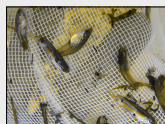


## Colour Vision is Largely Tuned by Opsins

- Colour vision is accomplished by comparing signals from cone cells that are tuned to different wavelengths of light
- Opsins are proteins expressed in cone cells that play a primary role in cone cell tuning and require no post-translational modification
- Opsins can drive variation in colour vision through either sequence level differences (changing the tuning of cone cells expressing those opsins) or through differences in the proportion of cone cells expressing the various opsins



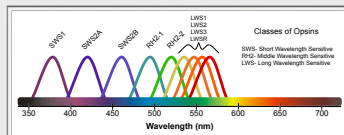
Normal Human Colour Vision  
(three opsins)



Same Scene As Perceived by Human  
Missing the LWS Opsin (Protanopia)

## Background

### Guppy Colour Vision



(Cartoon only: Absorbance spectra not to scale)

### Guppies Possess Nine Cone Opsin Genes!

- Guppies possess an unusually large number of Long Wavelength Sensitive opsins (LWS) - responsible for detecting red/orange colours - a key trait in female guppy mate choice decisions

## Guppy Mate Choice

### Natural-Sexual Selection Balance Results in Population Differences in the Strength of Female Preference for Red/Orange Male Colouration

- Watersheds in Trinidad were colonized independently from high to low predation habitats, resulting in replicated evolution
- Low predation habitats have frequently evolved stronger female preferences for red/orange coloration
- We focus on the Aripo and Marianne watersheds where stronger female preferences for red/orange are known to have evolved in low predation populations

High Predation Male  
Aripo Watershed



Low Predation Male  
Aripo Watershed

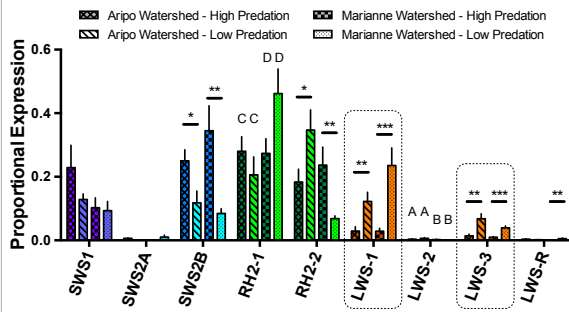


## Expression Differences

### Low Predation Populations Express Higher Levels of Long Wavelength Sensitive (LWS) Opsins

- Guppies from low predation populations expressed higher levels of the opsins detecting red/orange coloration (especially LWS-1 and LWS-3 opsins) than guppies from high predation populations in two independently colonized watersheds

### Proportional Opsin Expression (At 10:30 AM)



(Colour of bars correspond to wavelength range detected by that opsin class)

- There were no differences between males and females in opsin expression
- Opsin expression differed across timepoints throughout the day (07:30, 10:30, 13:30, 14:30) and these patterns varied across populations

## Allele Frequency Differences

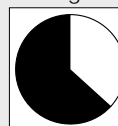
### The One Polymorphism for Amino Acids Known to Affect Tuning Varies Predictably Between Populations

- In guppies only LWS-1 is known to possess multiple alleles that differ in tuning: the amino acid at the 180 site varies from *Ala* to *Ser* and changes tuning of the opsin by 7nm
- Differences in the frequencies of these alleles between high and low predation populations was strikingly similar in both watersheds

High Predation

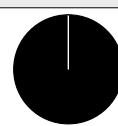
Low Predation

Marianne Watershed  
 $F_{ST} = 0.4393$



S/S - 36.7%  
S/A - 53.1%  
A/A - 10.2%

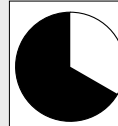
N = 49



S/S - 100%  
S/A - 0%  
A/A - 0%

N = 46

Aripo Watershed  
 $F_{ST} = 0.3211$



S/S - 40.7%  
S/A - 51.9%  
A/A - 7.4%

N = 54



S/S - 95.8%  
S/A - 4.2%  
A/A - 0%

N = 48

□ 180 Ala allele    ■ 180 Ser allele

### No Environmental Factors Explained Differences in Expression or Allele Frequency

- Parameters measured: Ap50, dissolved oxygen, water temperature, conductivity, pH, total dissolved solids, salinity

## Conclusions & Implications

### Colour Vision and Mate Preference Covary Across Populations

- Opsin expression and allele frequencies both differed in a consistent manner between high and low predation populations in two independently colonized watersheds

### Colour Vision Varies Within Species Across Populations

- Populations differed in opsin expression and allele frequencies

### Support for the Sensory Exploitation (SE) Hypothesis

- The SE hypothesis for the evolution of female mate preferences posits that differences in color-based mate preferences can be driven by differences in the tuning of the visual system

### Sensory Systems Vary Dramatically Within Species

- Modeling how species perceive their environment frequently relies on measures from one or a few individuals- this can be very misleading across populations



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