INCAR
Interdisciplinary Center for Aquaculture Research

Olympia Oyster (*Ostrea lurida*) Restoration in the United States

A Physiology and Genomic Perspective

Steven Roberts - University of Washington


FHL

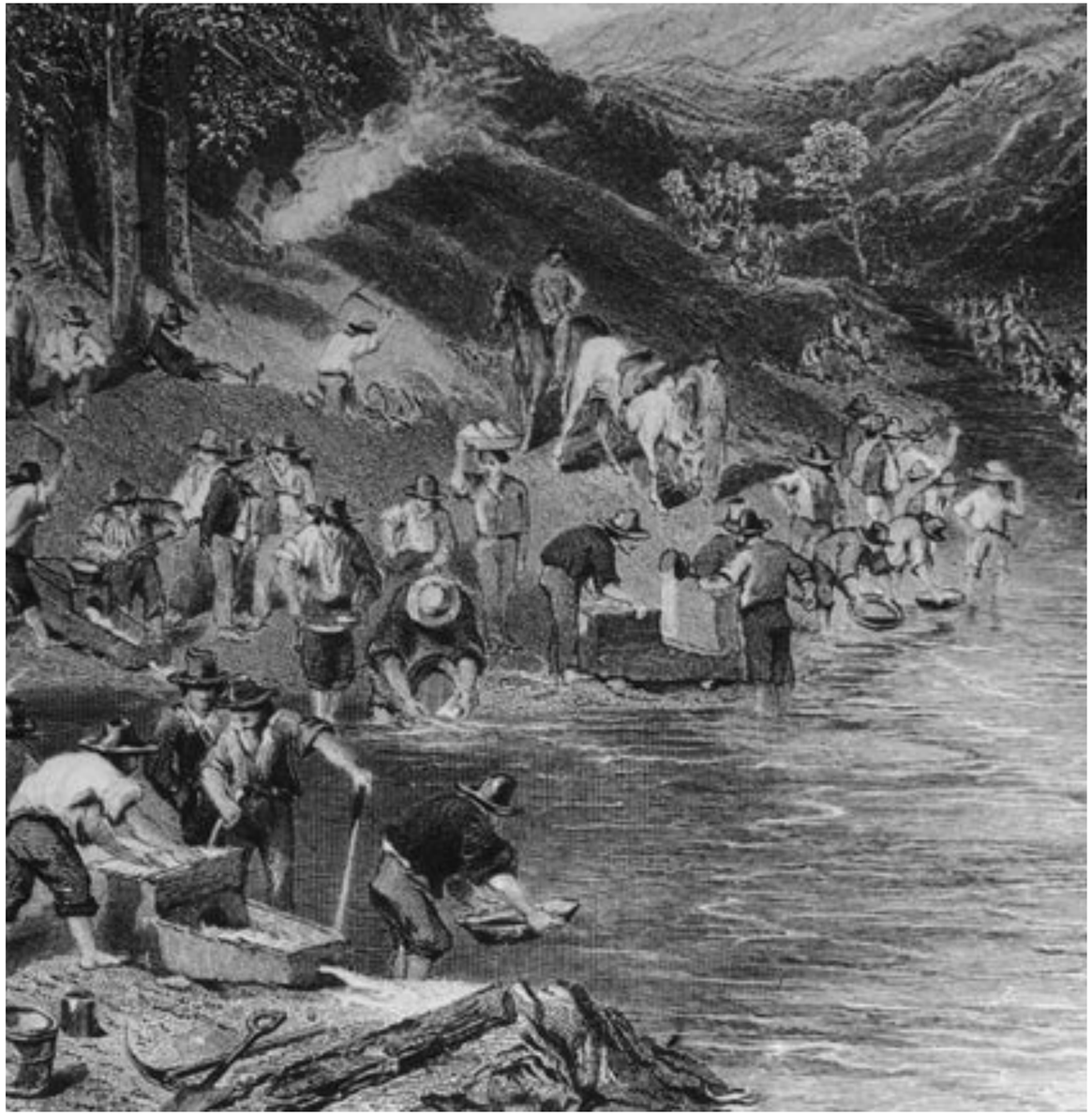

FHL


FHL

Olympia Oyster

Only native oyster on Pacific US

- Historic populations impacted by over-harvesting, pollution, habitat destruction, climate change.
- Restoration efforts are underway across the Pacific coast, mitigate against climate change
- For effective restoration need to have understanding on how populations are different.



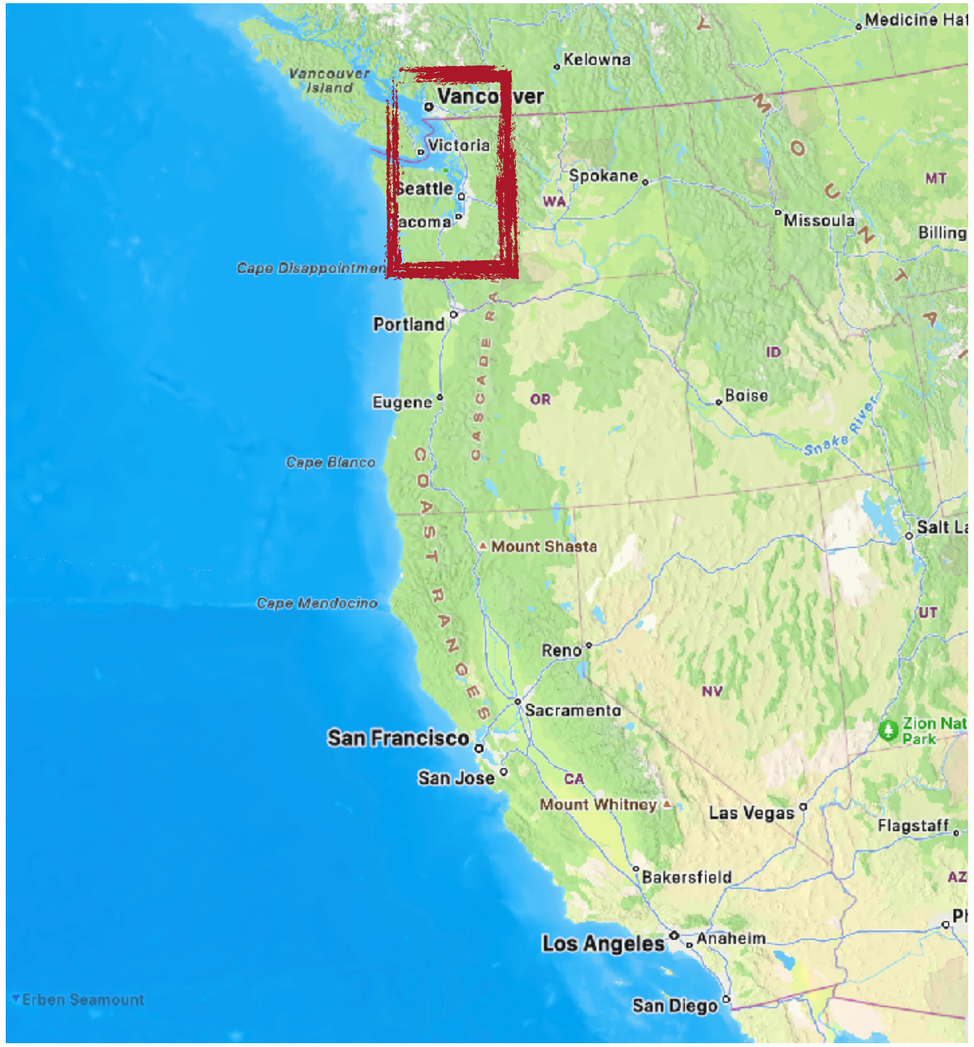
Revival of once-abundant Olympia population could help fight effects climate change

CBS NEWS BAY AREA

By Elizabeth Cook, Molly McCrea
Updated on: October 19, 2023 / 6:29 PM PDT / CBS San Francisco

Historic Populations

Pacific Northwest



WASHINGTON DEPARTMENT OF FISH & WILDLIFE'S HISTORIC LOCATIONS OF LARGE OLYMPIA OYSTER BEDS

Population Comparisons

Pacific Northwest

- Will provide research logic and results from years of studies.
  - In order to suggest questions to consider when undergoing restoration efforts.
  - Demonstrate fundamental organism trade-offs to better predict ecosystem outcomes.

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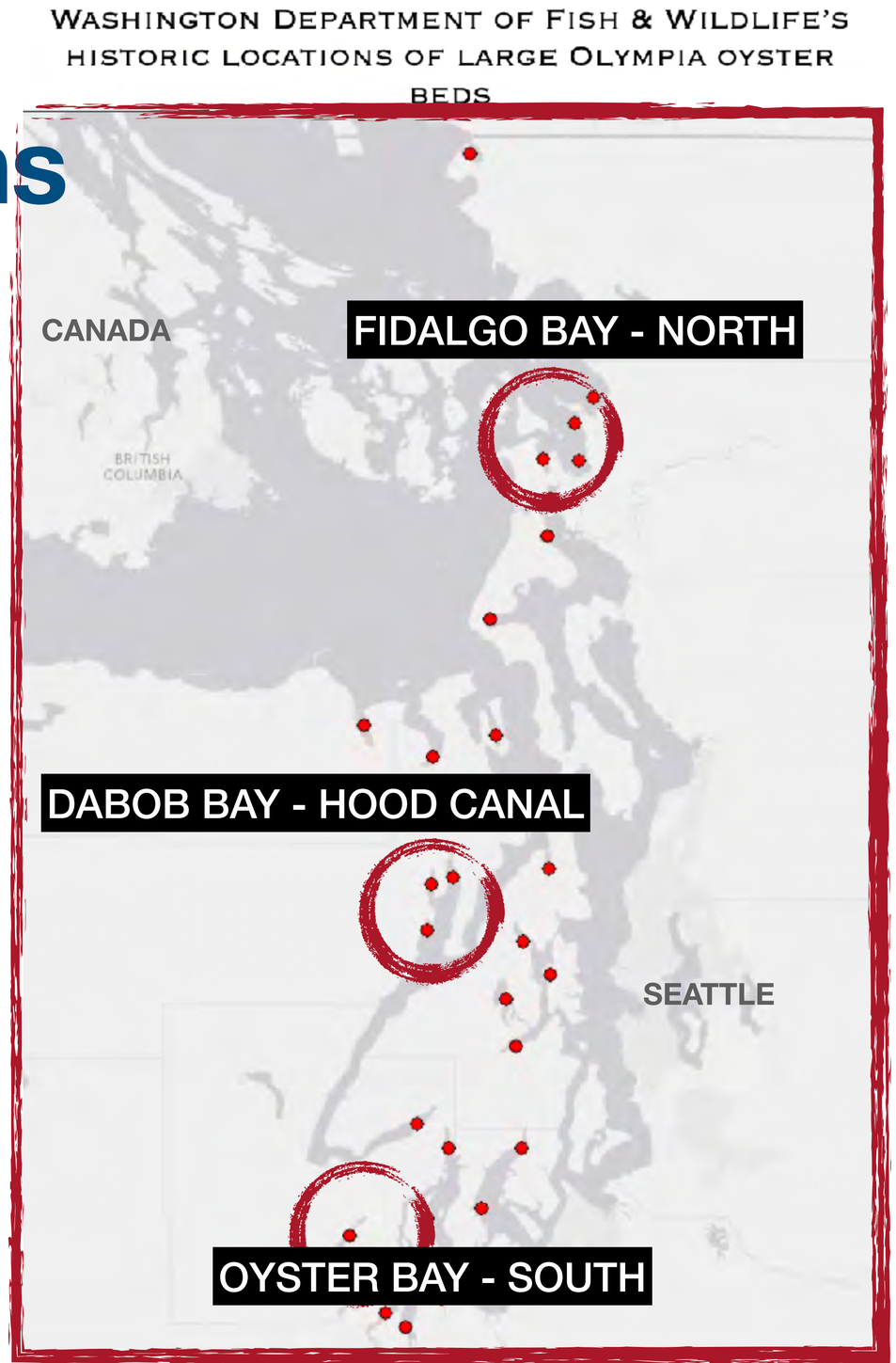

Need to know differences for proper decision making

Population Comparisons

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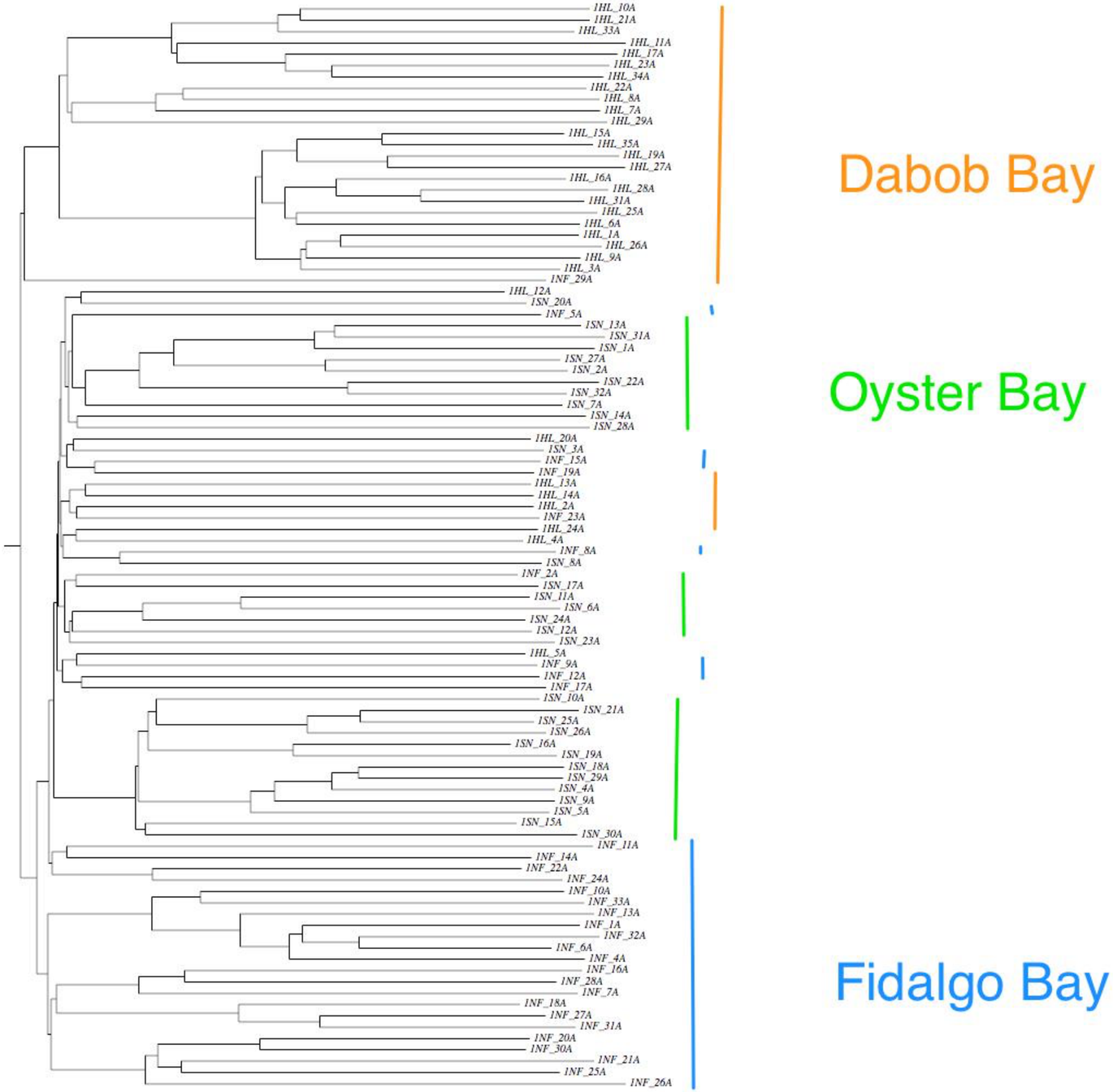
Genetics



Dabob Bay

Oyster Bay

Fidalgo Bay

Genotype-by-sequencing of three geographically distinct populations of Olympia oysters, *Ostrea lurida*

Samuel J. White, Brent Vadopalas, Katherine Silliman & Steven B. Roberts

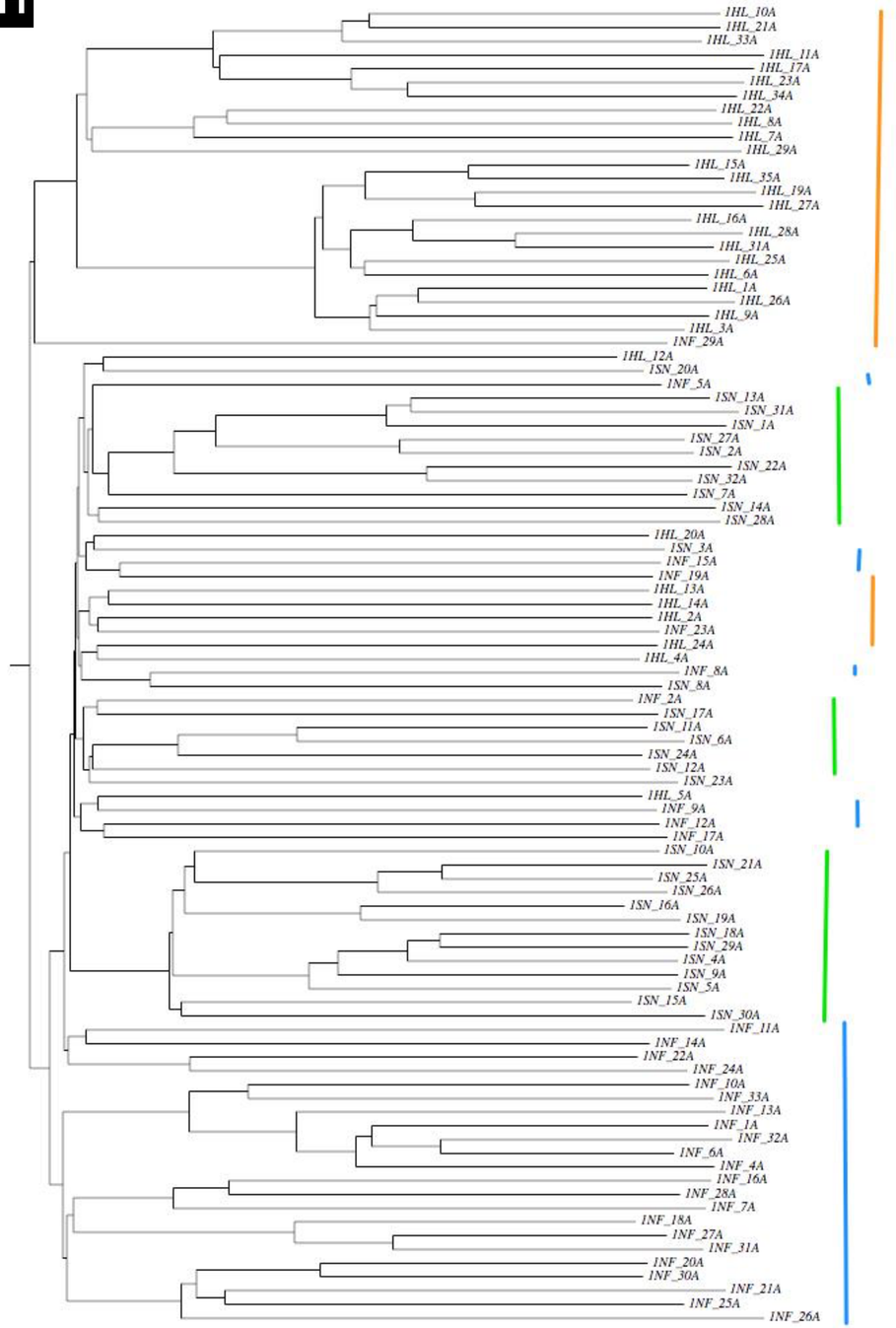
Scientific Data **4**, Article number: 170130 (2017) | Cite this article

Genetics

FIDALGO BAY - NORTH

DABOB BAY - HOOD CANAL

OYSTER BAY - SOUTH



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Adapted?

Or consequence of limited parents, plasticity etc.

Population Characteristics

Reciprocal transplant experiment

To test for adaptive differences between Olympia oysters populations a reciprocal transplant experiment was carried out monitoring survival, growth and reproduction. Performance differed for each population. ***Ostrea lurida from Dabob Bay had the highest survival at all sites but the lowest reproductive activity and growth***. Oysters from ***Oyster Bay demonstrated the greatest proportion of brooding females*** at a majority of sites with moderate growth and survival.

FIDALGO BAY - NORTH

DABOB BAY - HOOD CANAL

OYSTER BAY - SOUTH

Evidence of *Ostrea lurida* Carpenter, 1864, population structure in Puget Sound, WA, USA

Jake E. Heare, Brady Blake, Jonathan P. Davis, Brent Vadopalas, Steven B. Roberts

First published: 21 October 2017 | https://doi.org/10.1111/maec.12458 | Citations: 8

Differential Stress Response

Lab Stress trials - gene expression

Expression of genes associated with growth, immune function, and gene regulatory activity in oysters from Oyster Bay, Dabob Bay, and Fidalgo Bay were characterized following temperature and mechanical stress. We found that heat stress and mechanical stress significantly changed expression in molecular regulatory activity and immune response, respectively. We also found that oysters from ***Oyster Bay had the most dramatic response to stress at the gene expression level***.

‹ PeerJ

Differential response to stress in *Ostrea lurida* as measured by gene expression

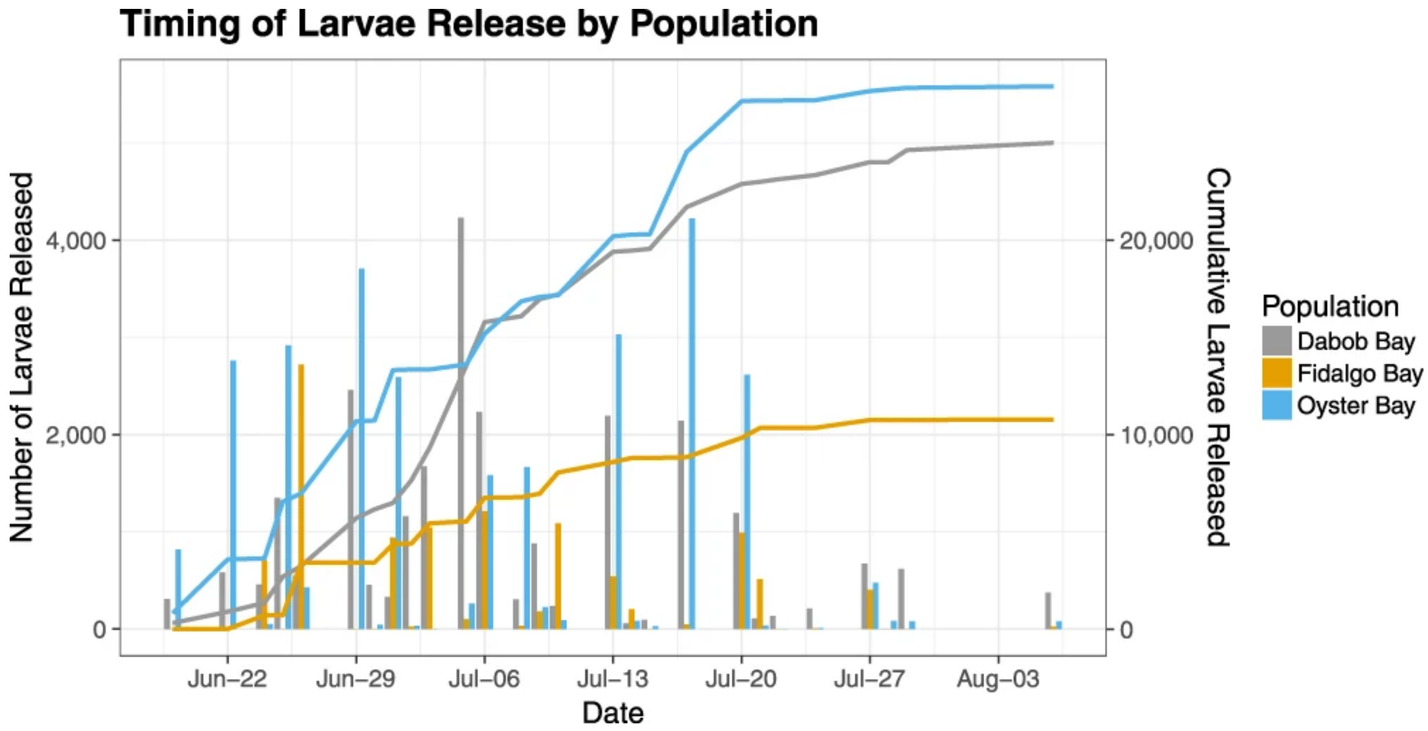
Research article | Aquaculture, Fisheries and Fish Science | Genetics

J. Emerson Heare, Samuel J. White, Brent Vadopalas, Steven B. Roberts

Fitness Traits

Multiple Generations

Using oysters raised under common conditions for up to two generations, we tested for evidence of divergence in reproduction, larval growth, and juvenile growth among three populations in Puget Sound, Washington. We found that the ***population with the fastest growth rate also exhibited delayed and reduced reproductive activity***, indicating a potential adaptive trade-off. *Variation in growth rate and differences in reproductive timing are consistent and have a strongly heritable component that cannot be entirely attributed to plasticity*.



Article | Open access | Published: 17 April 2018

Consistent differences in fitness traits across multiple generations of Olympia oysters

Katherine E. Silliman, Tynan K. Bowyer & Steven B. Roberts

Scientific Reports **8**, Article number: 6080 (2018) | Cite this article

Fitness Traits

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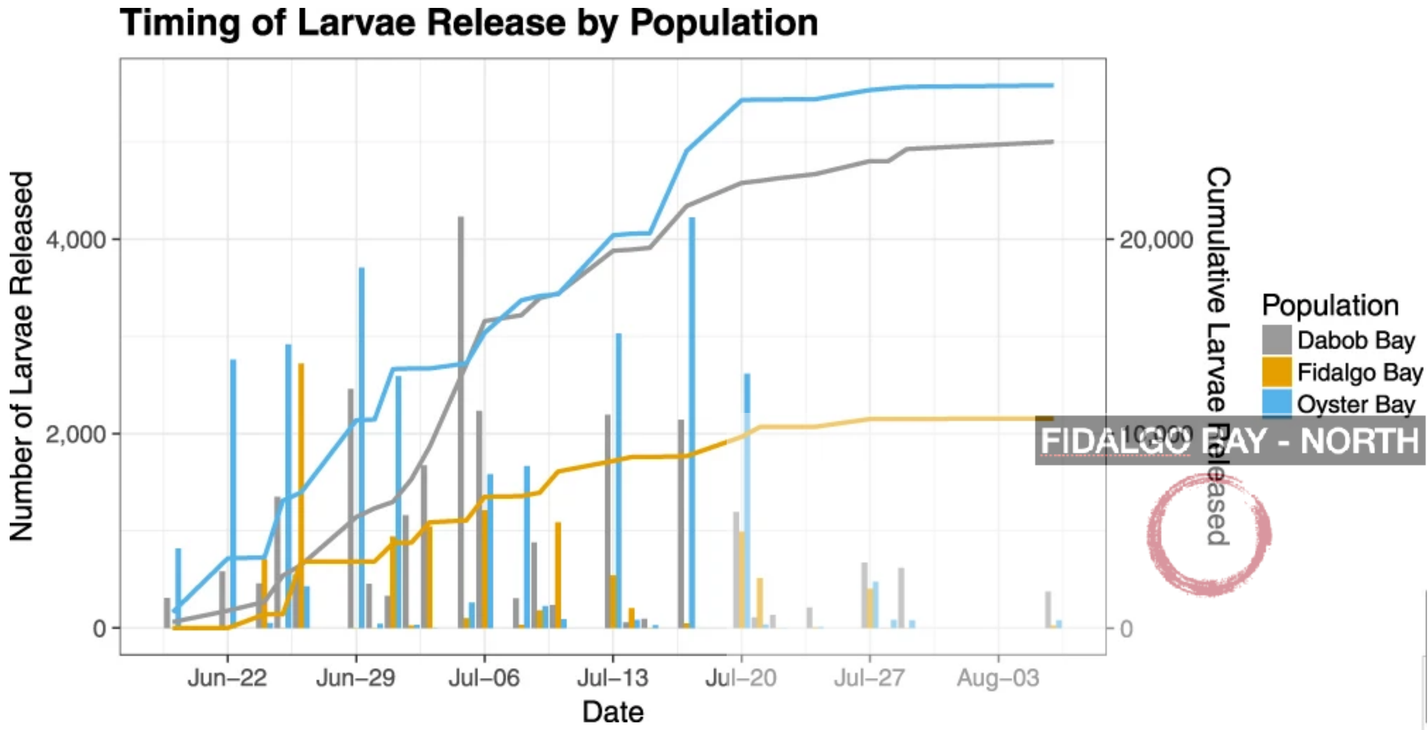


FIDALGO BAY - NORTH

DABOB BAY - HOOD CANAL

OYSTER BAY - SOUTH

Carry-over effects

A detailed look…

Carry-over effects

A detailed look…

Environmental Memory

Carry-over effects

A detailed look…

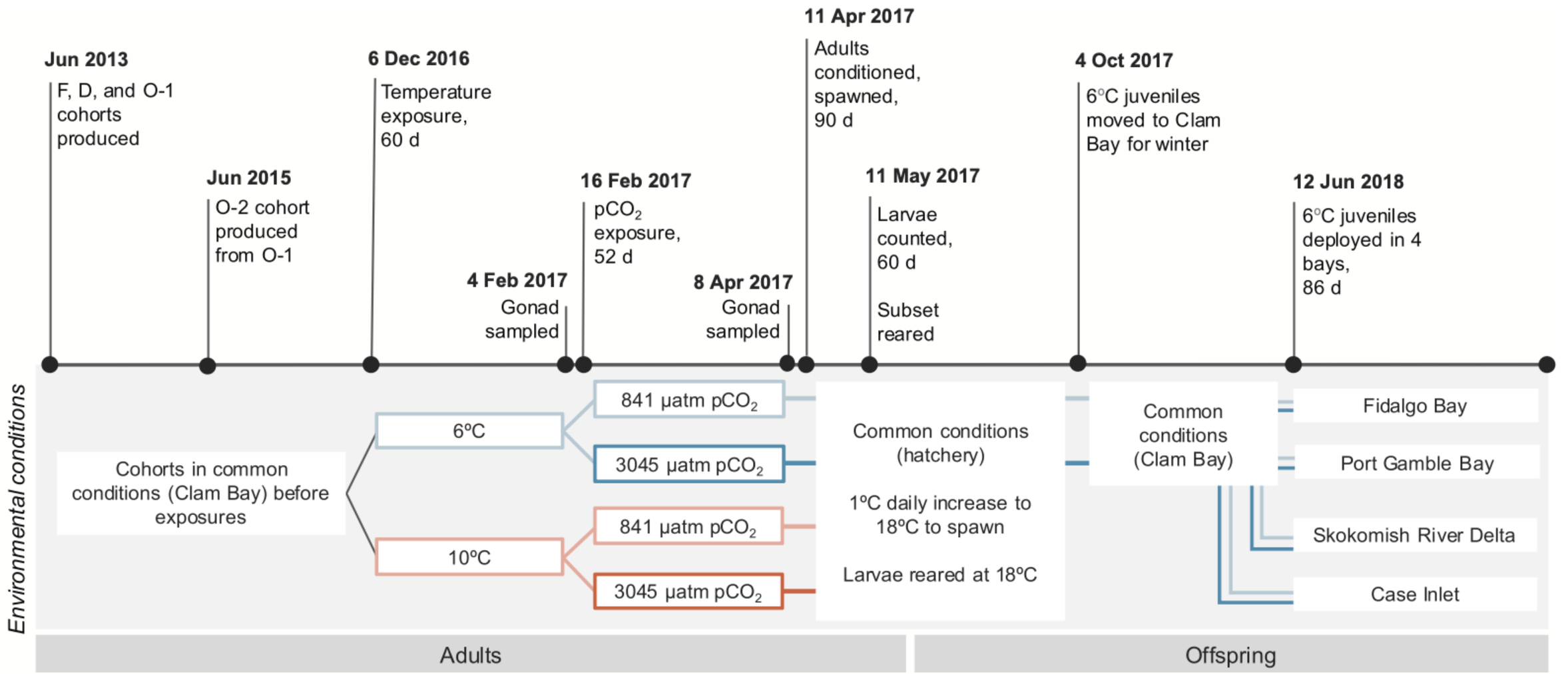
EFFECTS OF TEMPERATURE AND OA IN OLYMPIA OYSTER POPULATIONS

- Oysters were held at **two temperature regimes** (6°C and 10°C) for 60 days in December
- 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.

Carryover effects of temperature and pCO_2 across multiple Olympia oyster populations

Laura H. Spencer,[1] Yaamini R. Venkataraman,[1] Ryan Crim,[2] Stuart Ryan,[2] Micah J. Horwith,[3] and Steven B. Roberts[1,4]

TEXT

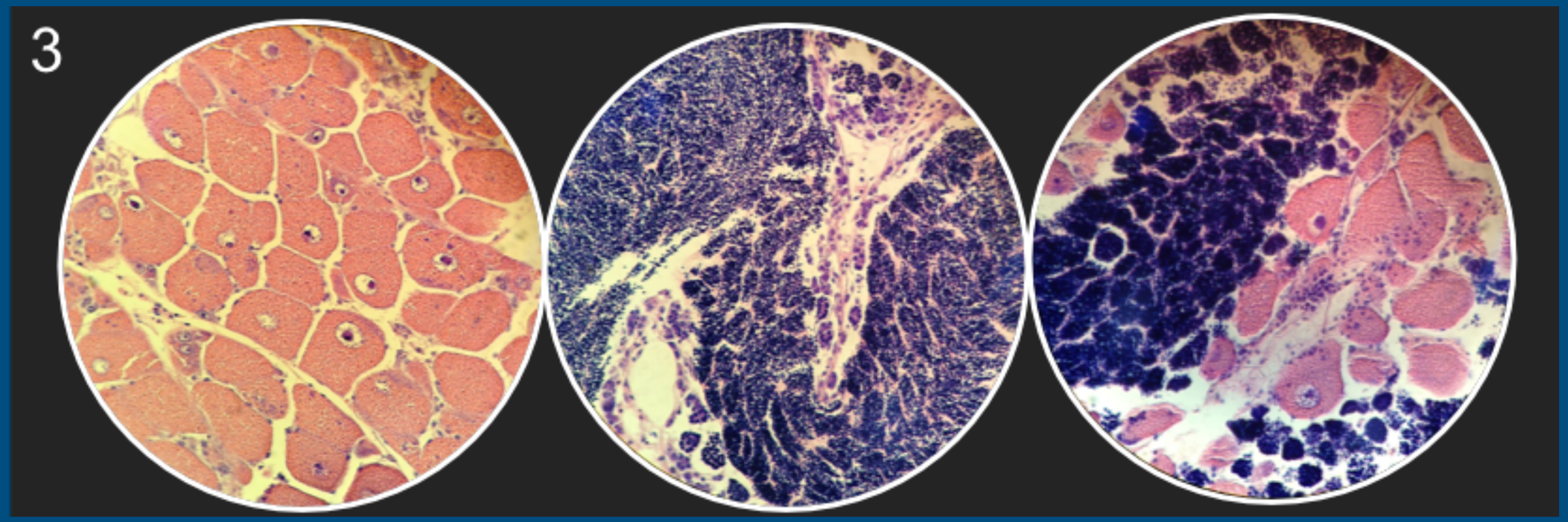

Jun 2013
F, D, and O-1 cohorts produced
Jun 2015
O-2 cohort produced from O-1
6 Dec 2016
Temperature exposure, 60 d
4 Feb 2017
Gonad sampled
16 Feb 2017
pCO2 exposure, 52 d
8 Apr 2017
Gonad sampled
11 Apr 2017
Adults conditioned, spawned, 90 d
11 May 2017
Larvae counted, 60 d
Subset reared
4 Oct 2017
6°C juveniles moved to Clam Bay for winter
12 Jun 2018
6°C juveniles deployed in 4 bays, 86 d
Environmental conditions
Cohorts in common conditions (Clam Bay) before exposures
6°C
10°C
841 µatm pCO2
3045 µatm pCO2
841 µatm pCO2
3045 µatm pCO2
Common conditions (hatchery)
1°C daily increase to 18°C to spawn
Larvae reared at 18°C
Common conditions (Clam Bay)
Fidalgo Bay
Port Gamble Bay
Skokomish River Delta
Case Inlet
Adults
Offspring

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.



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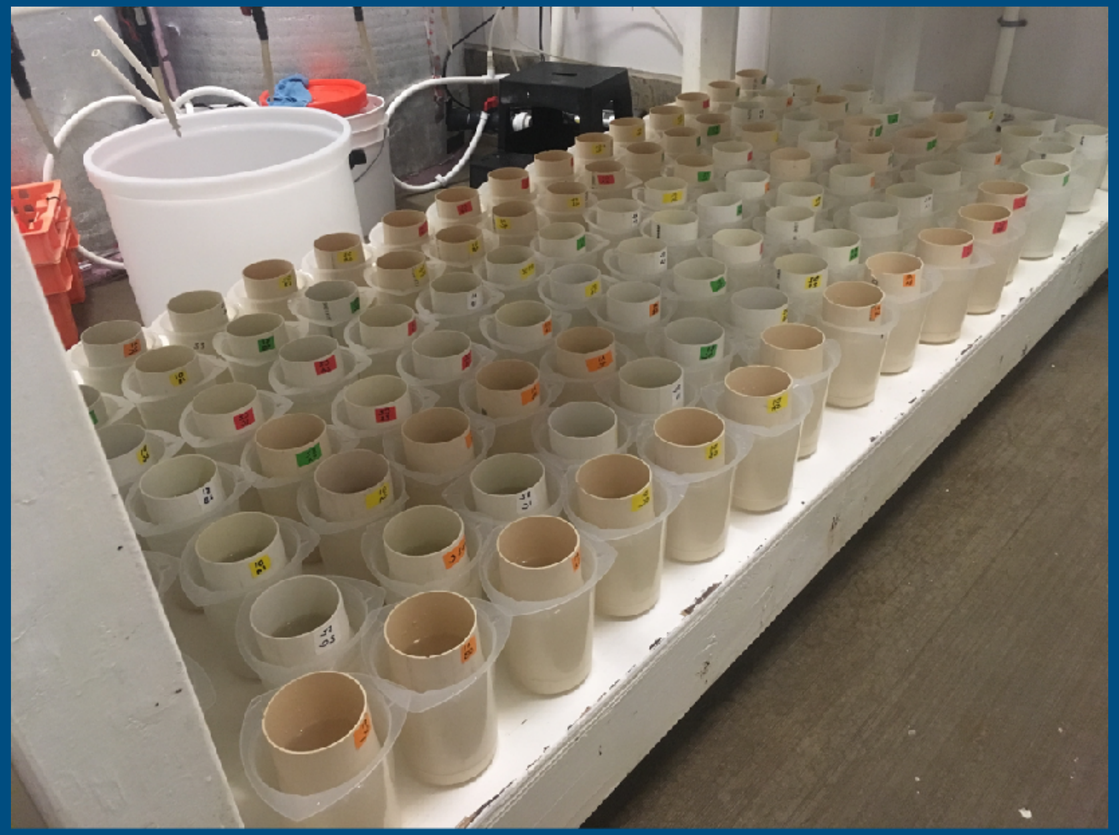

- Larval release occurred earlier in warm-exposed oysters
- Winter warming conditions increased larval production
- No effects on larval survival were detected
- **Juveniles of parents exposed to elevated pCO_2 had higher survival rates in the natural environment**

EFFECTS OF OA IN OLYMPIA OYSTER POPULATIONS

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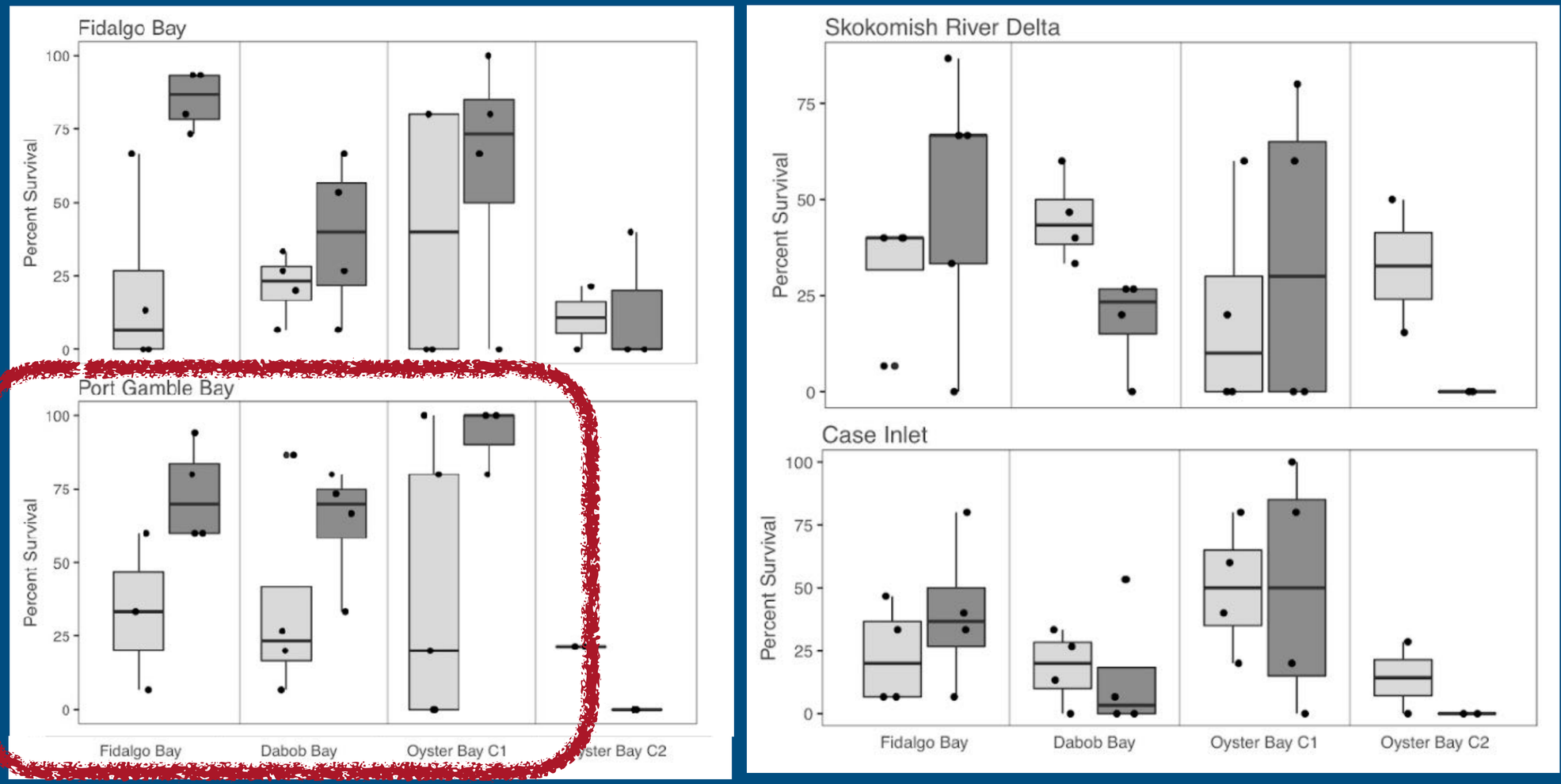
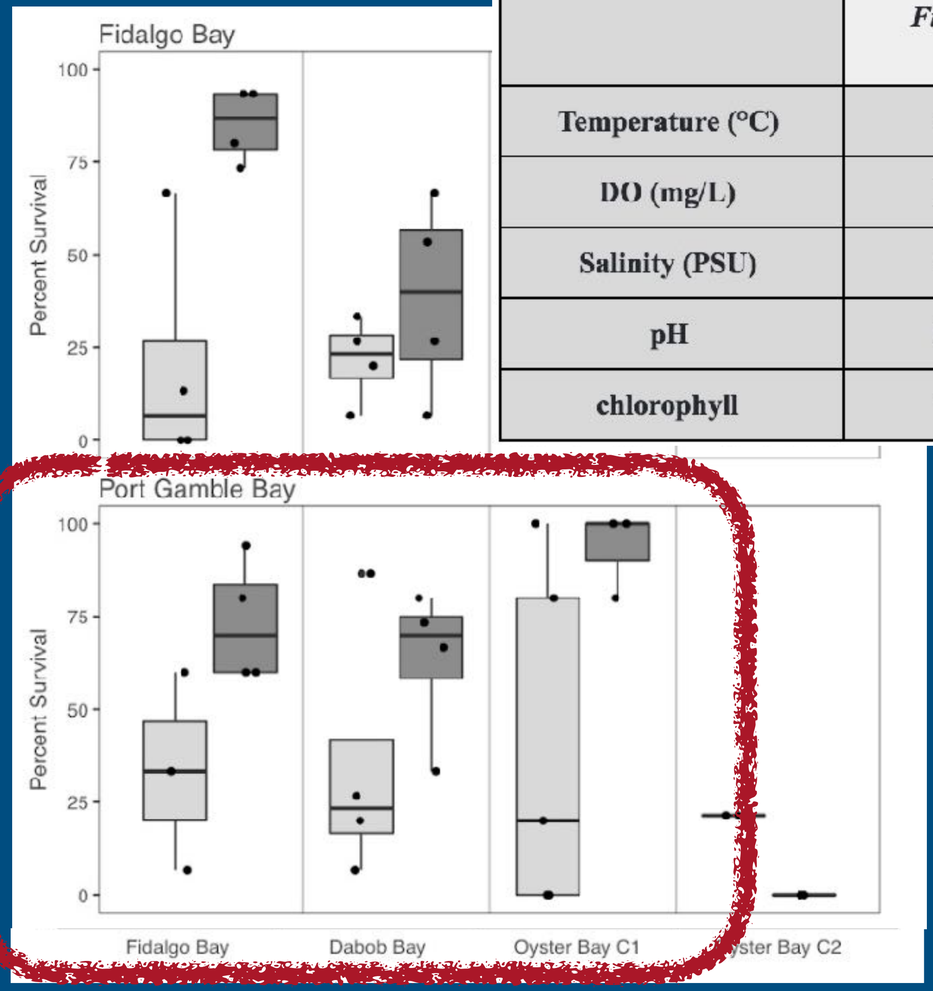


EFFECTS OF OA IN OLYMPIA OYSTER POPULATIONS

Parental pCO_2 Ambient High



	Fidalgo Bay	*Port Gamble Bay*	*Skokomish River Delta*	*Case Inlet*
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**

EFFECTS OF OA IN OLYMPIA OYSTER POPULATIONS

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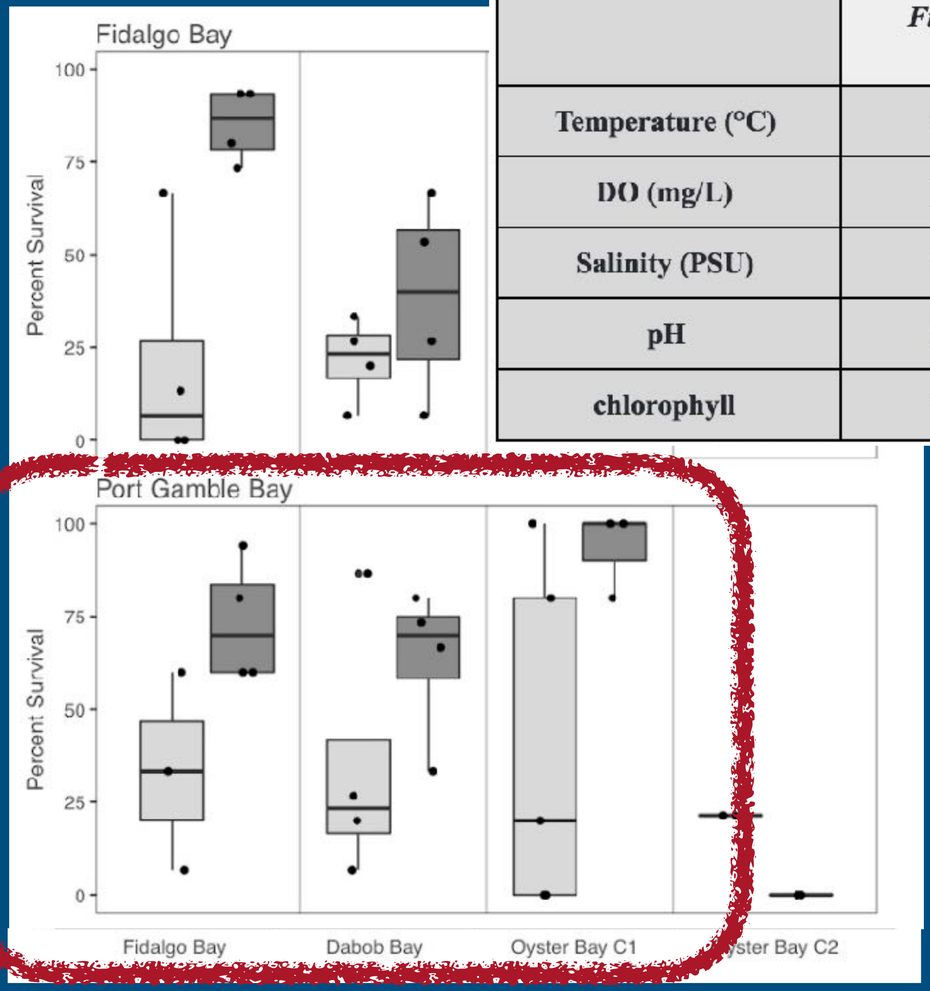

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- ENVIRONMENTAL MEMORY?

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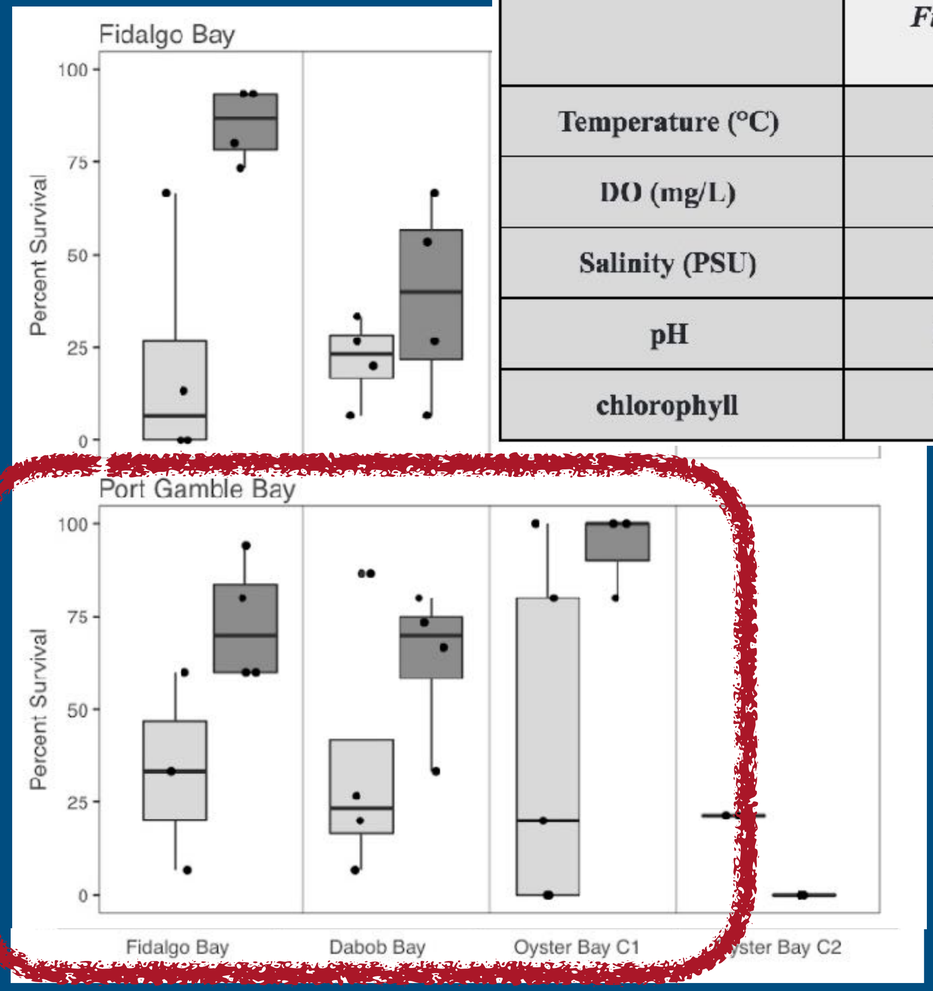

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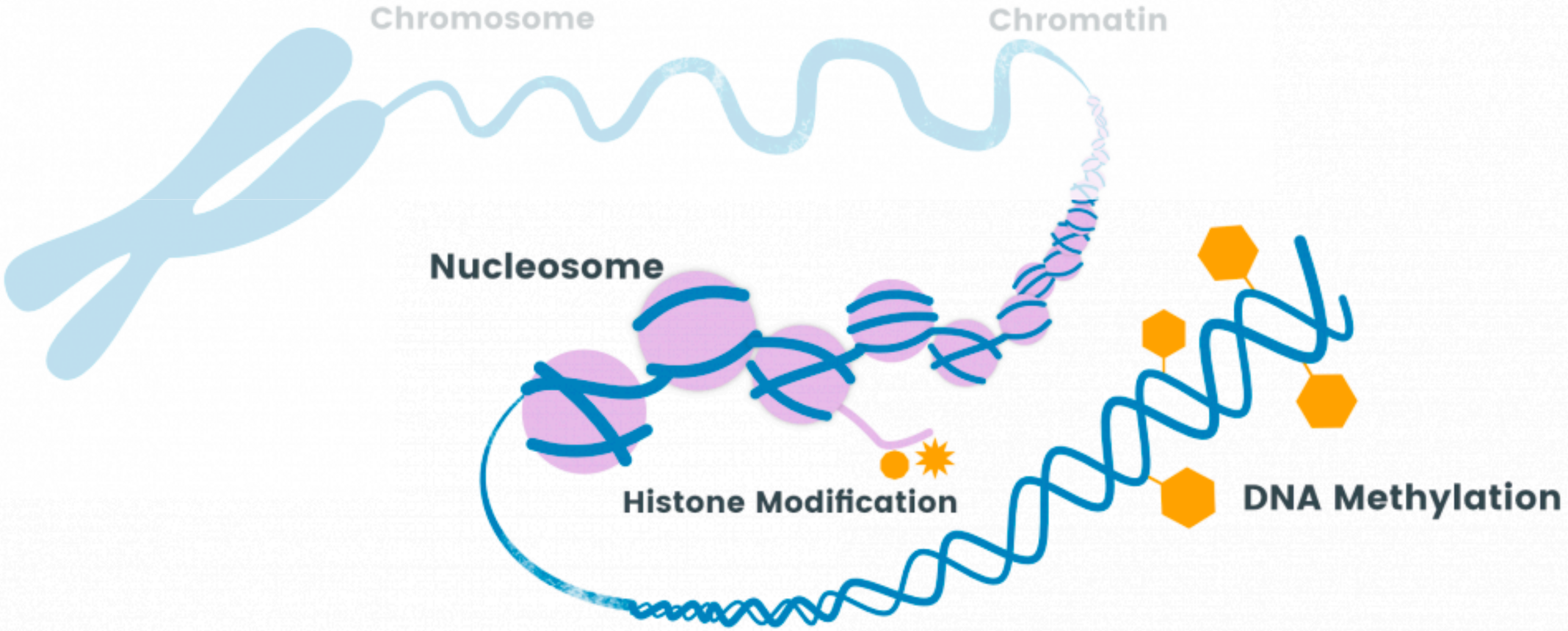
- ENVIRONMENTAL MEMORY?
- GENETICS?

Epigenetics

ALTERS THE PHENOTYPE (WITHOUT CHANGING DNA CODE); HERITABLE



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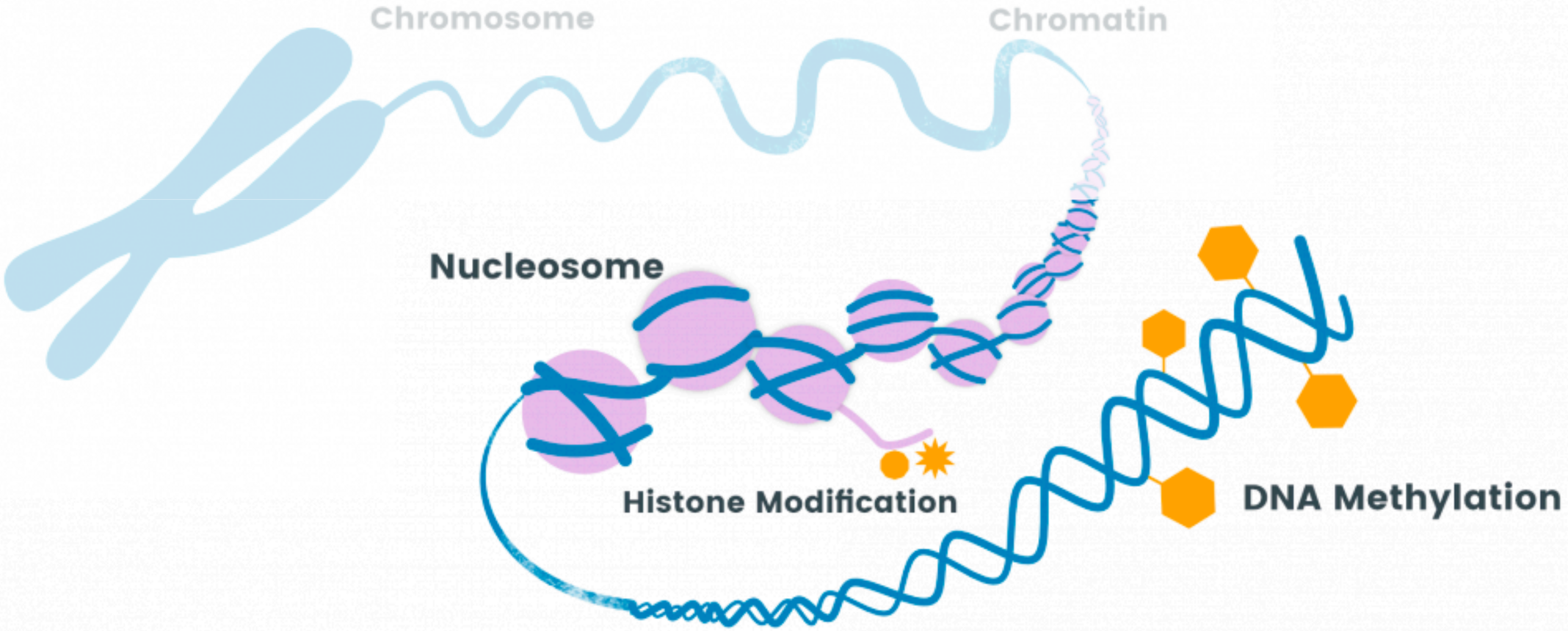
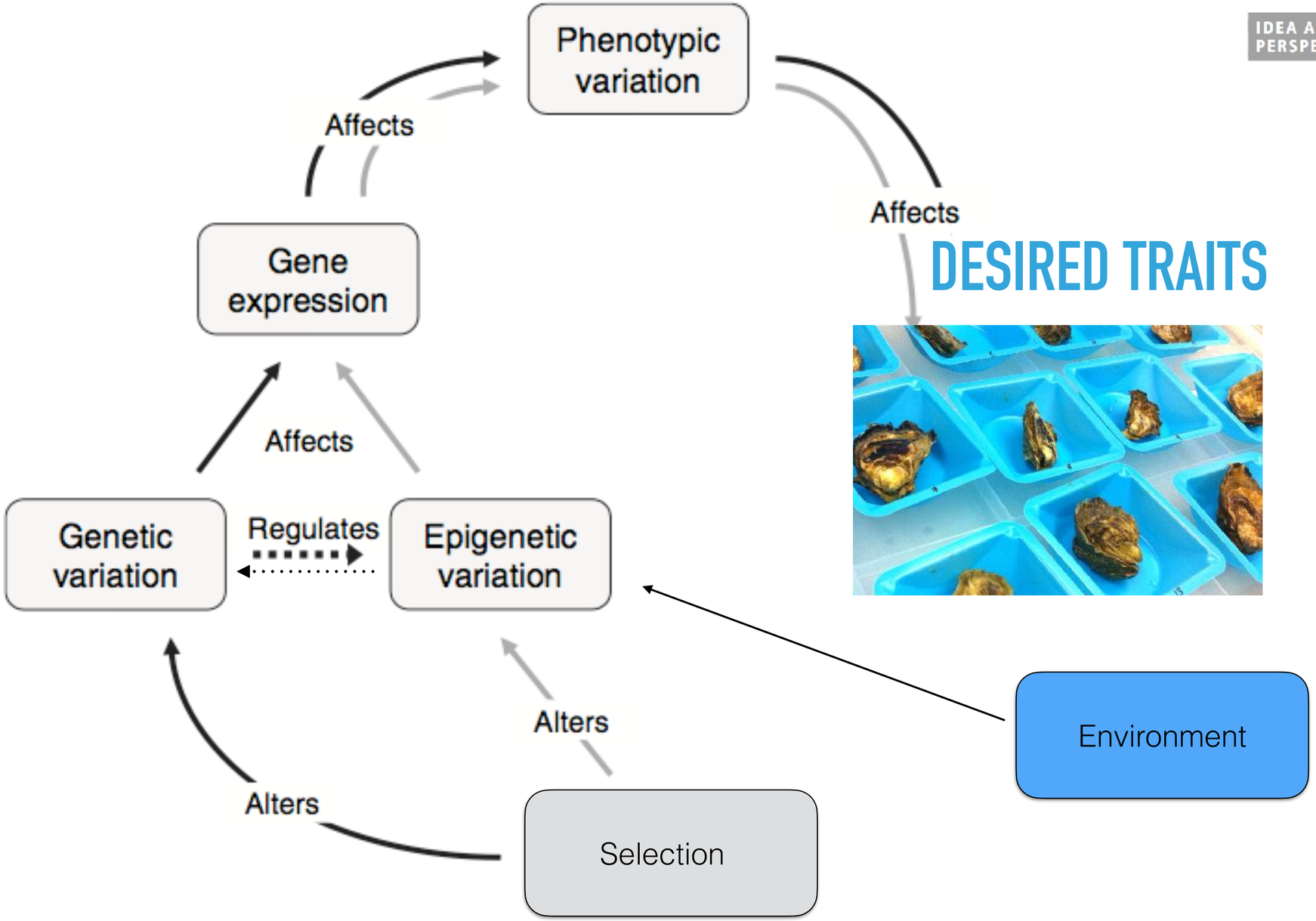


CAN BE INDUCED WITH ENVIRONMENTAL MANIPULATION

ECOLOGICAL EPIGENETICS



Ecology Letters, (2008) **11**: 106–115 doi: 10.1111/j.1461-0248.2007.01130.x

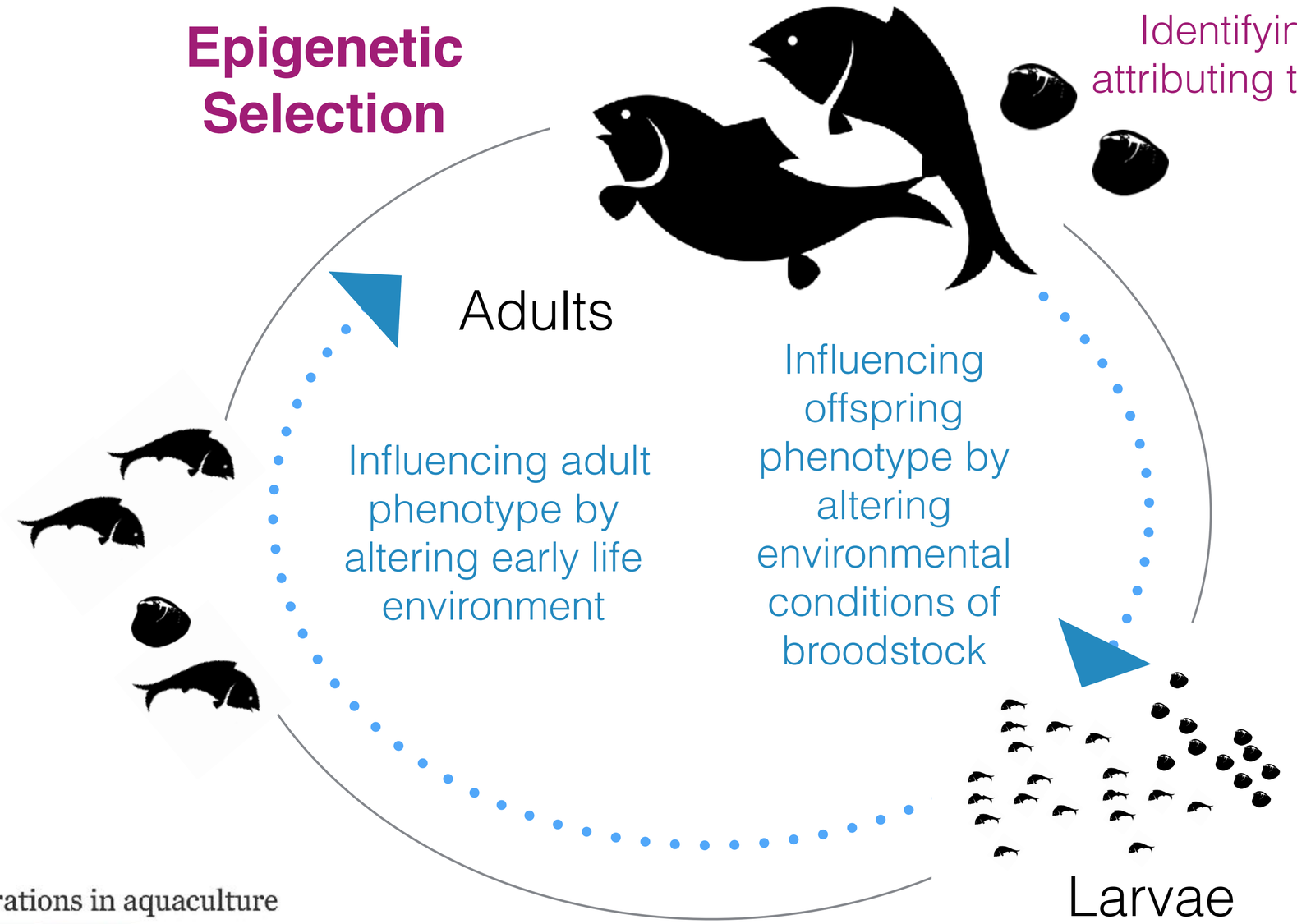
IDEA AND PERSPECTIVE

Epigenetics for ecologists

DESIRED TRAITS

Epigenetic Selection

Identifying individuals by attributing trait to epigenotype



Environmental Manipulation

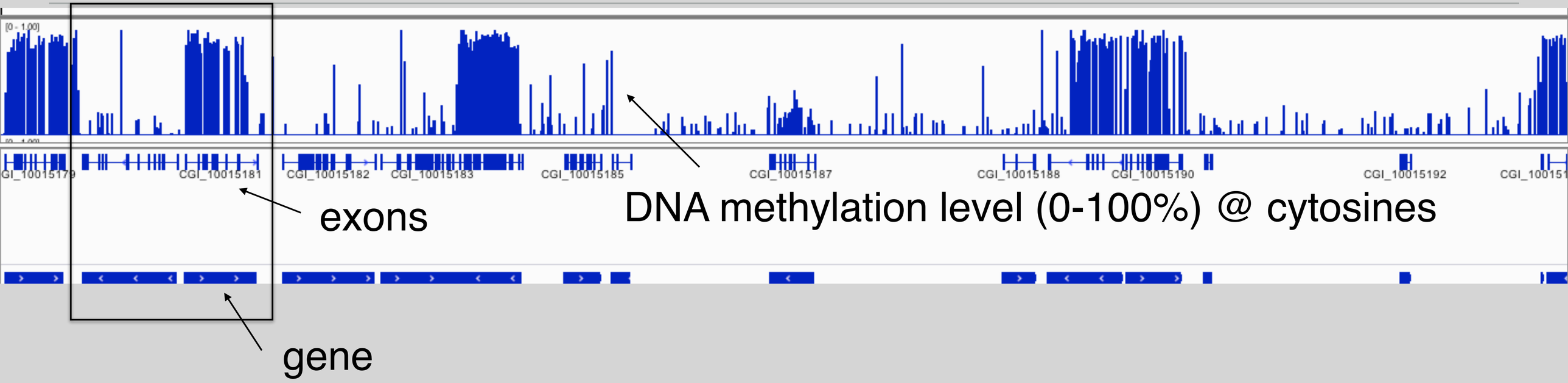
PEER-REVIEWED Aquatic Biology section >

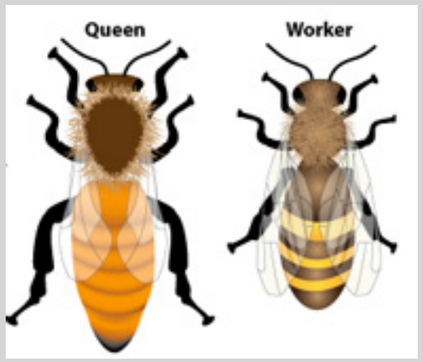
Epigenetic considerations in aquaculture

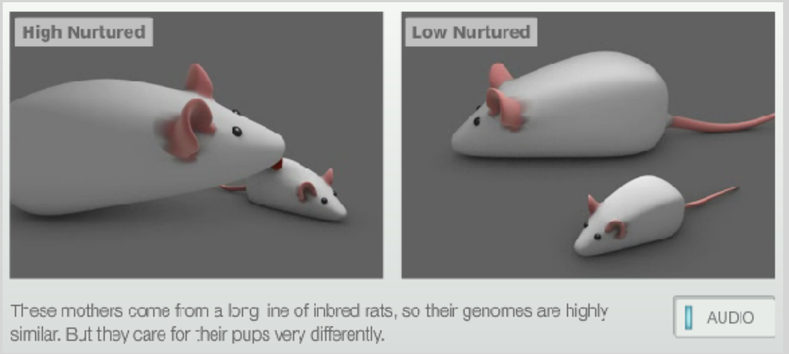
Literature review | Aquaculture, Fisheries and Fish Science | Molecular Biology

Mackenzie R. Gavery, Steven B. Roberts

METHYLATION LANDSCAPE IN MARINE INVERTEBRATES







EXCITING?
COMPLEX
‘LAYER’ OF RESILIENCE

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Genetic Linkage

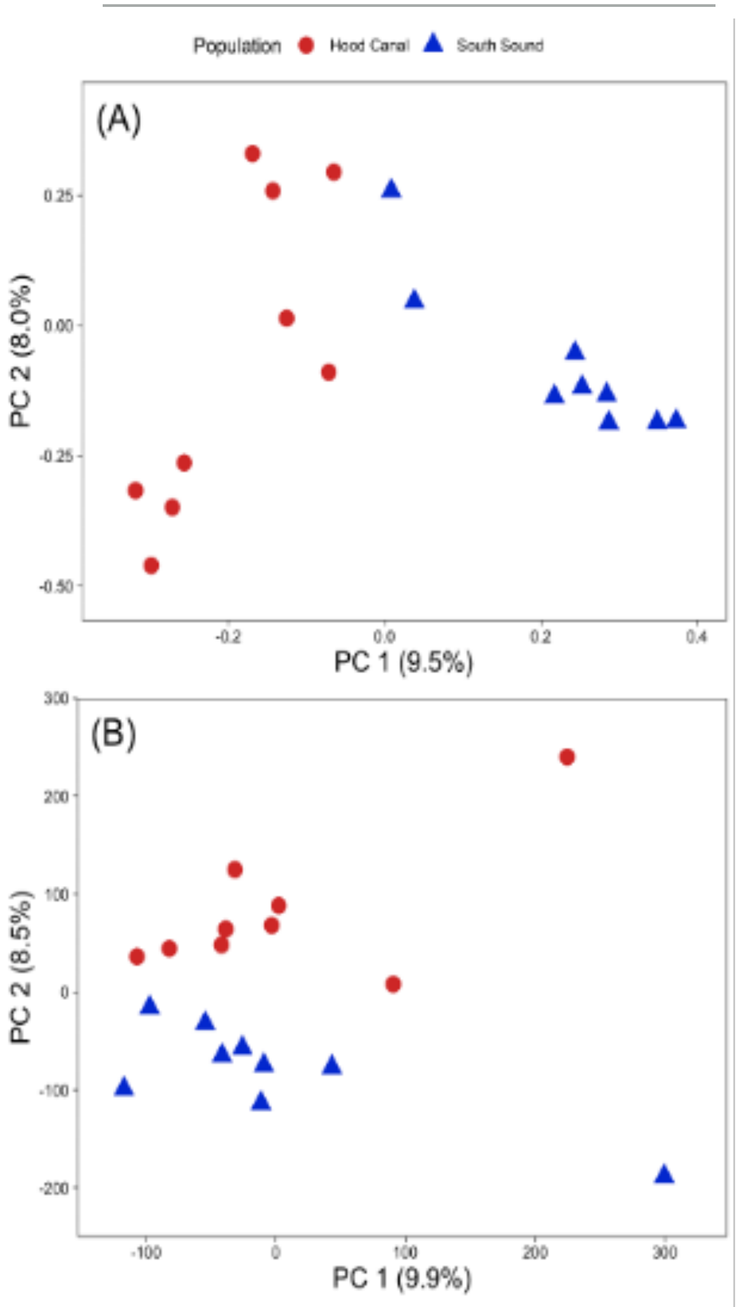
Epigenetic and Genetic Population Structure is Coupled in a Marine Invertebrate

Katherine Silliman [1,†], Laura H. Spencer [2,†], Samuel J. White[2], and Steven B. Roberts [2,*]

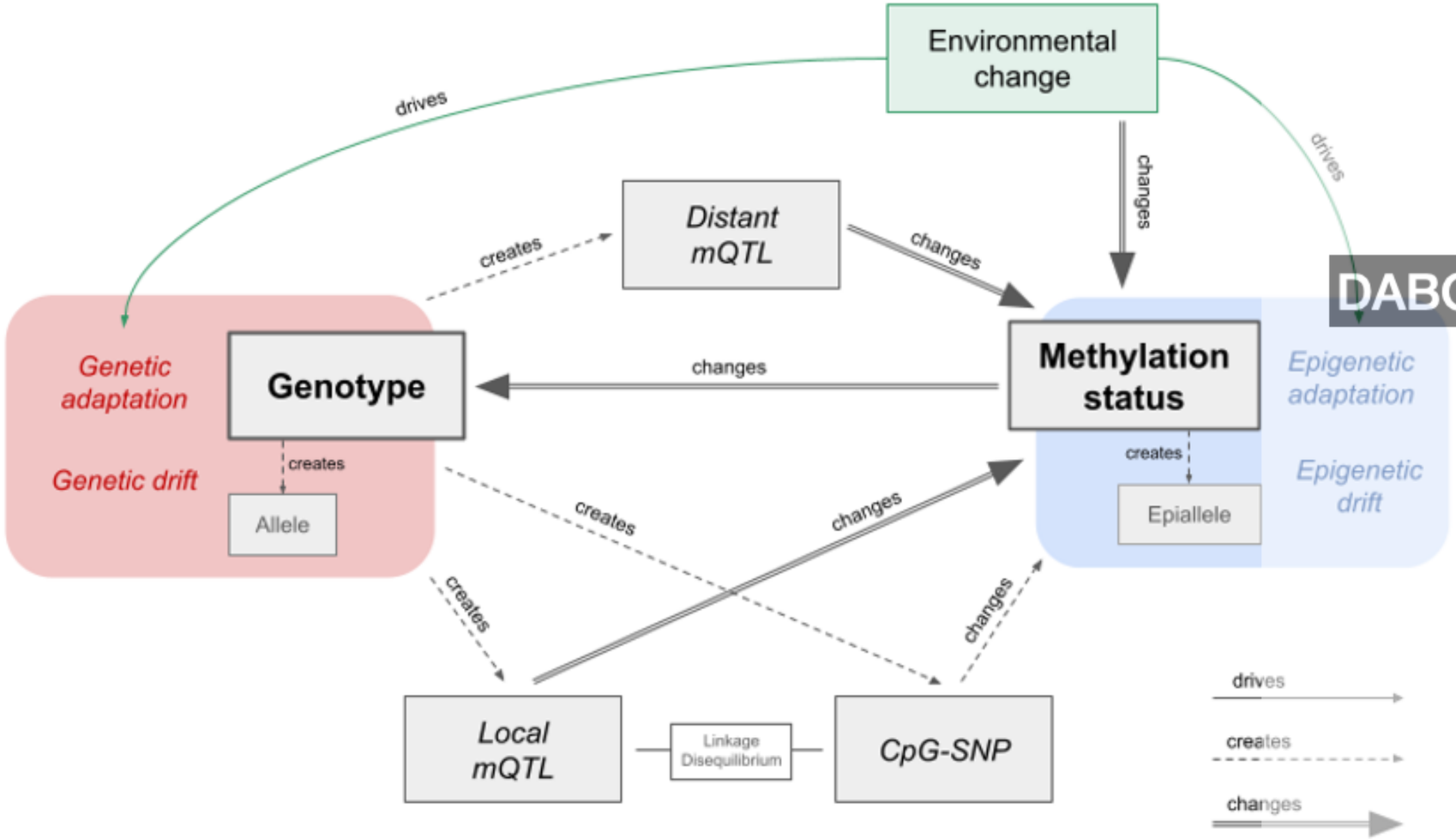
First characterization of genome-wide DNA methylation patterns in the oyster genus *Ostrea*

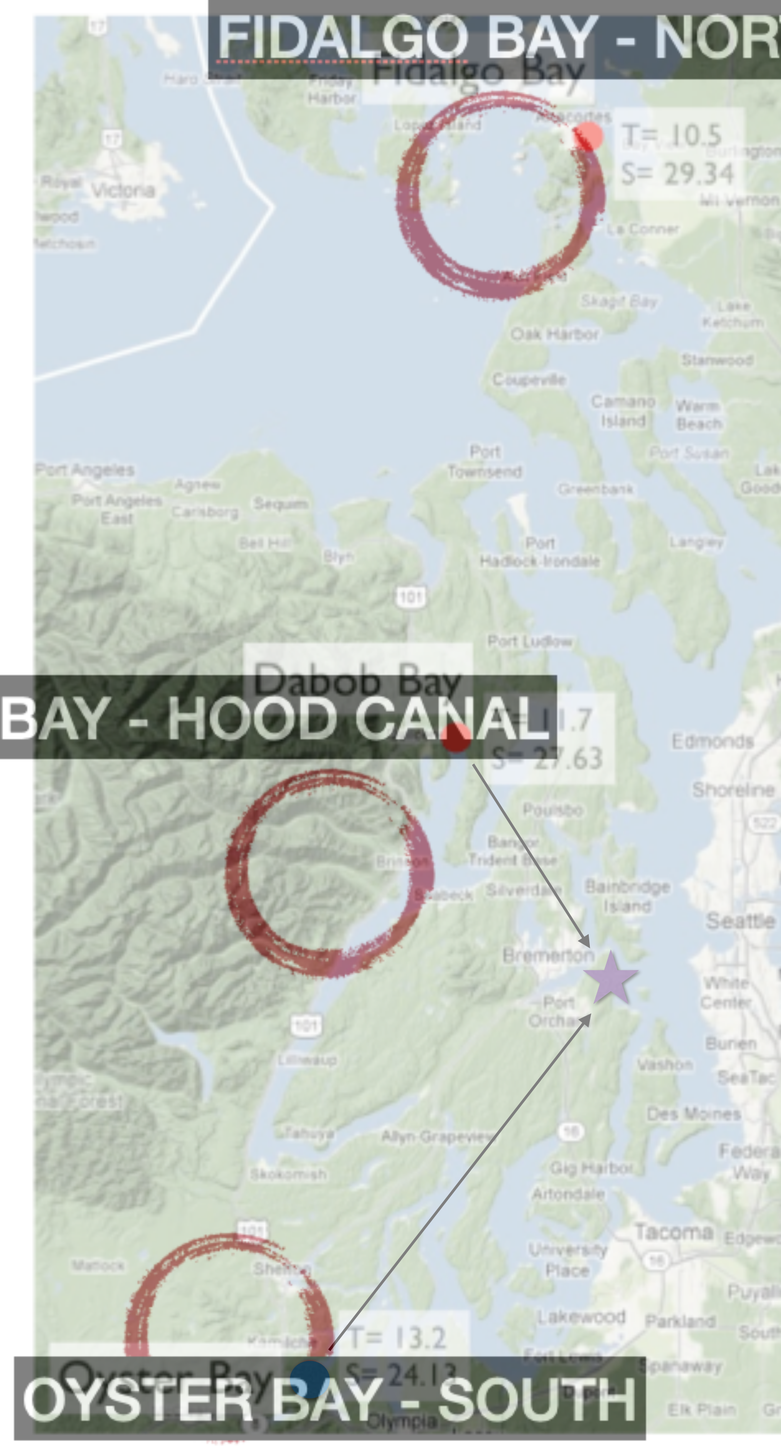
Identified 3,963 differentially methylated loci between populations. Clear coupling between genetic and epigenetic patterns of variation, **with 27% of variation in inter-individual methylation differences explained by genotype**.

Underlying this association are both direct genetic changes in CpGs (CpG-SNPs) and genetic variation with indirect influence on methylation (mQTLs).



EPIGENETIC AND GENETIC POPULATION STRUCTURE





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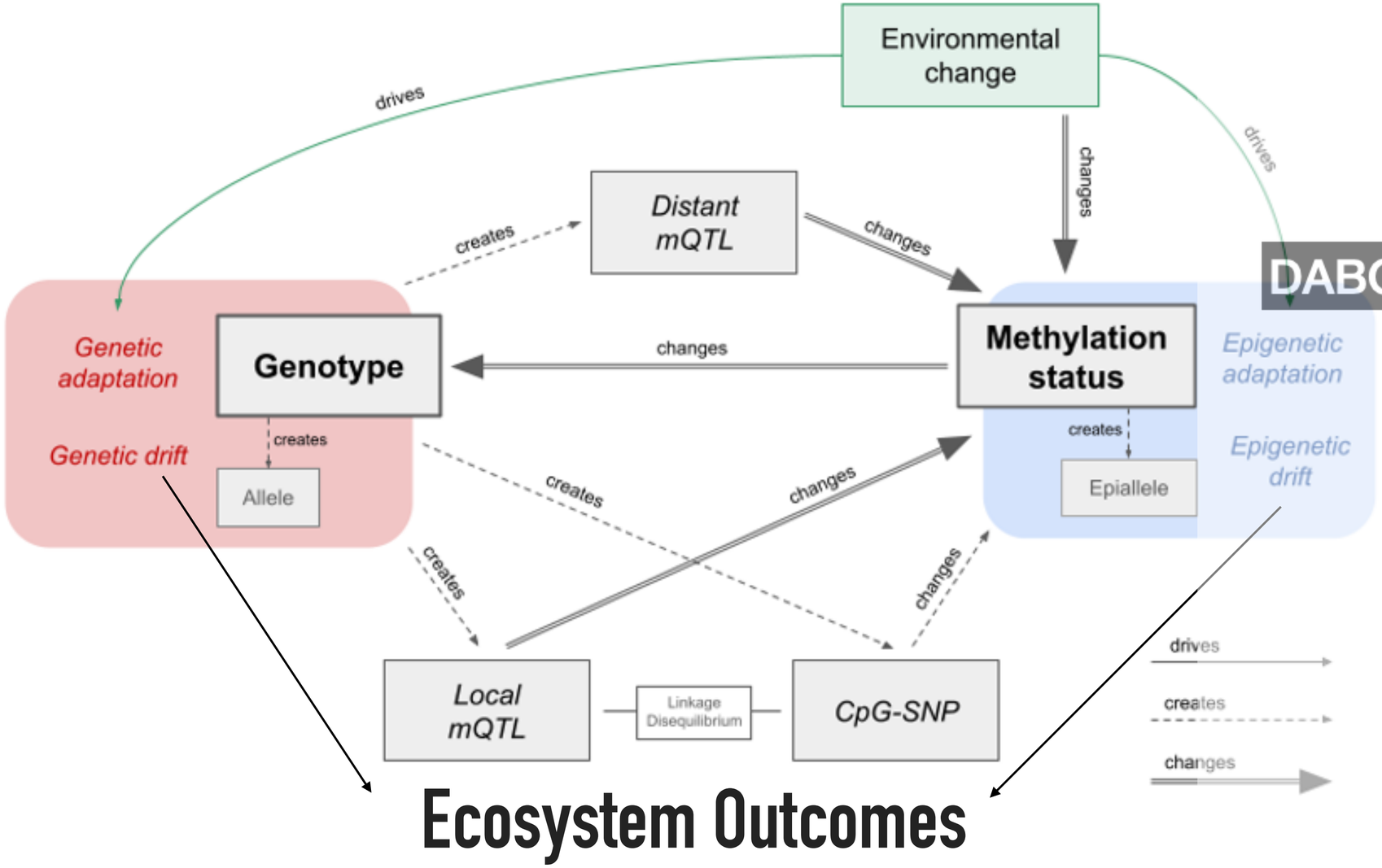

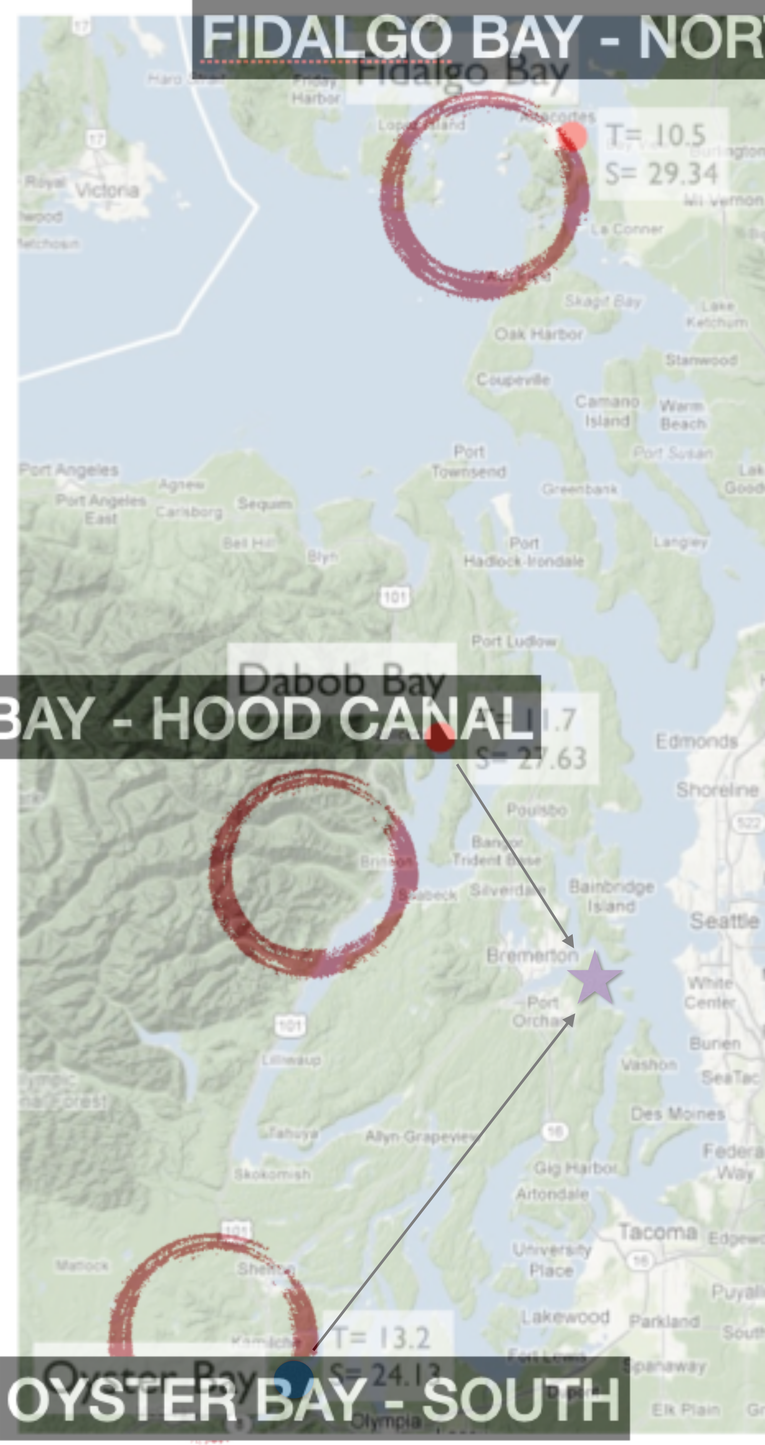

Summary

Considerations for Future Restoration Efforts

- **Oyster aquaculture is a valuable resource for both food commodity production and ecosystem restoration.**
- Local populations can have distinct characteristics that are important for restoration management and broodstock selection.
  - Climate change can have unique impacts on different populations.
- Oyster resiliency is attributable to epigenetics and environmental memory.
- For successful, sustainable production there needs to be a fundamental understanding of population characteristics.

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ACKNOWLEDGEMENTS

- Mackenzie Gavery (NOAA), Sam White (UW), Brent Vadopalas (UW), Shelly Wanamaker (GMGI), Sam Gurr (NOAA), Hollie Putnam (URI), Laura Spencer (UW), Katherine Silliman (NOAA), Yaamini Venkataraman (WHOI), Katie Lotterhos (NEU)

GITHUB.COM/SR320/TALK-DUKE-2024