

# **Exploring the tolerance of Pacific geoduck to low pH through comparative physiology, genomics, and DNA methylation**

**Shelly A. Trigg**

(strigg@uw.edu)

School of Aquatic and Fishery Sciences, University of Washington

**Co-authors:** Hollie M. Putnam and Samuel J. Gurr, University of Rhode Island

Steven B. Roberts and Kaitlyn R. Mitchell, University of Washington

Brent Vadopalas, Washington Sea Grant

Matthew Henderson, Jamestown S'klallam Point Whitney Hatchery

*12-minute talk*



**FOUNDATION FOR  
FOOD & AGRICULTURE  
RESEARCH**

# Pacific Geoduck are important

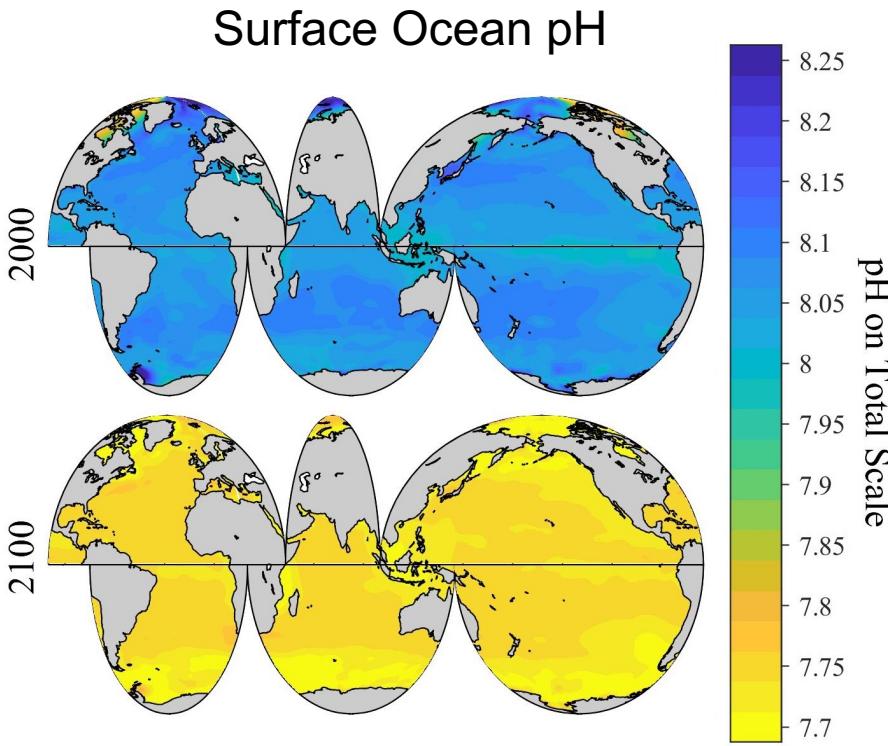
- Among most valuable farmed **shellfish** on a per acre basis
  - >\$20 M in annual sales in Washington alone
- Serve ecosystems as biofilters and prey
- Tribal sustenance



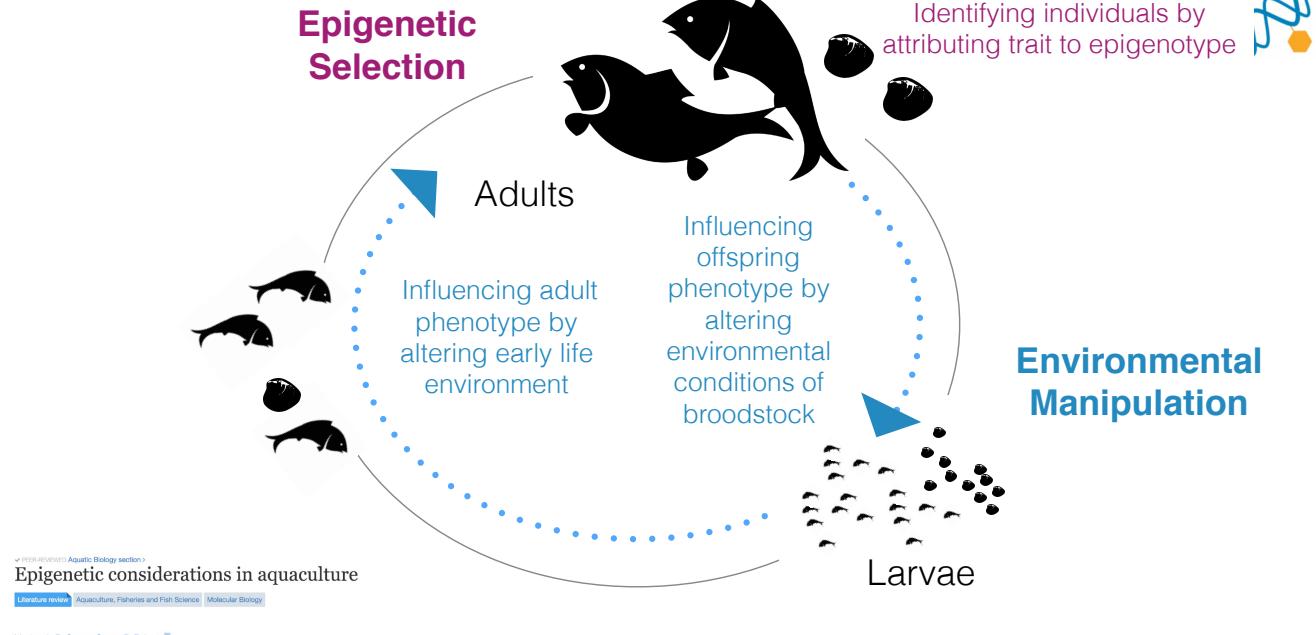
# How does pH affect geoduck?

*Overarching questions:*

- How will they fare under ocean acidification conditions predicted for the future?
- Could stress conditioning be beneficial for aquaculture?



Sustainable fisheries and aquaculture production



# How does pH affect geoduck?

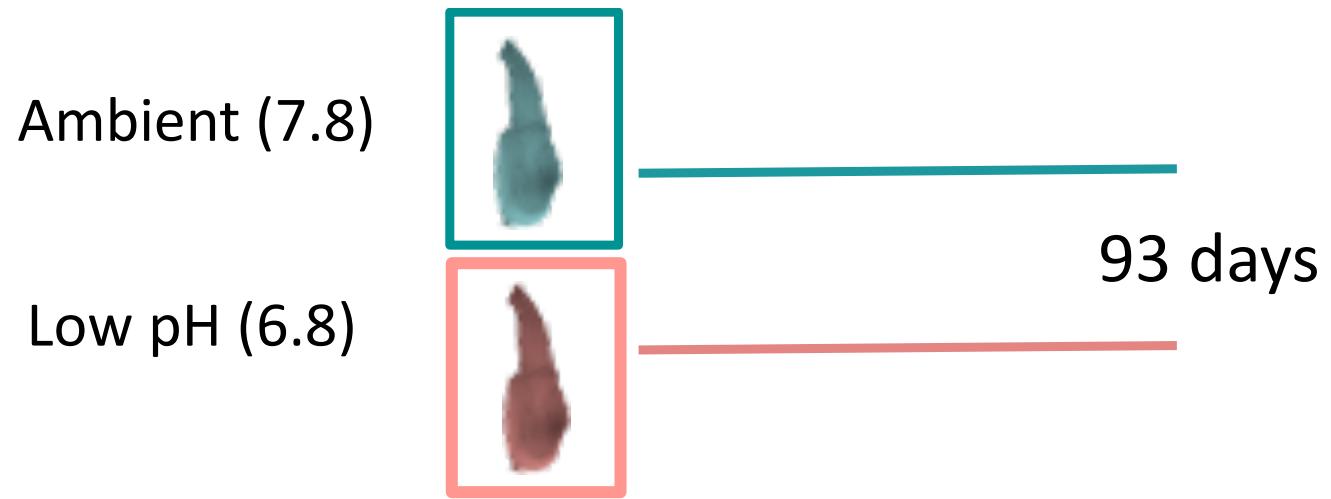
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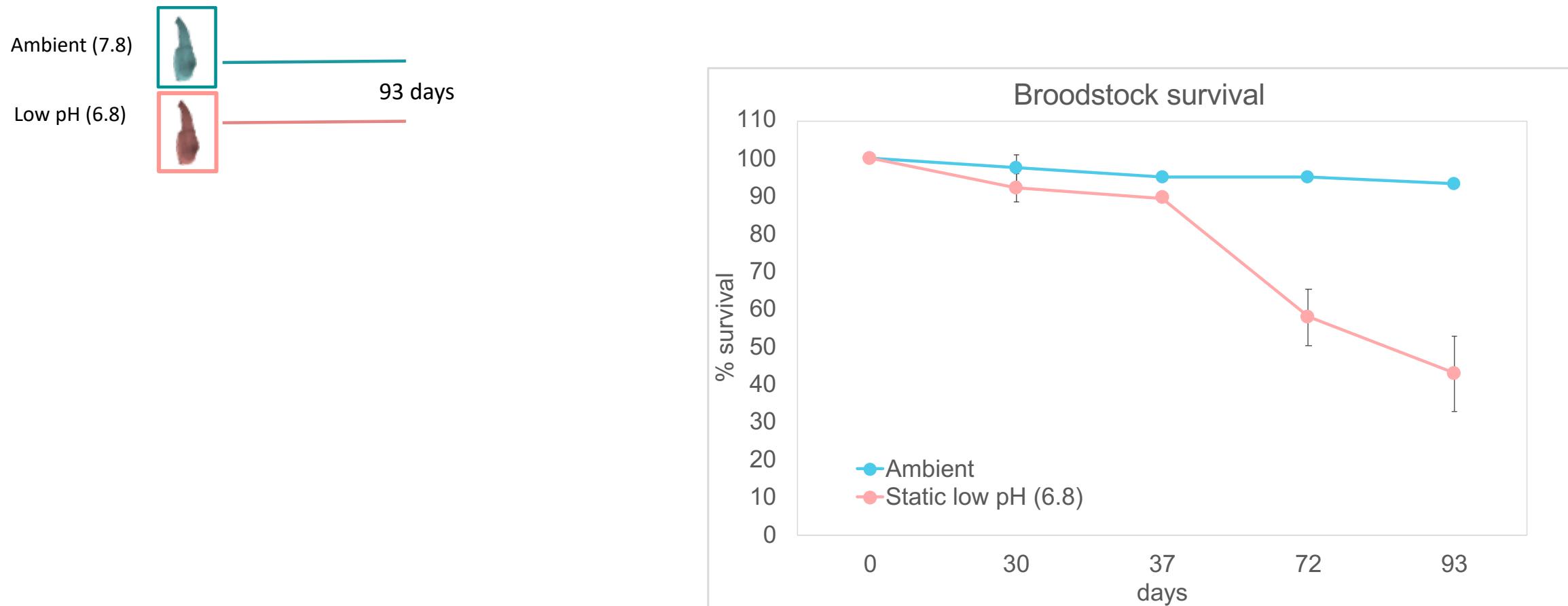
*Aspects to investigate:*

- Broodstock performance and reproductive development
- Juvenile development
- Carry over effects

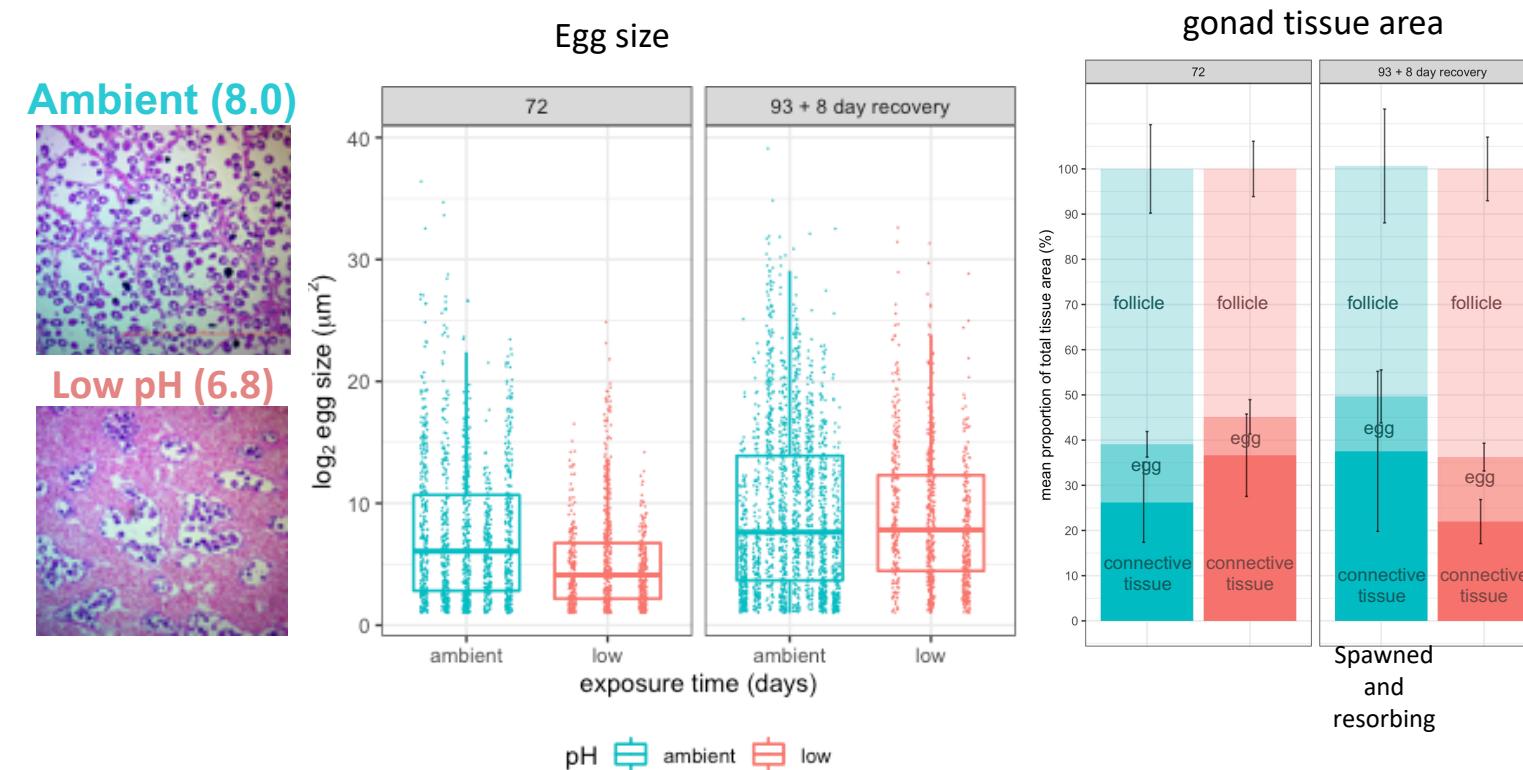
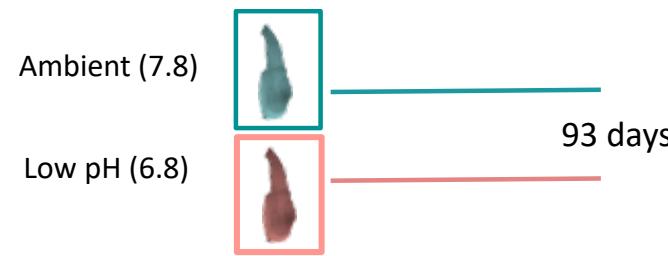
# Impact of static low pH on broodstock



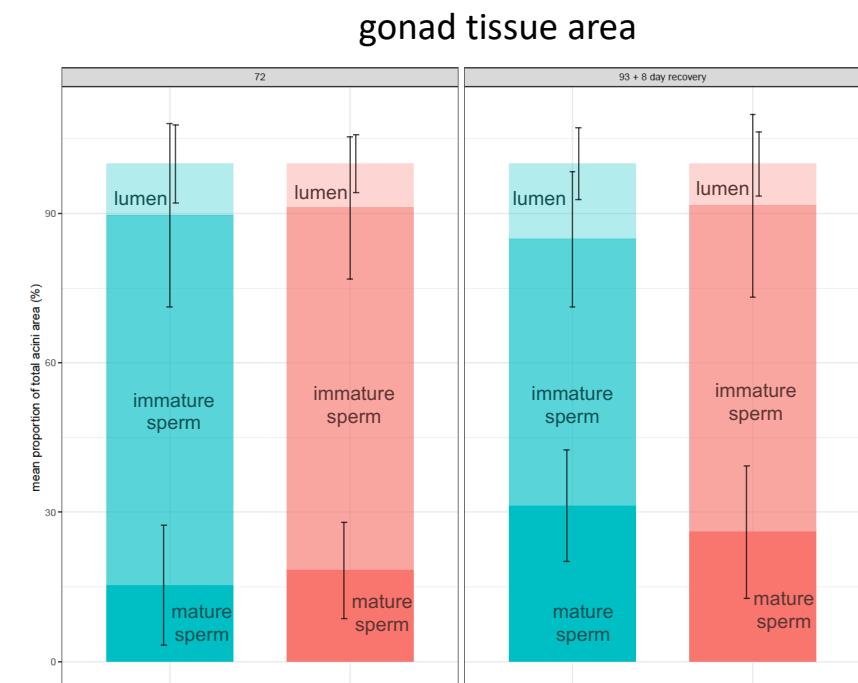
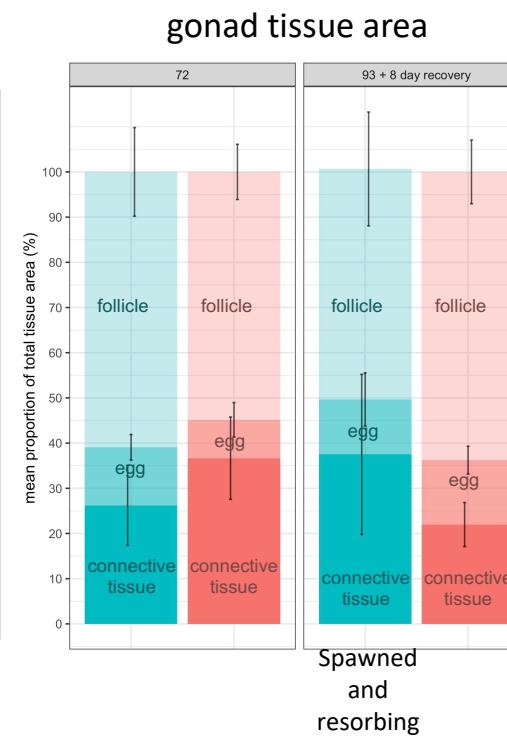
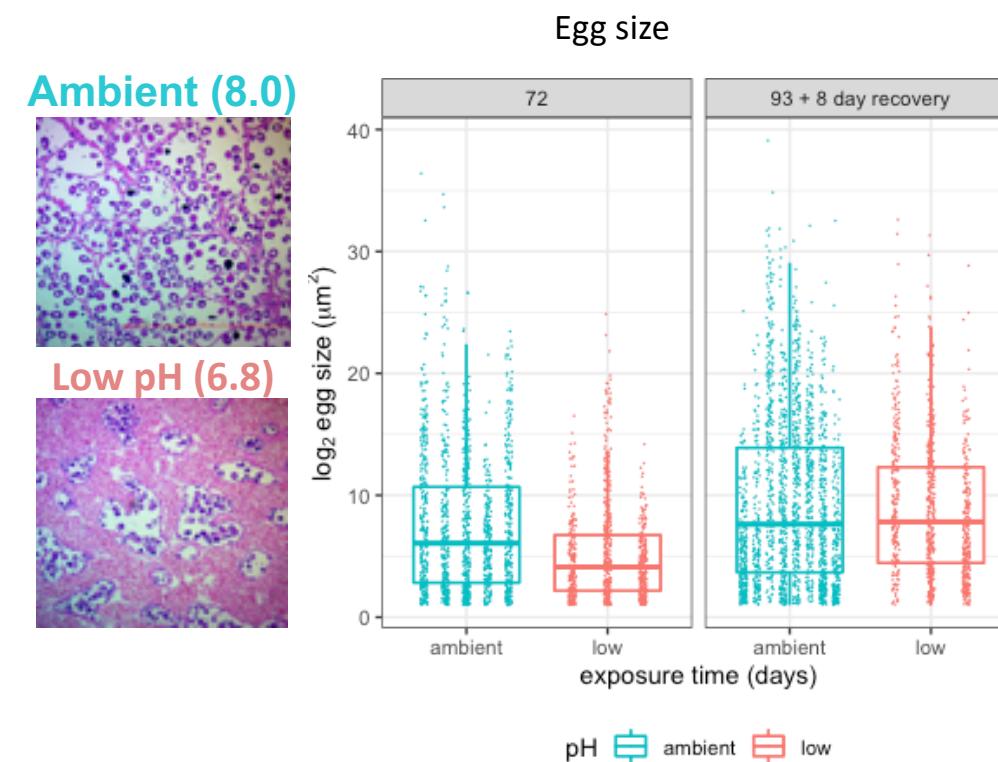
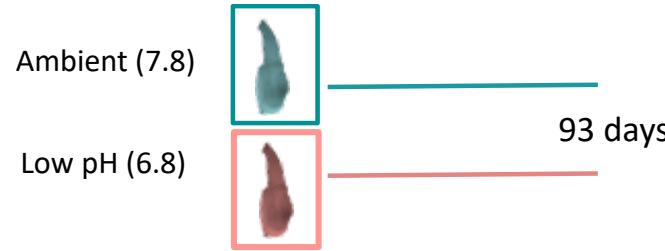
# static low pH negatively impacts broodstock survival



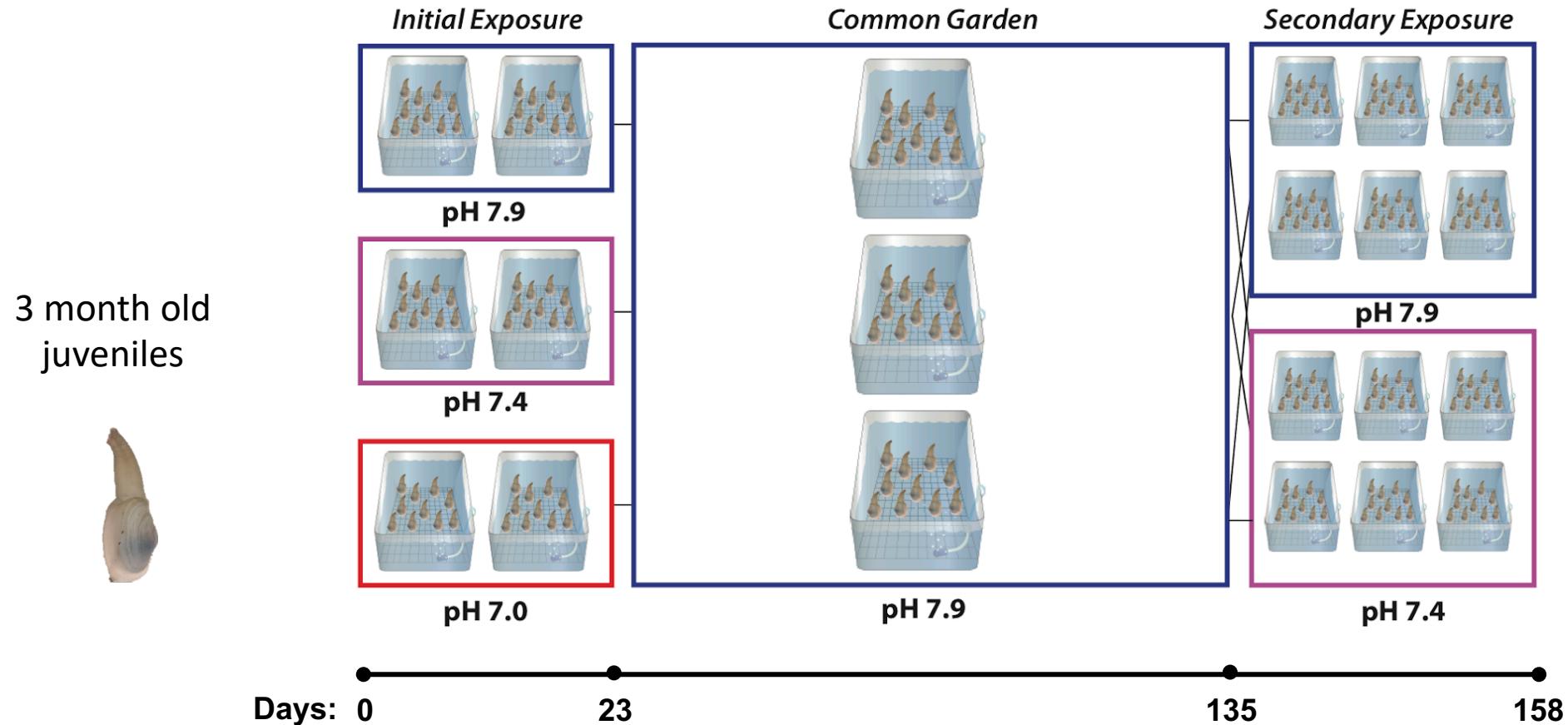
# static low pH delays female reproductive development



# static low pH does *not* delay male reproductive development

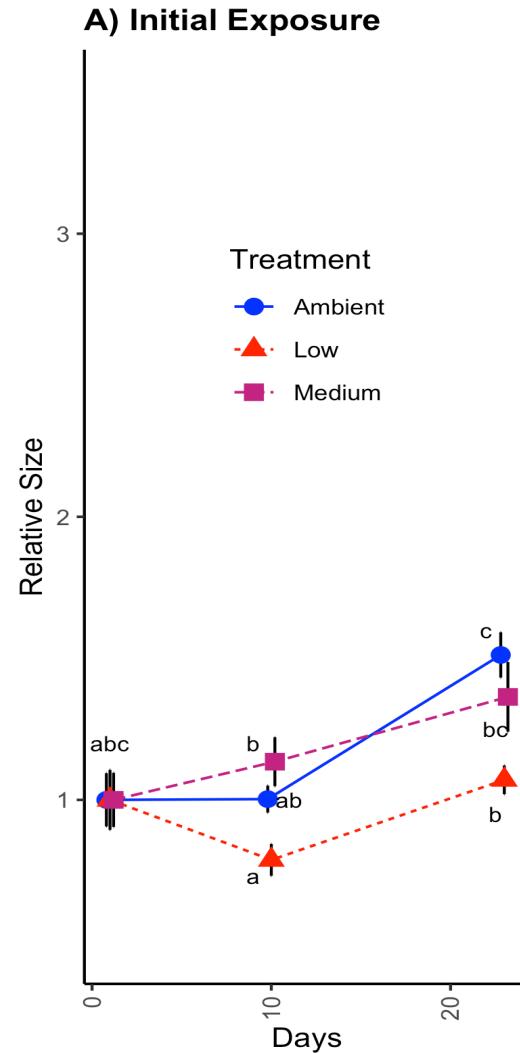


# Impact of static pH on juvenile development



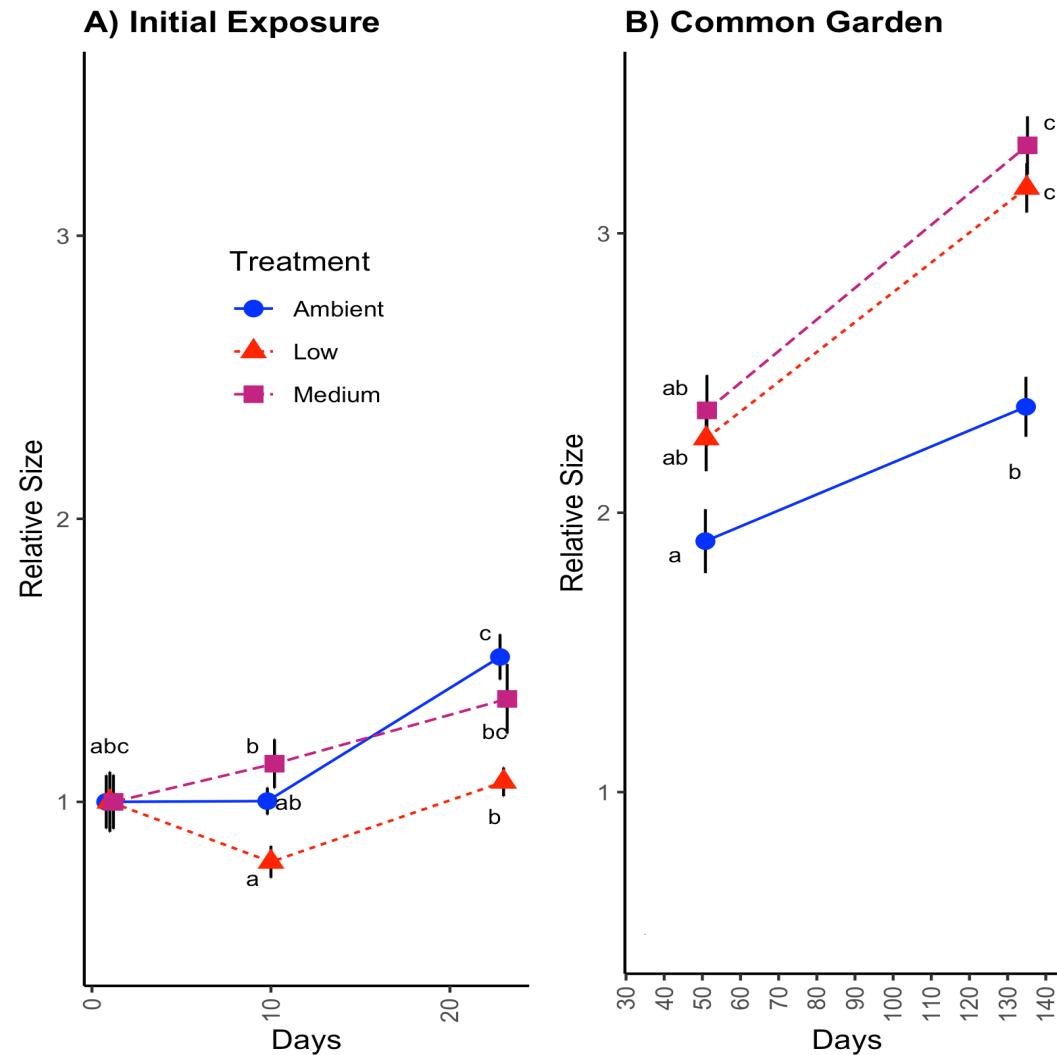
Hollie Putnam

# static low pH initial exposure delays juvenile growth



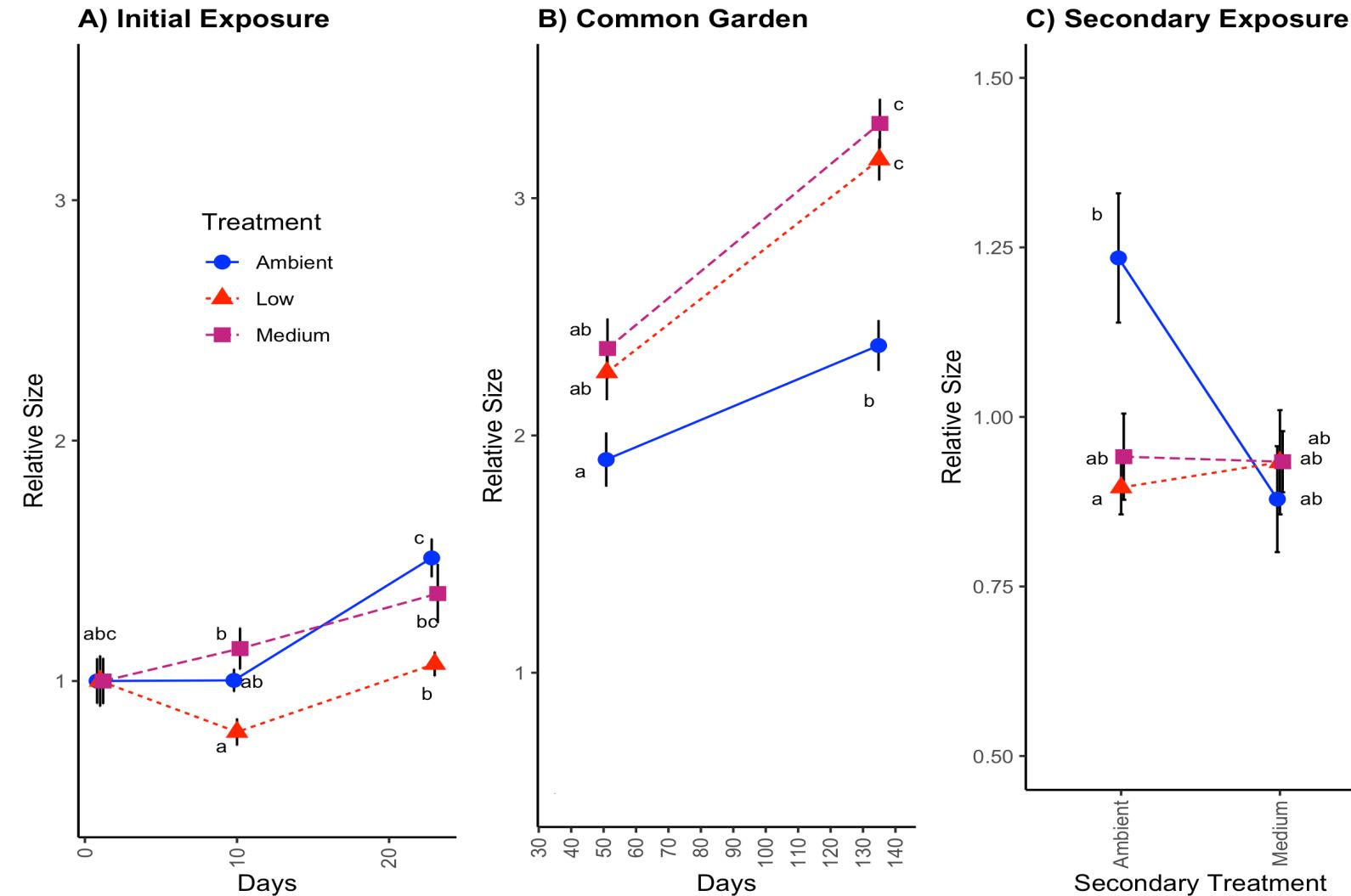
Hollie Putnam

# static moderate and low pH initial exposure leads to accelerated growth after common garden



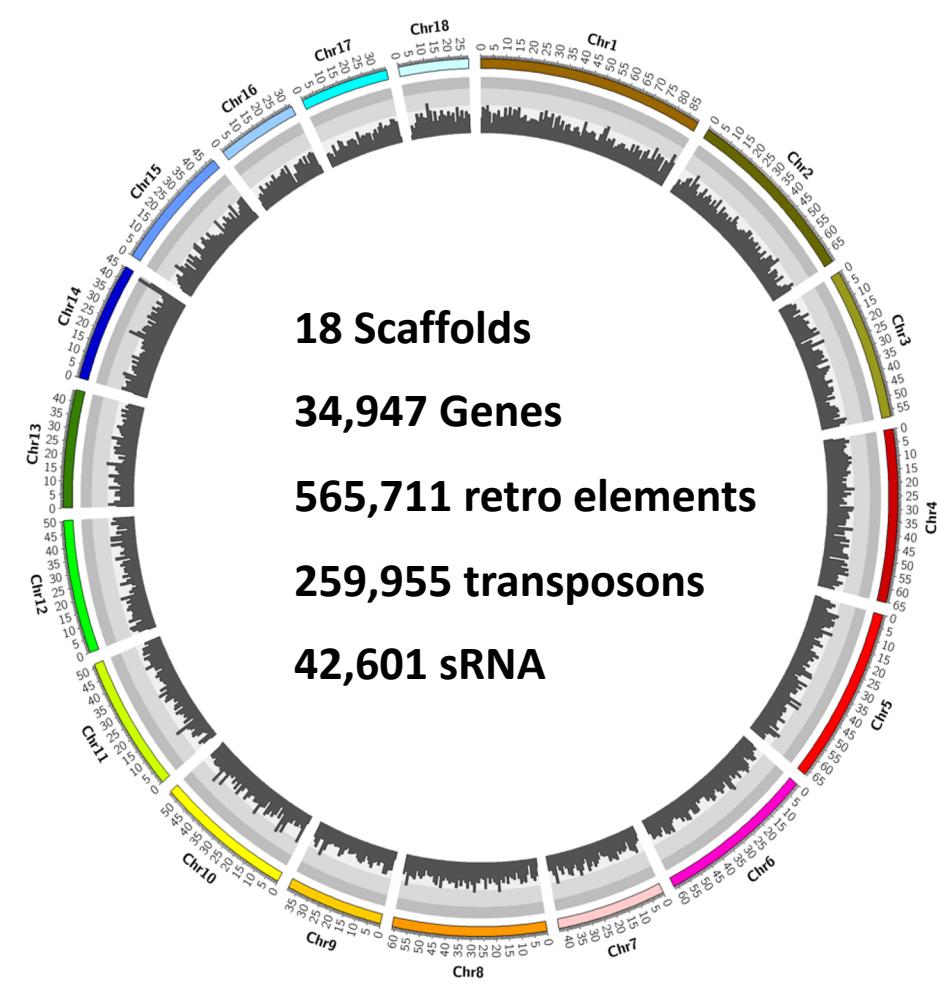
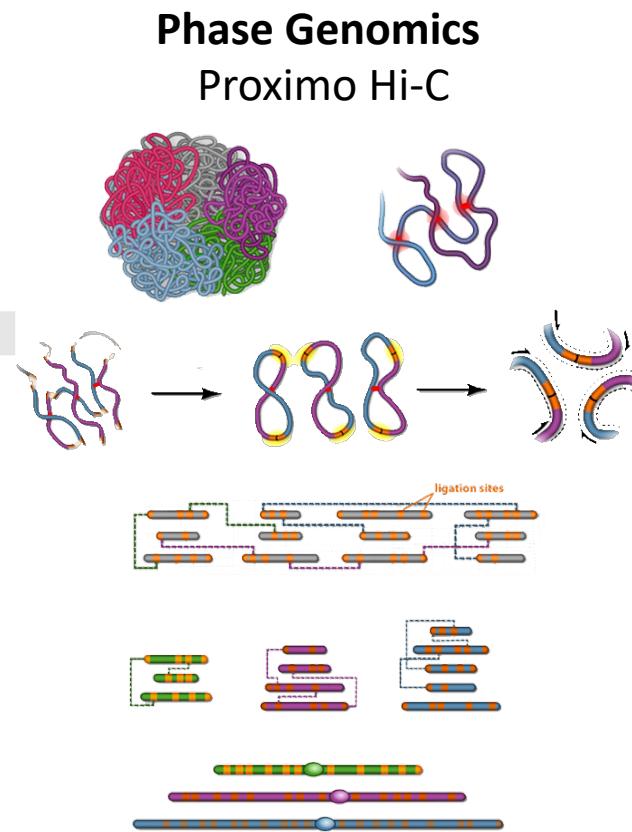
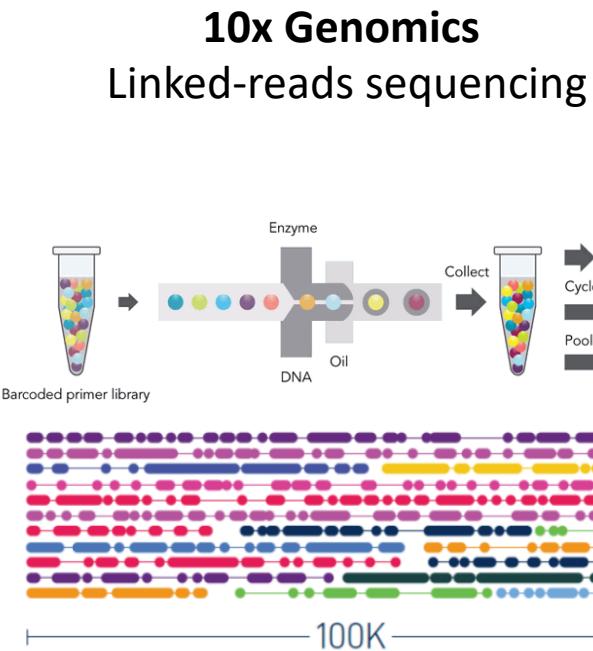
Hollie Putnam

# static moderate and low pH initial exposure protects against growth delay induced by secondary low pH exposure

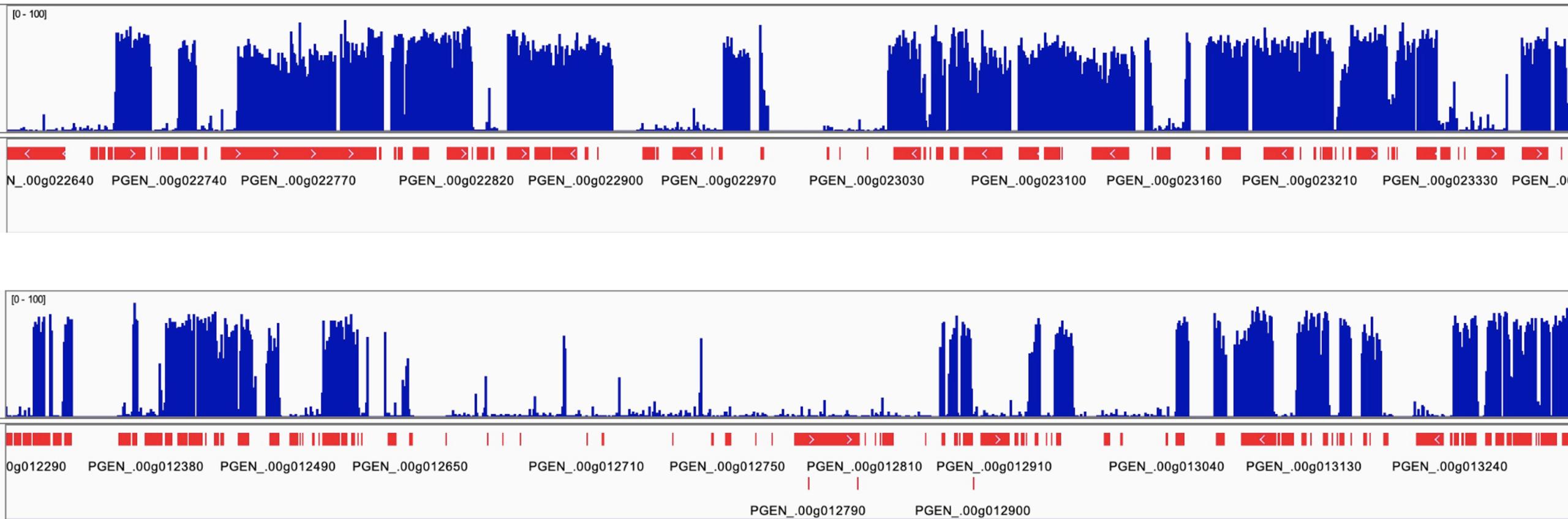


Hollie Putnam

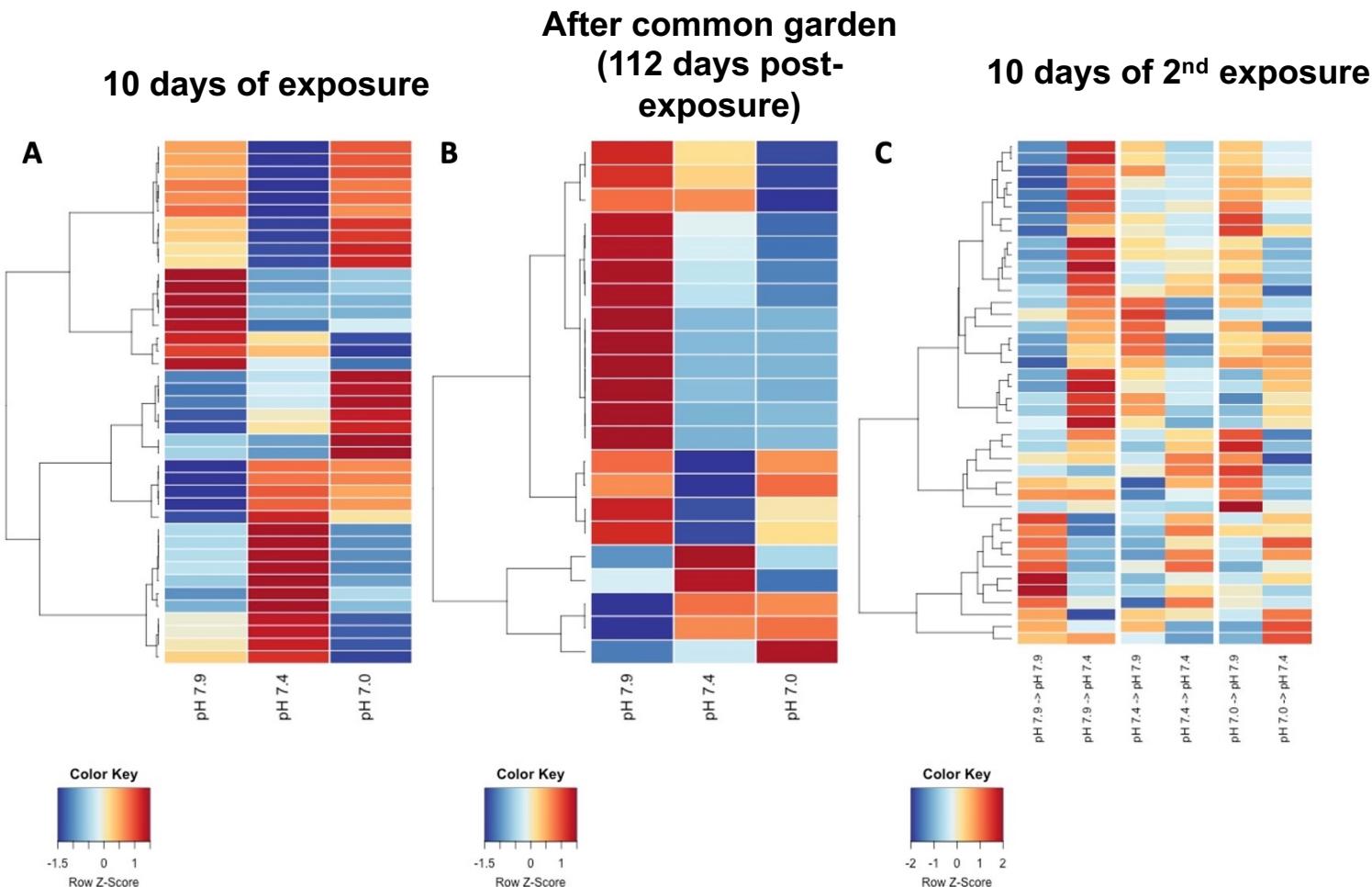
# Sequencing the geoduck genome



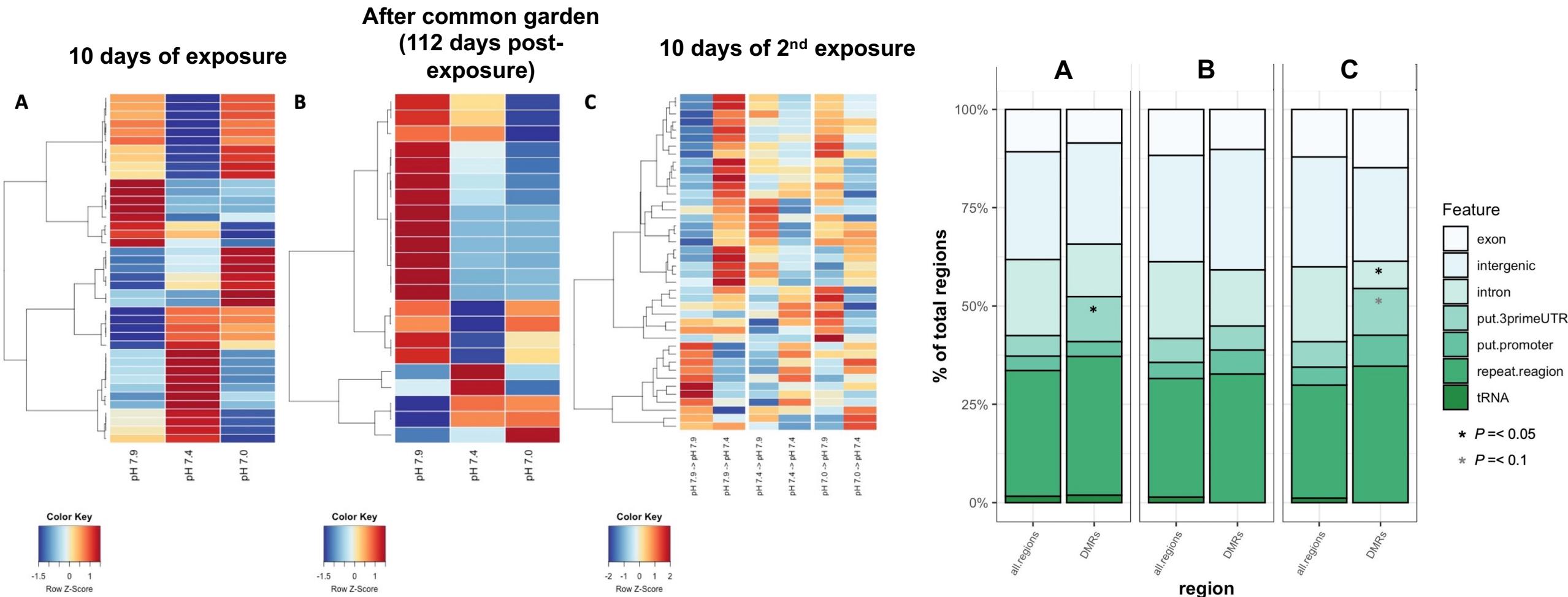
# Geoduck genome methylation landscape



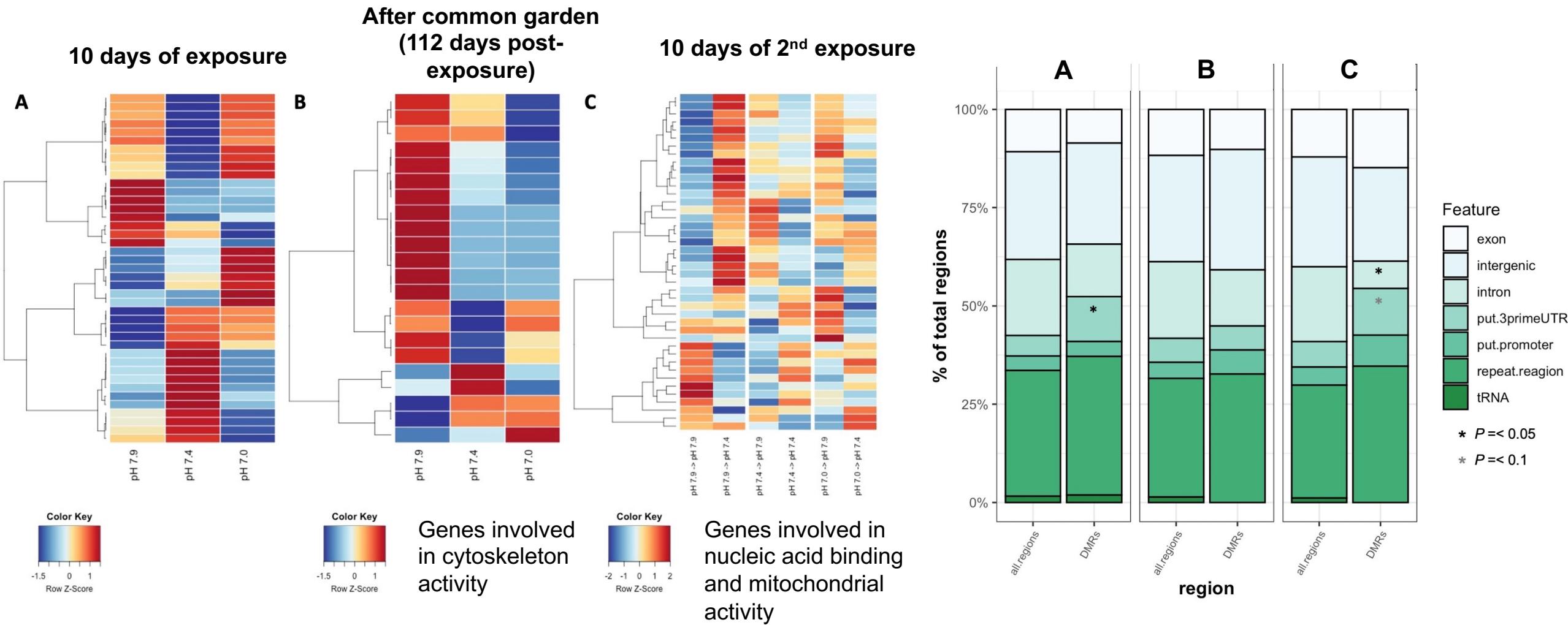
# Differentially methylated regions across low pH conditions



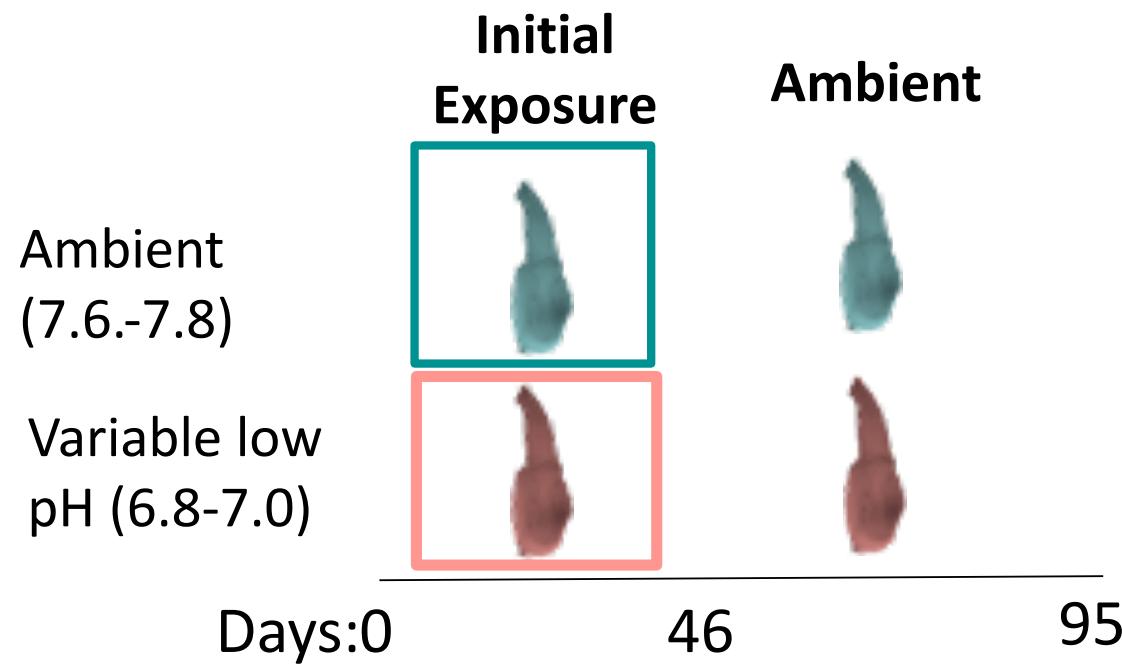
# Differentially methylated regions across low pH conditions



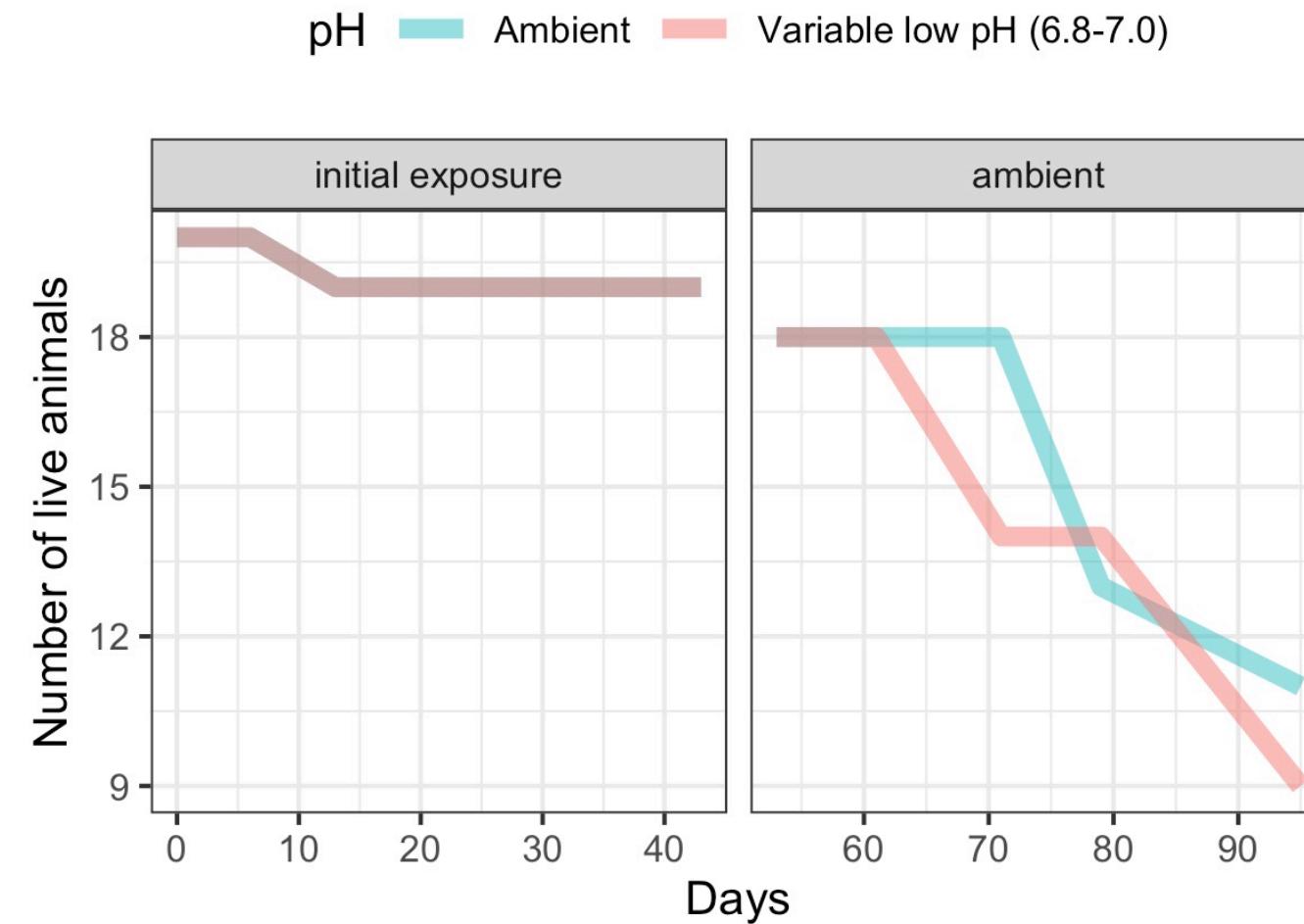
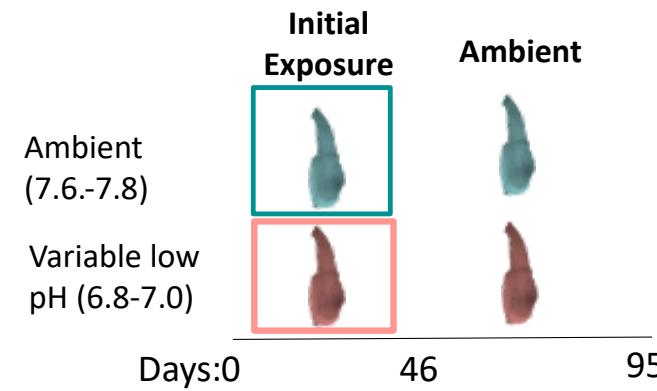
# Differentially methylated regions across low pH conditions



# Impact of variable low pH on broodstock



# variable low pH does not affect broodstock survival

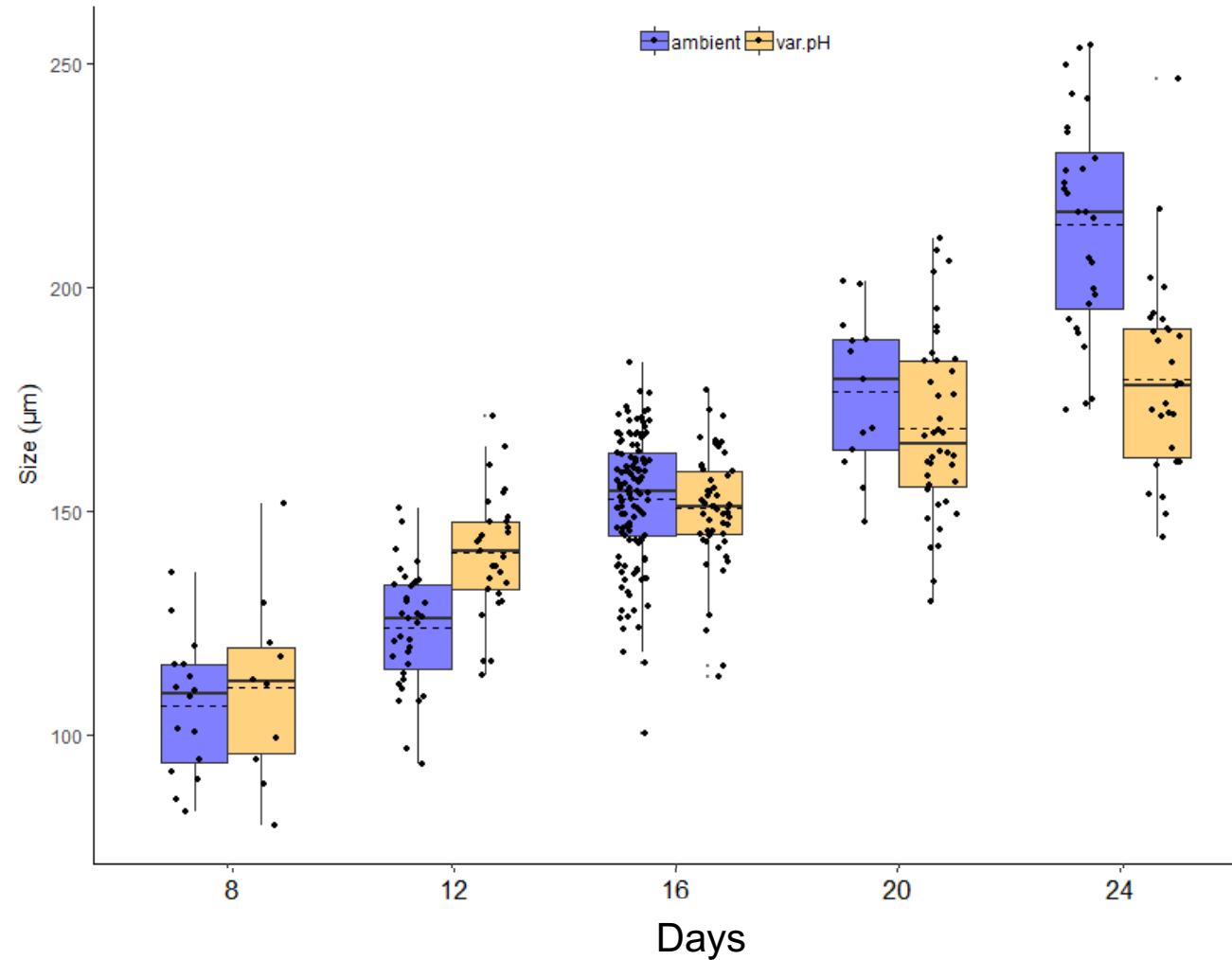


# **Impact of variable low pH on offspring development**

**Larval offspring reared under ambient conditions**

# Generally little impact from parental conditioning on larval growth

Larval offspring reared under ambient conditions

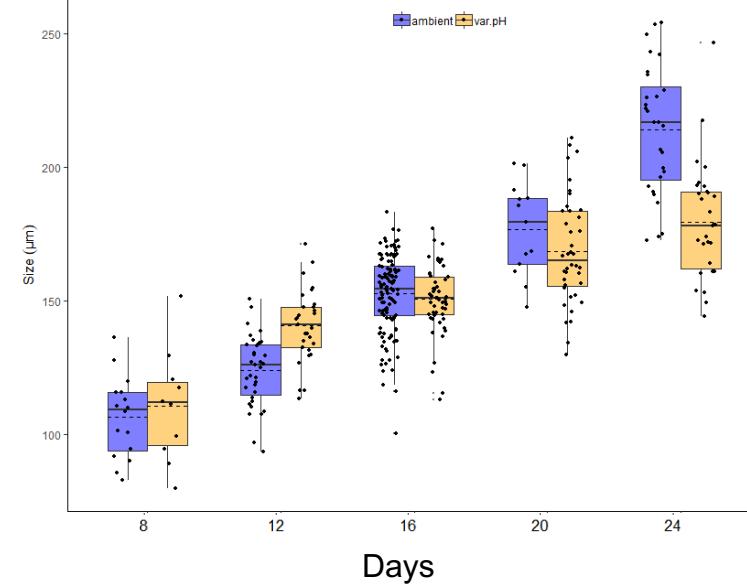


Sam Gurr

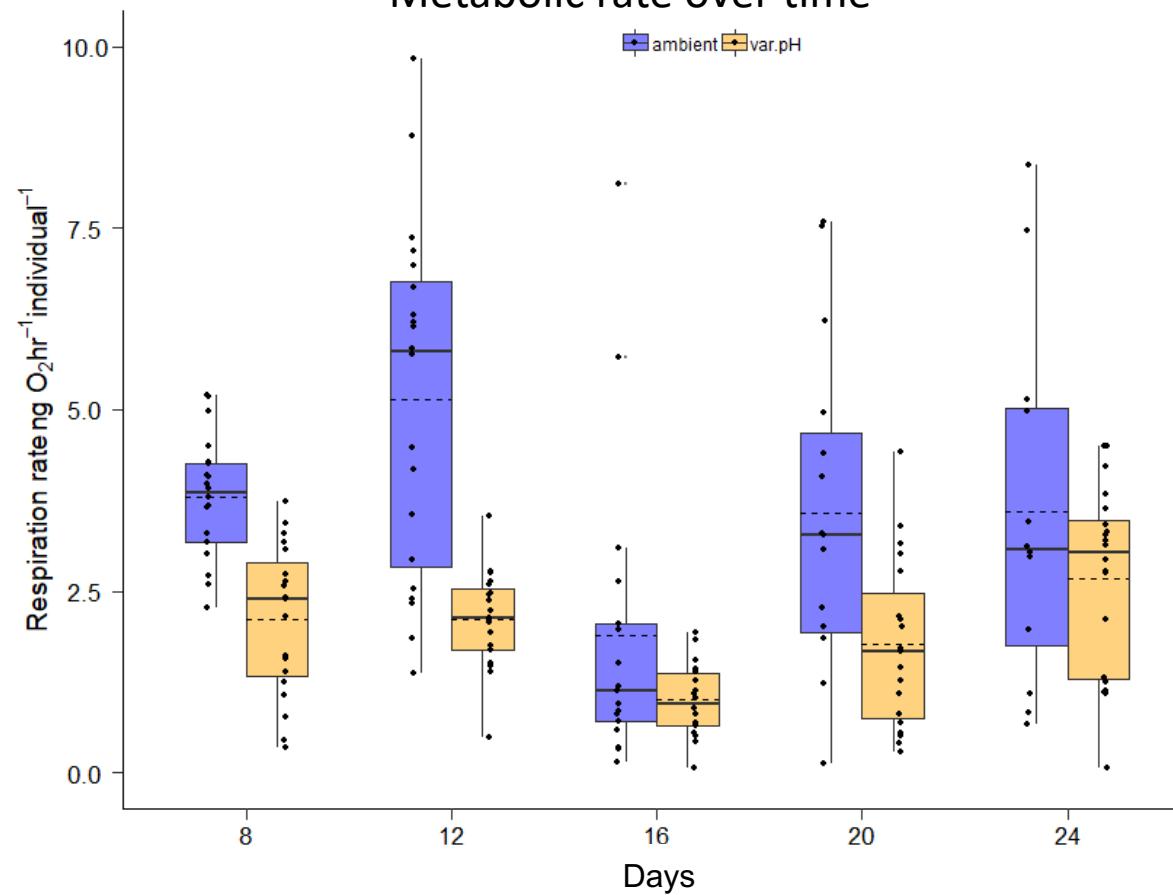
# Parental variable low pH exposure leads to reduced metabolic rates in larvae

Larval offspring reared in ambient conditions

Growth over time



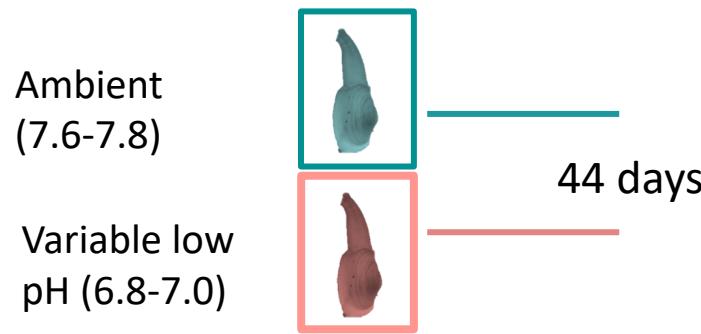
Metabolic rate over time



Sam Gurr

# Impact of variable low pH on juvenile offspring development

# Juvenile offspring

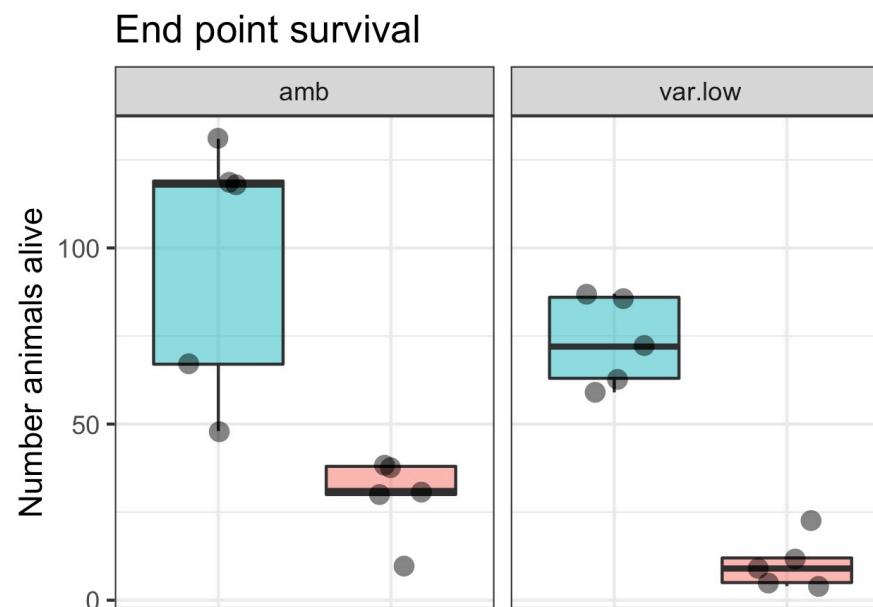
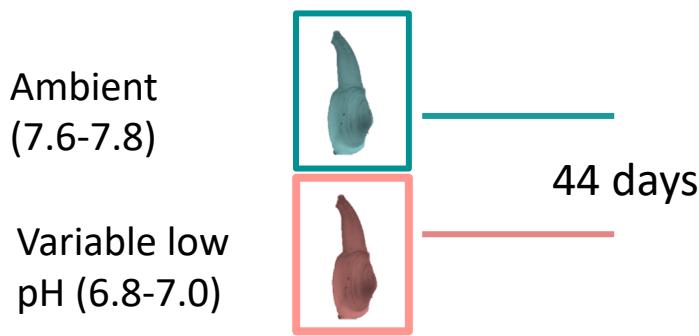


~ 100 juveniles per silo



# Variable low pH exposure led to lower survival regardless of parental conditions

## Juvenile offspring



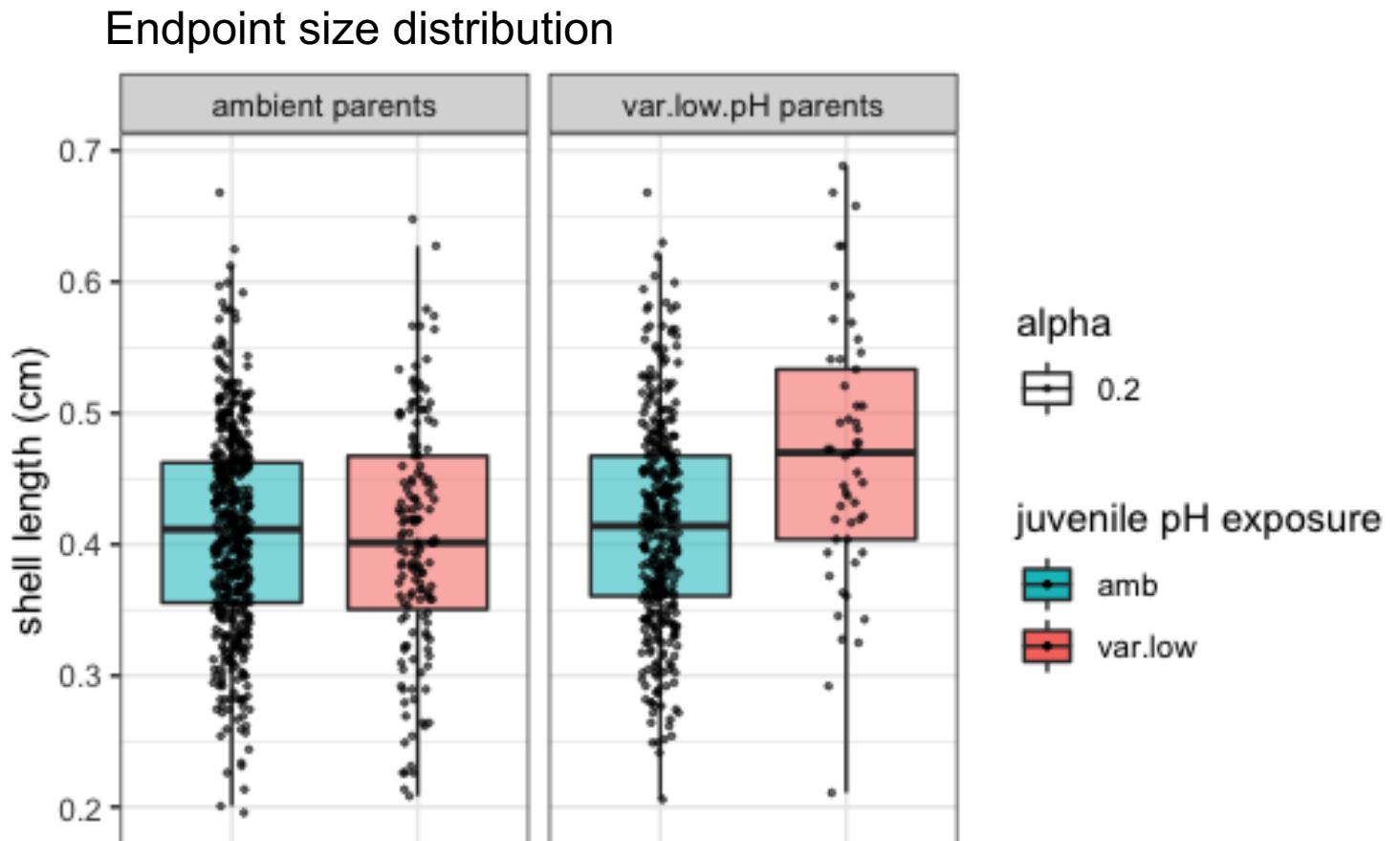
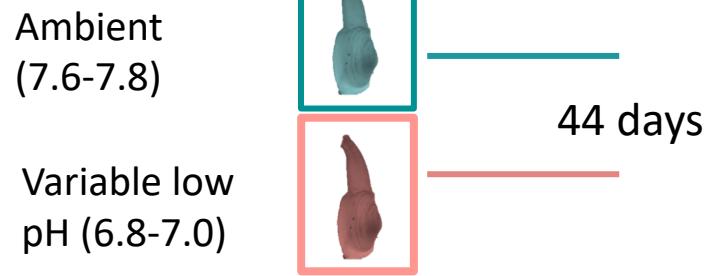
alpha      Significant effect from juvenile conditions ( $P = 6.69e-06$ )

juvenile pH exposure      Marginal effect from parental conditions ( $P = 0.0863$ )

Linear mixed effect model:  
# live animals ~ Parental condition + pH exposure + (1 | Silo)

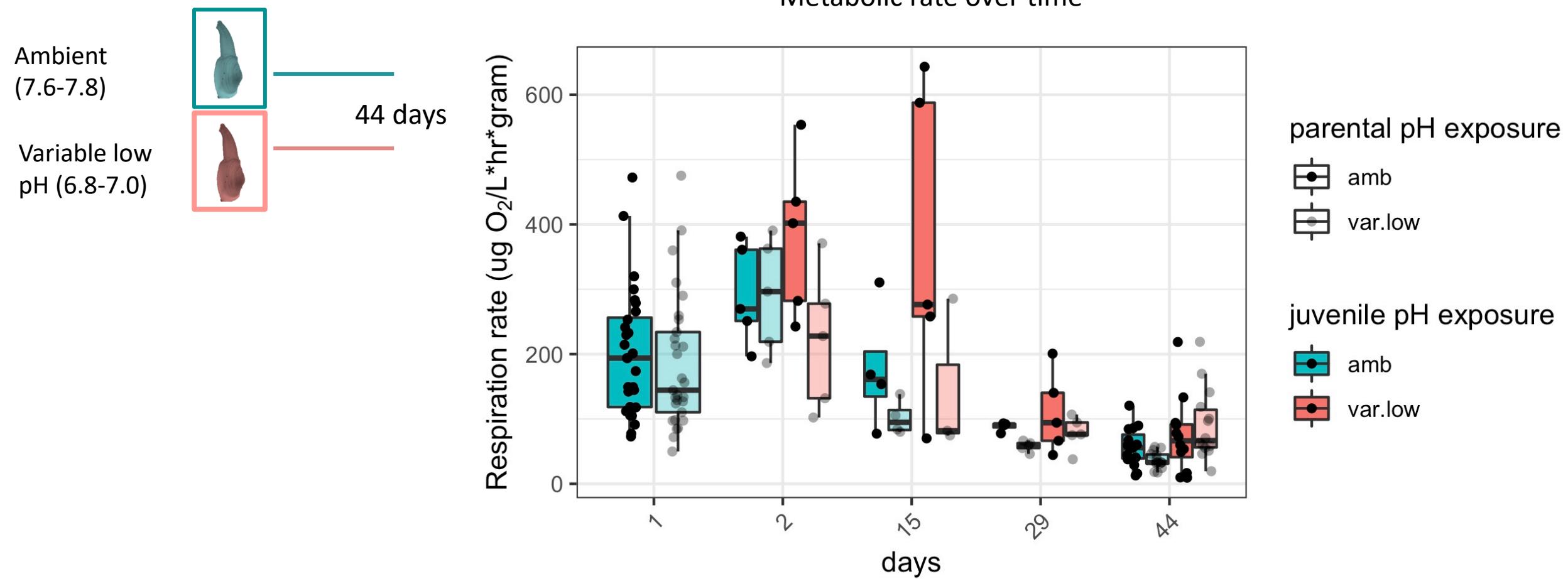
# Parental and juvenile variable low pH exposure led to larger size

## Juvenile offspring



# Parental variable low pH exposure generally led to lower metabolic rate in juveniles

## Juvenile offspring



# Summary

- **Broodstock and reproductive development**
  - Longer duration and constant low pH exposure is more detrimental to survival
  - Female reproductive development is more sensitive to low pH than males
- **Juvenile development**
  - Evidence for environmental memory
    - Initial low pH exposure led to larger animals 4 months after exposure
      - associated with methylation changes in genes related to cytoskeletal activity
    - Initial low pH exposure prevented growth delay seen in naïve juveniles
      - associated with methylation changes in genes related to nucleic acid binding and mitochondrial activity
- **Carry over effects**
  - Parental variable low pH conditioning leads to reduced energy demand in offspring that achieve the same or larger size under low pH conditions
    - Generally didn't impact larval growth
    - Led to reduced metabolic rates in larvae
    - Didn't impact survival in juveniles exposed to variable low pH
    - Led to larger size juveniles when exposed to variable low pH
    - Generally led to lower metabolic rate in juveniles

# Implications

- pH can be used to induce beneficial traits that persist over time
- Effects seems to be stage dependent
- Conditions need to be optimized

# Questions?

- Message me on the Pathable SICB meeting platform (Shelly Trigg)
- Email me at strigg@uw.edu