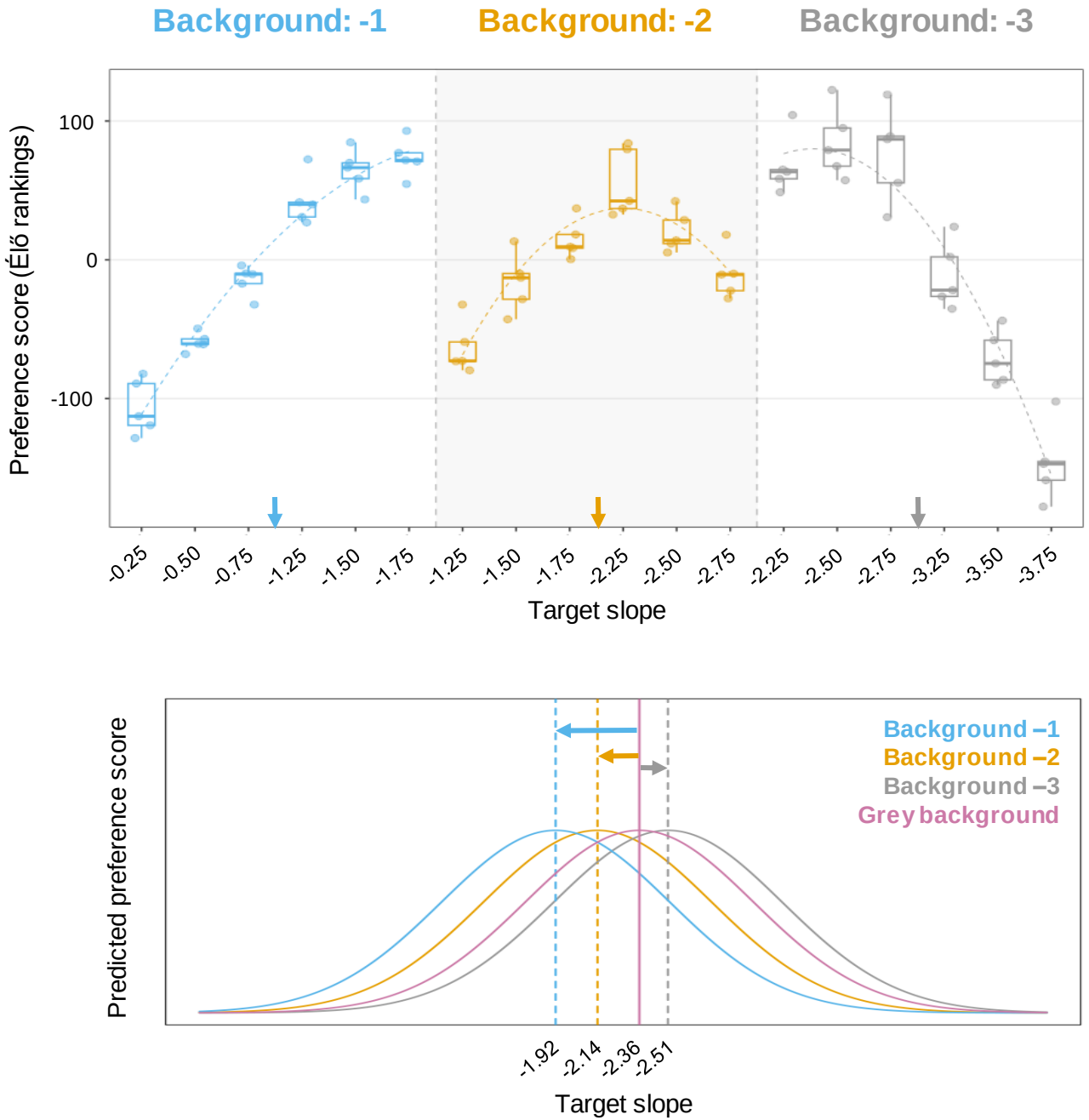
Héjja-Brichard et al., bioRxiv, 2023

Compare the patterns in the two circles, which one do you prefer?





Héjja-Brichard et al., bioRxiv, 2023

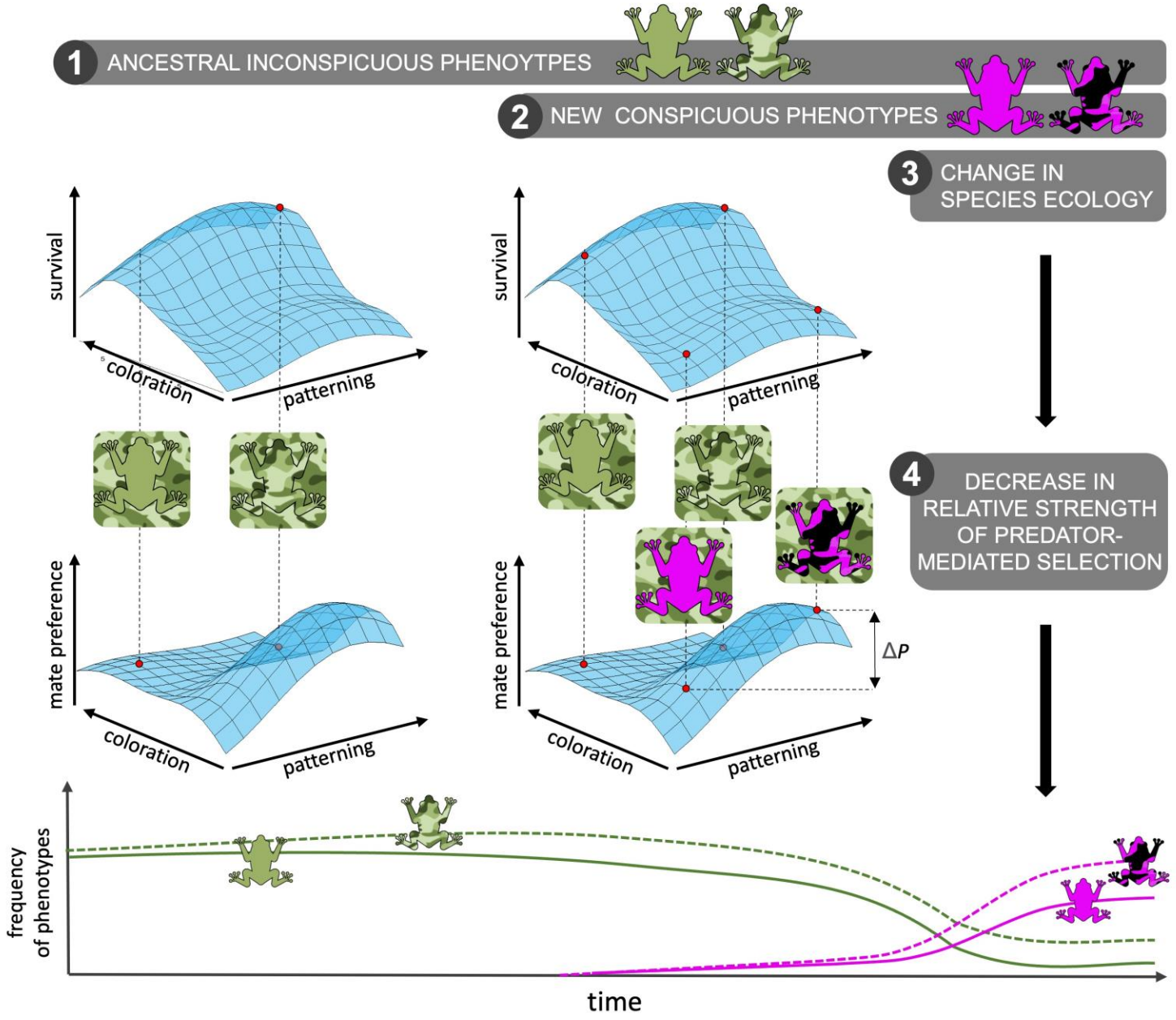


Héjja-Brichard et al., bioRxiv, 2023

Camouflage patterns could serve as evolutionary precursors of sexual signals

through the exploitation of processing bias

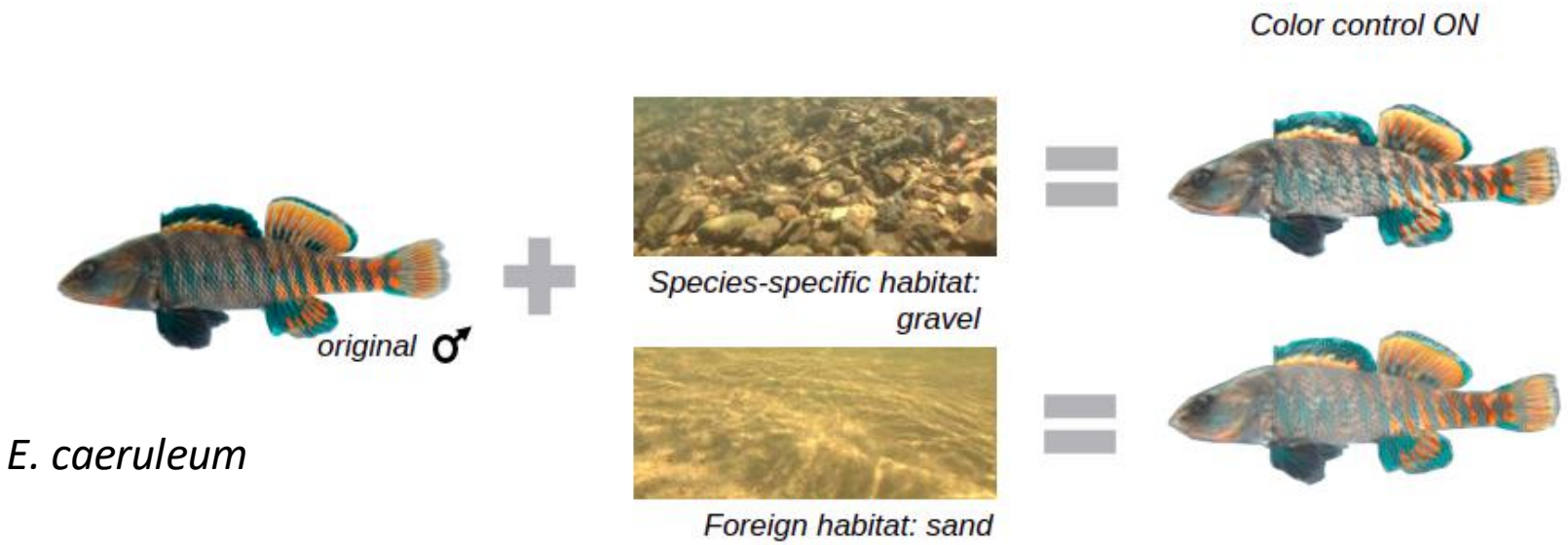
Ranitomeya benedicta



Darters

Generative AI to study the evolution of sexual signal design in an ornamented fish

Using AI to apply the statistics of a species' habitat to its sexual signal design



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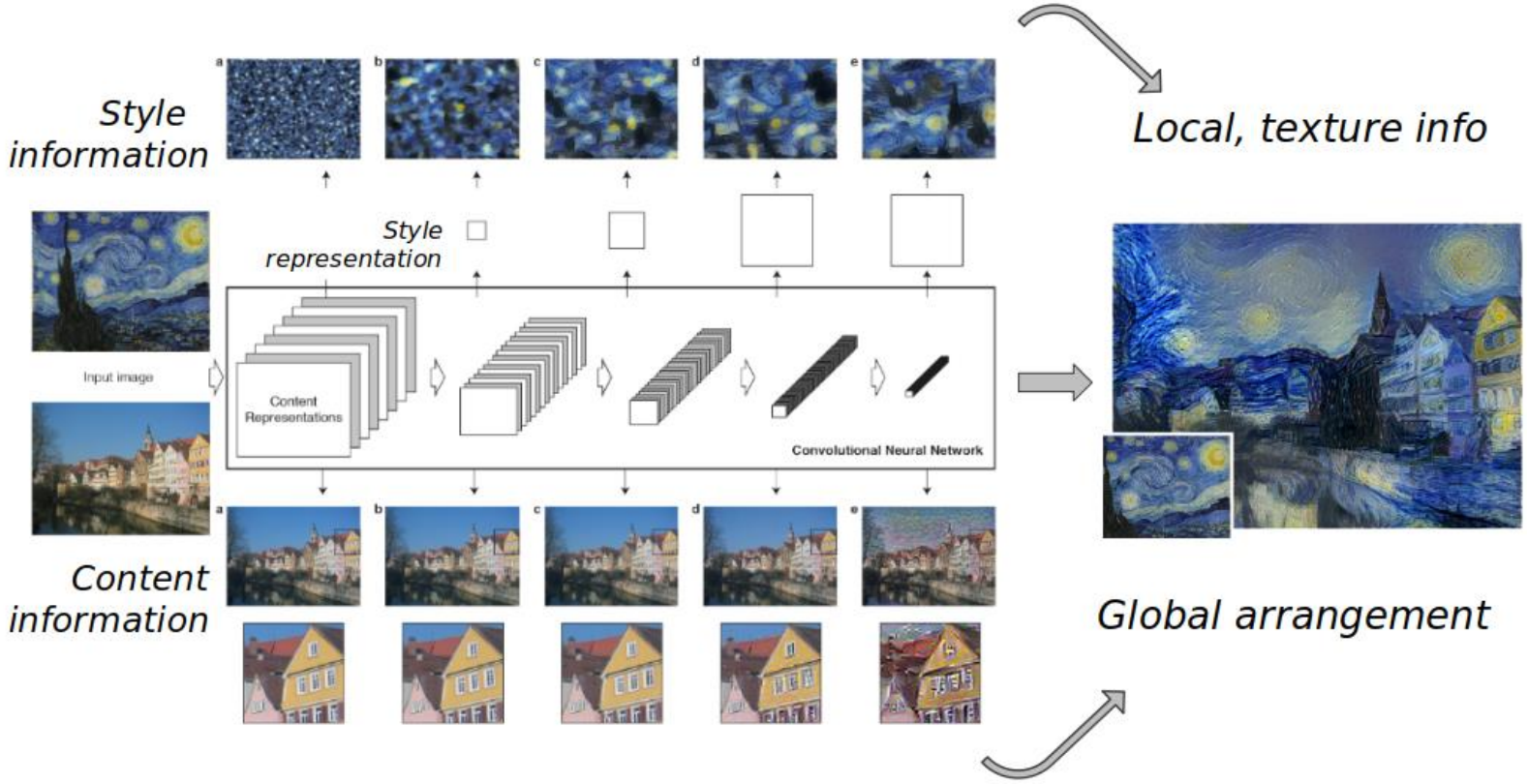

"Neural Style Transfer" (Gatys et al 2016)

Generative AI to study the evolution of sexual signal design in an ornamented fish

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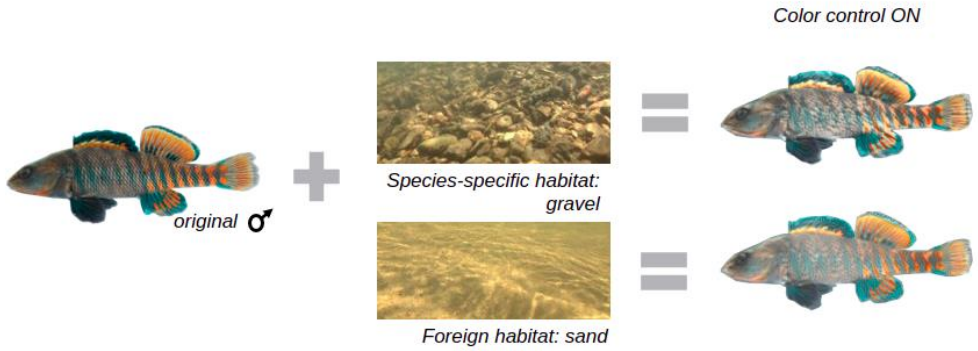
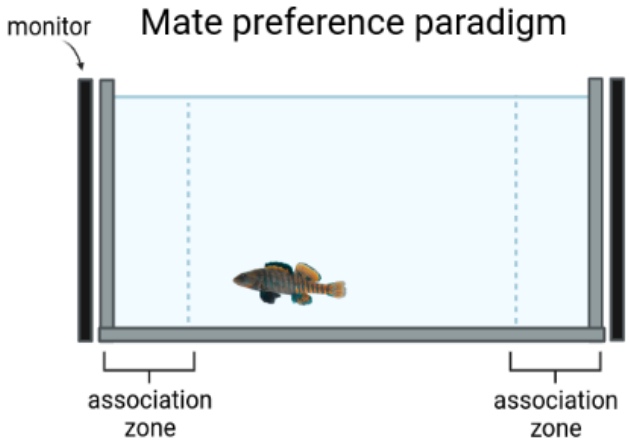
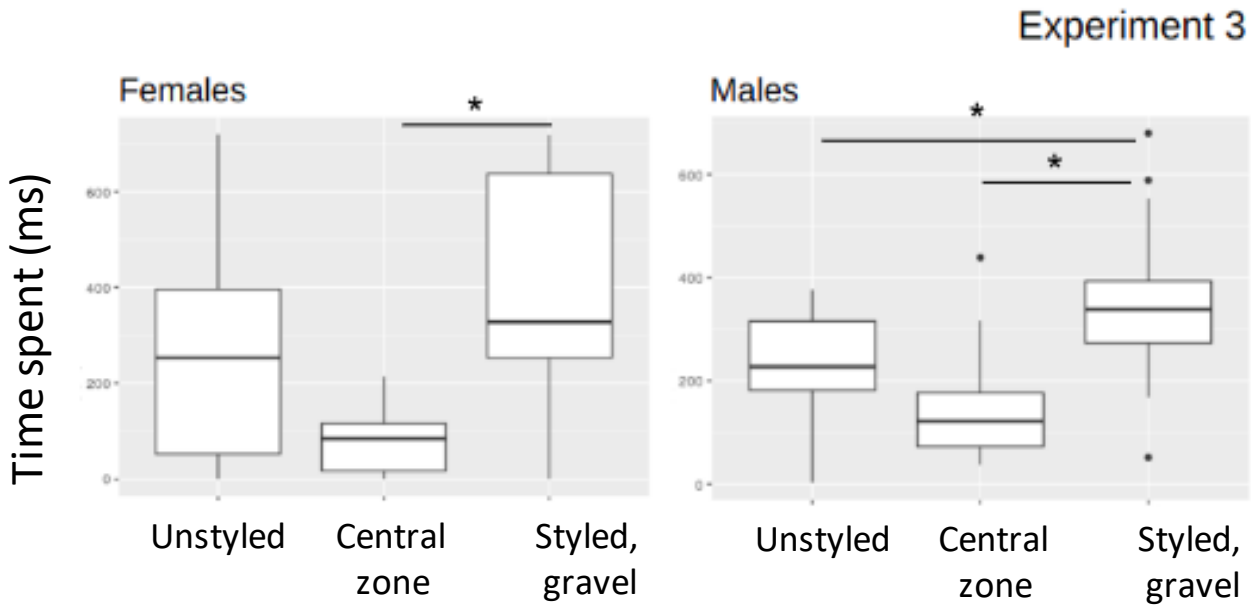


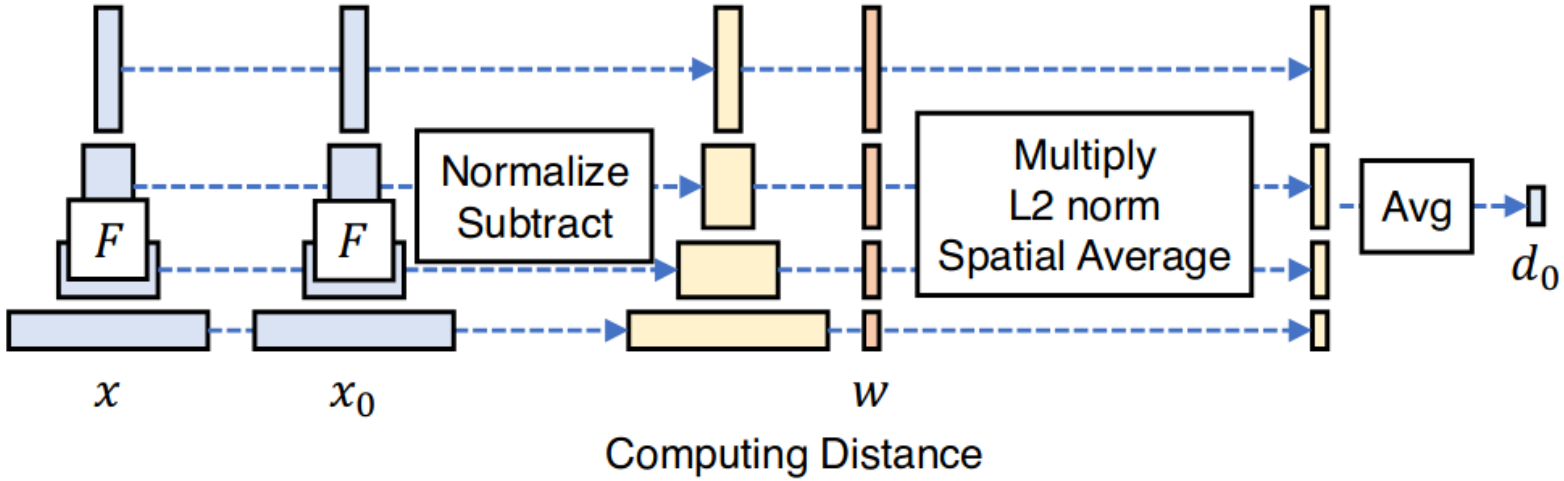




Héjja-Brichard et al., bioRxiv 2023

Deep Features as a Perceptual Metric

"Perceptual distance", a measure of how similar are two images



$$d(x, x_0) = \sum_l \frac{1}{H_l W_l} \sum_{h,w} ||w_l \odot (\hat{y}^l_{hw} - \hat{y}^l_{0hw})||_2^2$$

Zhang et al., 2018

Deep Features as a Perceptual Metric

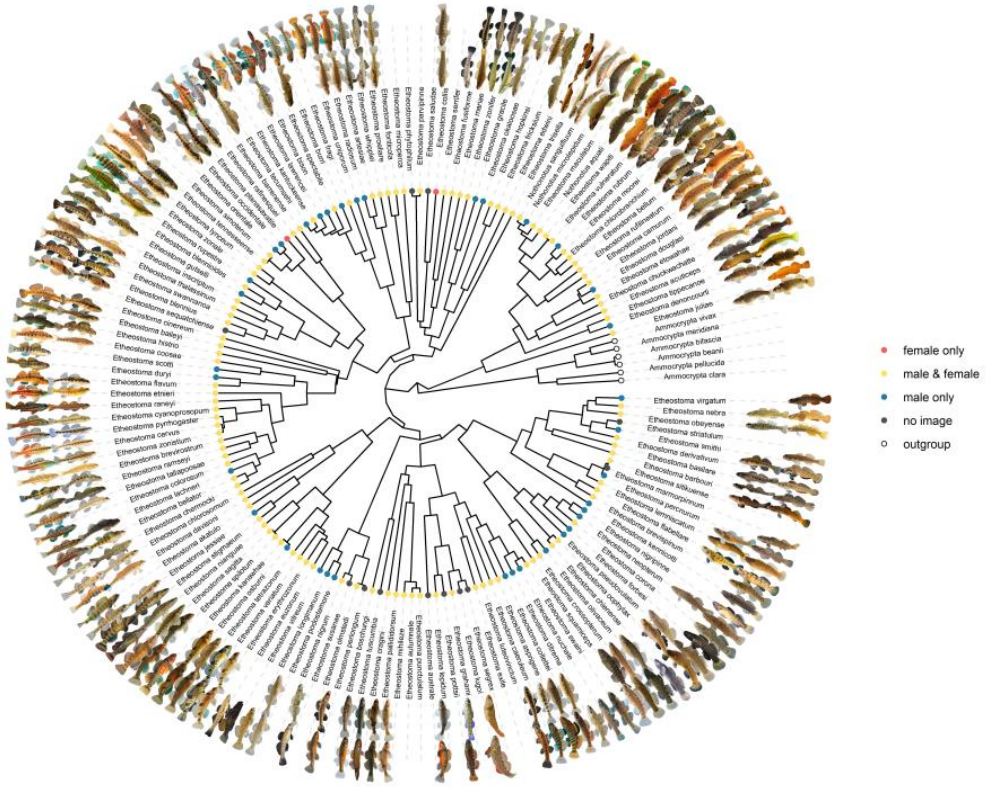
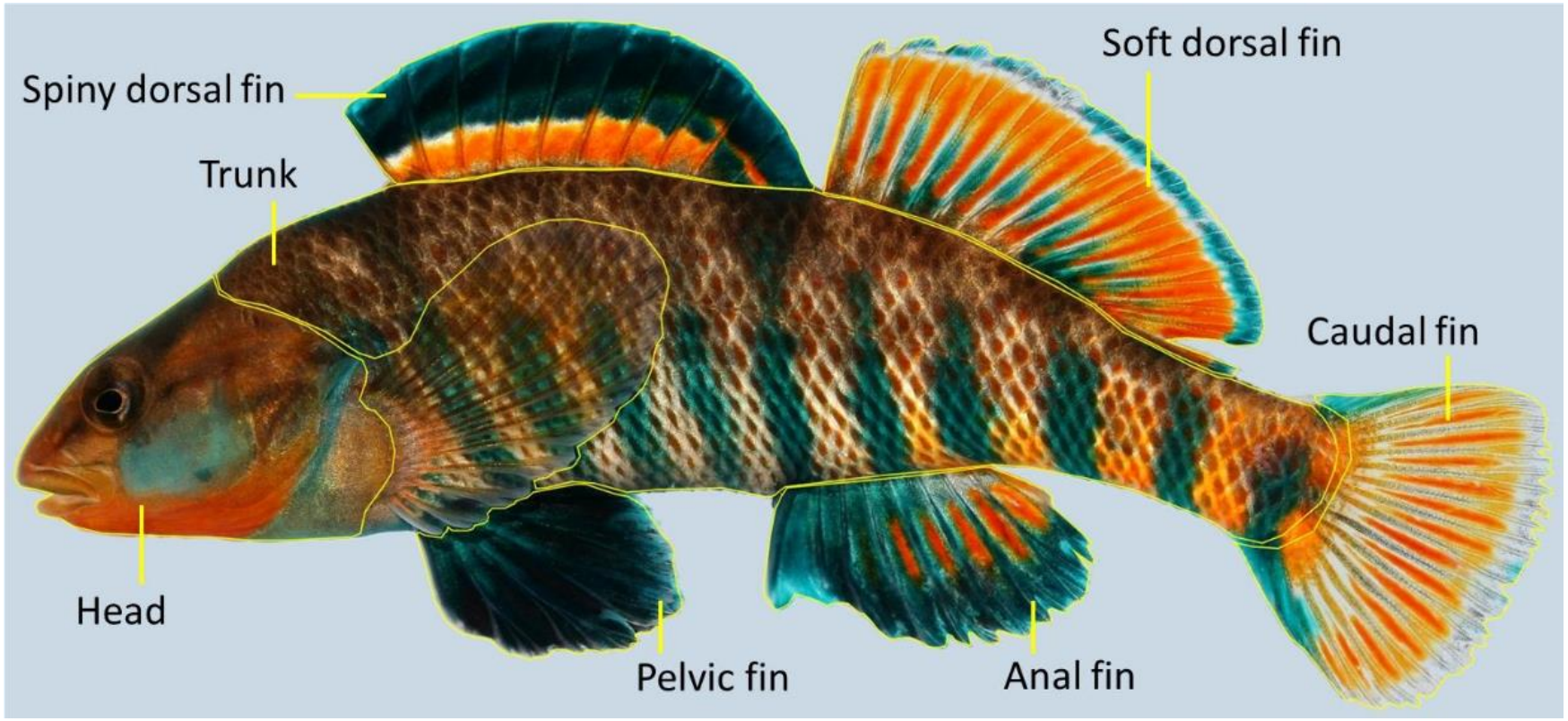


Image dataset: 268 images covering 153 species

habitat similarity matrices
based on written description

Moodie et al., in prep

Deep Features as a Perceptual Metric



Moodie et al., in prep

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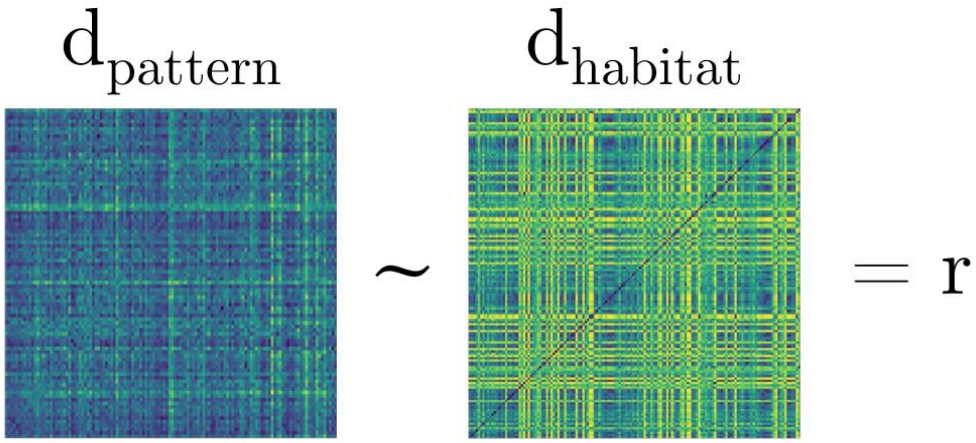
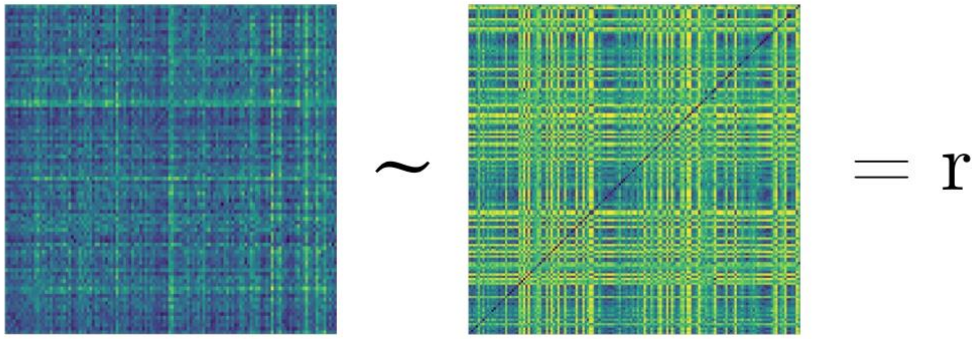
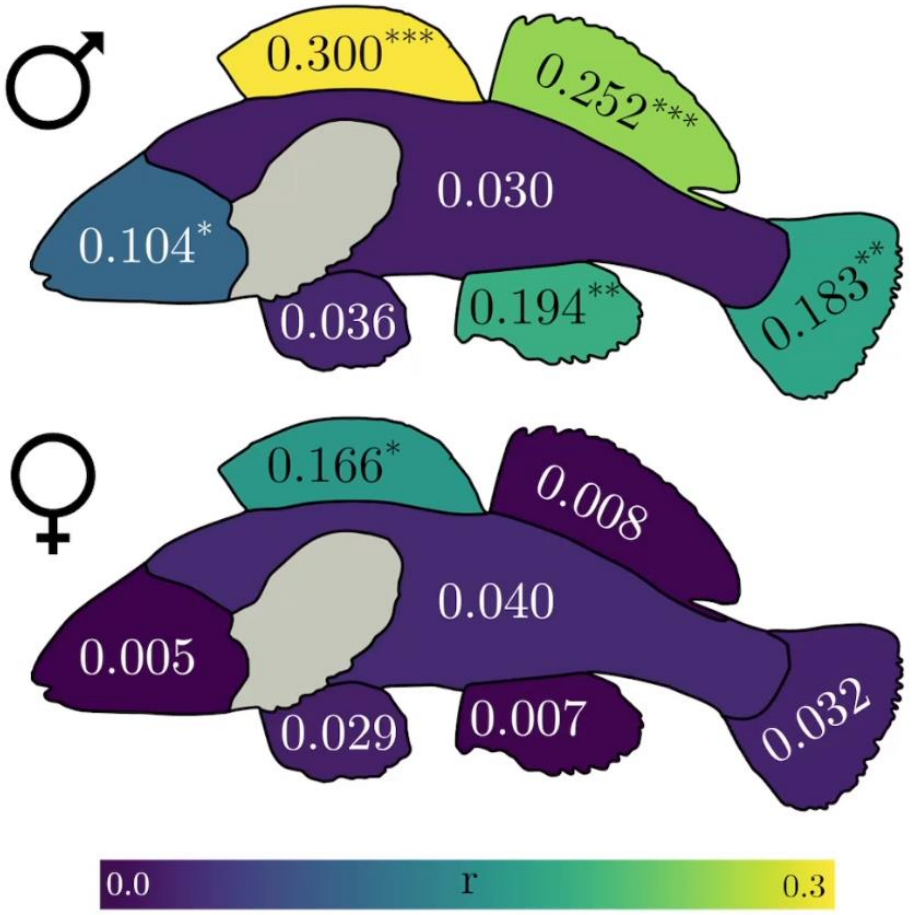


Darter vision: dichromatic model using cone sensitivities peaking at 525 and 603 nm (Gumm et al, 2012)

Moodie et al., in prep

Deep Features as a Perceptual Metric

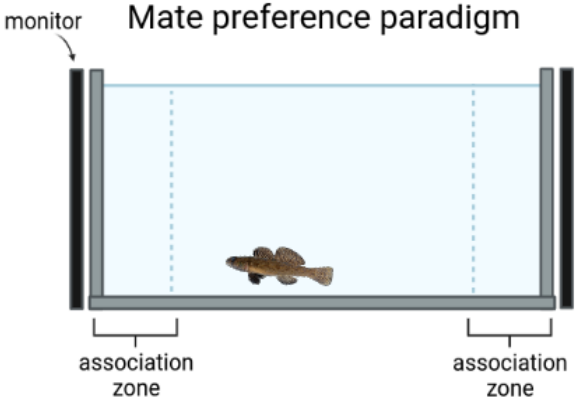




Moodie et al., in prep

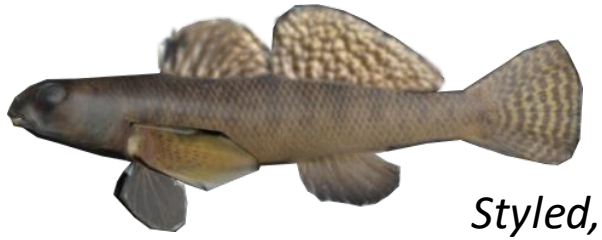
Testing the dorsal fin hypothesis

E. olmstedi



Unstyled

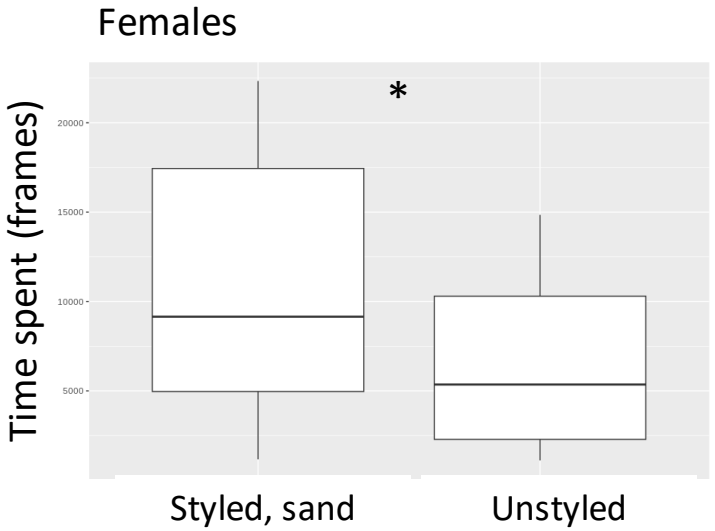
Styled, sand

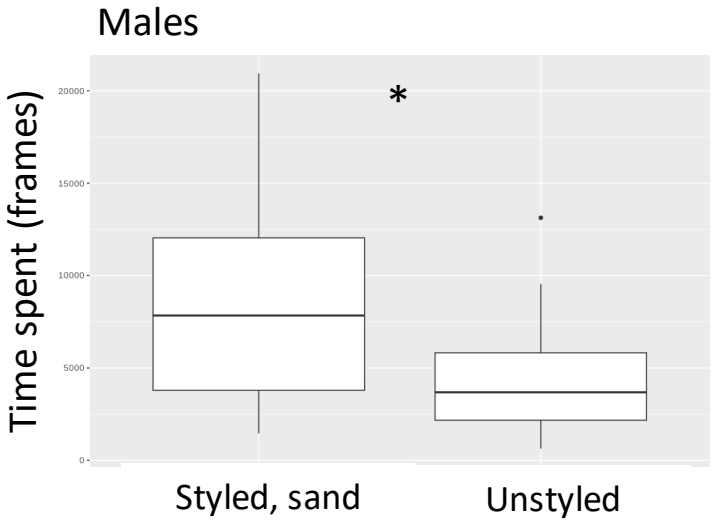


Styled, gravel

Renous et al., in prep

Testing the dorsal fin hypothesis





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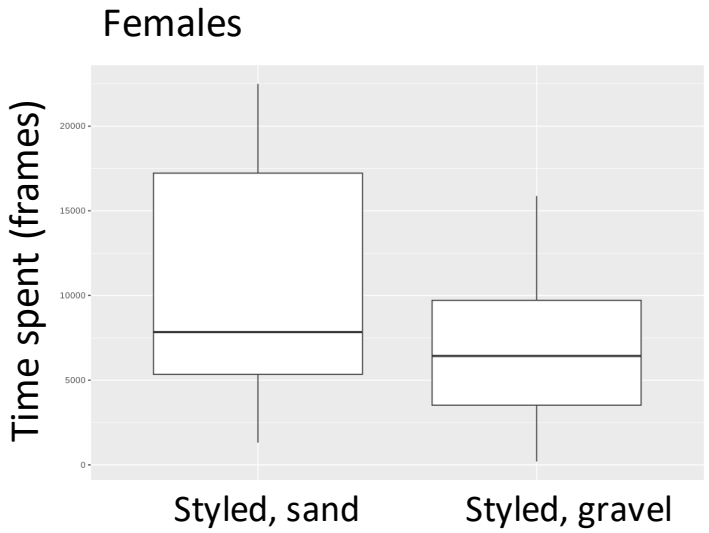

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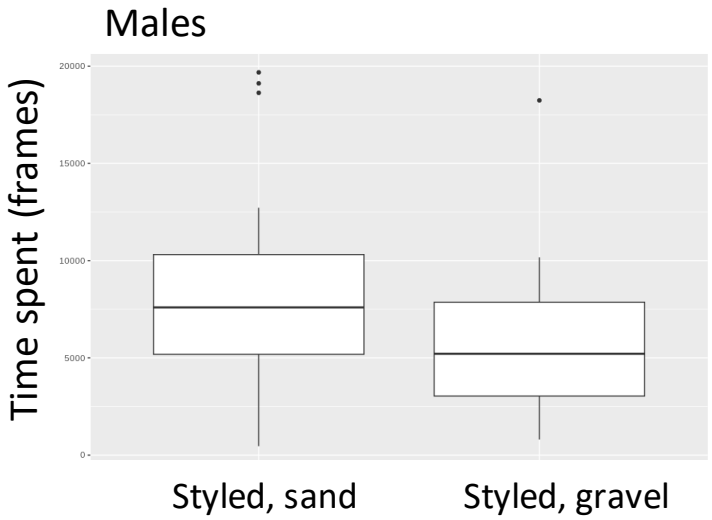
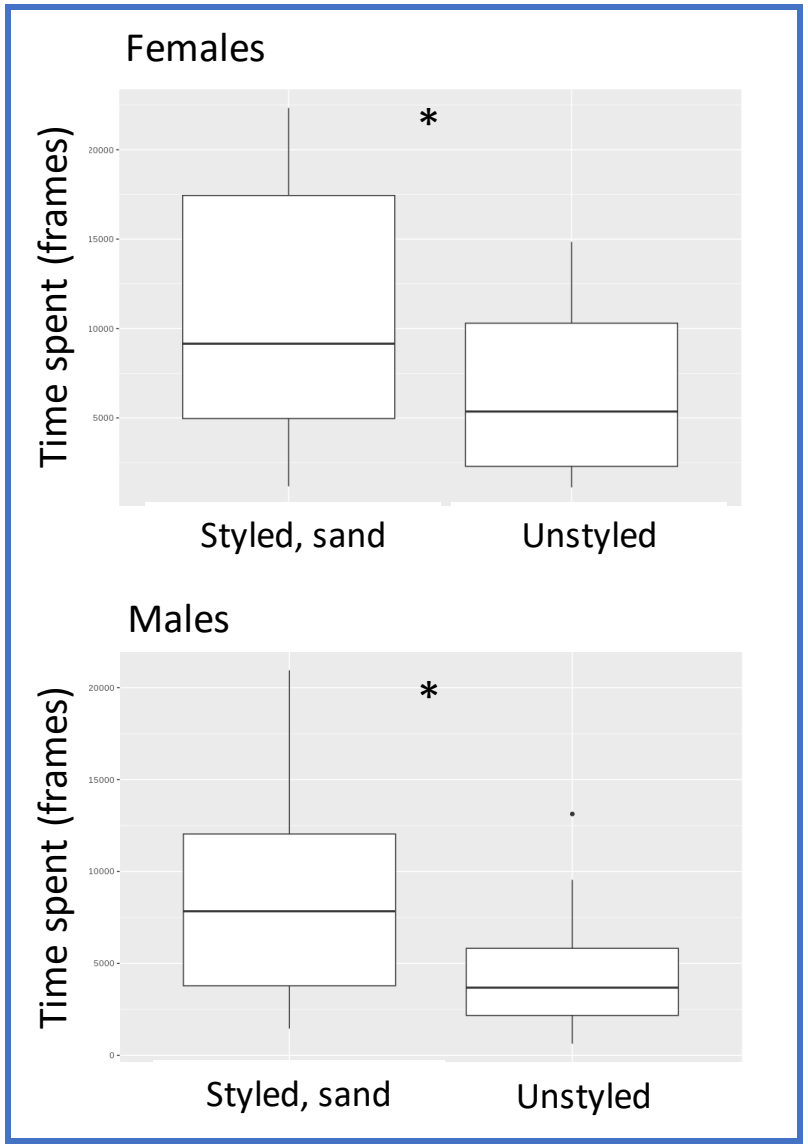
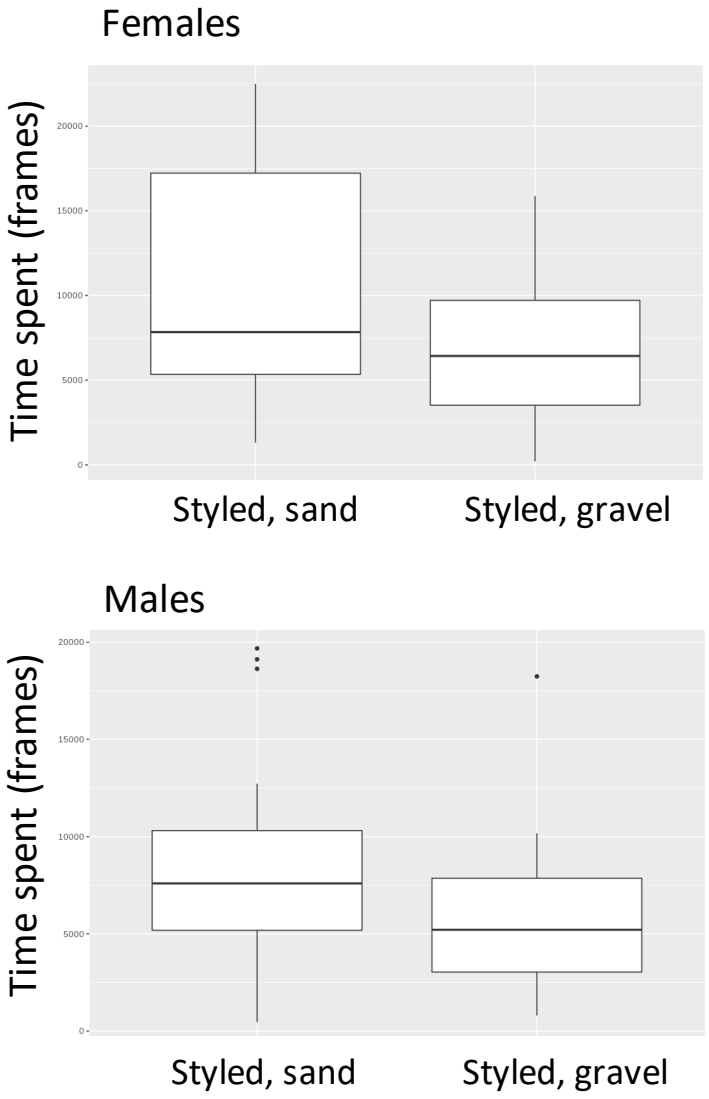


Renous et al., in prep

Testing the dorsal fin hypothesis





Unstyled

Styled, sand

Styled, gravel

Renous et al., in prep

Testing the dorsal fin hypothesis

Led by Kara Million

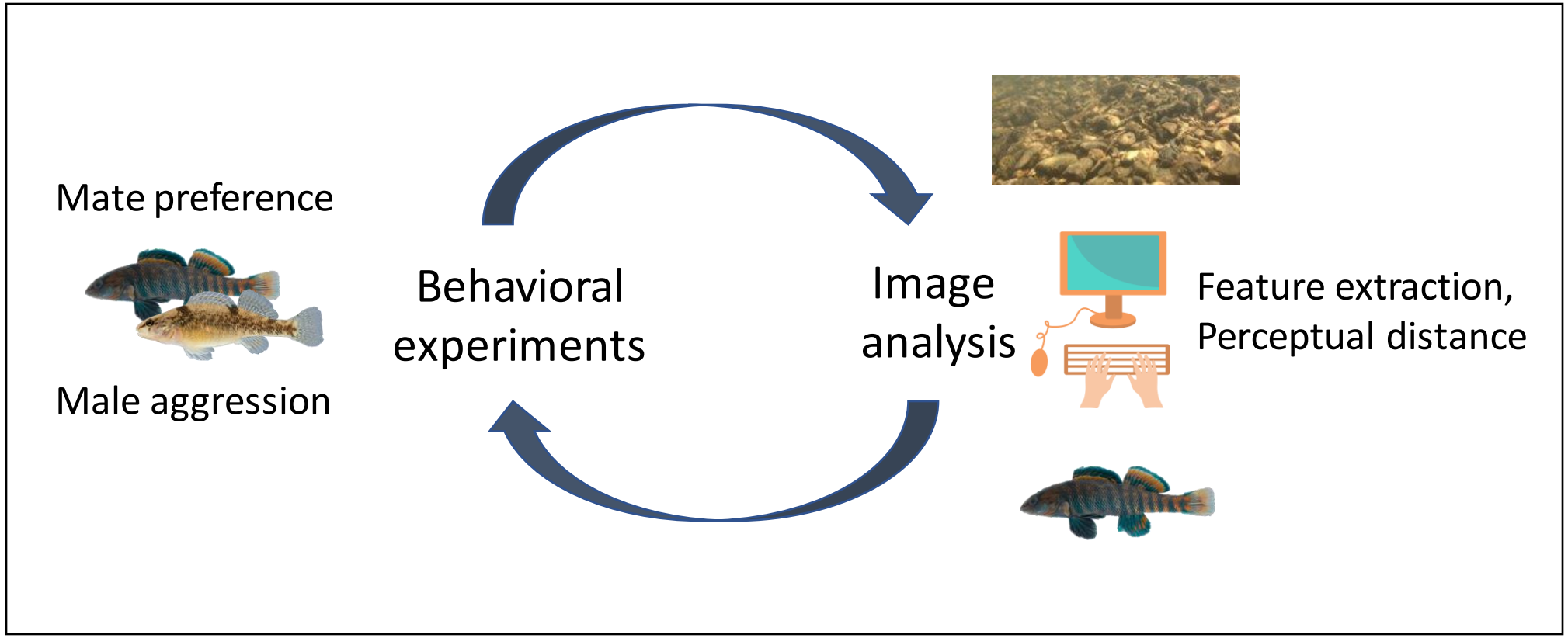
Why do *fish* choose certain mates?

- Fish prefer signals that match the natural stats of their habitats
- Supports the efficient processing hypothesis
- In *Etheostoma*, dorsal fins may be the salient signal

E. variatum

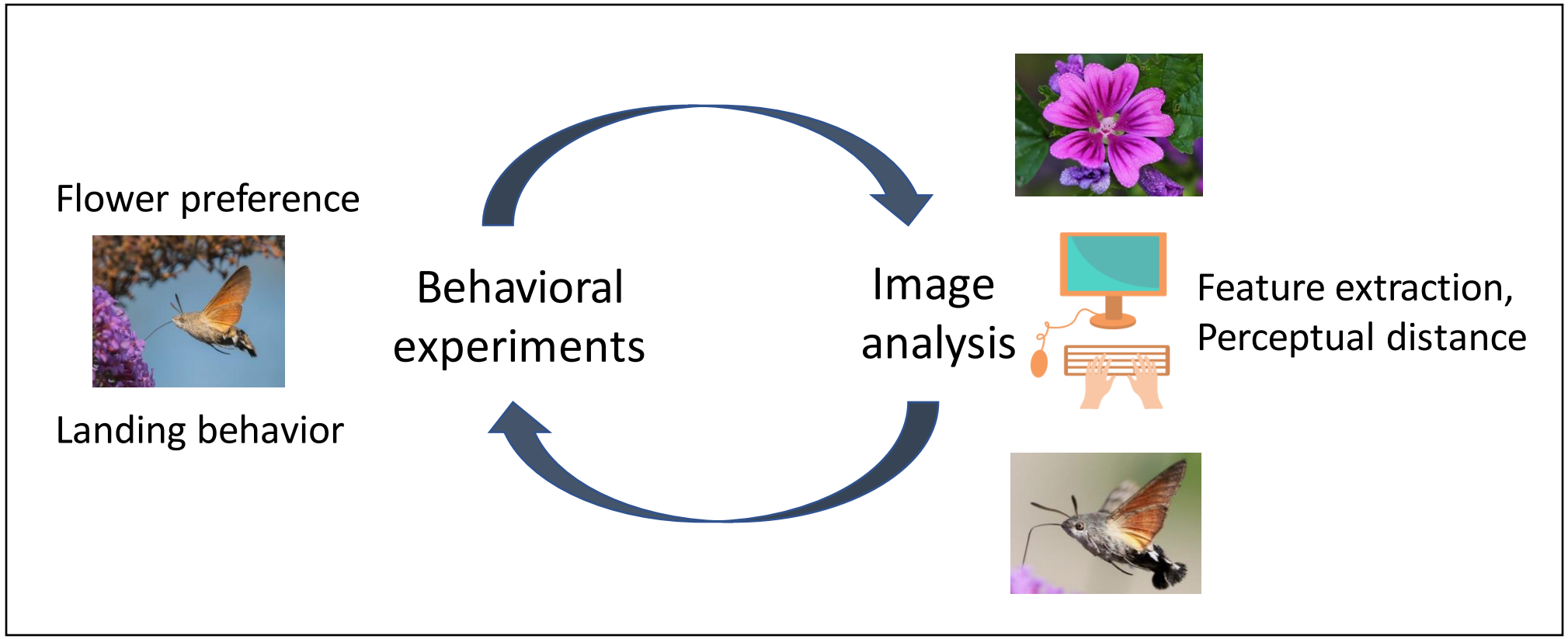
Mac Albin

DL is a transformative tool for visual ecology



Review paper: Renoult & Héjja-Brichard (*in prep*). Using artificial intelligence to advance the study of visual communication in ecology and evolution.

DL is a transformative tool for visual ecology



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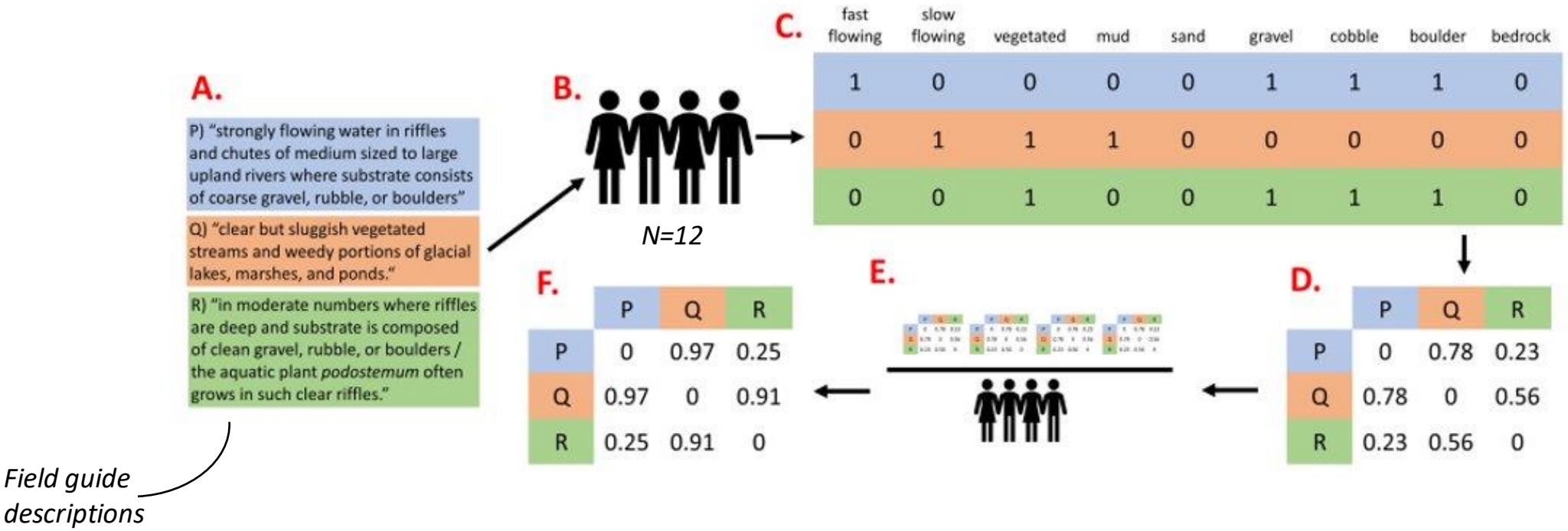
Thank you!

Tamra Mendelson & Julien Renoult

Method to convert written descriptions to habitat dissimilarity matrices