STEVEN B ROBERTS

KENNETH K CHEW ASSOCIATE PROFESSOR

LAURA SPENCER

YAAMINI VENKATARAMAN

HOLLIE PUTNAM

RICK GOETZ

SCHOOL OF AQUATIC AND FISHERY SCIENCES

CARRY OVER EFFECTS IN SHELLFISH AND SOME CONSIDERATIONS…

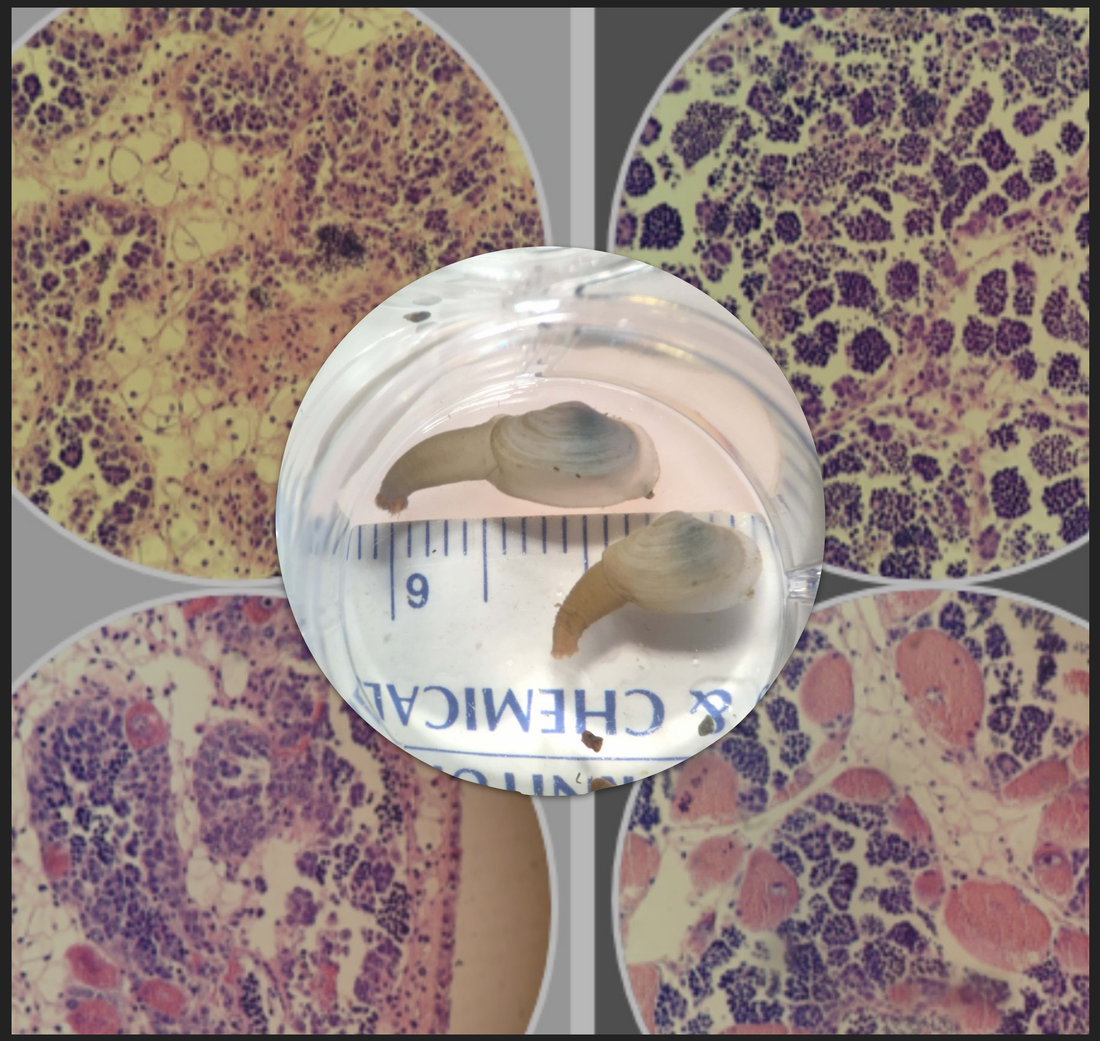
FHL

FHL

FHL

INFLUENCE OF PARENTAL CONDITIONS

- Selection
- Germ cells are present
- Maternal provisioning
- Paternal role?
- Beneficial versus detrimental
- Mechanisms at play



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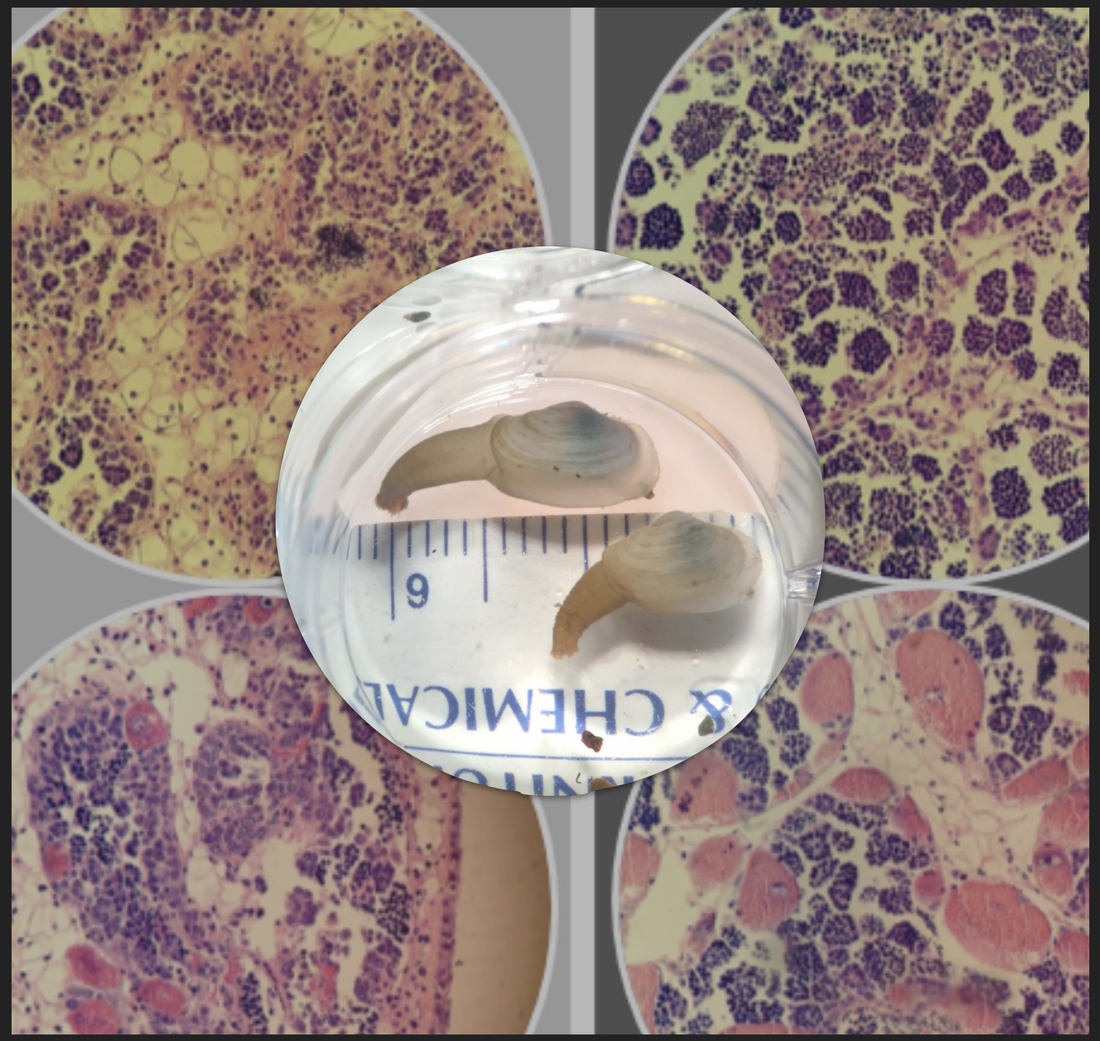


IMPLICATIONS FOR ECOSYSTEM RESILIENCE

- OLYMPIA OYSTER
- PACIFIC OYSTER
- GEODUCK

EFFECTS OF TEMPERATURE AND OA IN OLYMPIA OYSTER POPULATIONS

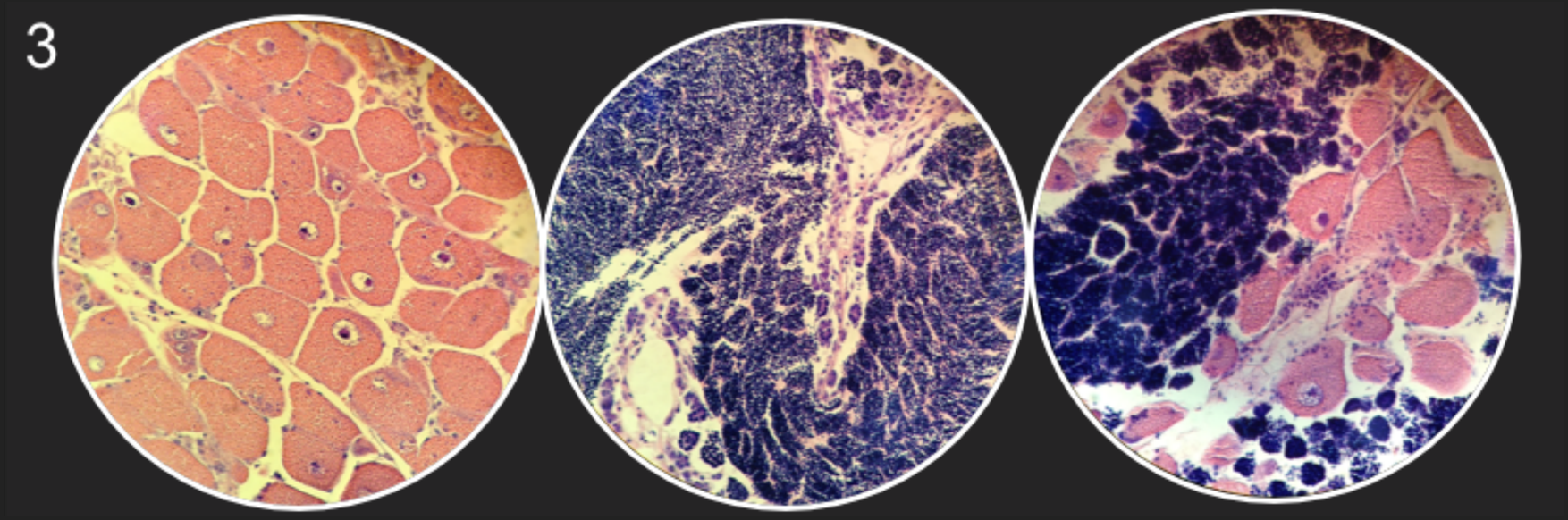
- Oysters were held at **two temperature regimes** (6°C and 10°C) for 60 days in December 2016
- A differential pCO2 exposure was **carried out after the temperature treatment ended**. Held at ambient pCO2 (841 µatm) or high pCO2 (3045 µatm) for 52 days, during the Winter.

LAURA SPENCER

EFFECTS OF TEMPERATURE AND OA IN OLYMPIA OYSTER POPULATIONS

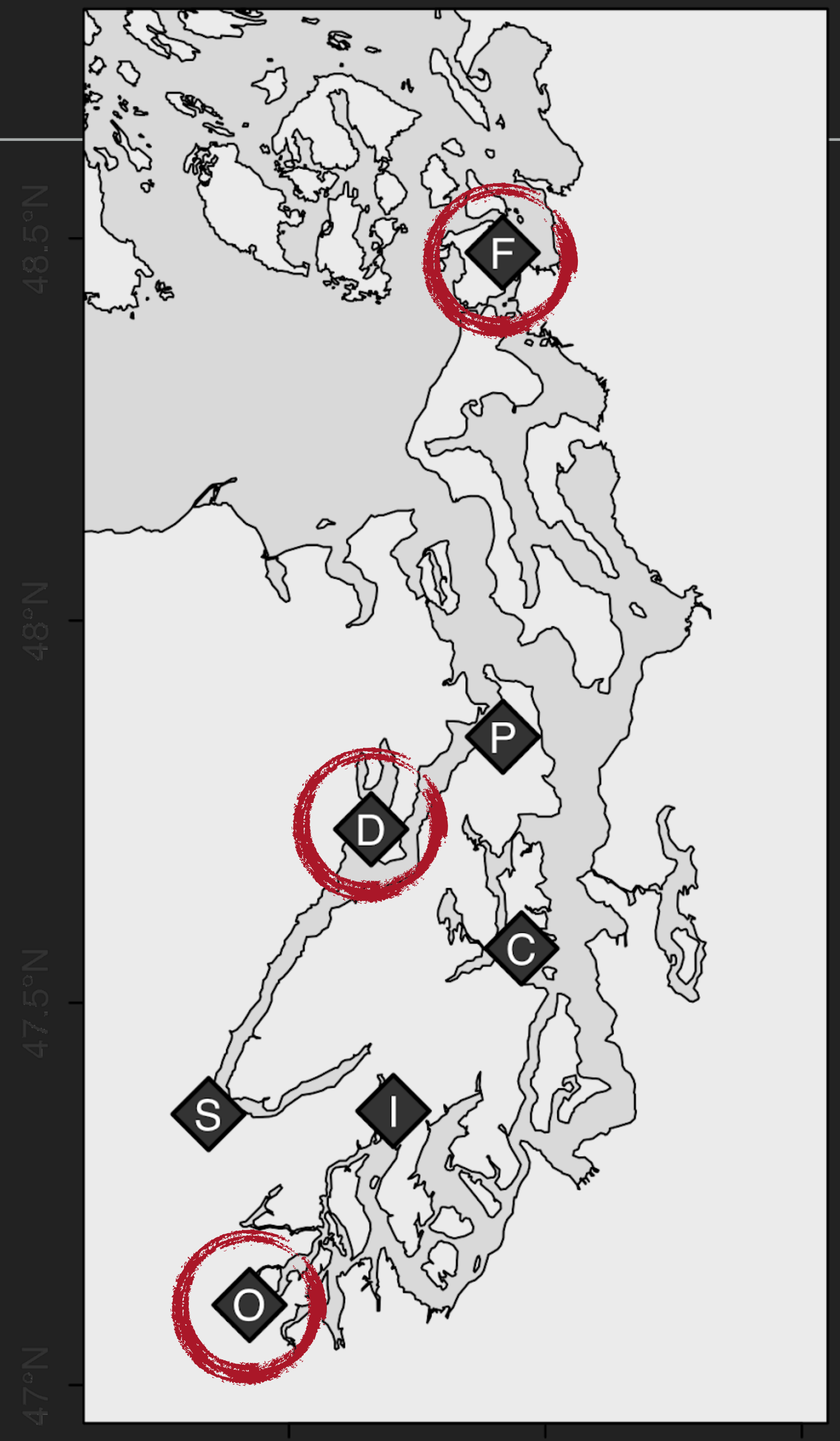
EFFECTS OF TEMPERATURE AND OA IN OLYMPIA OYSTER POPULATIONS

- Results indicate that **high pCO_2 slows gametogenesis**, and **elevated temperature accelerates it**, and these two environmental drivers act antagonistically on gonad development if occurring during the same reproductive season.



EFFECTS OF TEMPERATURE AND OA

- Broodstock used were from
  - Fidalgo Bay in North Puget Sound (F)
  - Dabob Bay in Hood Canal (D)
  - Oyster Bay in South Puget Sound (O)



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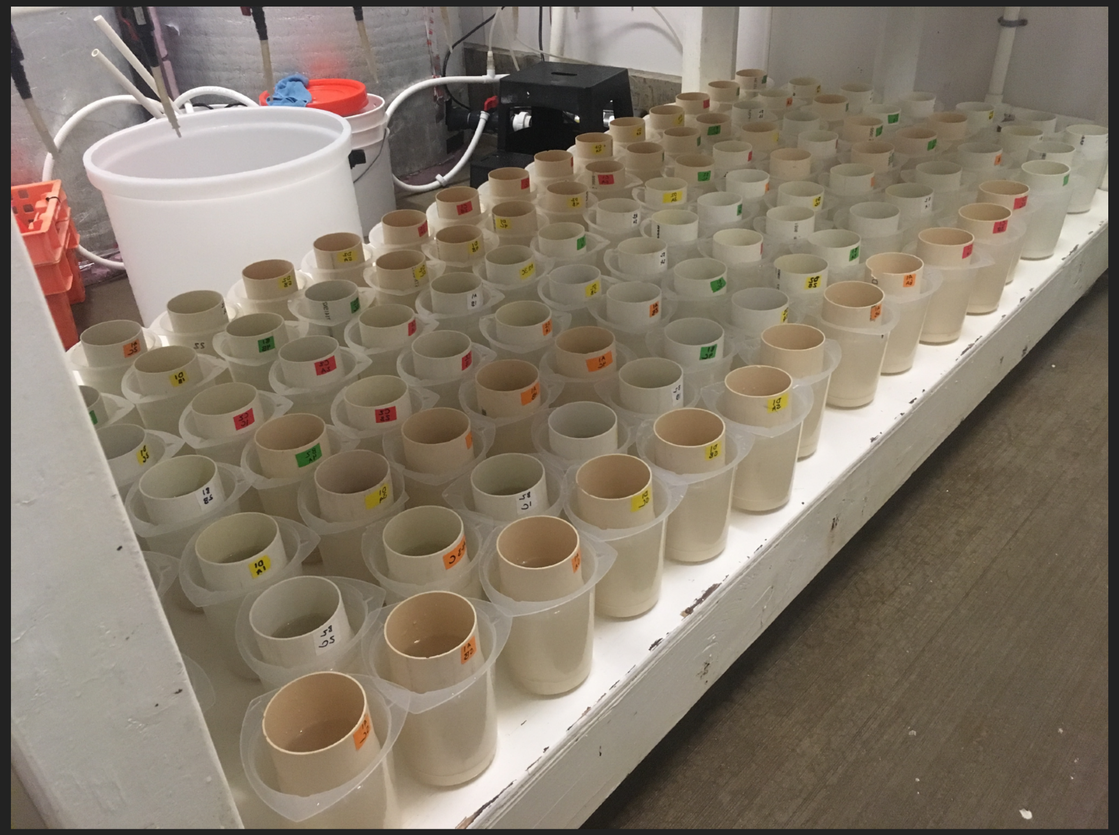

- Larval release occurred earlier in warm-exposed oysters
- Winter warming conditions increased larval production
- No effects on larval survival were detected
- **Juveniles of parents exposed to elevated pCO_2 had higher survival rates in the natural environment**

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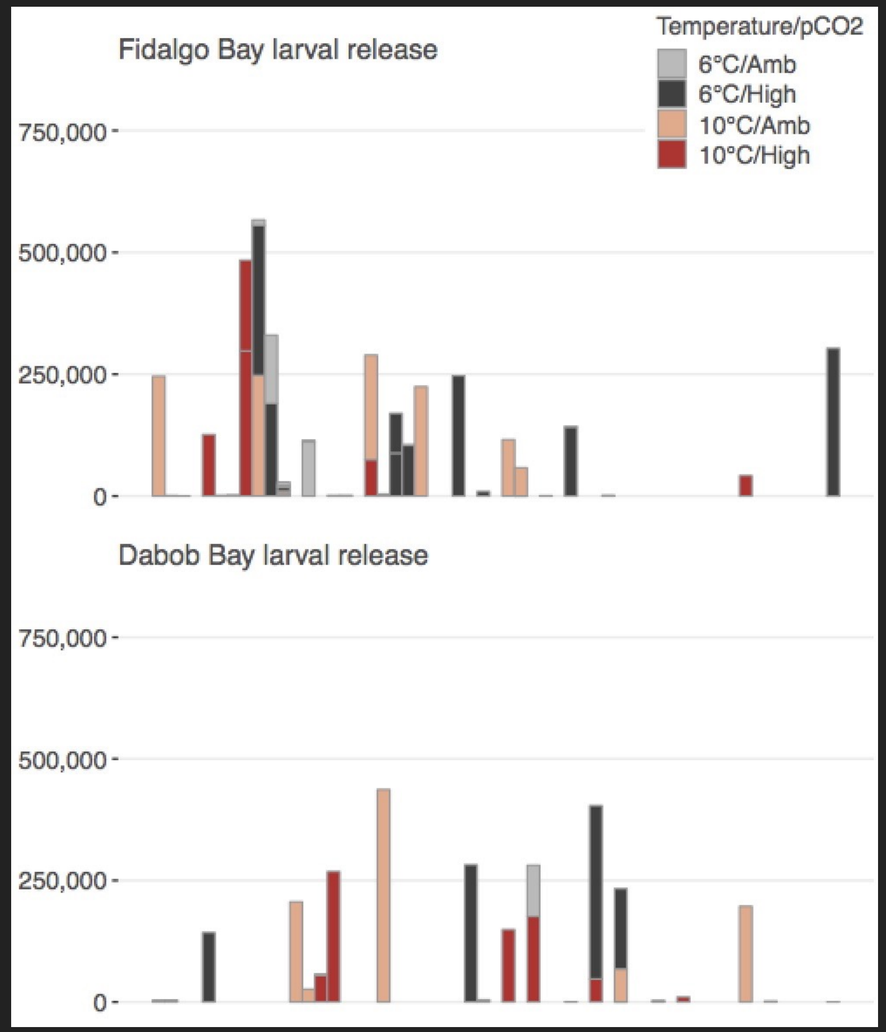

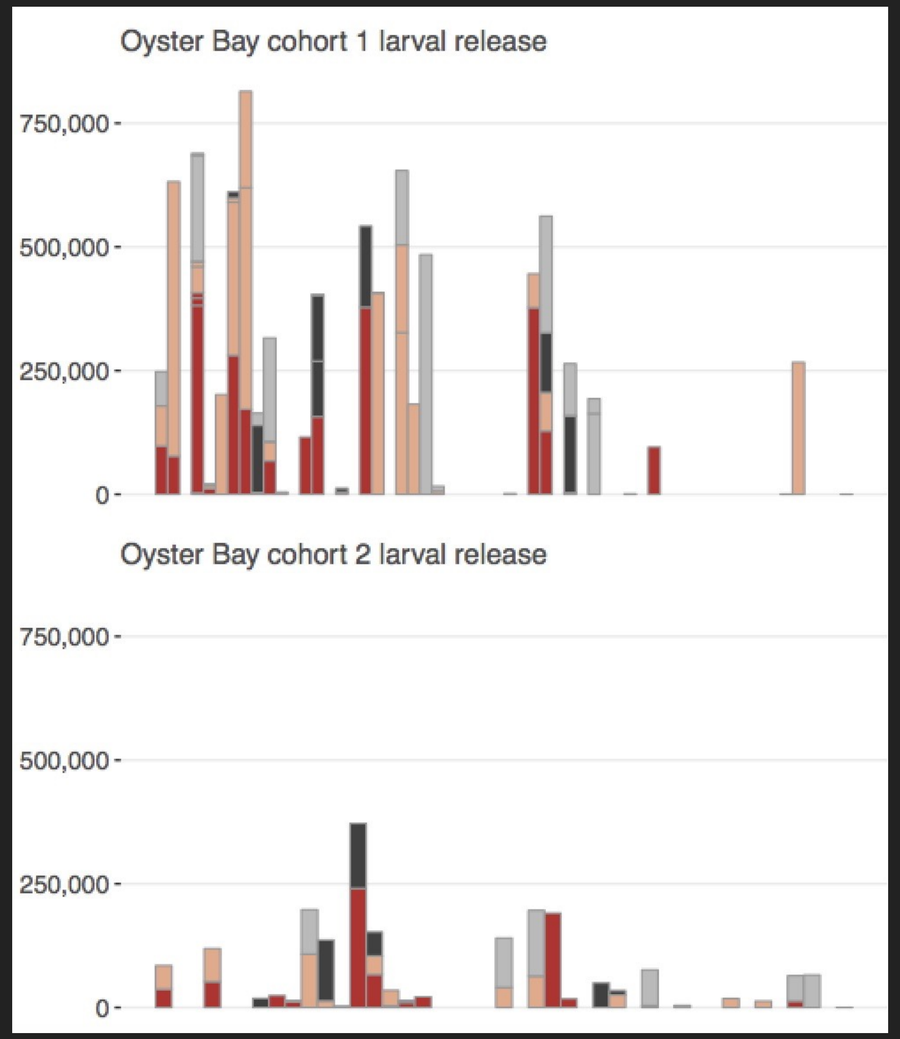

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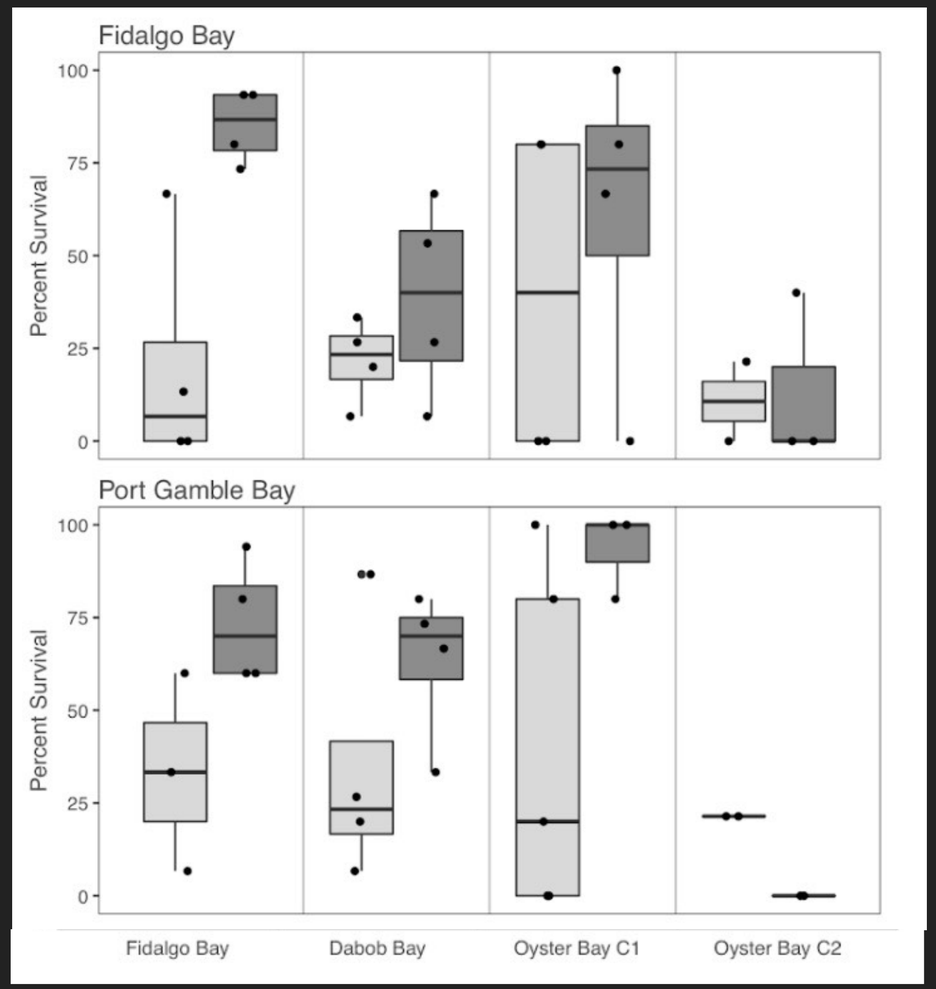

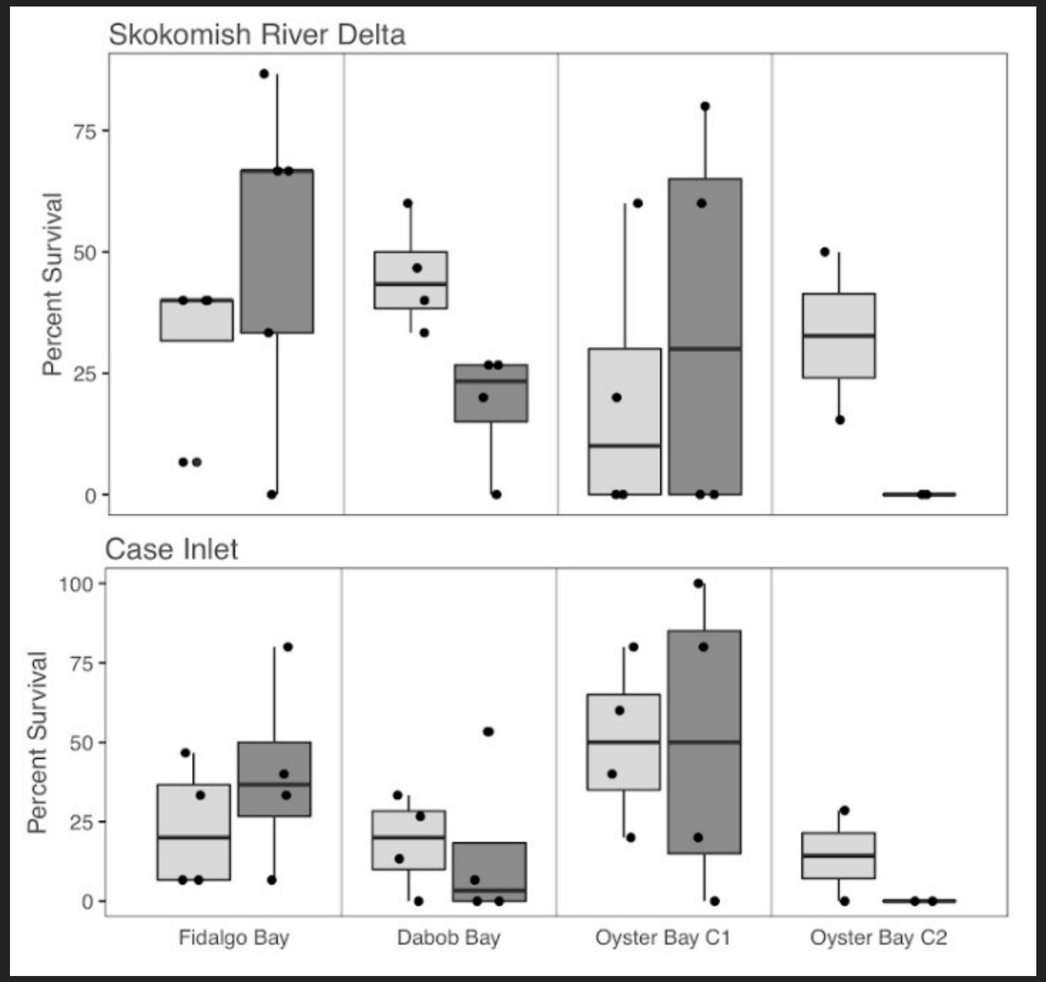

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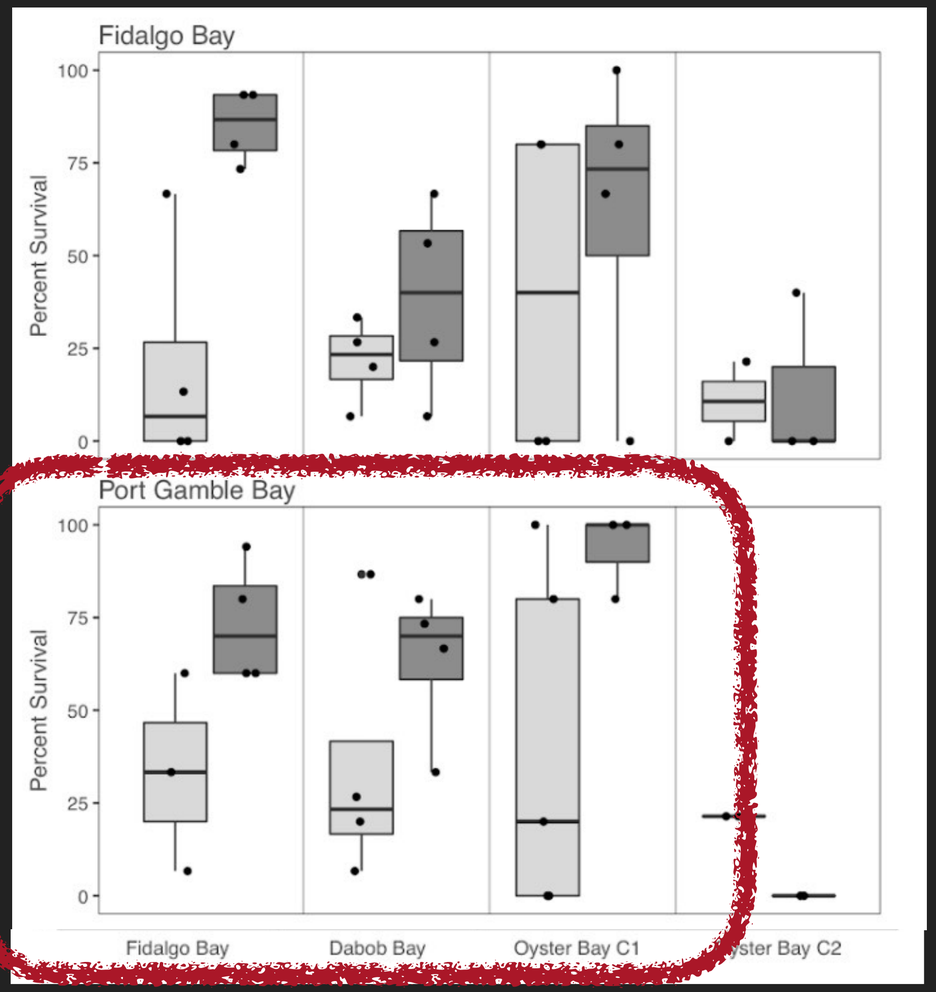
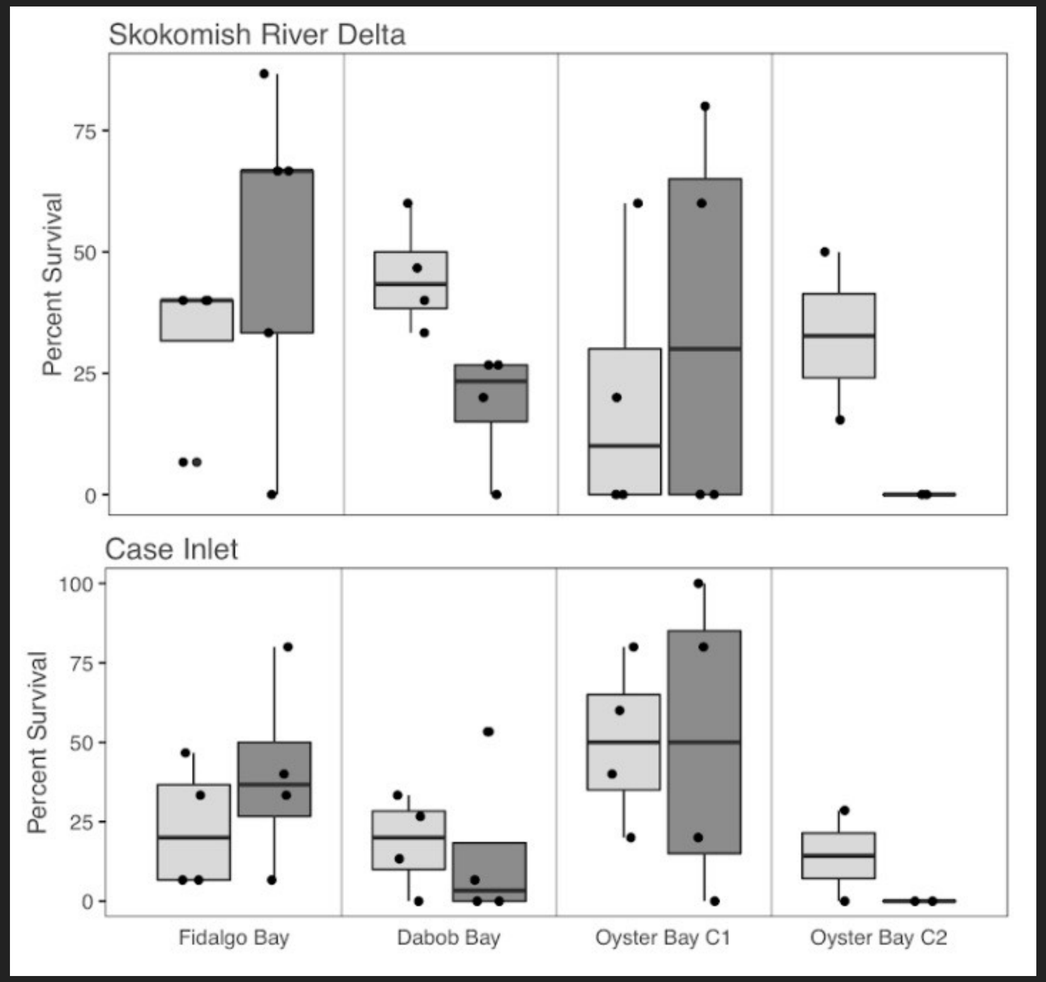
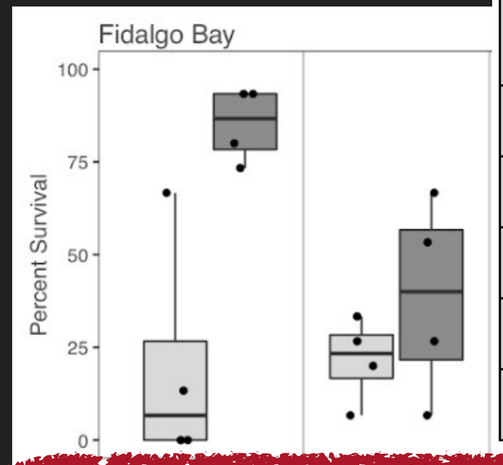
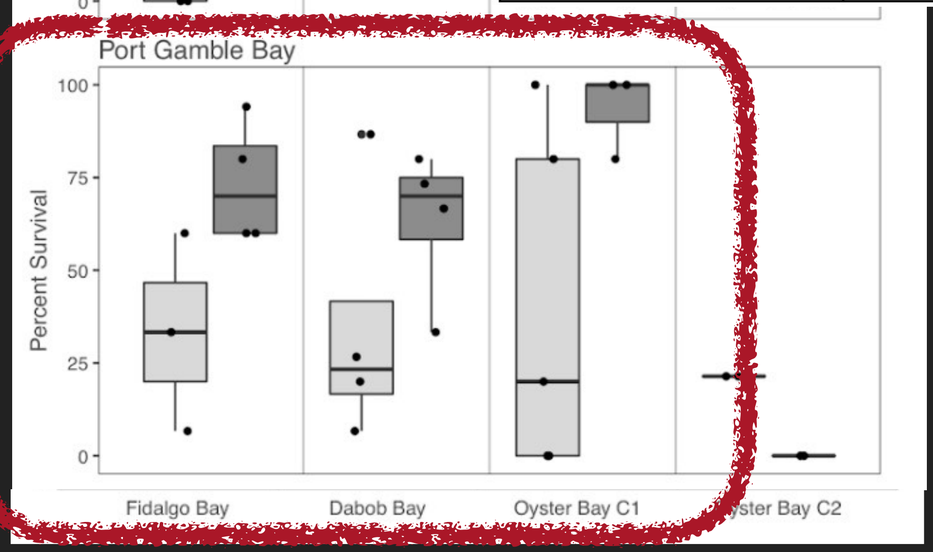




EFFECTS OF OA IN OLYMPIA OYSTER POPULATIONS

Parental pCO_2 Ambient High





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Temperature (°C)	**15.4±1.5**	**15.0±1.0**	**16.2±2.7**	**16.8±1.7**
DO (mg/L)	**10.6±2.4**	**10.5±1.9**	**10.2±3.9**	**11.2±2.8**
Salinity (PSU)	**28.5±3.9**	**31.9±2.0**	**29.6±1.3**	**24.6±1.7**
pH	**8.07±0.15**	**7.86±0.17**	**8.01±0.20**	**8.01.±0.16**
chlorophyll	**227±409**	**225±145**	**572±1536**	**331±613**

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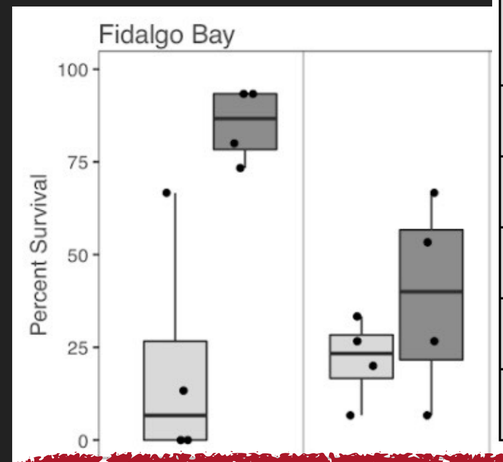

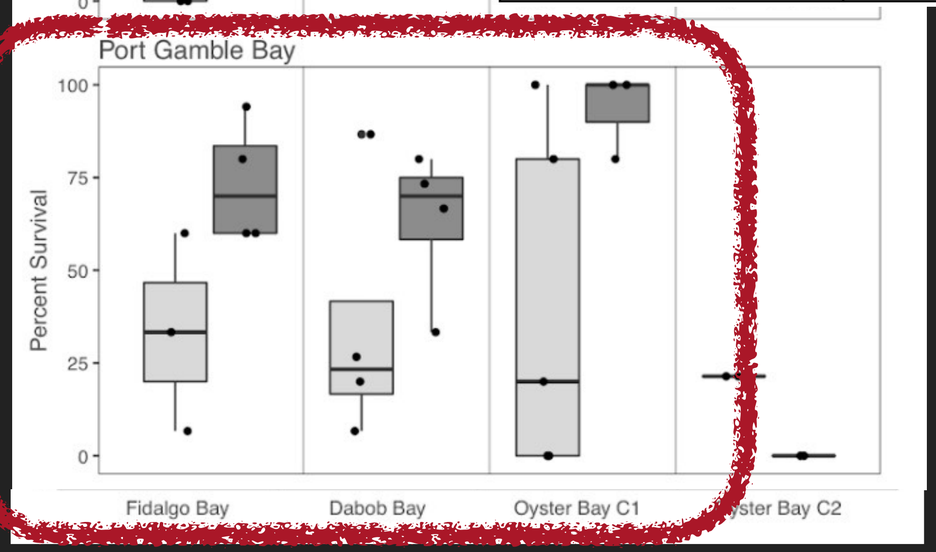

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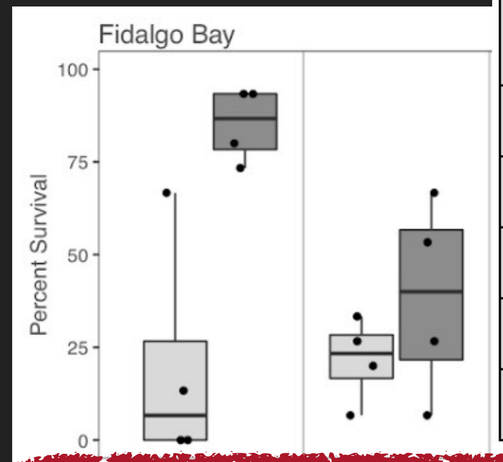

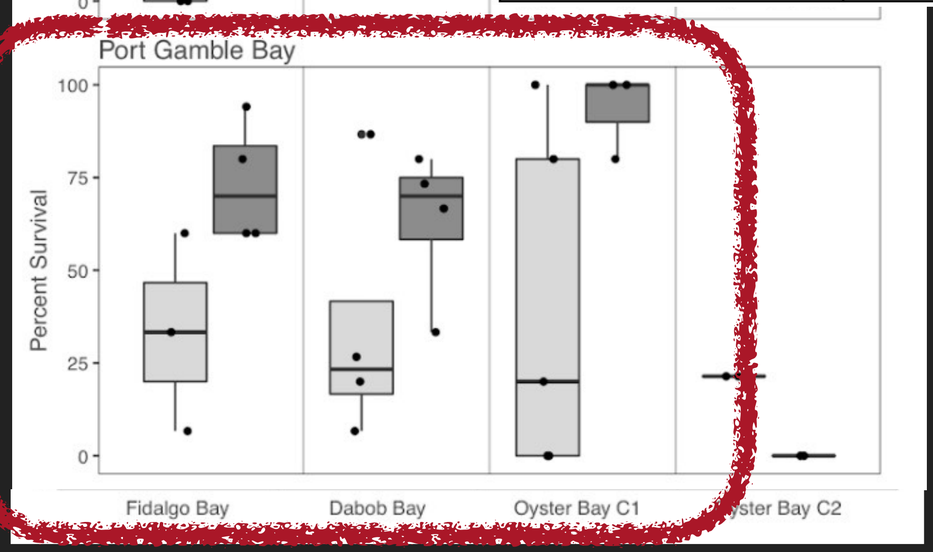

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- ENVIRONMENTAL MEMORY?
- GENETICS?

INFLUENCE OF PARENTAL CONDITIONS

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- **Germ cells are present**
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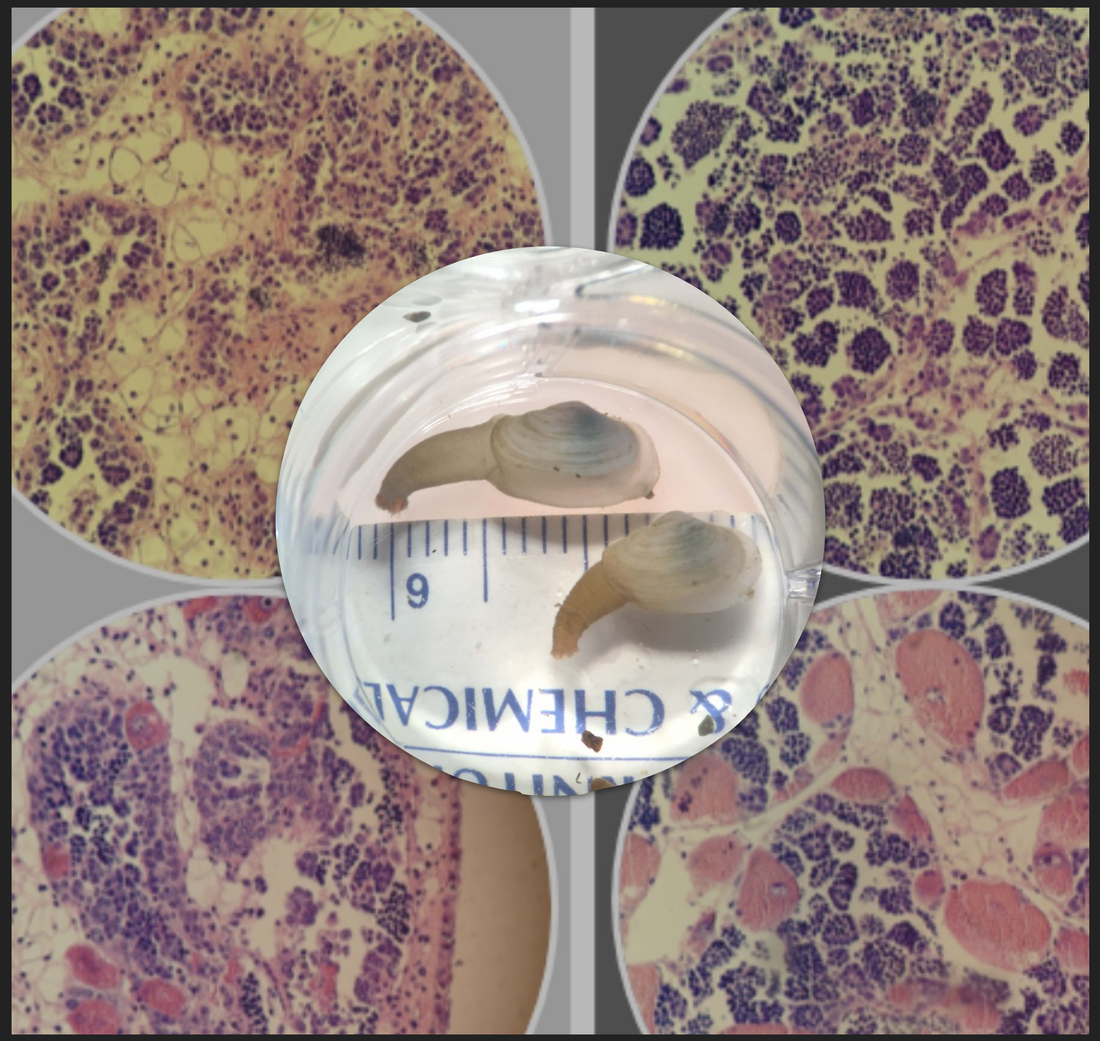
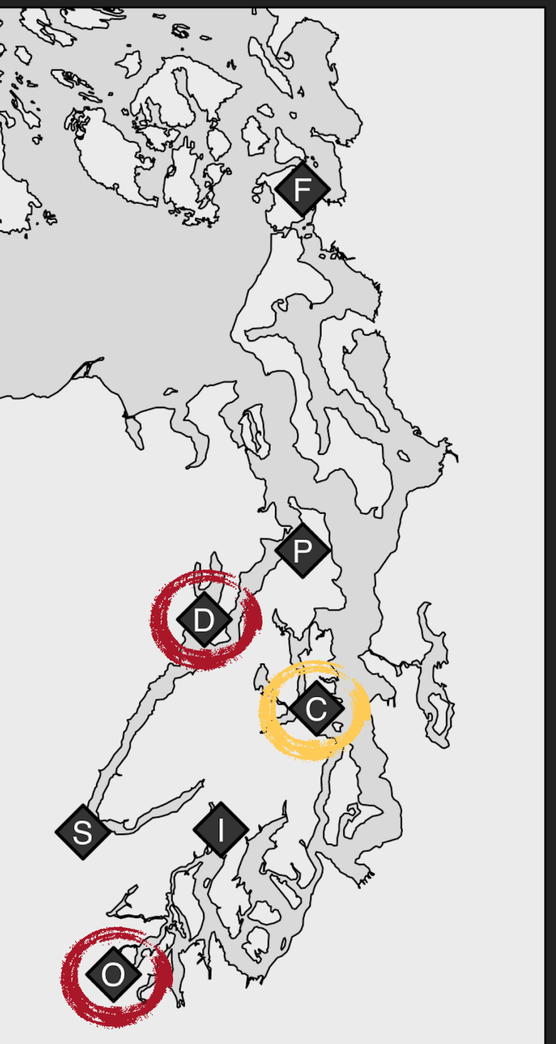
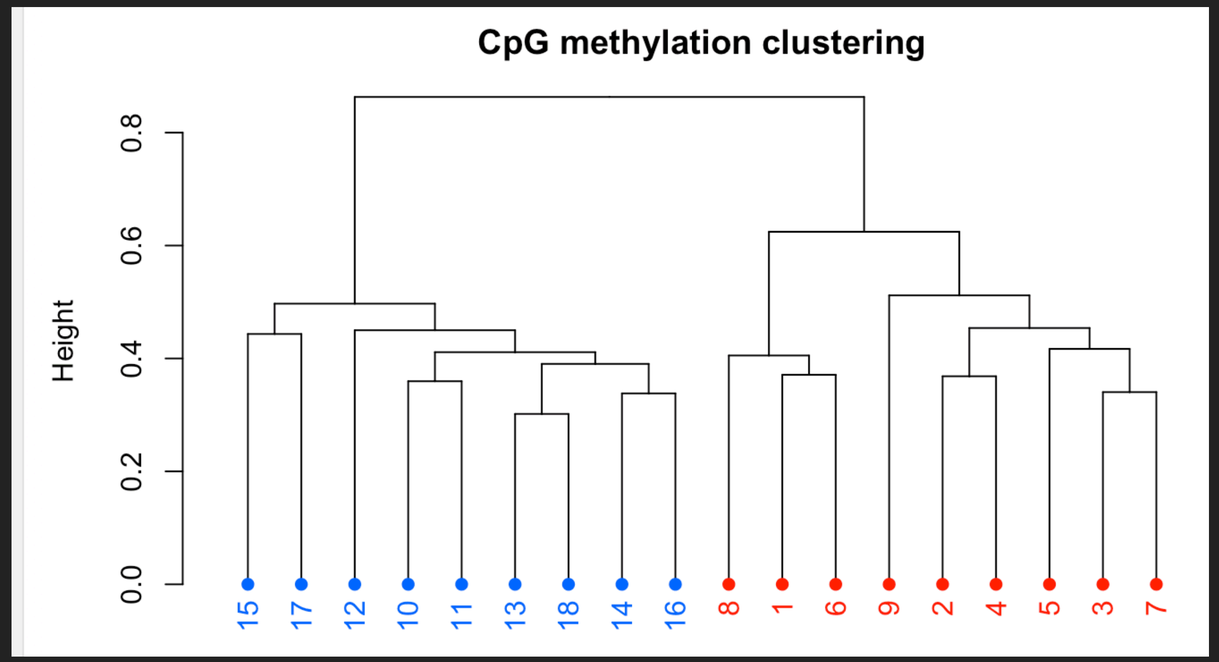
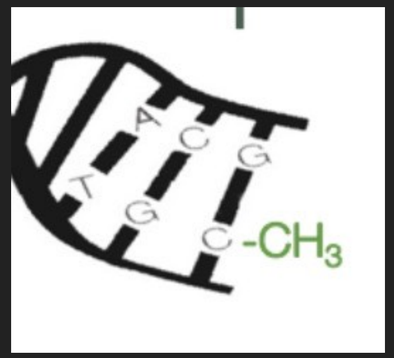


GENETICS (SELECTION) AND EPIGENETICS (ENVIRONMENTAL MEMORY)







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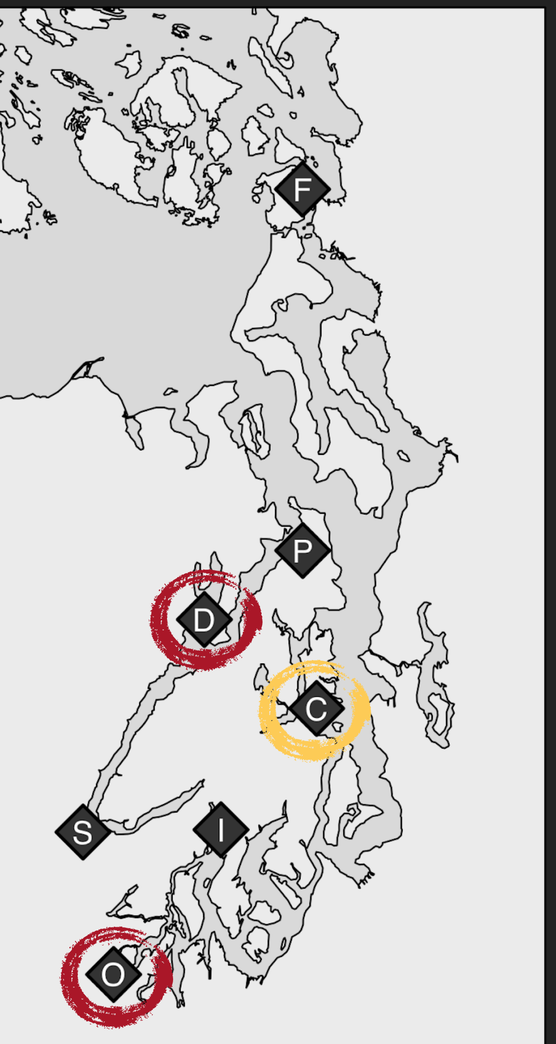

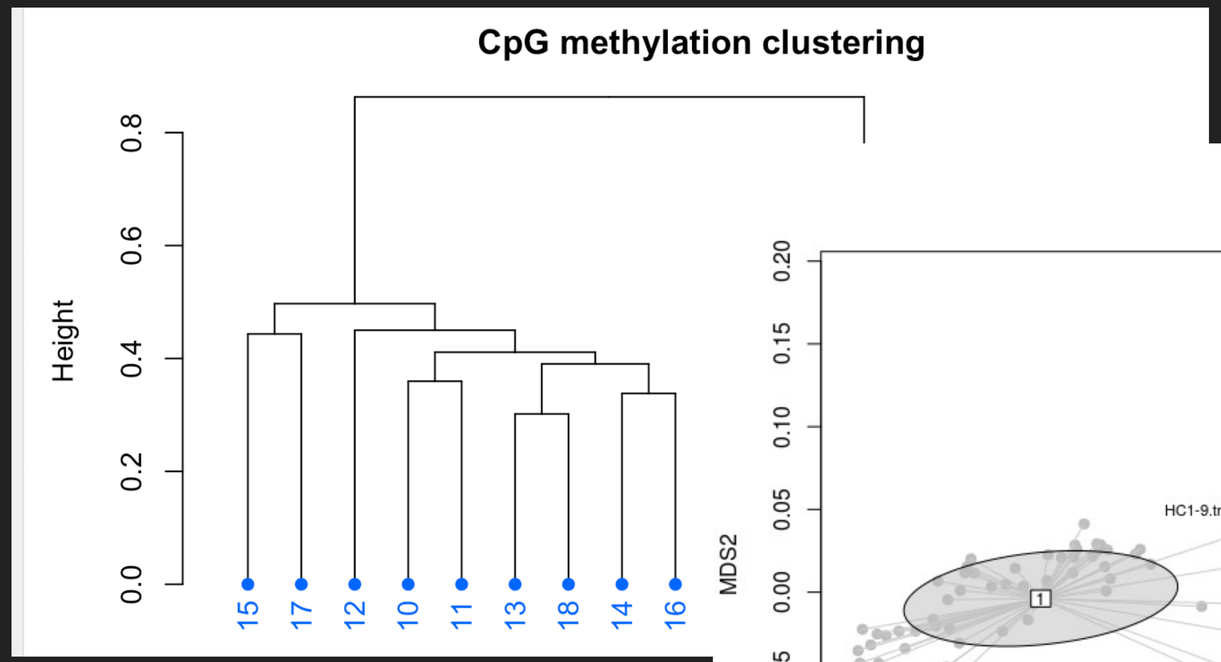

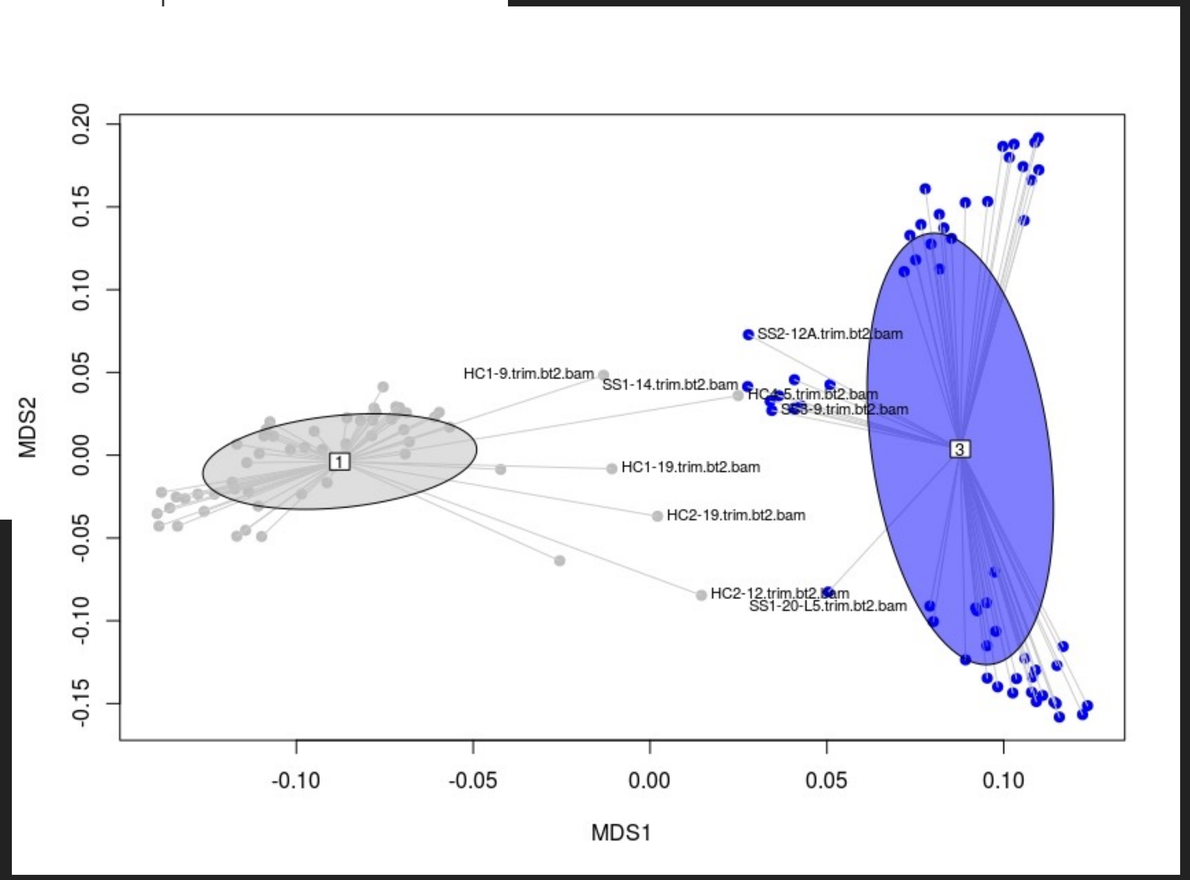

- OLYMPIA OYSTER
- PACIFIC OYSTER
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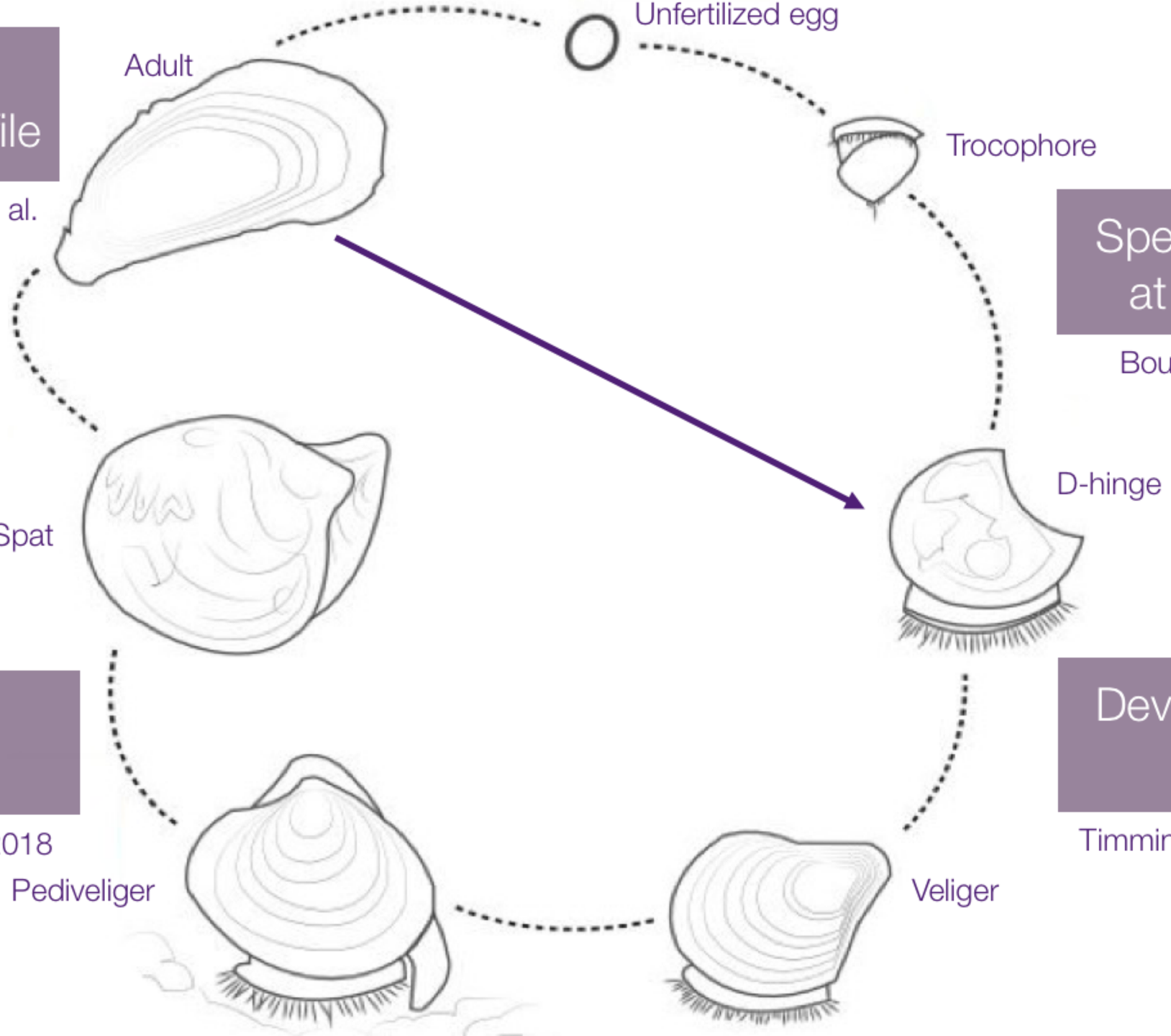
EFFECTS OF OA IN PACIFIC OYSTERS

- Oysters were exposed to either low pH (7.31) or ambient pH (7.82) conditions for seven weeks.
- Oysters were then held for eight weeks in ambient conditions, and subsequently reproductively conditioned for four weeks at ambient pH.

Altered proteomic profile

Timmins-Schiffman et al. 2014



Sperm inactive at pH < 7.0

Boulais et al. 2018

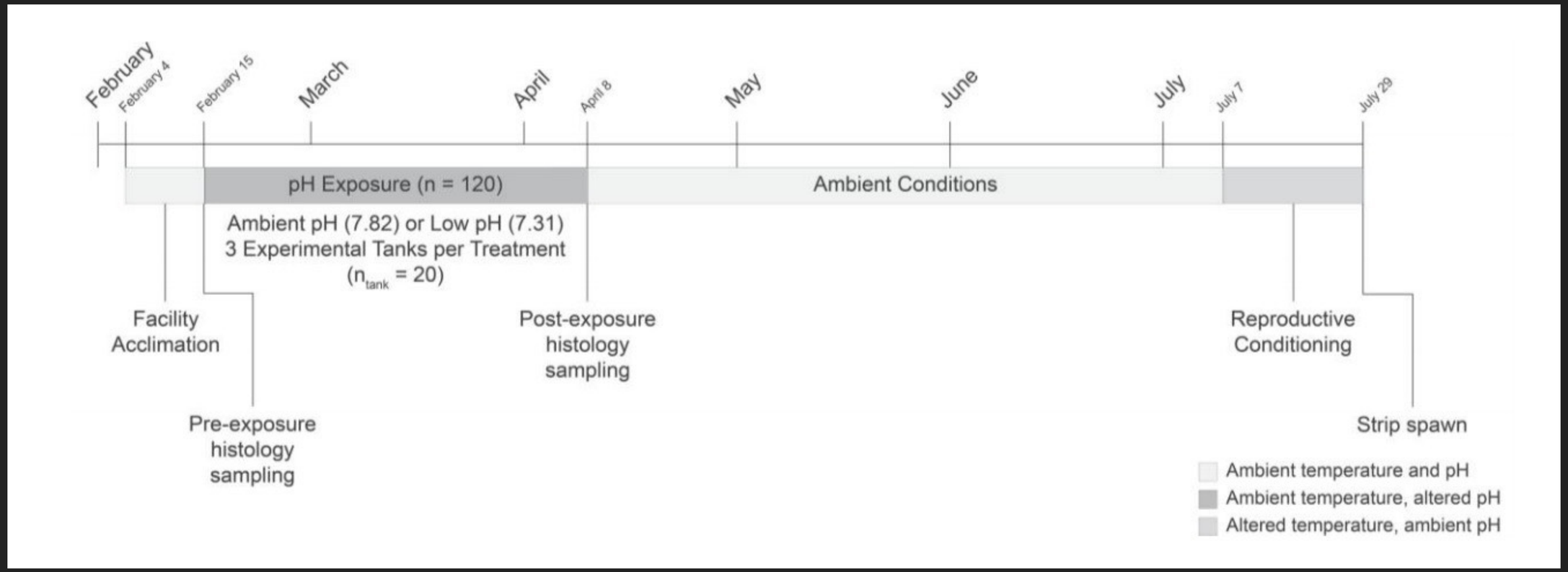
Developmental delays

Timmins-Schiffman et al. 2012

Reduced settlement

Burton et al., NSA 2018

EFFECTS OF OA IN PACIFIC OYSTERS



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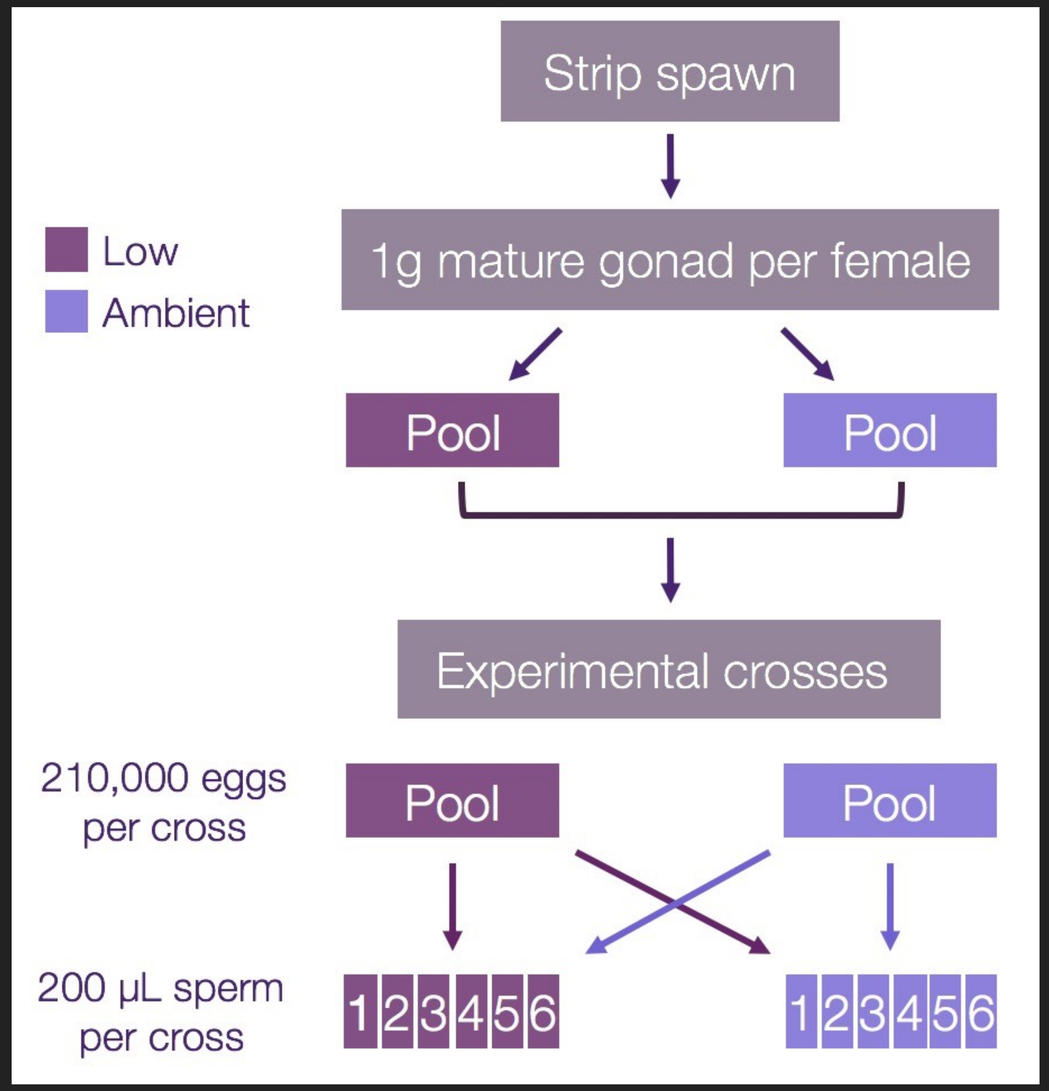

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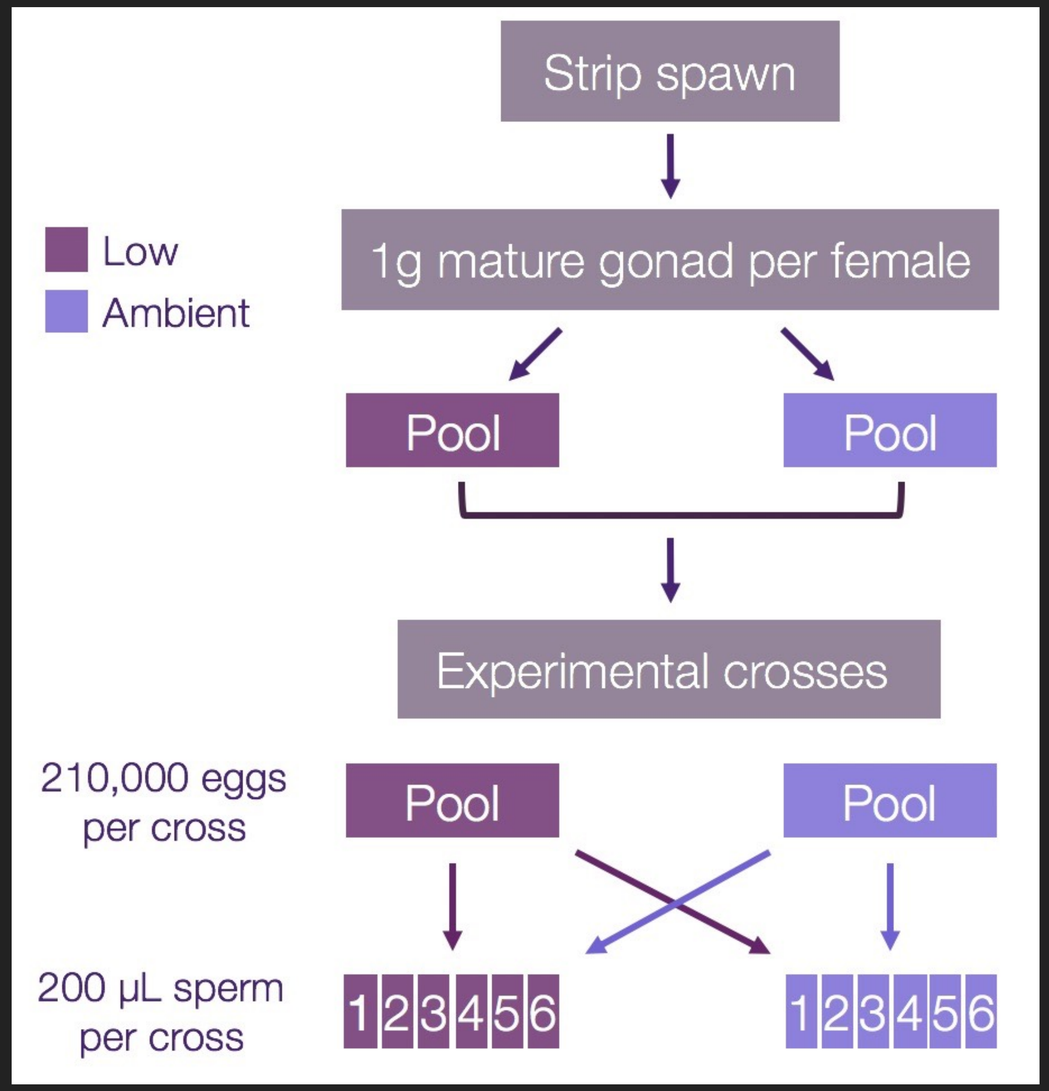

YAAMINI VENKATARAMAN

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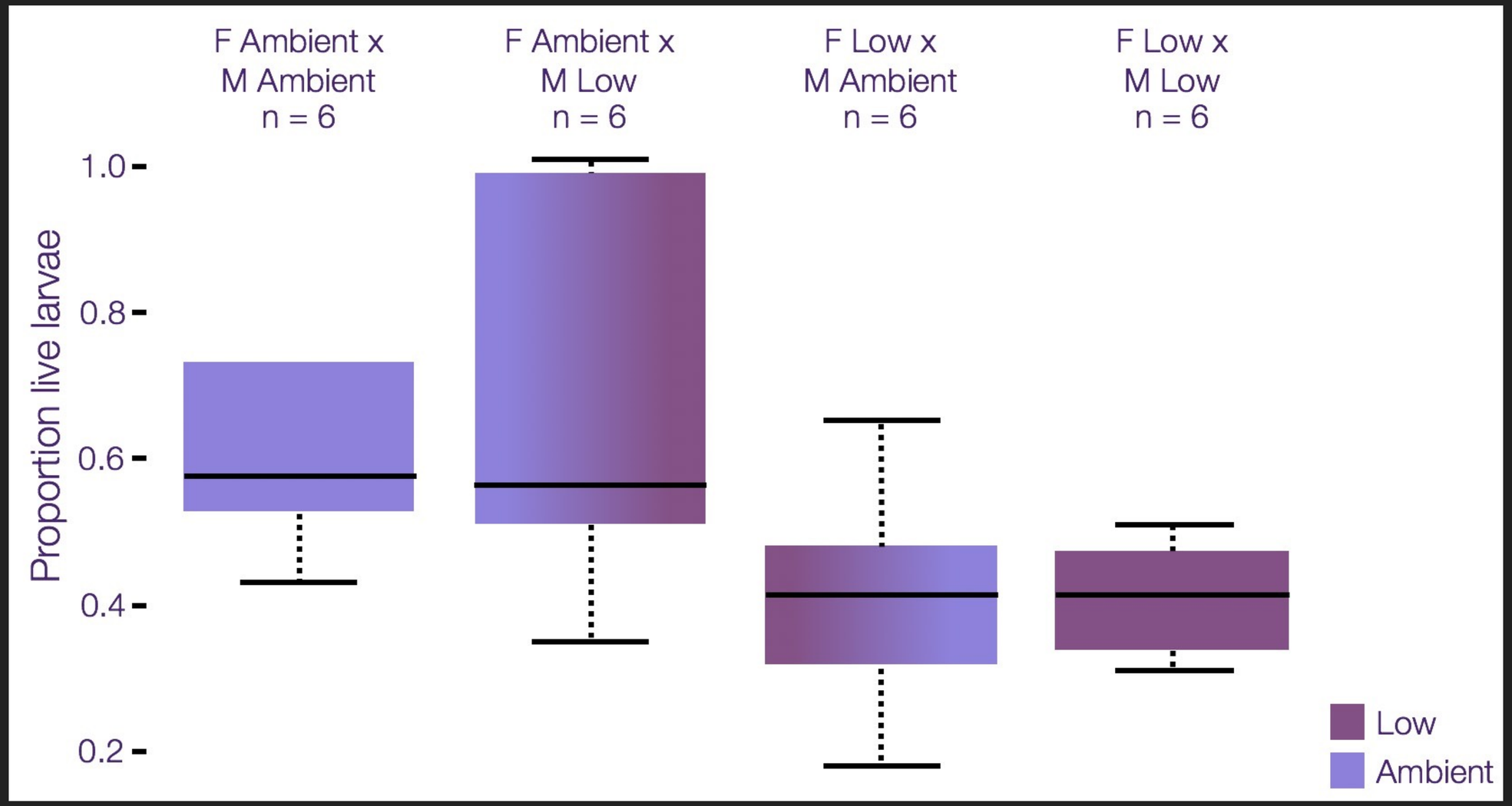
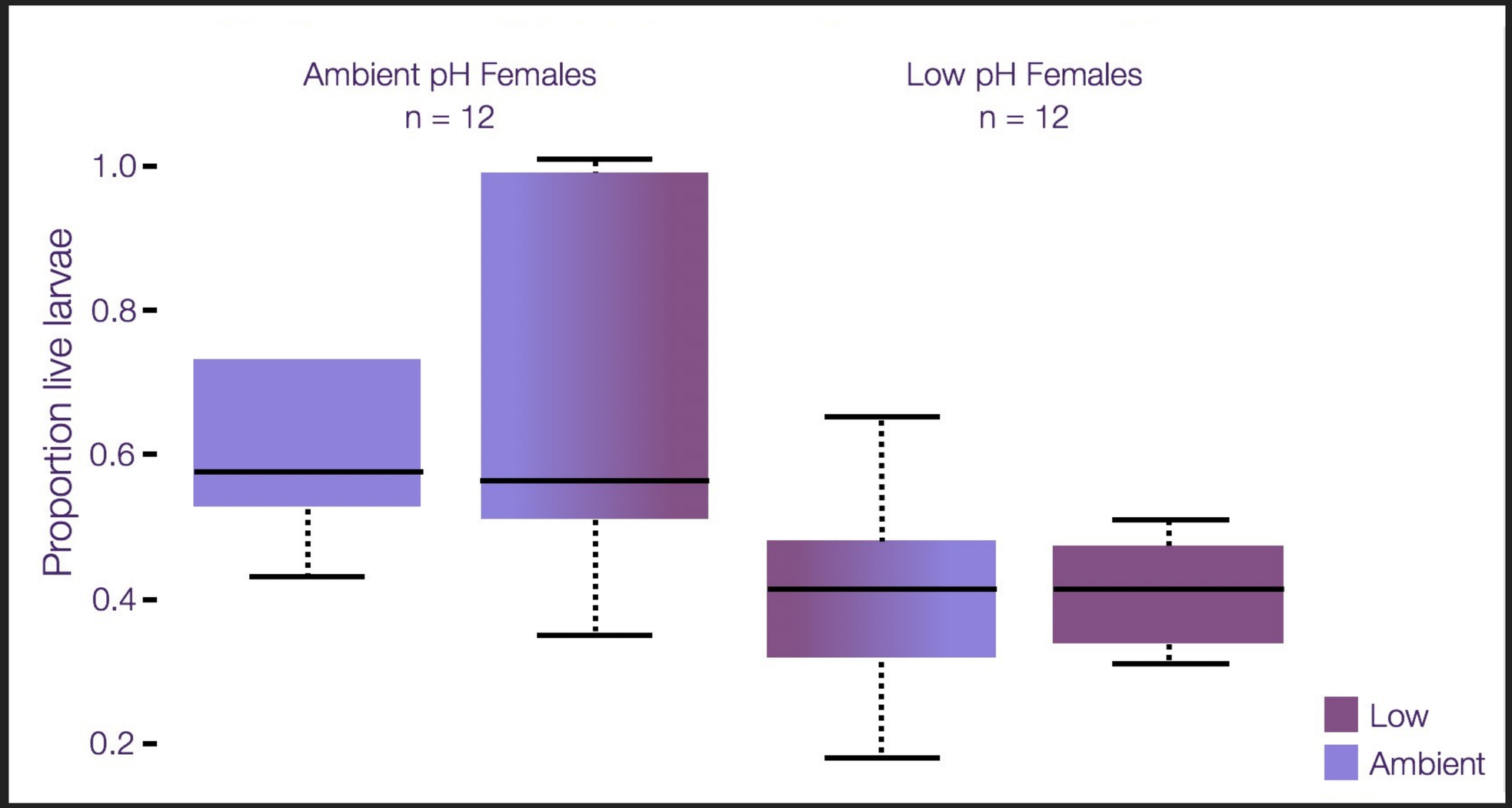

F Ambient x
M Ambient
n = 6
F Ambient x
M Low
n = 6
F Low x
M Ambient
n = 6
F Low x
M Low
n = 6
Proportion live larvae
1.0
0.8
0.6
0.4
0.2
Low
Ambient


Ambient pH Females
n = 12
Low pH Females
n = 12
Proportion live larvae
1.0
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0.6
0.4
0.2
Low
Ambient

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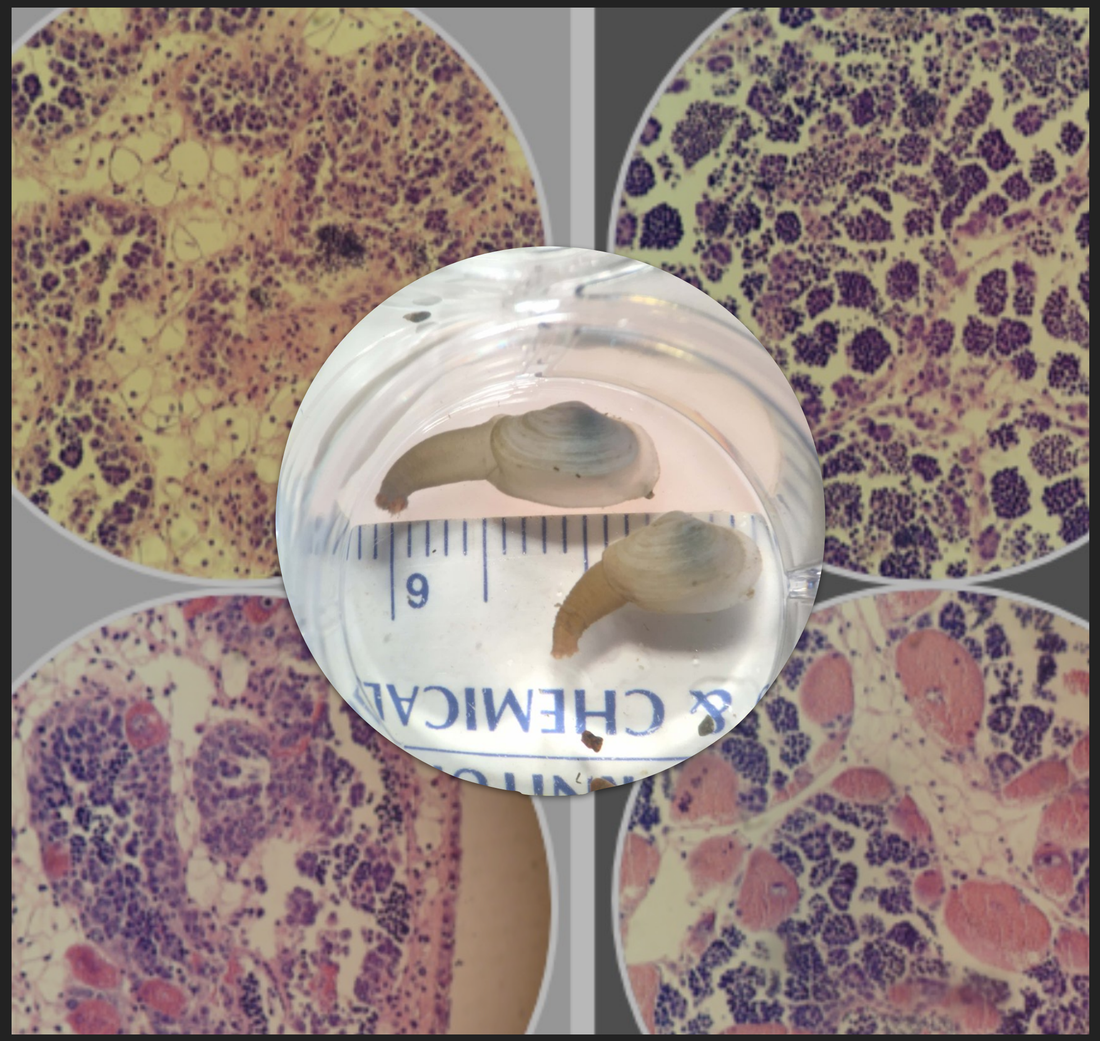

4 Week pH Exposure

Elevated pCO_2
(2800 µatm)

Control pCO_2
(400 µatm)

↓

DNA Extraction and Bisulfite Sequencing

↓

Identify Differentially Methylated Loci (DMLs)

Metabolic processes

$p = 1.21e-10$

Similar to previous work

Elevated pCO_2 induced higher metabolic rates in Eastern oysters (Beniash et al. 2010)

Hypermethylation

Genes for metabolic regulation less likely to be transcribed
Larvae may benefit from stable housekeeping genes

Hypomethylation

Genes more likely to be transcribed
Could increase phenotypic plasticity in larvae

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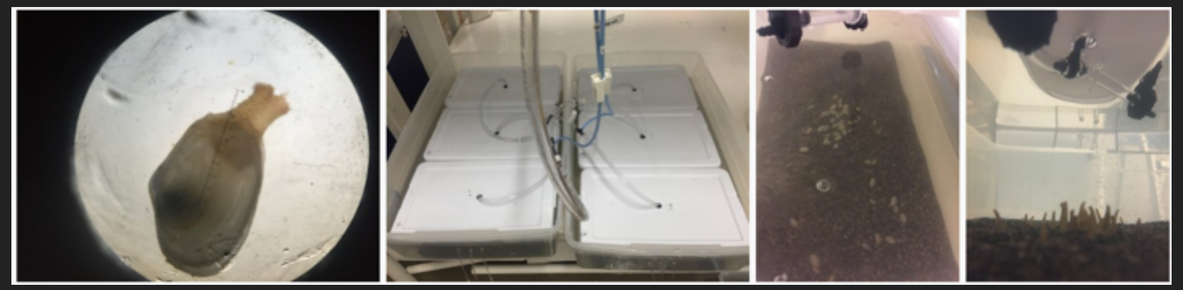
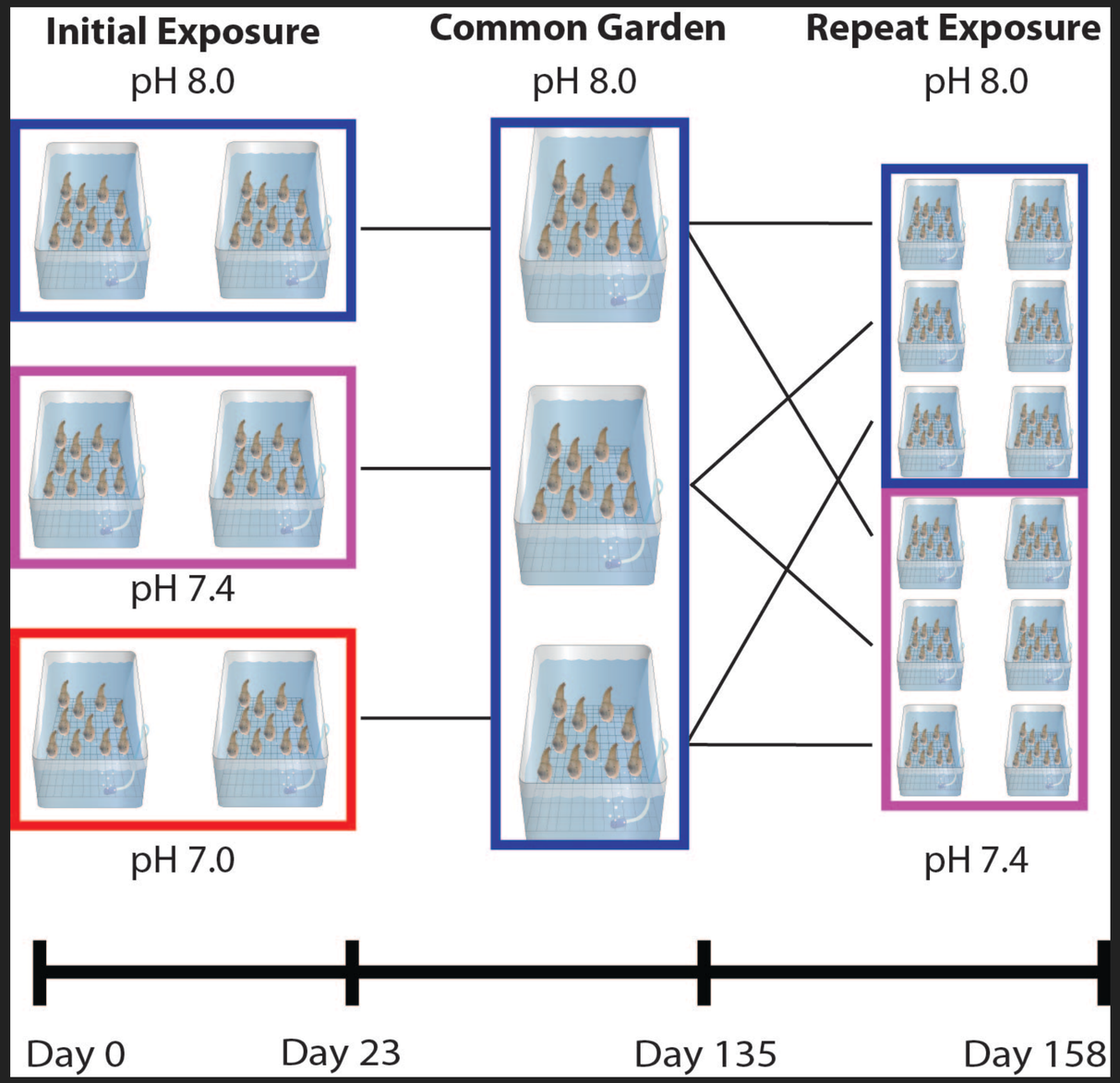
GEODUCKS AND OA



- Does conditioning to low pH confer tolerance within a generation?



GEODUCKS AND OA

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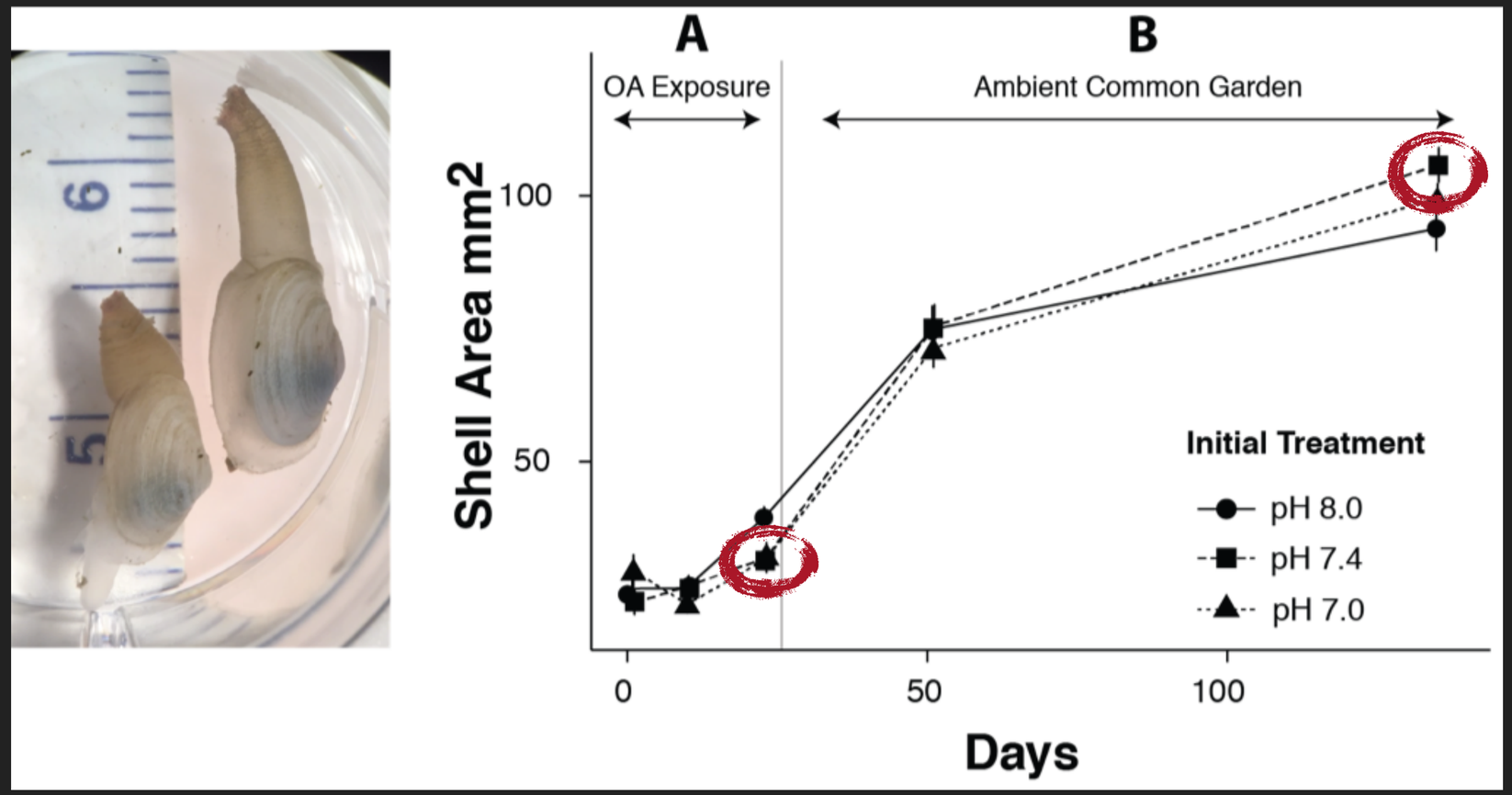

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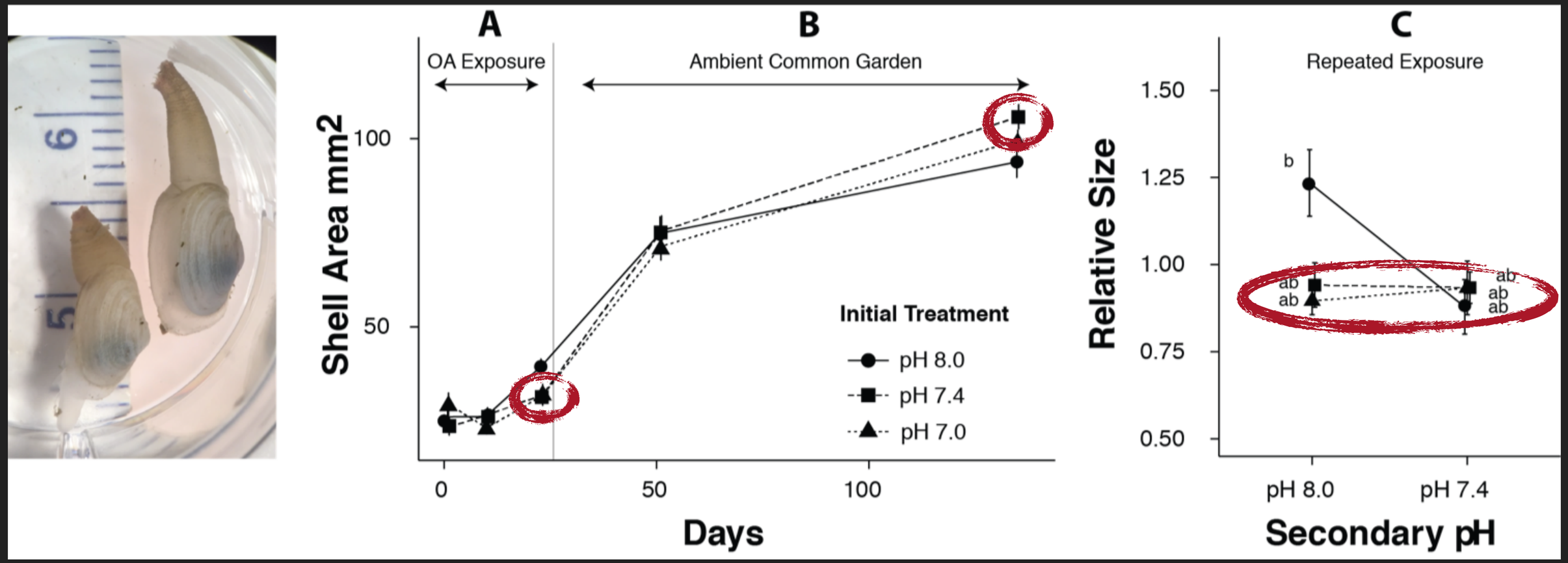

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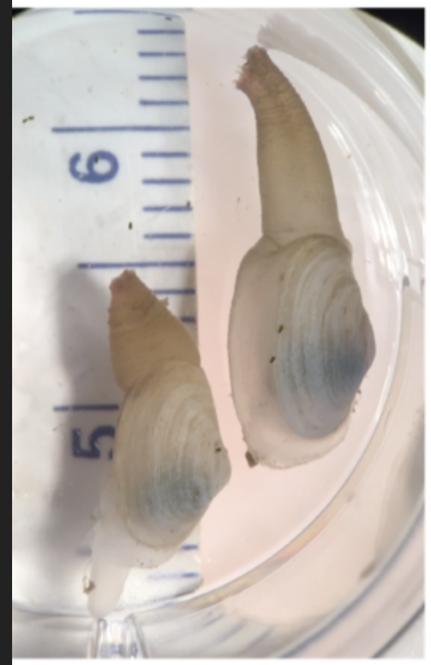
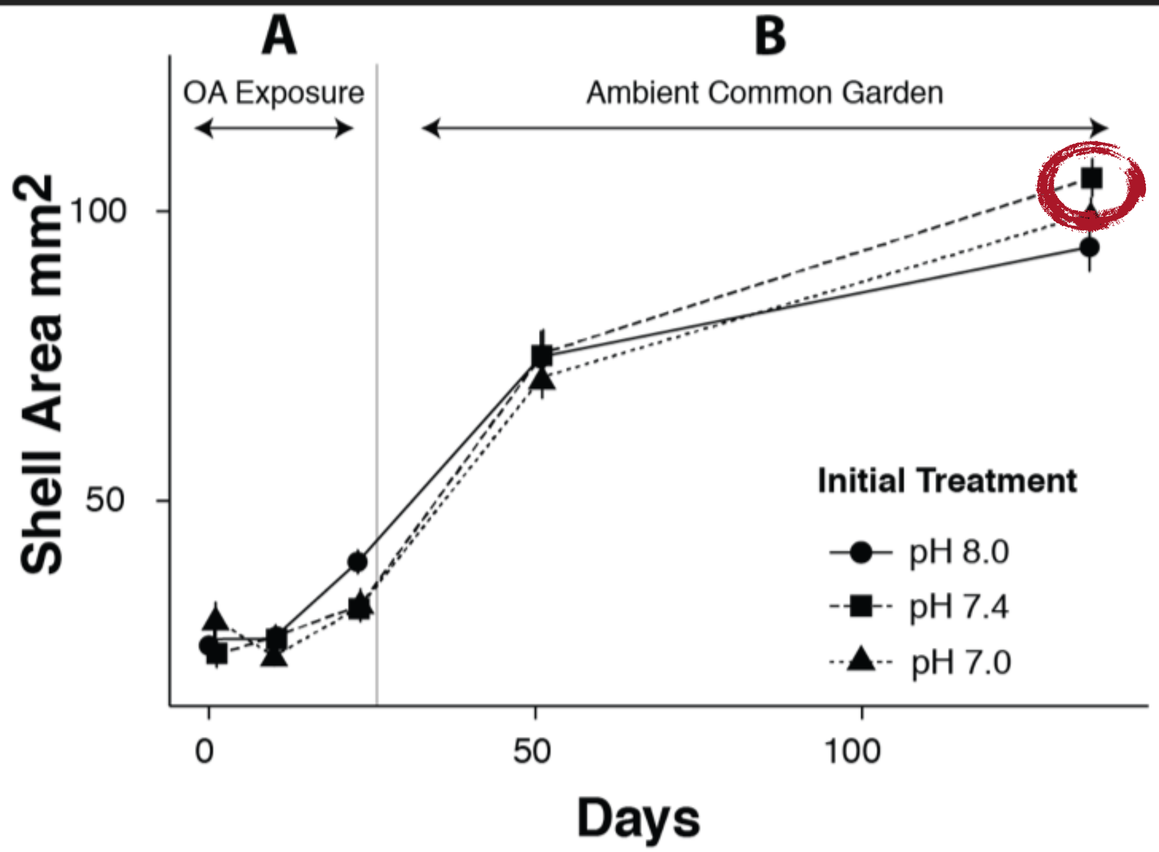
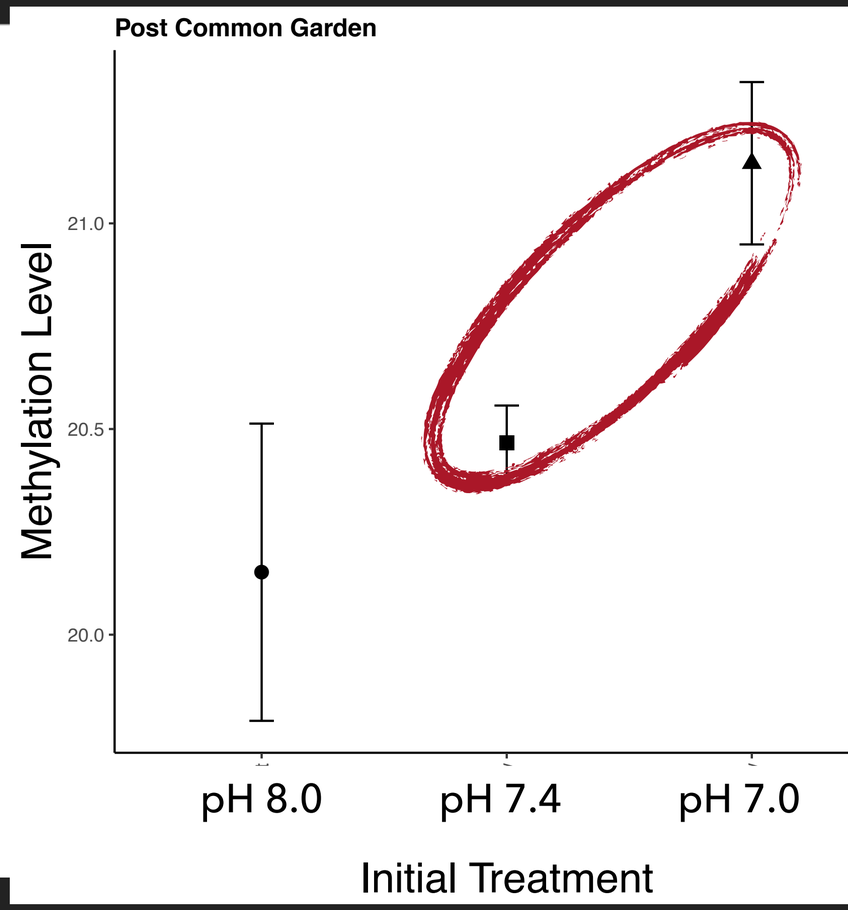




DNA METHYLATION



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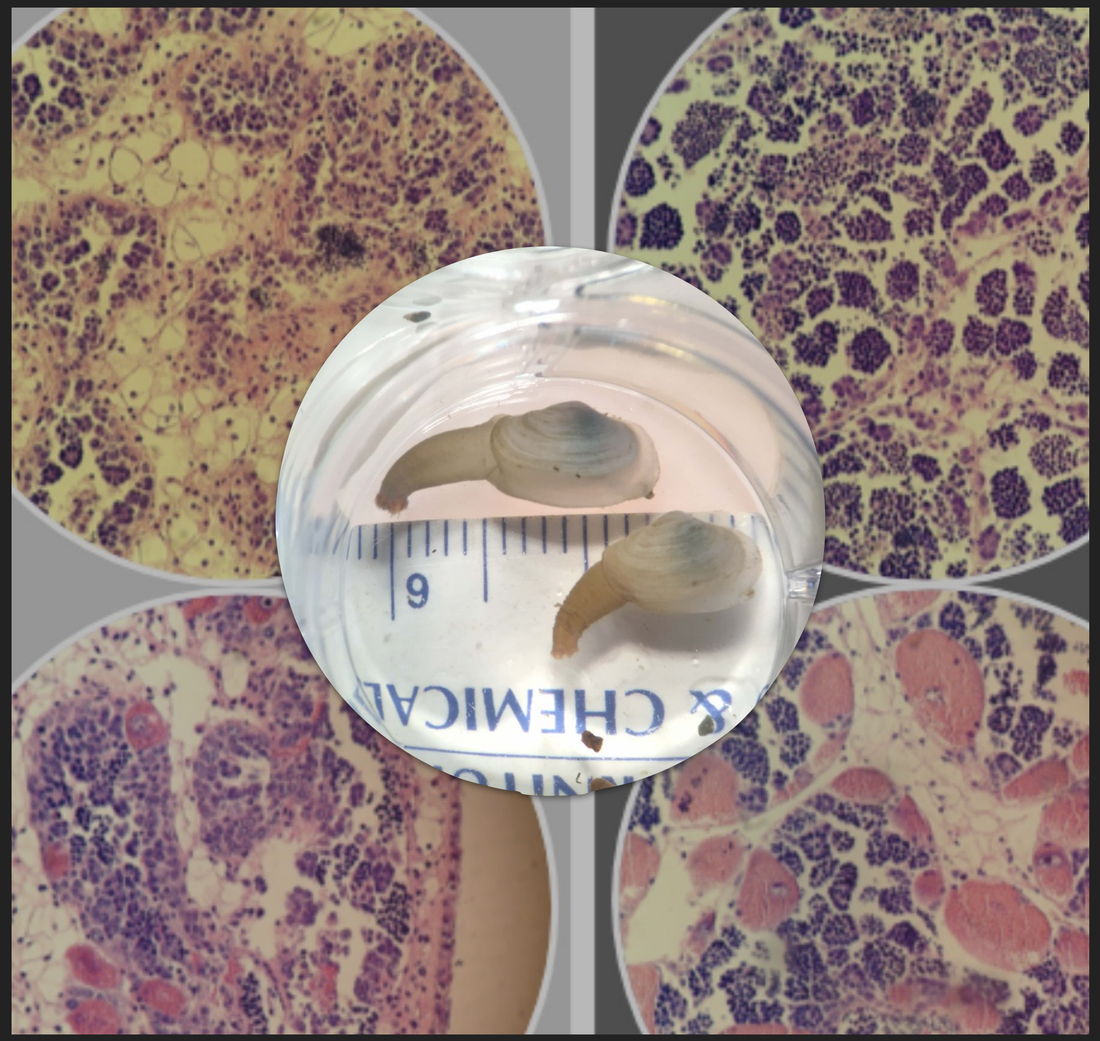
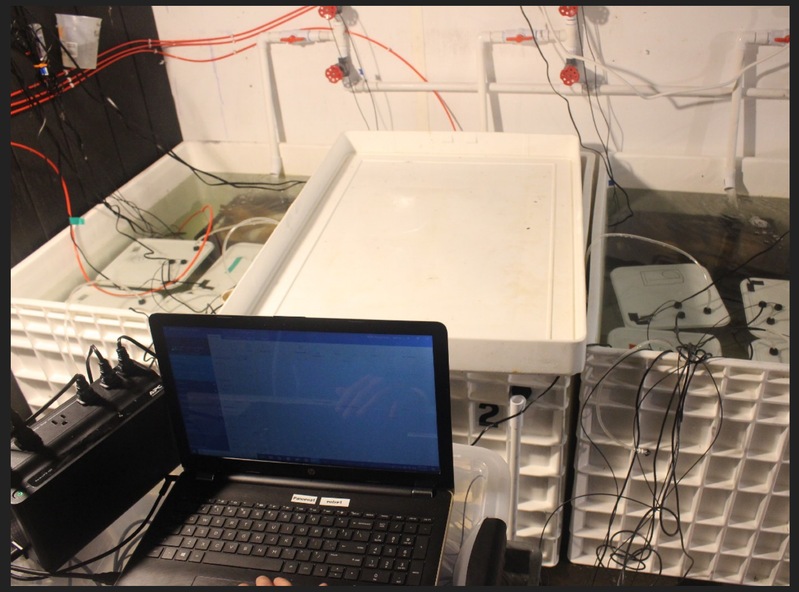
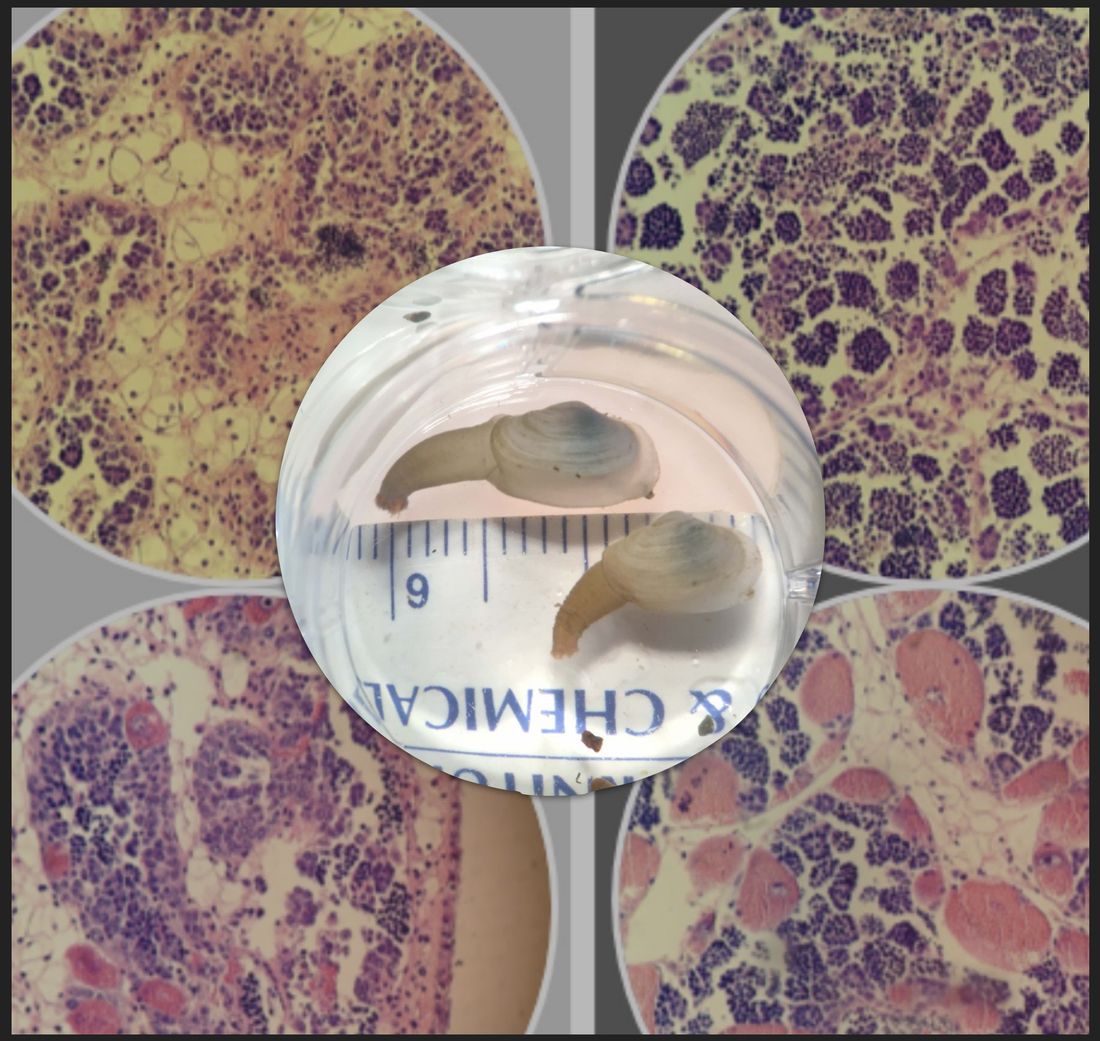


GEODUCKS AND OA



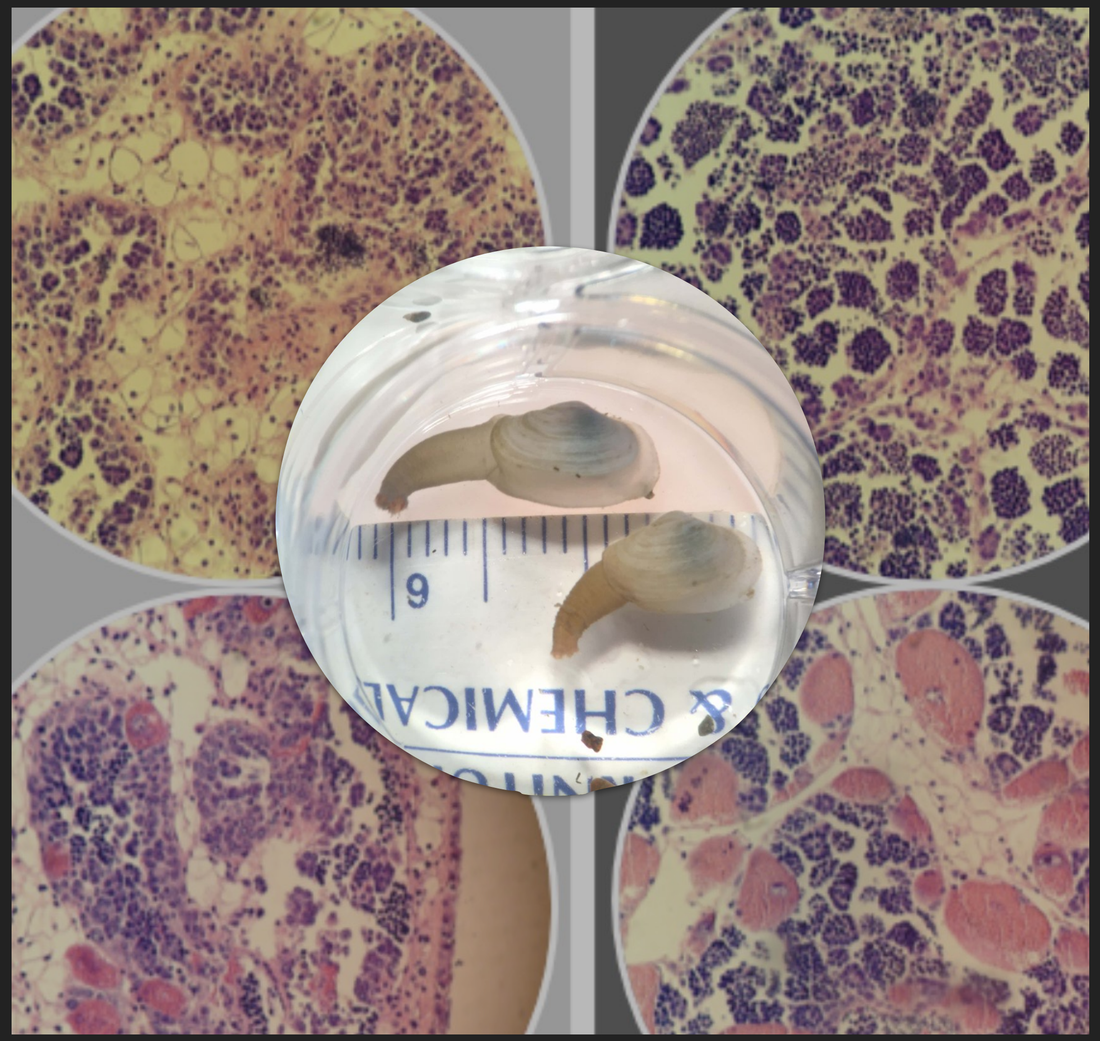
SUMMARY

- Complicated



SUMMARY

- Complicated
- Environmental exposure outside of gametogenesis has an impact
- Evidence for a beneficial impact of prior exposure
- Likely a combination of physiological burden and “hardening” dependent on phenotypic capacity



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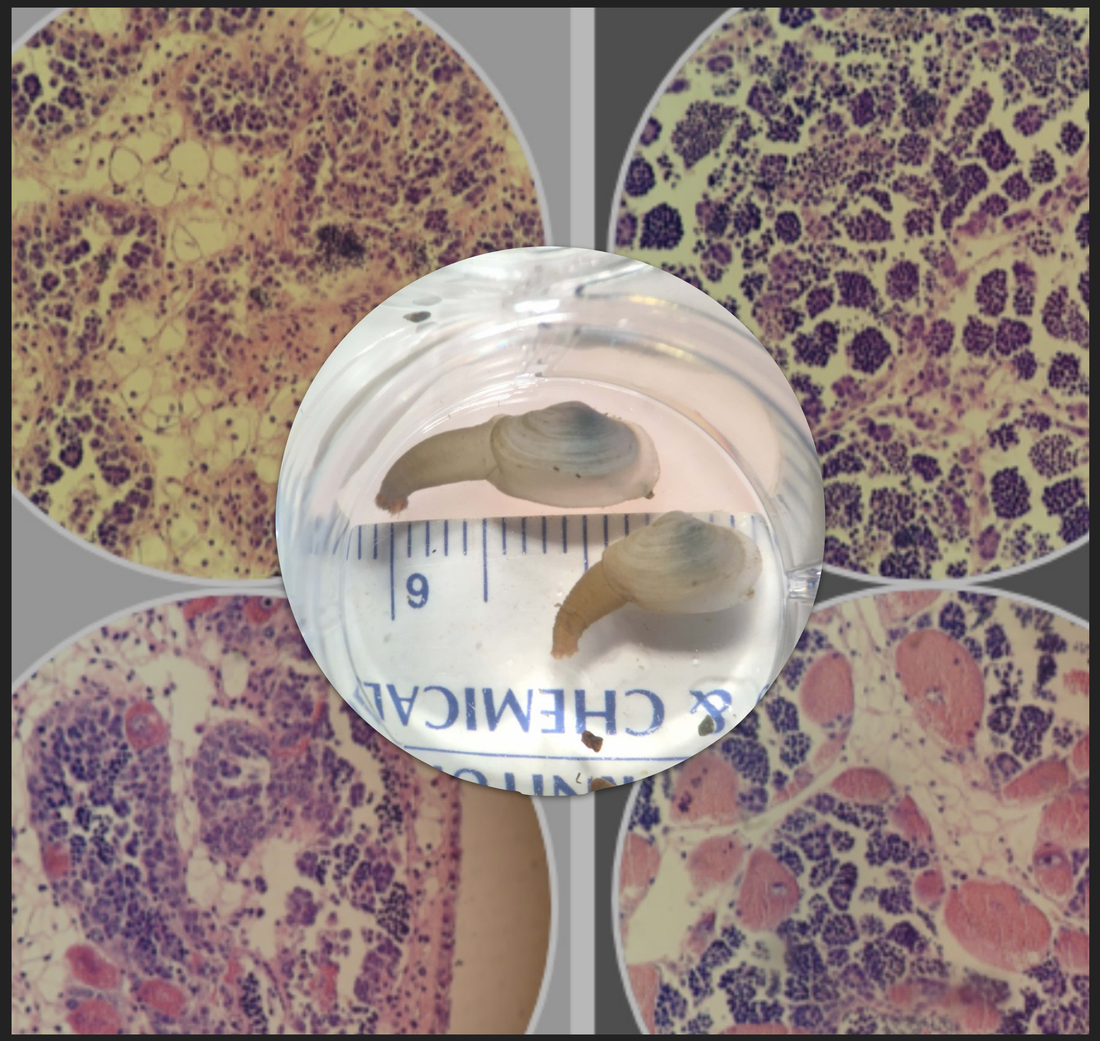

IMPLICATIONS FOR AQUACULTURE

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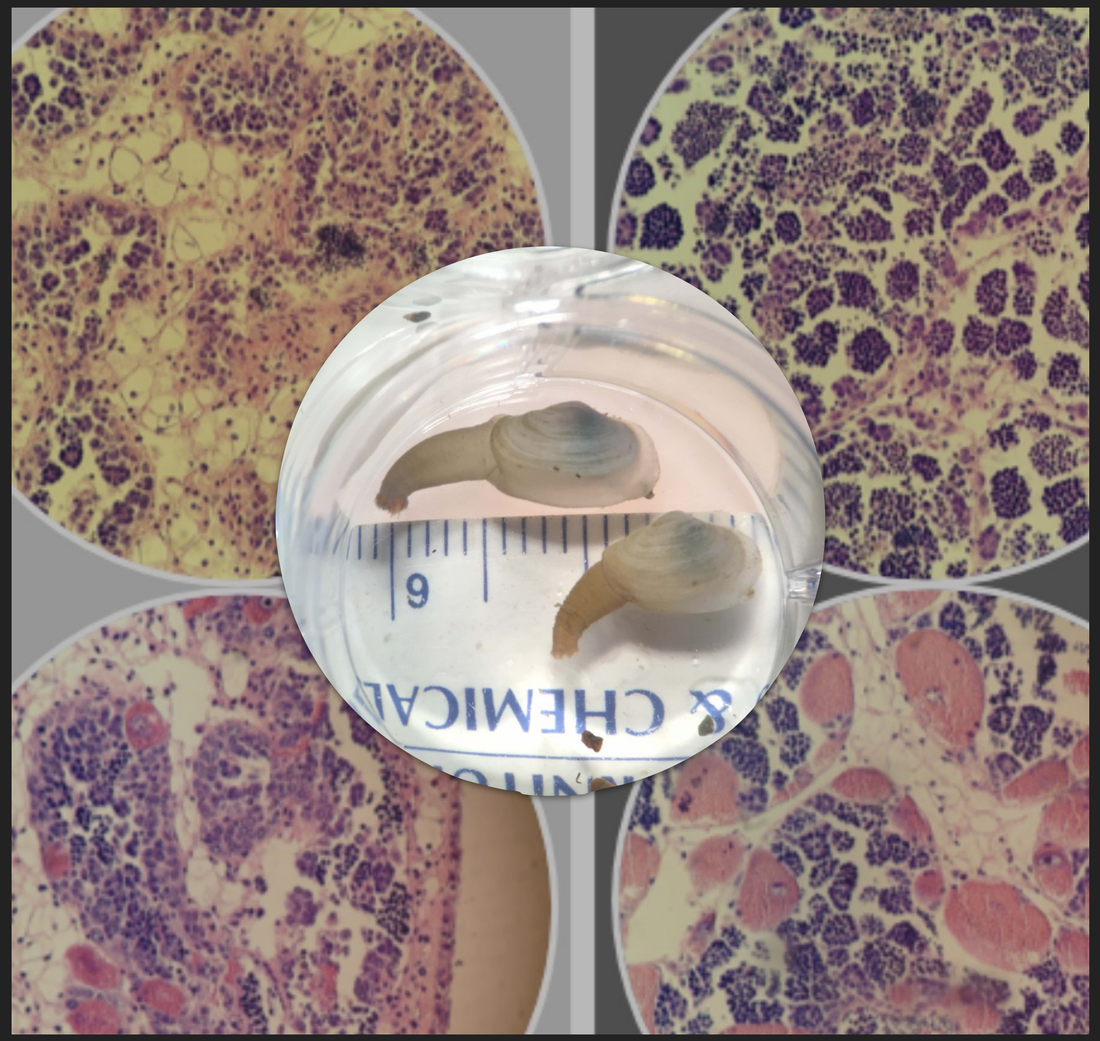

IMPLICATIONS FOR ECOSYSTEM RESILIENCE ?

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