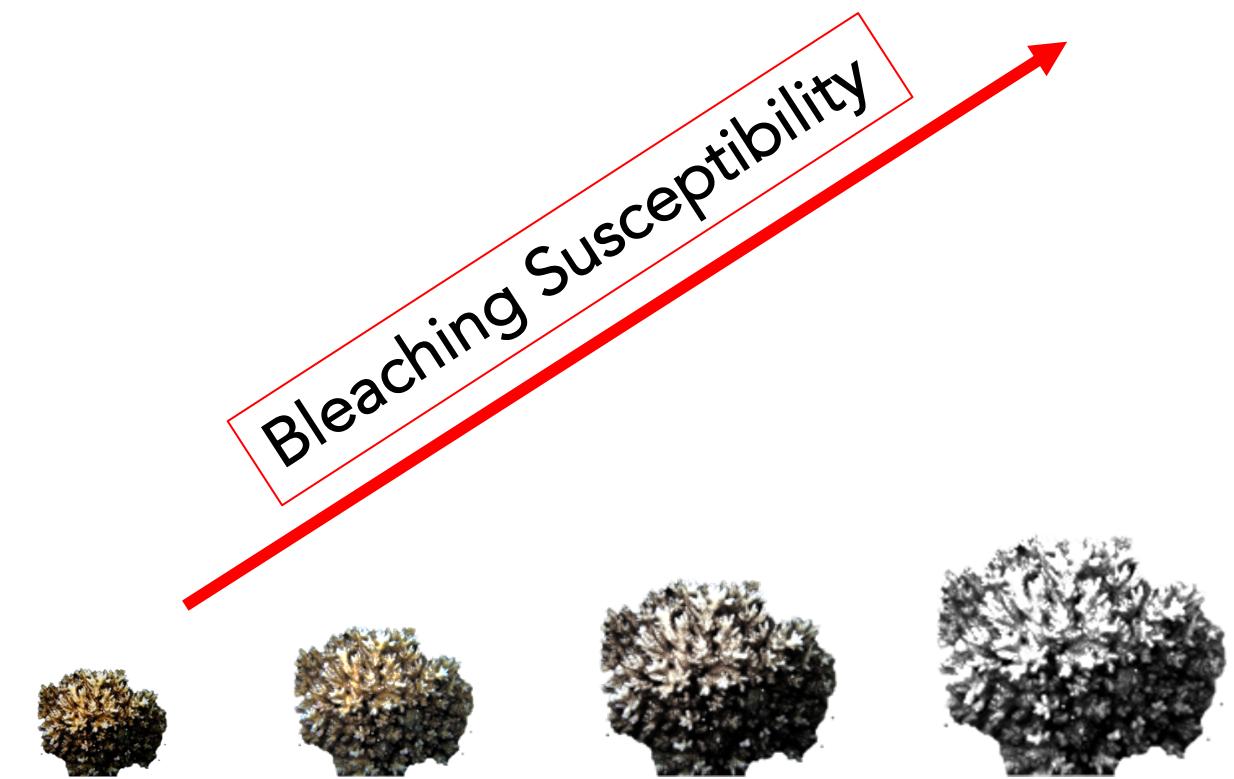


Liv Williamson  
@livwilliamson



Adapted from Shenkar et al. 2005

Shenkar et al. 2005, Alvarez-Noriega et al. 2018

Are there environmental and biological conditions that promote juvenile survival in high temperature?



## Larvae

Thermal exposure  
Embryonic development  
Settlement preferences

## Juveniles

Thermal exposure  
Nutrition  
Tissue fusion

## Parents

OA exposure  
Thermal exposure  
Nutrition



## Larvae

Thermal exposure  
Embryonic development  
Settlement preferences

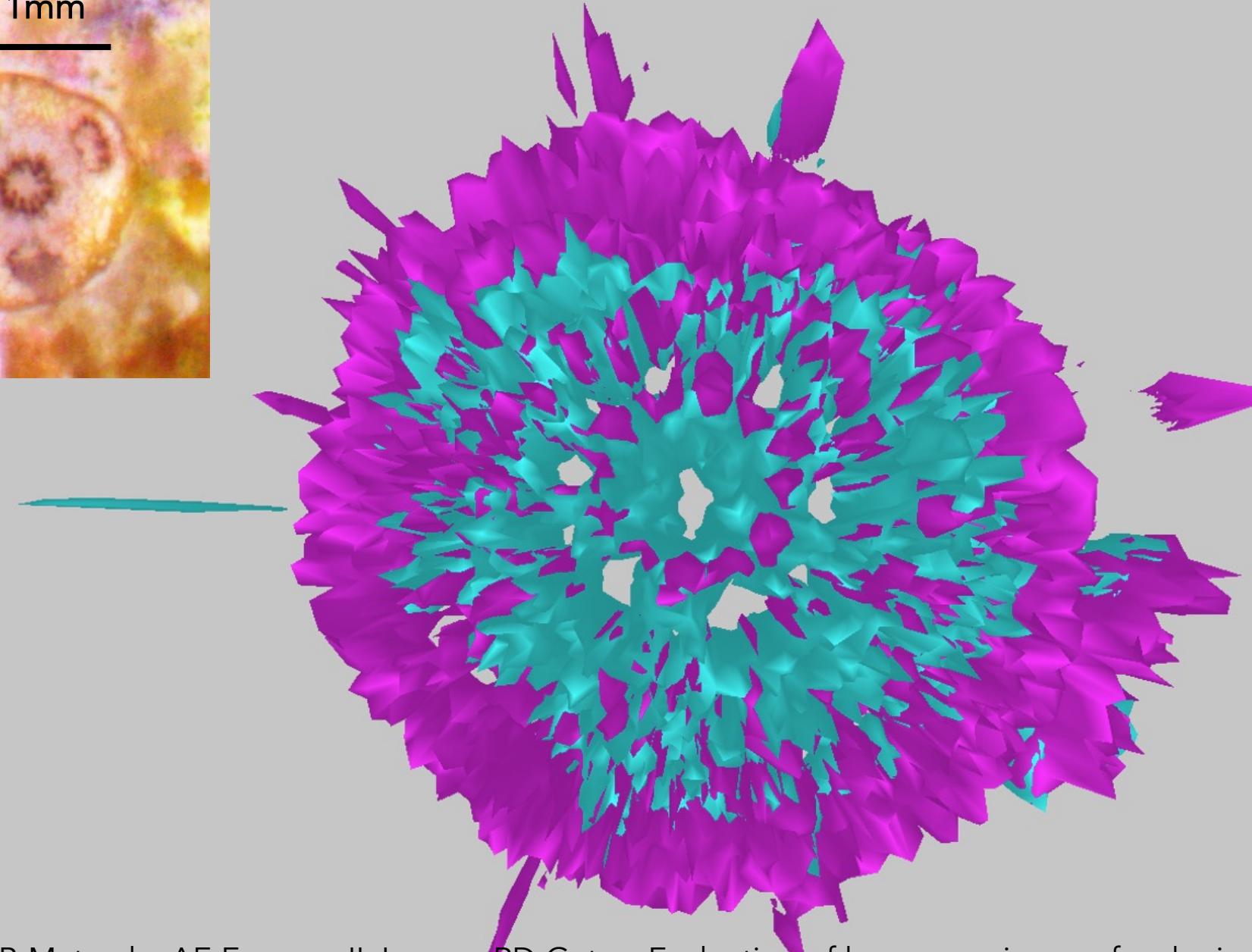
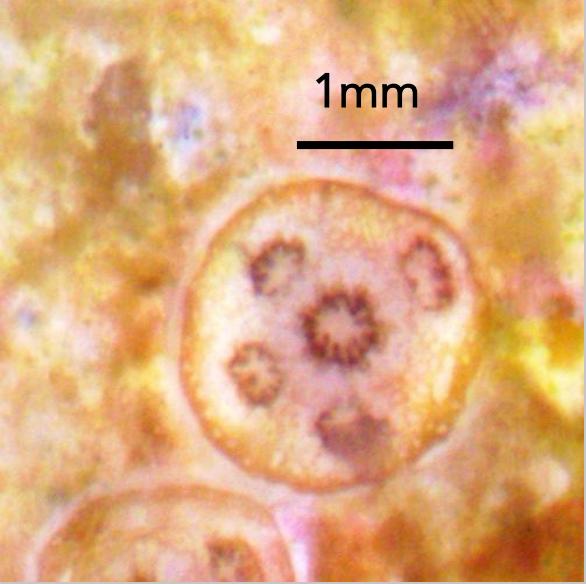
## Juveniles

Thermal exposure  
**Nutrition**  
Tissue fusion

## Parents

OA exposure  
Thermal exposure  
Nutrition





Shayle Matsuda

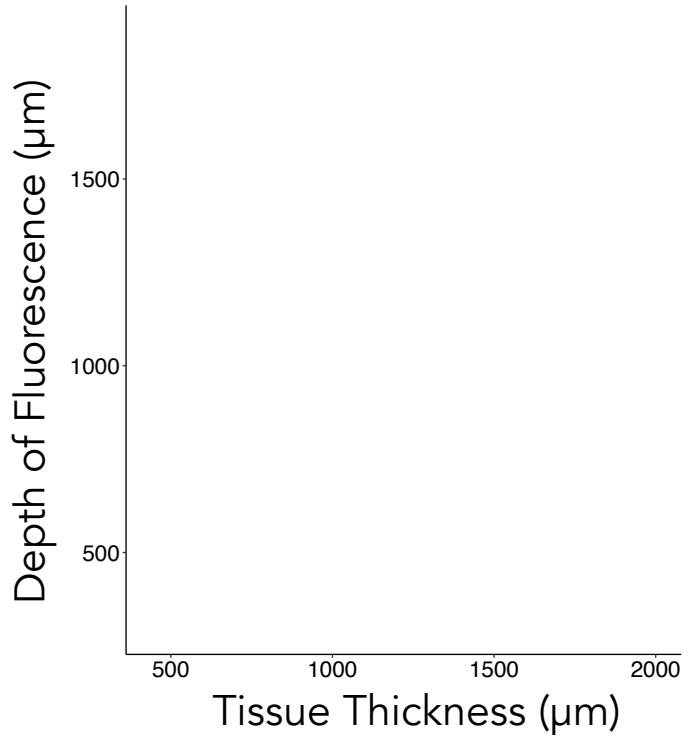


Amy Eggers

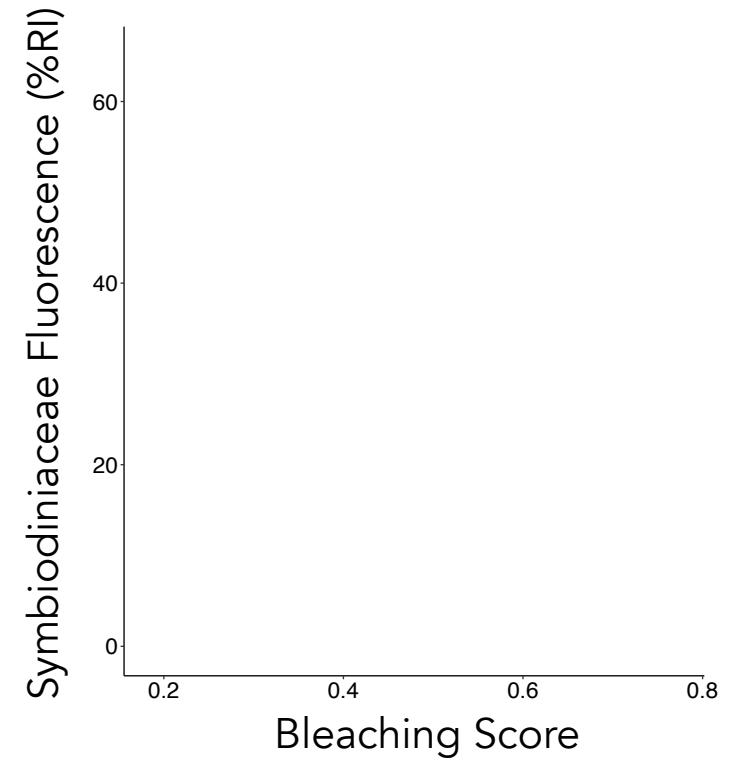
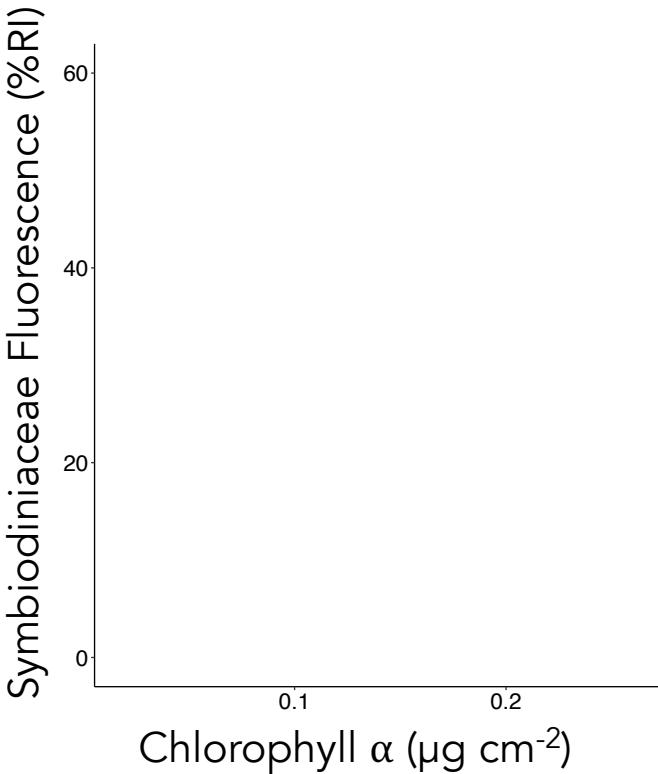
Huffmyer AS, SB Matsuda, AE Eggers, JL Lemus, RD Gates. Evaluation of laser-scanning confocal microscopy for measurement of reef-building coral tissue thickness and Symbiodiniaceae fluorescence. *In review. Journal of Experimental Biology.*

# LSCM is a non-destructive tool to measure physiology

Tissue Thickness



Symbiodiniaceae Fluorescence



Ambient

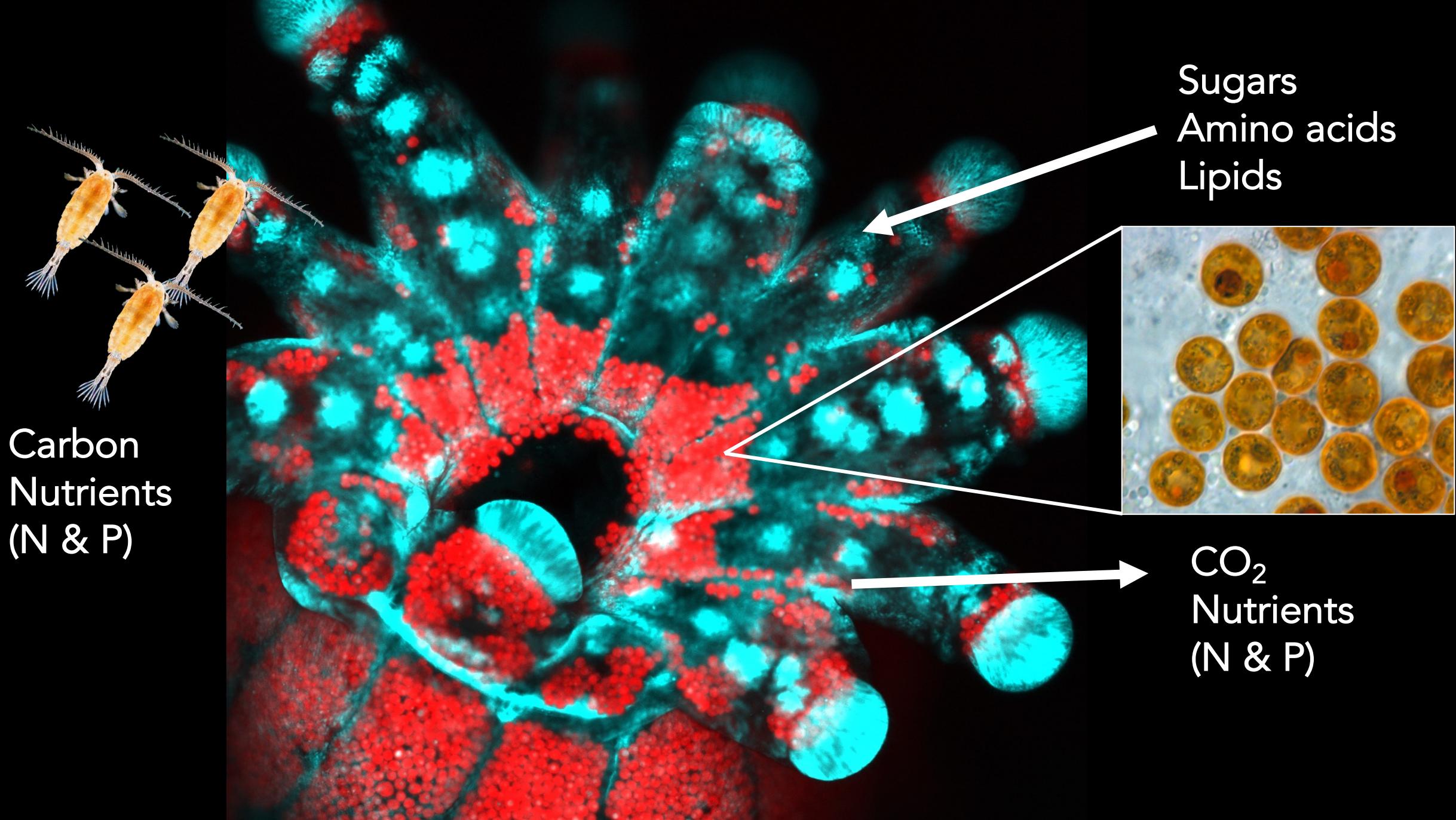
*P. acuta*

*M. capitata*

High

*P. acuta*

*M. capitata*

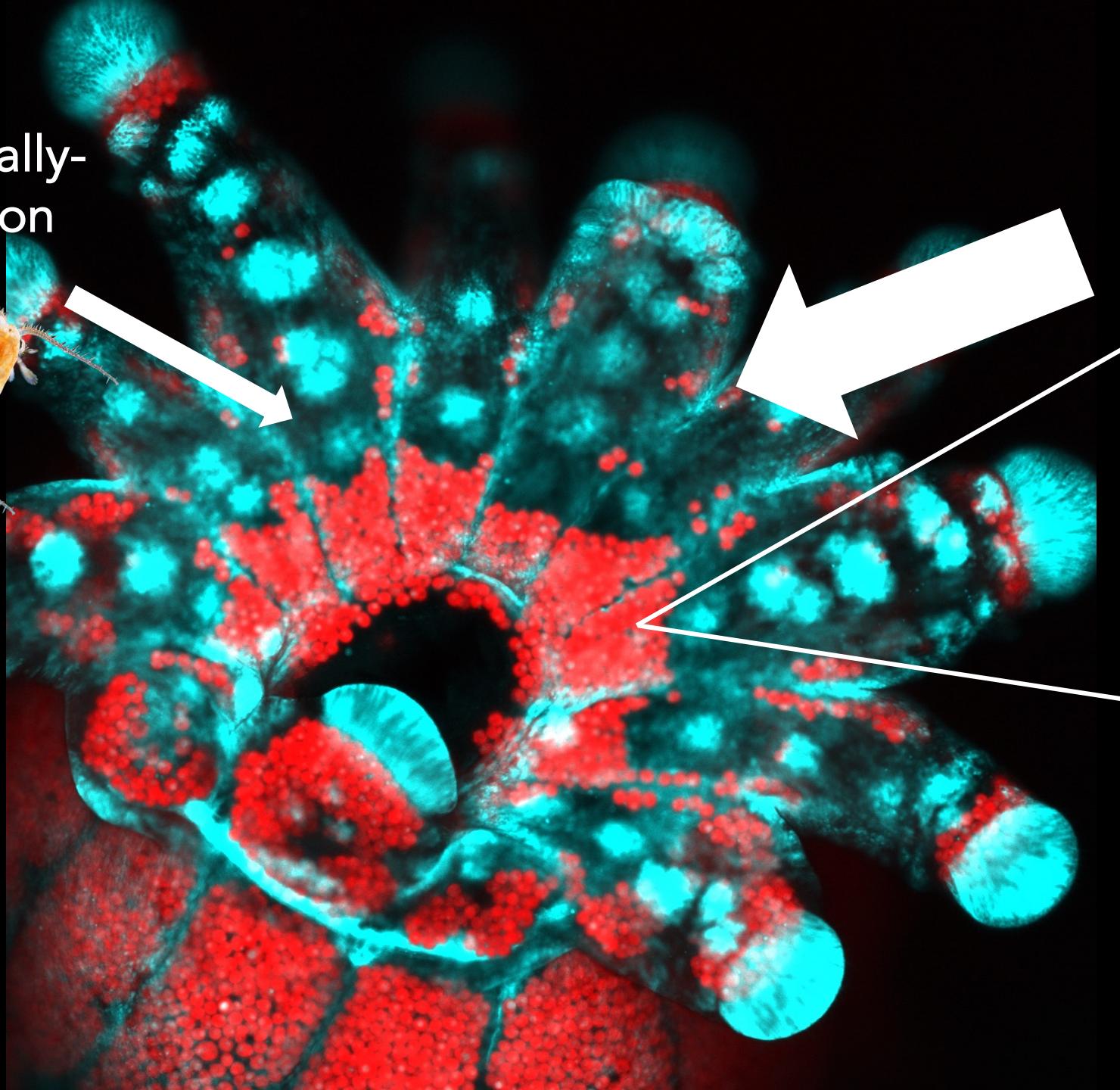


Carbon  
Nutrients  
(N & P)

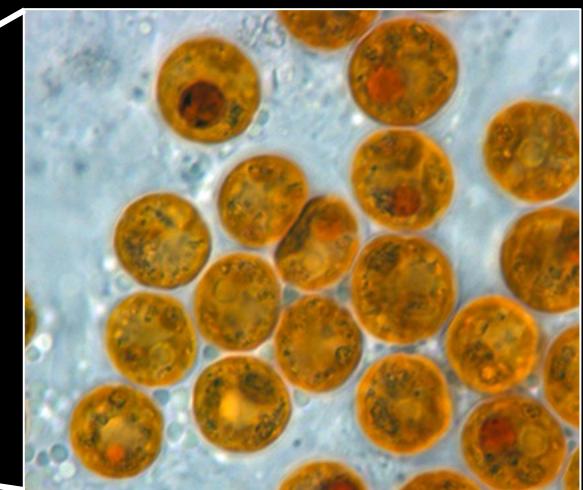
Sugars  
Amino acids  
Lipids

CO<sub>2</sub>  
Nutrients  
(N & P)

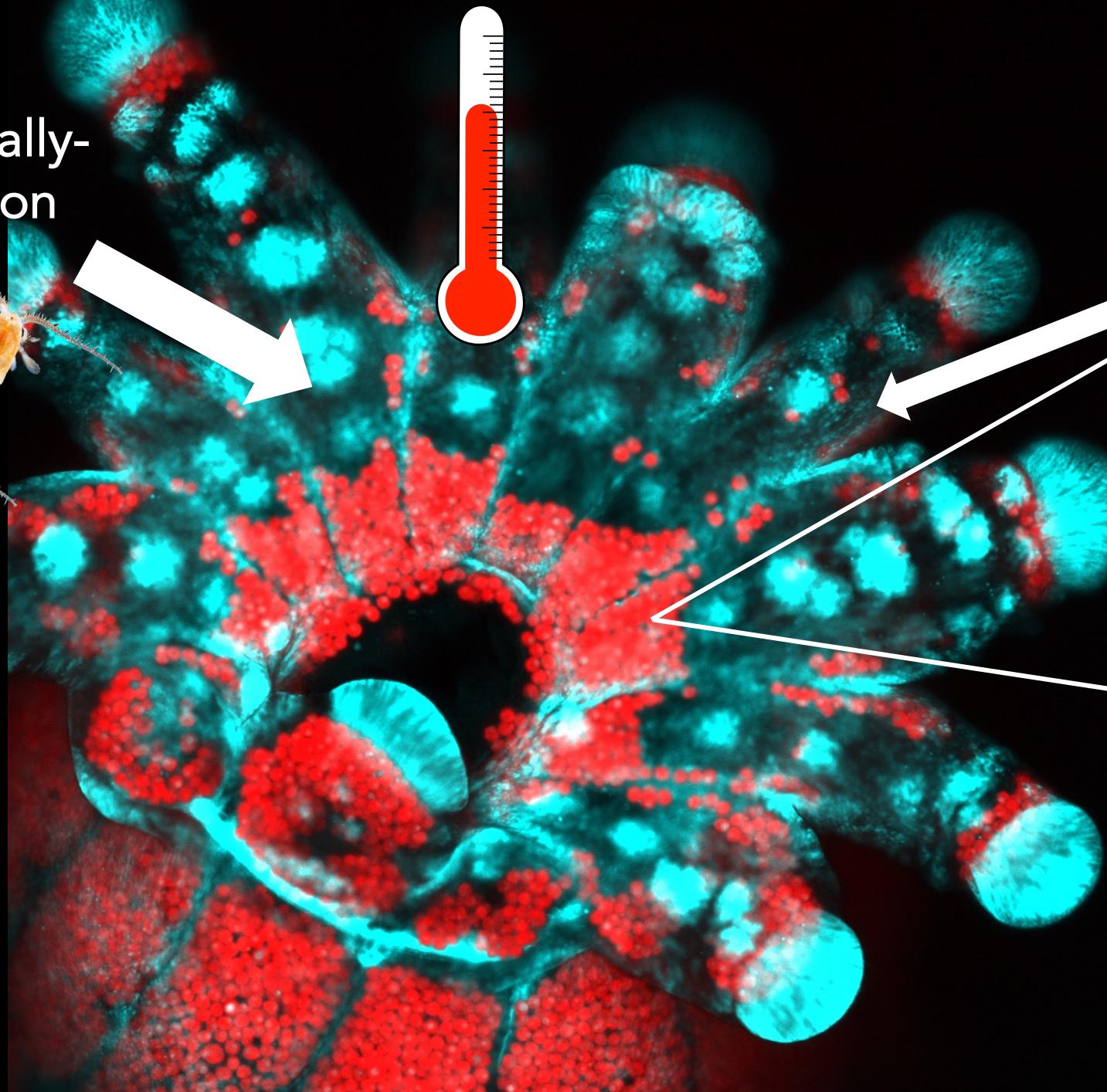
Heterotrophically-derived nutrition



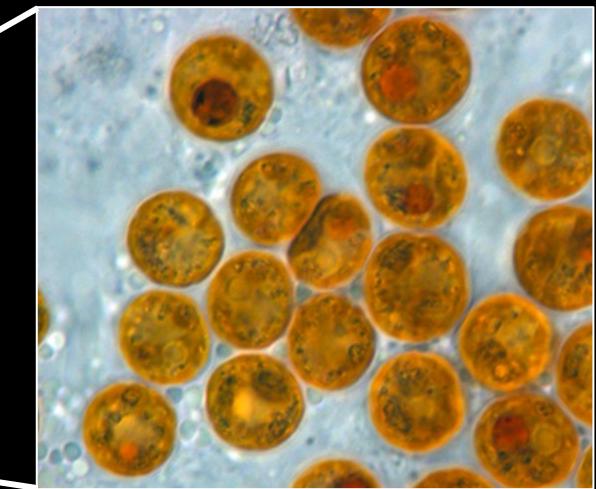
Autotrophically-derived nutrition



Heterotrophically-derived nutrition



Autotrophically-derived nutrition

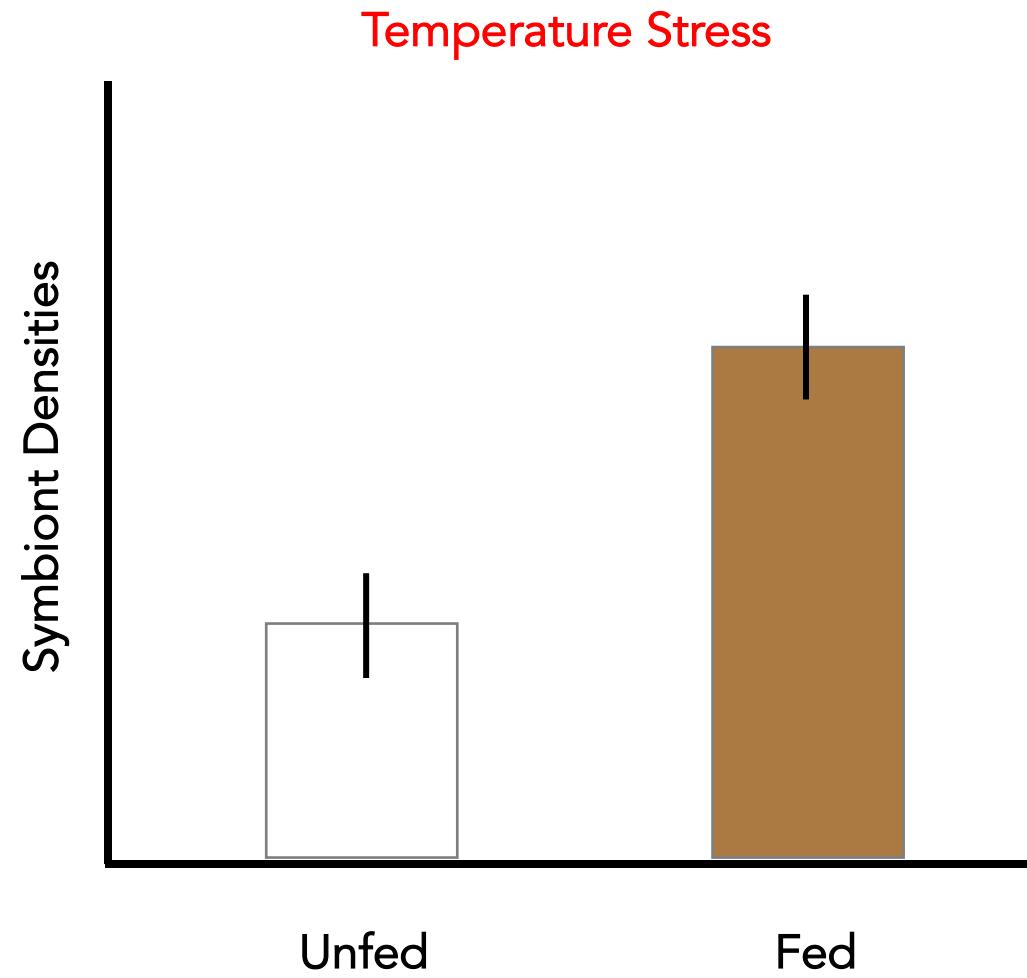


- + ROS
- Densities
- Chlorophyll

# Feeding is an important component of coral nutrition

- Calcification
- Energetic storage (e.g. lipids)
- Symbiodiniaceae densities
- Symbiodiniaceae chlorophyll
- Photosynthesis

Houlbreque & Ferrier-Pages 2009, Baumann et al.  
2014, Houlbreque et al. 2003

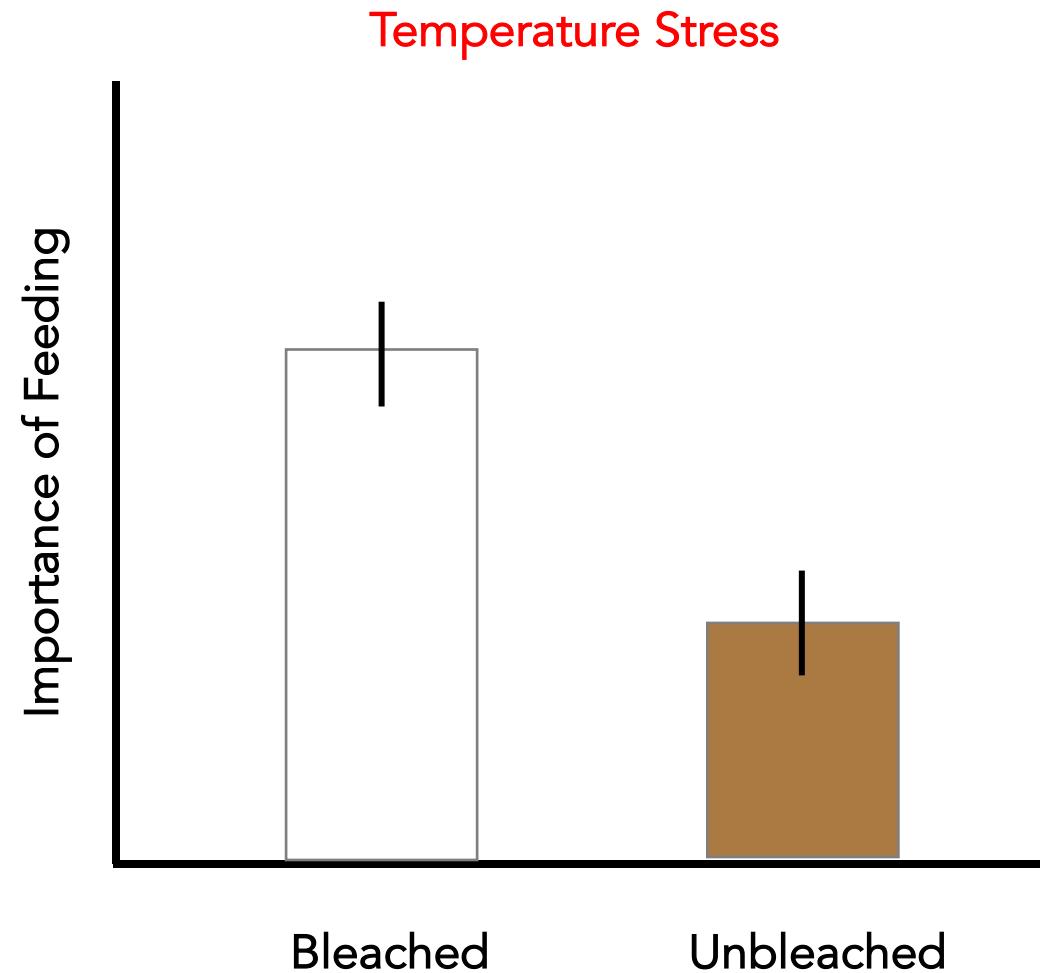


Adapted from Aichelman et al. 2013

# Feeding is an important component of coral nutrition

- Calcification
- Energetic storage (e.g. lipids)
- Symbiodiniaceae densities
- Symbiodiniaceae chlorophyll
- Photosynthesis

Houlbreque & Ferrier-Pages 2009, Baumann et al.  
2014, Houlbreque et al. 2003



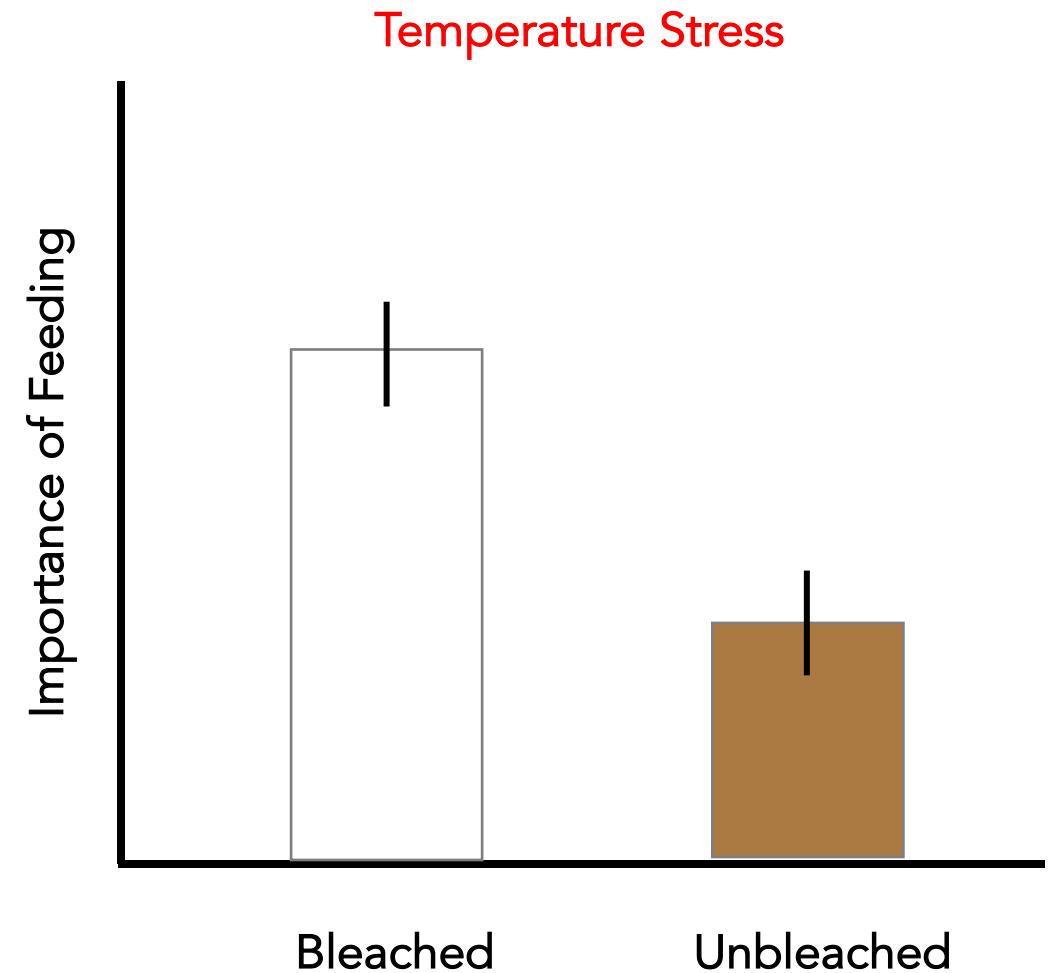
Adapted from Grottoli et al. 2006, Palardy et al. 2008

# Feeding is an important component of coral nutrition

## Variability in responses:

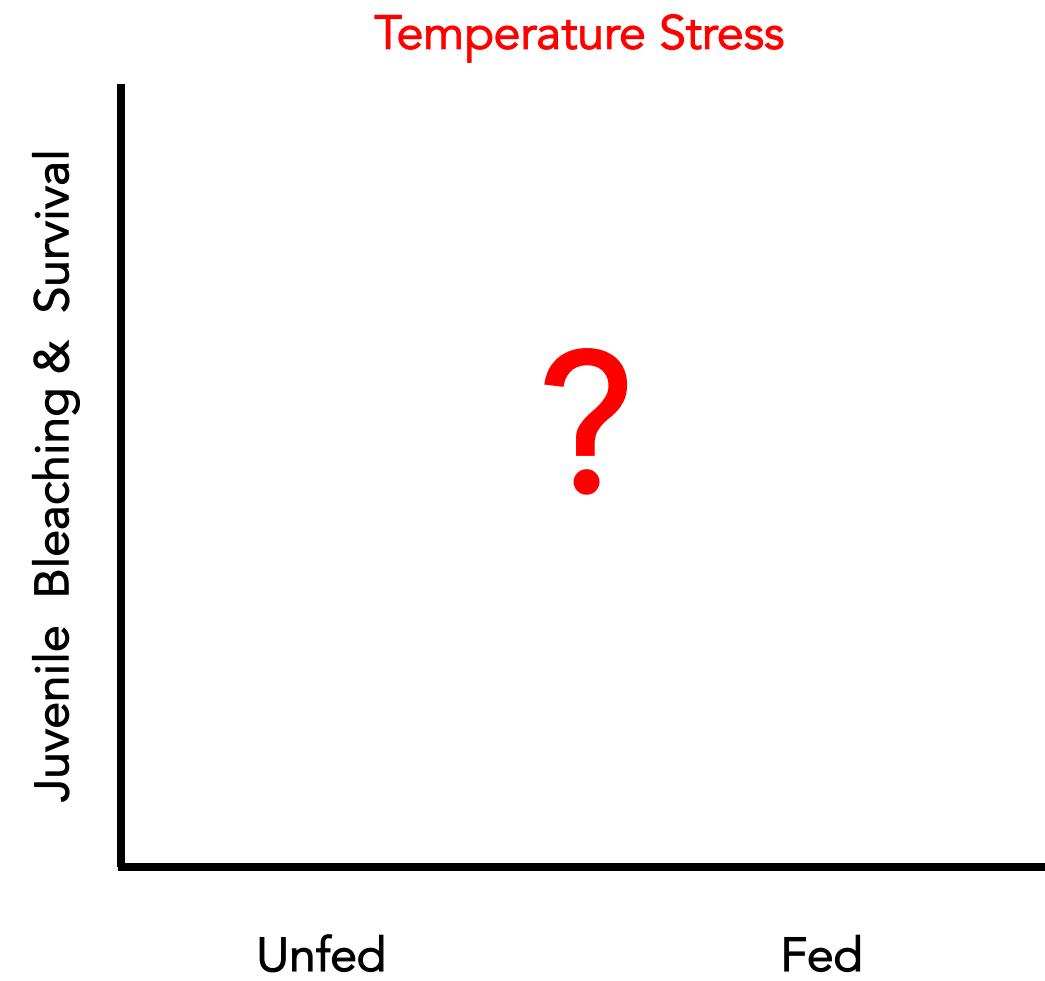
- Species
- Season
- Habitat

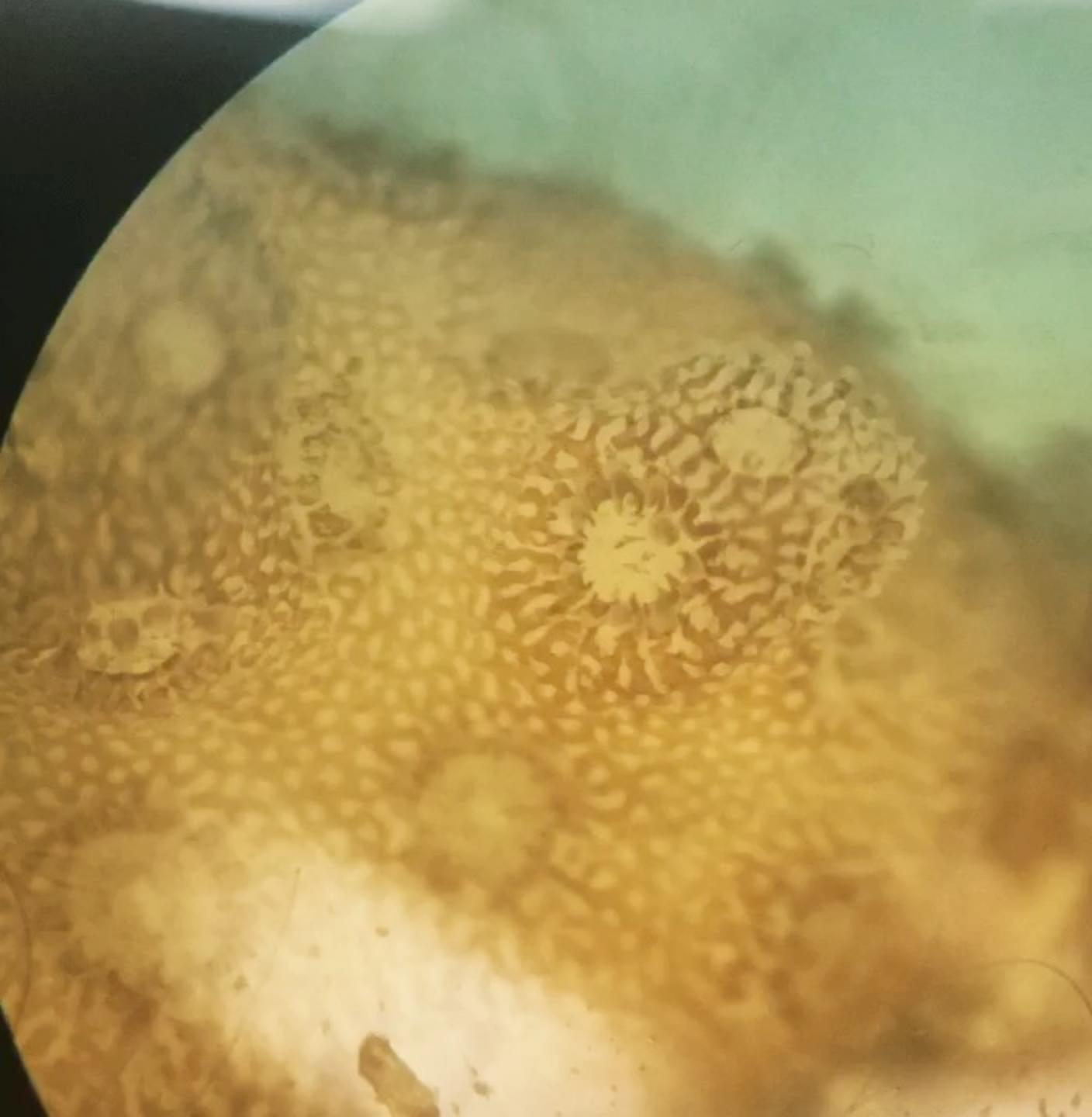
Fitt et al. 2000, Hoogenboom et al. 2010,  
Wall et al. 2019,



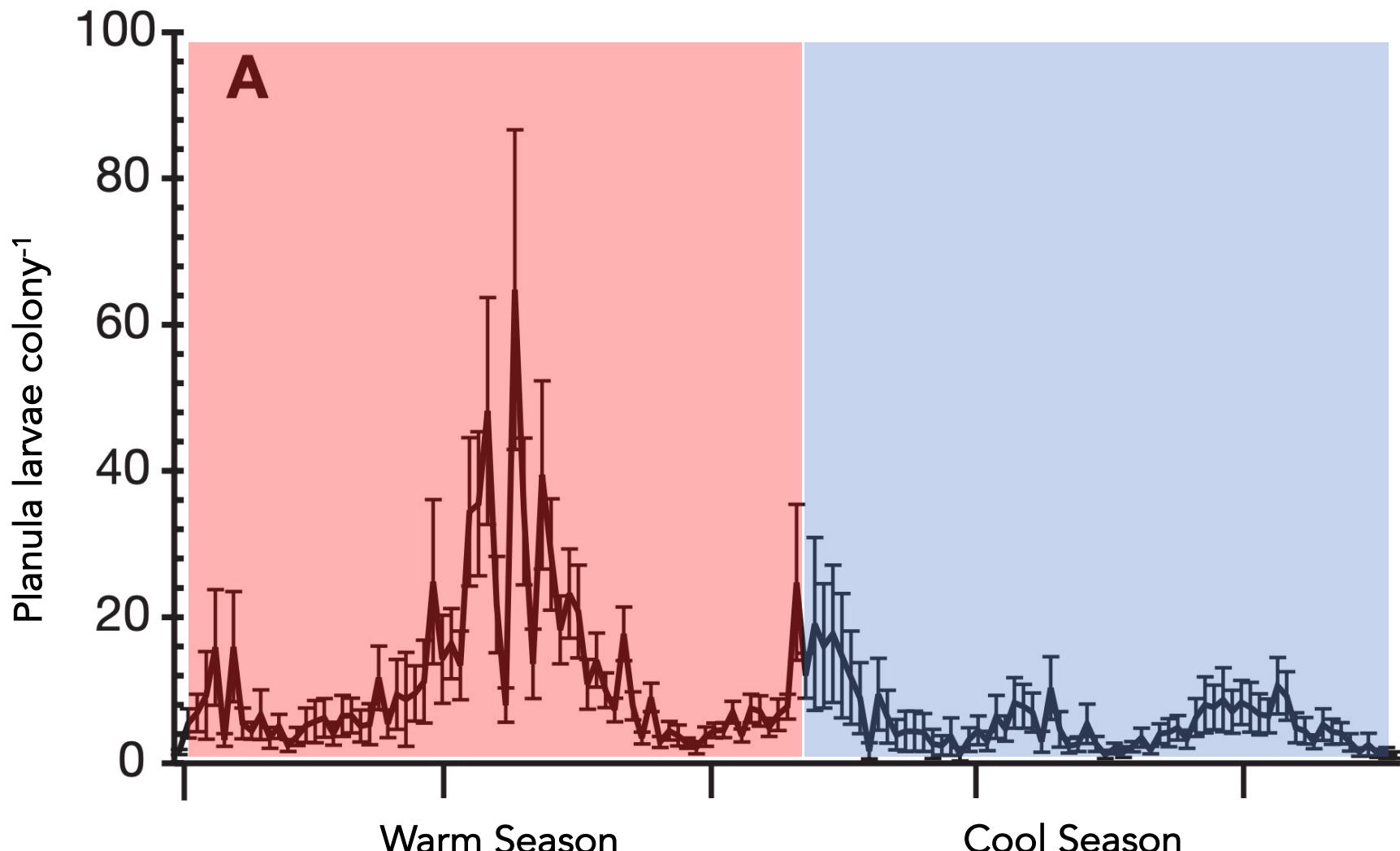
Adapted from Grottoli et al. 2006, Palardy et al. 2008

# Feeding is an important component of coral nutrition

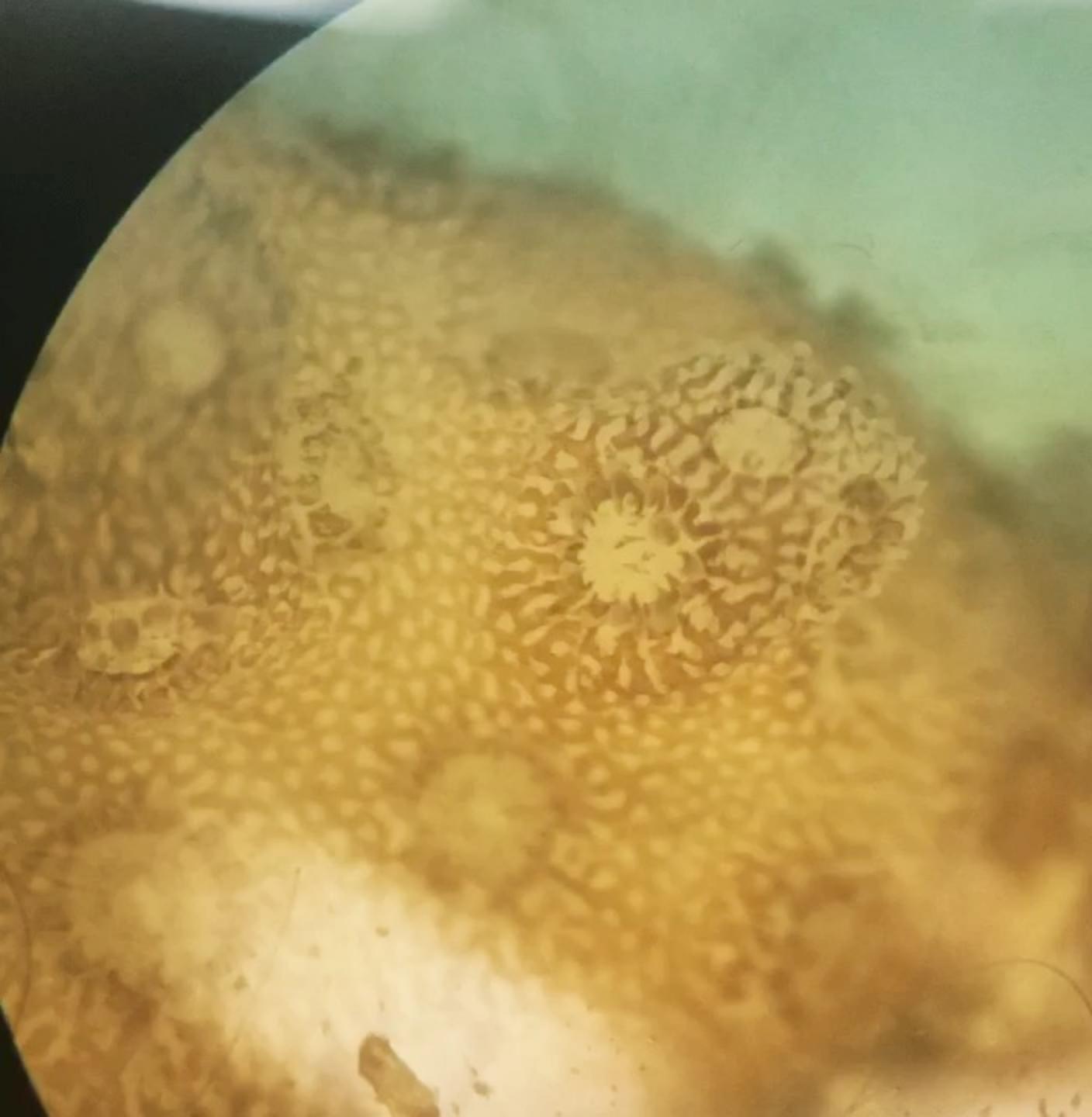




Does heterotrophy  
increase juvenile *P.  
acuta* survival in  
high temperature?

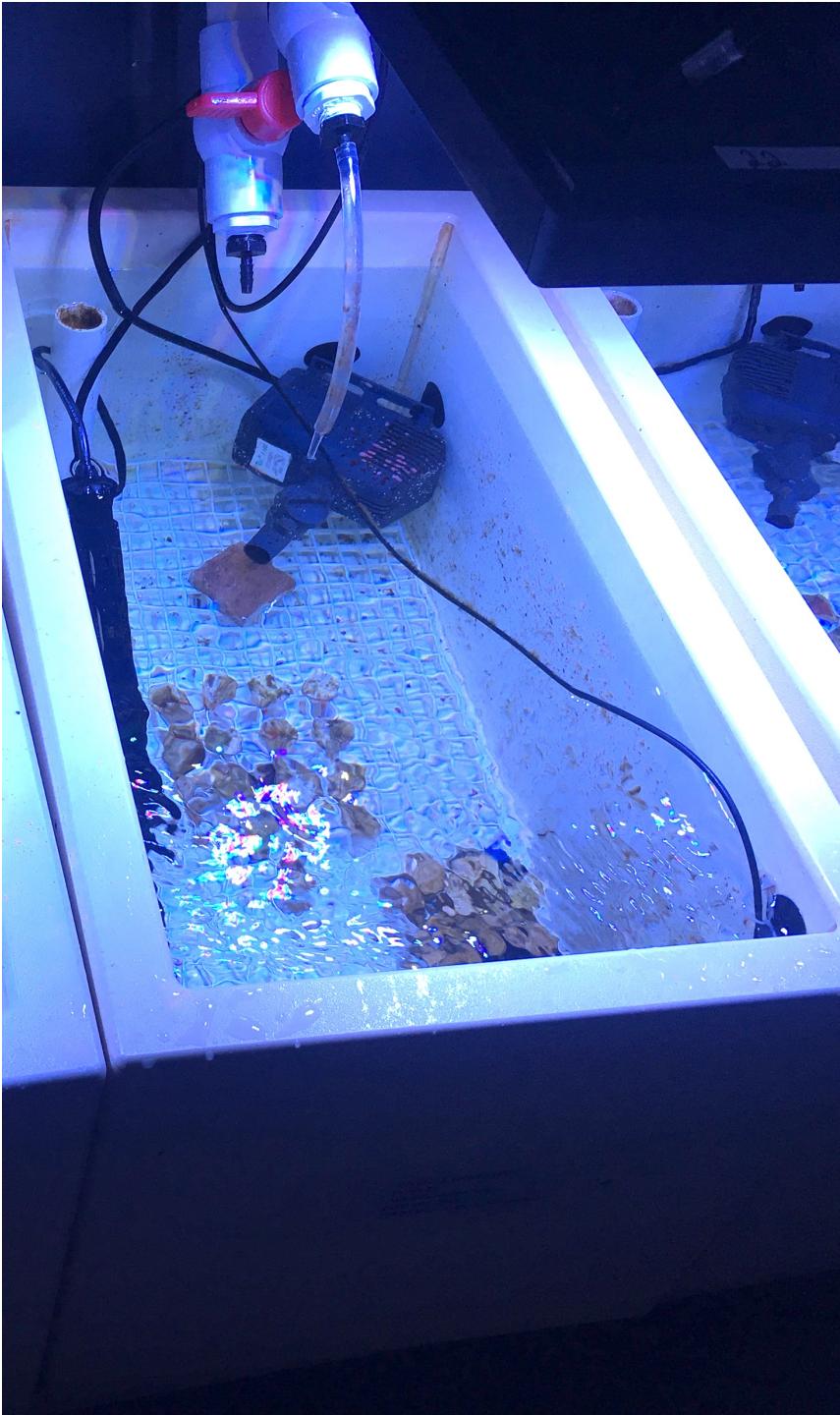


Adapted from Zakai et al. 2006

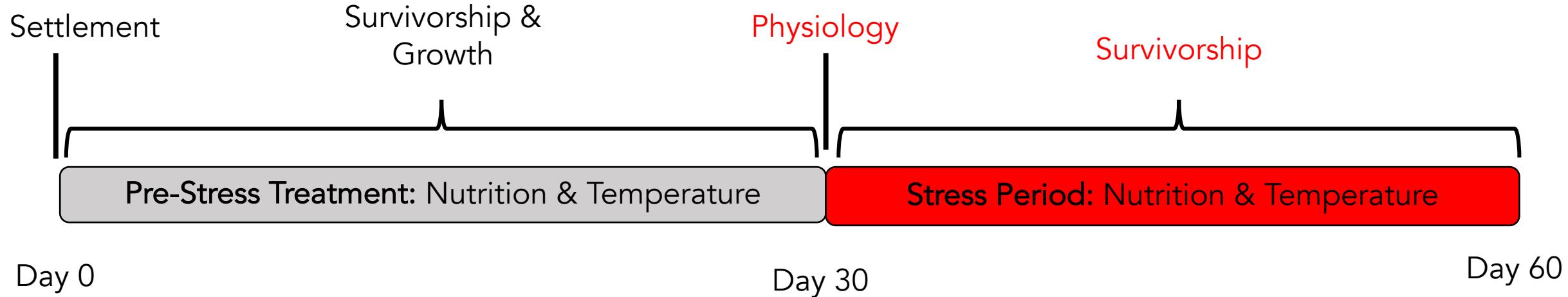
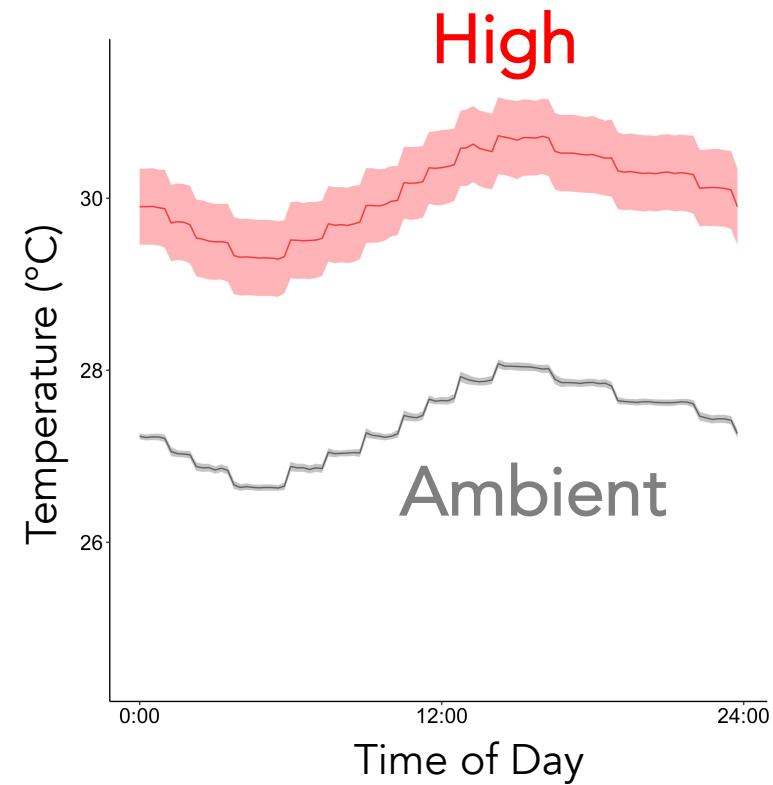
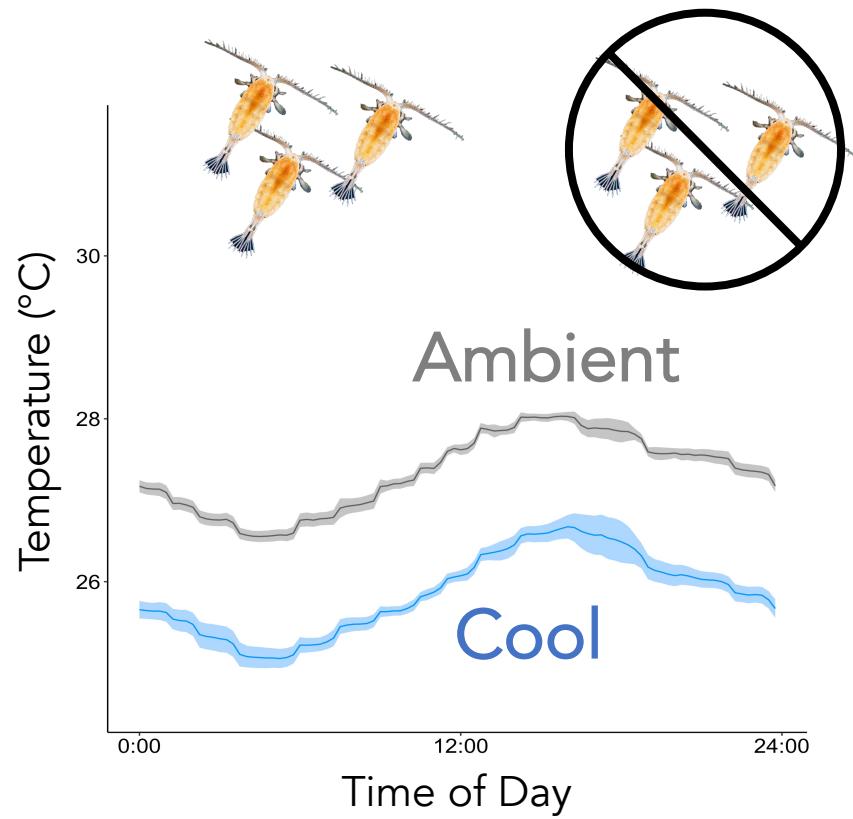


Does heterotrophy  
increase juvenile  
survival in high  
temperature?

Do these effects  
vary with exposure  
to different  
seasonal  
temperatures?



S. Matsuda





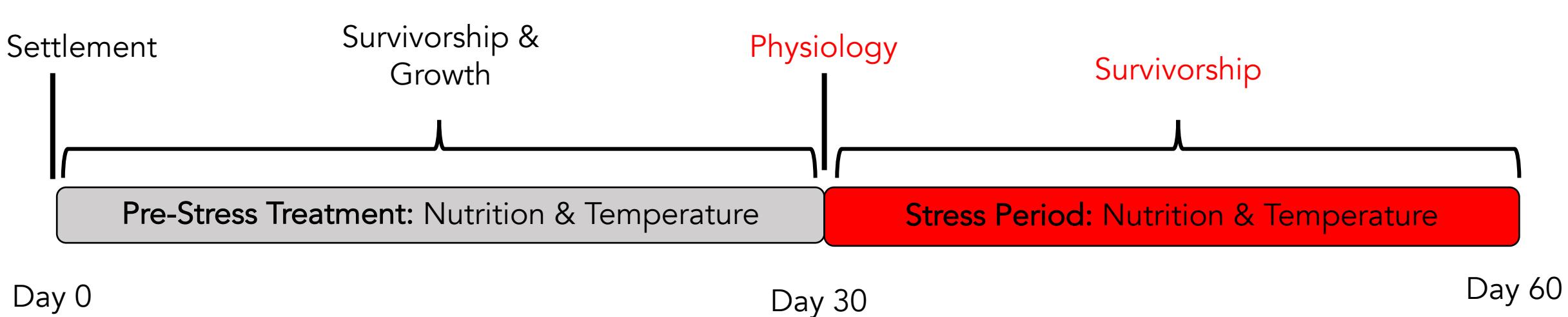
Colton Johnson

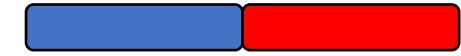
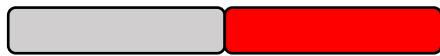
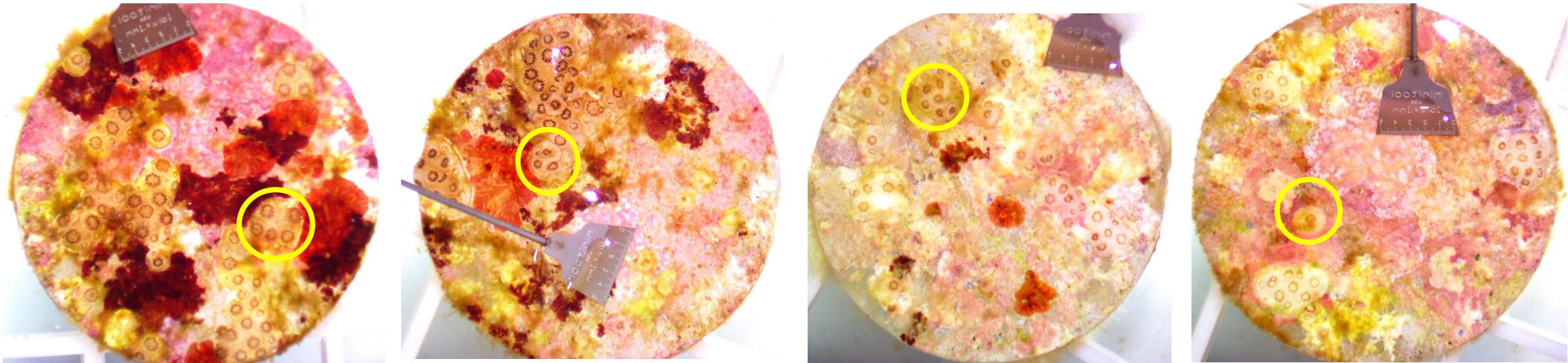


Ashleigh Epps



Jenna Dilworth



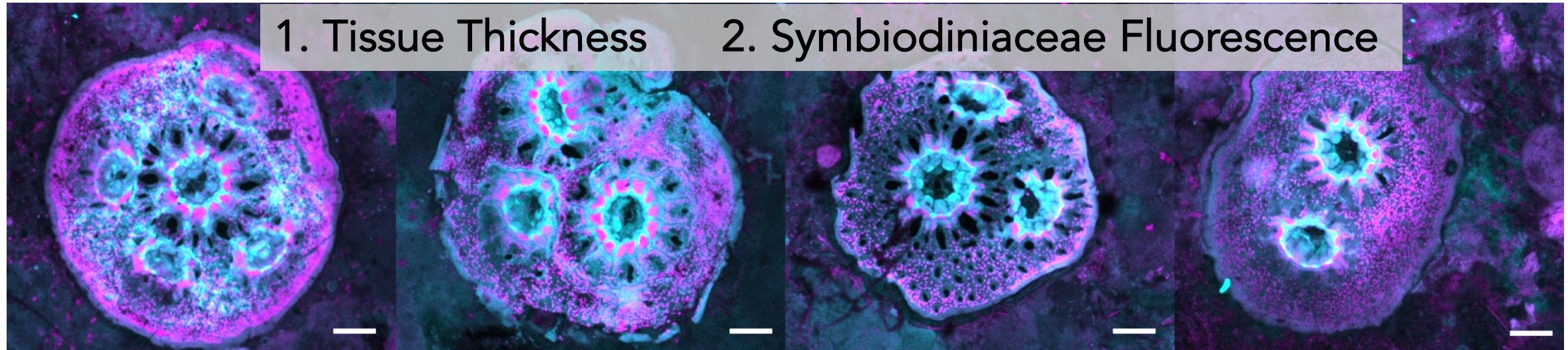
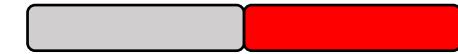
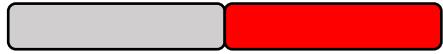
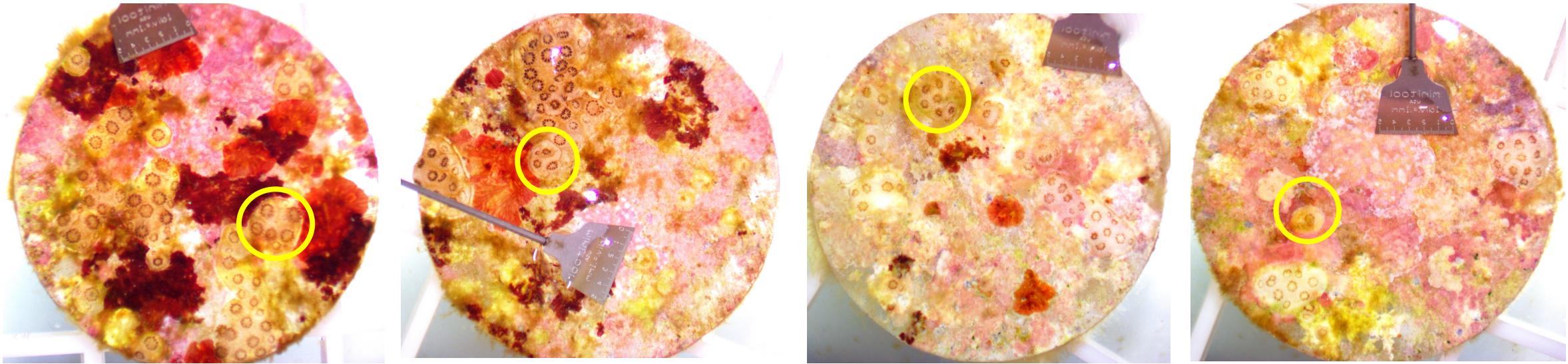


Growth (Linear Extension)



>

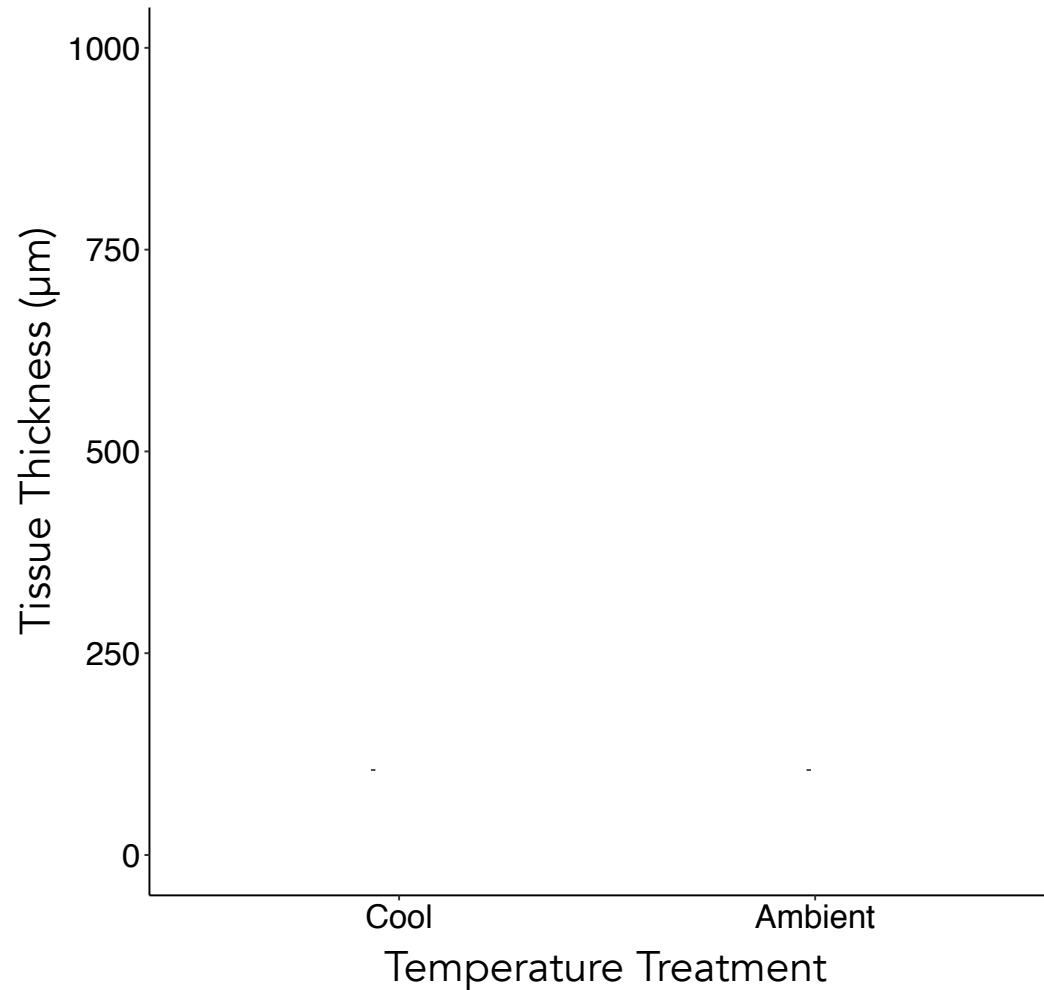




1. Tissue Thickness

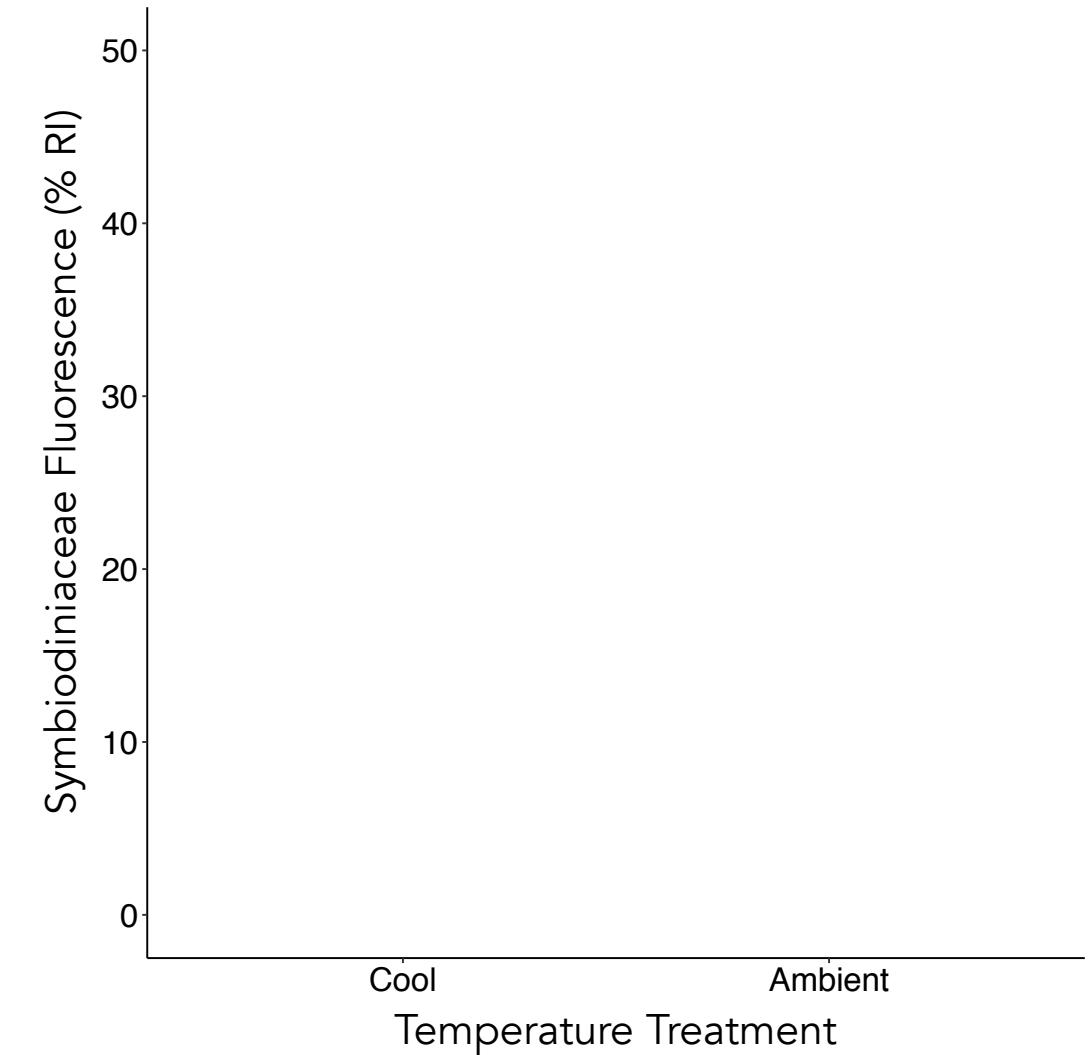
2. Symbiodiniaceae Fluorescence

# Tissue Thickness



Heterotrophy

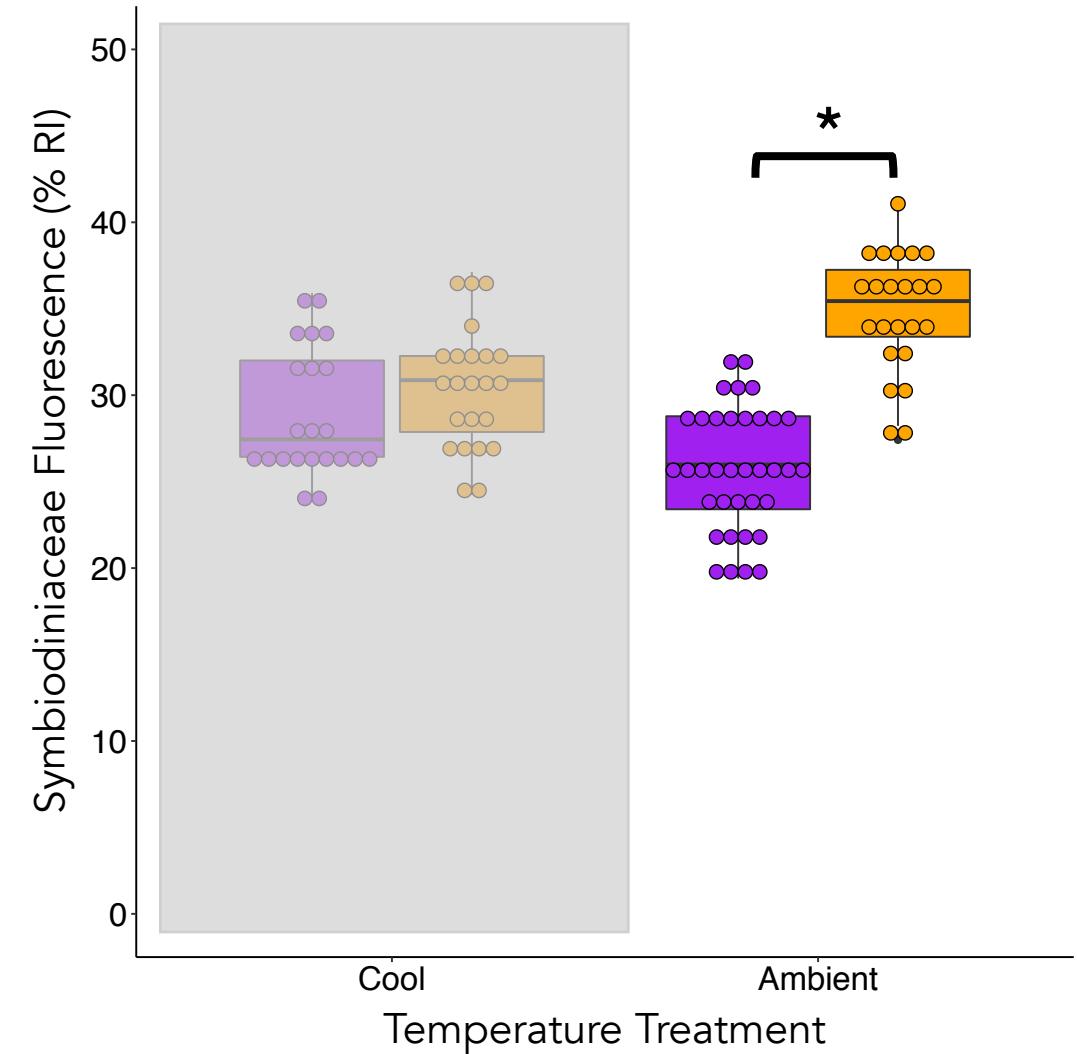
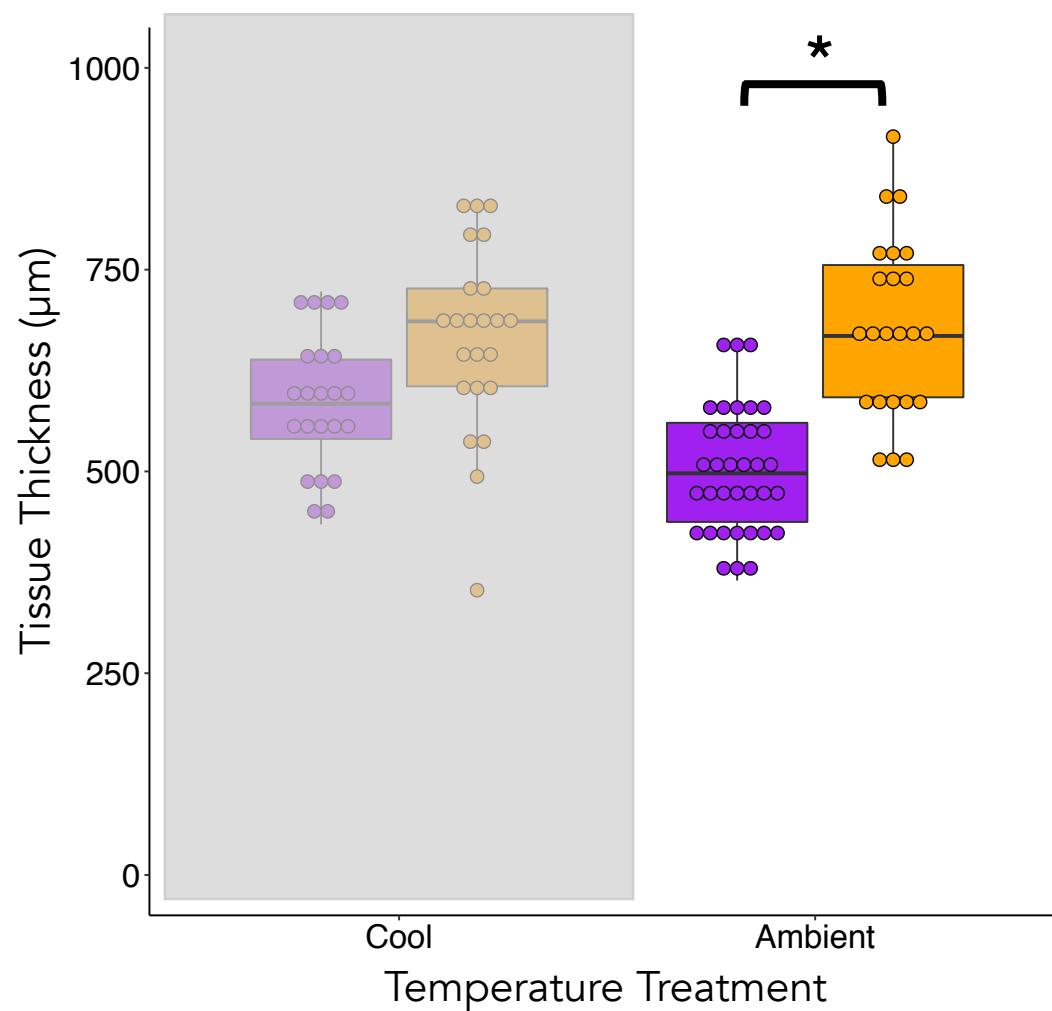
# Symbiodiniaceae Fluorescence



No Heterotrophy

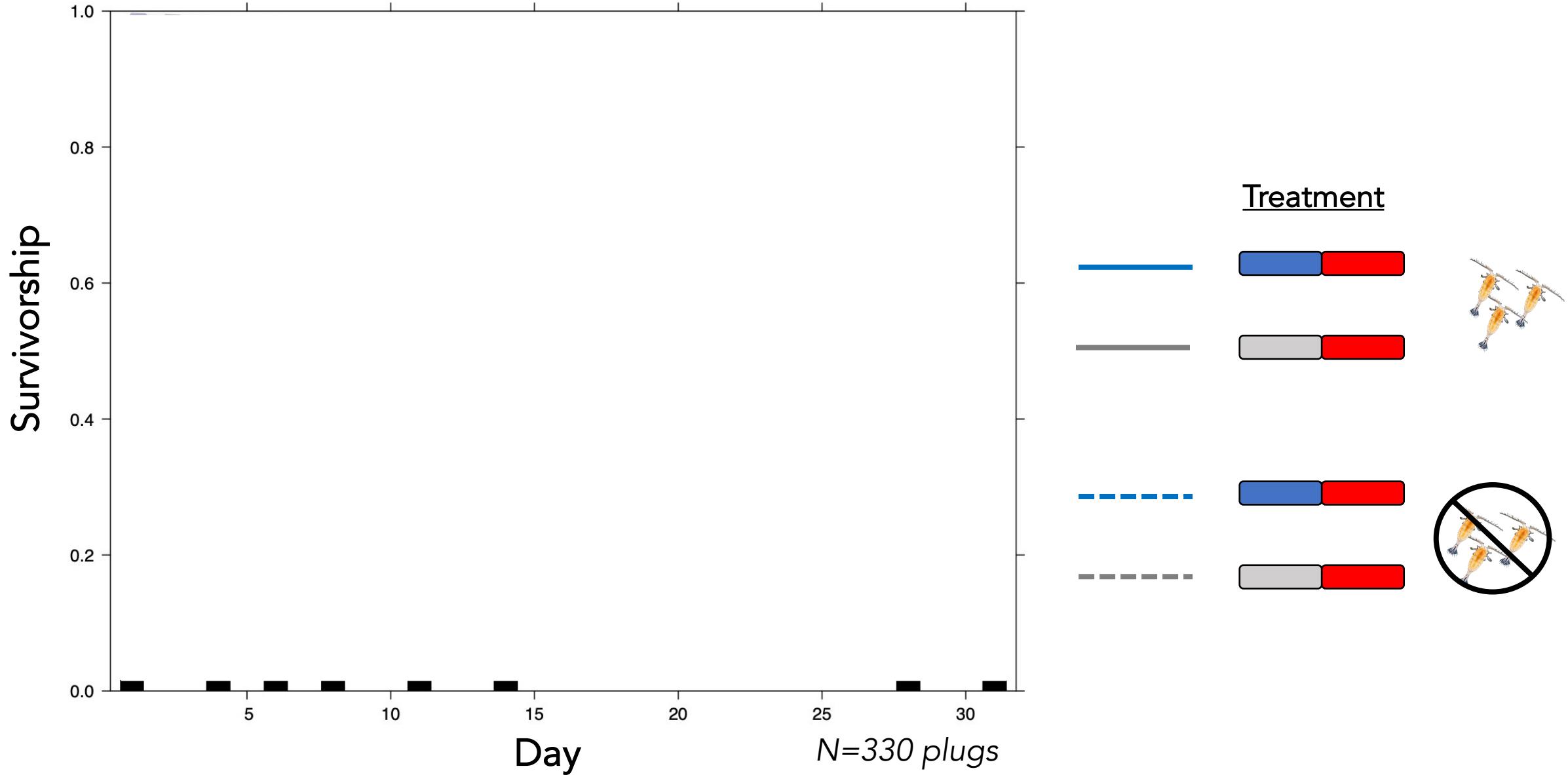
$\text{Imer}(\text{physiological characteristic} \sim \text{temperature} * \text{nutrition} + \text{surface area} + (1/\text{cohort}) + (1/\text{tank/plug}))$

# Corals require heterotrophy to maintain tissue growth and symbiosis in ambient temp.

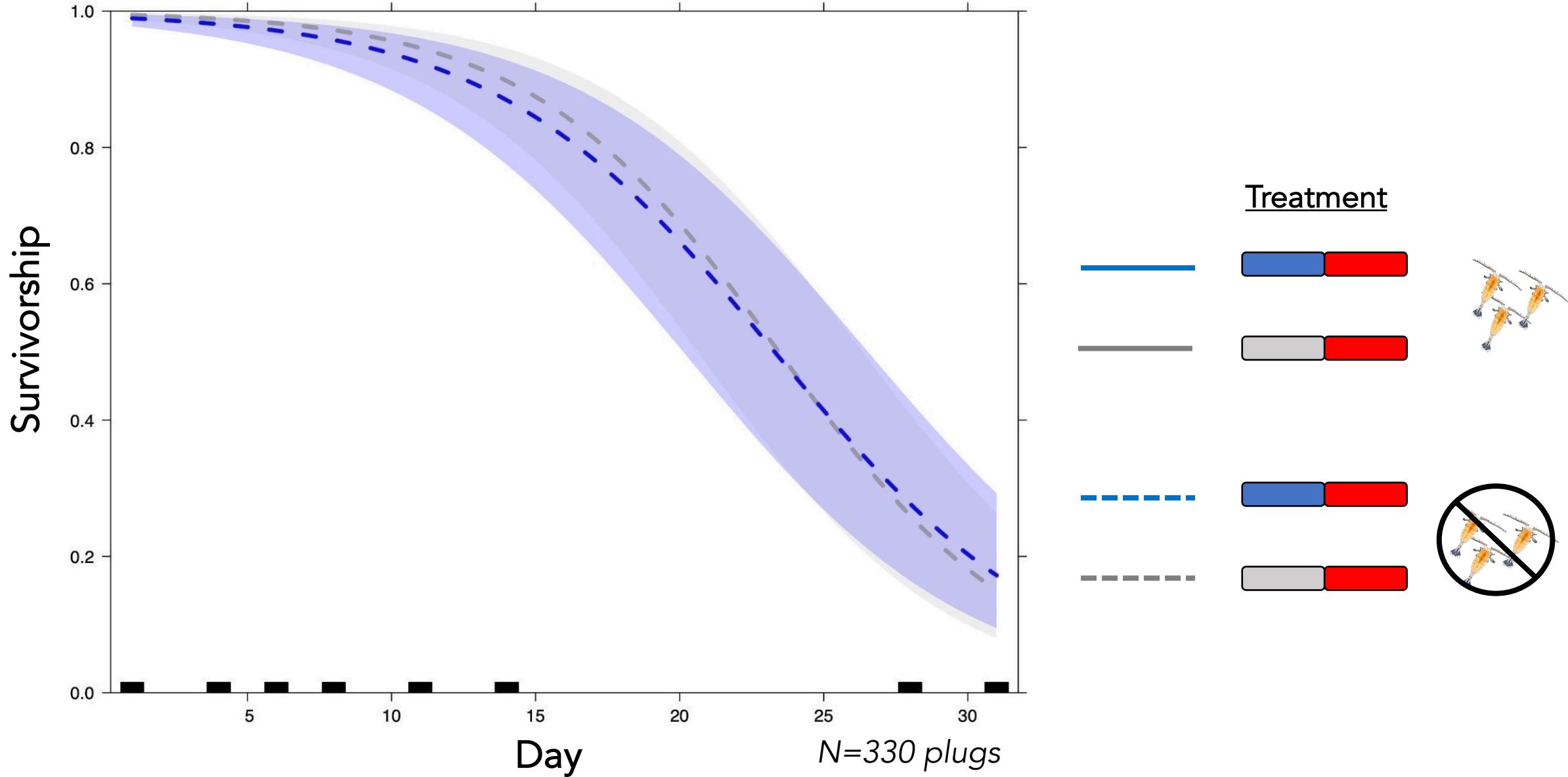


Elevated respiratory demand at ambient temperature ( $27.3^\circ\text{C}$ ) vs. cool temperature ( $25.6^\circ\text{C}$ )

# Survival in High Temperature

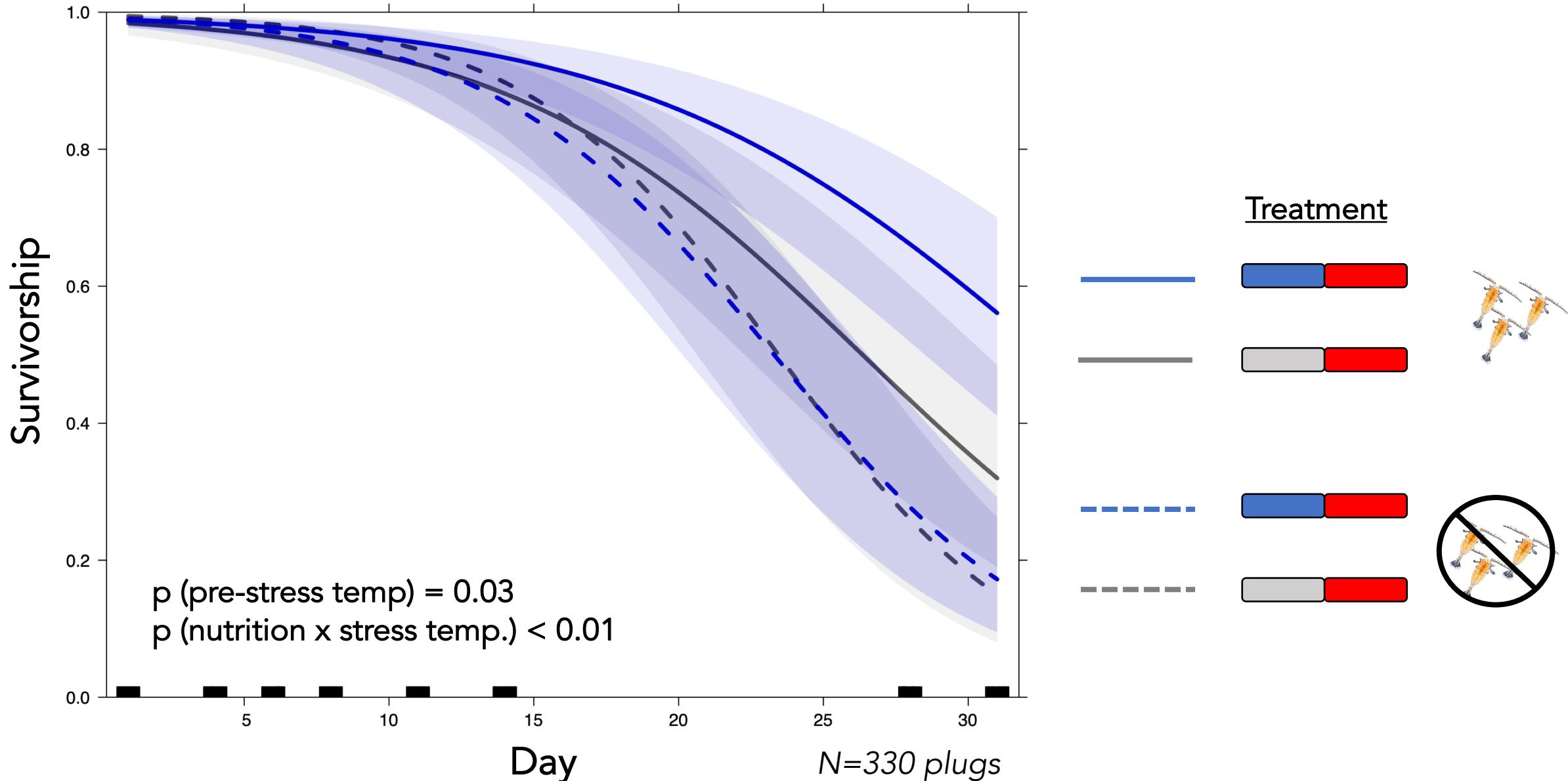


# Survival in High Temperature



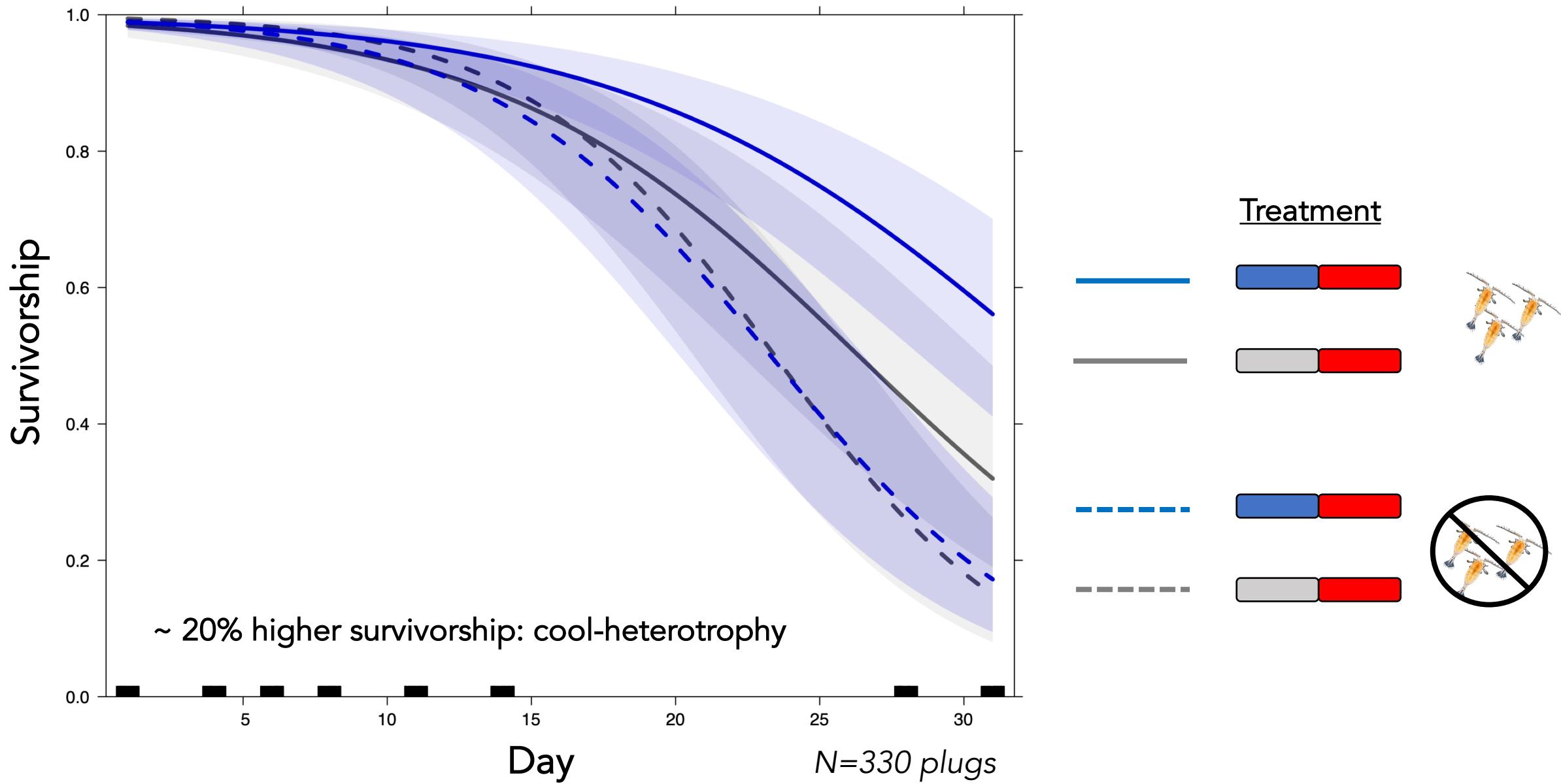
*lmer(survival ~ temperature \* nutrition \* stress test temperature \* day + (1|tank/plug) + (1|cohort), family=binomial)*

# Survival in High Temperature



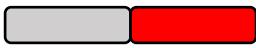
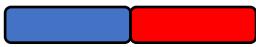
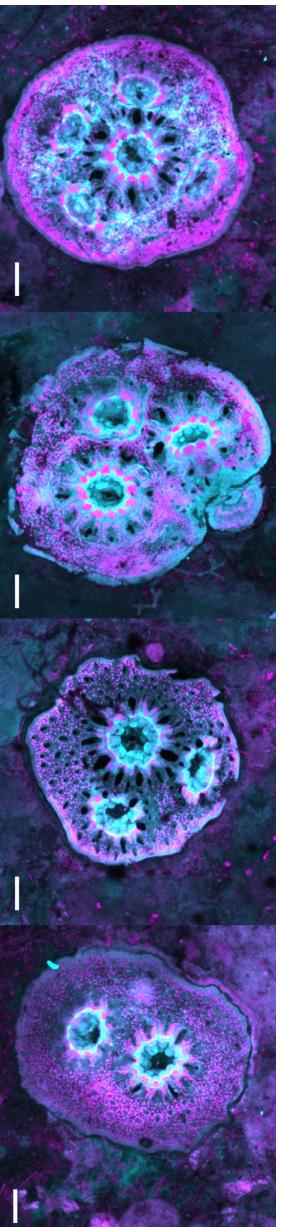
*lmer(survival ~ temperature \* nutrition \* stress test temperature \* day + (1|tank/plug) + (1|cohort), family=binomial)*

# Heterotrophy promotes juvenile survival in high temperature.

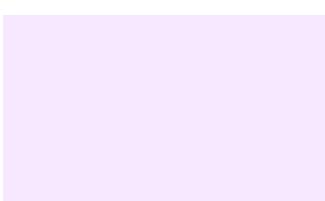


```
lmer(survival ~ temperature * nutrition * stress test temperature * day + (1|tank/plug) + (1|cohort), family=binomial)
```

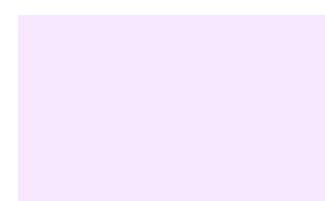
## Temperature – Nutritional Treatment



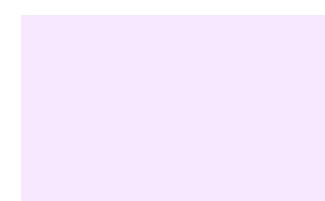
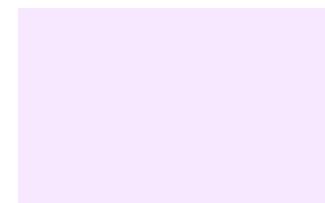
## Tissue Thickness



## Symbiodiniaceae Fluorescence



## High Temperature Survival



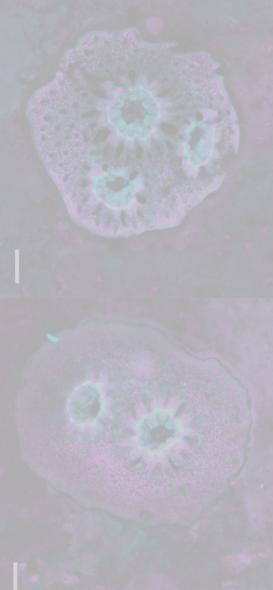
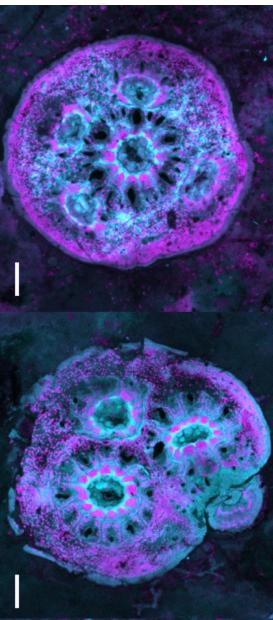
More



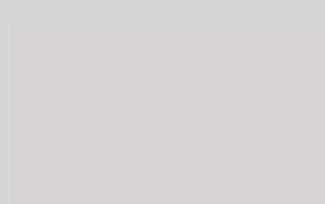
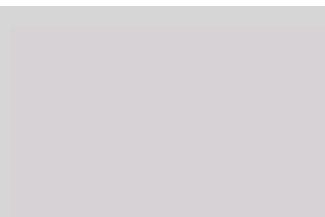
Less



## Temperature – Nutritional Treatment



## Tissue Thickness



## Symbiodiniaceae Fluorescence

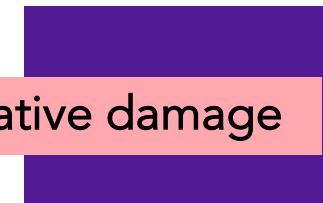


Higher risk of oxidative damage



Lower risk of oxidative damage

Cunning & Baker 2013



More



Less

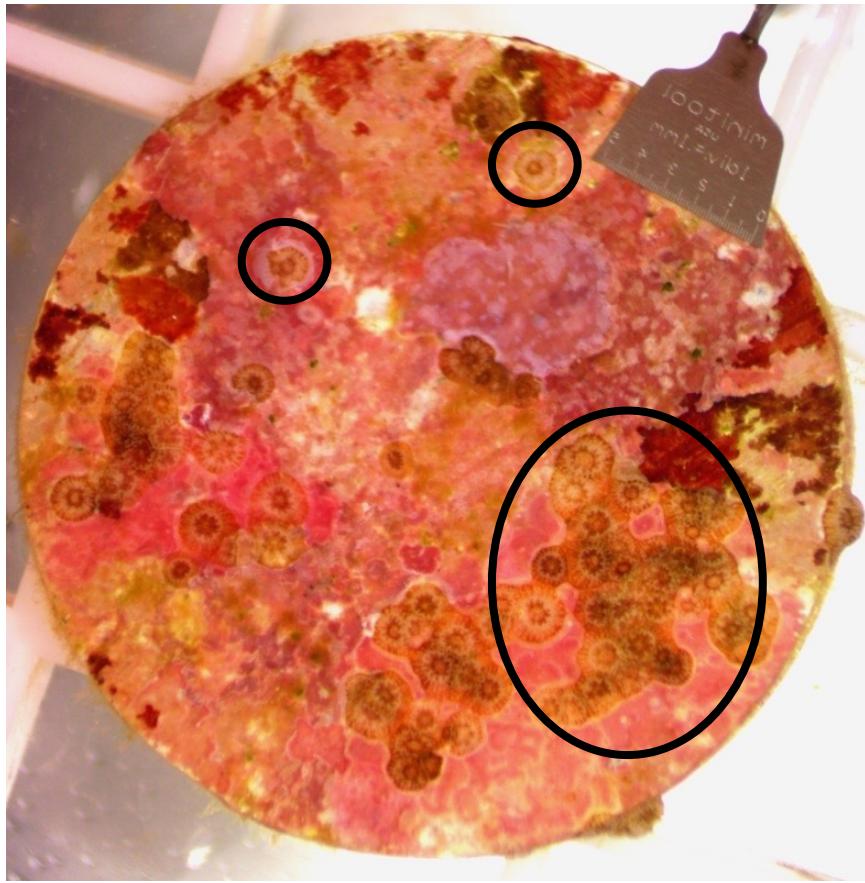


## High Temperature Survival

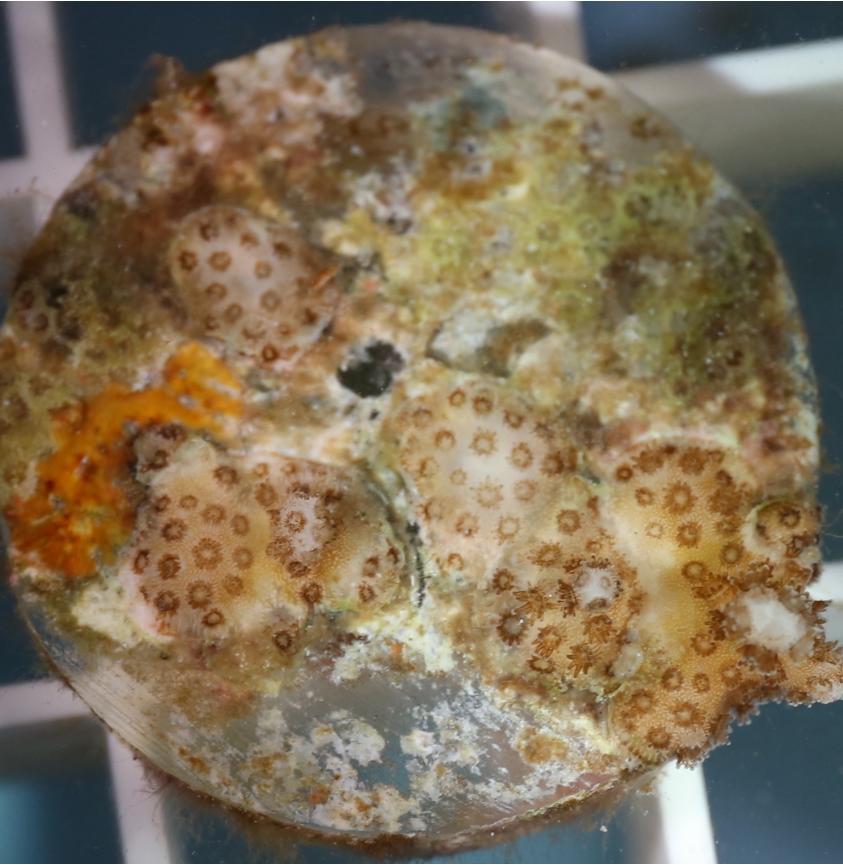
Heterotrophy is necessary for juvenile *P. acuta* tissue growth and stress tolerance.



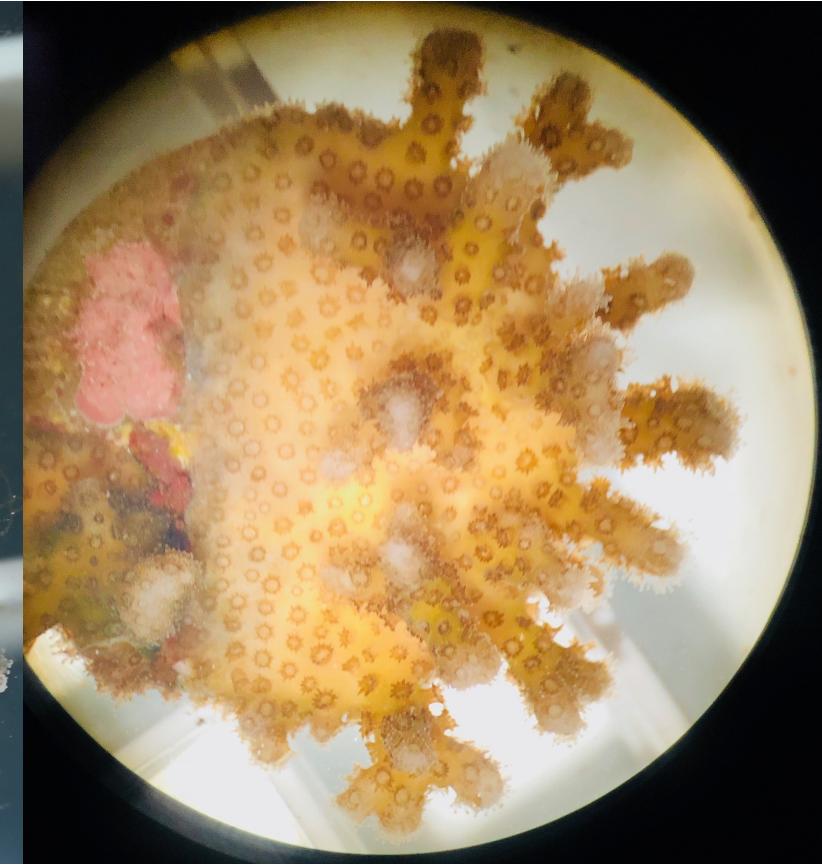
Huffmyer AS, CJ Johnson, AM Epps, JD Lemus, RD Gates. Heterotrophic feeding enhances tissue growth and thermal tolerance of *Pocillopora acuta* juvenile corals. *In prep.*



Settlement



6 months



12 months

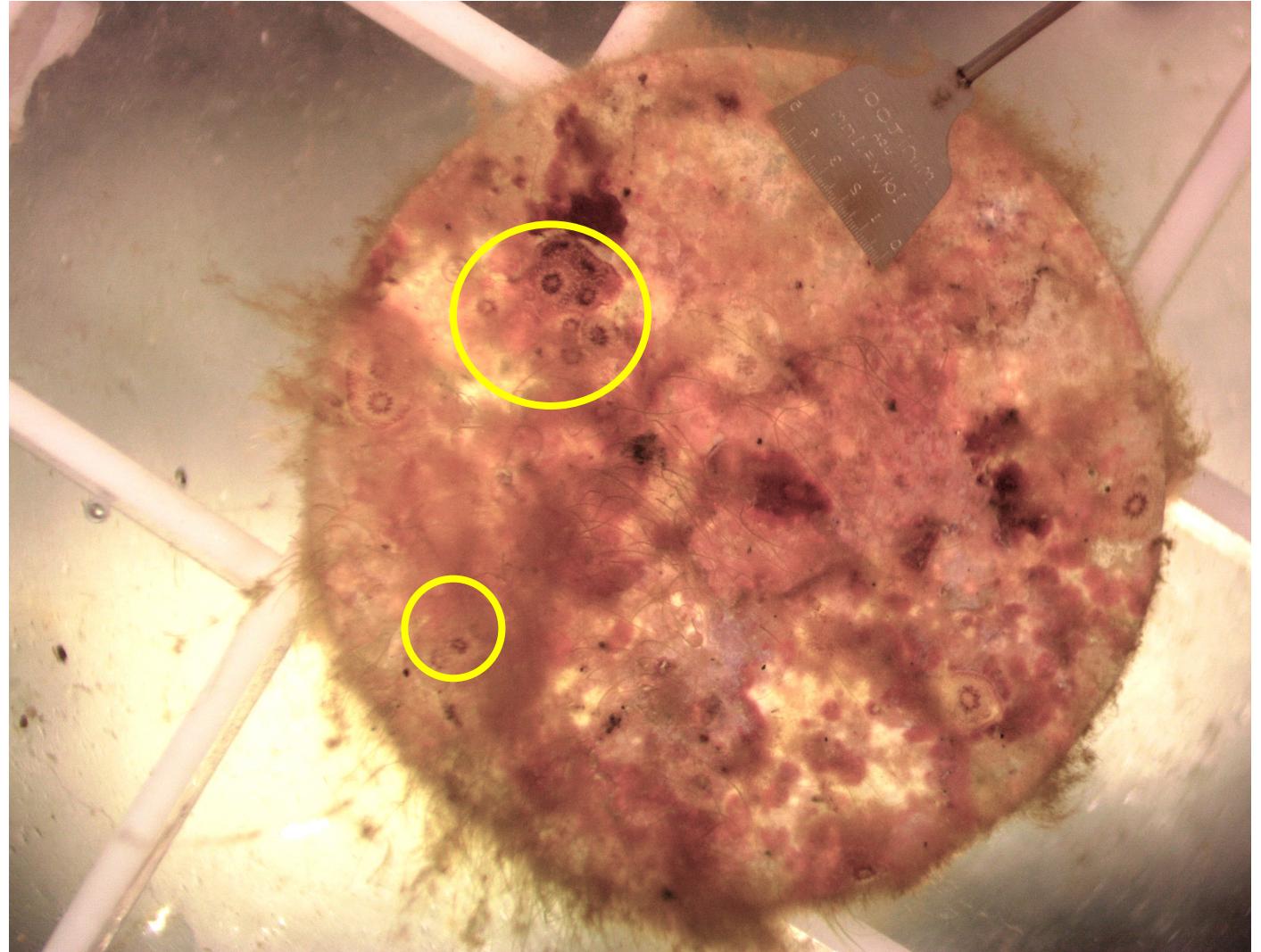
50% higher survivorship in fused juvenile corals

# Fusion: Opportunity for increased colony size

Decreased mortality risk

Energetic resources and feeding capacity

Raymundo & Maypa 2004, Puill-Stephan et al. 2012, Rinkevich 2019



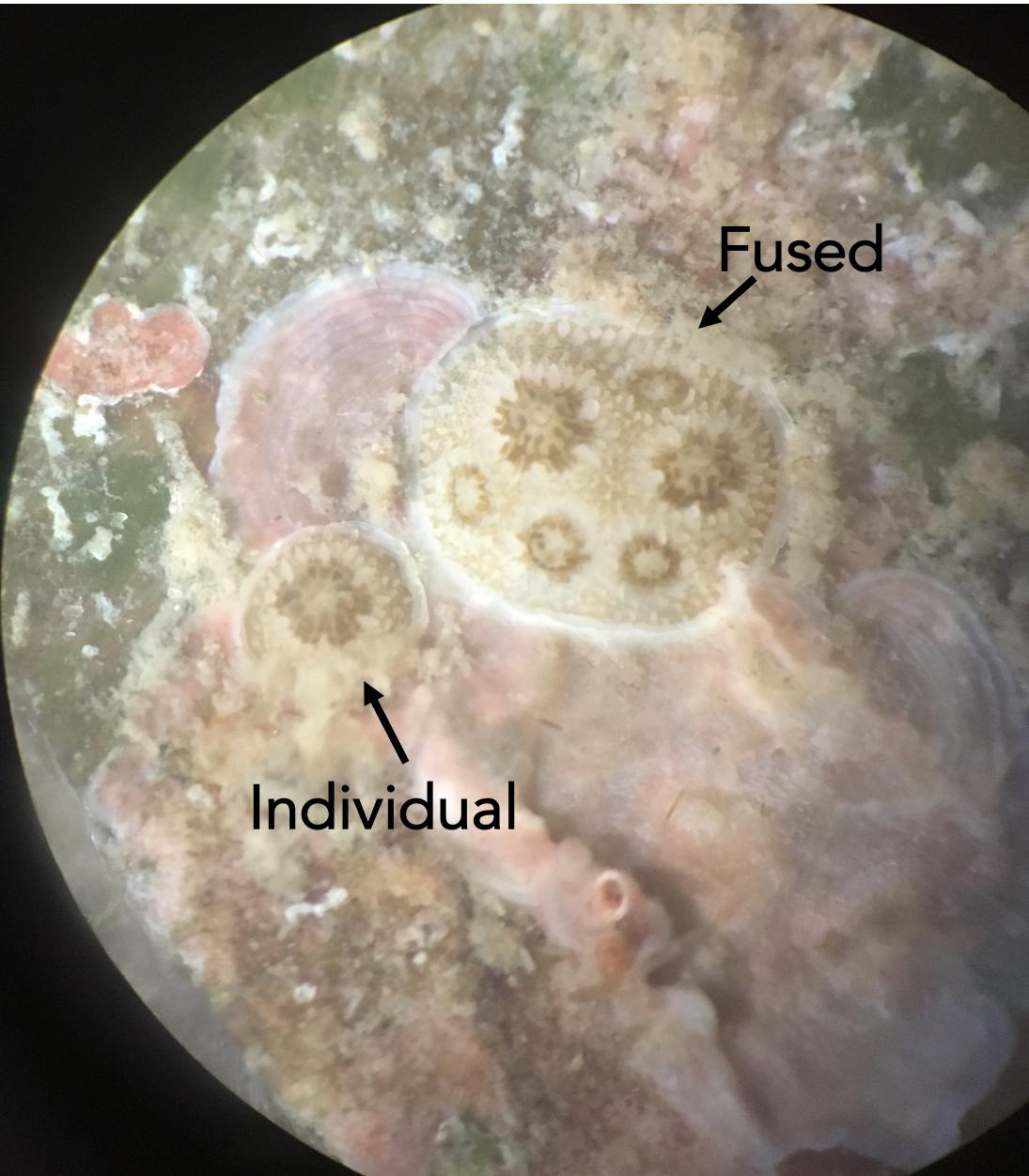
# Fusion: Opportunity for increased genetic diversity



- Risk of intra-colony competition
- Potential strategy to survive stress

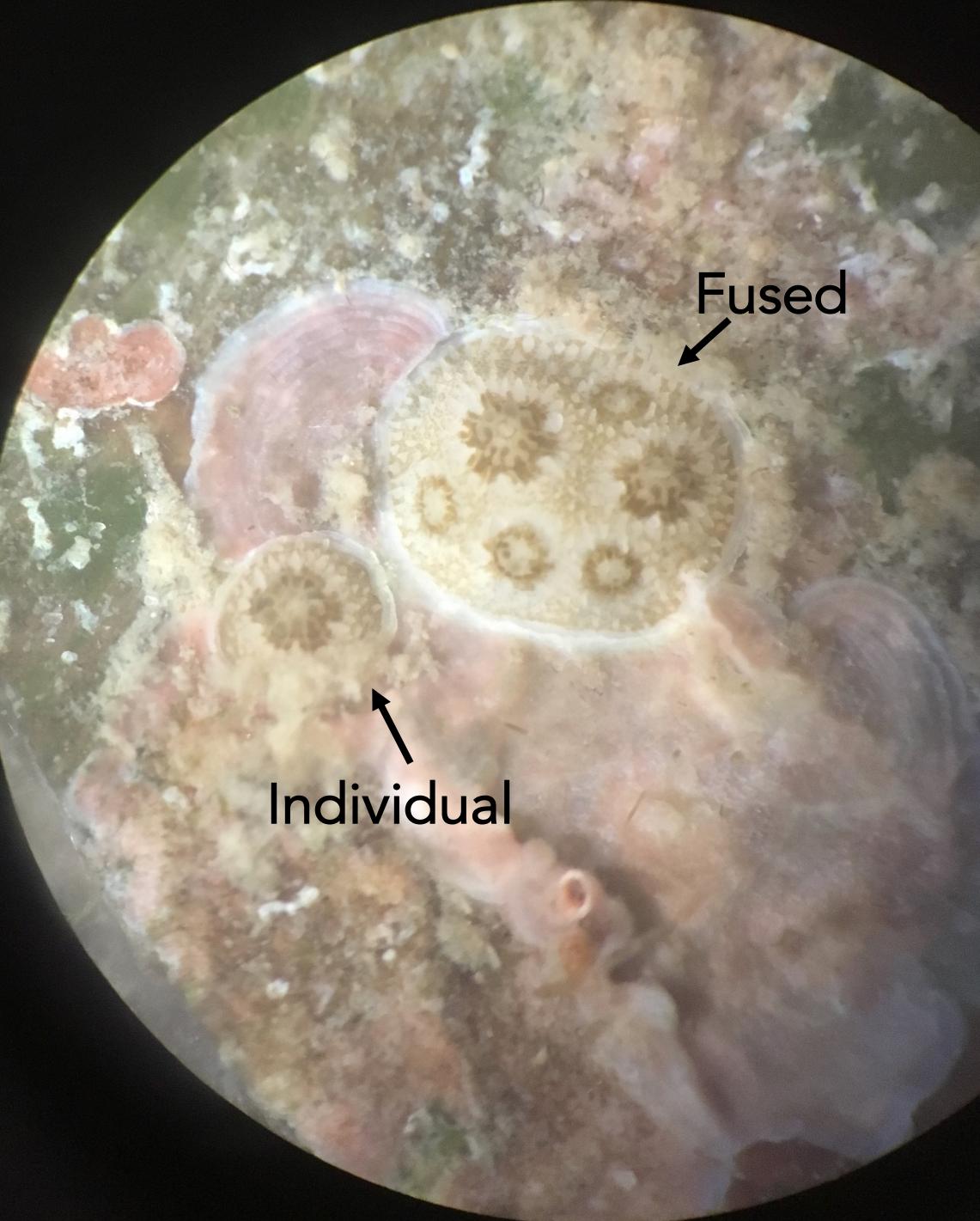
Puill-Stephan 2009, 2012; Hidaka 1985; Amar 2008, Rinkevich 2019

# Fusion: Opportunity for increased genetic diversity



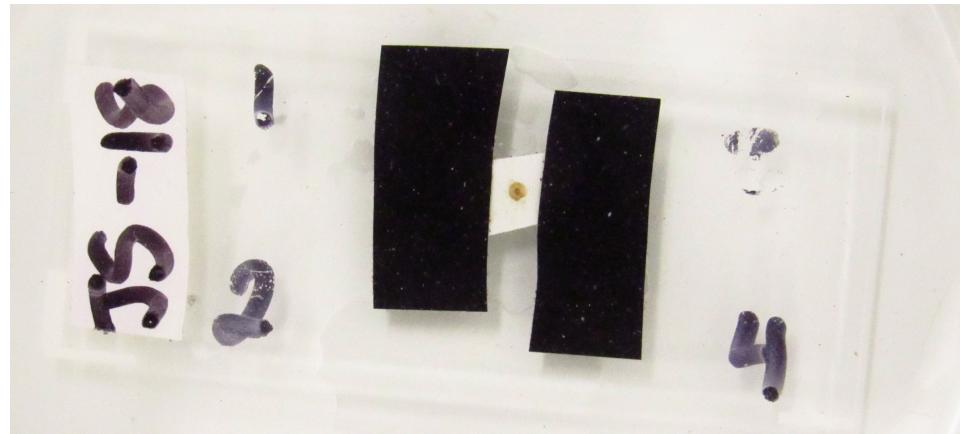
- “Window of opportunity” for multi-genotype fusions in early life stages

Puill-Stephan 2009, 2012; Hidaka 1985; Amar 2008, Rinkevich 2019



Does juvenile tissue fusion promote survival in thermal stress?

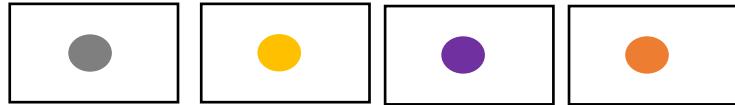
If so, are advantages due to an increase in size or genetic diversity?



Genotyping with Next Generation Sequencing, identity-by-state in ANGSD

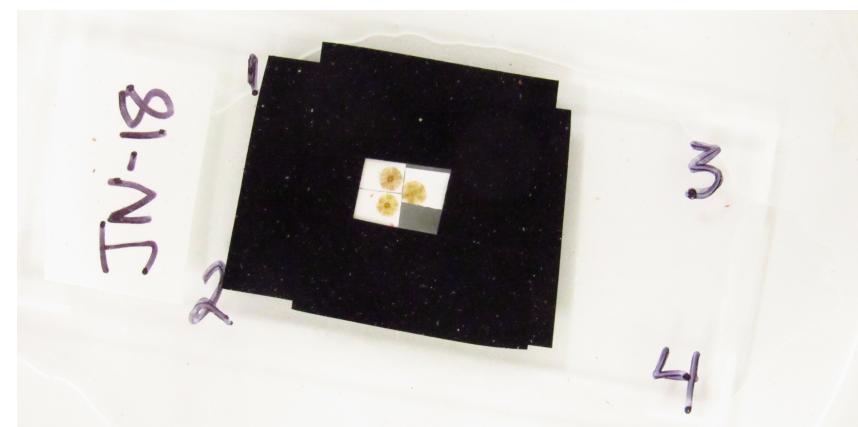
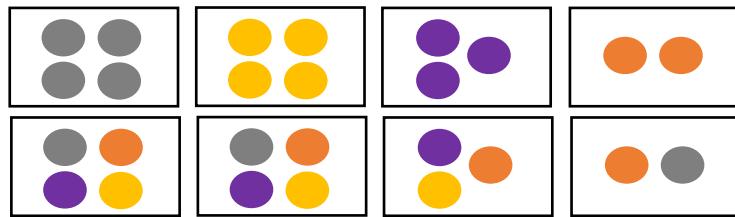
Genotypic Richness = 1

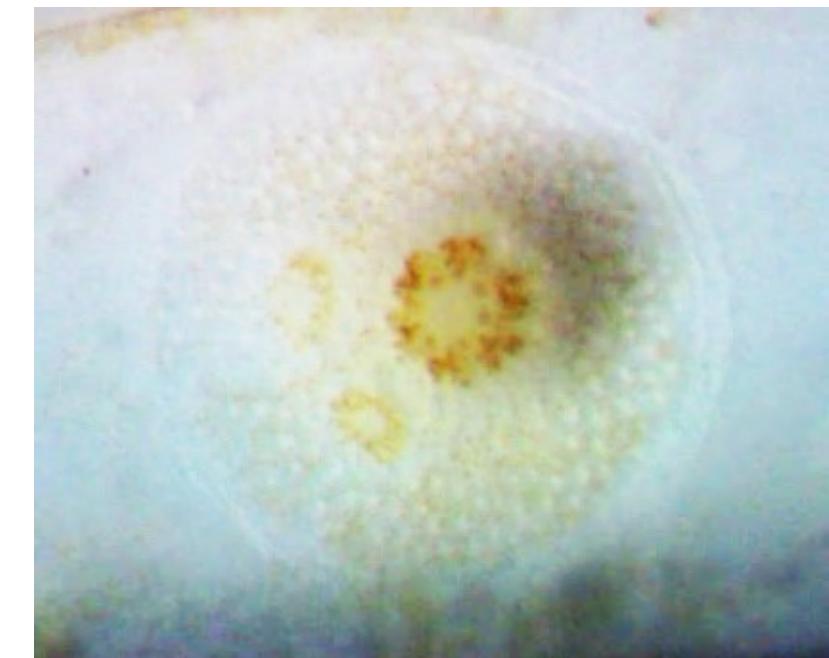
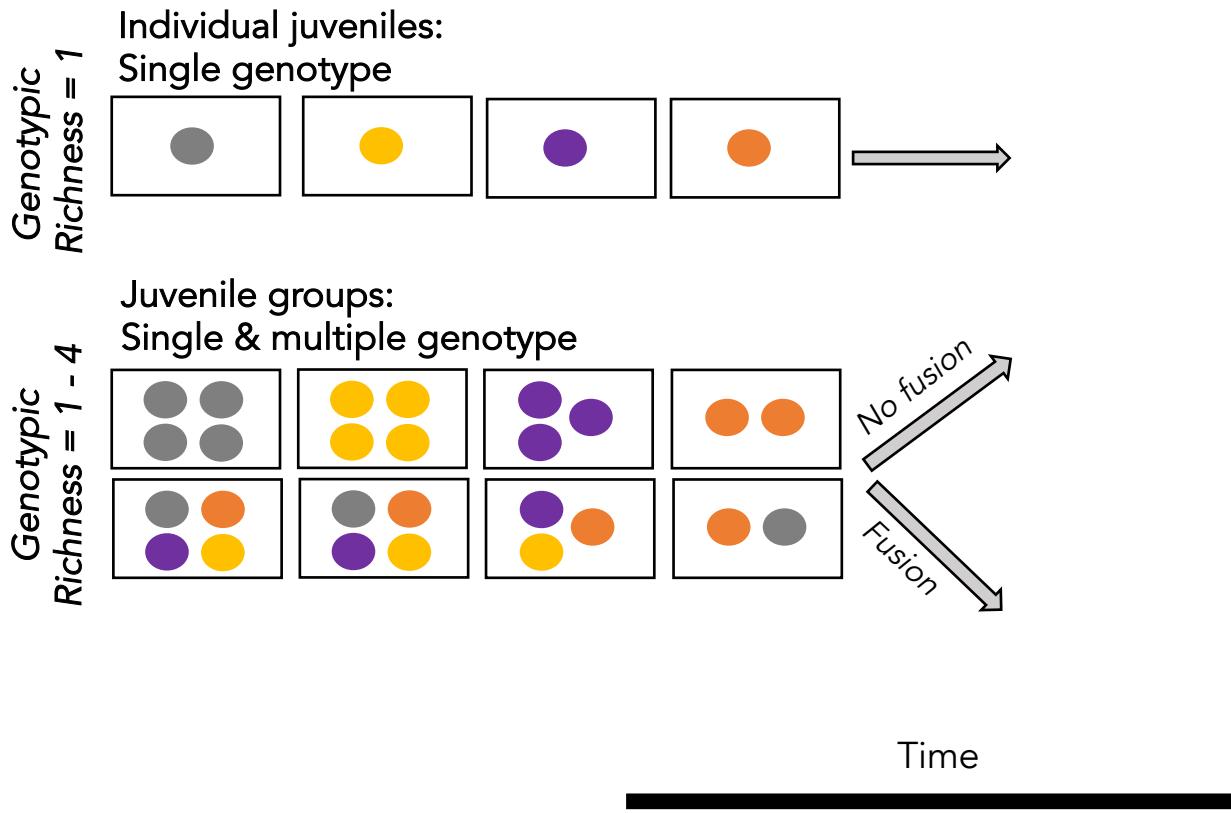
Individual juveniles:  
Single genotype

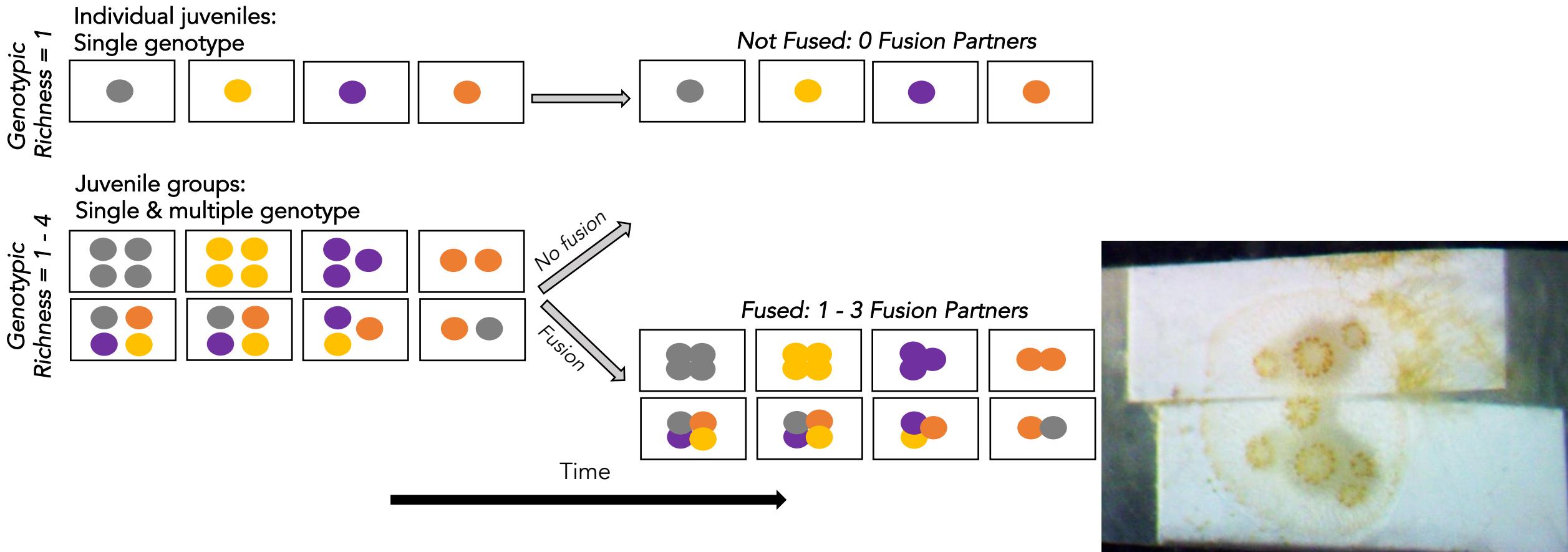


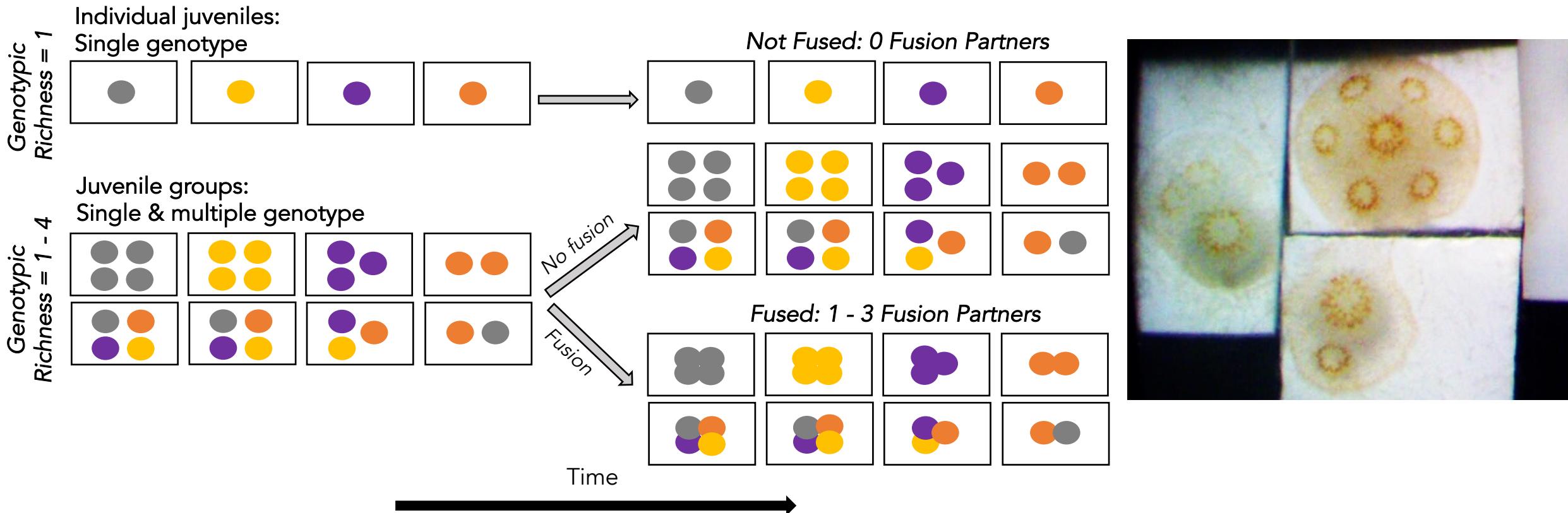
Genotypic Richness = 1 - 4

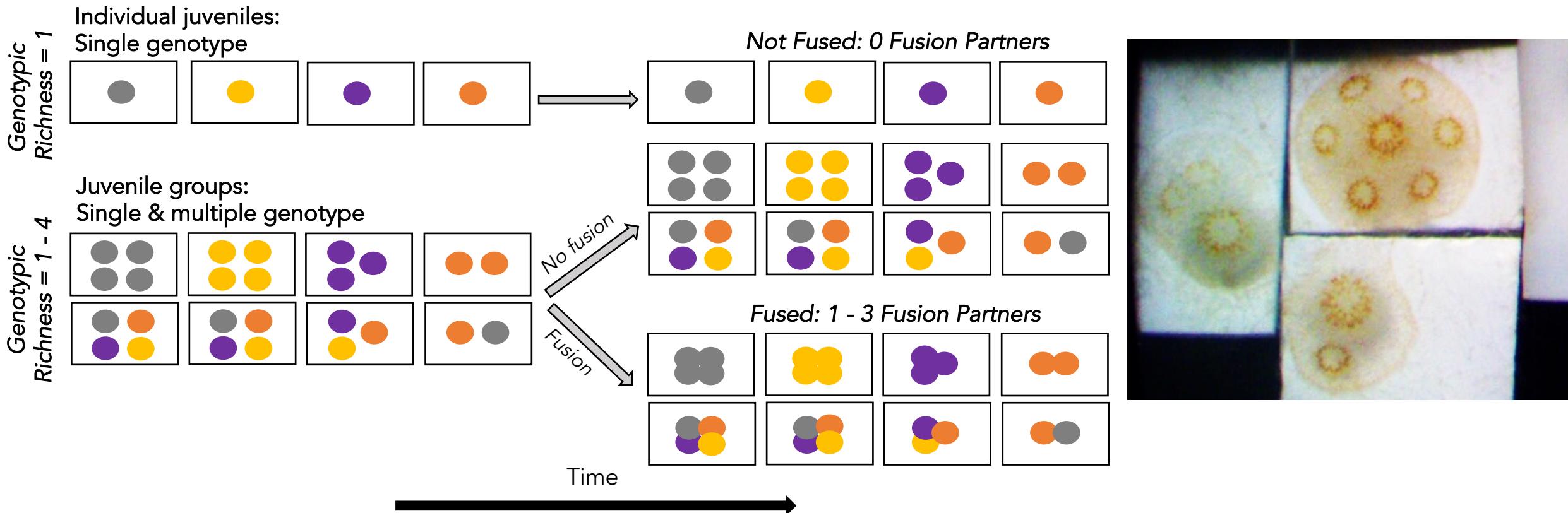
Juvenile groups:  
Single & multiple genotype



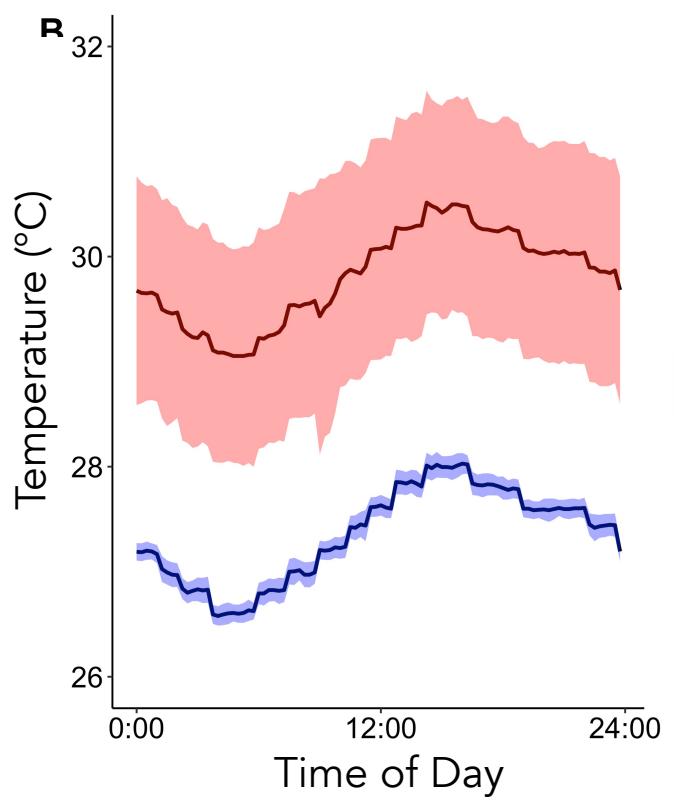
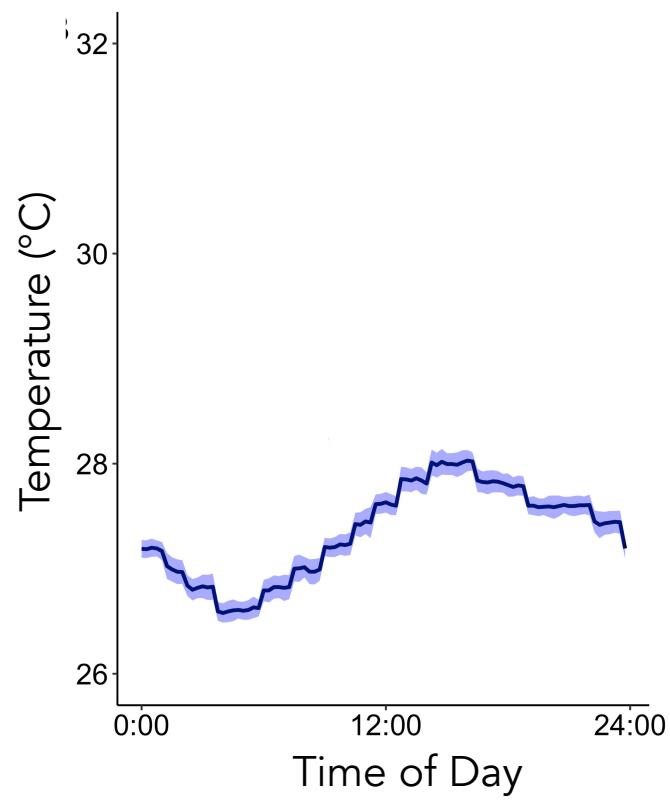








Collected data at the level of the *individual juvenile*



Manipulation

**Survivorship,**  
Growth, Fusion

**Survivorship,**  
Growth, Fusion

Day 0

Day 15

Day 45

Ford Drury



Nina Bean



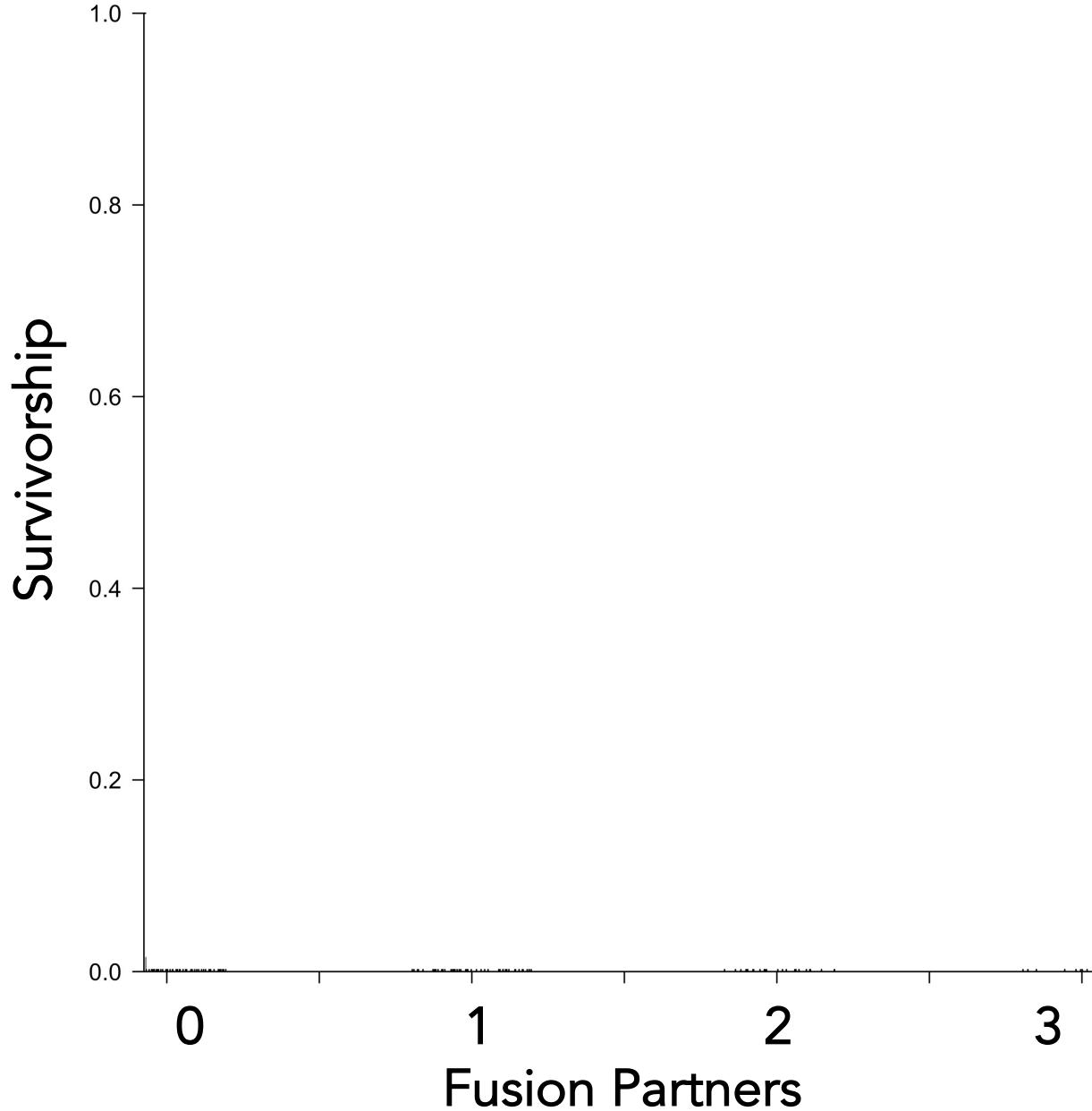
Casey Harris



Eva Majerová

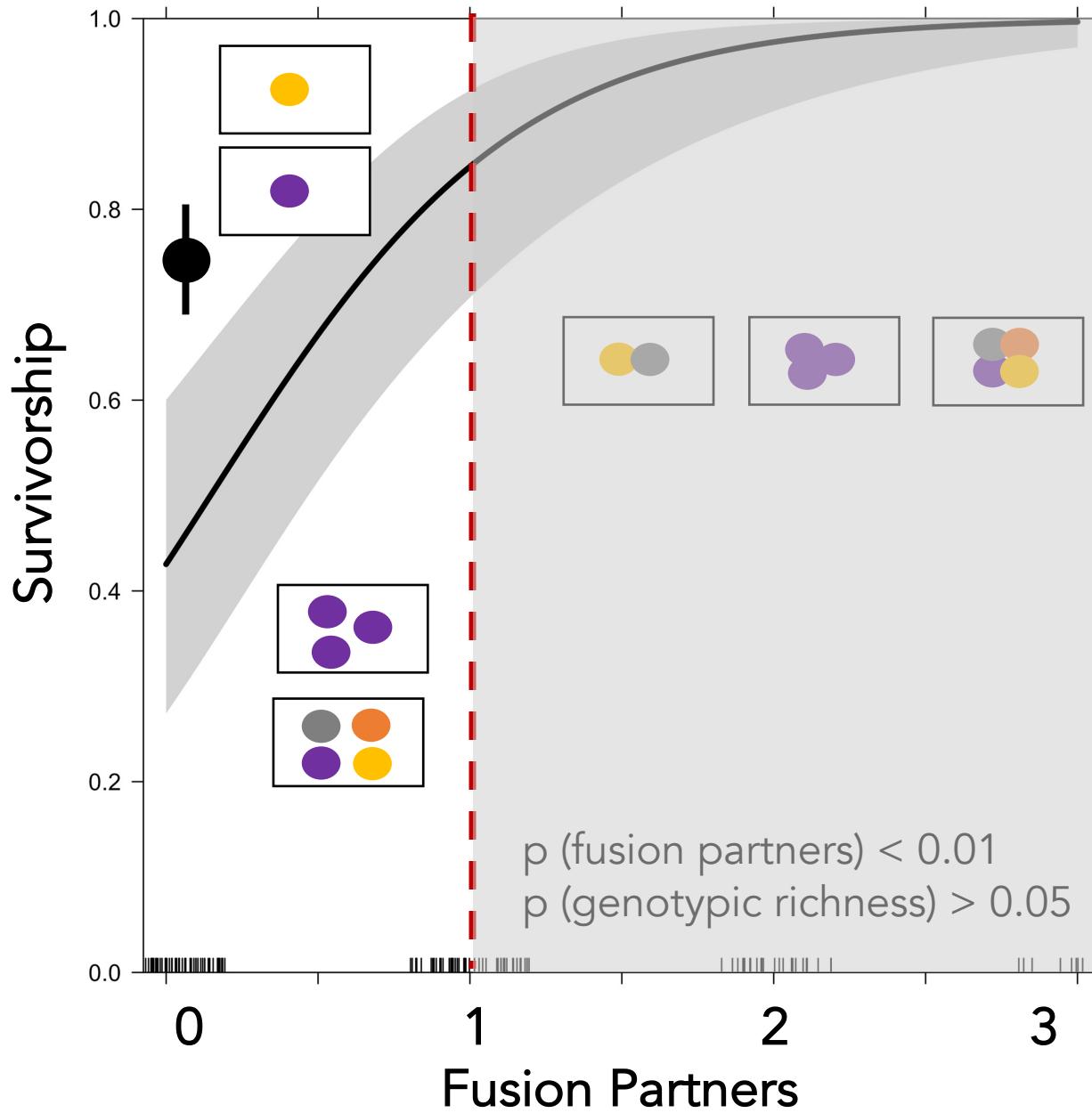


# Survival during grow-out period



```
glmer(survival ~ fusion partners * genotypic richness + (1|parent site/colony) + (1|tank) + (1|slide), family=binomial, subset=c(Community=="Group"))
```

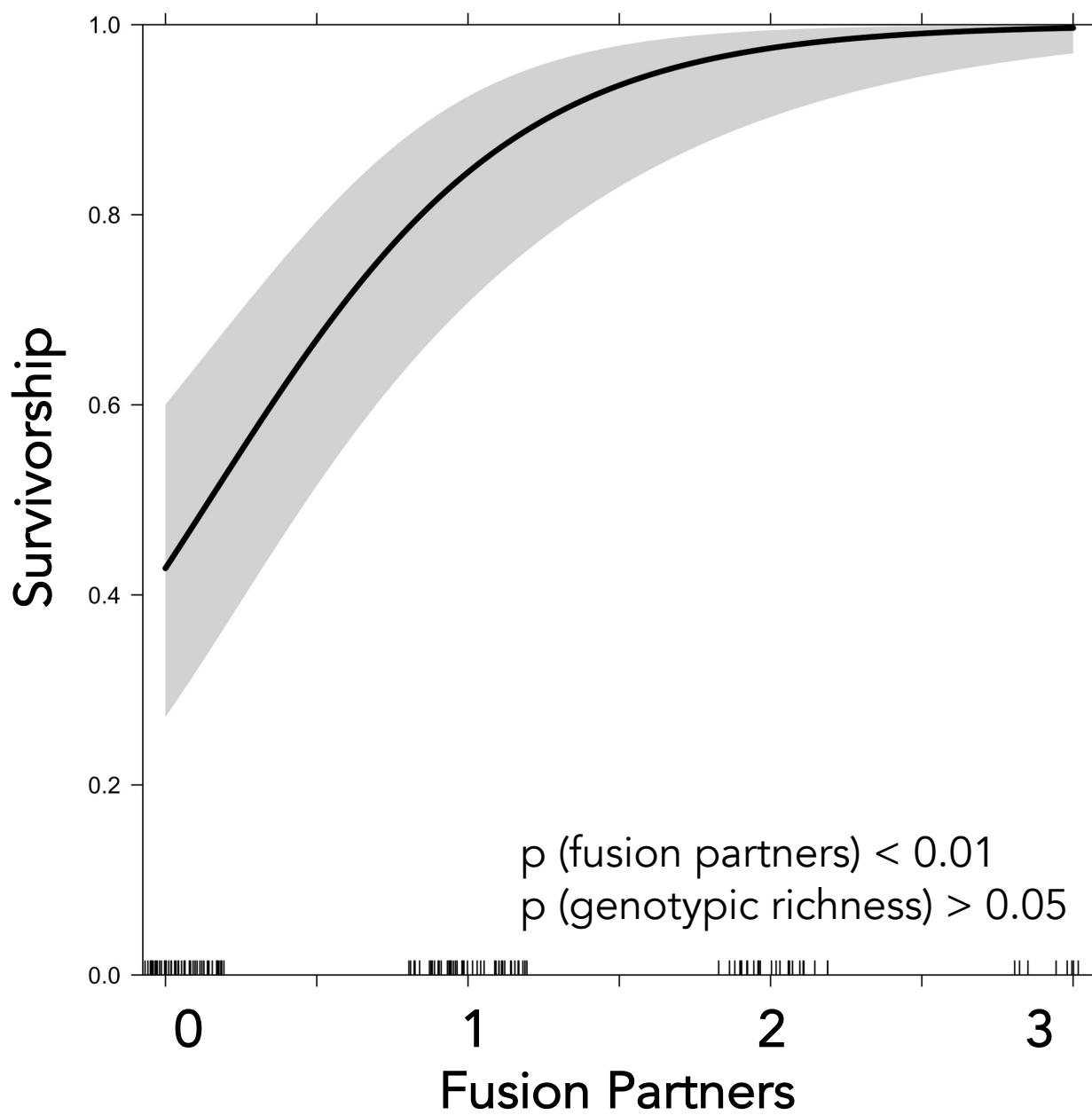
# Survival during grow-out period



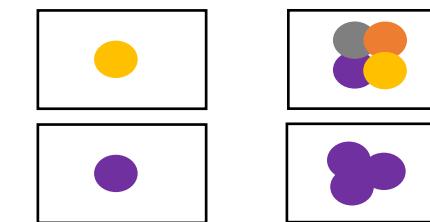
Survival increases with fusion

Competition between non-fused juveniles

# Survival during grow-out period

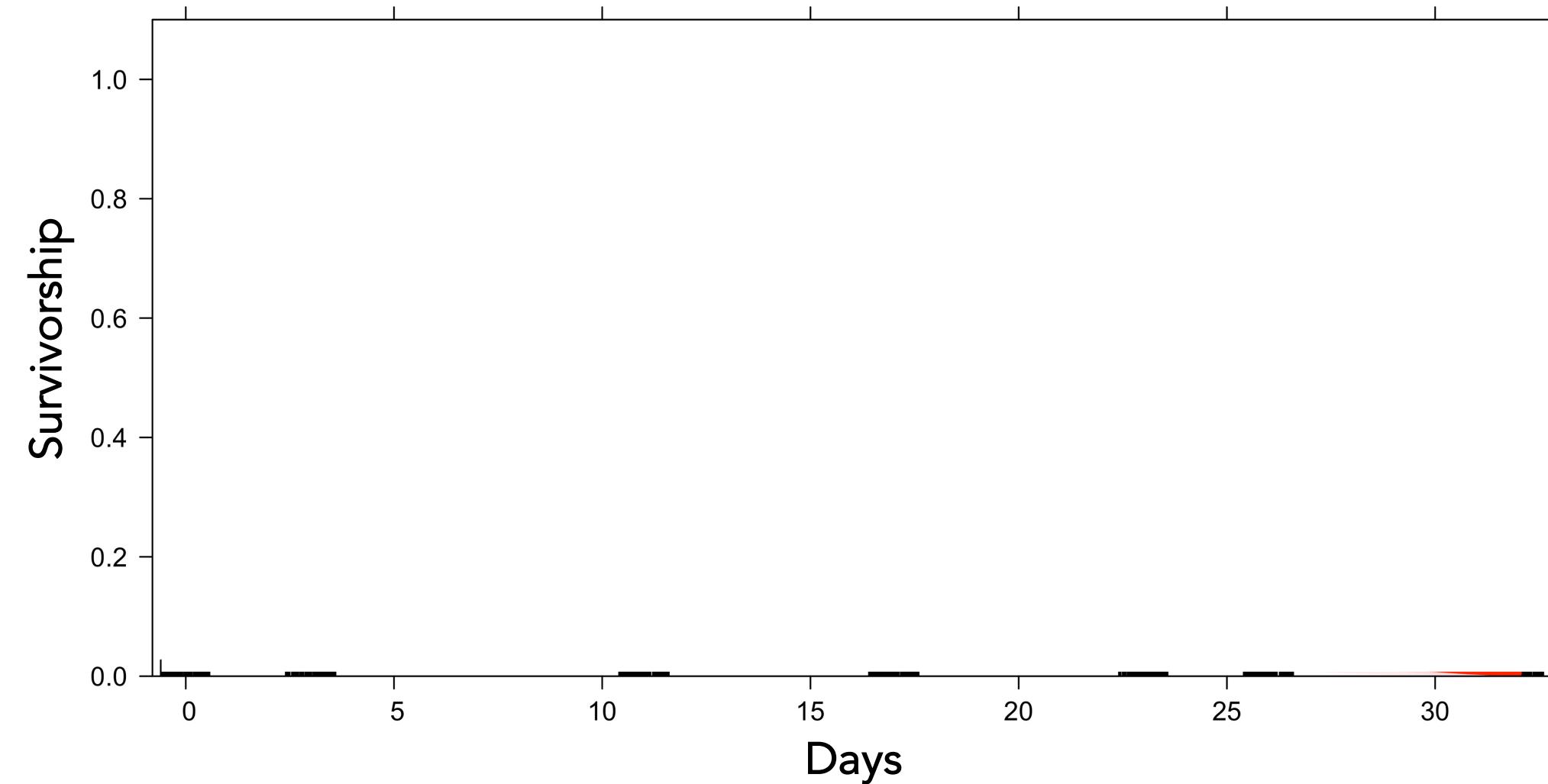


Thermal Stress Test:  
Individual & fused juveniles

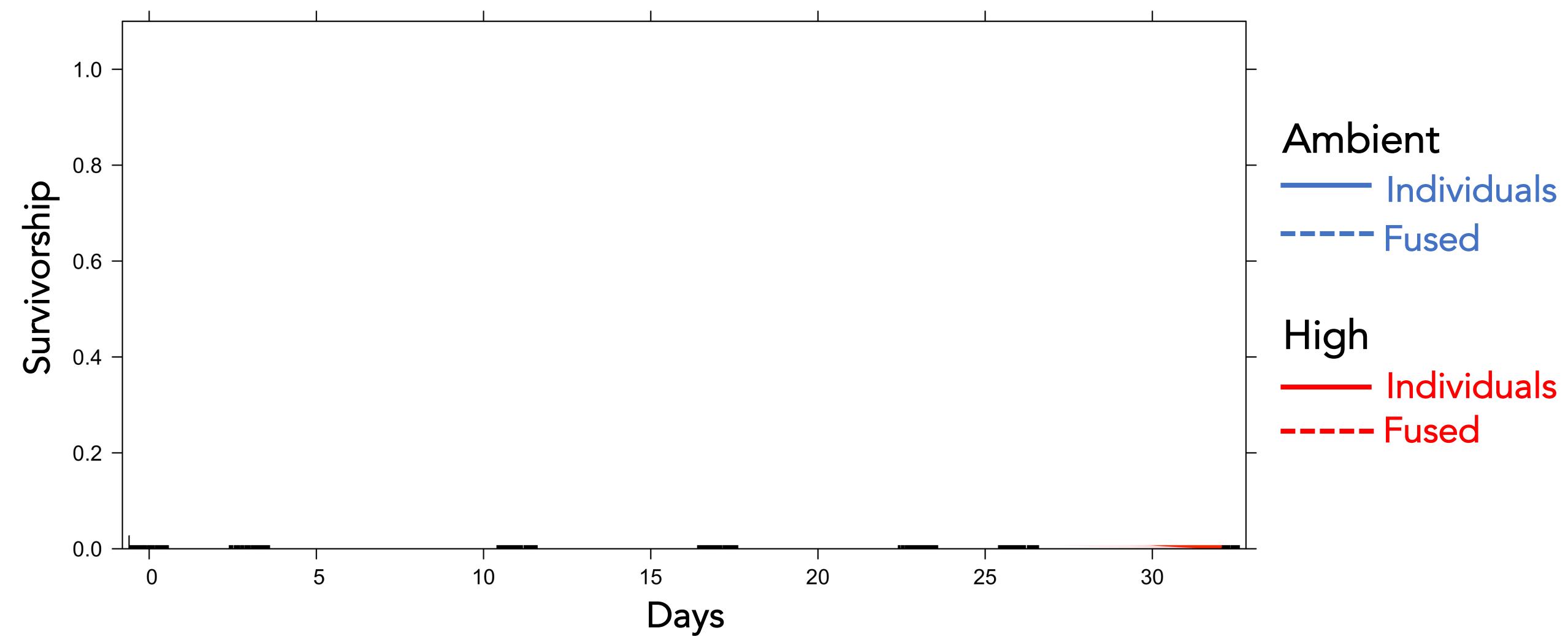


```
glmer(survival ~ fusion partners * genotypic richness + (1|parent site/colony) + (1|tank) + (1|slide), family=binomial, subset=c(Community=="Group"))
```

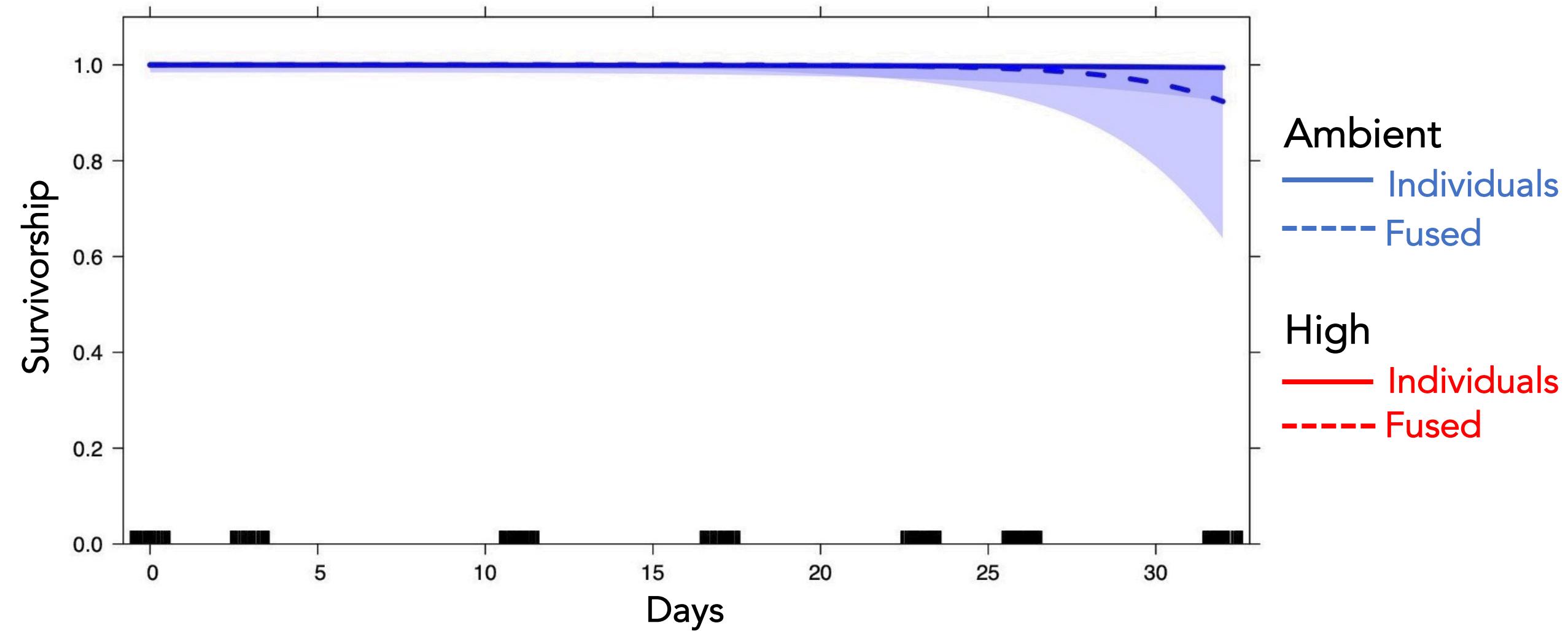
## Survival during thermal stress period



`glmer(survival ~ day * fusion * genotypic richness * temperature + (1|parent site/colony) + (1|tank) + (1|slide), family=binomial)`

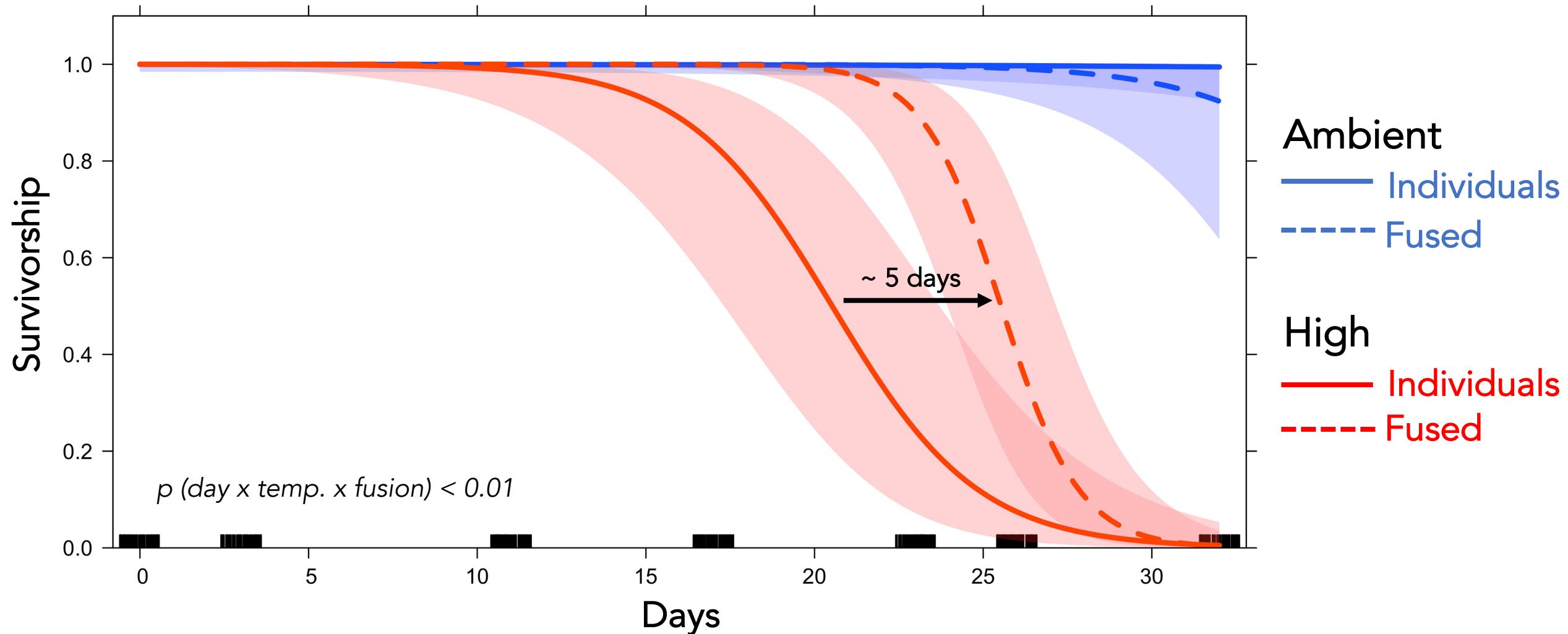


`glmer(survival ~ day * fusion * genotypic richness * temperature + (1|parent site/colony) + (1|tank) + (1|slide), family=binomial)`



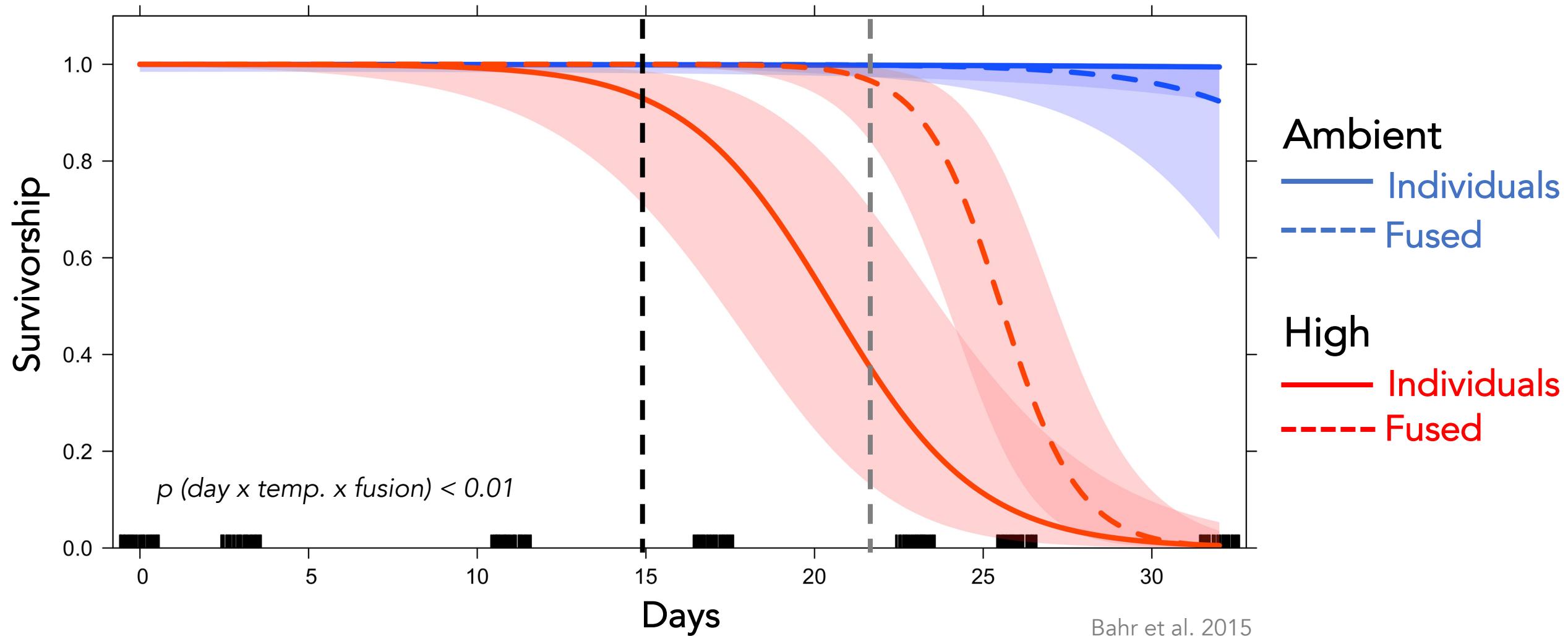
`glmer(survival ~ day * fusion * genotypic richness * temperature + (1|parent site/colony) + (1|tank) + (1|slide), family=binomial)`

# Fused corals survive longer in high temperature.

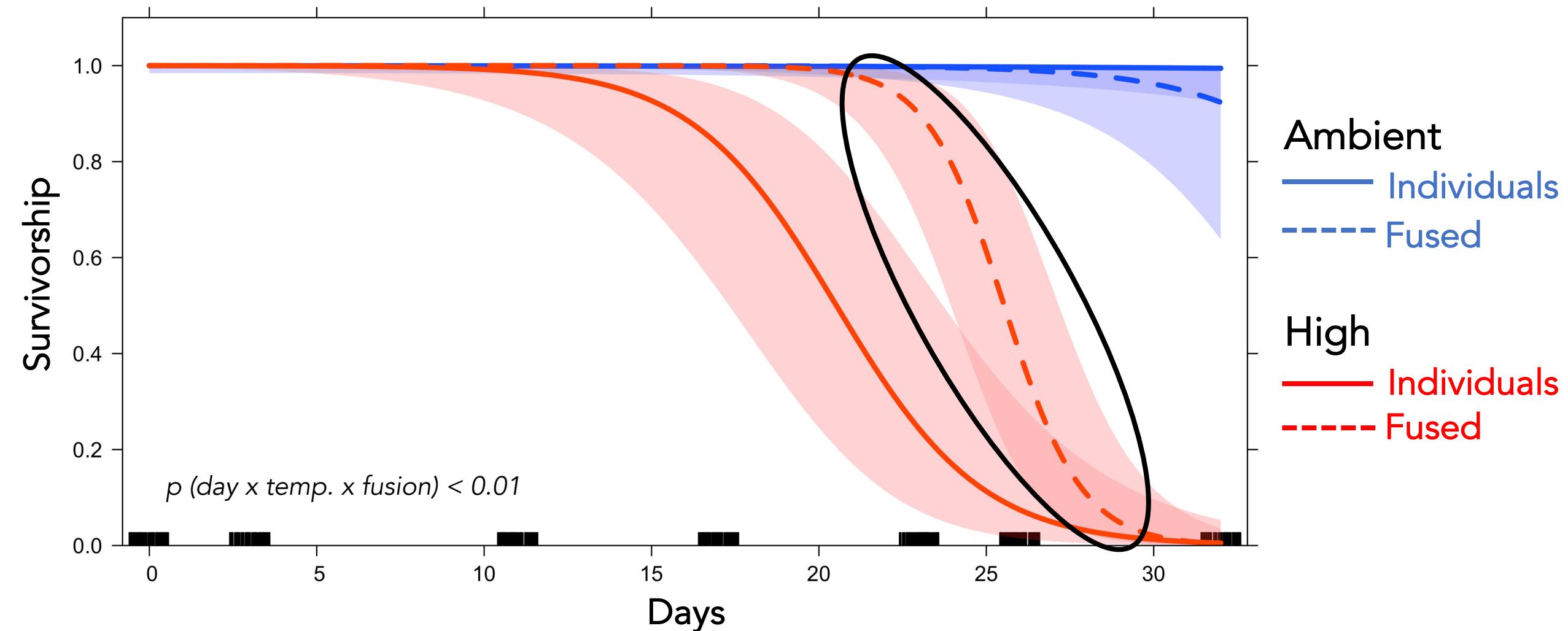


`glmer(survival ~ day * fusion * genotypic richness * temperature + (1/parent site/colony) + (1/tank) + (1/slides), family=binomial)`

# Fused corals survive longer in high temperature.



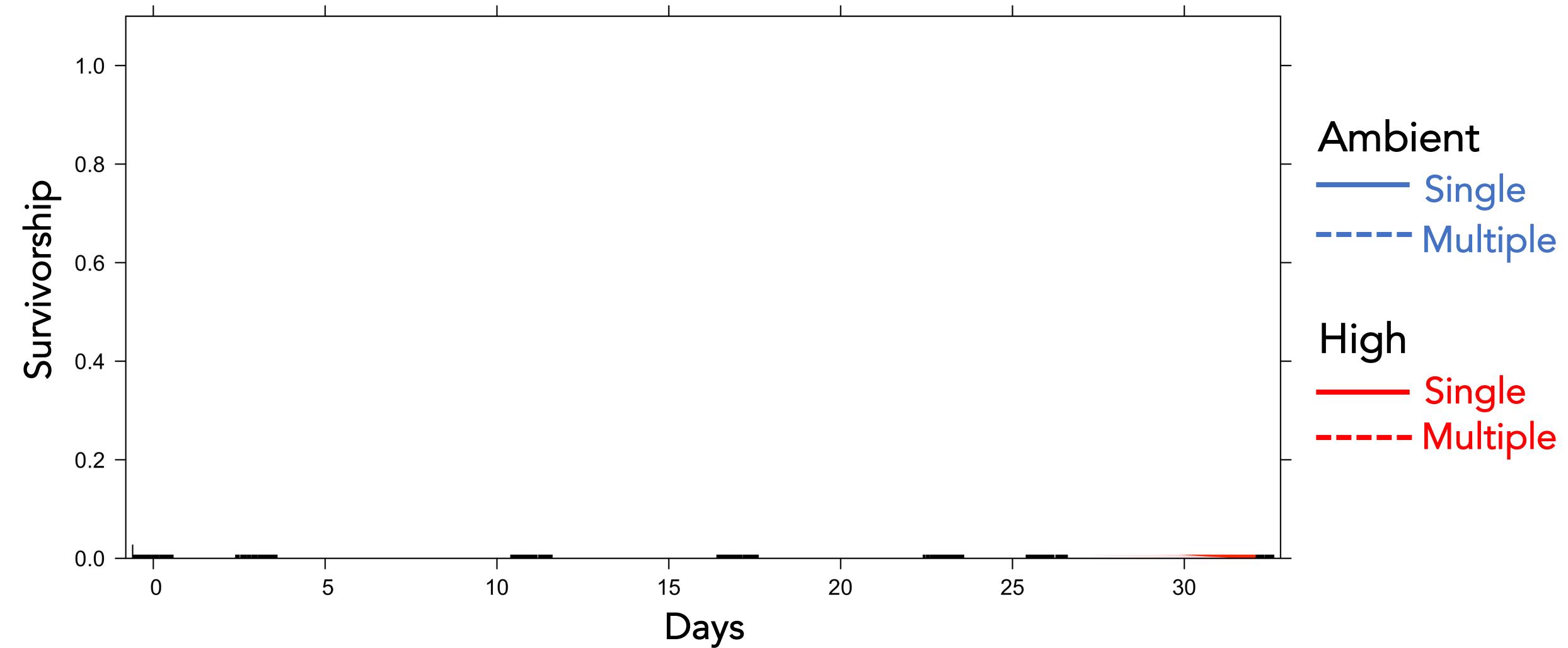
# Fused corals survive longer in high temperature.



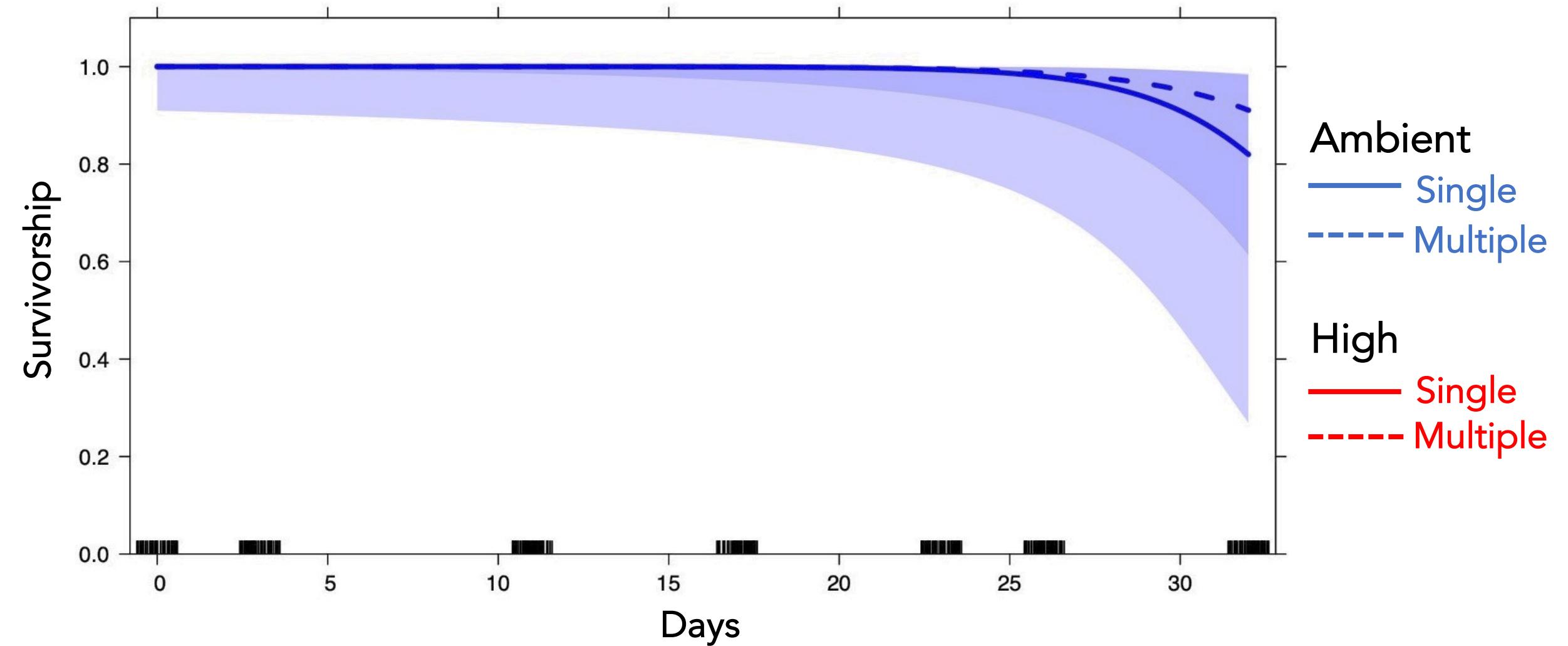
`glmer(survival ~ day * fusion * genotypic richness * temperature + (1|parent site/colony) + (1|tank) + (1|slide), family=binomial)`



compared to

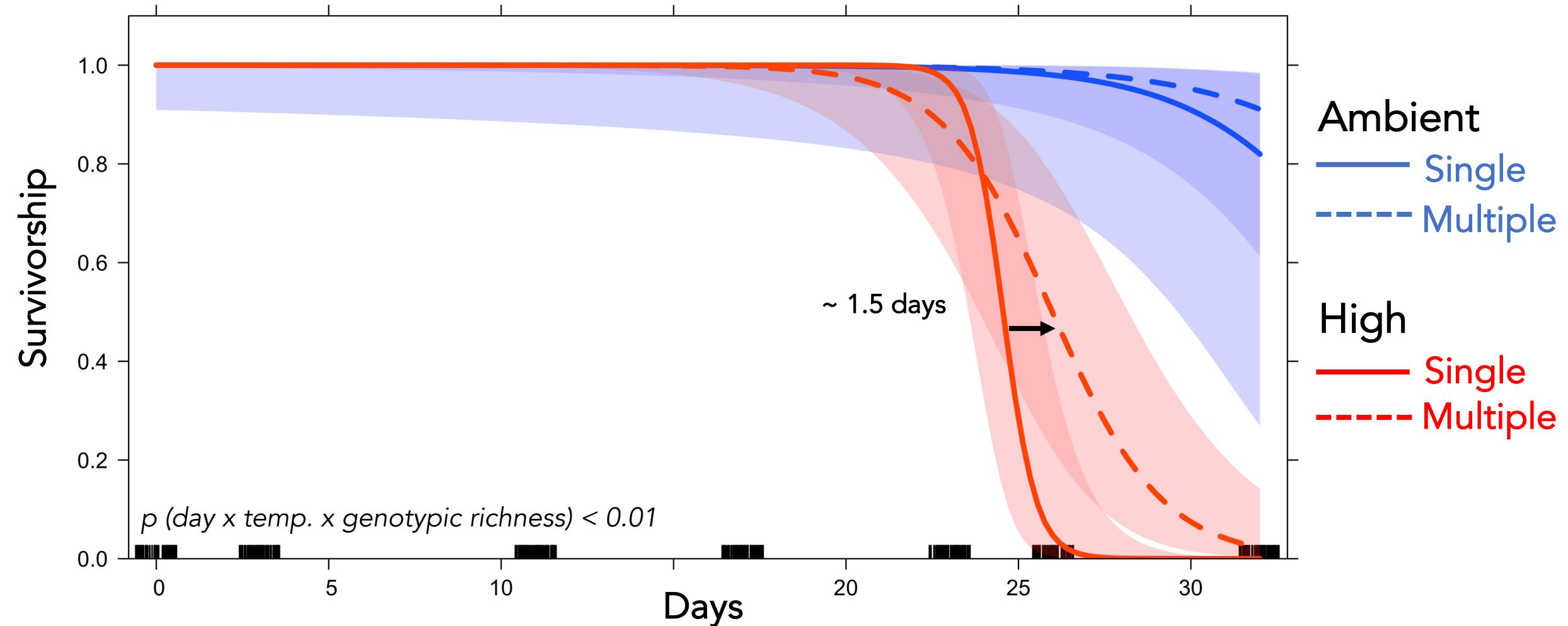


`glmer(survival ~ day * fusion * genotypic richness * temperature + (1|parent site/colony) + (1|tank) + (1|slide), family=binomial)`



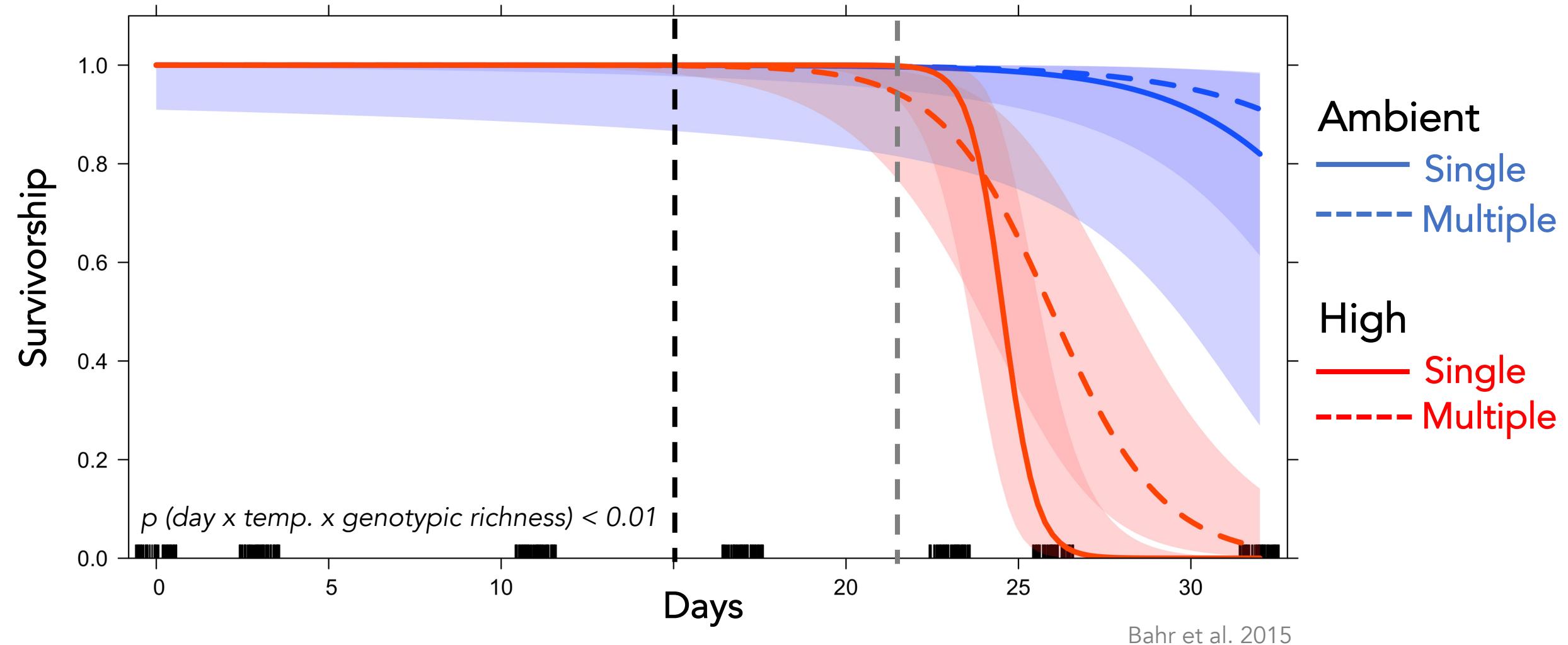
`glmer(survival ~ day * fusion * genotypic richness * temperature + (1|parent site/colony) + (1|tank) + (1|slide), family=binomial)`

# Genetically diverse fusions survive longer in high temperature.



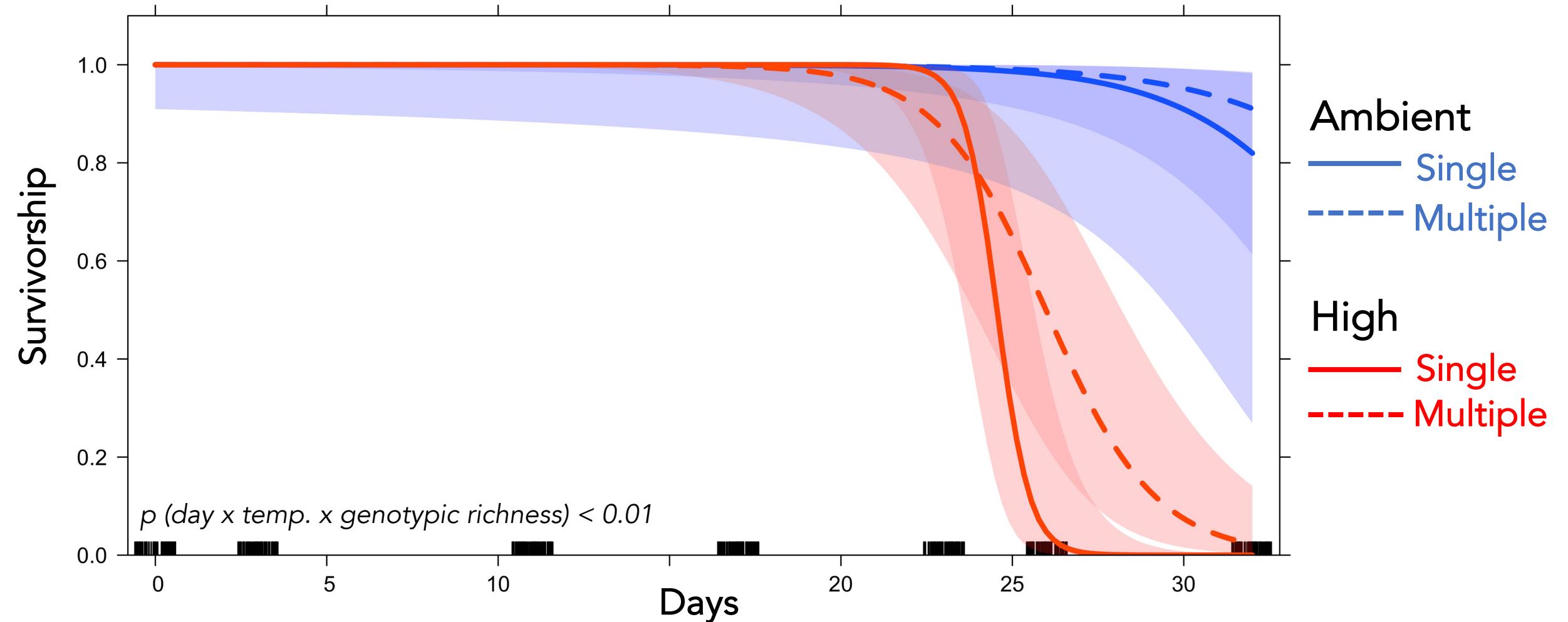
`glmer(survival ~ day * fusion * genotypic richness * temperature + (1/parent site/colony) + (1/tank) + (1/slides), family=binomial)`

# Genetically diverse fusions survive longer in high temperature.

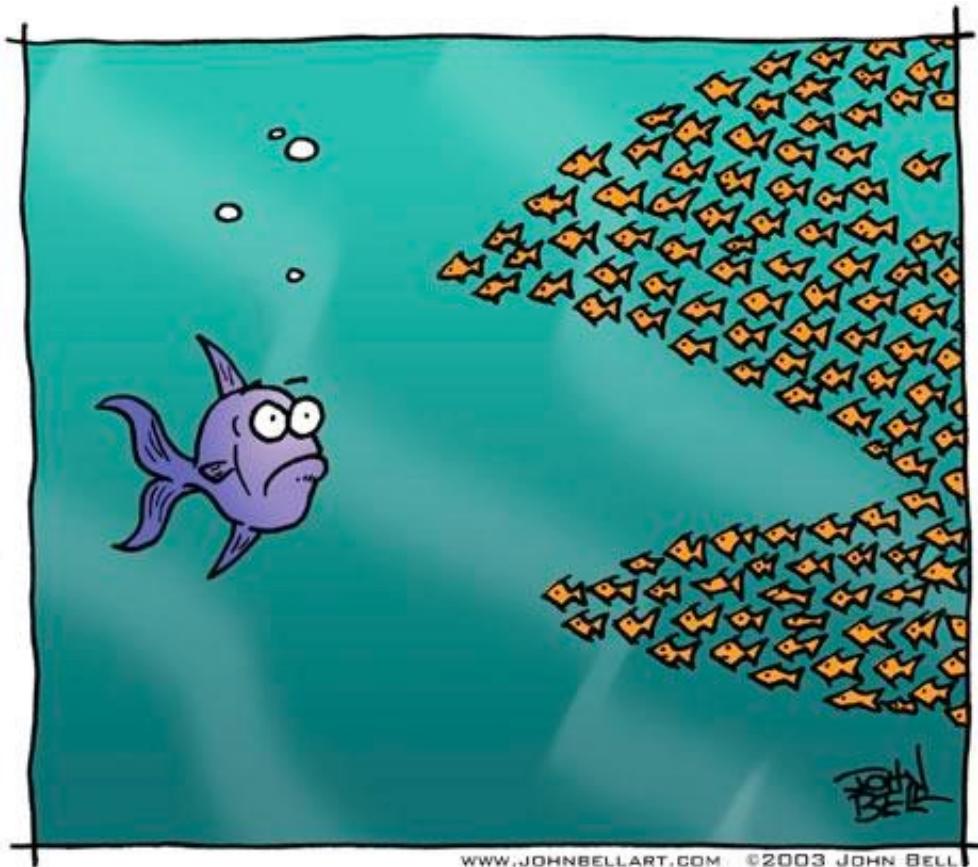


`glmer(survival ~ day * fusion * genotypic richness * temperature + (1|parent site/colony) + (1|tank) + (1|slide), family=binomial)`

# Prolonged exposure to high temperature results in high mortality.



`glmer(survival ~ day * fusion * genotypic richness * temperature + (1/parent site/colony) + (1/tank) + (1/slides), family=binomial)`

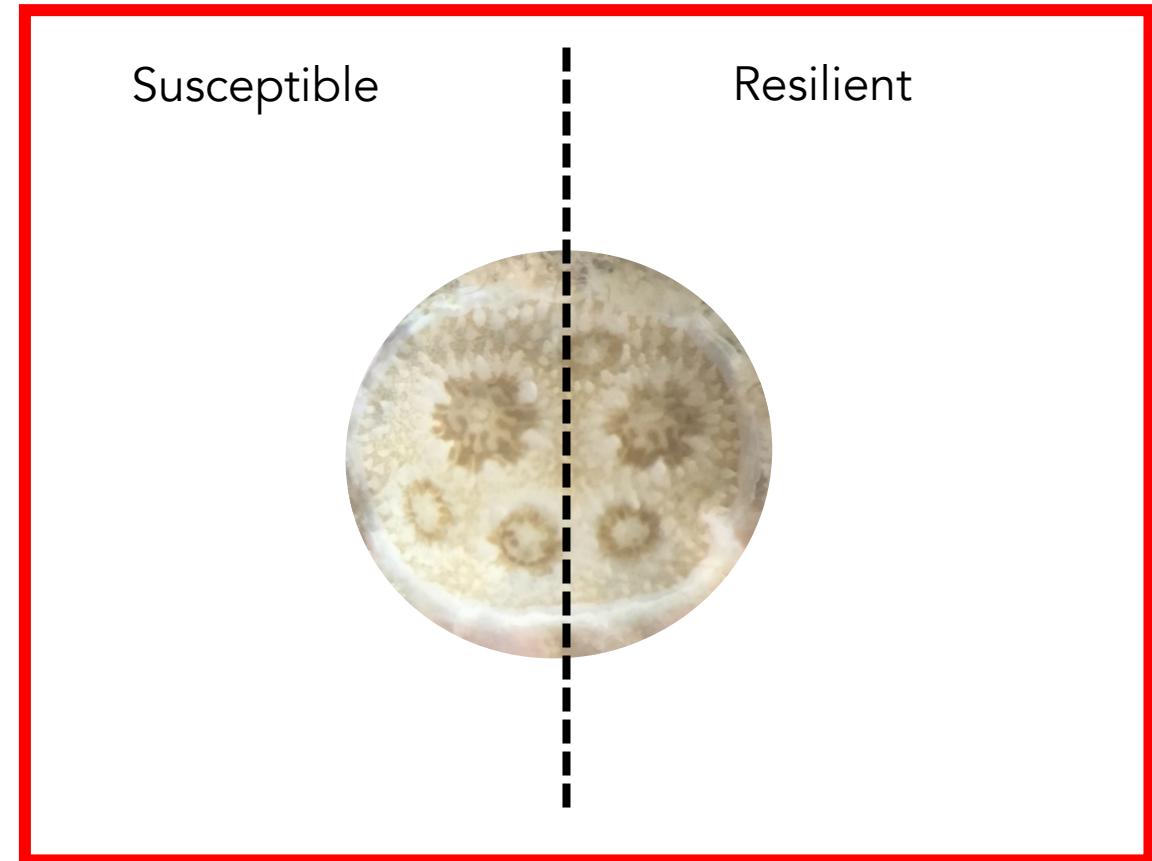
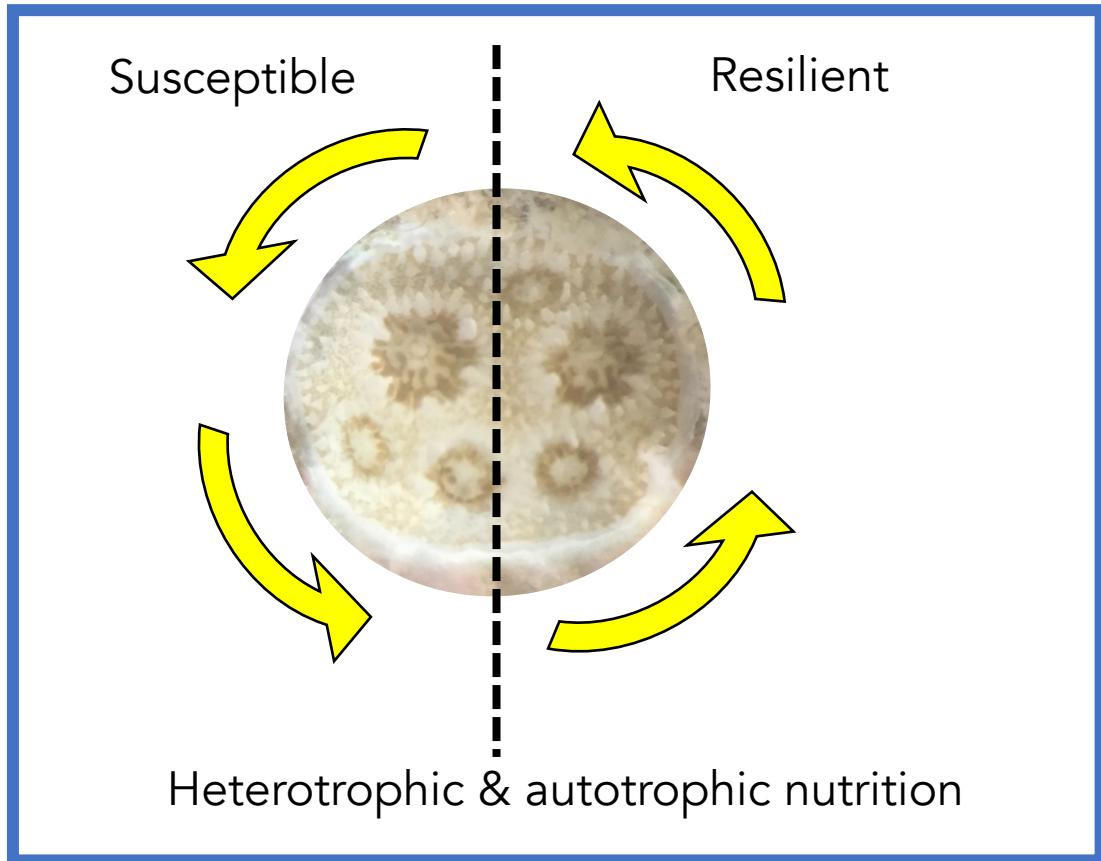


## Tissue fusion: safety in numbers

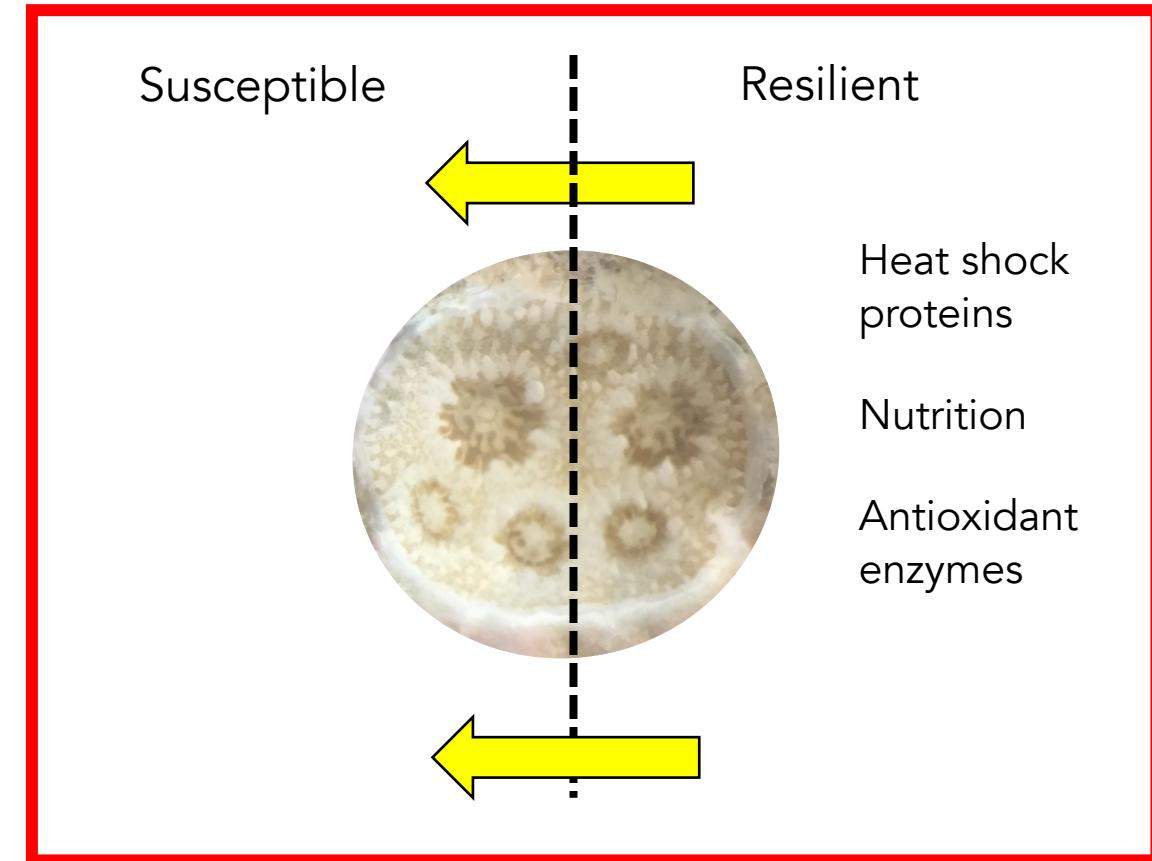
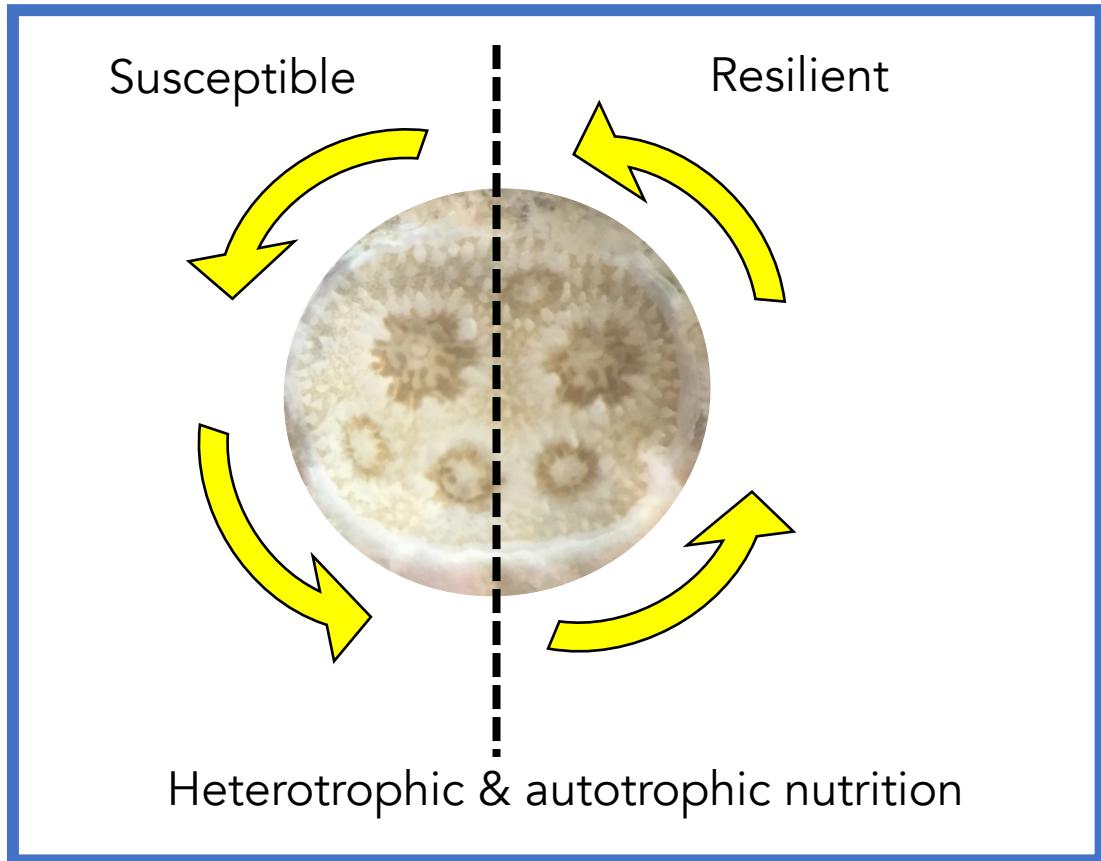
- Increase survival
- Ameliorate competitive interactions

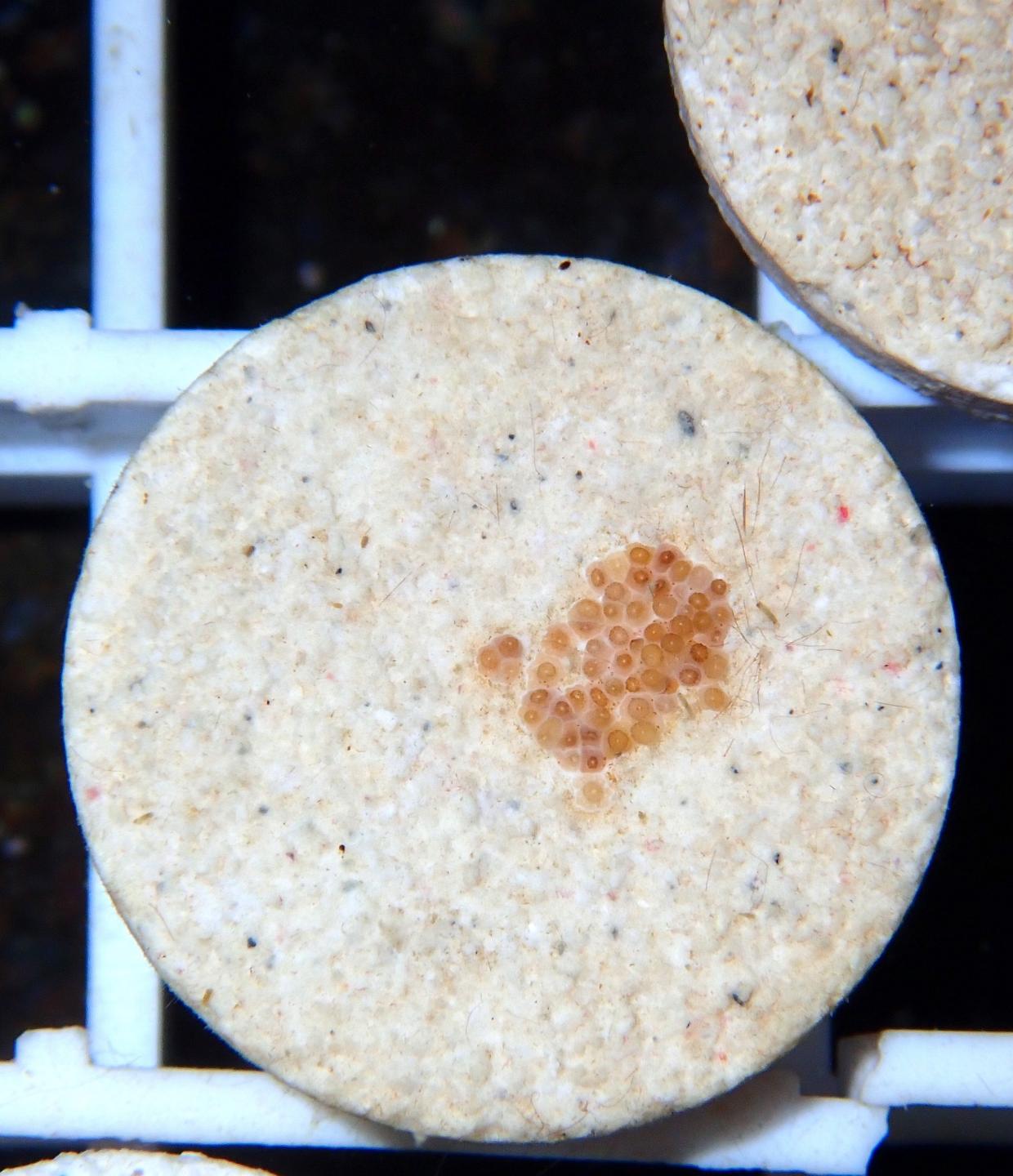
Huffmyer AS, C Drury, E Majerova, N Bean, C Harris, JD Lemus, RD Gates. Tissue fusion provides a survival advantage for juvenile *Pocillopora acuta* corals during thermal stress. *In prep.*

# “Rescue effect” in fusions with genetic diversity



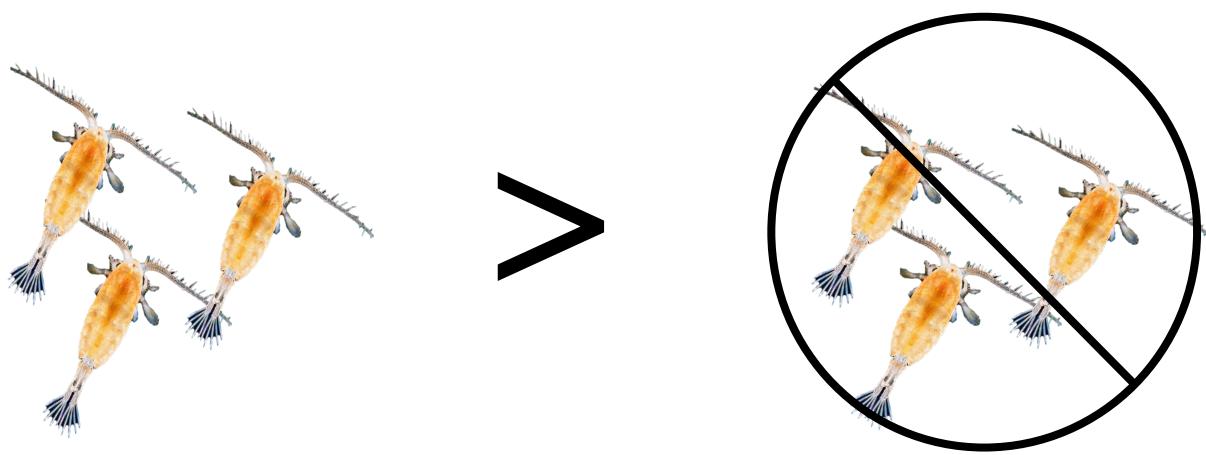
# “Rescue effect” in fusions with genetic diversity





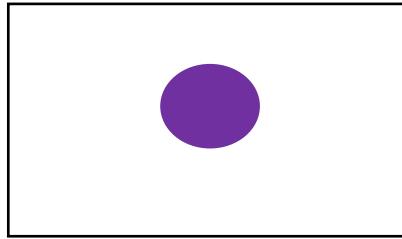
Are there environmental and biological conditions that promote juvenile survival in high temperature?



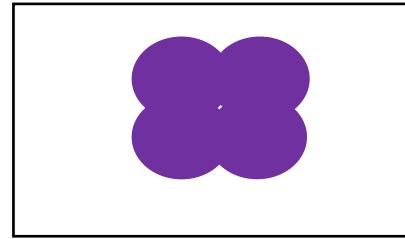


Huffmyer AS, CJ Johnson, AM Epps, JD Lemus, RD Gates. Heterotrophic feeding enhances tissue growth and thermal tolerance of *Pocillopora acuta* juvenile corals. *In prep.*

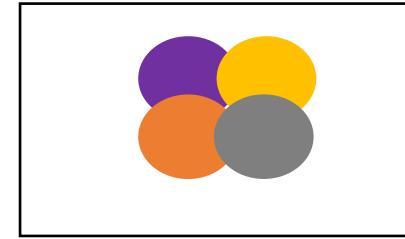




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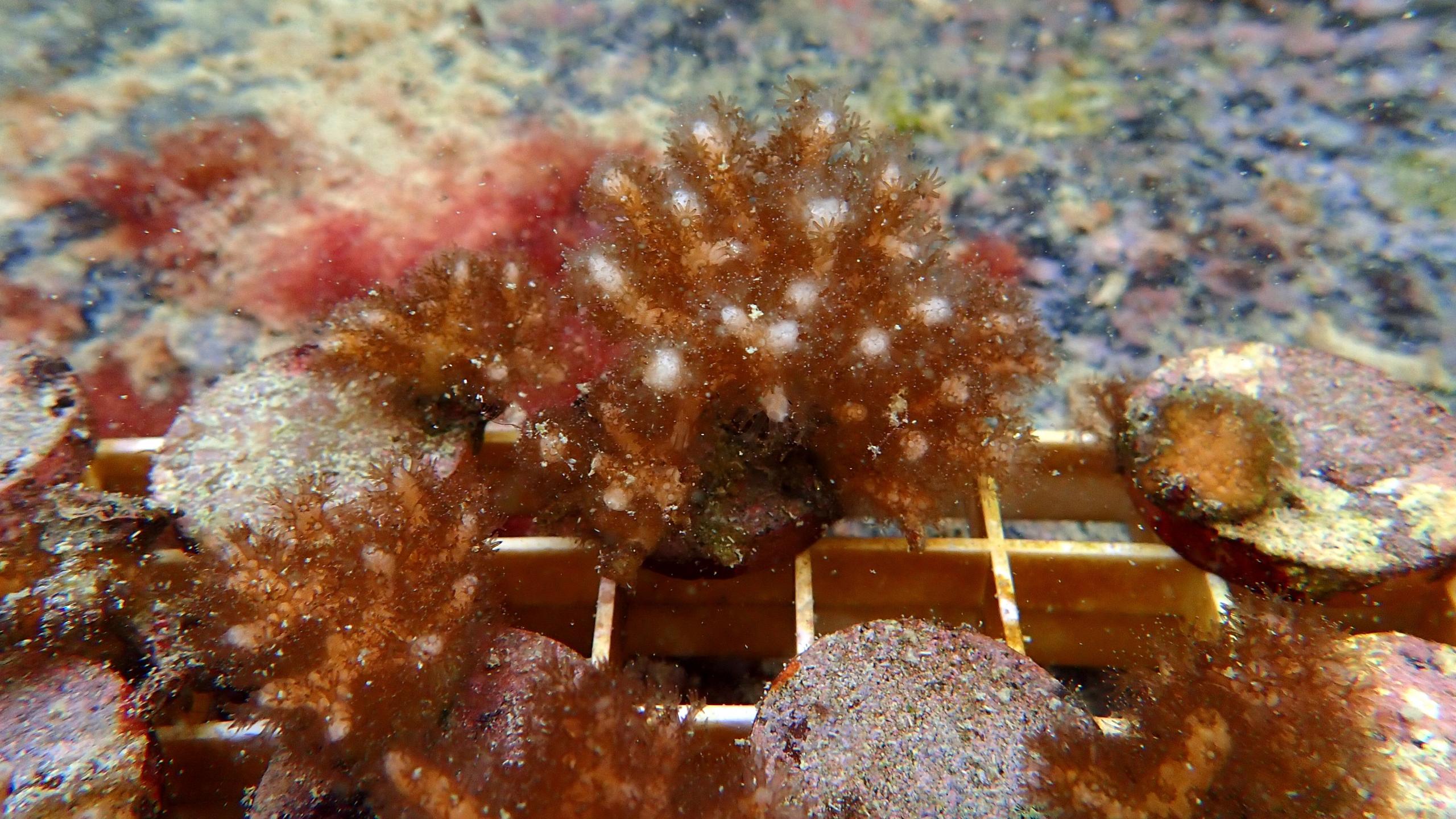


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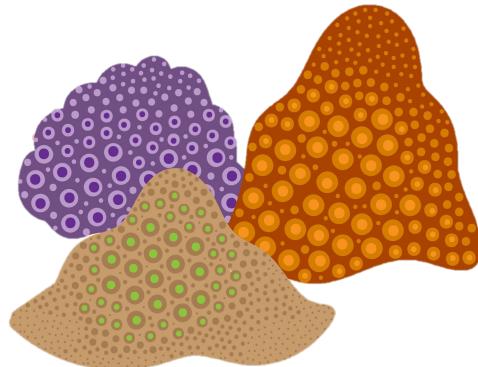
Huffmyer AS, C Drury, E Majerova, N Bean, C Harris, JD Lemus, RD Gates. Tissue fusion provides a survival advantage for juvenile *Pocillopora acuta* corals during thermal stress. *In prep.*



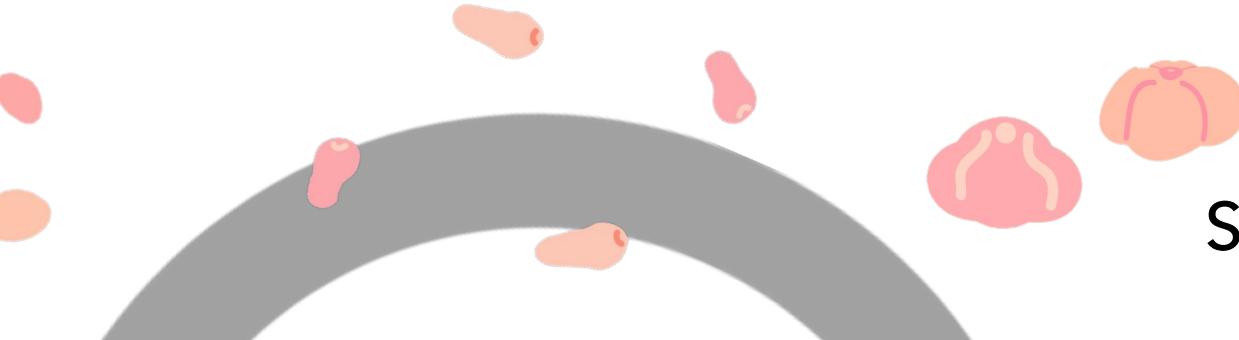


**Early scientists:**  
Initial interest in science

Foster next-generation of scientists



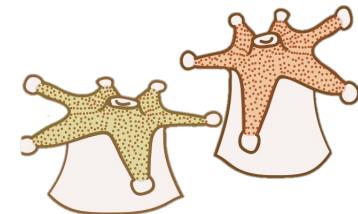
**Maturation in science:**  
Reach desired science career



## **Scientist Life Cycle**

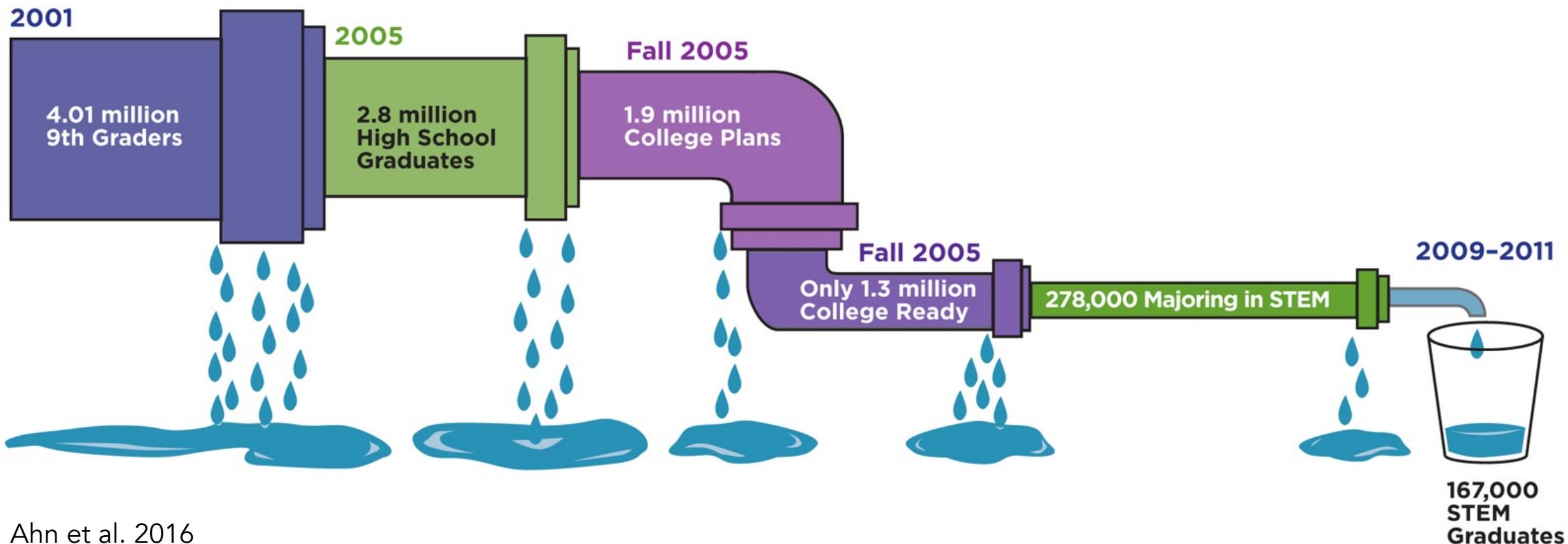


**Science “recruits”:**  
Start science education

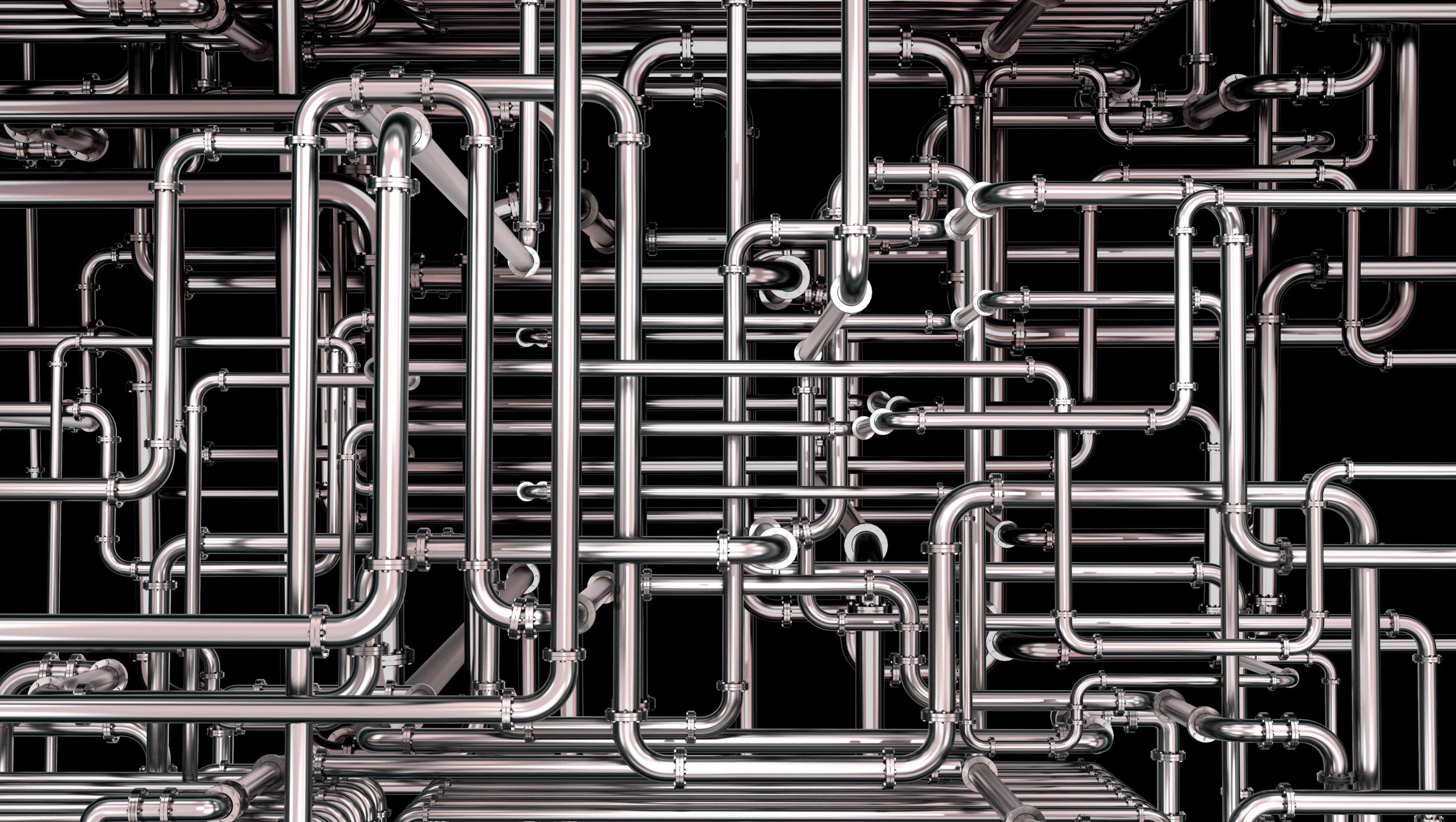


**Science “juveniles”:**  
Development & growth in education pathway

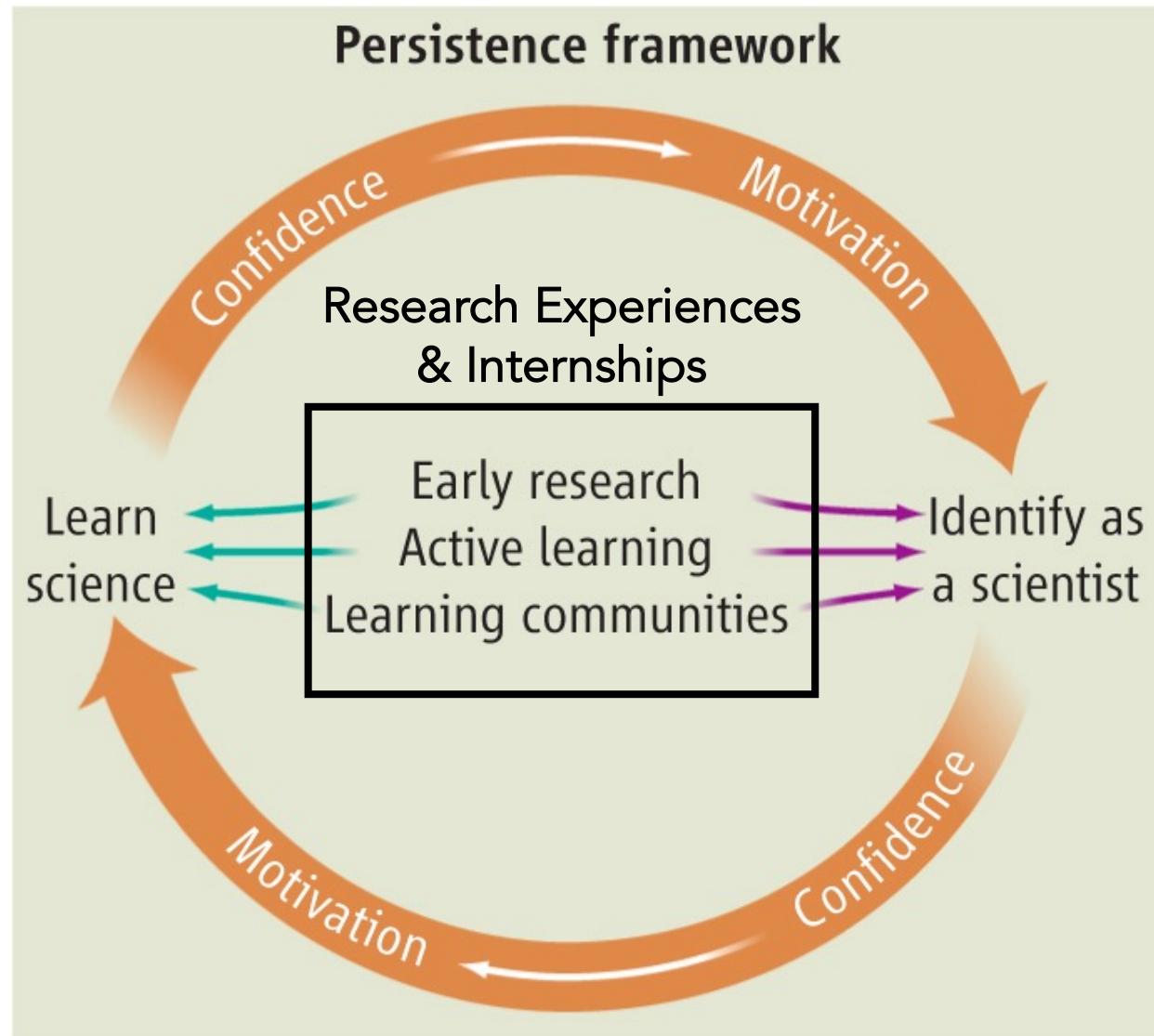
## A Leaking STEM Pipeline



Underrepresented groups in STEM: Gender, race, ethnicity inequities

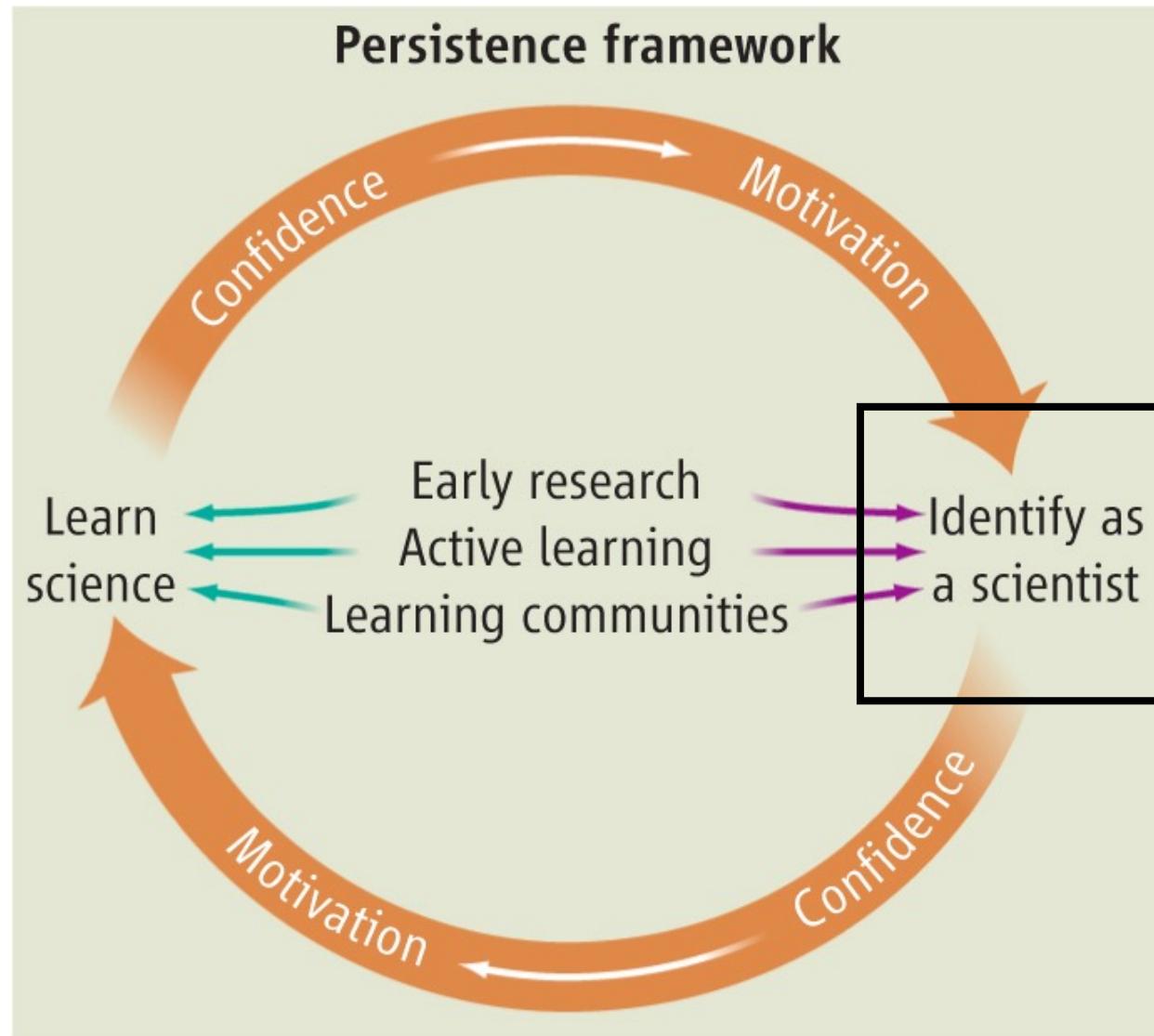


# Supporting student persistence in science



Graham et al. 2013

# Supporting student persistence in science



Graham et al. 2013

Expectancy-value: *Can I be successful in science?*

Personal views: *Am I a scientist?*

Interest: *Am I interested in science?*

Views of others: *Do others view me as a scientist?*

## Science Identity

Mismatches: *Is science what I expected it to be?*

Values: *Is science important to me?*

Motivation: *What kind of scientist am I?*

Social environment: *Do I “fit in” in science?*

Expectancy-value: *Can I be successful in science?*

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## Science Identity



Views of others: *Do others view me as a scientist?*

Mismatches: *Is science what I expected it to be?*

## Persistence

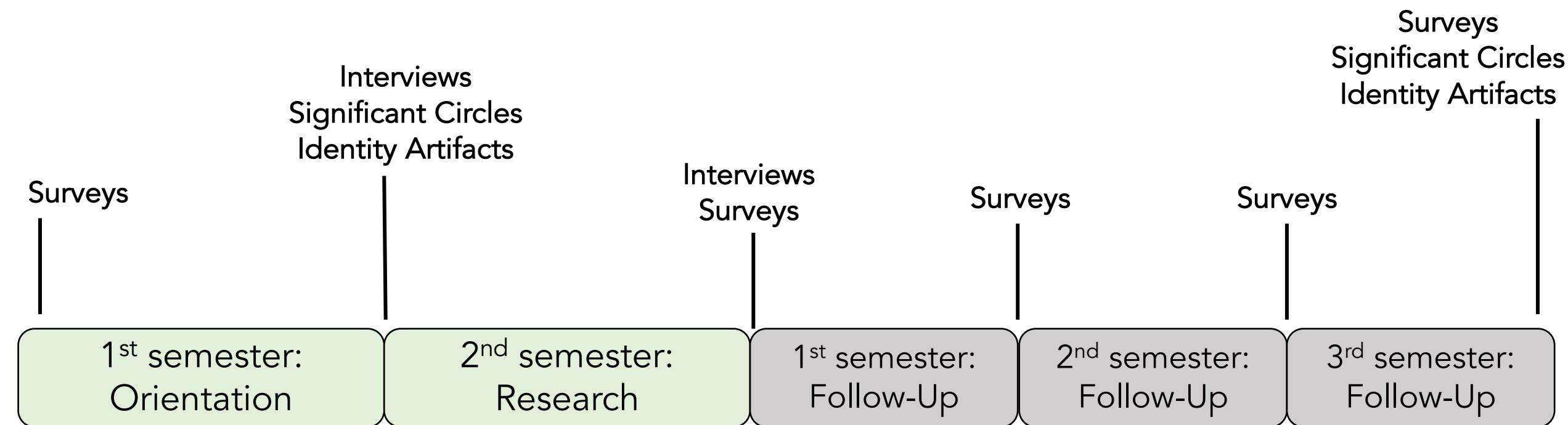
Values: *Is science important to me?*

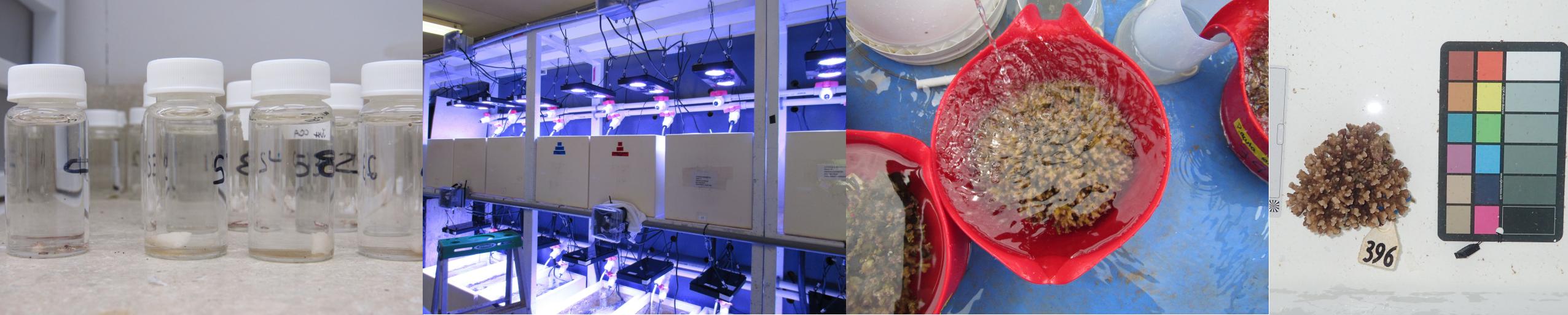
Motivation: *What kind of scientist am I?*

Social environment: *Do I “fit in” in science?*

# How does early participation in research influence community college student science identities and career trajectories?

## Impacts of experience, science identity, trajectories





# Independent research projects in coral biology

||

1<sup>st</sup> semester:  
Orientation

2<sup>nd</sup> semester:  
Research

1<sup>st</sup> semester:  
Follow-Up

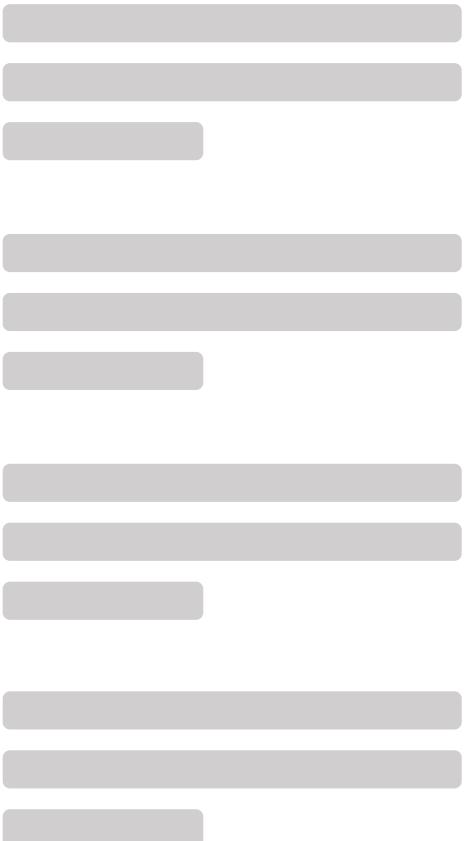
2<sup>nd</sup> semester:  
Follow-Up

3<sup>rd</sup> semester:  
Follow-Up

# Qualitative research: Thematic analysis

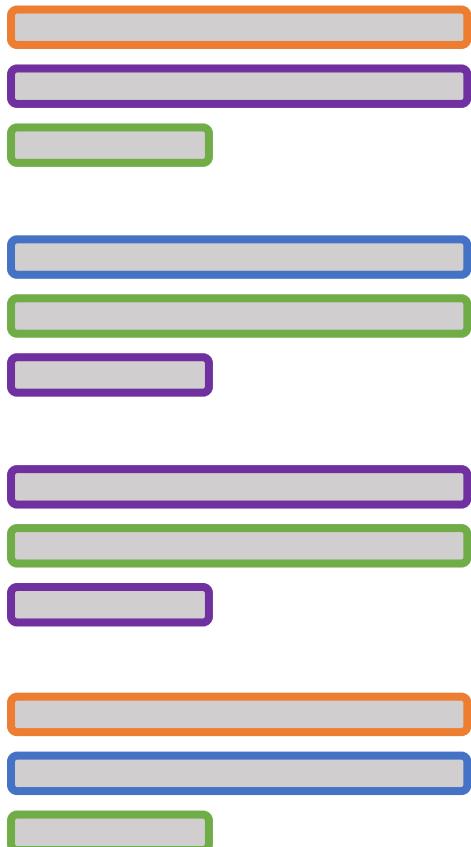
Raw Data: Transcript

Open Coding

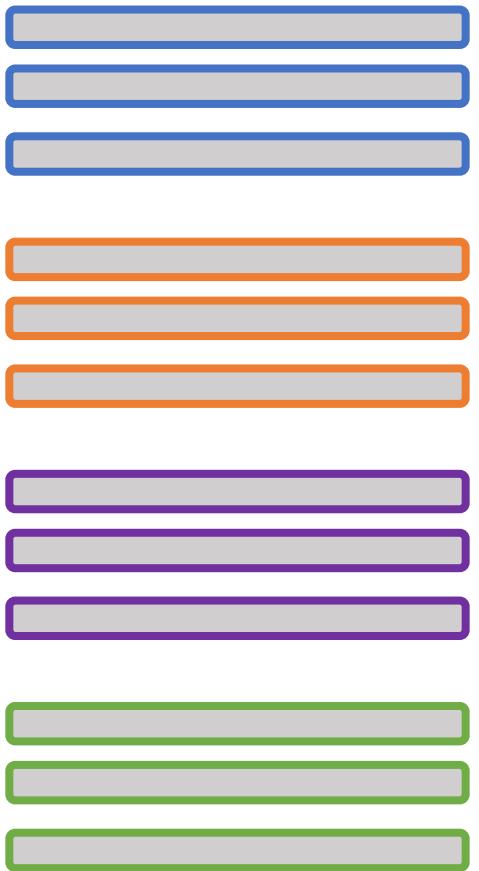


# Qualitative research: Thematic analysis

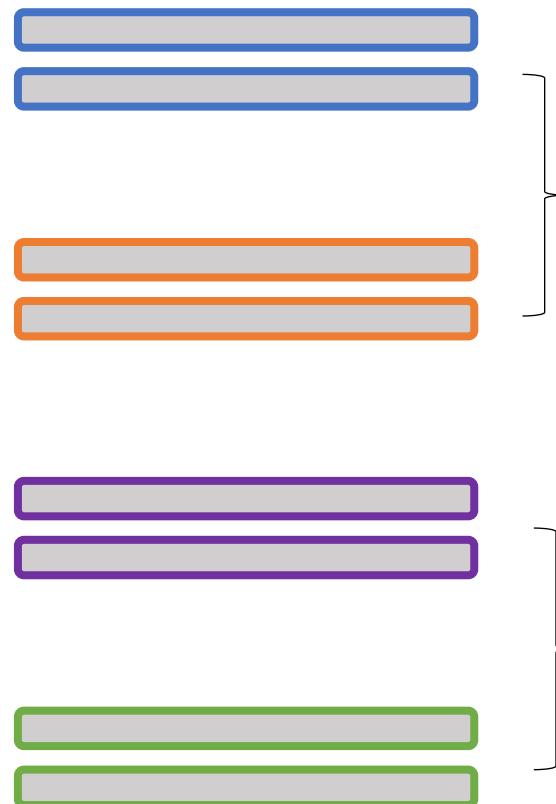
Raw Data: Transcript  
Open Coding



Secondary Coding



Axial Coding



Themes

Theme 1

Theme 2

# 1. Students reported increases in science understanding

## Coral Biology

"I gained more knowledge about corals."

"I loved learning about corals."

## Scientific Practices

"Showed me how real research is done."

"I learned science is never linear."

## Understanding of their own interests

"I realized I could not see myself in a lab."

"Helped me realize my passionate interests."

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Involve early education students in internships

## 2. Students were challenged by data analysis

"I am good at everything in research except the math."

"I need to work on how to understand data sheets."

"I had a hard time with data analysis and making graphs."

"Numbers and math are not my strong suit."

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Provide early & often data analysis practice during internships

### 3. Students expressed science identities

#### Views of science identity

1. Curiosity & desire to learn
2. Benchmarks & qualifications

*"Yes, I am a scientist. Anyone who wants to learn more about the environment or world around them is a scientist."*

*"I'm not at the PhD level, but I think I fit along the lines of a scientist because I'm curious and I want to know about life. So, I think that's good enough."*

*"Junior scientist... I feel like [scientists] have at least an Associate's or some experience like a real job."*

... but were unsure of their professional identity

## Professional Identity

*Student identification with a career that fits their motivations, interests, and goals in science.*

“I don’t really know what I would do as a job.”

“I don’t know if there is a job description out there for me.”

# Five Semesters

Research in a lab



Marine geology

Marine biology



Marine research

Work with animals



Wildlife conservation

Ocean engineering



Environmental planning

Marine research  
& education



Biology, conservation &  
community outreach

# Five Semesters

Research in a lab



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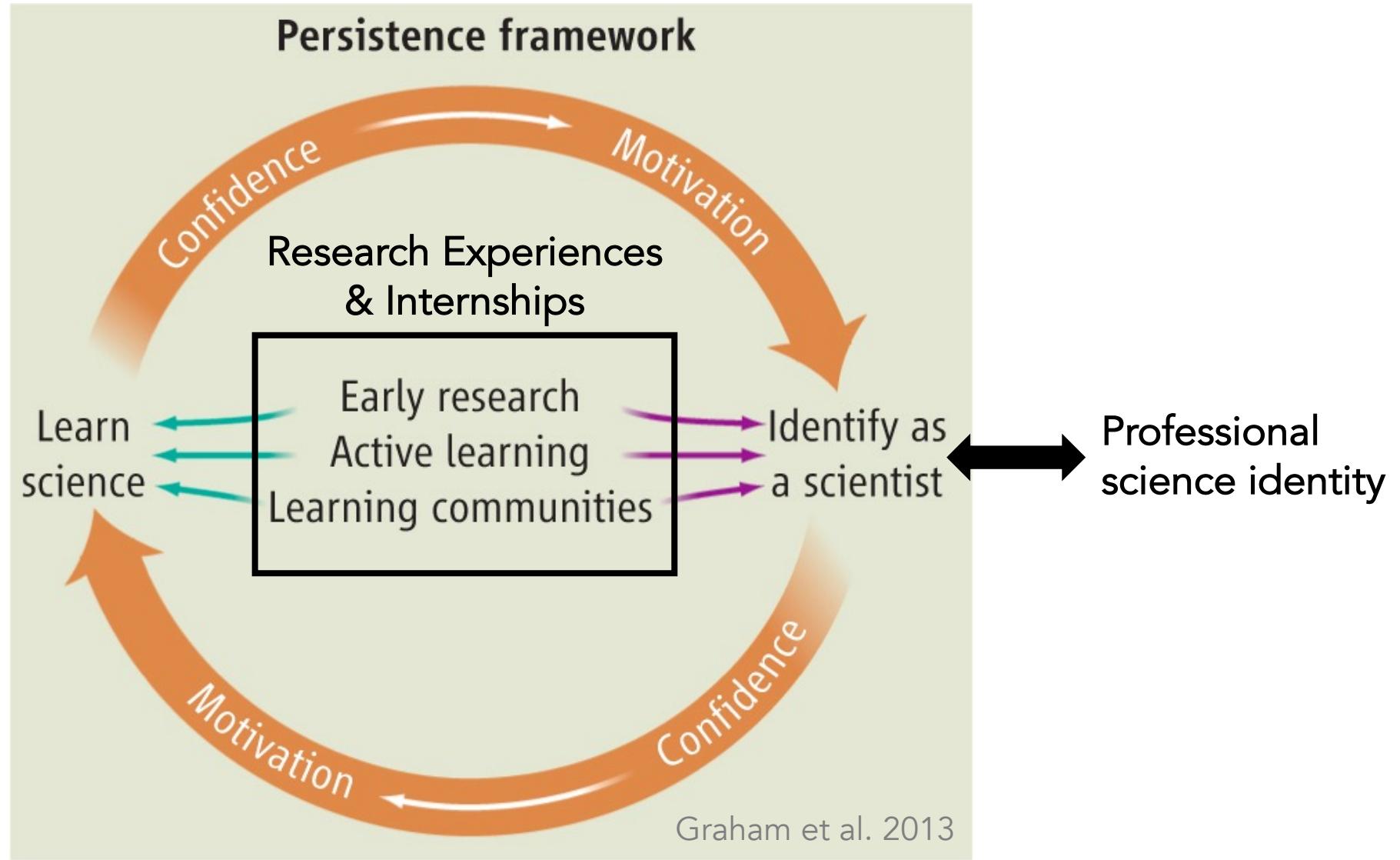
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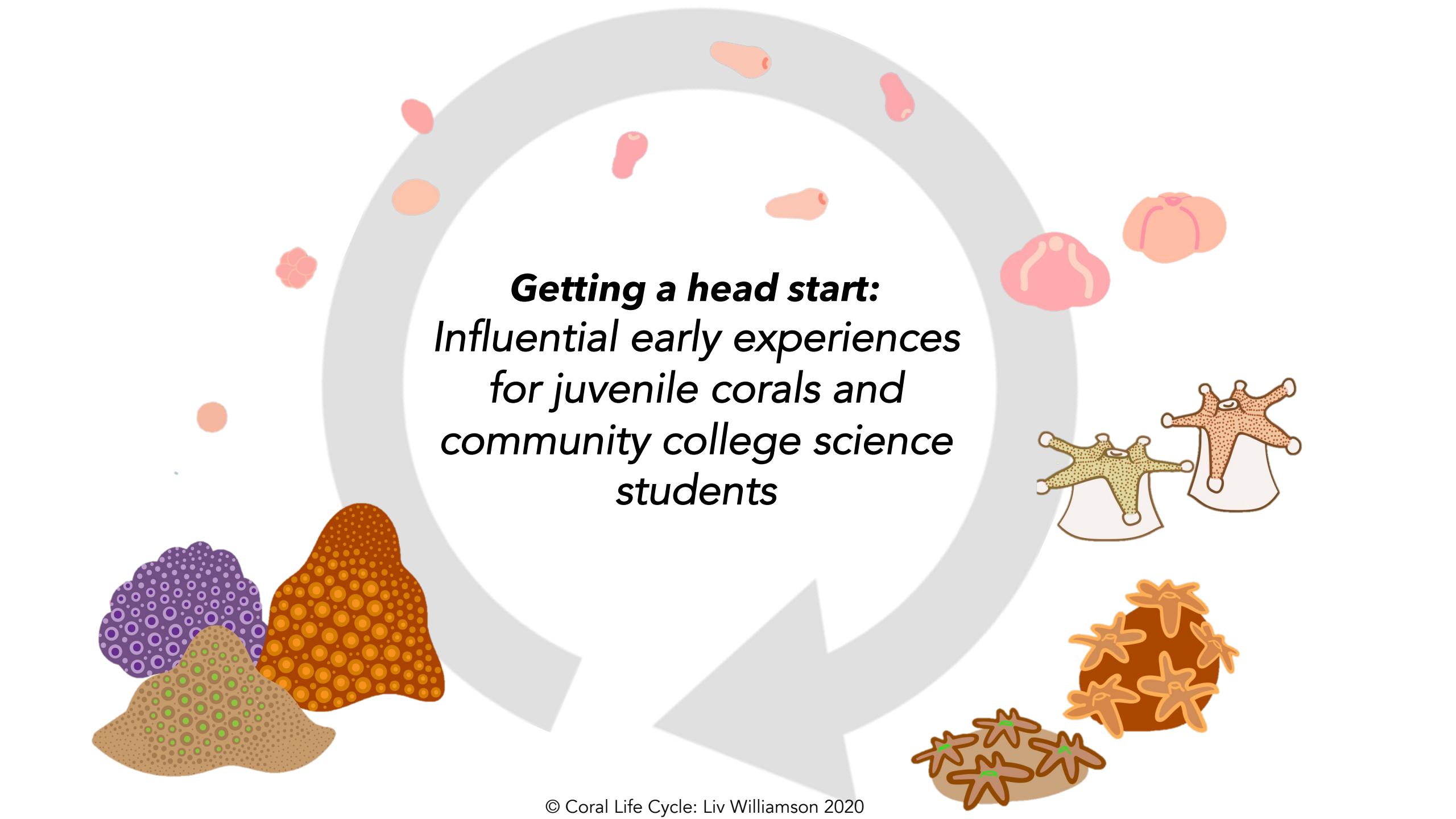
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Incorporate student identity discussions and career coaching

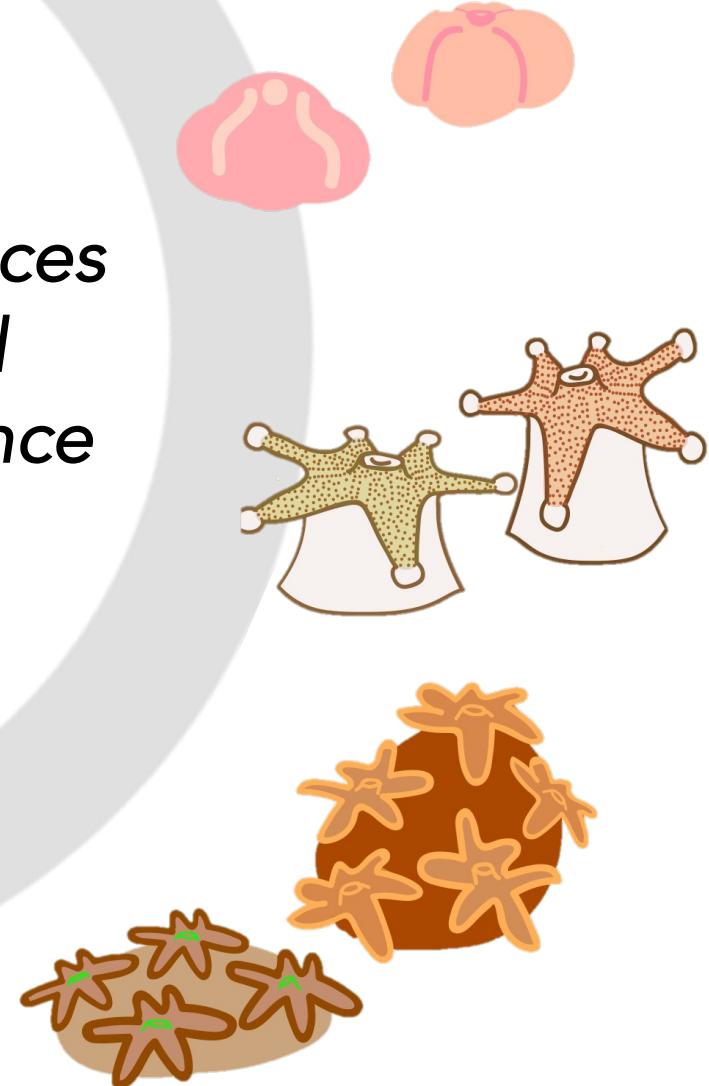
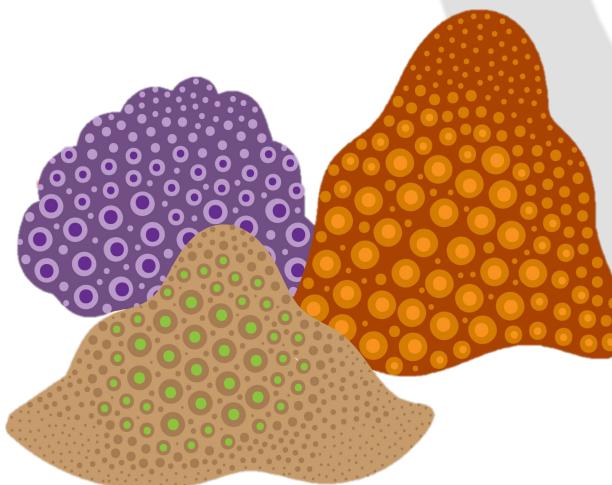
# Supporting identity development in early education



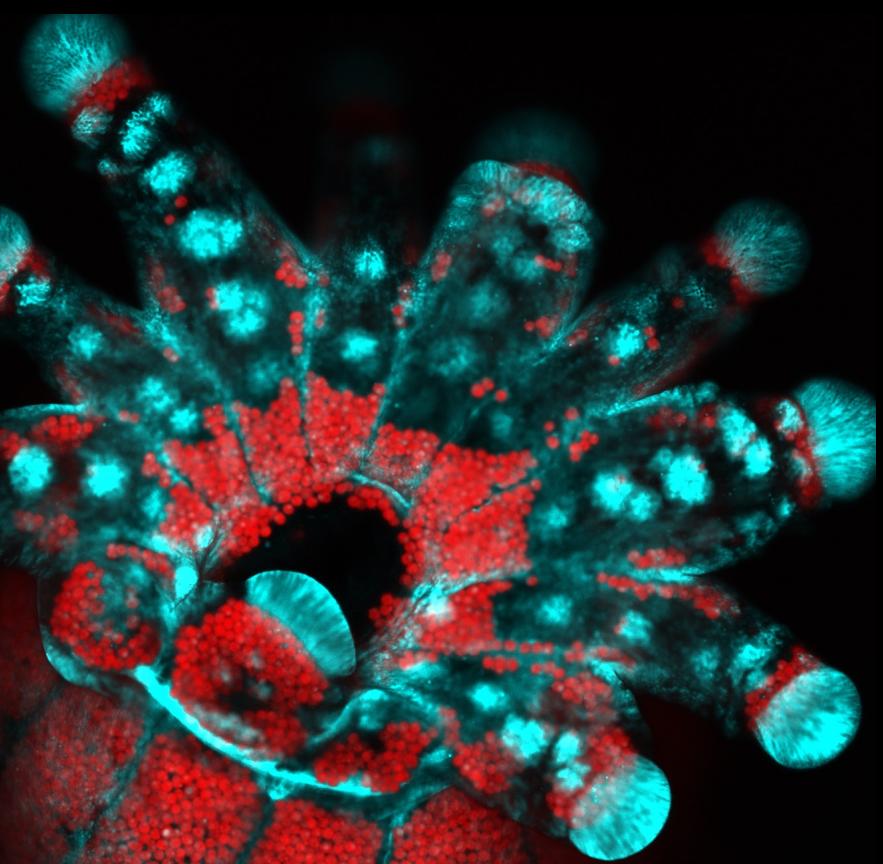
Huffmyer AS, T O'Neill, JD Lemus. Expanding our understanding of science internships for community college students: A need to integrate learning and science practice with support for professional identity in science. *In prep.*



***Getting a head start:***  
***Influential early experiences***  
***for juvenile corals and***  
***community college science***  
***students***



# Acknowledgements

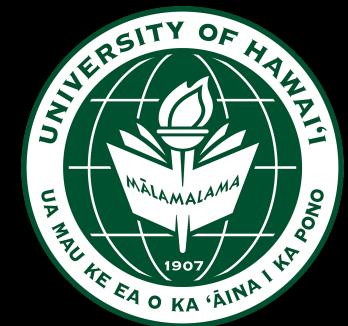


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# Thank you!



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