The Impact of Benthic Organisms on Water Filtration in the Indian River Lagoon

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NSF REU Symposium, July 2021

Outline

- Introduction
- Succession of Benthic Organisms on Living Docks
  - Progression at Melbourne Beach Pier
  - Modeling Settlement
- Calculating the Filtration Ability of Benthic Organisms
- Conclusions
- Future Work

Introduction

The Indian River Lagoon

The IRL consists of three bodies of water...

- Indian River
- Banana River
- Mosquito Lagoon

Photo credit: U. S. Fish and Wildlife Service

This creates one of the most biologically diverse estuaries in North America!

Pollution in the IRL

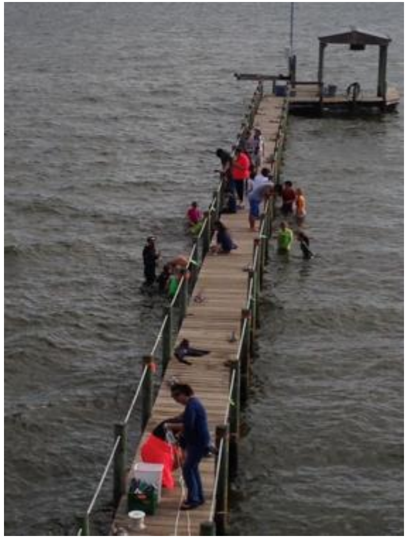
- Boom in population
- Over harvesting
- Coastline construction
- River runoff

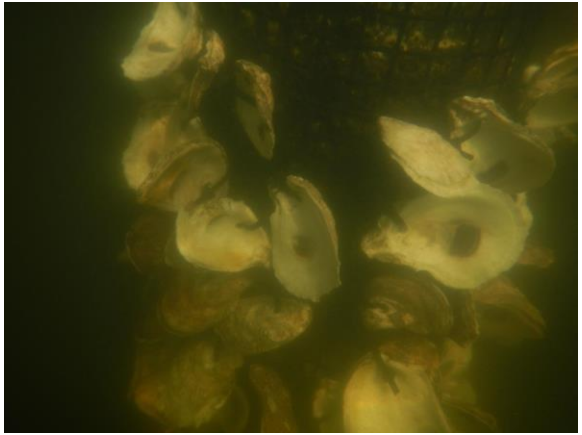
Photo credit: Amy Green

Photo credit: Bill Klein

Introduction to Living Docks

- “A community-based approach to Indian River Lagoon Restoration”
- Promote growth of benthic filter feeders in IRL
- Oyster mats to pilings





Benthic Filter Feeders

- Living on, near, or in the seabed
- Oysters known for large volume of filtering capabilities
- Remove suspended particles from water column

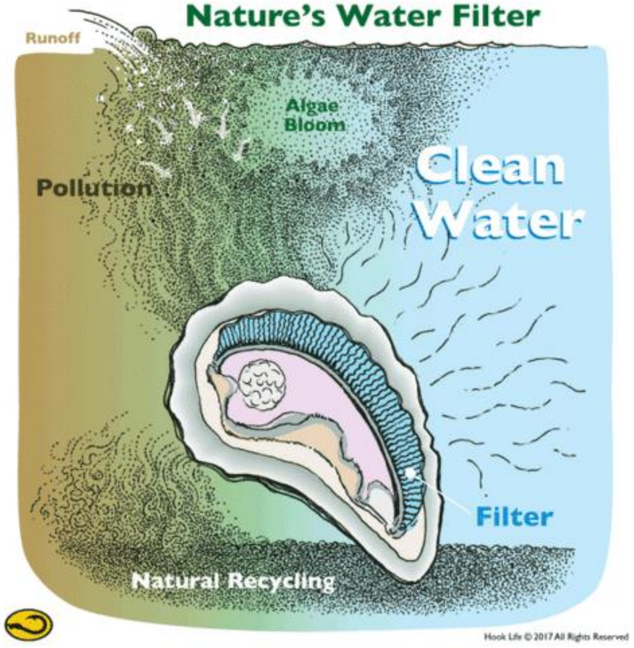


Photo credit: Intonaturesc.com

BUT, it's not just the oysters....

Barnacles

Encrusting Bryozoan

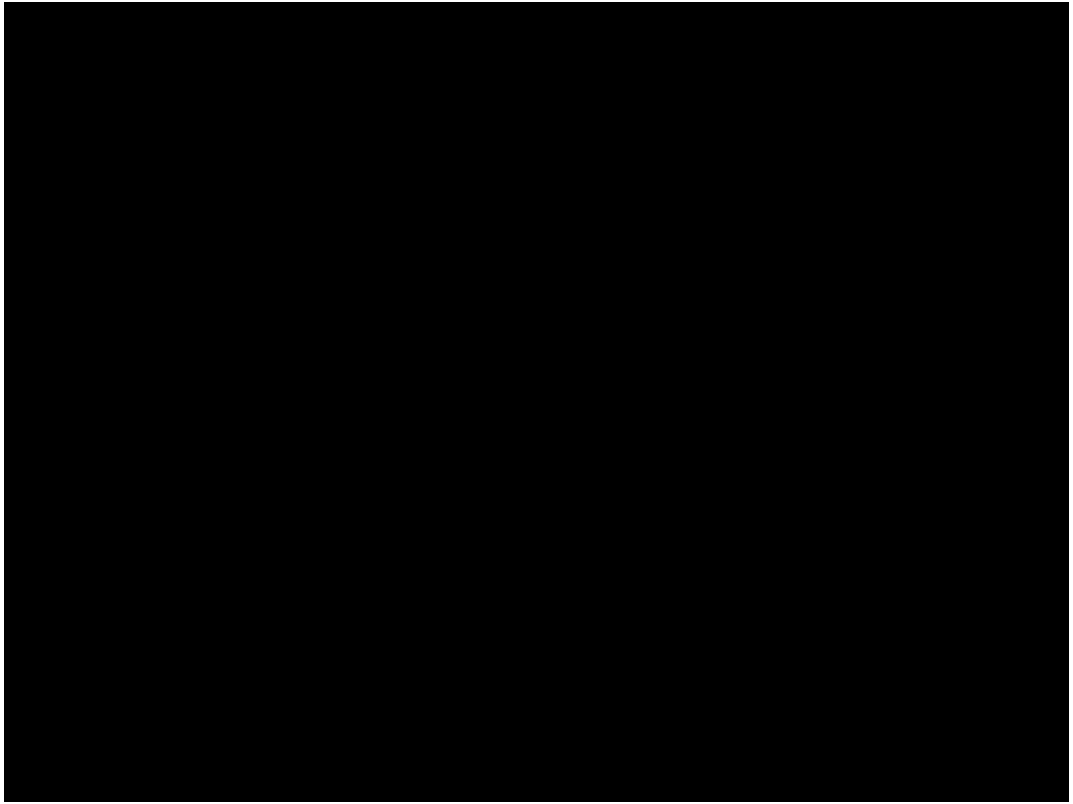
Sea squirt

Tubeworm

Sponge

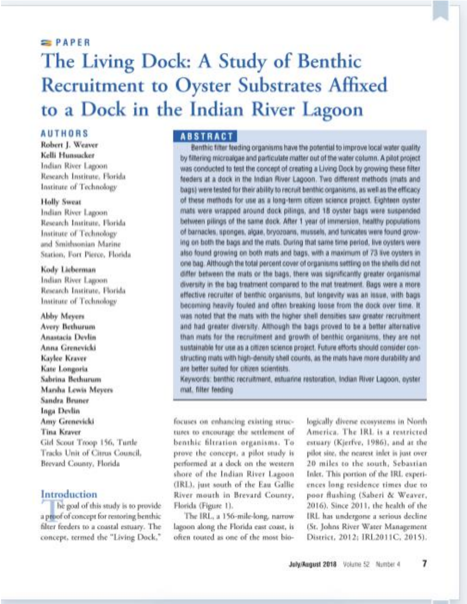
Mussels

Living Dock Benthic Filtration



Literature Review

- History of Living Docks program
- What has worked in the past


PAPER

The Living Dock: A Study of Benthic Recruitment to Oyster Substrates Affixed to a Dock in the Indian River Lagoon

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ABSTRACT

Benthic filter feeding organisms have the potential to improve local water quality by filtering microalgae and particulate matter out of the water column. A pilot project was conducted to test the concept of creating a Living Dock by growing these filter feeders at a dock in the Indian River Lagoon. Two different methods (mats and bags) were tested for their ability to recruit benthic organisms, as well as the efficacy of these methods for use as a long-term citizen science project. Eighteen oyster mats were wrapped around dock pilings, and 18 oyster bags were suspended between pilings of the same dock. After 1 year of immersion, healthy populations of barnacles, sponges, algae, bryozoans, mussels, and tunicates were found growing on both the bags and the mats. During that same time period, live oysters were also found growing on both mats and bags, with a maximum of 73 live oysters in one bag. Although the total percent cover of organisms settling on the shells did not differ between the mats or the bags, there was significantly greater organismal diversity in the bag treatment compared to the mat treatment. Bags were a more effective recruiter of benthic organisms, but longevity was an issue, with bags becoming heavily fouled and often breaking loose from the dock over time. It was noted that the mats with the higher shell densities saw greater recruitment and had greater diversity. Although the bags proved to be a better alternative than mats for the recruitment and growth of benthic organisms, they are not sustainable for use as a citizen science project. Future efforts should consider constructing mats with high-density shell counts, as the mats have more durability and are better suited for citizen scientists.

Keywords: benthic recruitment, estuarine restoration, Indian River Lagoon, oyster mat, filter feeding

Introduction

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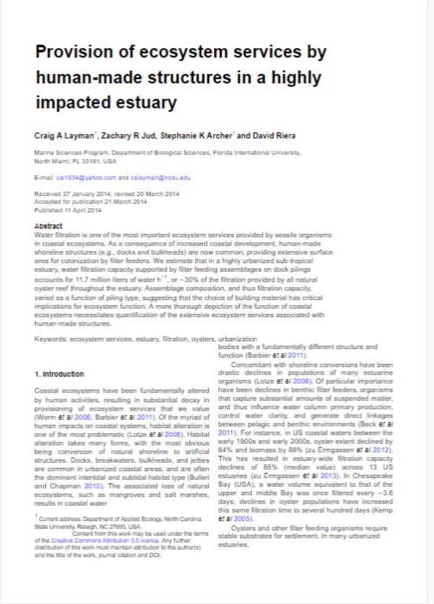
Provision of ecosystem services by human-made structures in a highly impacted estuary

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Abstract

Water filtration is one of the most important ecosystem services provided by sessile organisms in coastal ecosystems. As a consequence of increased coastal development, human-made shoreline structures (e.g., docks and bulkheads) are now common, providing extensive surface area for colonization by filter feeders. We estimate that in a highly urbanized sub-tropical estuary, water filtration capacity supported by filter feeding assemblages on dock pilings accounts for 11.7 million liters of water h^{-1}, or ~30% of the filtration provided by all natural oyster reef throughout the estuary. Assemblage composition, and thus filtration capacity, varied as a function of piling type, suggesting that the choice of building material has critical implications for ecosystem function. A more thorough depiction of the function of coastal ecosystems necessitates quantification of the extensive ecosystem services associated with human-made structures.

Keywords: ecosystem services, estuary, filtration, oysters, urbanization

1. Introduction

Research Question

How can benthic filter feeding organisms help alleviate algal blooms and other suspended particles due to climate change / human impacts?

Hypothesis

The water temperature, turbidity, and salinity of an area in the lagoon contributes to the growth of organisms and subsequently affects settlement

Projects

Project 1: Succession of Benthic Organisms on Living Docks

Project 2: Calculate the Filtration Ability of the Benthic Organisms

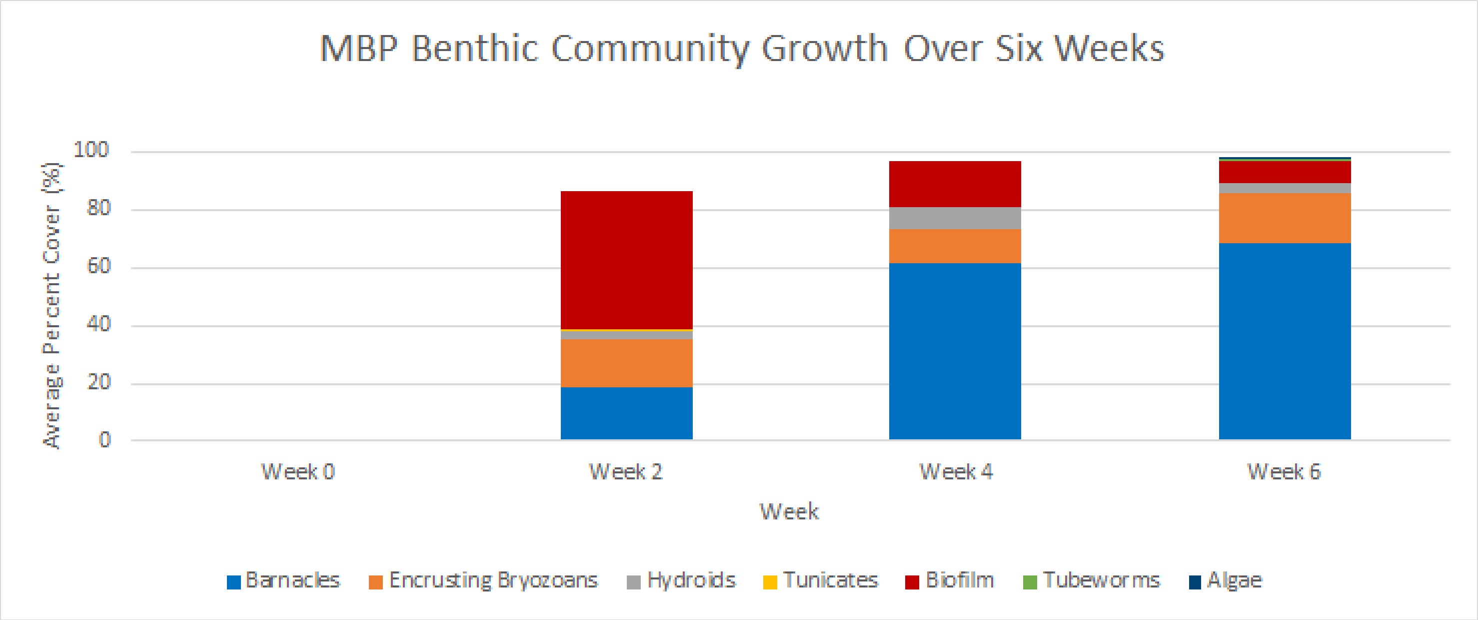
Project 1: Succession of Benthic Organisms on Living Docks

Making our Own Oyster Mat

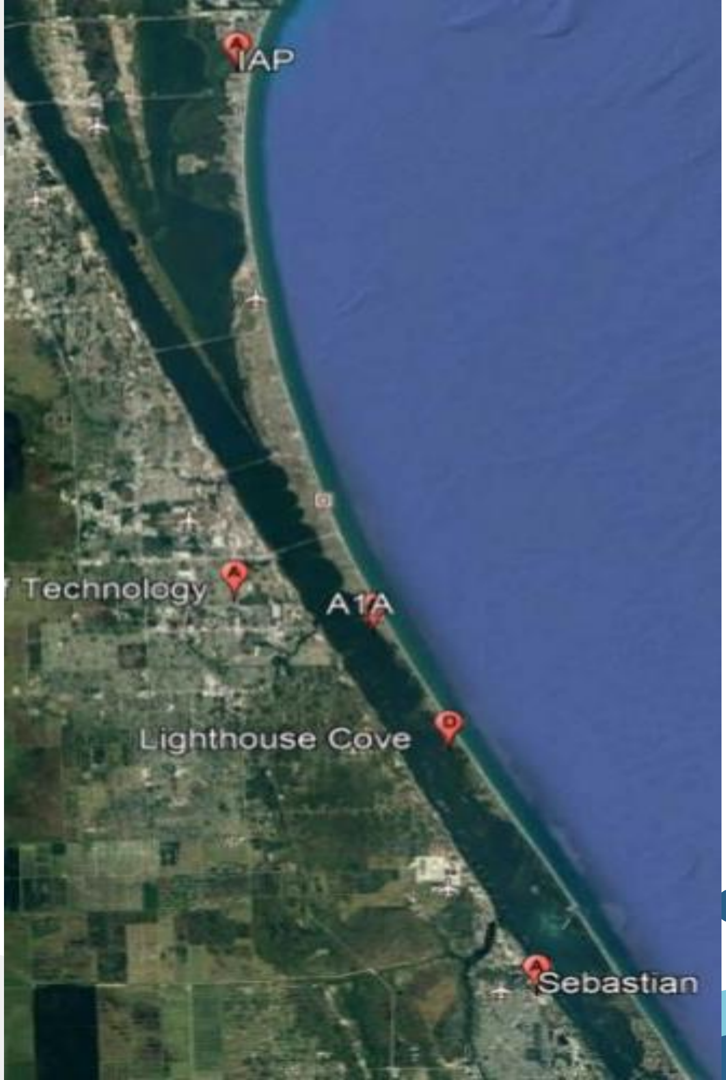
Progression at Melbourne Beach Pier

Week 0 vs Week 2 vs Week 4 vs Week 6

MBP Project Results



Existing Living Docks Visited during Summer 2021



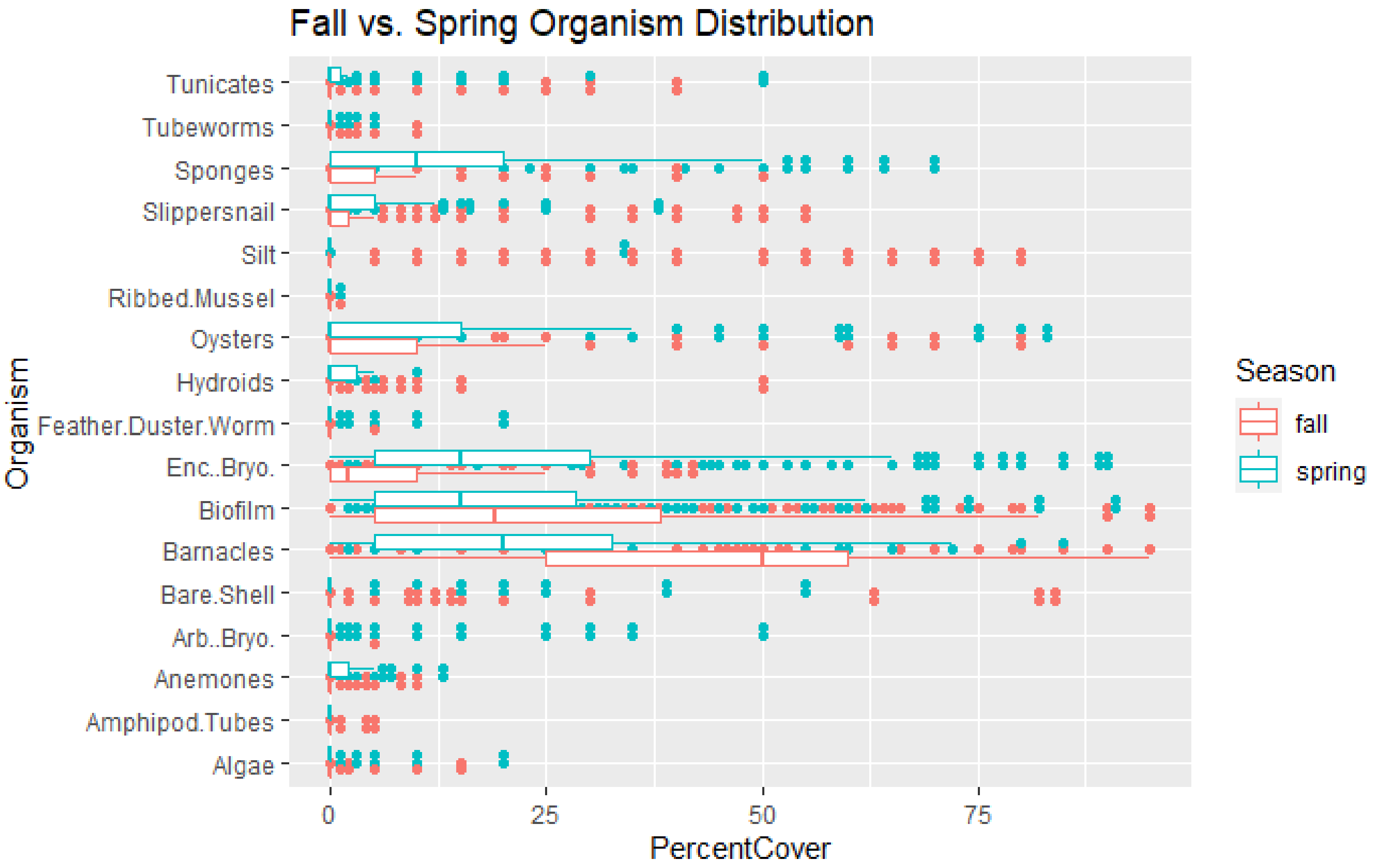
A1A

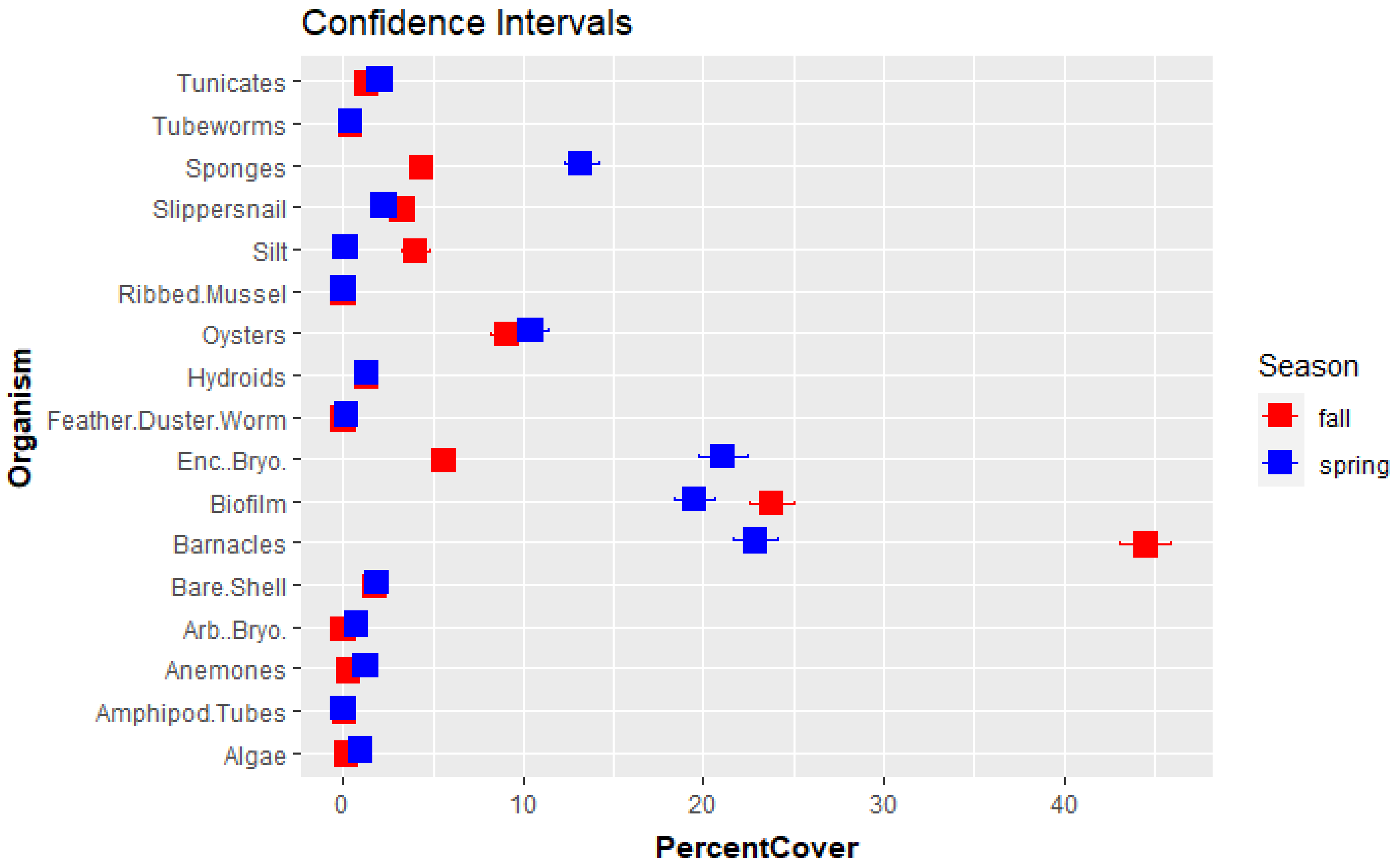
IAP

Lighthouse Cove

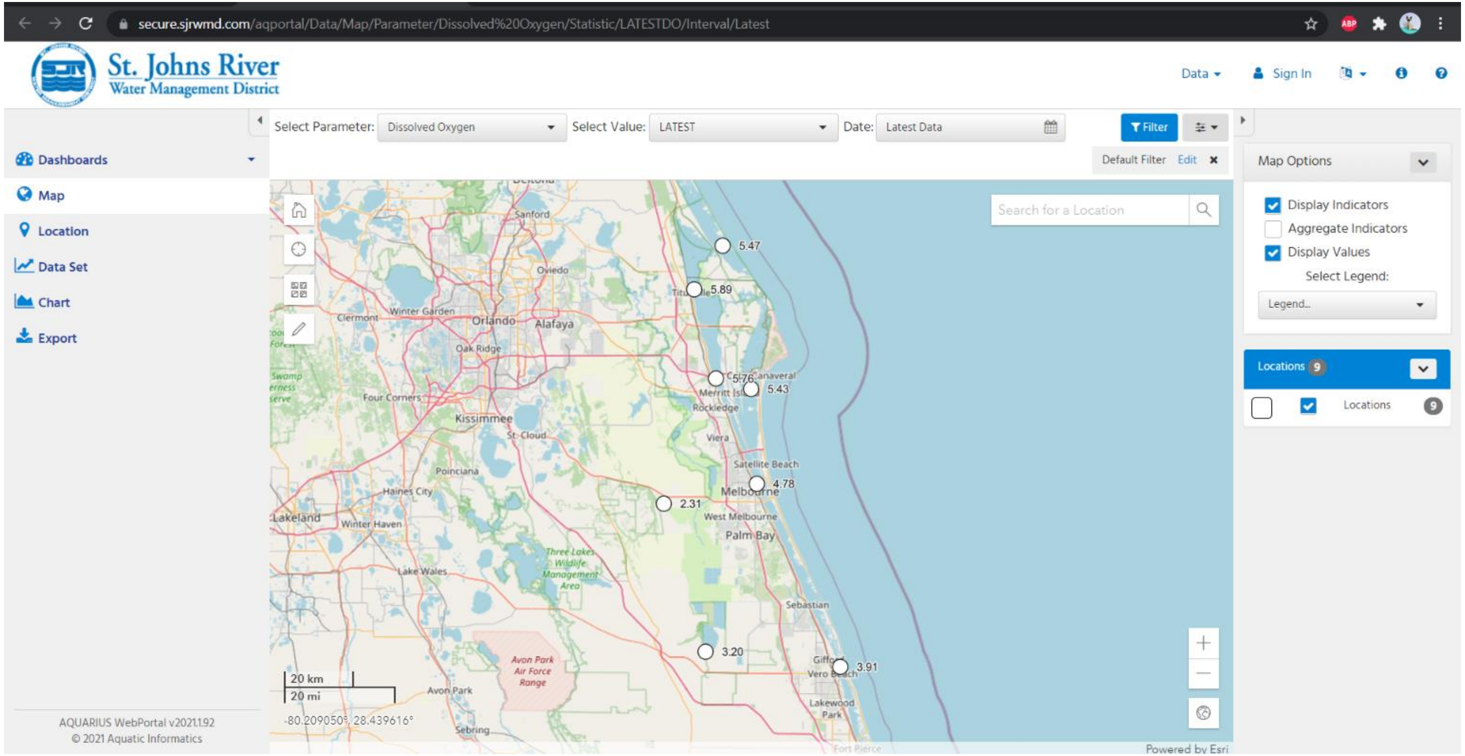
Sebastian

Living Docks Data

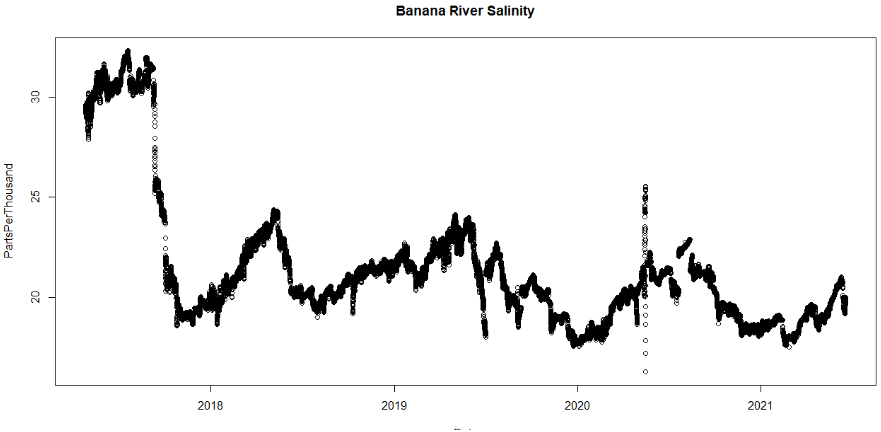

Fall vs. Spring Organism Distribution
Tunicates
Tubeworms
Sponges
Slippersnail
Silt
Ribbed.Mussel
Oysters
Hydroids
Feather.Duster.Worm
Enc..Bryo.
Biofilm
Barnacles
Bare.Shell
Arb..Bryo.
Anemones
Amphipod.Tubes
Algae
Organism
0
25
50
75
PercentCover
Season
fall
spring

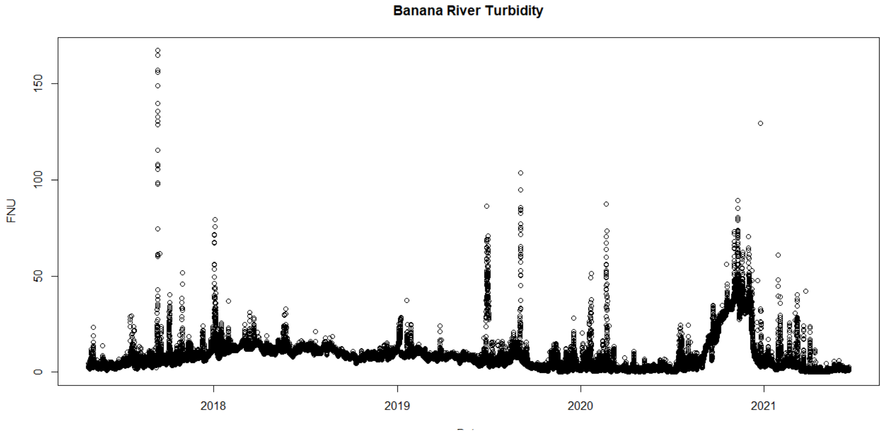

Confidence Intervals
Tunicates
Tubeworms
Sponges
Slippersnail
Silt
Ribbed.Mussel
Oysters
Hydroids
Feather.Duster.Worm
Enc..Bryo.
Biofilm
Barnacles
Bare.Shell
Arb..Bryo.
Anemones
Amphipod.Tubes
Algae
Organism
0
10
20
30
40
PercentCover
Season
fall
spring

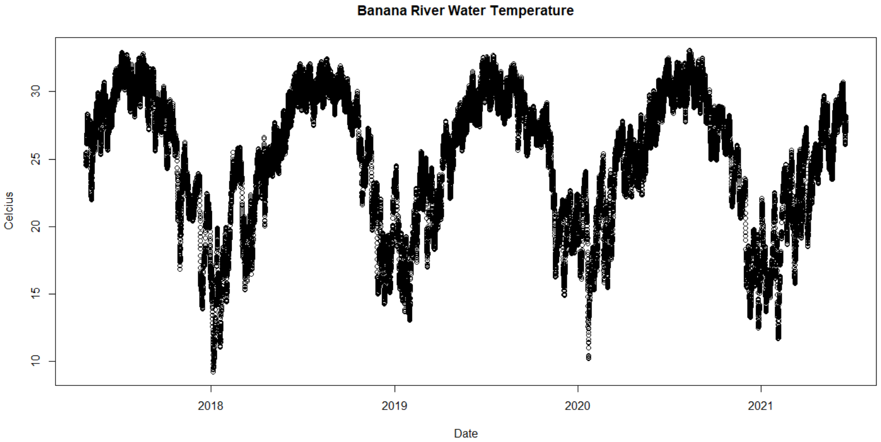
Water Quality Data Acquired from St. Johns River Water Management

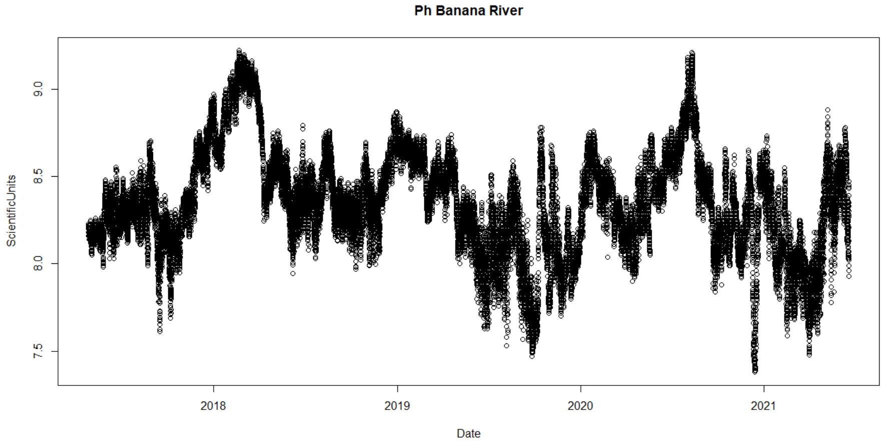


Example Raw Water Station Data

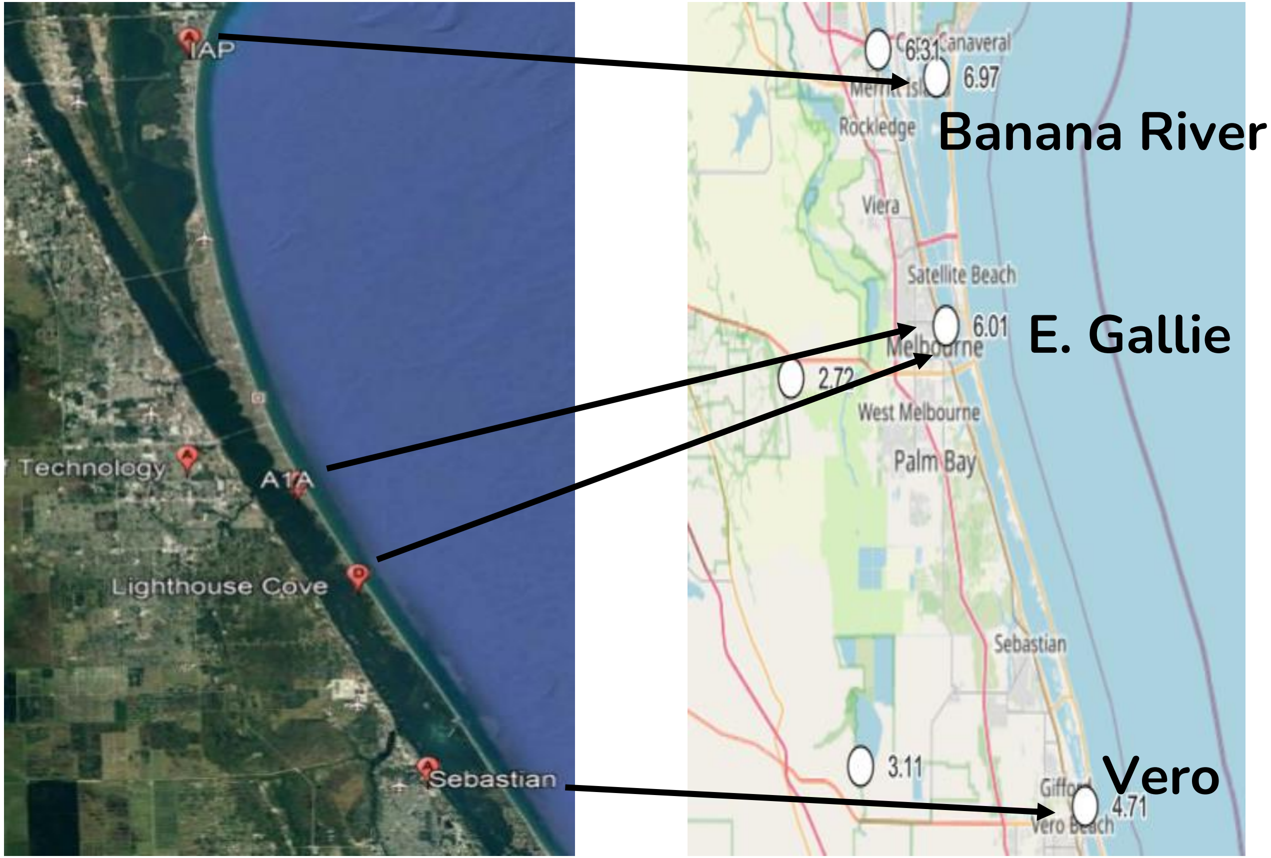








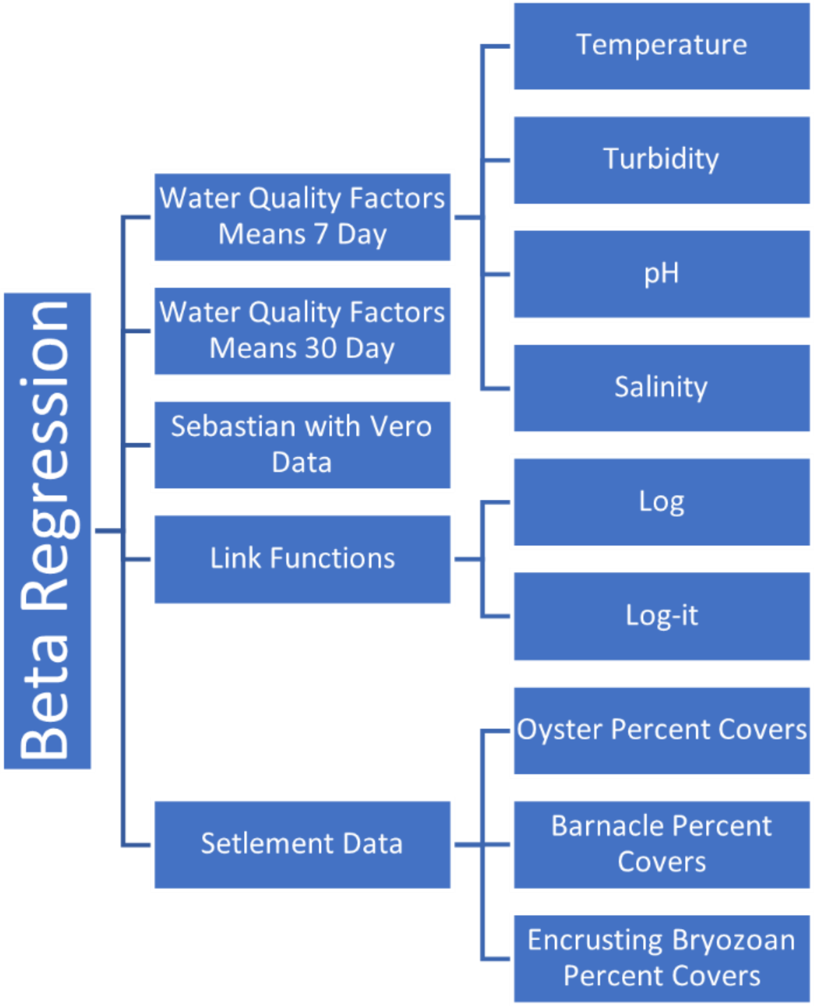
Living Docks and Correlating Water Station



Modeling Settlement

Beta Regression

- Data was percents, on interval (0,1)
- Betareg package in R
- Useful for finding patterns within data, making predictions


Beta Regression
Water Quality Factors Means 7 Day
Water Quality Factors Means 30 Day
Sebastian with Vero Data
Link Functions
Setlement Data
Temperature
Turbidity
pH
Salinity
Log
Log-it
Oyster Percent Covers
Barnacle Percent Covers
Encrusting Bryozoan Percent Covers

Barnacle Growth Best Models

Model	Pseudo r^2	AIC	p-value (phi coefficient)	Significant Observations
Barnacles ~ Dock + Season + pH + Salinity + Temperature + Turbidity, Log-link Function, 7-Day Means	0.2941	-602.9704	<2e-16	Dock, salinity, turbidity, almost season almost temperature
Barnacles ~ Dock + Season + pH + Salinity + Temperature + Turbidity, Logit-link Function, 30-Day Means	0.3098	-595.731	<2e-16	Dock, salinity, turbidity

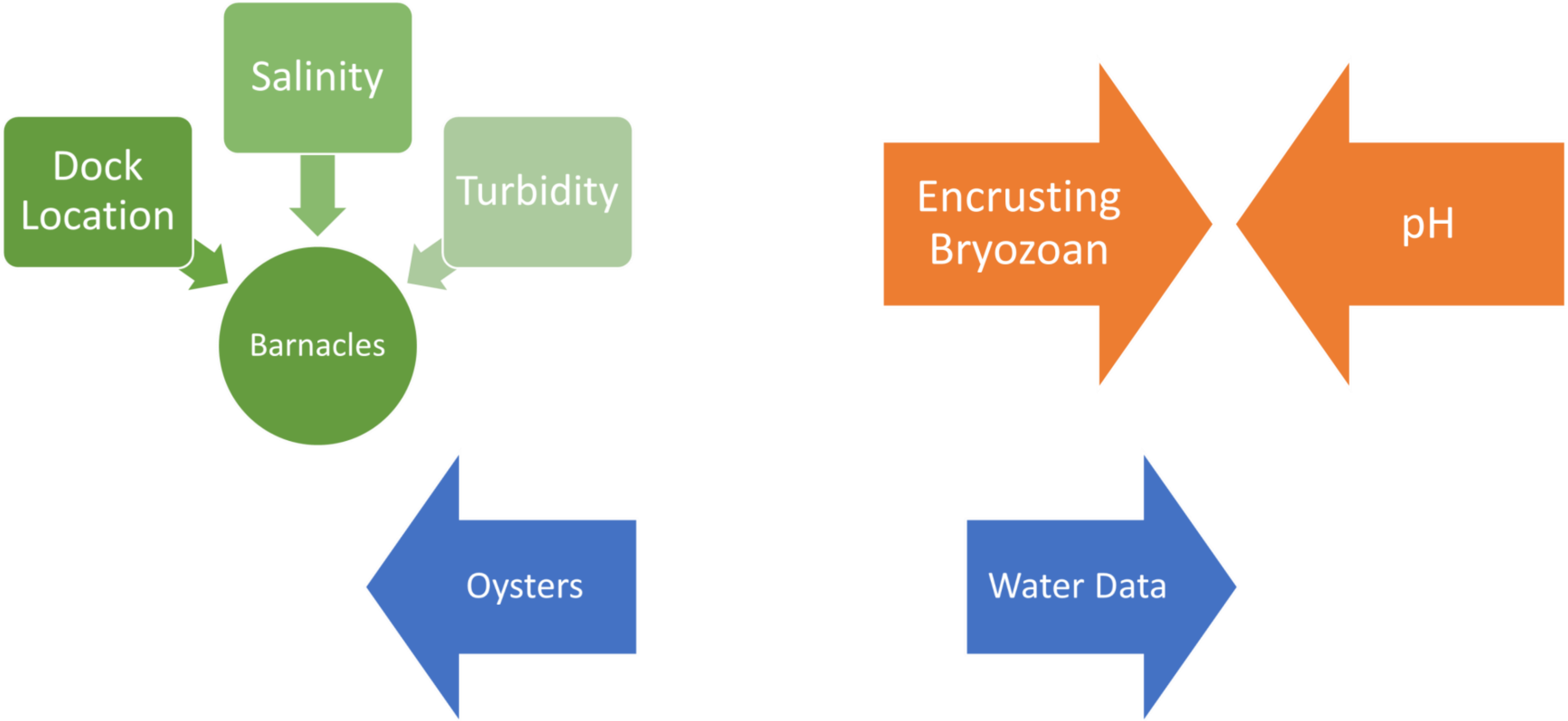
Oyster Growth Best Models

Model	Pseudo r^2	AIC	p-value (phi coefficient)	Significant Observations
Oysters ~ Dock + Season + pH + Salinity + Temperature + Turbidity, Log-link Function, 7-Day Means, Vero data for Sebastian	0.3555	-3032.185	<2e-16	Only dock and season significant
Oysters ~ Dock Log-link Function, 7-Day Means	0.352	-3039.451	<2e-16	Dock

Encrusting Bryozoan Growth Best Models

Model	Pseudo r^2	AIC	p-value (phi coefficient)	Significant Observations
Encrusting Bryozoans ~ Dock + Season + pH + Salinity + Temperature + Turbidity, Logit-link Function, 7-Day Means	0.3189	-2264.38	<2e-16	Dock, season, pH, salinity, almost temp almost turbidity
Encrusting Bryozoans ~ Dock + Season + pH + Salinity + Temperature + Turbidity, Log-link Function, 7-Day Means Vero data used for Sebastian	0.2997	-2265.164	<2e-16	Dock, season, pH and temperature significant

Beta Regression Patterns



Model Discussion

Oyster

- Southernmost parts of the lagoon foster more oyster settlement
- Data shows less oyster growth in northern IRL

Encrusting Bryozoan

- Acidity of the water impacts the growth
- Favors cooler water temperatures
- Seasonal preferences

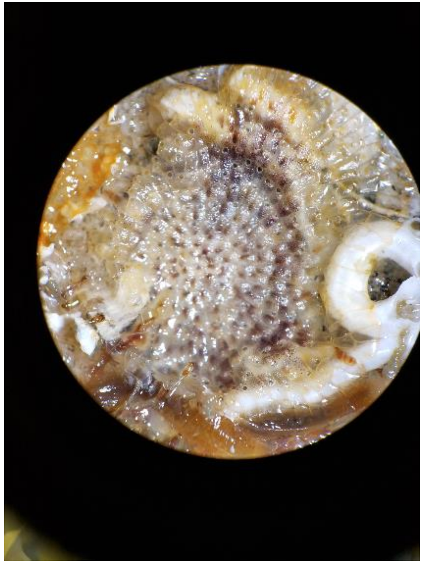
Barnacles

- Feeding rates are dependent on turbidity
- Preferred ranges of both salinity and temperature

Project 2: Calculate the Filtration Ability of the Benthic Organisms

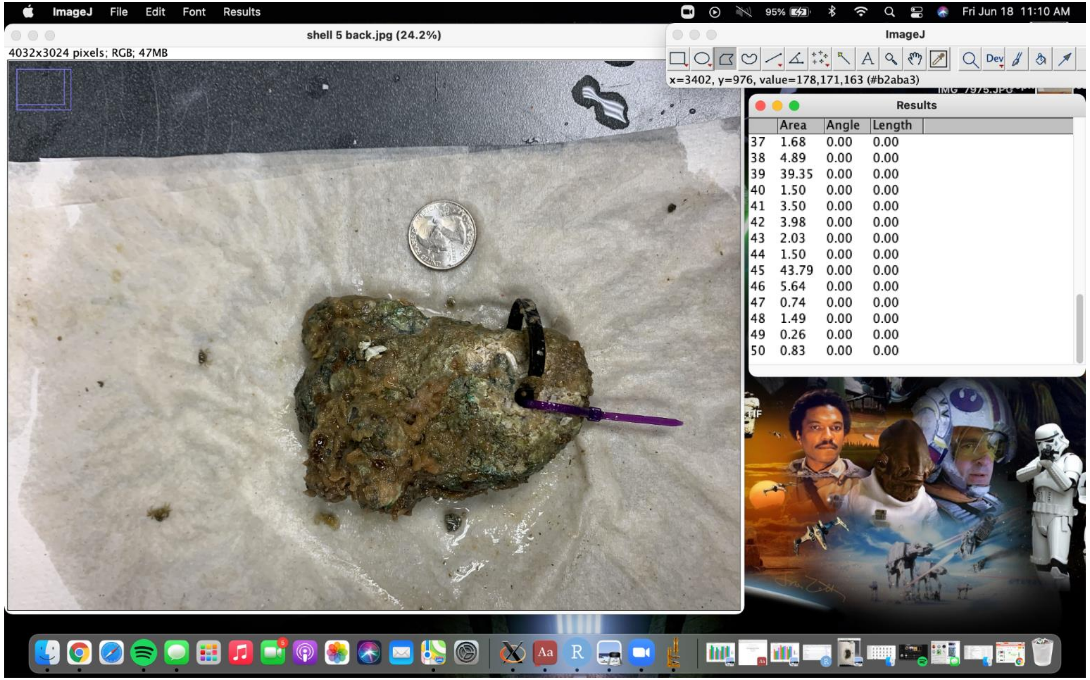
Estimating Dock Filtration

- 10 shells collected from IAP and Lighthouse Cove docks
- Harvesting organisms
    - Barnacles
    - Encrusting Bryozoans

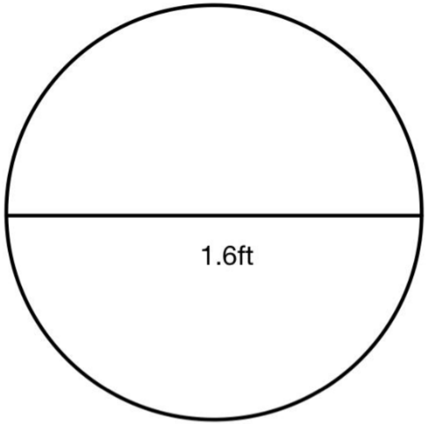


Imagej and Encrusting Bryozoan Filtration

1	Shell	Total Surface Area	SA covered
2	BGreen	65.53	26.37
3	FGreen	78.62	18.63
4	BNone	67.03	6.37
5	FNone	60.12	13.65
6	BAqua	64.06	12.14
7	FAqua	62.73	13.39
8	BAquaPink	39.35	12.51
9	FAquaPink	43.79	8.95
10	BPurple	65.44	5.78
11	FPurple	68.76	18.01
12	BPink	40.52	7.31
13	FPink	41.55	2.24
14	BRed	83.4	10.48
15	FRed	89.03	7.85
16	BPurpleGreen	45.9	3.47
17	FPurpleGreen	48.73	2.17
18	BYellow	42.31	5.55
19	FYellow	41.33	0
20	BYellowRed	42.83	2.24



Encrusting Bryozoan Filtration Calculations



Filter: 2000 gallons per day

↓

$$\frac{2{,}000{,}000 \text{ zooids}}{1 \text{ day}}$$

$\text{Area} = \pi r^2$

$\text{Area} = \pi \left(\frac{1.6}{2}\right)^2$

$\text{Area} = 2.01 ft^2$

$ft^2 \rightarrow cm^2$

$1 ft^2 = 929 cm^2$

$2.01 ft^2 = 1867.351 cm^2$

Filtration Calculation

$$\frac{20.2 \text{ cm}^2}{1 \text{ shell}} \times \frac{2000 \text{ gallons}}{1867.93 \text{ cm}^2} \times \frac{1 \text{ day}}{24 \text{ hours}} \times \frac{3.7 \text{ L}}{1 \text{gallon}} = 3.3344 \text{ L/h}$$

Barnacle Filtration Calculation

$$\frac{\text{Total number of barnacles}}{\text{1 shell}} \cdot 0.1 \text{ L/h}$$

Dock Filtration Calculation

$$\frac{4.021\ L}{1\ h * 1\ shell} * \frac{70\ shells}{1\ mat} * \frac{20\ mats}{IAP\ dock} = 8{,}347.716\frac{L}{h}$$

$$\frac{5.963\ L}{1\ h * 1\ shell} * \frac{70\ shells}{1\ mat} * \frac{50\ mats}{LHC\ dock} = 14{,}073.569\frac{L}{h}$$

Comparing Filtration

Lighthouse Cove

- 30 more mats than IAP
- Fewer barnacles than IAP
- Less area of encrusting bryozoan than IAP

IAP

- 30 less mats than LHC
- More barnacles than LHC
- Greater area of encrusting bryozoan than LHC

Conclusions

Project 1 Conclusions:

Organisms have seasonal preferences, and the location of the docks within the Indian River Lagoon impacts settlement.

Project 2 Conclusions:

Expanding the Living Docks program and implementing more mats will facilitate mass benthic organism filtration within the Indian River Lagoon.

Future Work

- Regression model
  - Optimizing model date retrieval
  - Incorporating organism temperature and salinity preferences
- Continue dock assessments
- Extrapolate the filtration rates to more docks in the lagoon

References

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