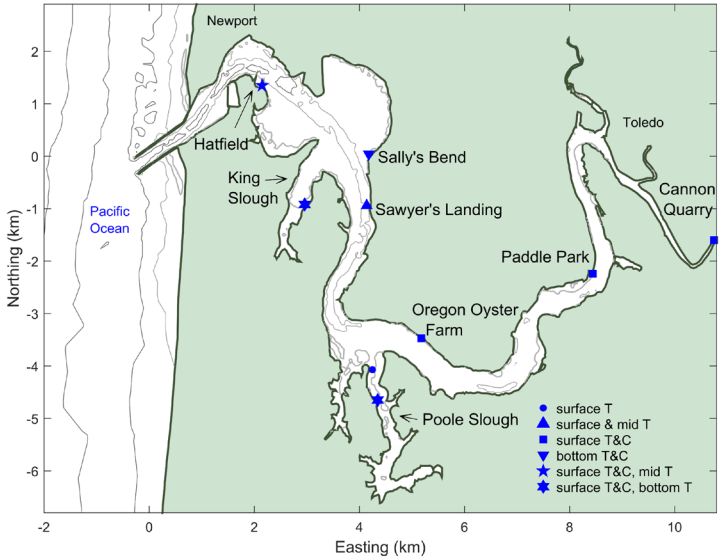
Oregon State University OSU College of Earth, Ocean, and Atmospheric Sciences

Olympia Oyster Growth and Survival with Climate Change: Space for Time Field Experiments

PI: George Waldbusser
Project Team (students): Margaret Conley, Rachel Dumas, Alaina Houser, Antonio Ortiz Laboy, Nathaniel Lapic, Drew Moreland, Marlena Penn.

Project Objectives

1. Measure Olympia Oyster shell and tissue growth throughout Yaquina Bay
2. Monitoring of continuous and discrete environmental variables that could affect growth (temp, salinity, food, CO2 chemistry)
3. Synthesize environmental data to characterize locational ‘climatology’
4. Statistical growth model to determine effects of measured parameters



Project Status Outcomes

While the funding has concluded, I am still working on a reduced set of monitoring at three sites and continuing to compile and analyze environmental data and oyster data.

Student Support/Outcomes (3 graduate students, 4 undergraduates):

Partially support for one Ph.D. (2025)
Supported one M.S. (2023)
One Honor's College Thesis (2025)
One NSF-REU student (2022)
Currently supporting work for online M.S. student in Geography (thermal risk models)
Currently supporting work for two Honor's College Students
Independent Projects (experiential learning credits) for three undergraduates

Peer Reviewed Papers:

Conley, M. M., Lerczak, J. A., Waldbusser, G. G., and Fewings, M. R. (submitted) Temperature Dynamics in a small Pacific Northwest estuary and its sloughs. Estuaries and Coasts.

Houser et al. (in prep) OSU Honor's College Thesis

Waldbusser et al. (in prep) Controls on Olympia and Pacific Oyster growth in a Small Mountainous River estuary

Waldbusser et al. (in prep) Carbon dioxide concentrations in surface waters of Yaquina Bay

Project Status Continued Work Underway

The OOST funding provided resources to continue monitoring conditions through the Yaquina estuary (including previous OSG and unfunded work back to 2018).

1. Continued integration of high frequency monitoring data from the 2018 initiation to current (temperature data complete, salinity data good from 2021 onward, pH complete through 2025
2. Summarizing and comparing local climatologies among sites via MS Geography student
3. Continued data collection T, S, pH (+discrete) at HMSC, Oyster Farm, and Poole Slough though summer 2025, and planned unfunded work through 2026
4. Continued work on oyster growth data (size data problematic from previous analyses of images, HC student developing A.I. Image Classification for re-analyses)
5. Ongoing work on oyster models (discussed interest in Pacific Oyster model with shellfish growers at Marine Science Day).

There are a lot of data and opportunities I am pursuing, utilizing motivated undergraduates largely who want to develop various skills and satisfy degree requirements.

Data Collected to Date

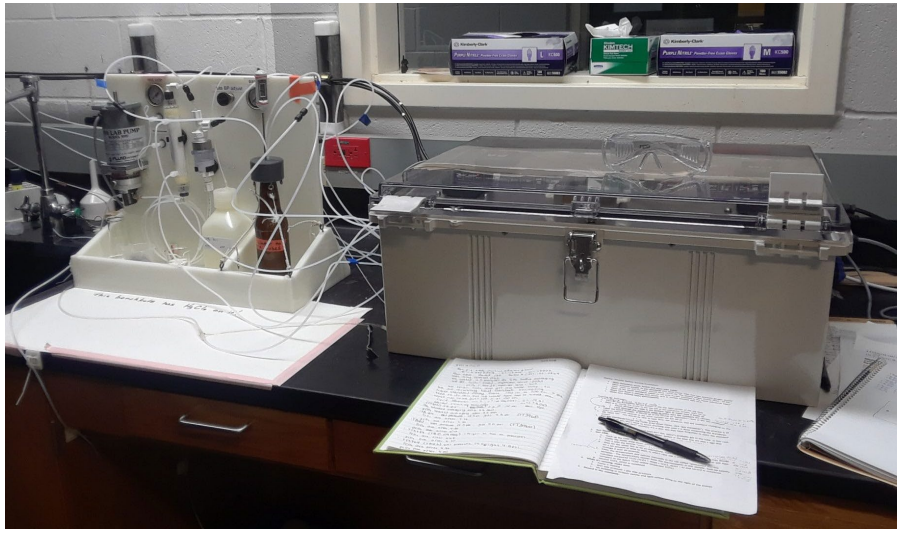
Temp & Salinity Monitoring (2022 onward, back to 2018 at some sites)

Oyster Measurements (July 2022 to Feb 2024)

Discrete samples for CO_2 and Particulates (food quality and quantity)
Over 200 samples each

Surface Surveys (PCO2, T, S)

pH Monitoring
2022 ~6 weeks one site
2023 ~6 months three sites
2024 ~5 months three sites
2025 ~3 months three sites



Data Highlights

Oyster responses to environmental data:

- Growth rate driven by temperature (salinity and pH limited importance)
- There do appear to be some site effects on overall sizes
- We found a possible Mg:Ca thermometer calibration with the Olympia Oyster shells

Time series data:

- Seasonal patterns expected
- Salinity and Temperature generally highly correlated (seasonal variations)
- Data used to build thermal model of Yaquina Estuary (M. Conley)

Surface Survey Data:

- Several expected patterns in estuarine gradient (some preliminary GIS maps from Geography student)
- Some unexpected variations during high discharge events and also extreme low tides

Discrete Data:

- Some differences in food among sites, 4/5 sites very similar
- Alkalinity/Salinity relationship from discrete CO_2 data

Oyster Growth Responses

Environmental Conditions to follow

Oyster ~~Sizes~~ and Weights (Jan 2024)

100 Olympia Oysters per site (per cohort)
Cohort #1 in 2022, Cohort #2 in 2023

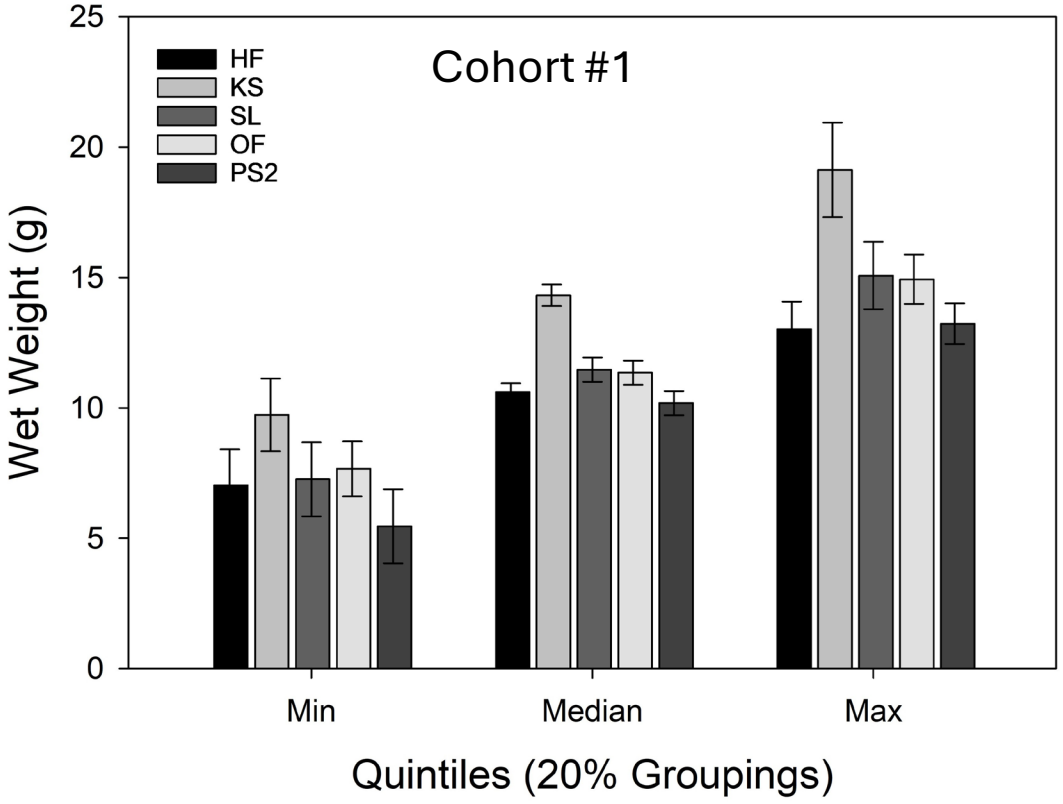
Much of the size data were compromised by poor measurement quality, redoing via 'AI'

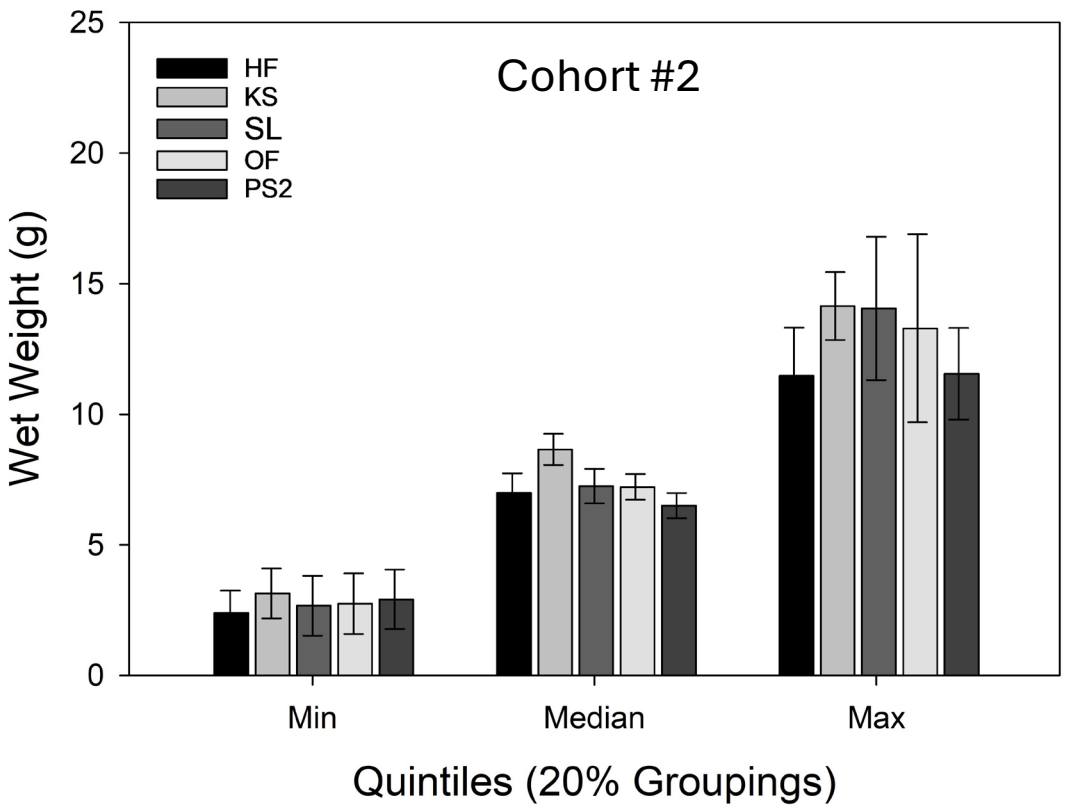
Two challenges in the data:

- Large range in natural variation in sizes
- Not tracking individuals
- Thus Binned by Quintile

For much of the analyses will be using the Median quintile to predict averages

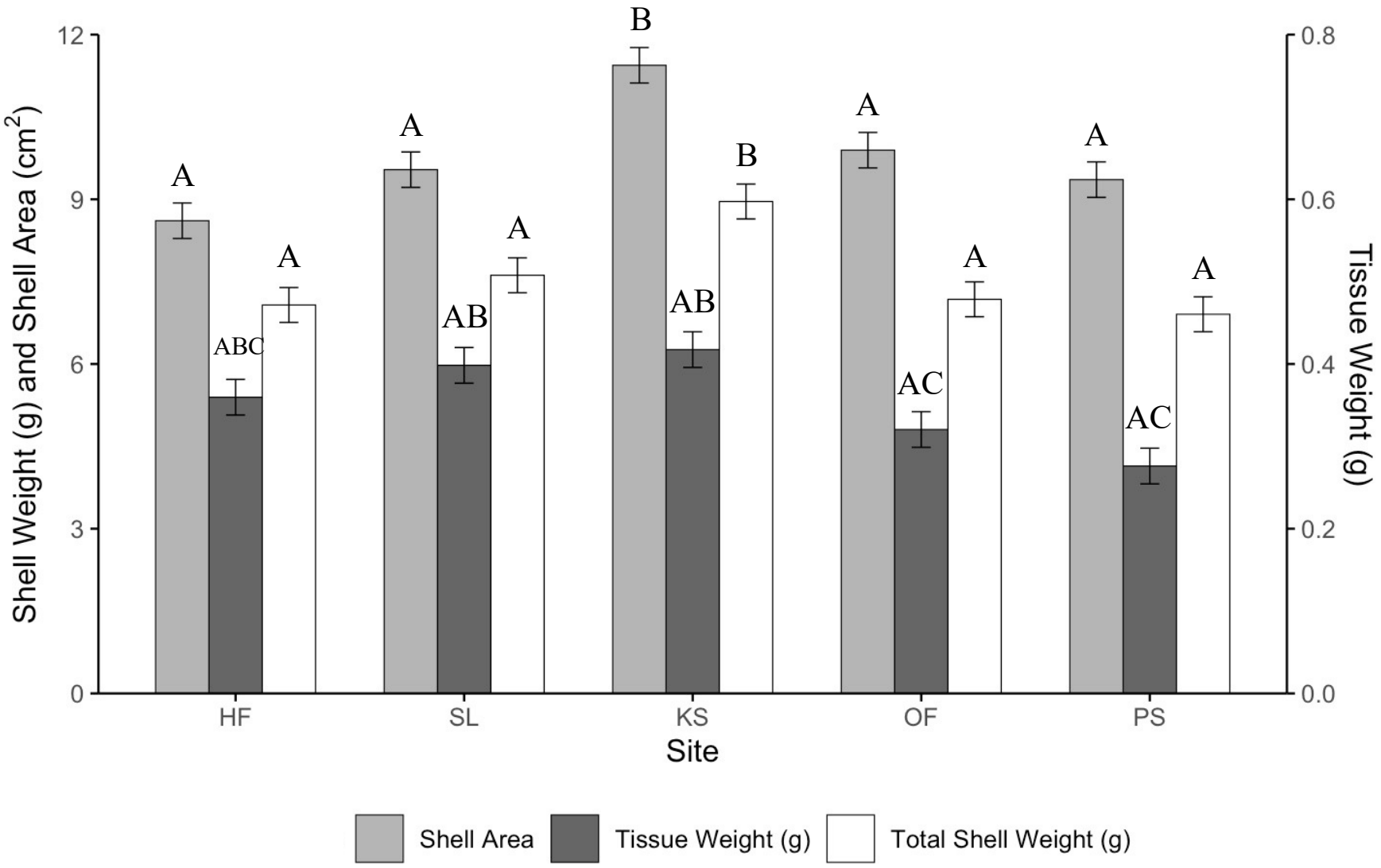
However, there is likely value in looking at the Min or Max quintiles…





Results

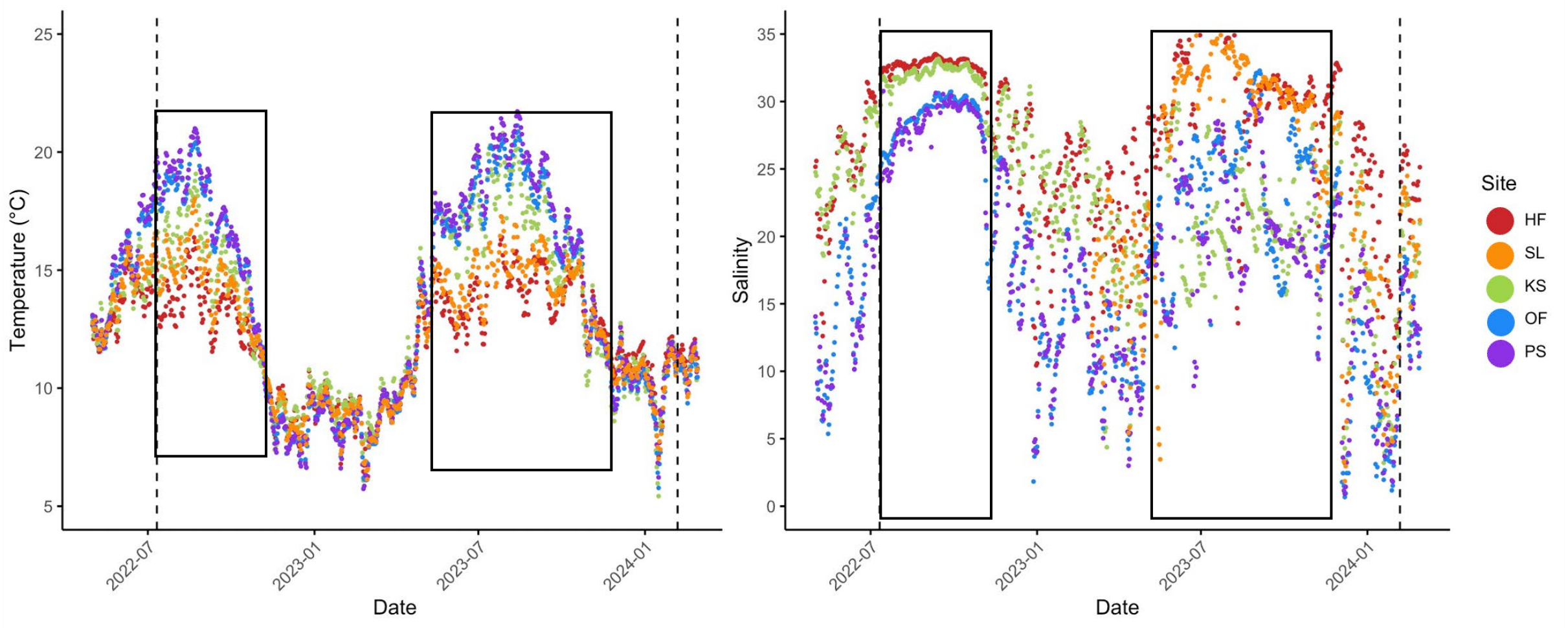
- ANOVA used for statistics
- Significant differences are indicated by different letters
- Significance displayed is only for within the same measurement
- Dry shell weight, dry tissue weight and area were all greatest at KS



Measurements from Cohort #1 in Jan 2024 (shell size good!)
Dry Tissue Weight

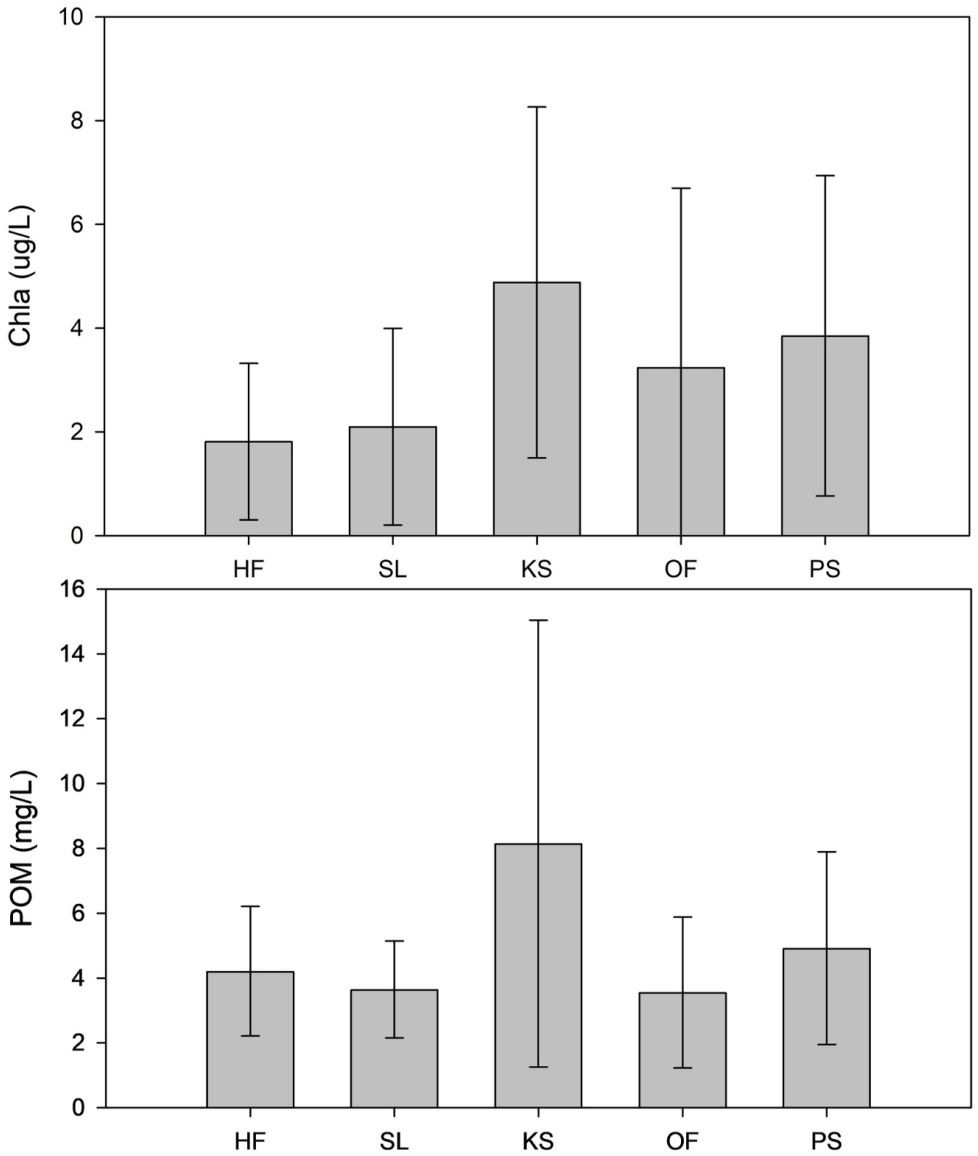
Houser Thesis (2025)

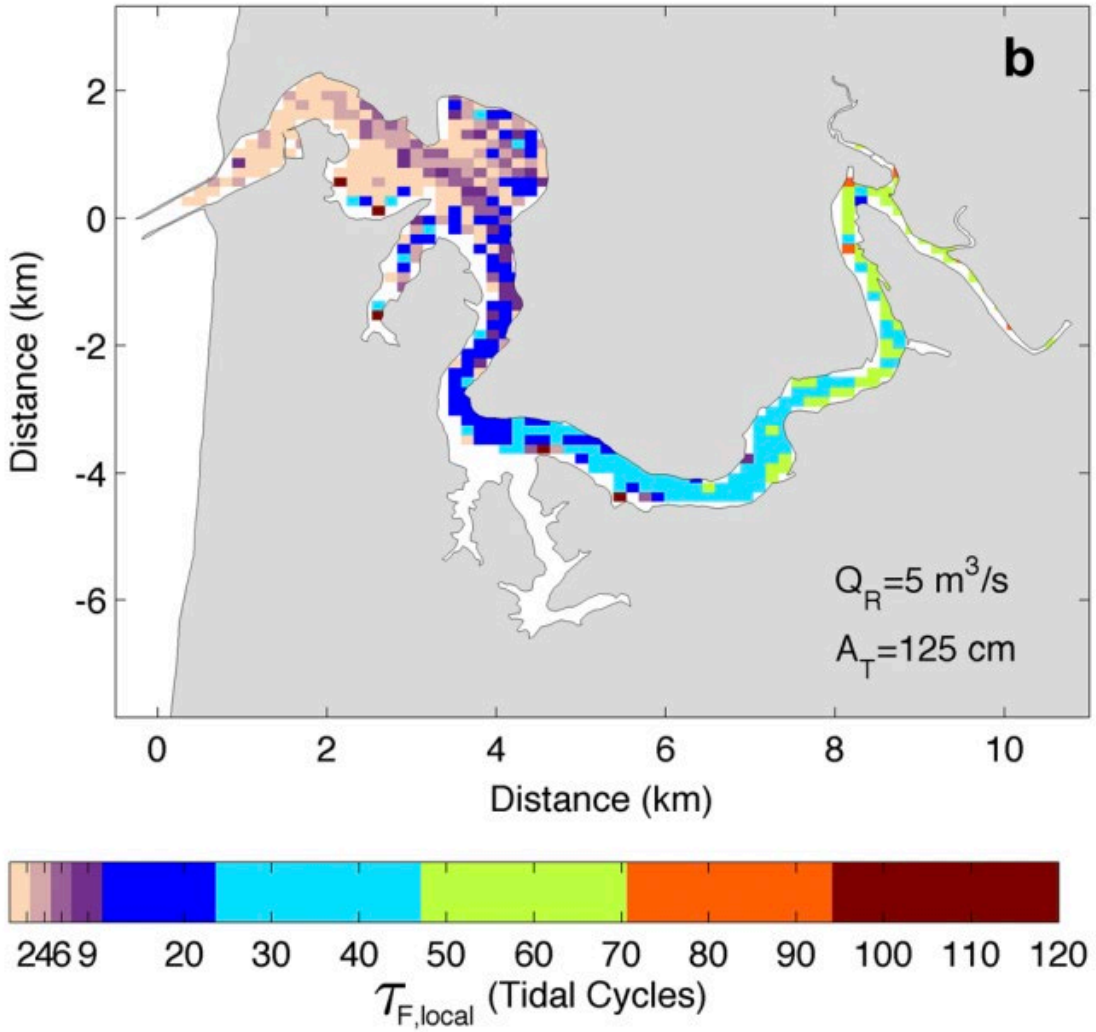
T&S During Oyster Growth



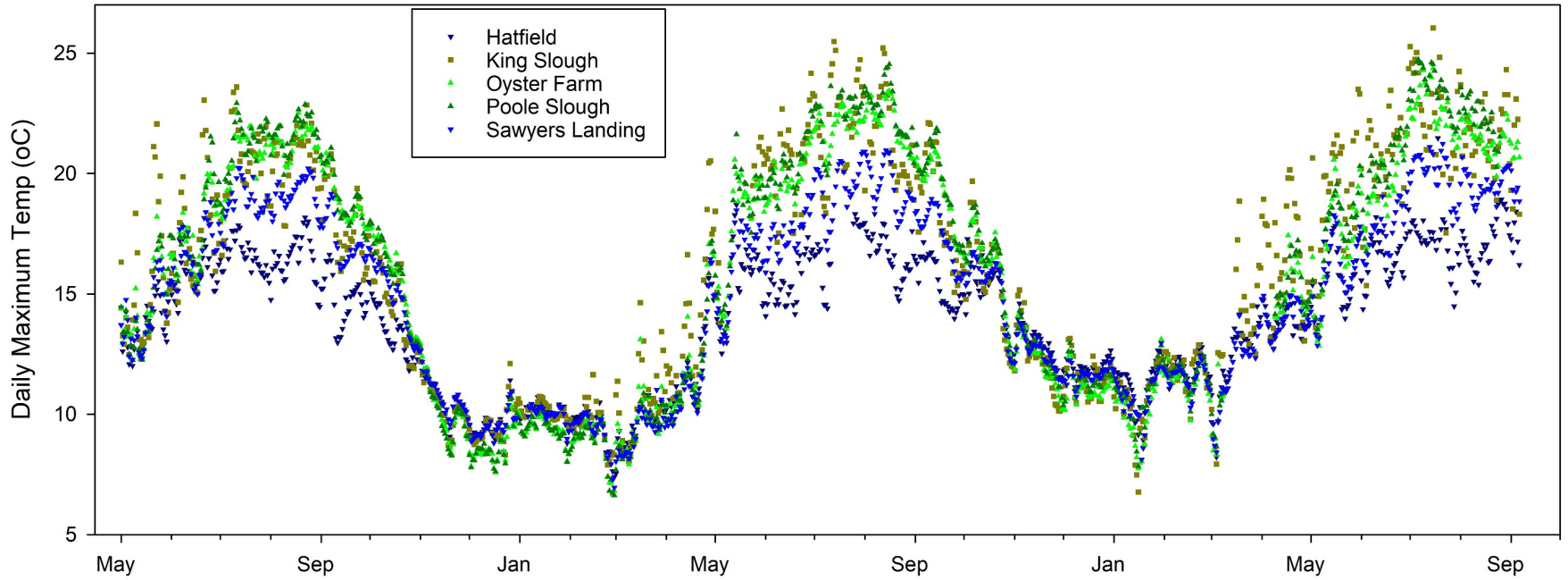
- Only data from the growing seasons were used for comparison
- Summer 2022 was drier than Summer 2023, especially during August and September

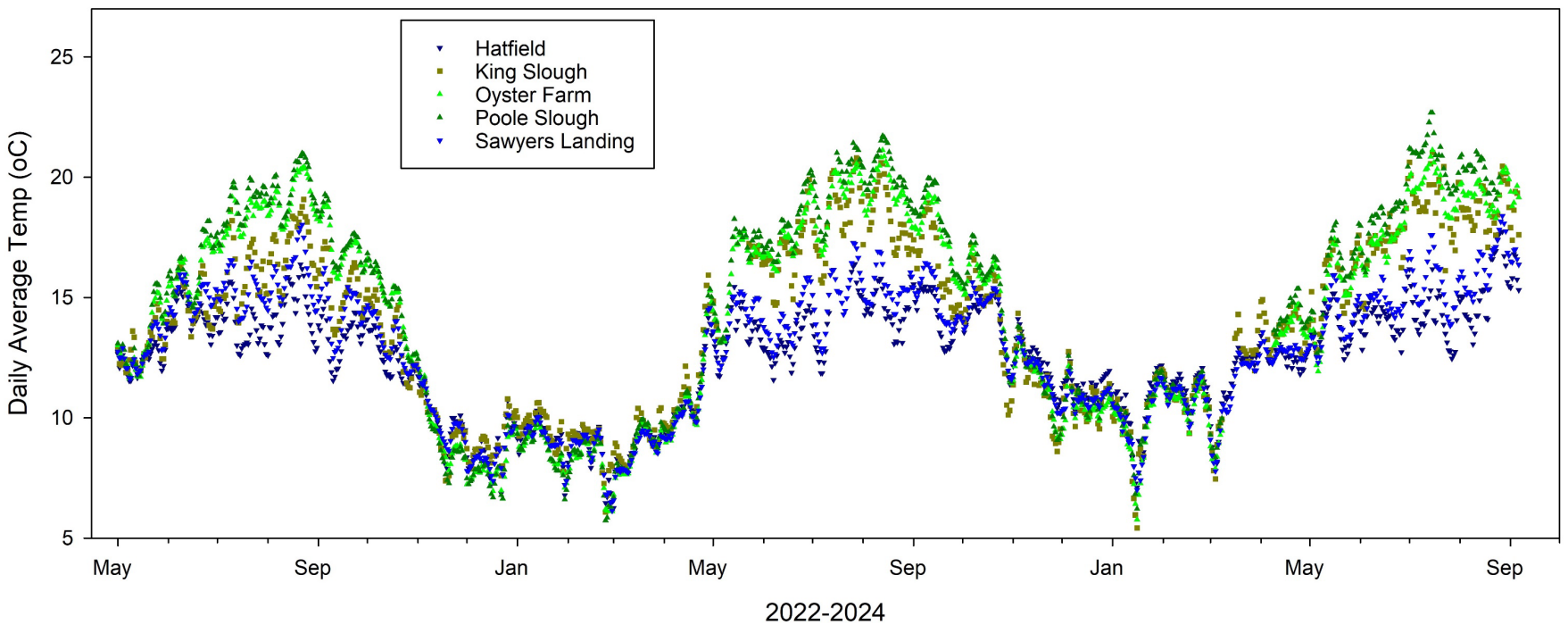
King Slough Conundrum





Lemagie and Lerczack 2014





Notable differences between the Daily Average and Daily Max temp

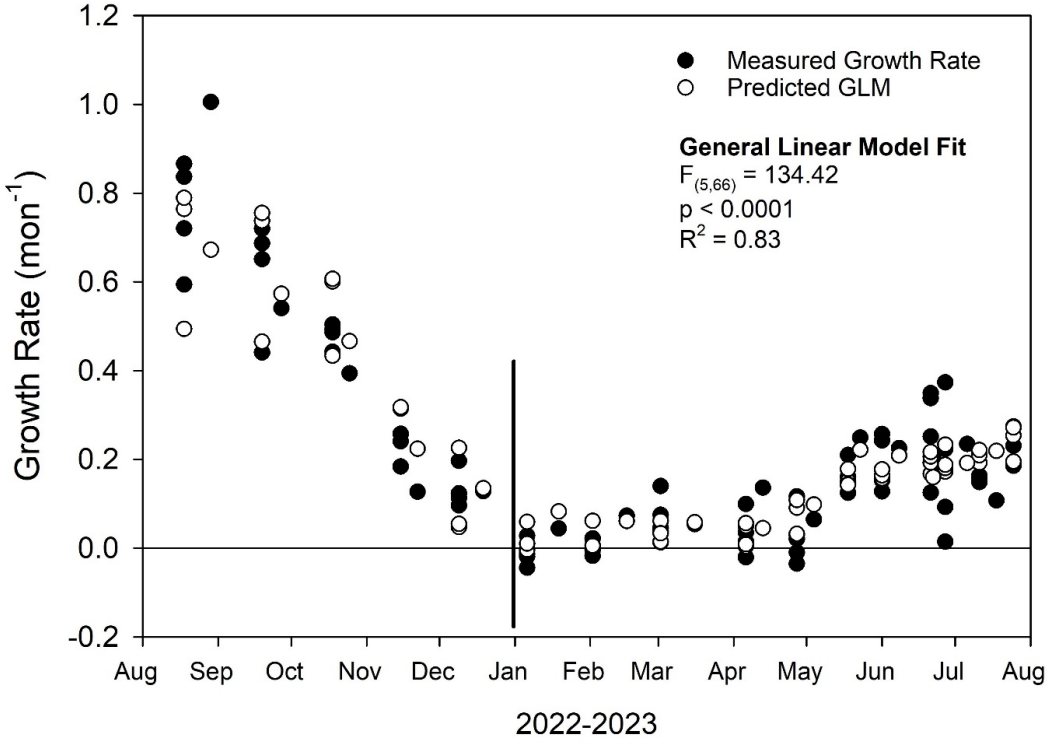
Especially King Slough

Modeling Oyster Growth Rates

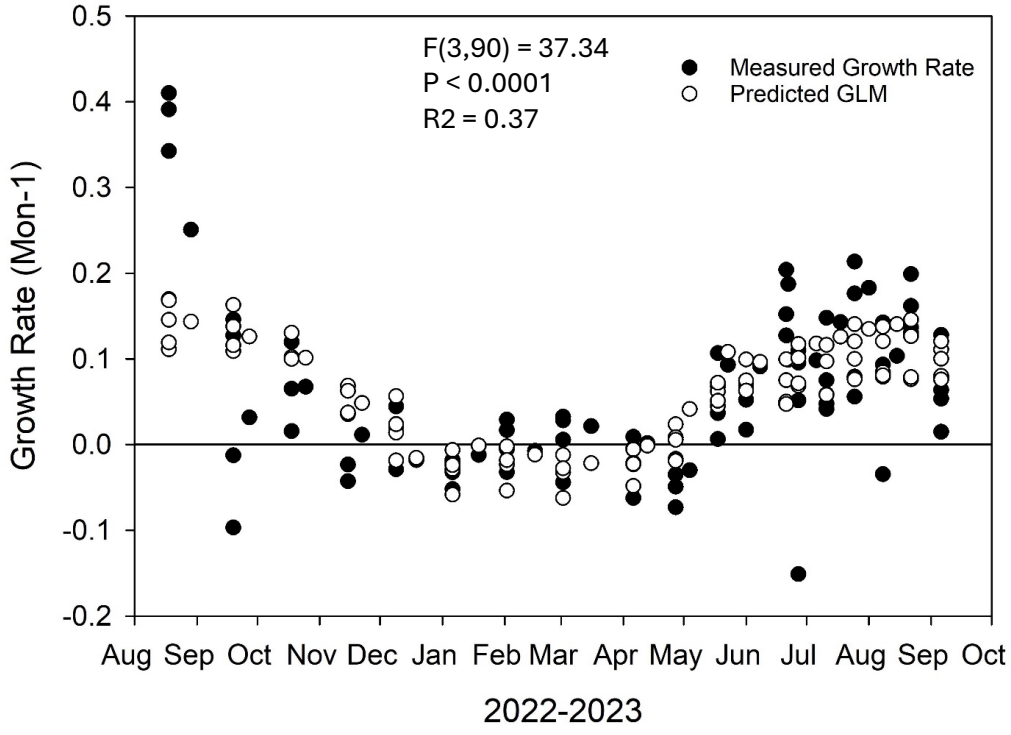
Fitting General Linear Model with exploratory model reduction fits.

- Thus far, Temp significant, Sal only for Pacifics, and difference by year (**pH little to no effect**)
- Some additional data QA/QC needed on weight data
- Haven't updated the env data and re-run with most recent Sal corrections yet
  - More rainfall in Aug & Sept 2023 (0.1 vs 0.5 and 0.1 vs 3.4)

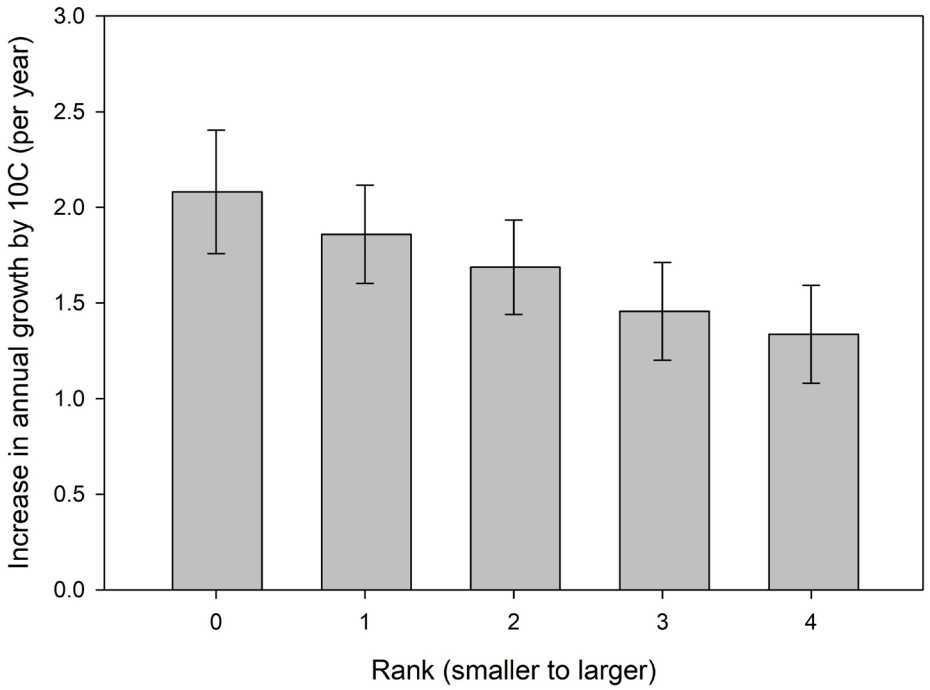
Pacific Oysters Median quintile

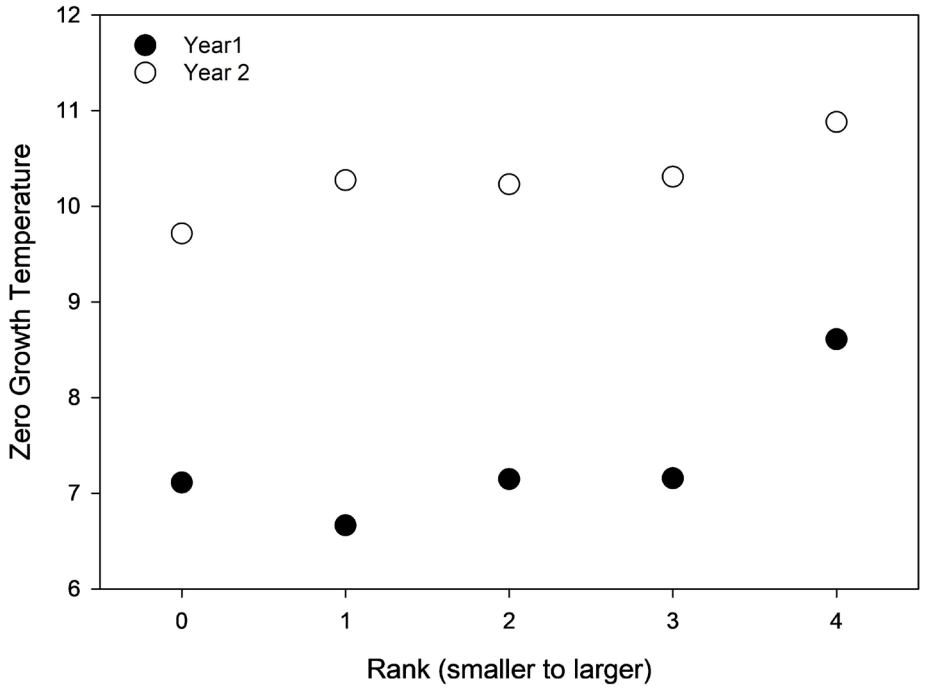


Olympia Oysters Median quintile



Modeling Oyster Growth Rates (Cohort #1)





A significant (but messy) model provides some opportunities to explore possible responses to change

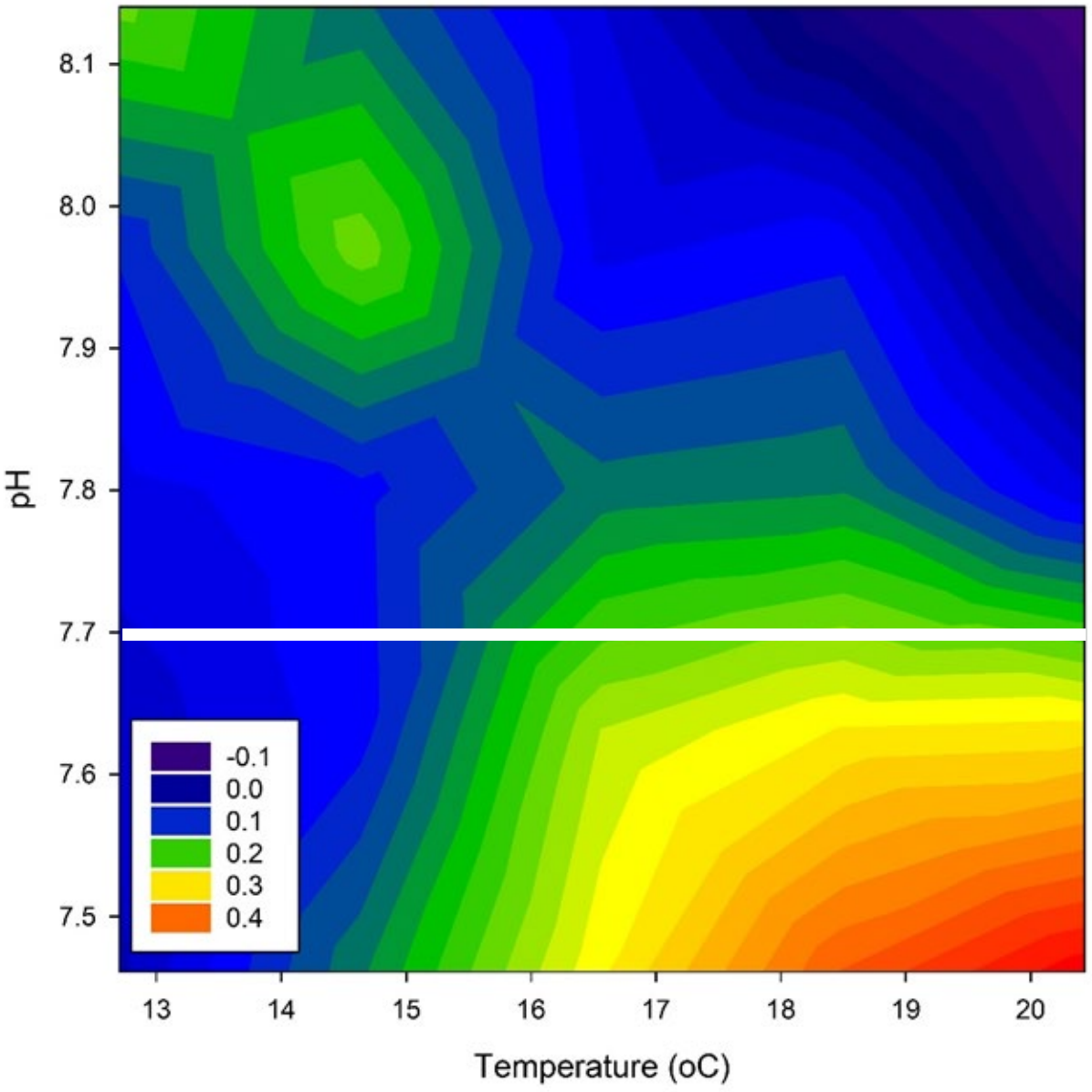
Temperature sensitivity to growth rate

- Smaller sizes increase growth faster with increase temp

Low temperature Initiation of growth

- Smaller sizes begin growing slightly cooler temps
- Nearly 3C difference between Year 1 and Year 2 (either ontological or covariate in conditions)

Olympia Oyster Responses to pH & Temp (median quintile)



Limited pH data below 7.7

Temp more important than pH

Likely other factors during higher temps

- Vibrio?
- Domoic Acid?

In the range of current environmental conditions, doesn't seem like OA is directly important to adult Olympia oyster growth.

Key Take Homes for Olympia Oyster Growth

Acidification small/undetectable effect under natural conditions

Temperature primary driver (with possible food responses too)

Other factors correlated with temp… (we are seeing in different project)

Few current estimates of high-resolution growth rates in Olympias

Helps provide basis for model development

From a Restoration Perspective!

Interestingly highest growth rates in King Slough (warm waters and elevated food)

BUT also has shorter residence time (less larval settlers retained)

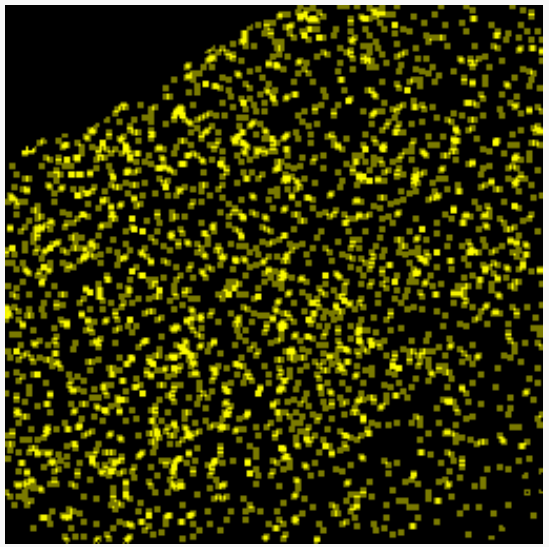
Olympia Oyster Shell Composition

Very little information on Olympia oyster shell composition

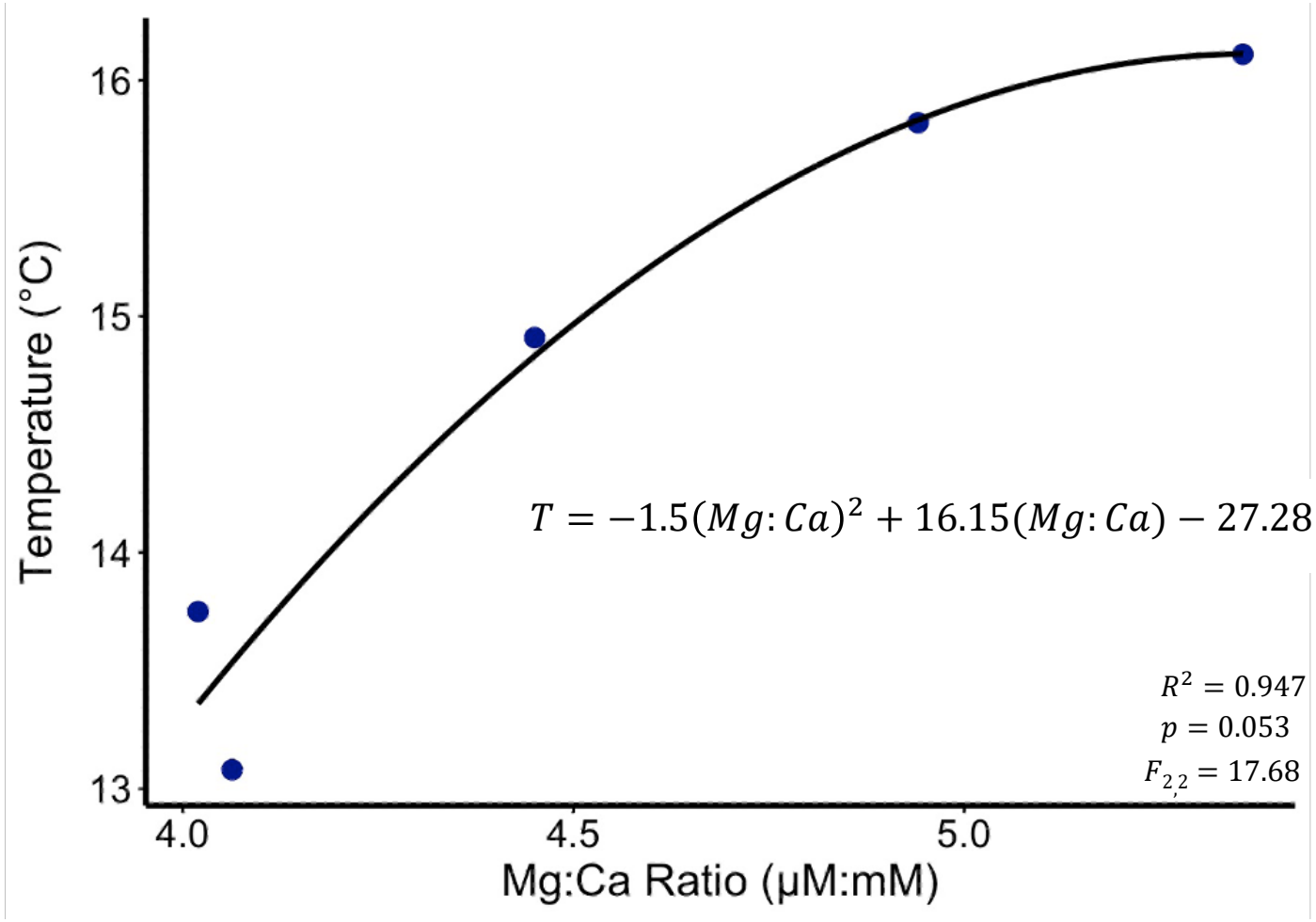
Especially linked to concurrent measurements of environmental conditions

Houser Thesis work

Results



Mg count



Needs some more investigation, but possible utility for reconstruction from shell middens.

Houser Thesis (2025)

Proxy for temperature reconstruction?

Results - Scanning Electron Microscopy

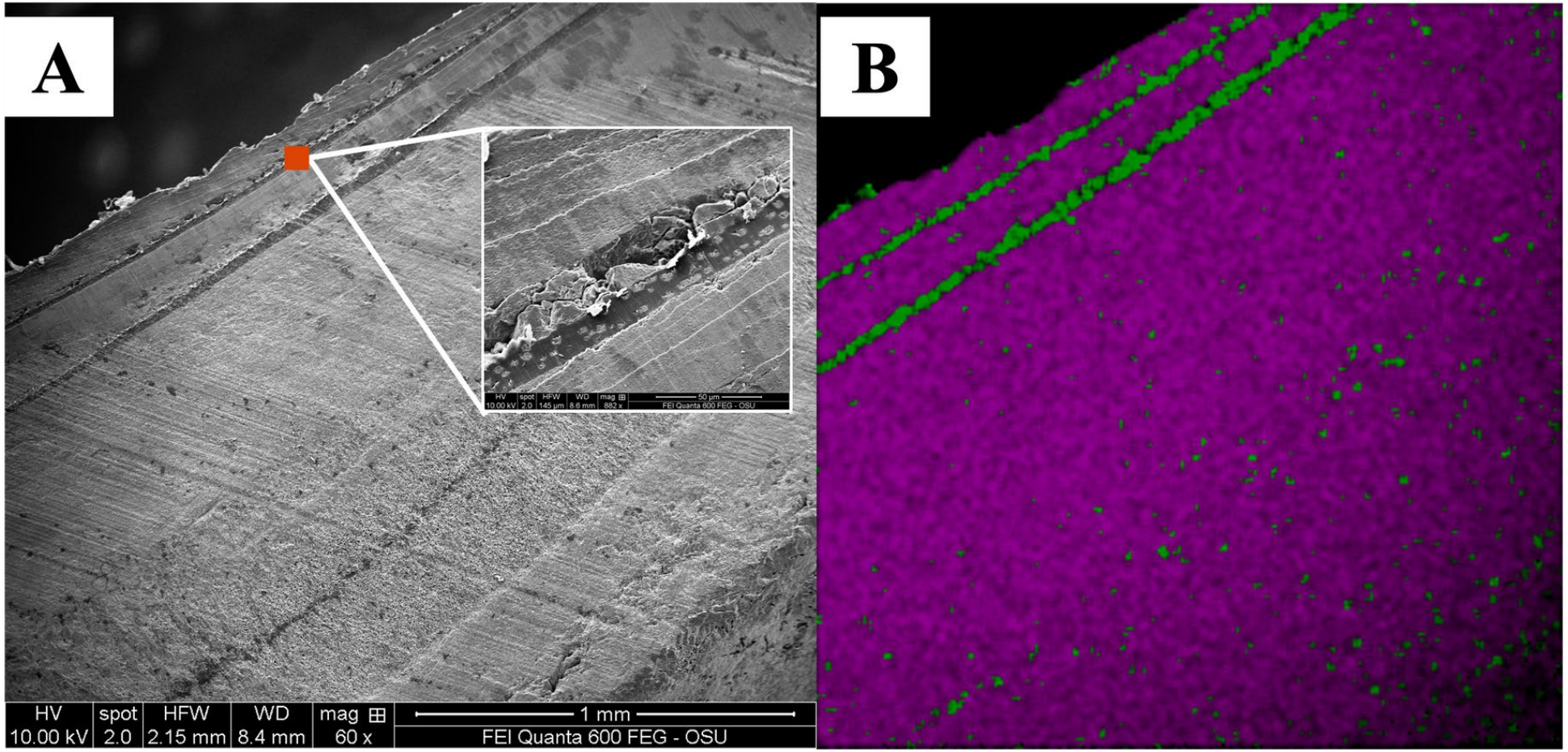
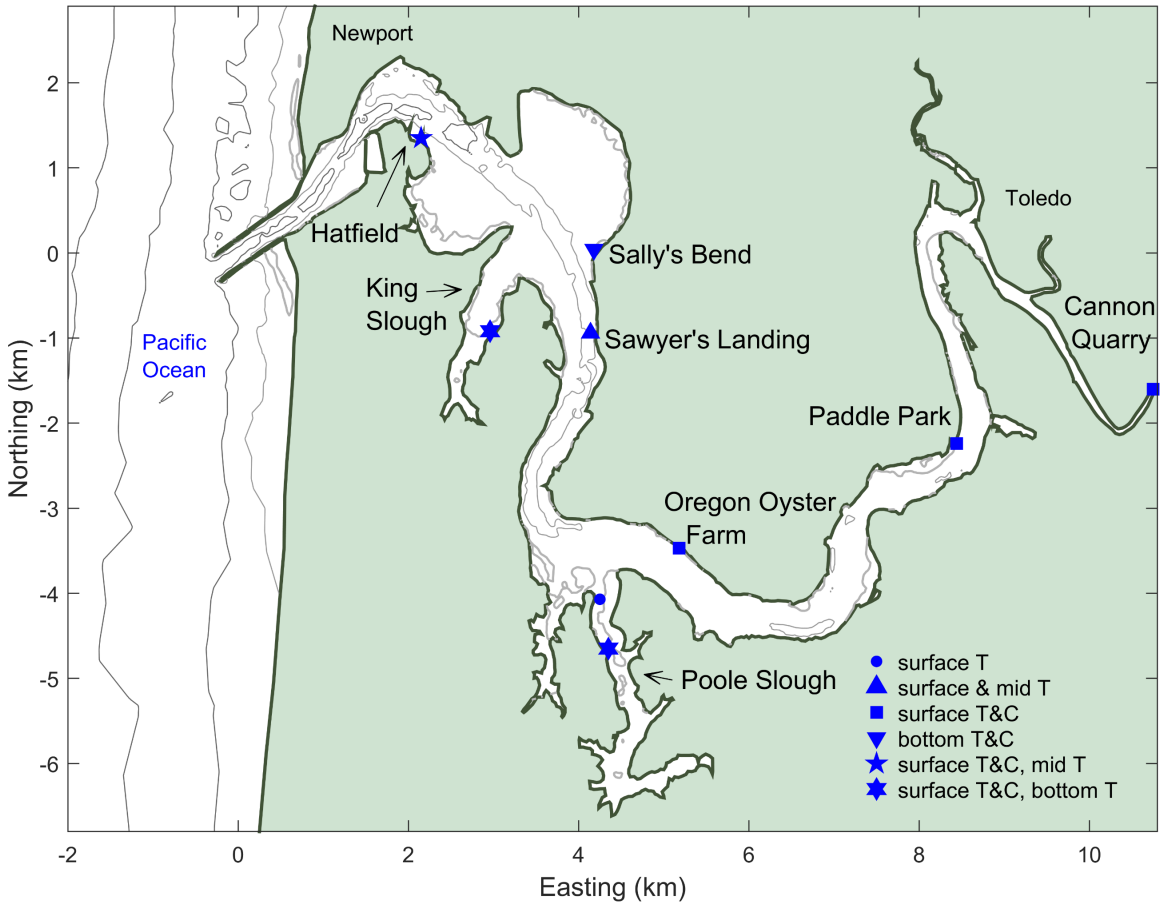


Fig 6. Scanning Electron Microscopy image of the cross-section of an Olympia oyster shell from OF (A). Elemental mapping of calcium (pink) and carbon (green) in on the same cross section of the shell (B).

C-Rich layers may be due to exposure to HABs (evidence emerging from other ongoing work).

Not N-rich, but organic in nature.

Environmental Conditions



Generally:

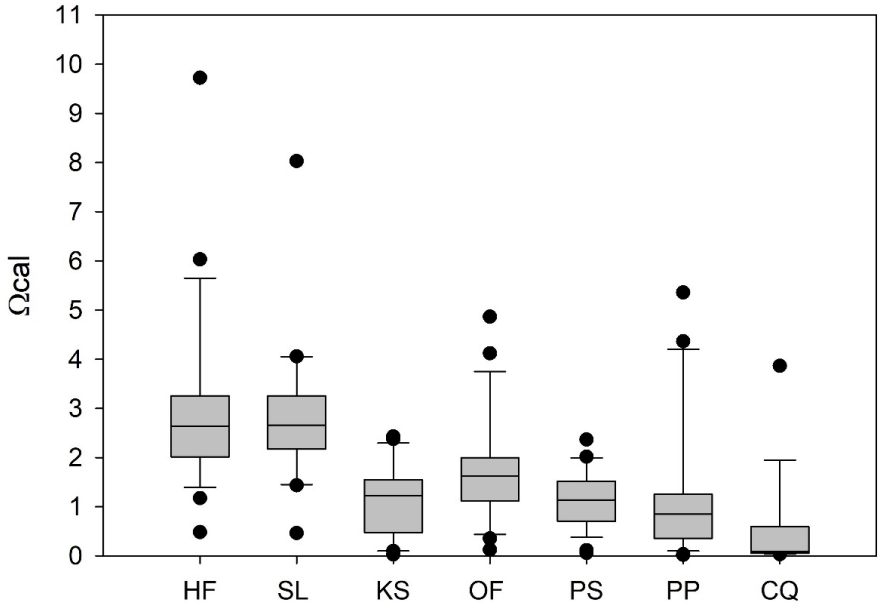
Seasonally Conditions Converge in Winter, Diverge in Summer

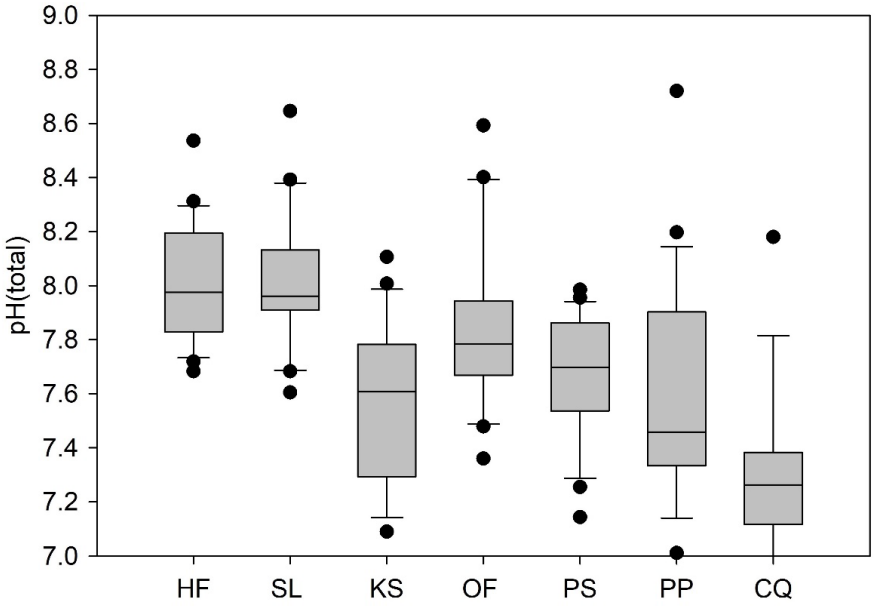
Warmer, fresher, and higher CO2 up estuary

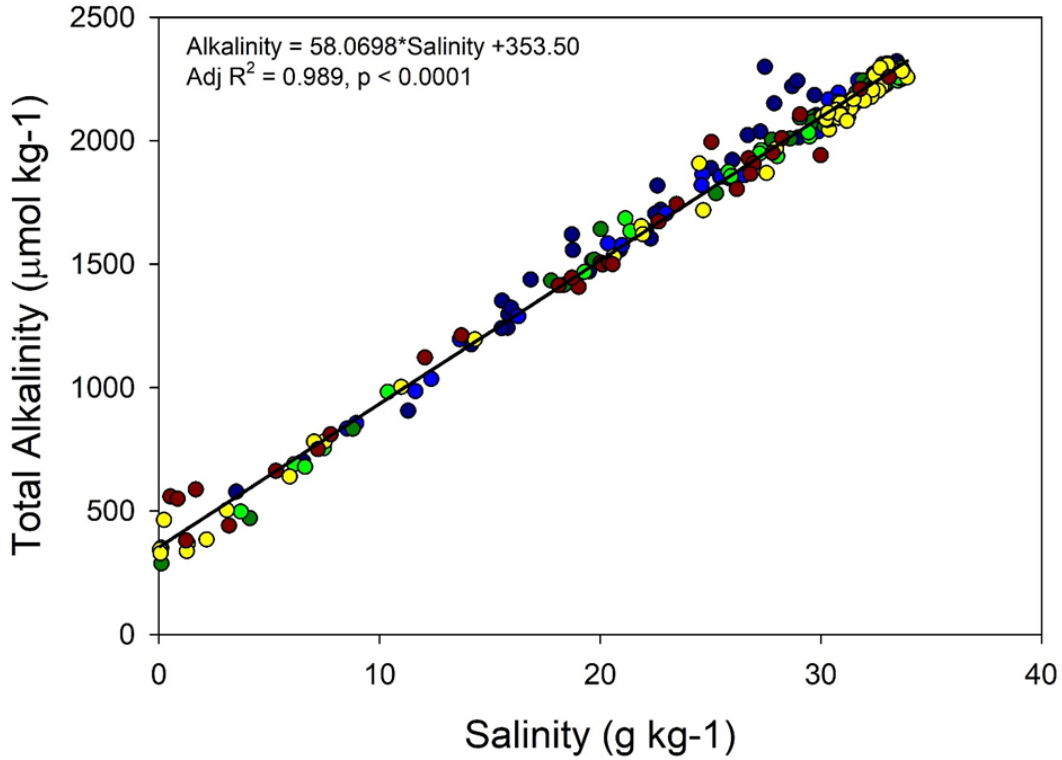
Temp and Sal loosely inversely correlated

Food typically higher upriver, but not always

Environmental Conditions (Carbonate Chemistry: Discrete)







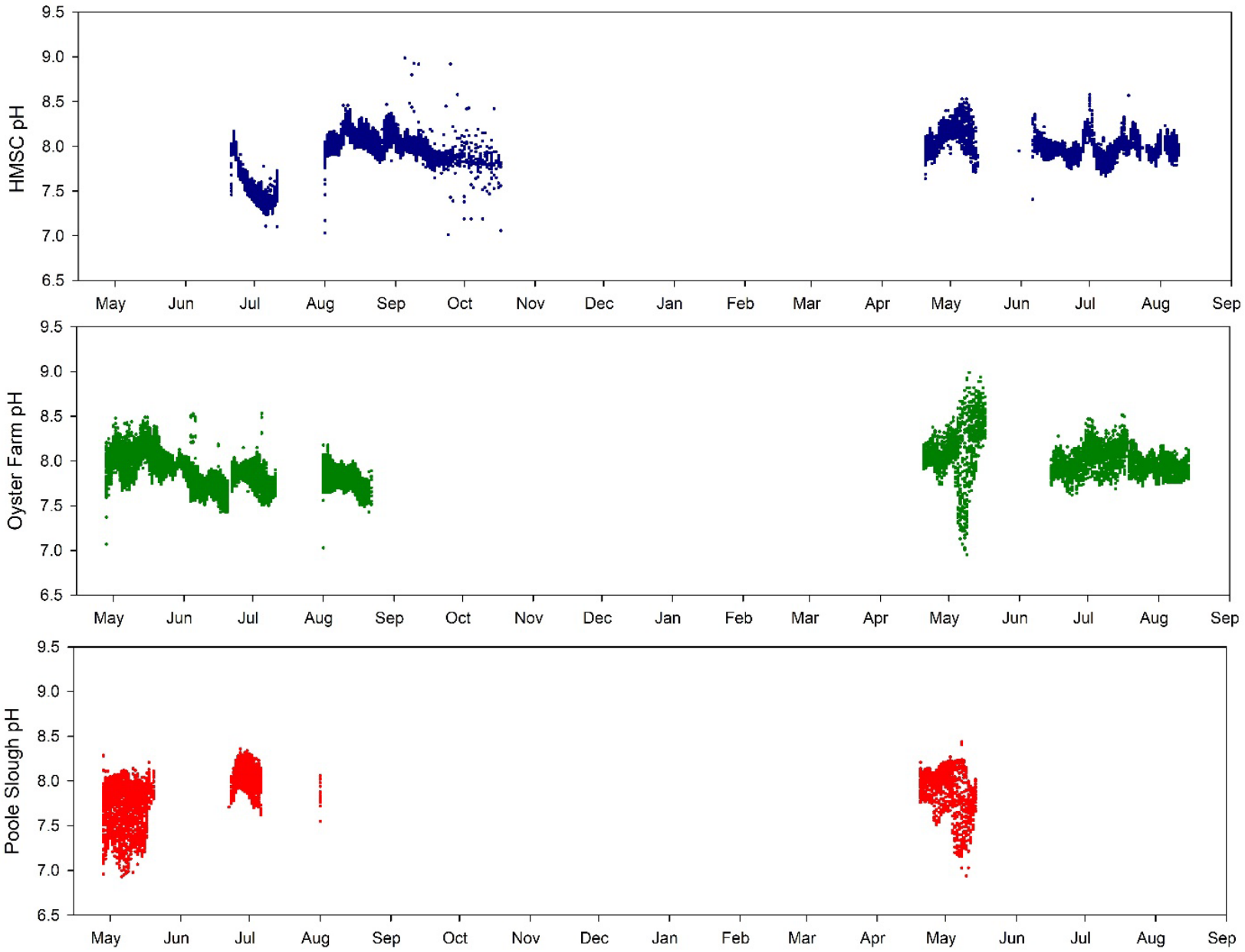
Generally expected patterns through estuary

Oddity in King Slough

Alkalinity-Salinity relationship is valuable for estimating carbonate chemistry

Exploring Correlations Among Sites (can we related HMSC to sites?)

Environmental Conditions (pH Time Series 2023-2024)



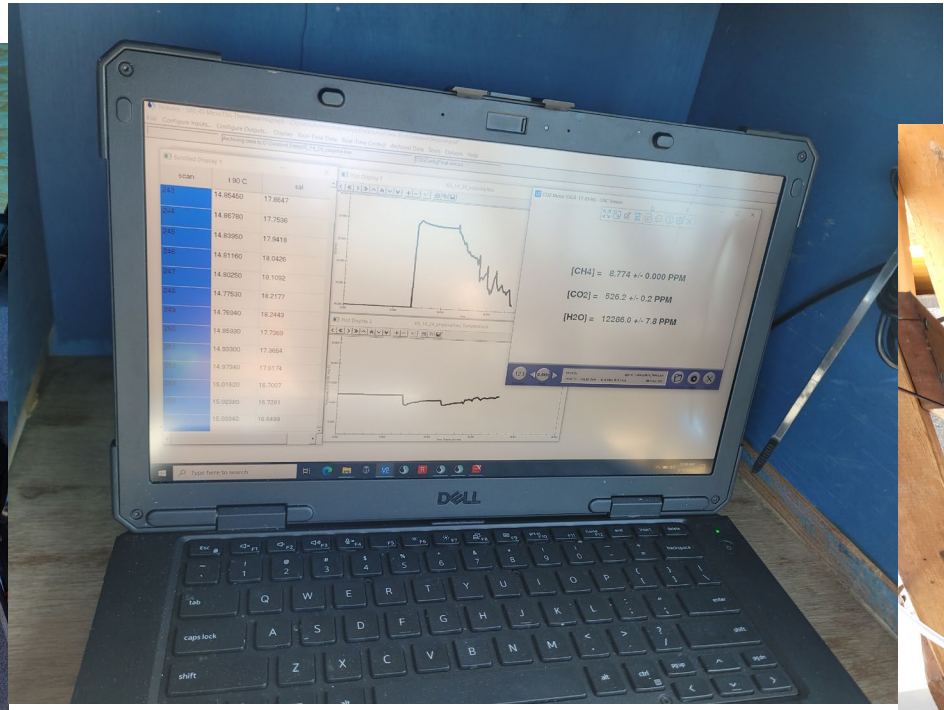
2025 data being processed

Sensor blackouts for service or repairs

Some similar patterns, potential for possible statistical models?

While some sites on average look similar, variations are quite different

Surface PCO2, Temperature, and Salinity Surveys

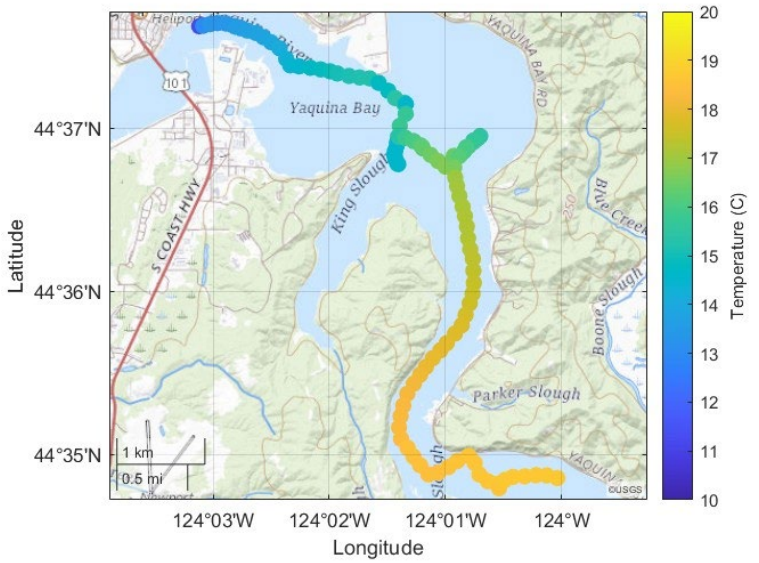


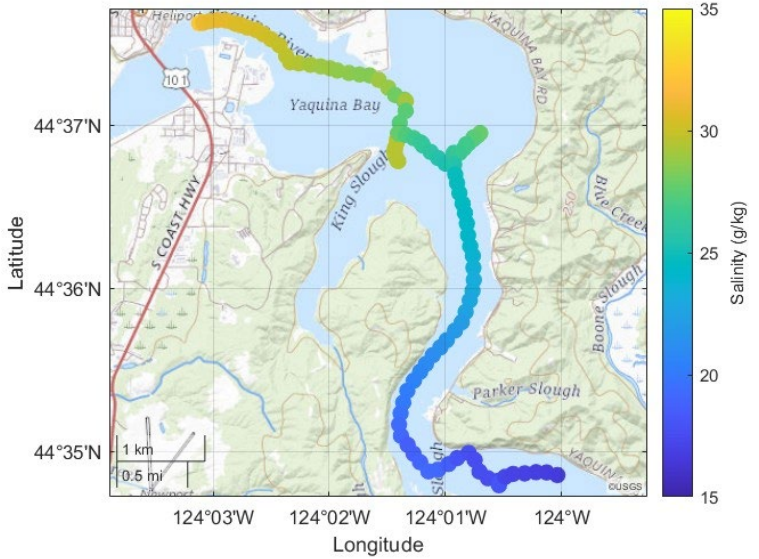
SeaBird TSG
Los Gatos Gas Analyzer
Garmin GPS/Transducer
LiFePO4 Battery

Data combined and averaged to 1min resolution

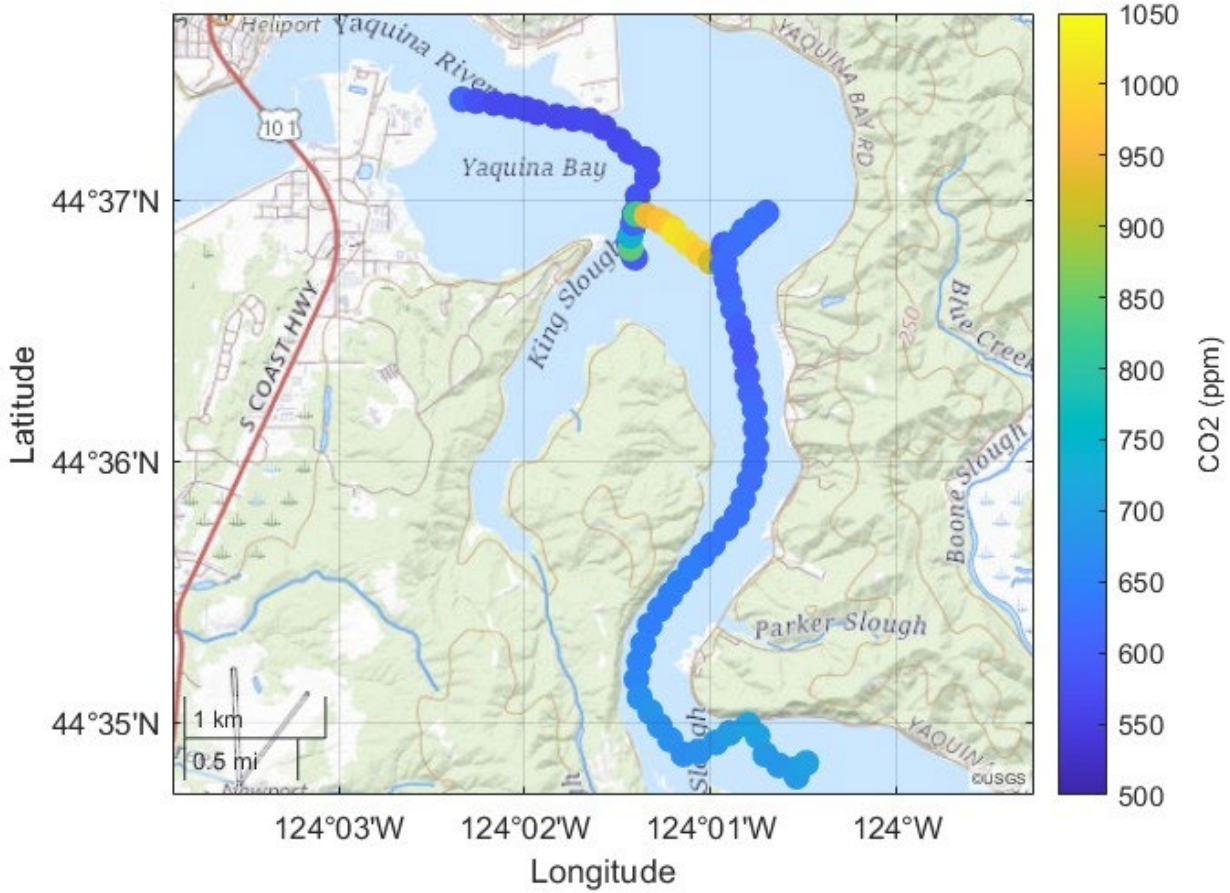
Boat speed varies ~4-5 mph

June 5 2023





Minus 2 ft tide
Early morning
Notable gradients in T&S
Elevated PCO2 near TideFlats

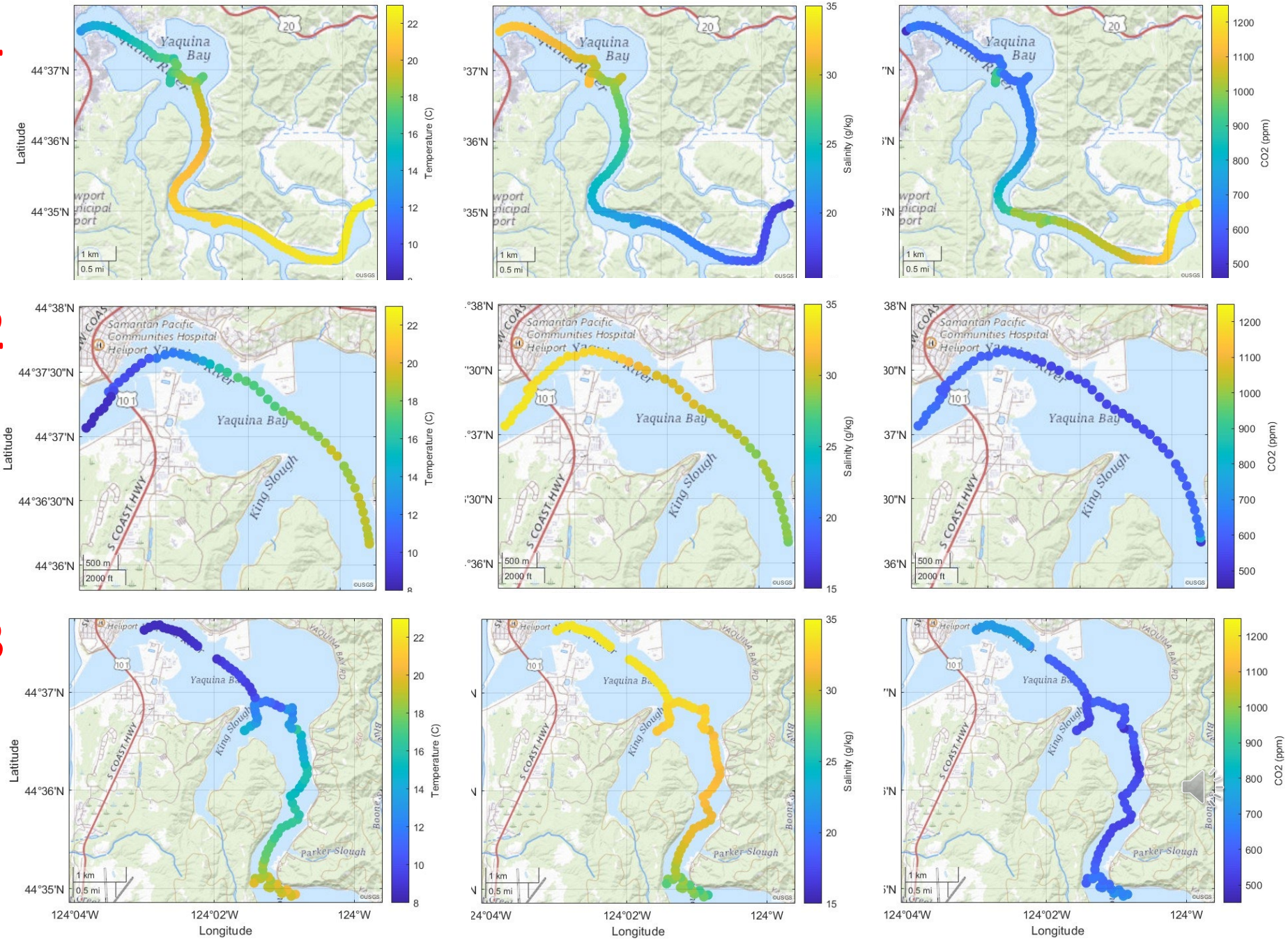


July 3 2023

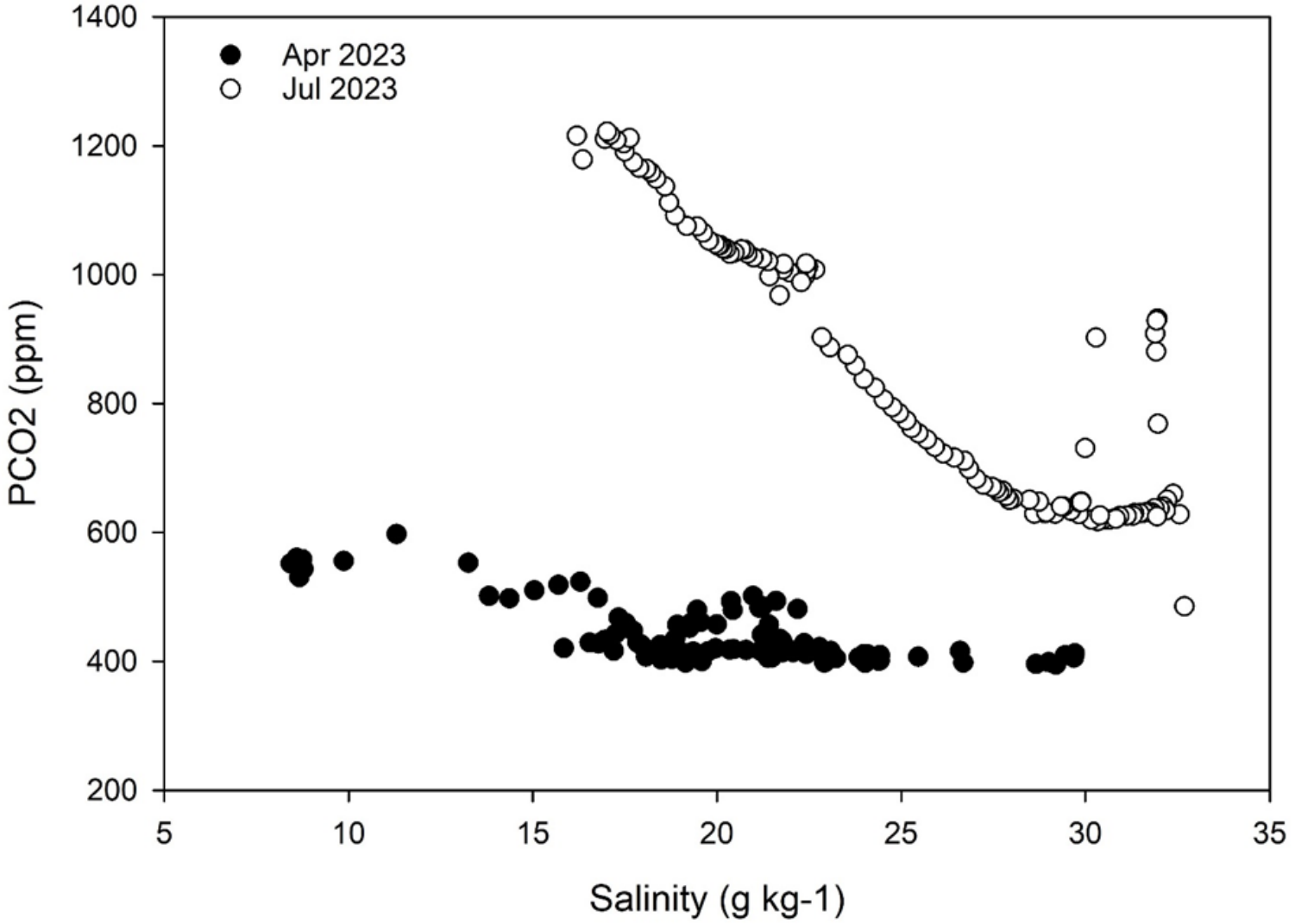
Low Tide (-2ft)
Dawn

Incoming Tide
Early morning

Nearing High tide
Mid-day



Surface PCO2, Temperature, and Salinity Surveys



Seasonal changes in estuarine gradients and within estuary processes

Will tide, discharge, and upwelling be able to forecast PCO2 conditions?

Ongoing and Derivative Work Built on the OOST Support

Peer Reviewed Papers:

Conley, M. M., Lerczak, J. A., Waldbusser, G. G., and Fewings, M. R. Temperature Dynamics in a small Pacific Northwest estuary and its sloughs. Submitted to Estuaries and Coasts.

Houser et al. (in prep) OSU Honor's College Thesis

Waldbusser et al. (in prep) Controls on Olympia and Pacific Oyster growth in a Small Mountainous River estuary

Waldbusser et al. (in prep) Carbon dioxide concentrations in surface waters of Yaquina Bay

Ongoing Student Projects:

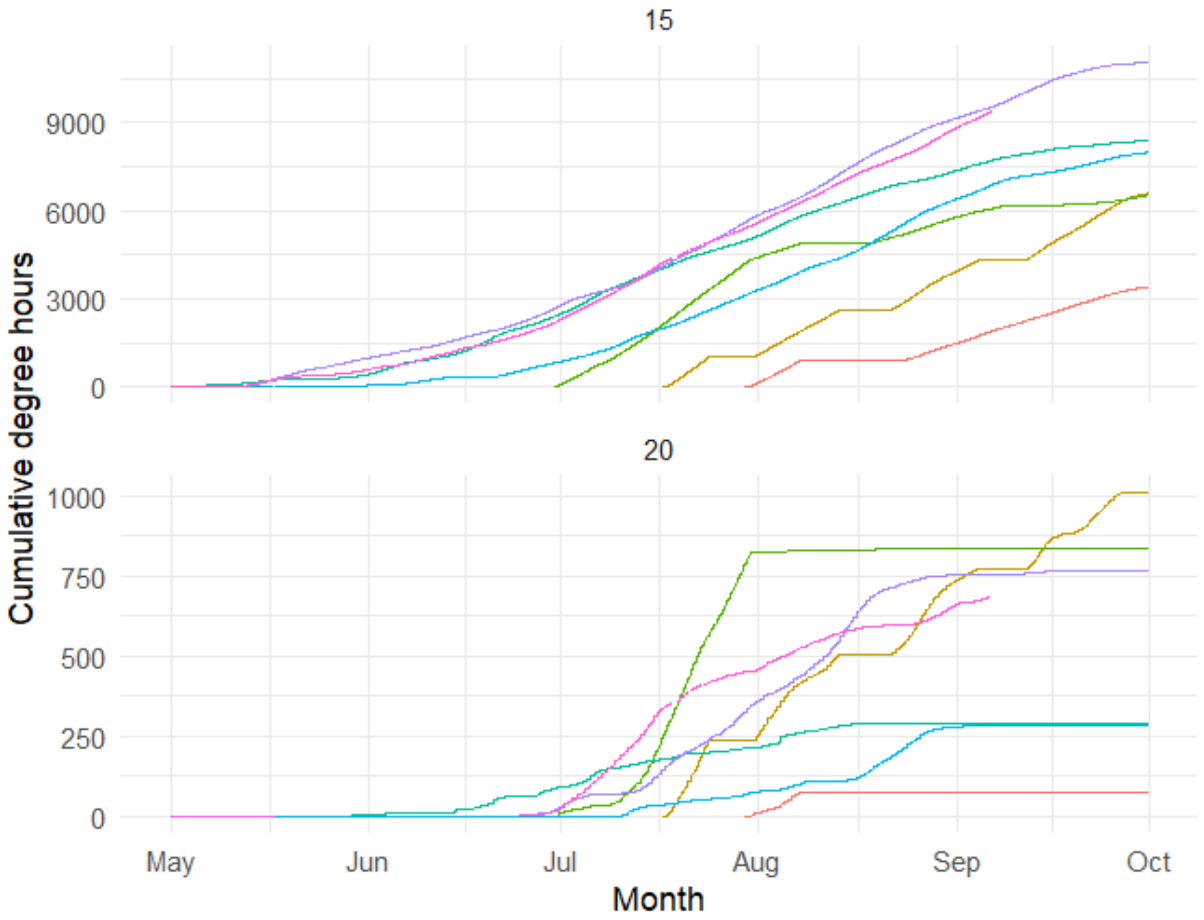
Sophie Widenhouse, OSU Honor's College, Machine Learning Methods for Automation of Oyster Sizing

Casey Harper, Geography MS, Geospatial Dynamics of Temperature Regimes in Yaquina Bay, Assessment of Degree Hour Models for Vibrio risk and Olympia Oyster growth.

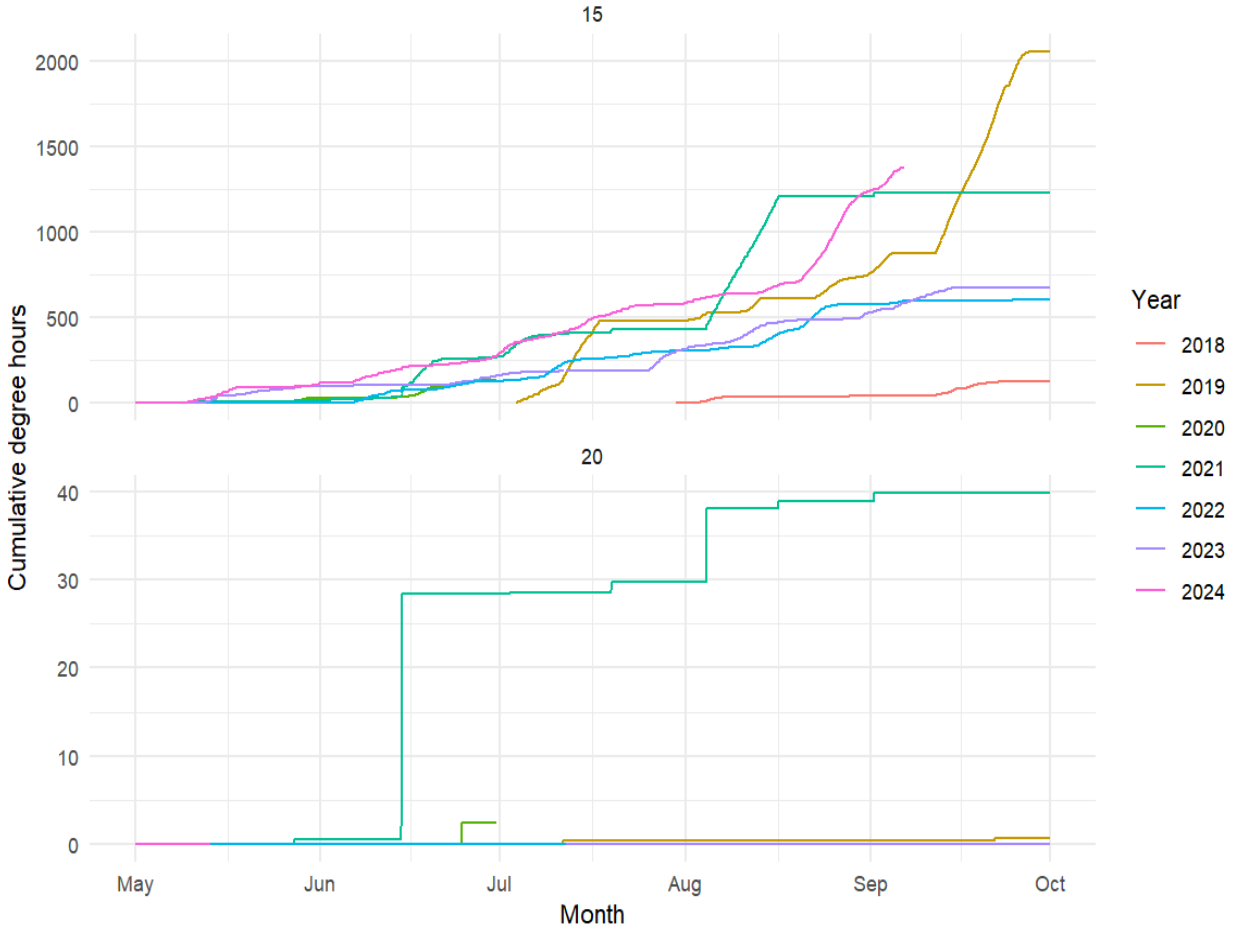
Degree Hour Modeling of Temperature Dynamics in Yaquina Bay

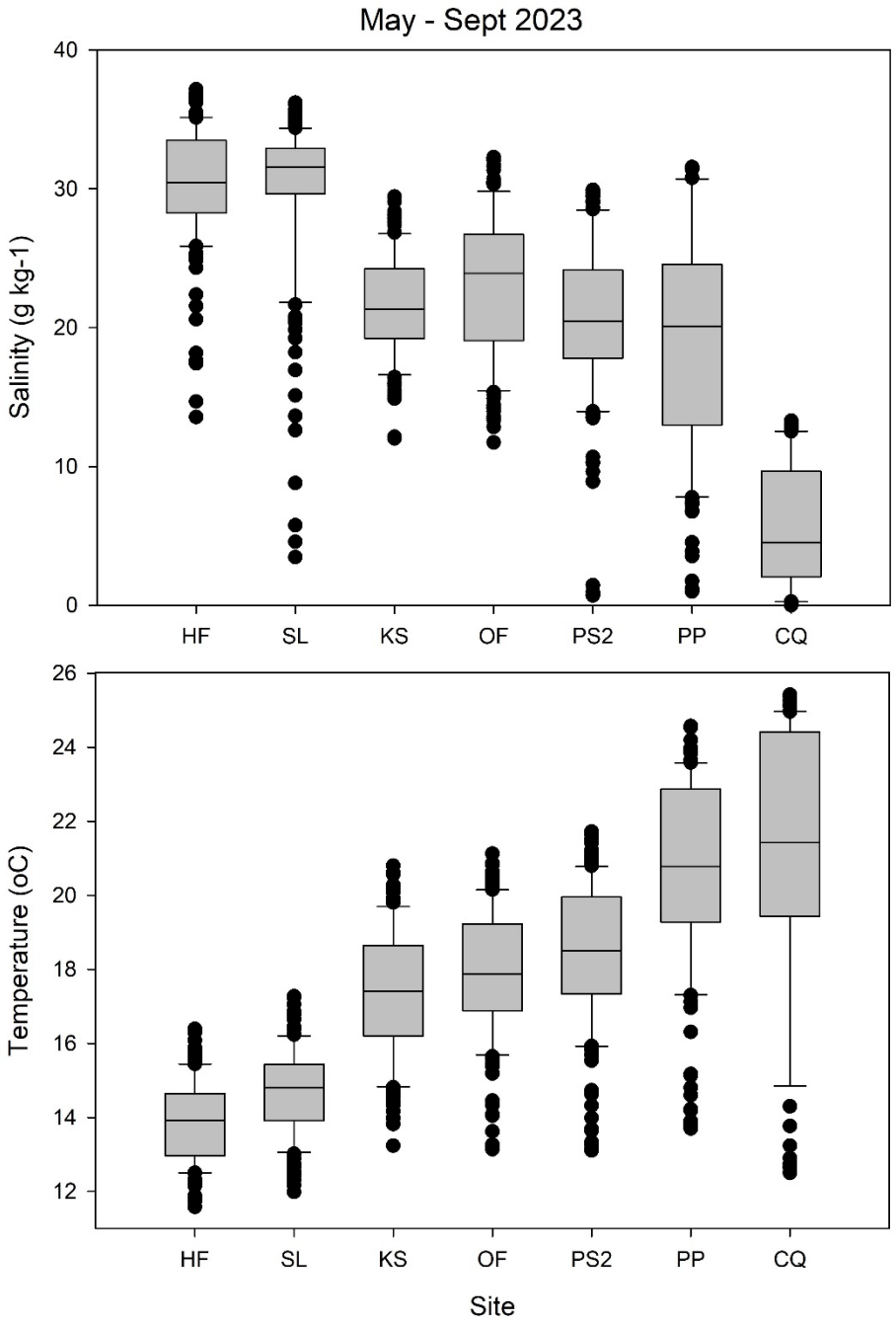
Degree Day type models widely used in Ag Settings
Rely on accumulation of threshold exceedance over span of time (Risk and Growth approaches)

Oregon Oyster Farm

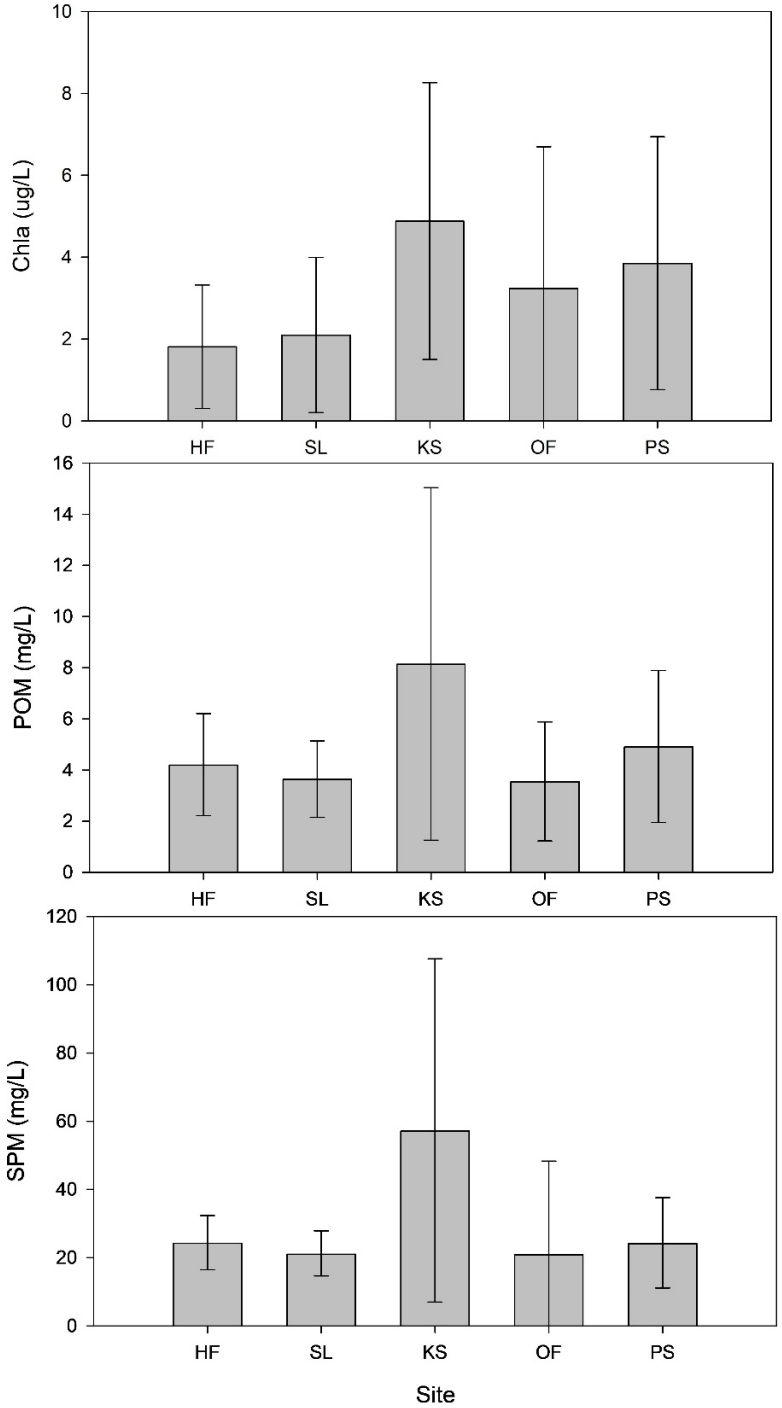


HMSC





General Patterns of Salinity and Temperature for the 2023 ‘Growing Season’

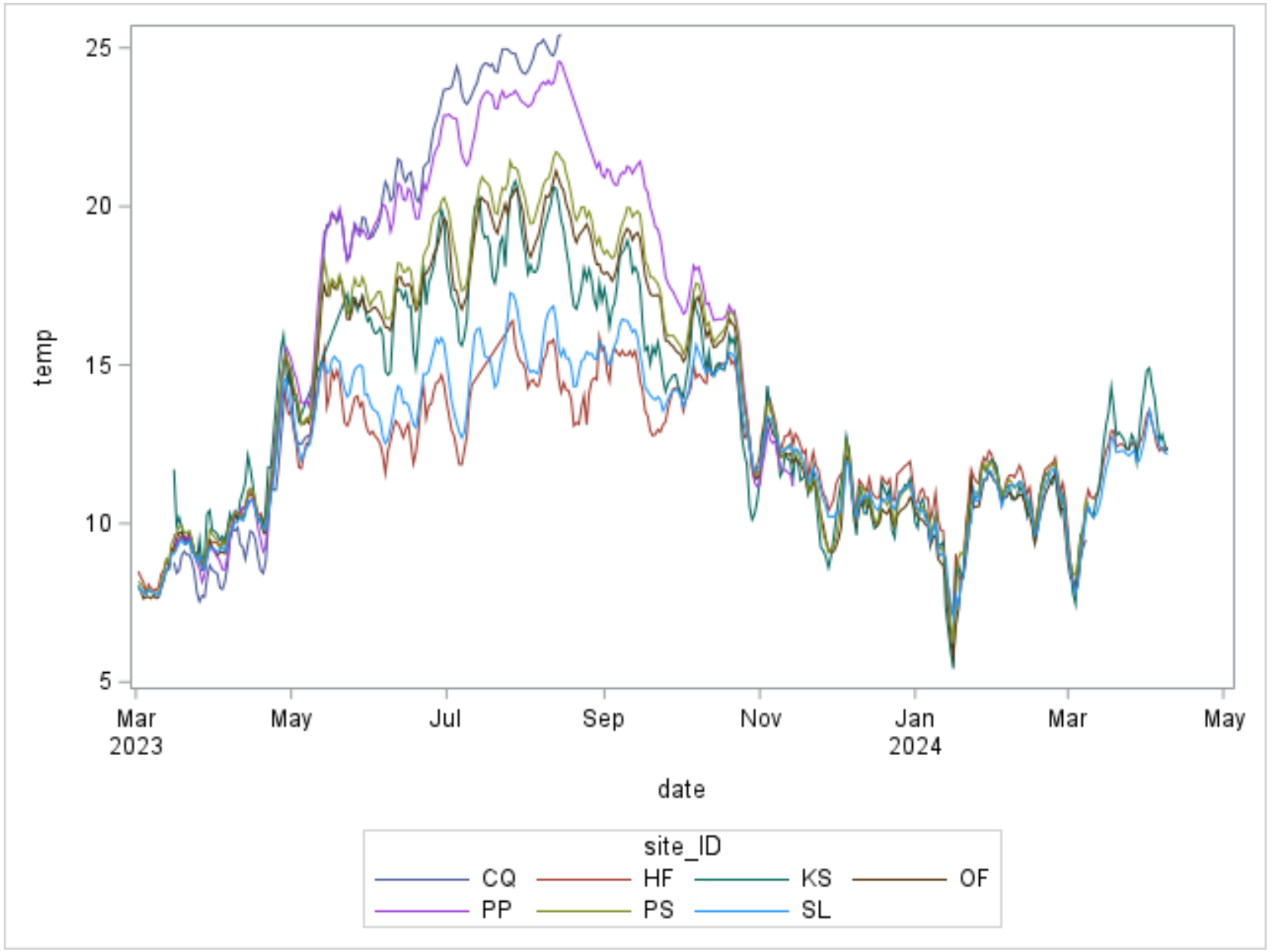


Compiled Averages from Discrete Samples collected from 2022 -2023

Recall King Slough- Largest Olympia Sizes.

Variable but on average more Chla and POM

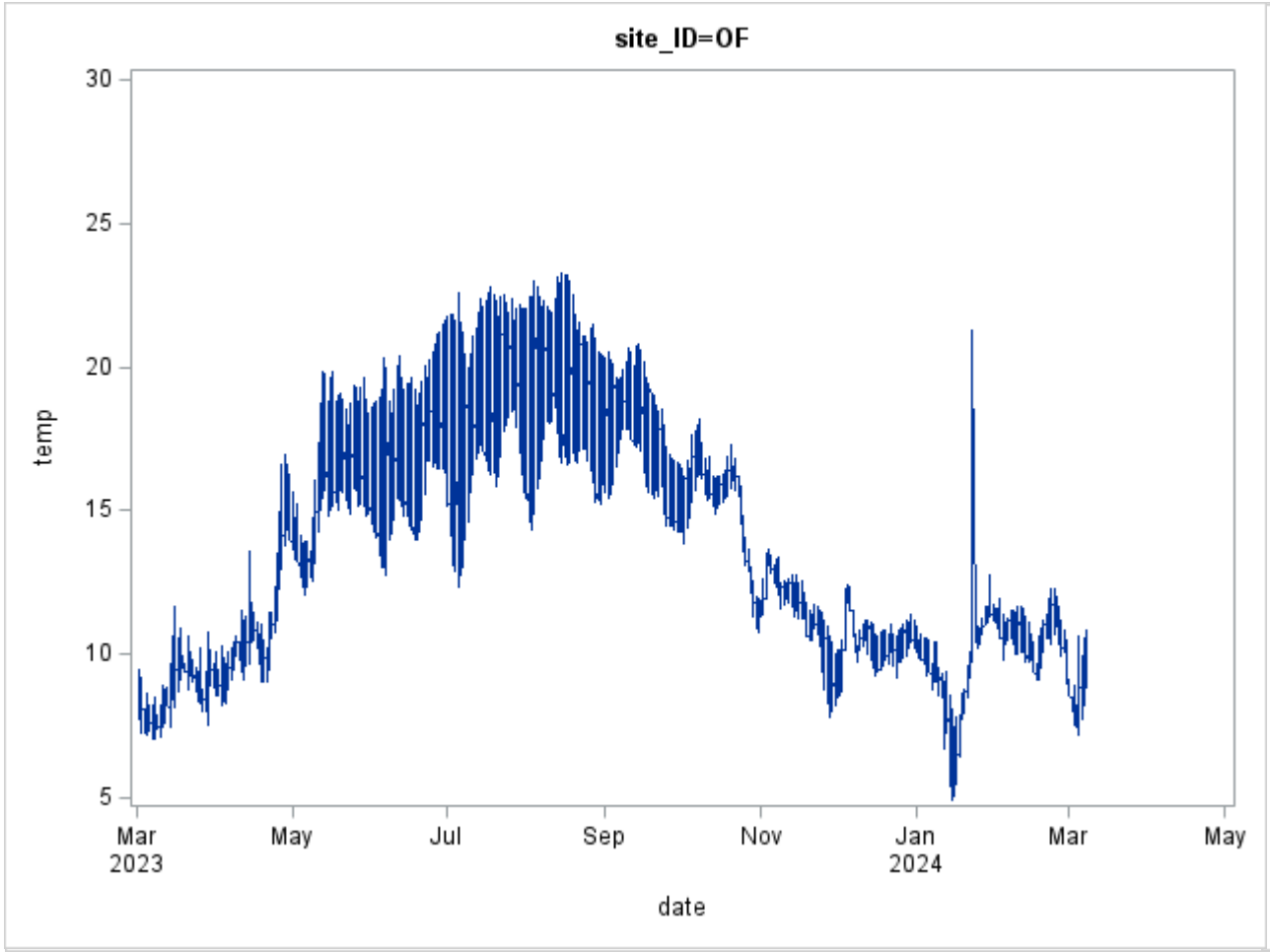
Time Series Data (T&S)

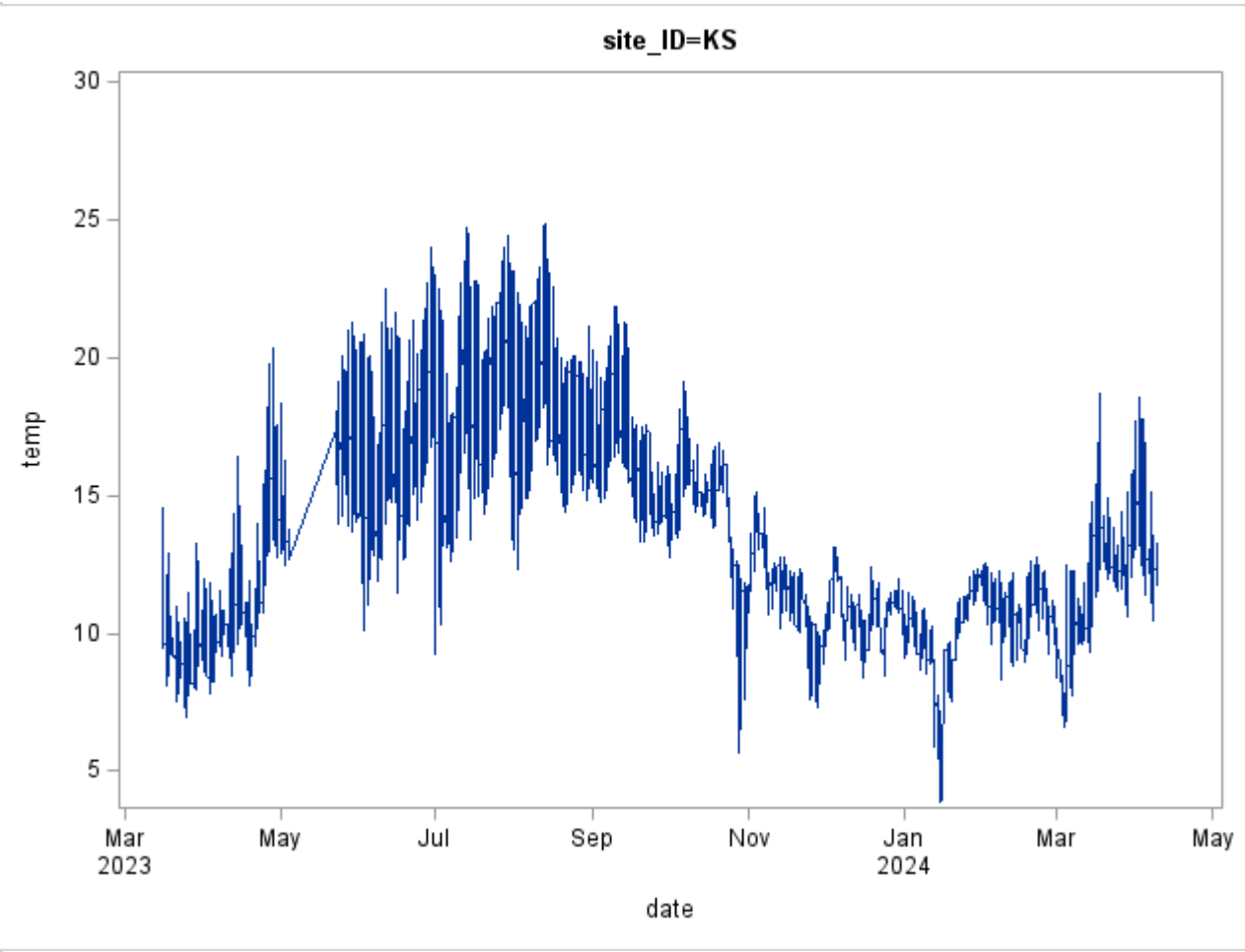


Daily Means

- Summer differences
- Winter similarities
- Events

Time Series Data (T&S)

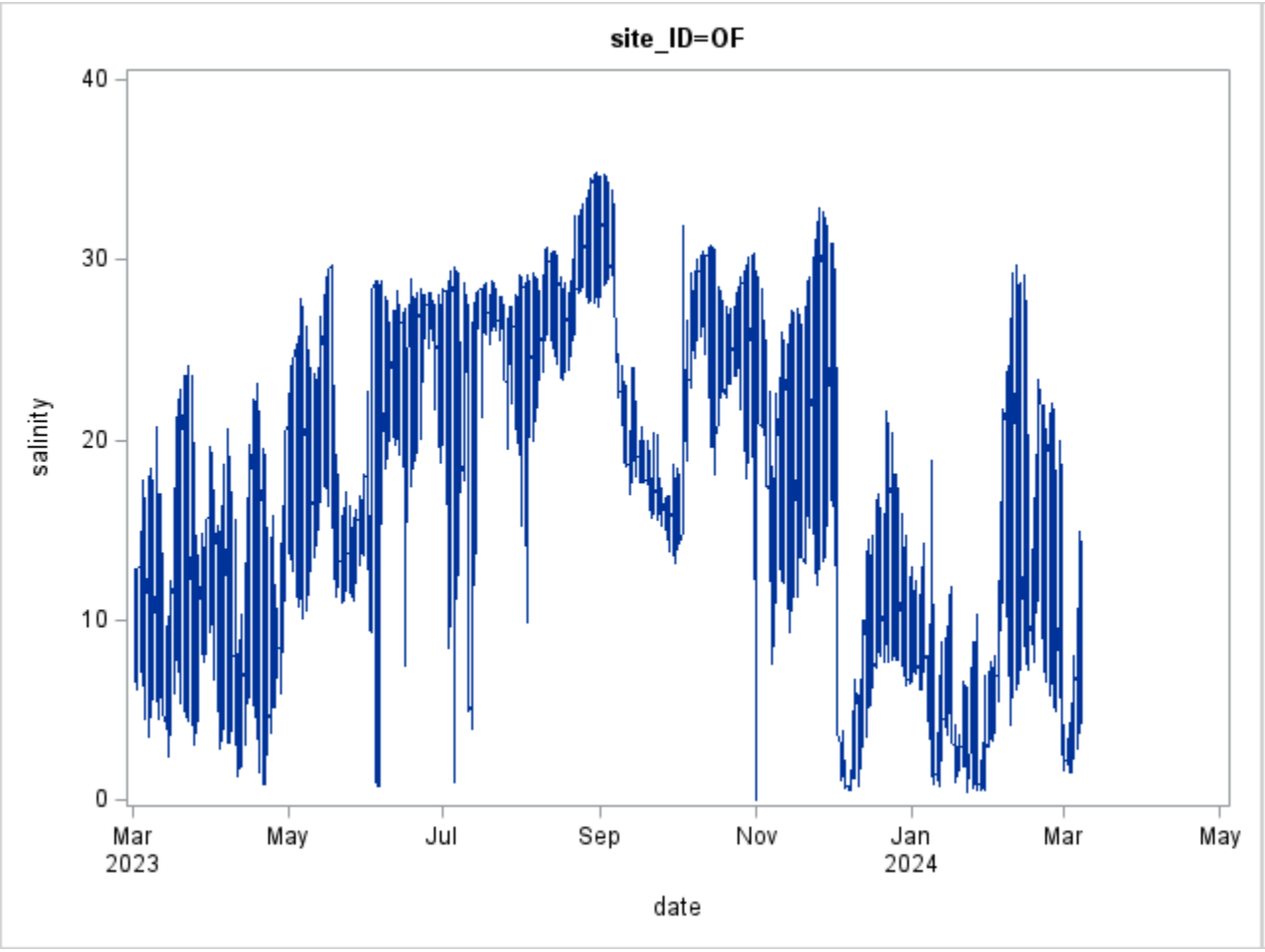


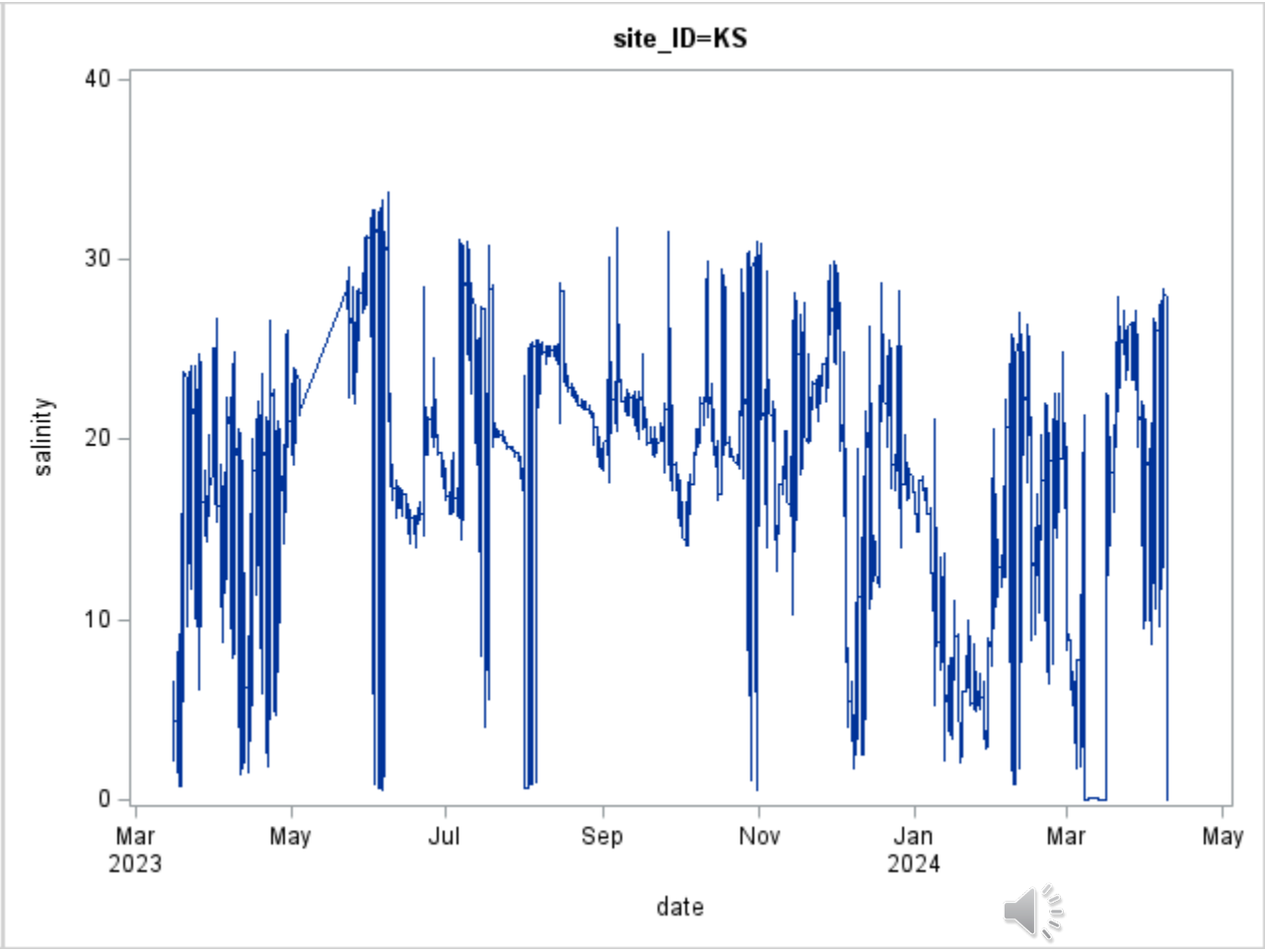


Hourly Means

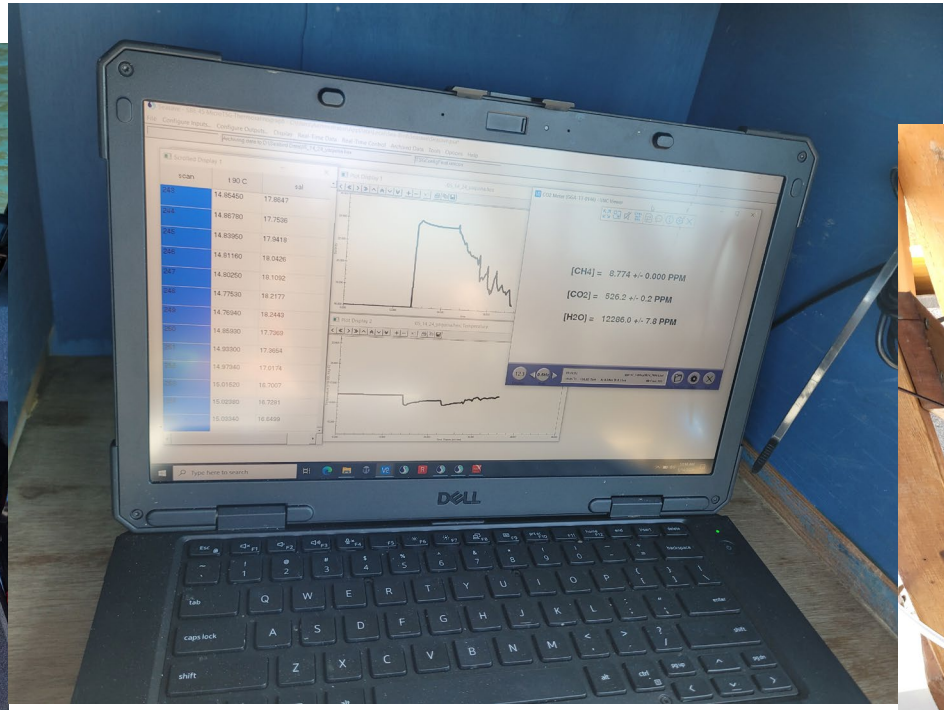
- Tidal Effects
- Local Climatologies

Time Series Data (T&S)





Surface PCO2, Temperature, and Salinity Surveys

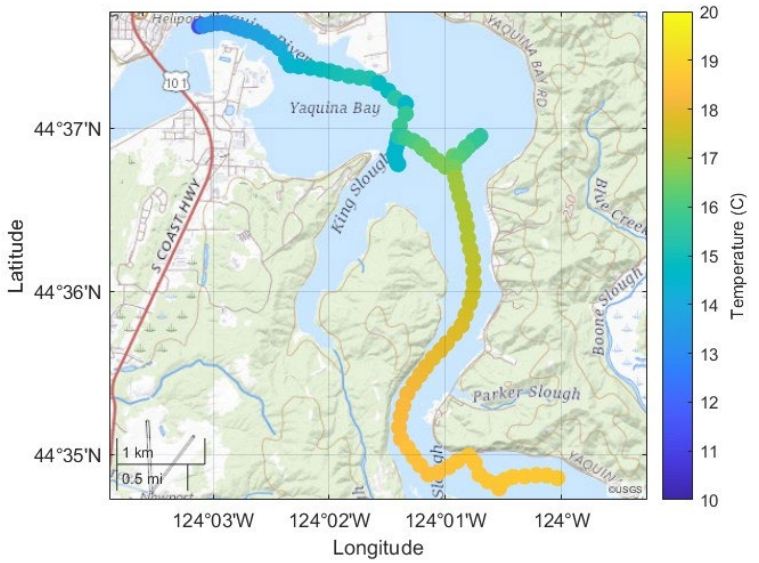


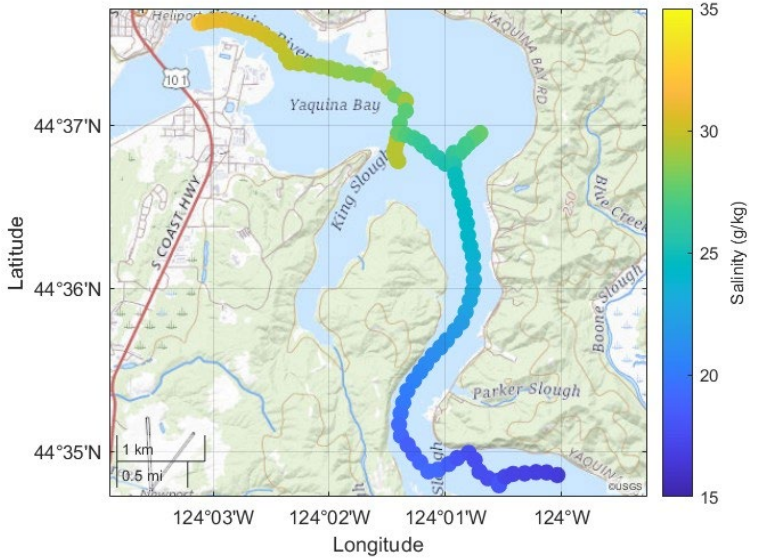
SeaBird TSG
Los Gatos Gas Analyzer
Garmin GPS/Transducer
LiFePO4 Battery

Data combined and averaged to 1min resolution

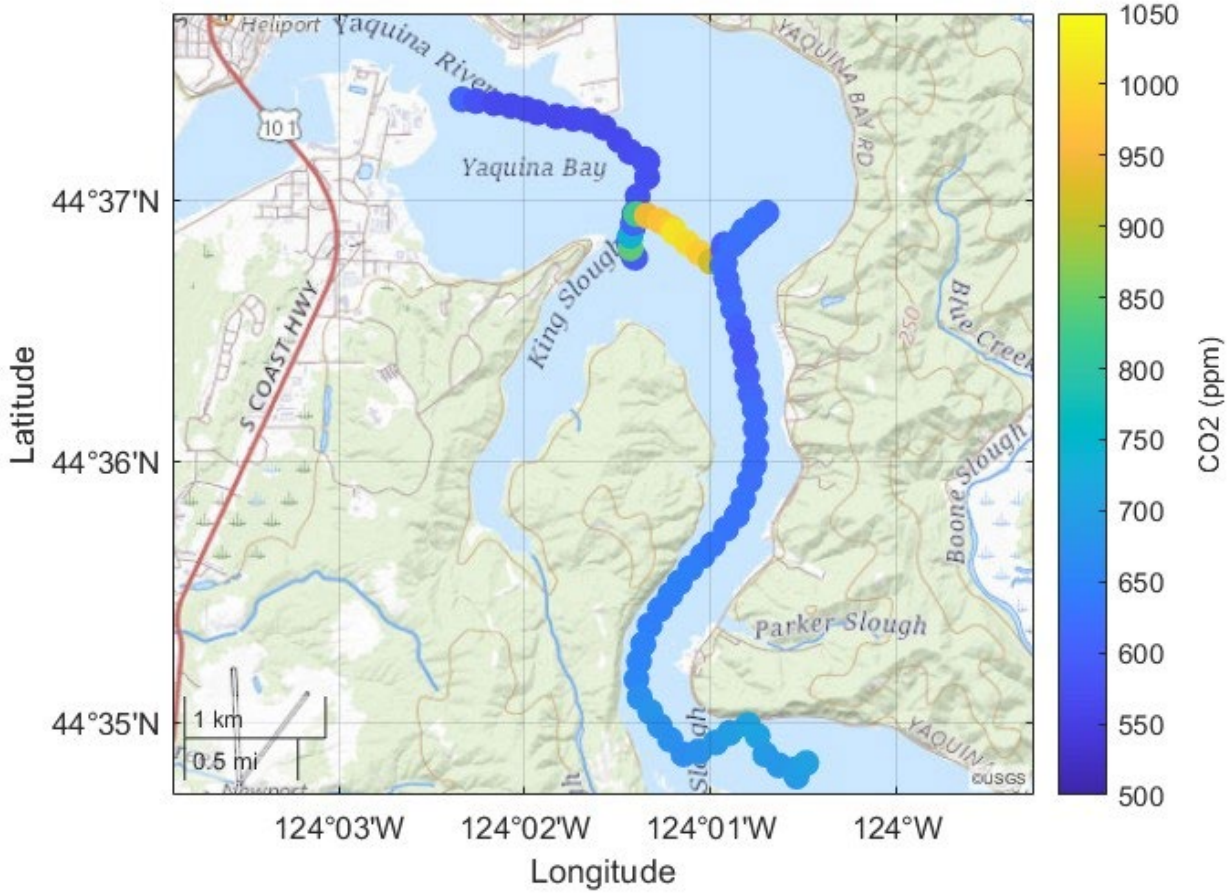
Boat speed varies ~4-5 mph

June 5 2023





Minus 2 ft tide
Early morning
Notable gradients in T&S
Elevated PCO2 near TideFlats

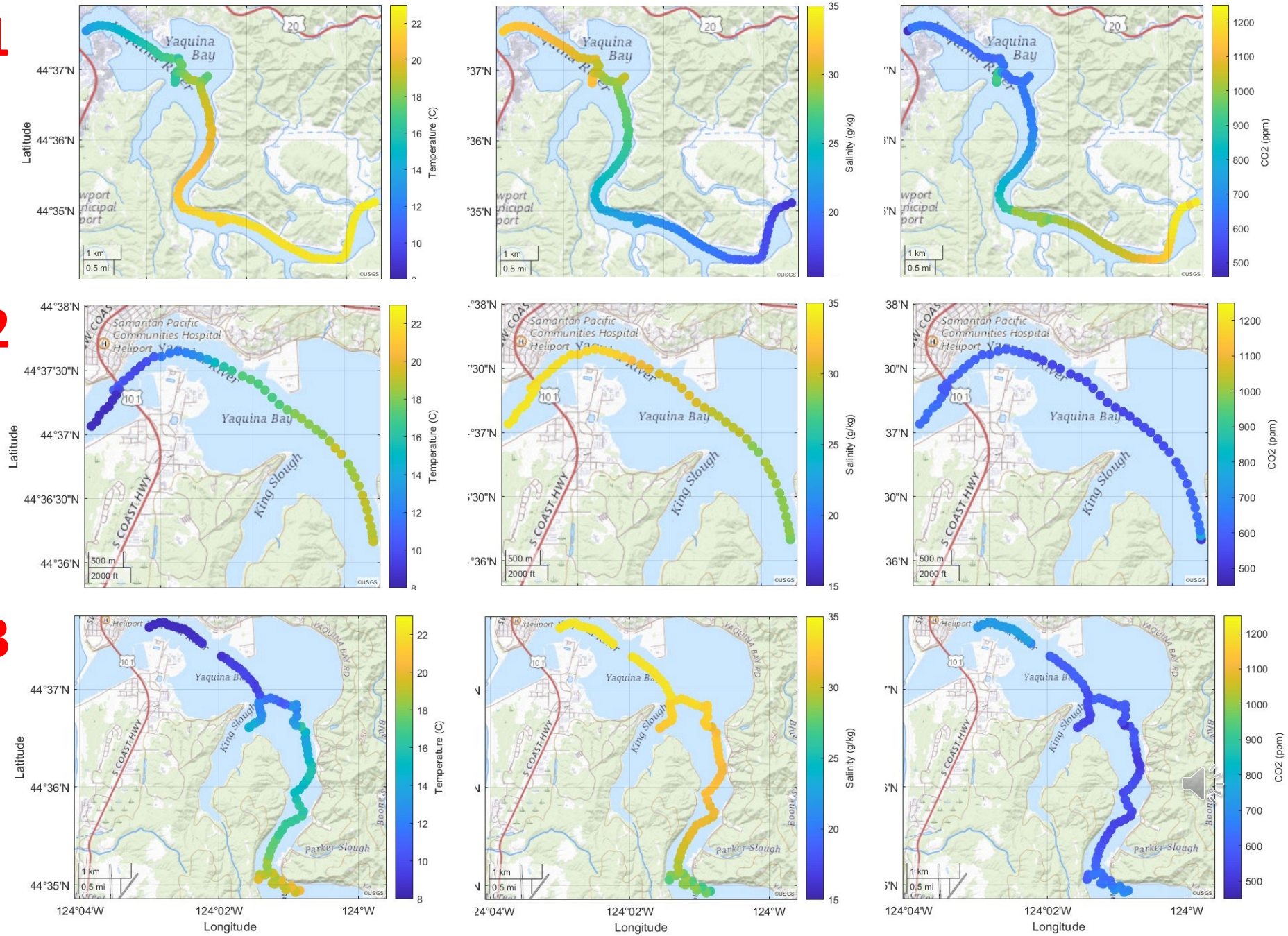


July 3 2023

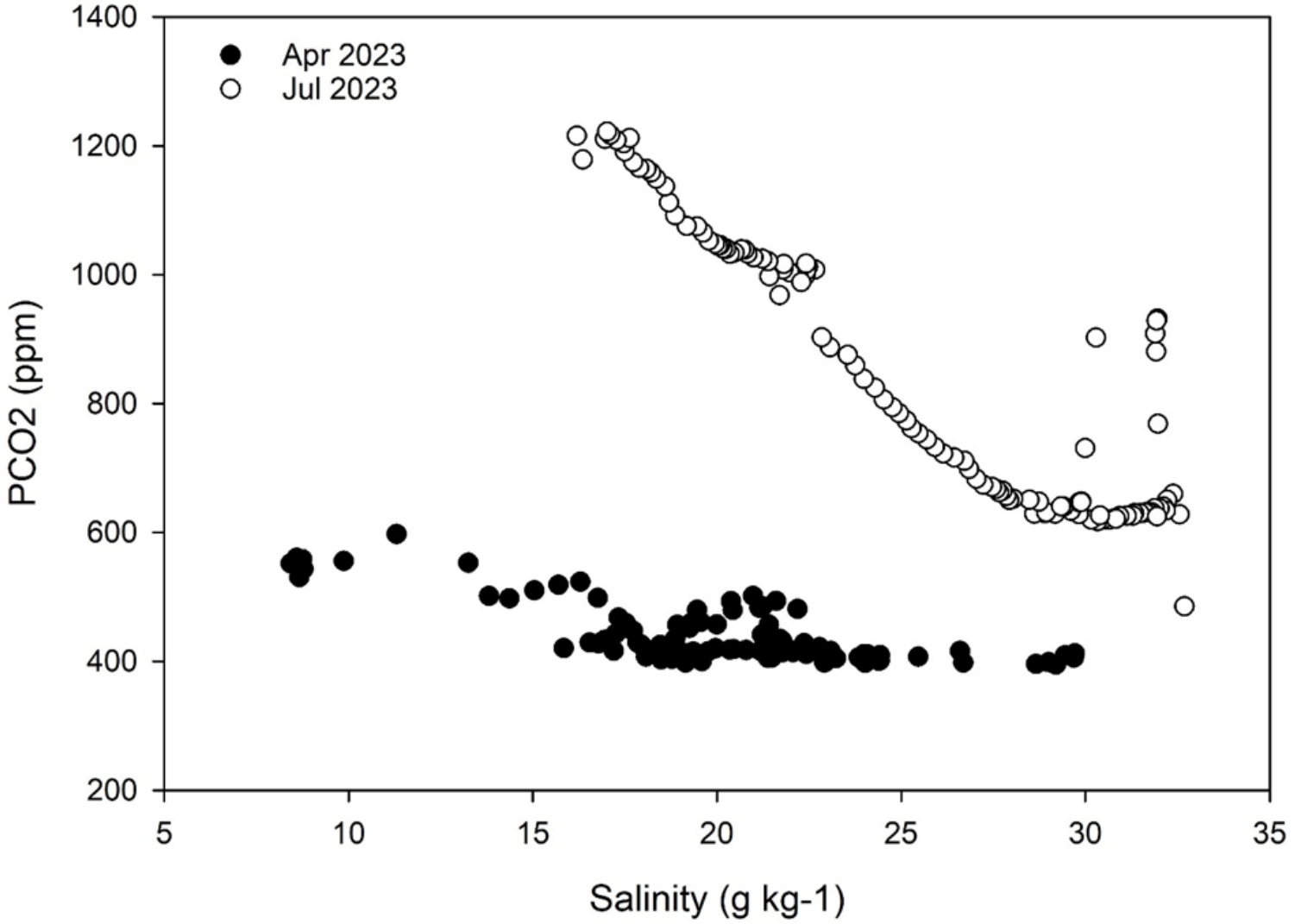
Low Tide (-2ft)
Dawn

Incoming Tide
Early morning

Nearing High tide
Mid-day



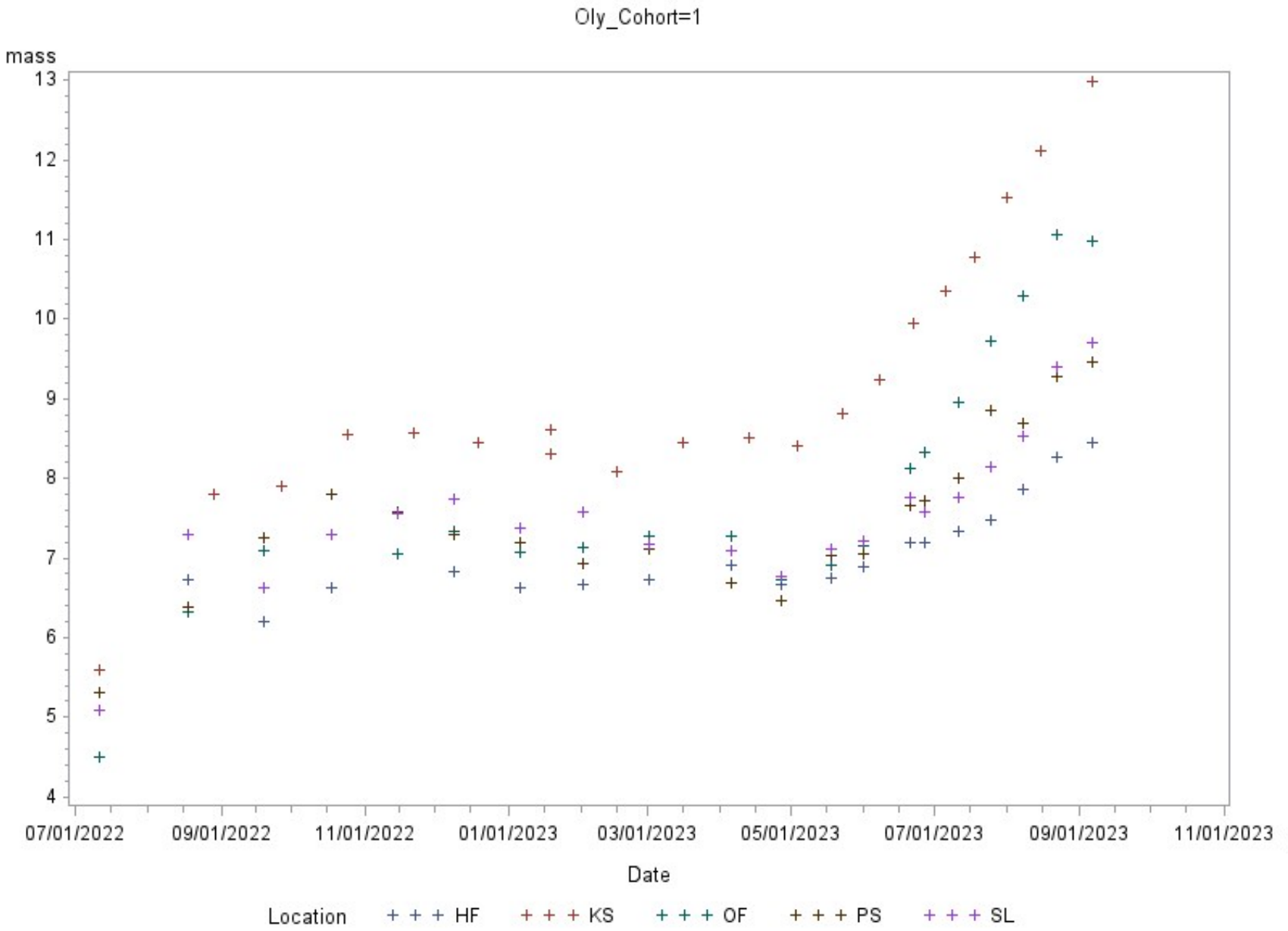
Surface PCO2, Temperature, and Salinity Surveys



Seasonal changes in estuarine gradients and within estuary processes

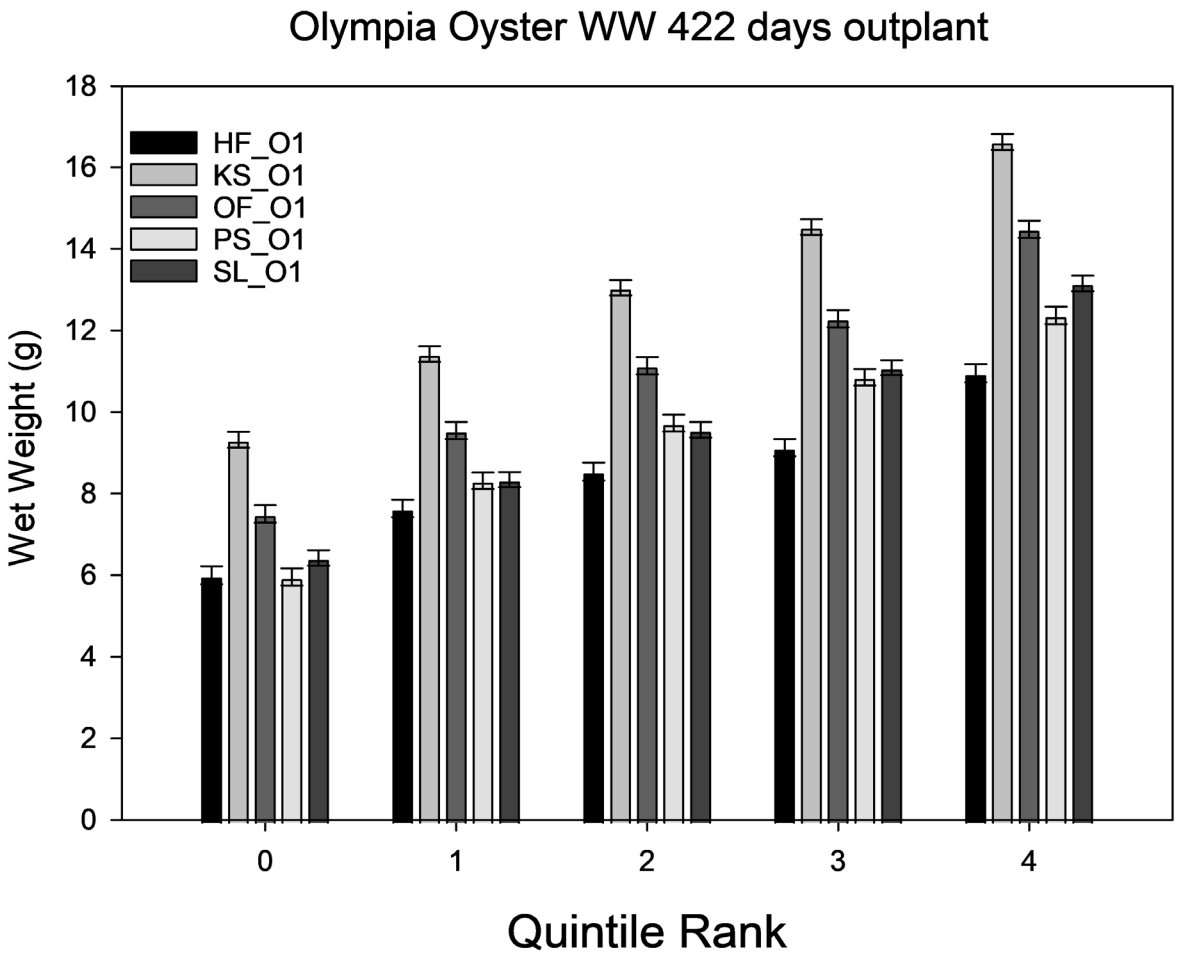
Will tide, discharge, and upwelling be able to forecast PCO2 conditions?

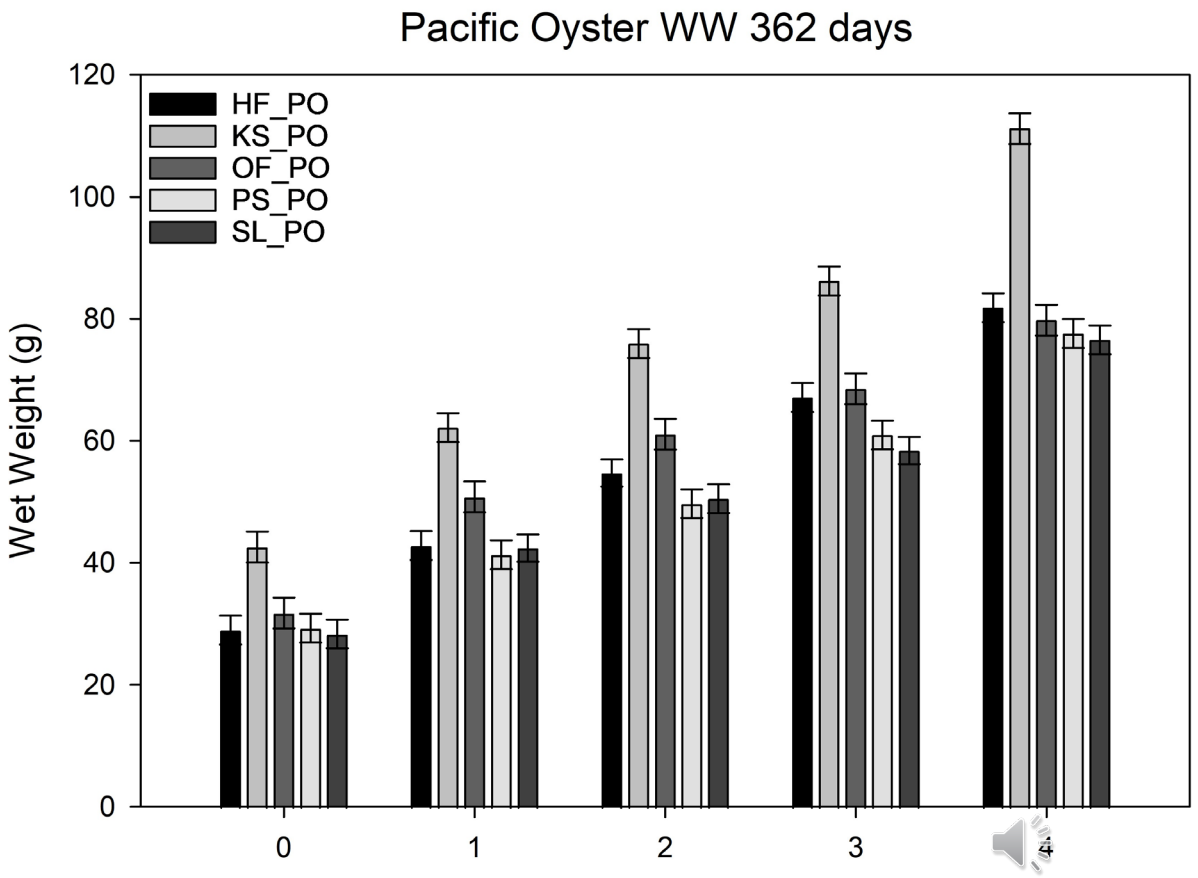
Oyster Size and Growth



Oyster Size and Growth

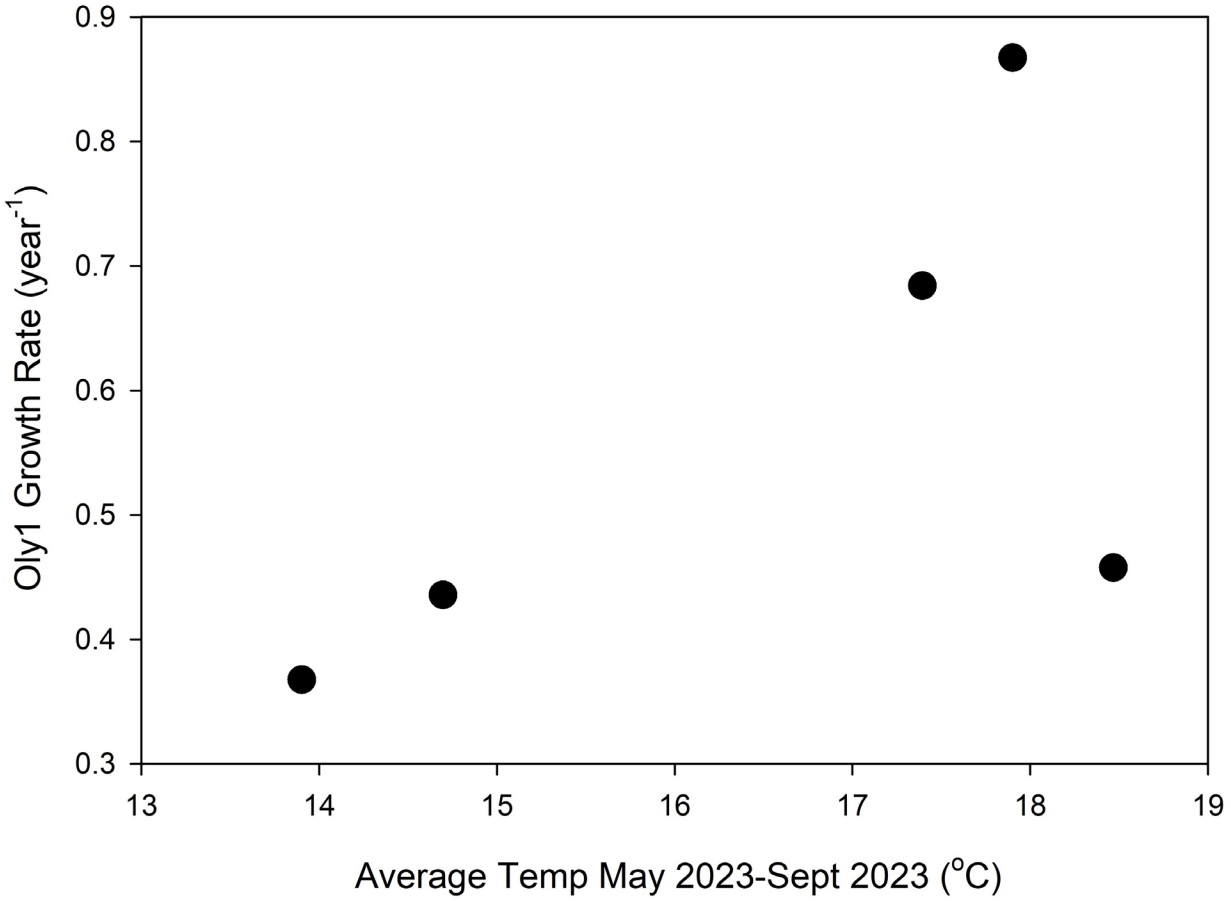
Quintile Ranks are averages of binned values

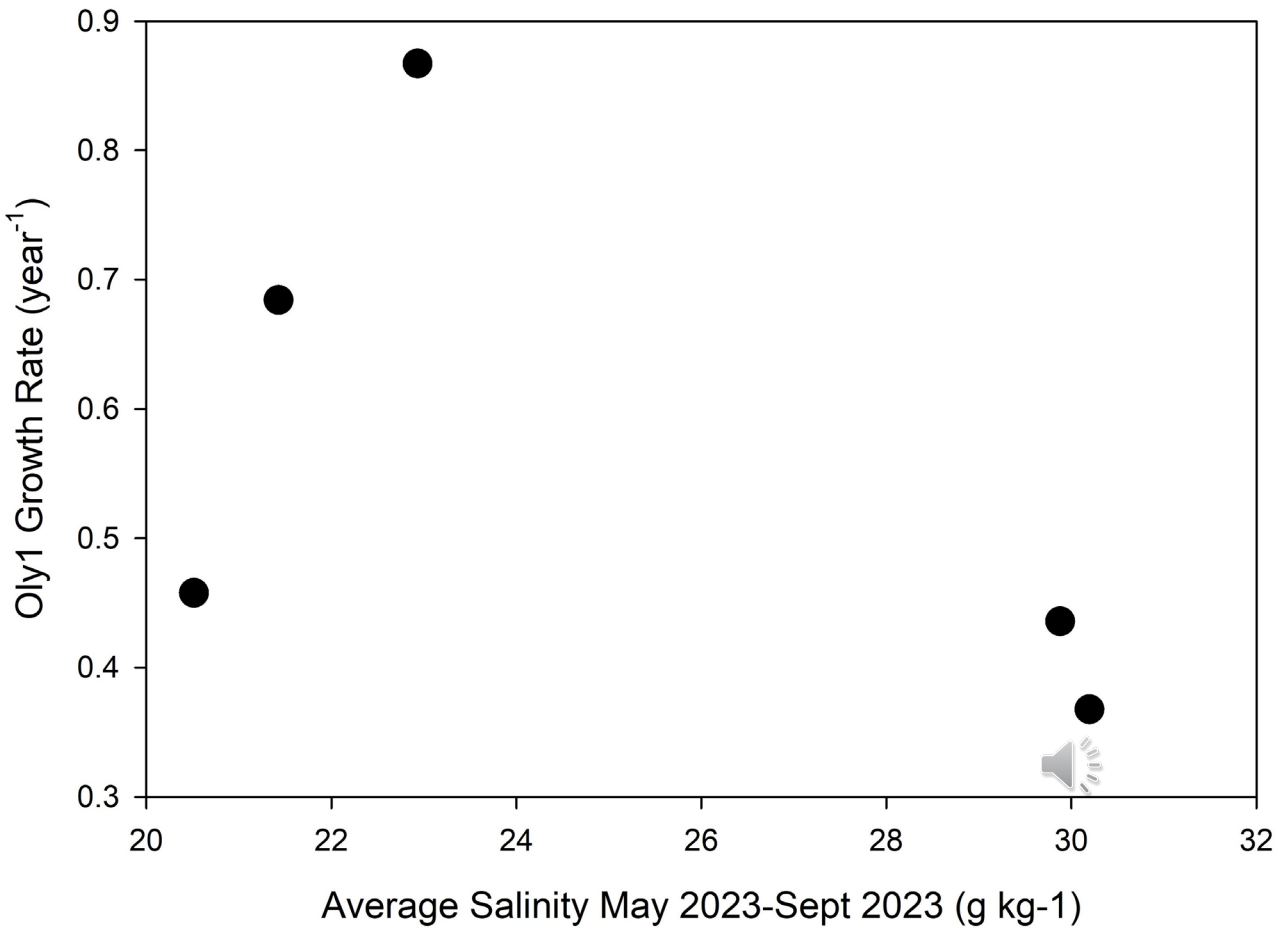




Oyster Size and Growth

Growth rate of the largest 20% of oysters at each site
Temp and salinity are just the overall mean during the growing season





Ongoing work/Status

Time Series Data:

- Temperature Data OK
- Nearing completion of QA/QC on Salinity Data (standard corrections applied, visual inspection)
- iSammi pH data nearing completion of corrections and filtering of flagged values

Discrete Samples:

- Compiling discrete sample data
- Mostly up to date on sample processing
- Beginning to combine with time series (i.e. discrete salinometer to validate sensor data)

Oyster Data:

- Close on weight data QA/QC
- Size data/images need more work (working on image classification/segmentation Nvidea helping)
- Re-run growth rate calculations (programs written)

Spatial Surveys:

- Additional runs planned to examine patterns and responses to rainfall and upwelling

Statistical Modeling:

- Some preliminary work looks promising linking environmental variables to growth
- Examine sensitivities to carbonate chemistry!
- Developing climatologies from high-frequency data (i.e. degree day models)