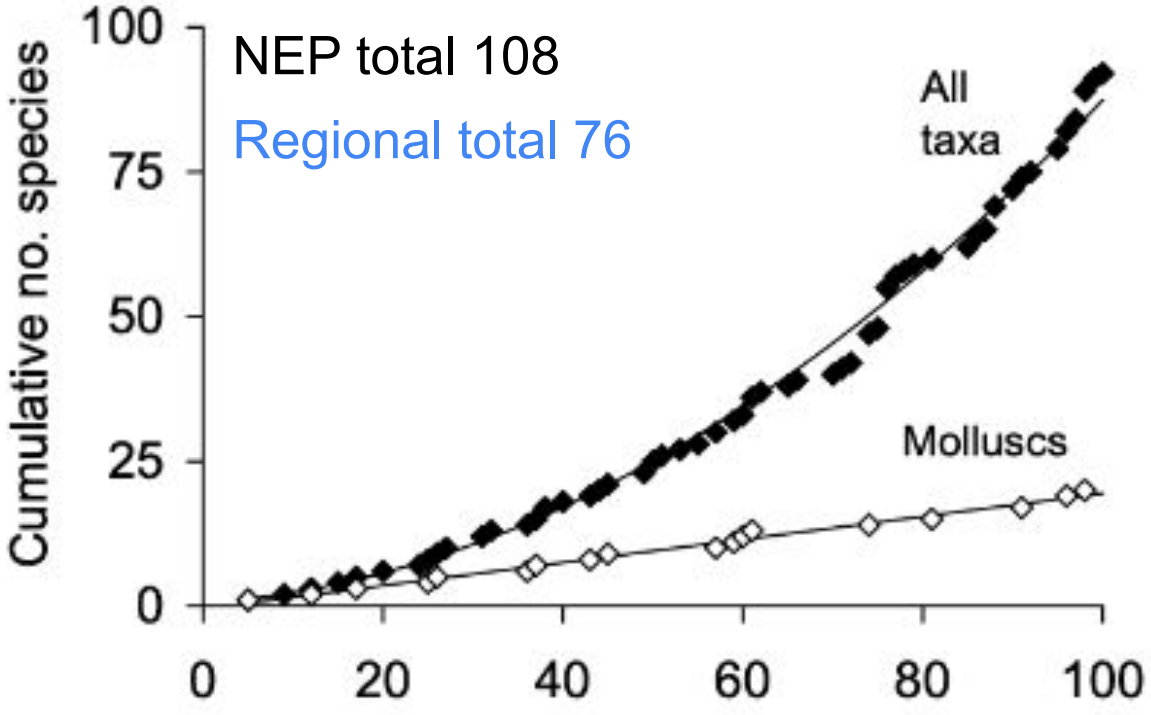
Biotic Resistance to Multiple Bioinvaders: A Case Study

Authors (alphabetical): Trevan Bischoff, Chase Cantu, Avantika Dutt, Jonas Ecker, Tatiana Egbert, Spencer Hill, Ellie In, Rory Kliewer, Justin Kwok, Bryan Lemus, Marco Martinez, Serena Miewald, Ellen Pak, Owen Proulx, Kate Robertson, Kate Stevens, McKenna Sweet, Nick Ward.

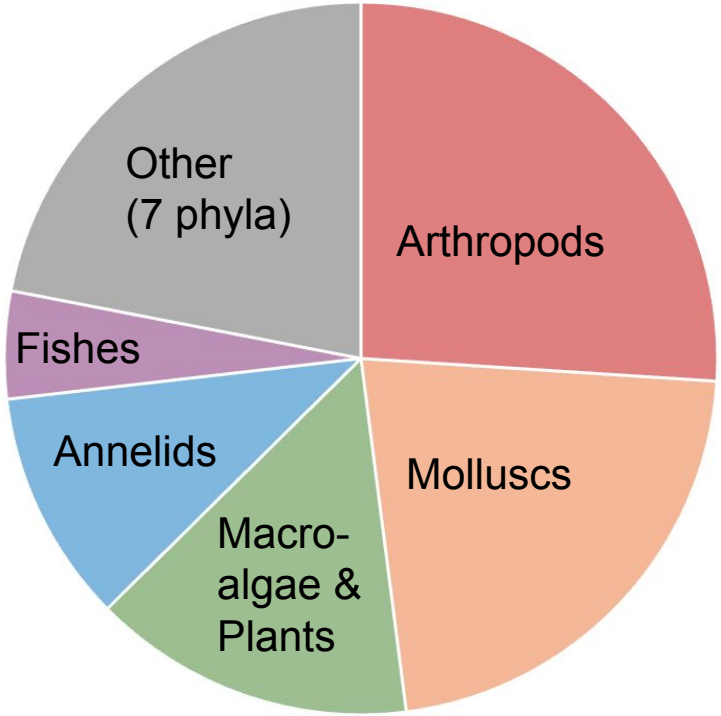
FHL 470, Novel Marine Ecosystems
Marjorie Wonham, Indra Behar, Rachel Merz

Bioinvasions are increasing in NE Pacific

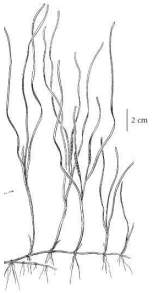


Wonham & Carlton 2005

Regional bioinvasions bring benefits and concerns

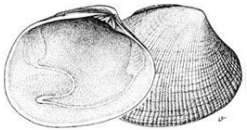


Wonham & Carlton 2005



Japanese eelgrass *Zostera japonica*

Cordgrass *Spartina* spp.



Japanese littleneck *Ruditapes philippinarum*

"sea vomit" tunicate *Didemnum vexillum*

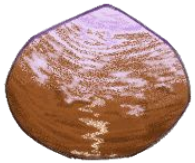
Pacific oyster *Magallana gigas*

Eurasian green crab *Carcinus maenas*

https://www.fao.org/fishery/docs/CDrom/aquaculture/I1129m/file/en/en_japanesecarpetshell.htm
https://www.fao.org/fishery/docs/CDrom/aquaculture/I1129m/file/en/en_pacificcuppedoyster.htm
https://bavnature.org/2012/10/15/marine-vomit-coho-fry-and-a-malicious-killing/
https://www.alamy.com/stock-photo/spartina.html?imgt=8&sortBy=relevant
https://www.whatcomcountymrc.org/projects/european-green-crab/
https://linnet.geog.ubc.ca/Atlas/Atlas.aspx?sciname=Zostera%20japonica&noTransfer=0

NE Pacific bioinvaders at (or coming to) Argyle Beach, SJI

Nuttallia obscurata
(mahogany/purple varnish clam)
1990s via ballast water



Ruditapes philippinarum
(Manila clam)
1920s via ballast water

Carcinus maenas
(Eurasian green crab)
* In SJIs but not yet here *

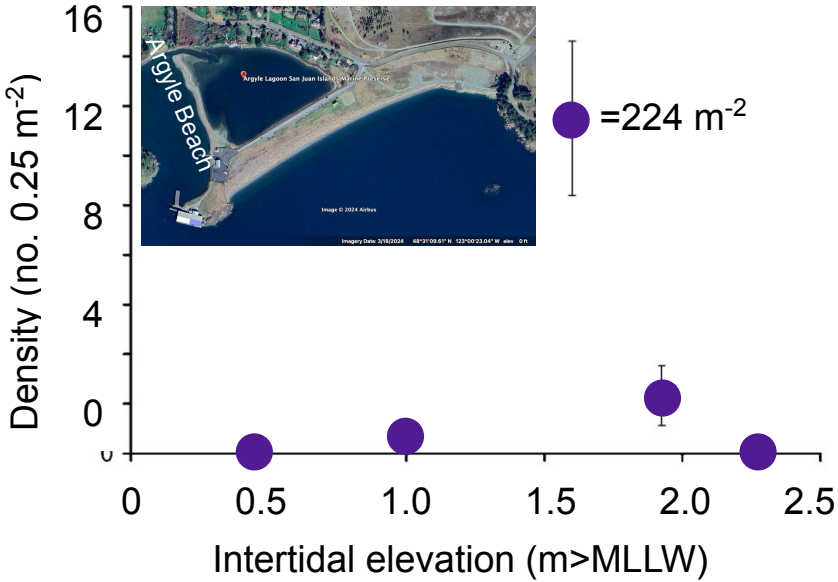
Clams: Ellen Pak; Crabs: R. Hibpshman, https://www.whatcomcountymrc.org/projects/european-green-crab/

Varnish clam poses a bioinvasion/resistance puzzle

NWP to NEP 1990s, via ballast water
Very successful! (800 m^{-2} !)

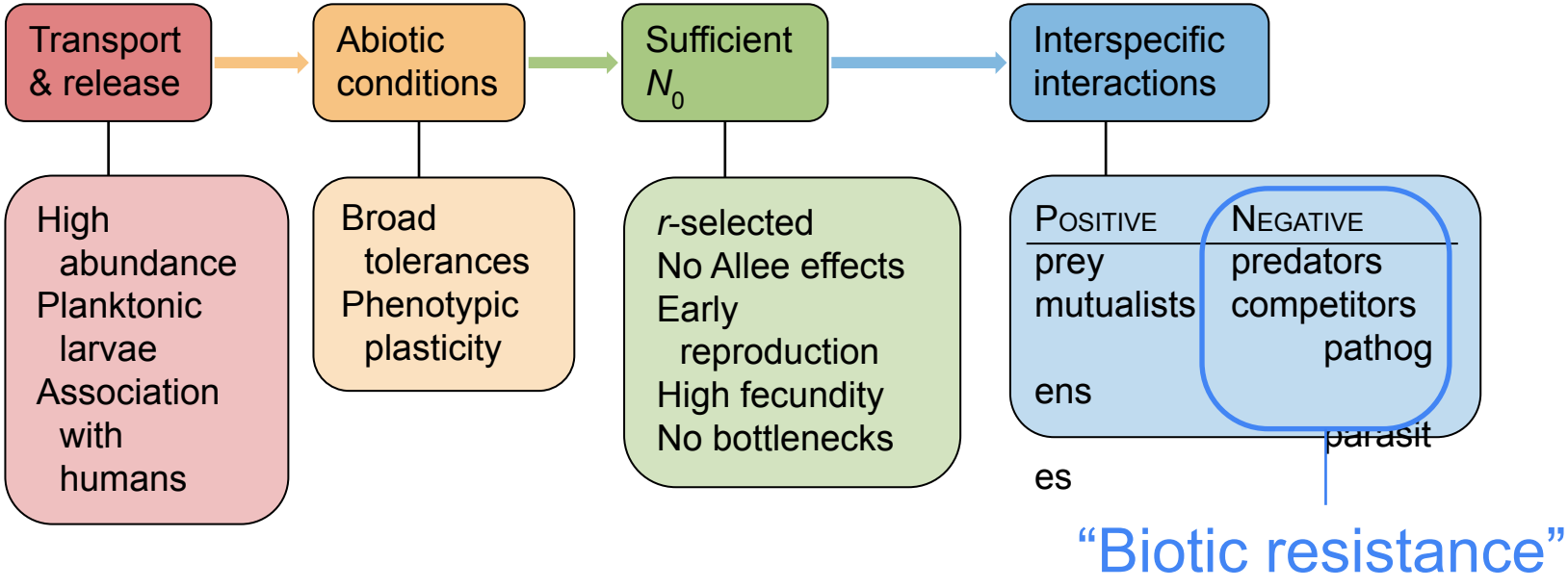
Dudas & Dower 2006

Why only in upper intertidal?



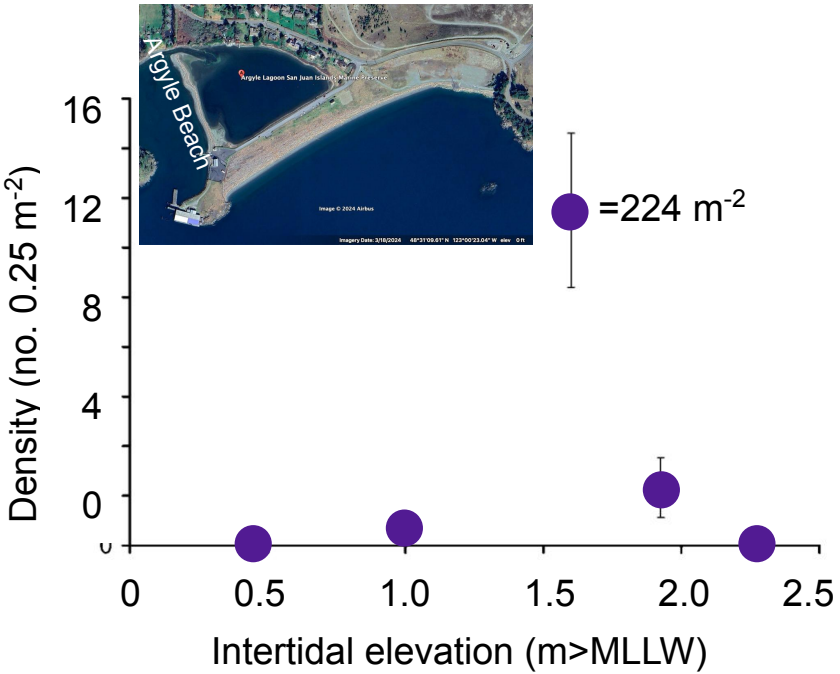
Byers 2002

Which bioinvasions succeed?



After Carlton REF, Blackburn REF, Geburzi & McCarthy 2018

Why is varnish clam limited? Biotic resistance candidates

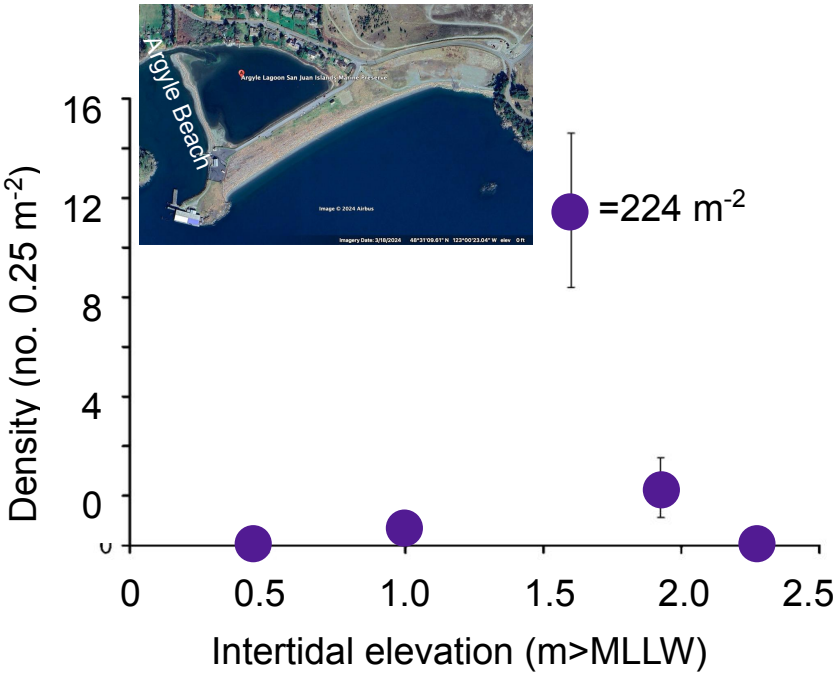


Crabs

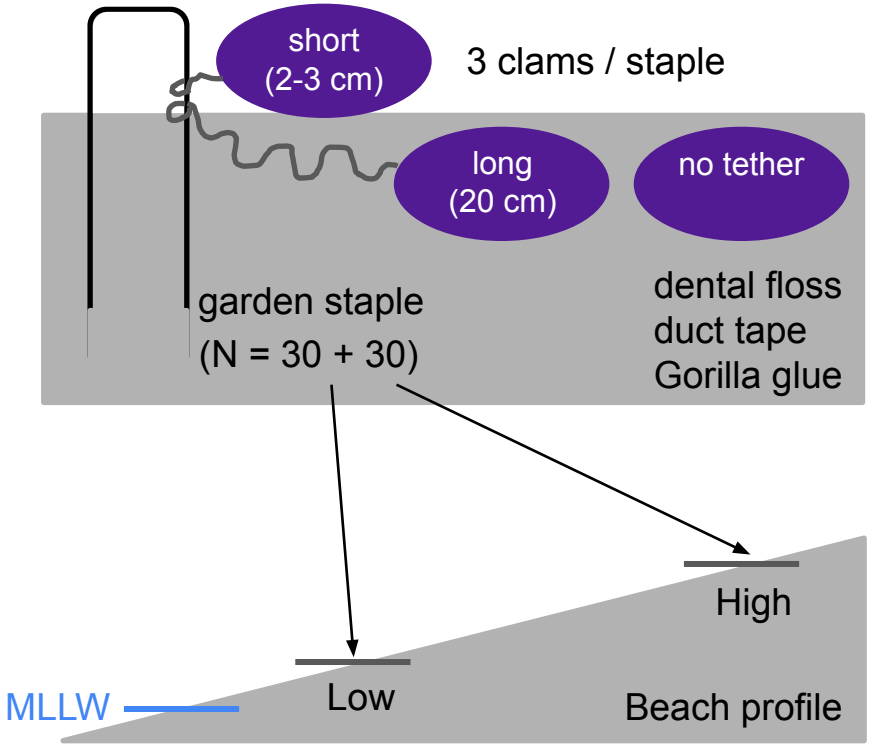
Birds

Birds: https://www.aviaway.com/seagulls
https://www.nationalgeographic.com/animals/article/140403-crow-intelligence-animal-smarts-science

Why is varnish clam limited?



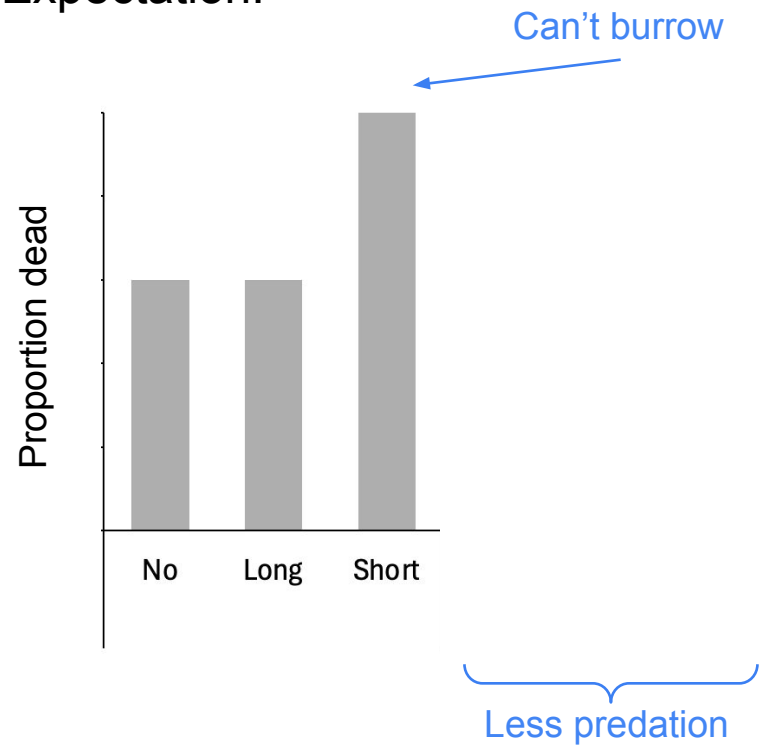
Tethering experiment (24h)



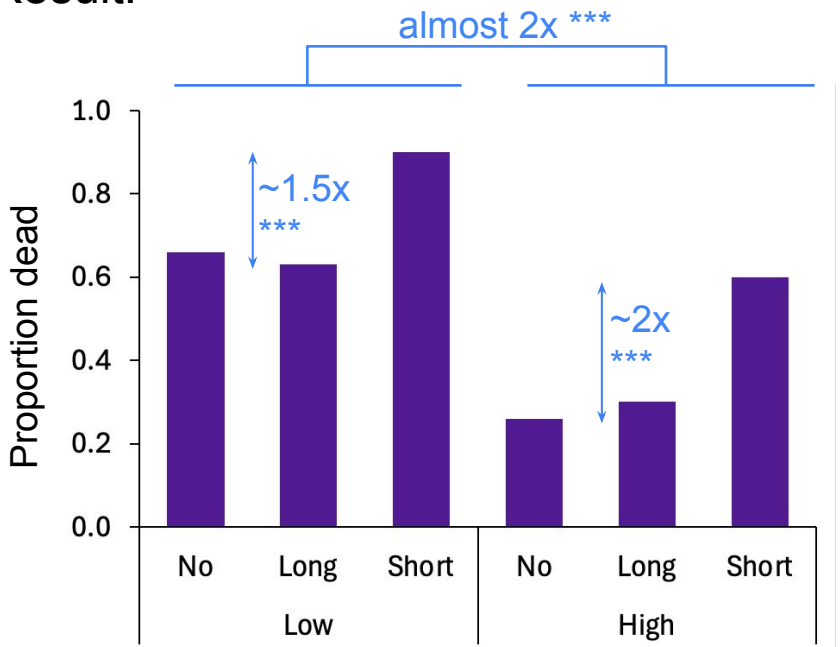
Byers 2002

Biotic resistance greater (more predation) at lower elevation

Expectation:



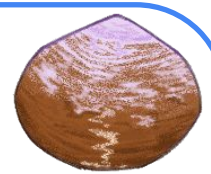
Result:



Byers 2002

Compelling questions

1. Is biotic resistance to varnish clams (via predation) as intense today?



2. How intense is biotic resistance to the Manila clam?

3. How does predation intensity compare on native littleneck clam?

4. Will predation intensity change when green crabs arrive?

Tethering experiment

Nuttallia obscurata
varnish clam

vs.

Ruditapes philippinarum
Manila clam

vs.

Leukoma staminea
native littleneck

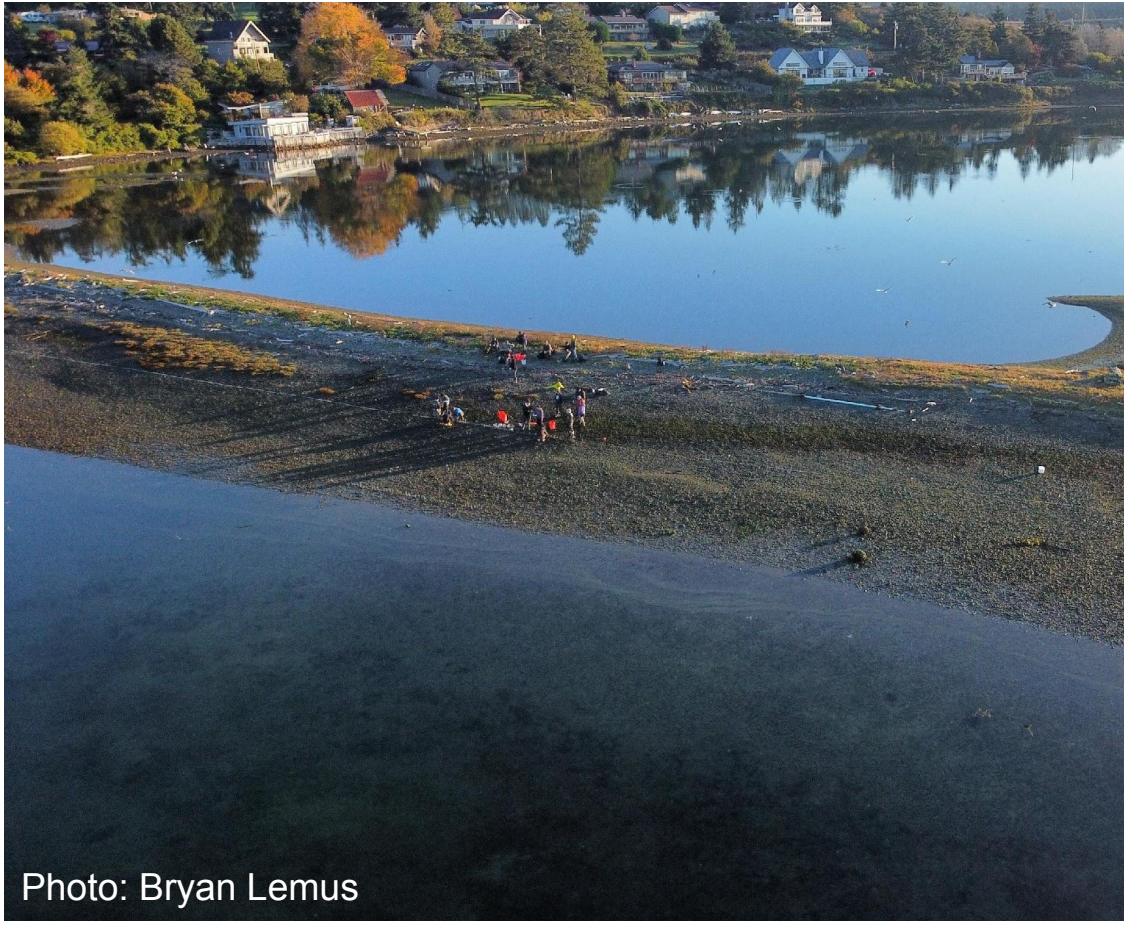


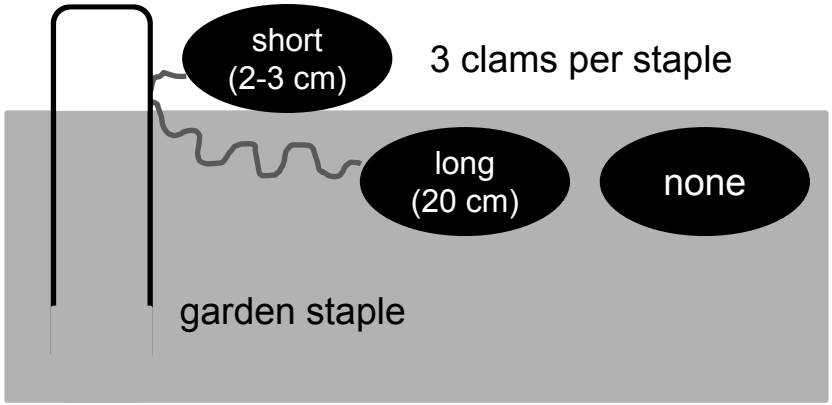
Photo: Bryan Lemus

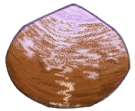
Tethering experiment

1. Collected clams

2. Rinsed, air-dried, sanded
3. Labeled, measured

4. Tethered



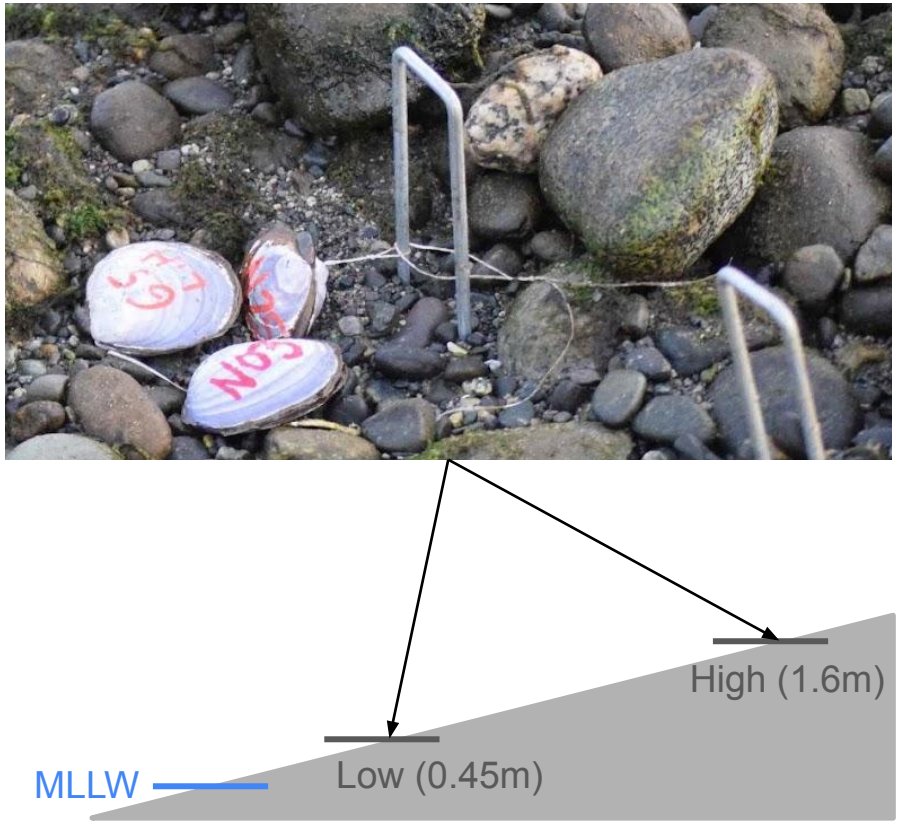


Varnish clam N=28–29 staples x2

Manila clam N=12–14 staples x2

Native littleneck N=14 staples x2

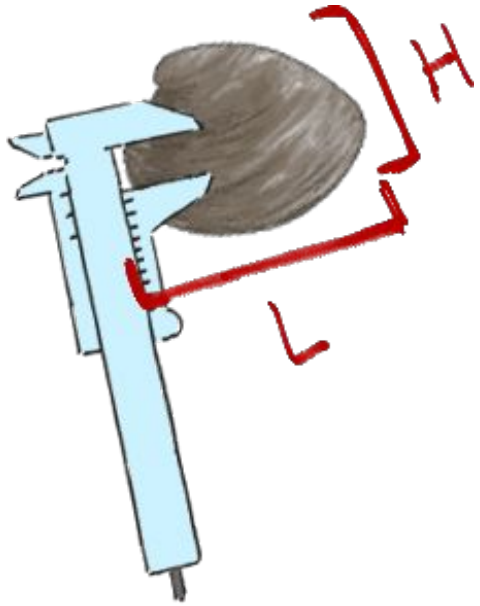
Tethering experiment



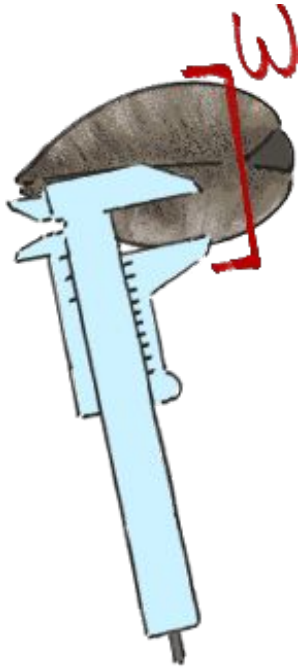
Tethering experiment

Aside: clam morphometrics

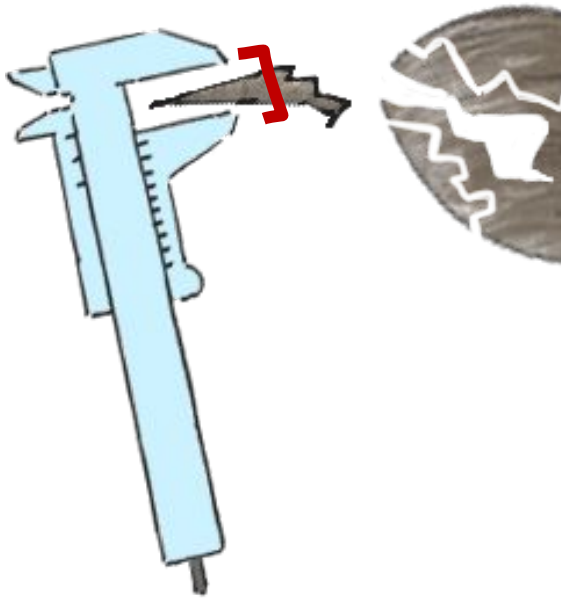
Length: Anterior to Posterior
Height: Umbo to Ventral edge



Width: Left to Right

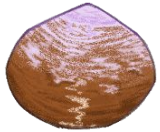


Thickness: Shell edge

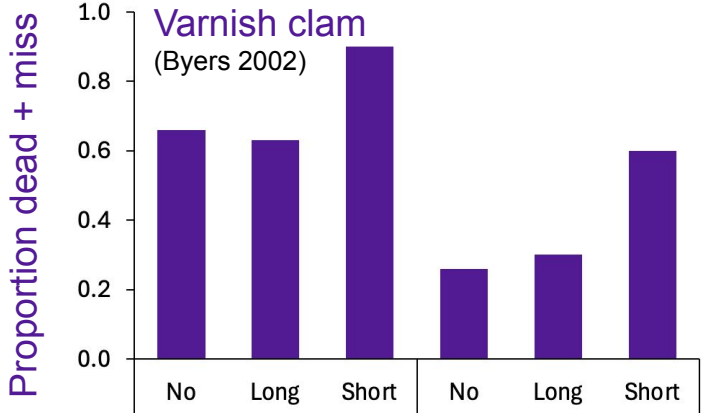


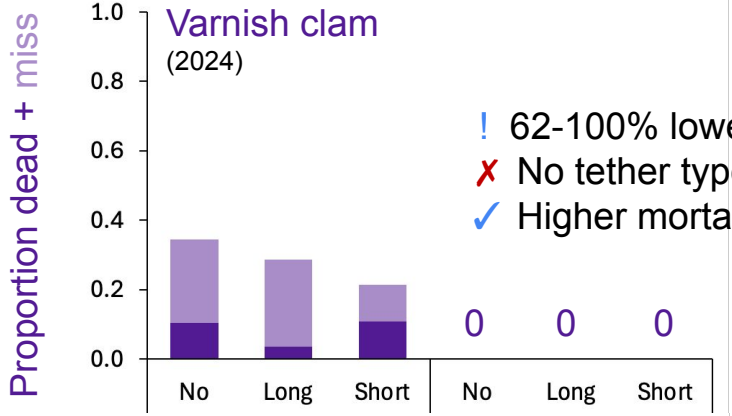
Illustrations: Ellen Pak

Predation intensity hypotheses

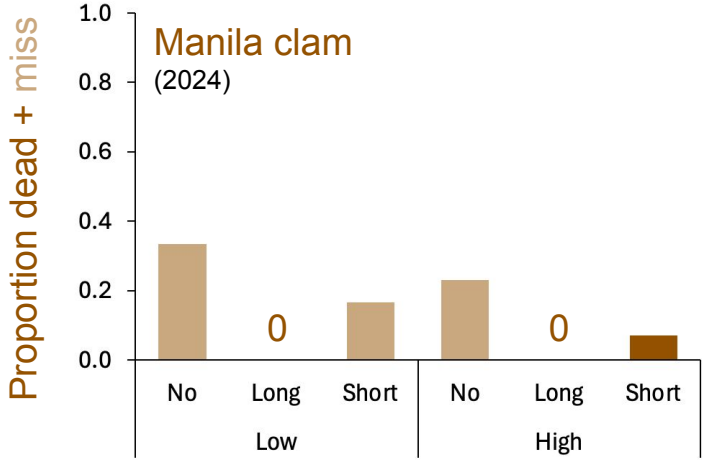
	Species	Bio-geography	Intertidal elevation	Burrowing depth	Meat: shell	Shell		
						Width	Thickness	Surface
	Varnish clam	Introduced (1990s)	High	Deep	Low			Smooth
	Manila clam	Introduced (1920s)	Mid-low	Shallow	High			Ridged
	Pacific littleneck	Native	Mid-low	Mid	High			Ridged

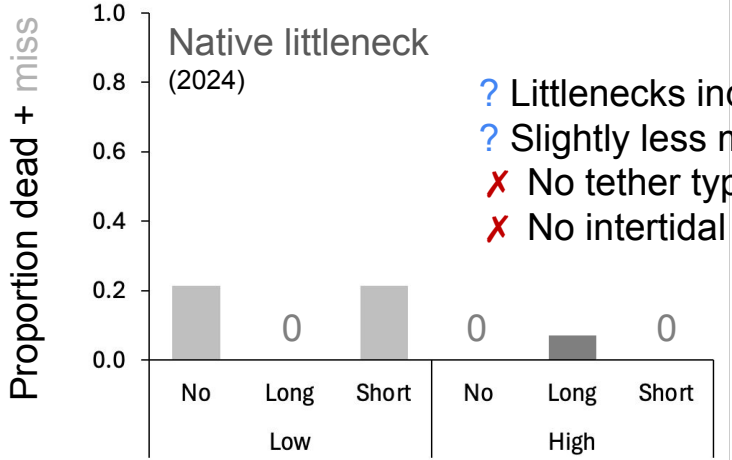
How did mortality compare among the three clams?





! 62-100% lower mortality than 2002
✗ No tether type pattern
✓ Higher mortality at low elevation

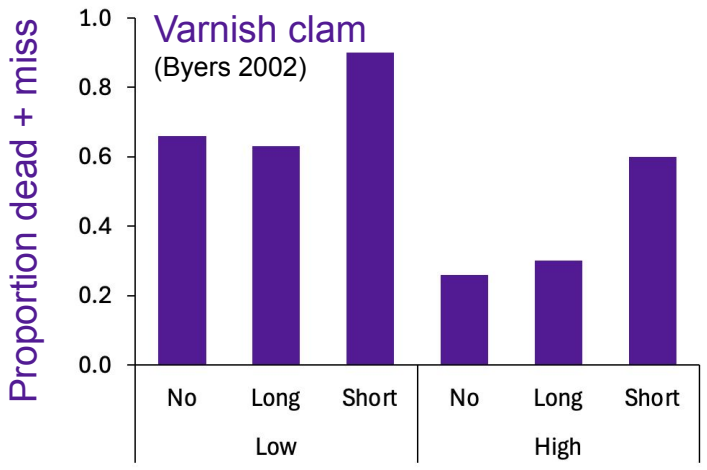


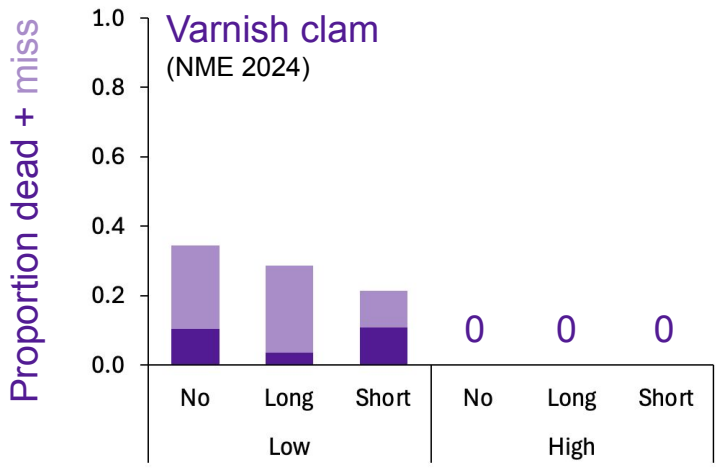


? Littlenecks indistinguishable
? Slightly less mortality than *Nuttallia*
✗ No tether type pattern
✗ No intertidal elevation pattern

Compelling questions:

1. Why was varnish clam mortality so much lower in fall 2024 (vs. summer 2000)?
2. Who ate the clams? (crabs? birds?)
3. What was the fate of the missing clams? (eaten? buried farther away?)
4. How will these predation levels change when the green crab arrives?





Compelling questions

1. Is biotic resistance to varnish clams as intense today?

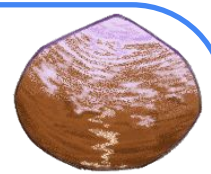
   Much lower (but…)

2. How intense is biotic resistance to the Manila clam?

   Lower than to varnish clams (but…)

3. How does predation intensity compare on native littleneck clam?

   Similar to Manila clam (but…)



4. Will predation intensity change when green crabs arrive?

   Stay tuned.

Pilot studies (~5 days):

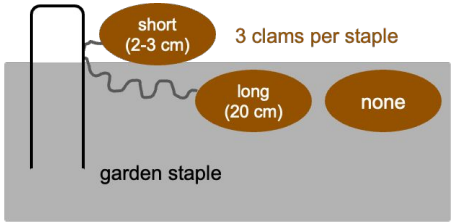
How secure are labels and tethers?

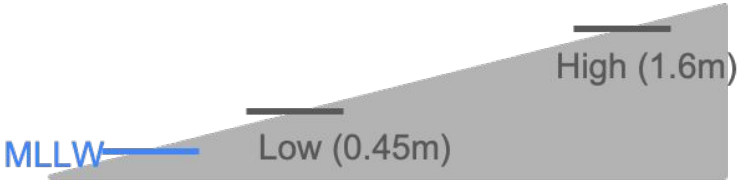
Which clams are easiest to open?

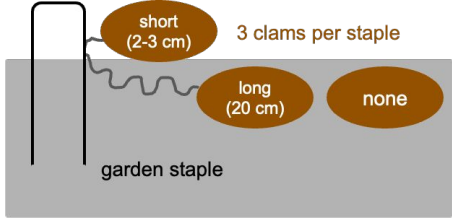
Do tethers attract/ deter crabs?

Where are clams distributed?

Which clams do red rock crabs prefer?







Questions and Reasoning

Hypotheses

Q_1: What force rips tethers off of clams?

Multiple tethers came off before planting.

H_{1A}: *Ruditapes* tethers require least amount of force.

(They had the most missing tethers)

H_{10}: No difference in tether strength.

Q_2: What marking method works best?

Many marks were degraded beyond legibility in the field.

H_{2A}: Sanded, black, Sharpie are best. *Nuttallia* are the worst.

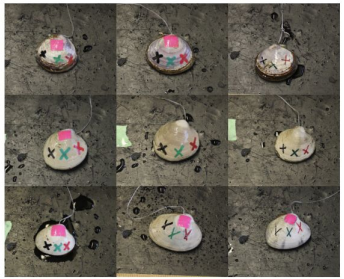
(Anecdotal observations; shell porosity)

H_{20}: No difference in legibility.

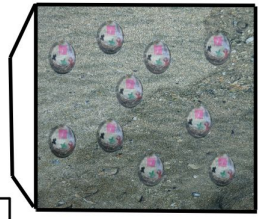
Jonas Ecker, Tatiana Egbert, Owen Proulx, and McKenna Sweet

Methods

Q2



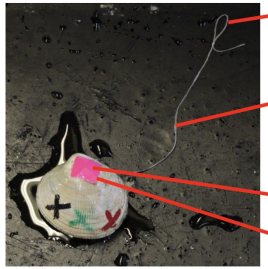
N total= 90
N each species = 30
N each medium = 10
Each side of clam marked (sanded and unsanded).
3 x's marked on each side of clams, one of each color (**Black**, **Green**, **Red**).
All x's were approximately **1 cm length** for each line.

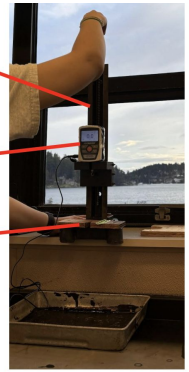


~4in sediment for **24 hours**

Q1

Tether was attached to sanded side

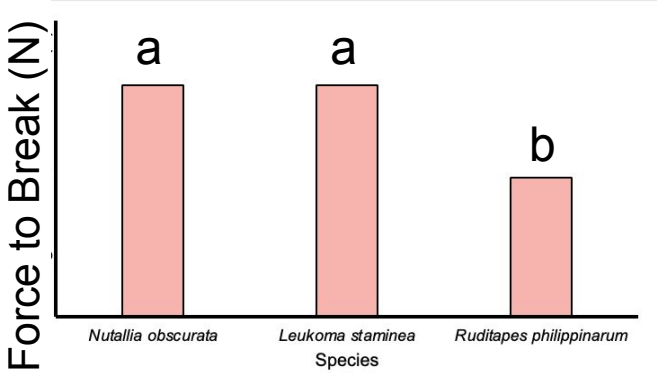


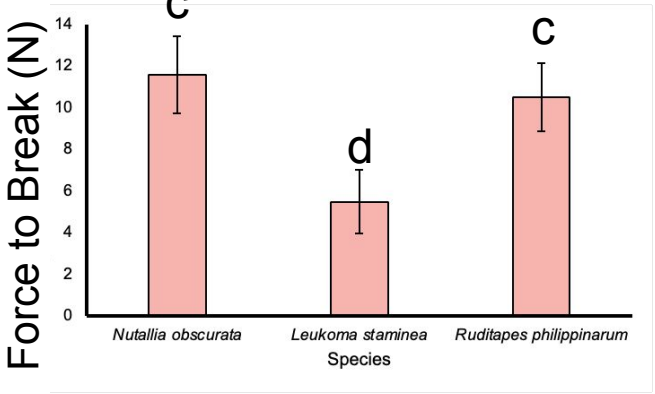


Expected Results

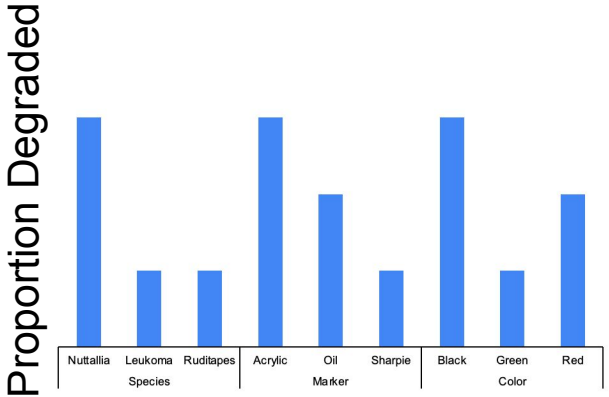
Actual Results

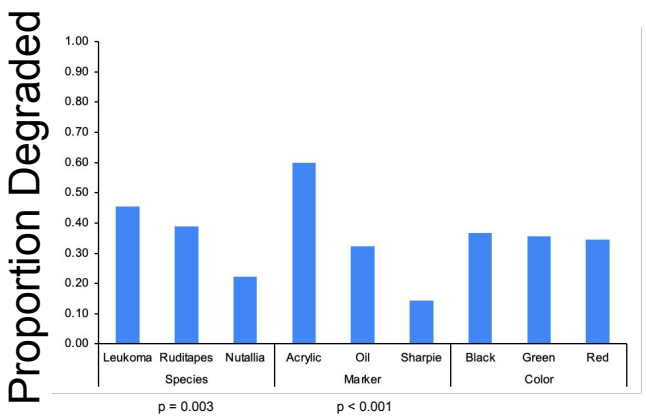
Tether





Marking





Summary

Q_1: What force rips tethers off?

Tethers were twice as strong for *Nuttallia* and *Ruditapes* than they were for *Leukoma*. Not expected!

Q_2: What marking method works best?

Legibility: No significant differences.

Degradation: **Sharpie 6x better**. Expected.

Nuttallia was the least degraded species. Not expected!

Implications

$$

Valuable clams

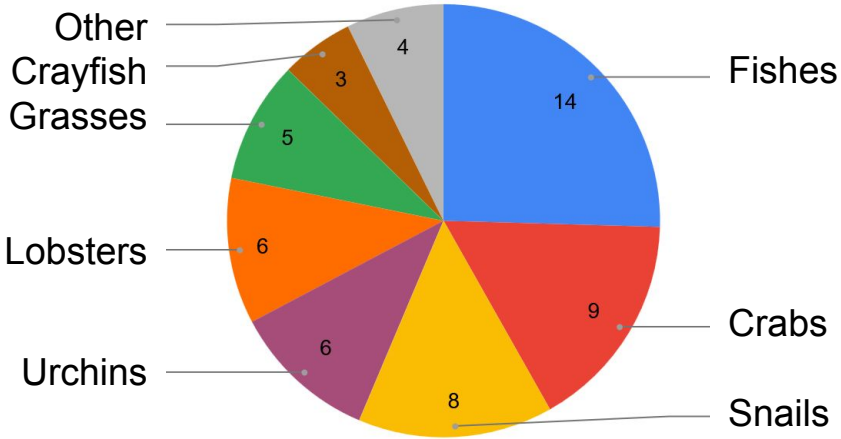
Mark-recapture procedures

Source: wadertales

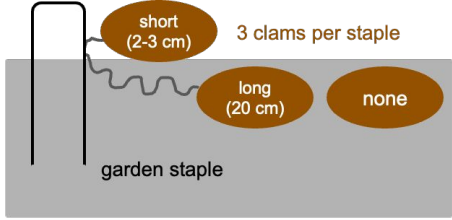
Question

Do tethering materials affect red rock crab predation on *Nuttallia*?

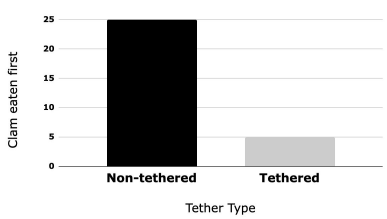
Widespread Method (N=60)



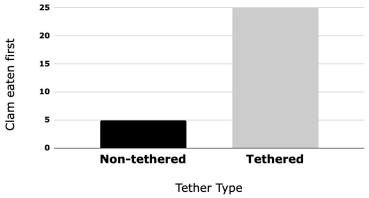
Hypotheses



H_1: Crabs prefer non-tethered clams.



H_2: Crabs prefer tethered clams.

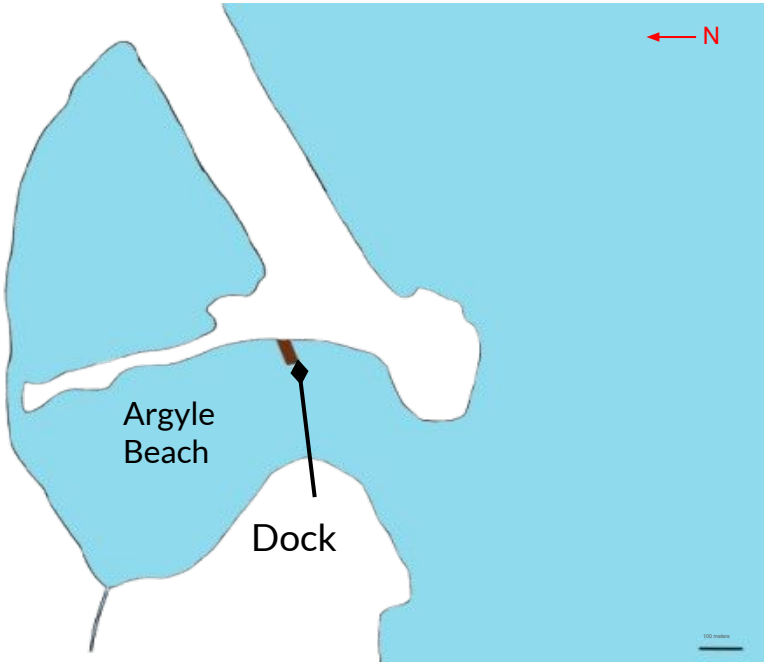


H_0: Crabs show no preference between treatments.

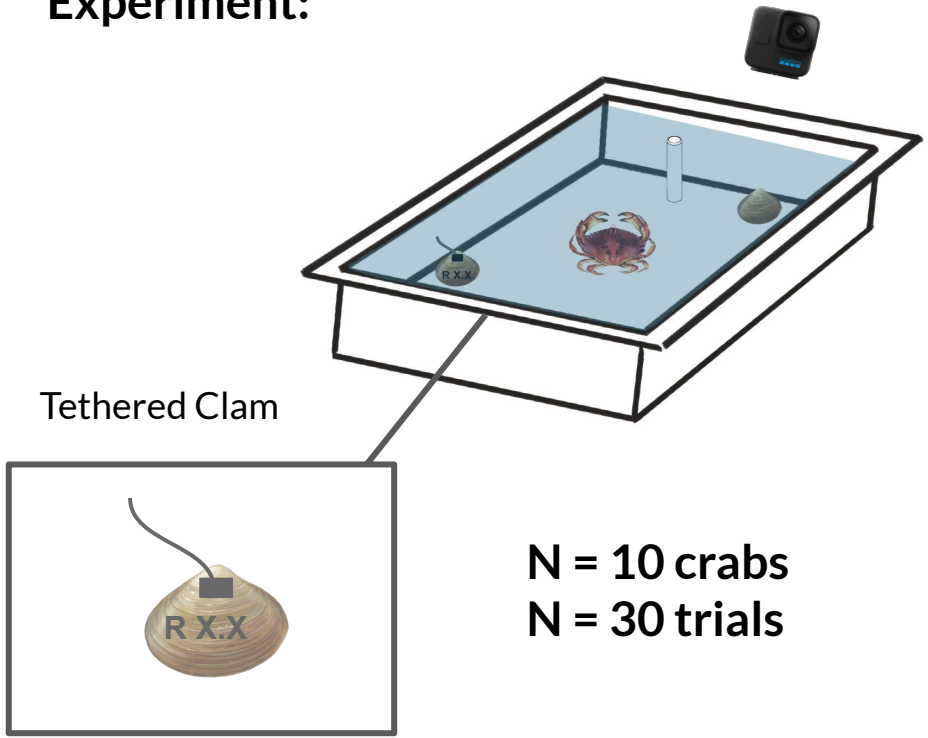
Avantika Dutt, Bryan Lemus, Spencer Hill, Nick Ward

Methods

Collection:



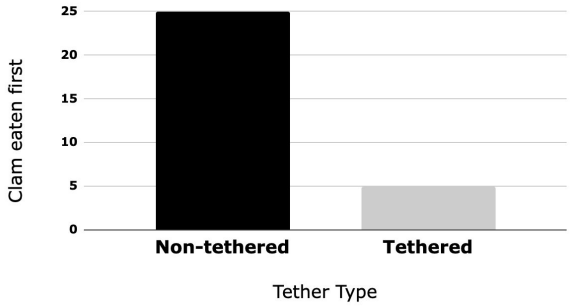
Experiment:



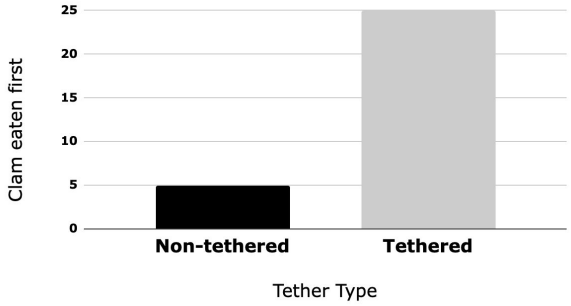
N = 10 crabs
N = 30 trials

Expected Results

H_1:

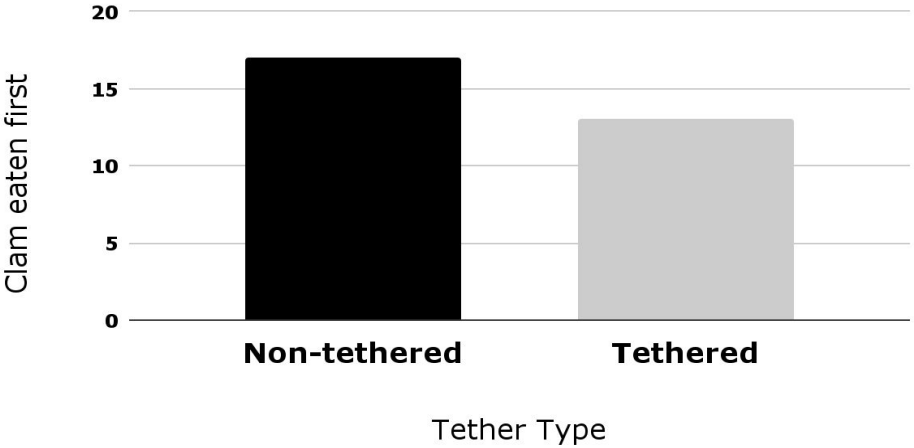


H_2:



Actual Results

No preference

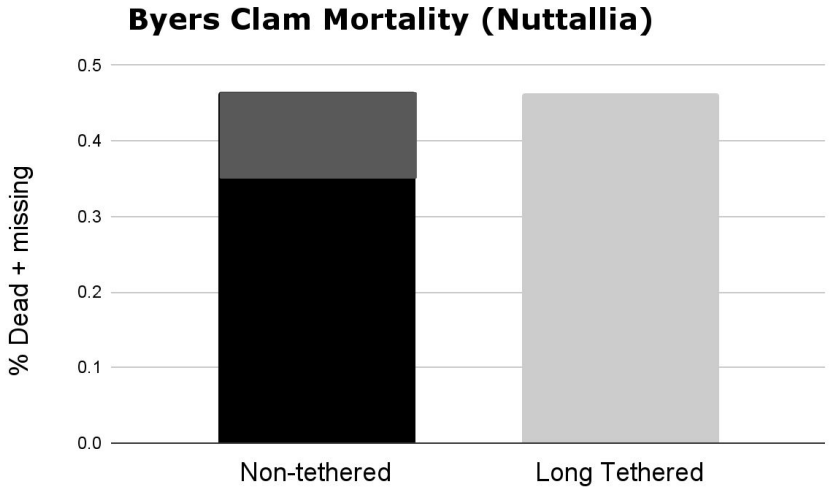


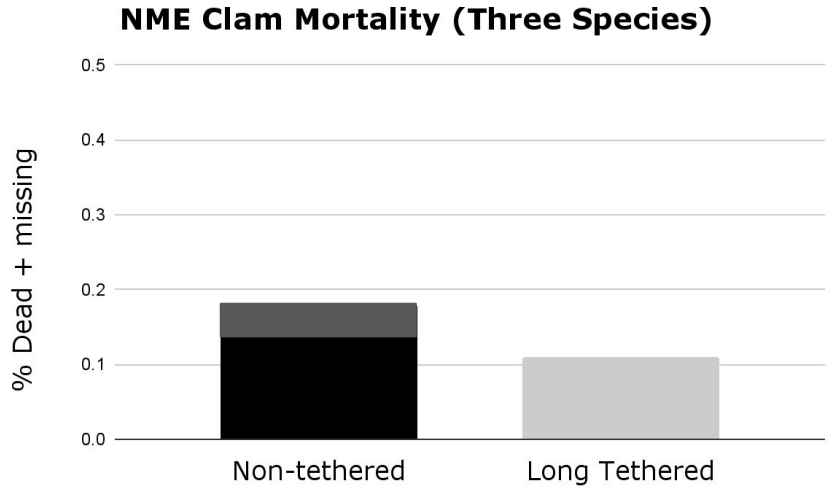
- p = 0.946
- Power = 0.1
- N required for power of 0.8 = 449 trials (150 crabs)

Conclusion & Implications

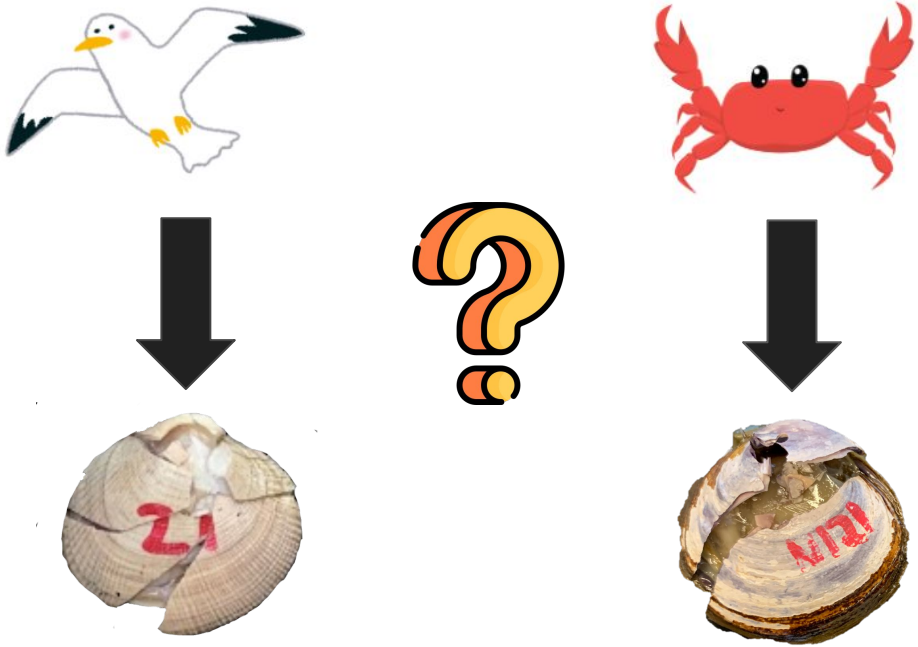
Do tethering materials impact predation rates on *Nuttallia*?

Answer: 24% deterrence due to tethers (not significant)





How much force is required to break clam shells?



Understanding predator-prey interactions is important to understanding biotic resistance and invasion dynamics.

Kate Stevens, Serena Miewald, Justin Kwok, Ellen Pak

Dropping Hypotheses

H_1: Thinner shells break at lower heights.

H_2: Heavier shells break at lower heights.

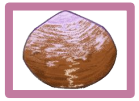
H_0: No difference among species.

Piercing Hypotheses

H_1: Thinner shells break at lower force.

H_0: No difference among species.

Dropping Methods



Piercing Methods

n=48 clams per species

Ladder to drop from higher locations

Vertical measuring tape

2.31 m

2.00 m

1.68 m

1.37 m

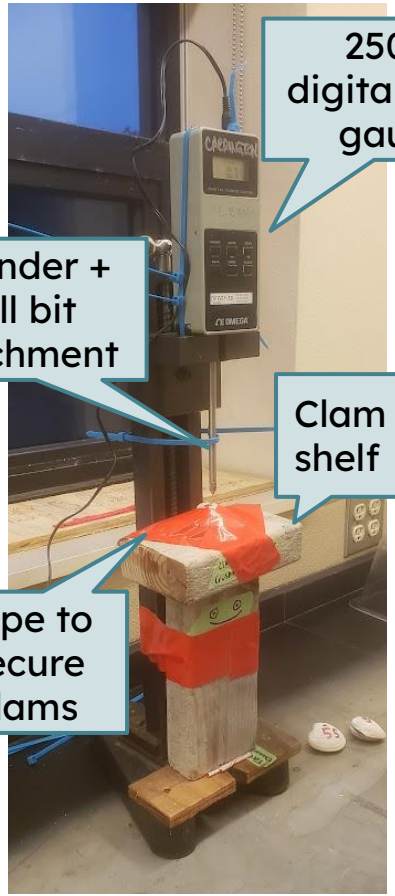
1.06 m

0.75 m

0.44 m

Dropping Heights

n=12 clams per species



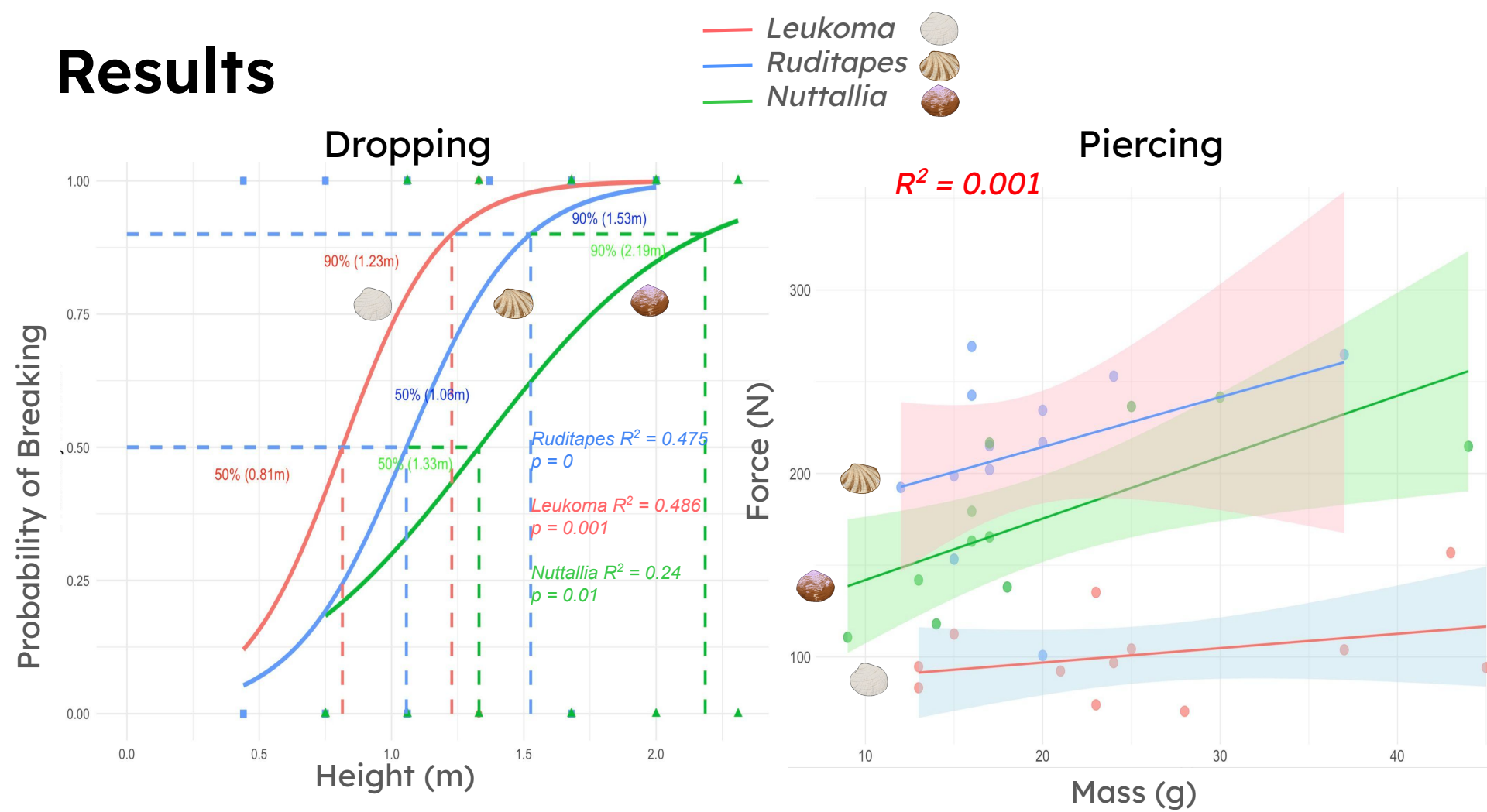
250 N digital force gauge

Extender + drill bit attachment

Clam shelf

Tape to secure clams

Results


Leukoma
Ruditapes
Nuttallia
Dropping
Probability of Breaking
Height (m)
90% (1.23m)
90% (1.53m)
90% (2.19m)
50% (0.81m)
50% (1.06m)
50% (1.33m)
Ruditapes R^2 = 0.475
p = 0
Leukoma R^2 = 0.486
p = 0.001
Nuttallia R^2 = 0.24
p = 0.01
Piercing
R^2 = 0.001
Force (N)
Mass (g)

Implications

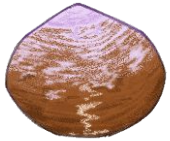
Ruditapes and *Leukoma* broke at ~75% the height of *Nuttallia.*
So, they may be preferred by birds.

- But, sediment types vary on beaches: more testing required.




Leukoma pierced at ~30-50% the force of *Nuttallia* and *Ruditapes.*
So, it may be easier for crabs to open.

- But *Nuttallia shattered* at higher forces, so may be easier to eat.

If pilot results hold, may help explain success of *Nuttallia* in Northeast Pacific predict an increase in population size.

Question
What clam species do red rock crabs prefer?

Why? To understand predator/prey and invasion dynamics

Ellie In, Rory Kliewer, Kate Robertson

Hypotheses

H_1: Crabs prefer *Nuttallia* > *Ruditapes* = *Leukoma*,
because of shell morphology

H_2: Crabs prefer *Nuttallia* > *Ruditapes* > *Leukoma*,
because of novelty

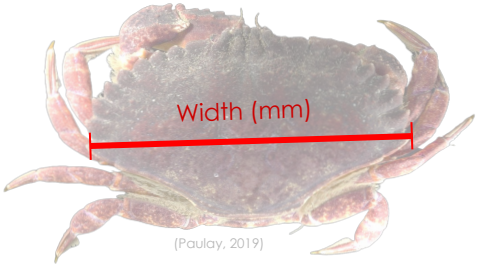
H_3: Crabs prefer *Leukoma* > *Ruditapes* > *Nuttallia*,
because of familiarity

H_0: Crabs show no preference,
Nuttallia = *Ruditapes* = *Leukoma*

Methods

1. Collection

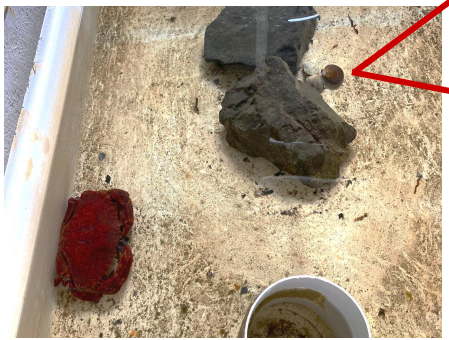
2. Measurement

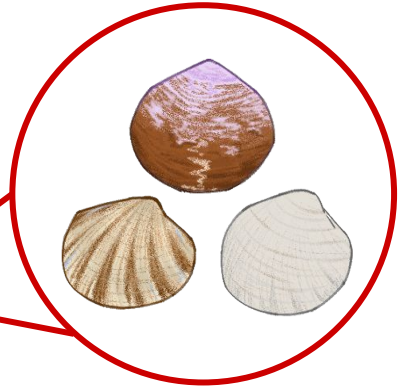


(into S, M, L)

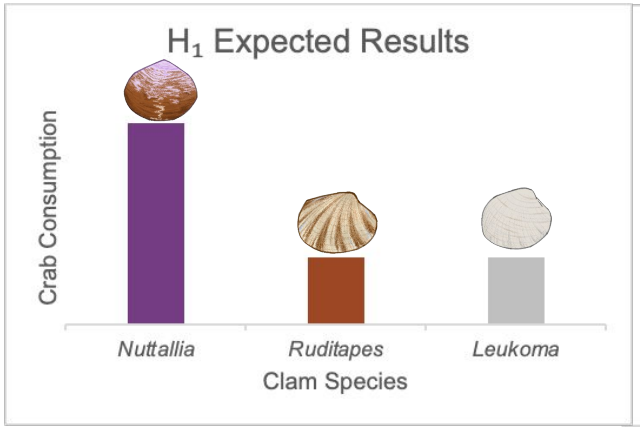
3. Stuffing + Starving

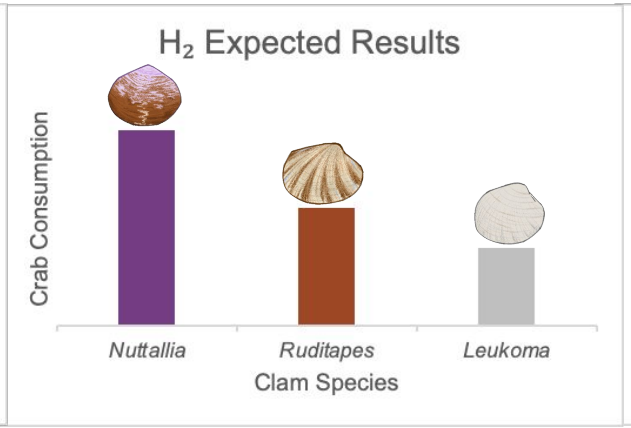
4. Feeding Trials

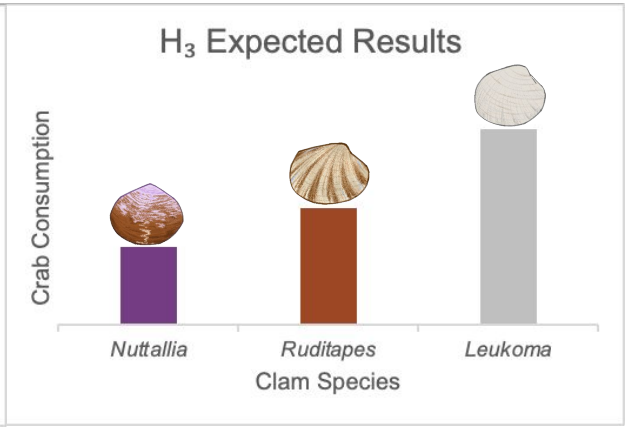


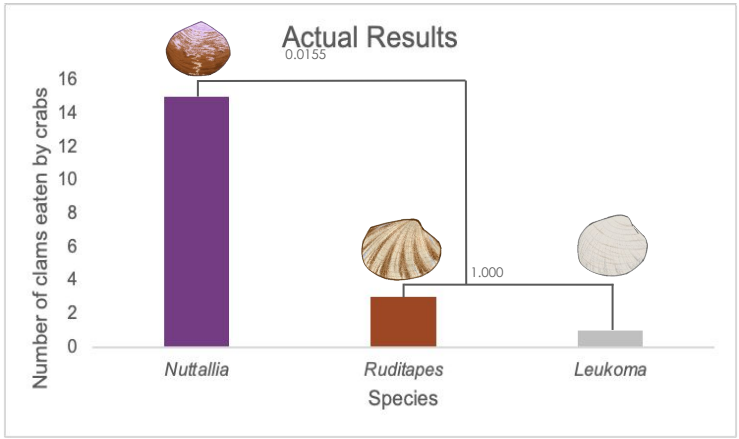


Results









Chi-Squared:
$X^2 = 18.1$, df = 2, $p < 0.001$

Post-hoc Fisher's Exact Tests:
Nuttallia > *Ruditapes* = *Leukoma*

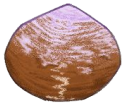
Crabs prefer *Nuttallia* 5x more than *Ruditapes* or *Leukoma*.
H_1 is supported.

Implications & Extra Observations

Red rock crabs prefer *Nuttallia* by 5x.

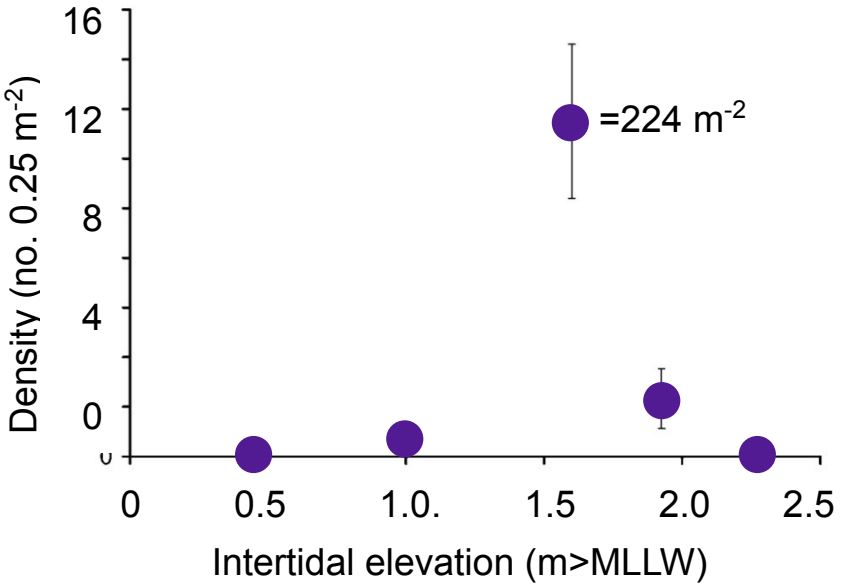
The feeding ecology of the red rock crab plays a key role in the biotic resistance of Argyle Beach against bioinvader *Nuttallia*.

Had difficulty with thick shells, tried stabbing claw into hinge, gave up.



Easier to open thin shells, crushed anterior and peeled shards off.

What is the clam distribution at Argyle Beach in November 2024?



Hypotheses

Null: There will be no change in the clam distribution along Argyle Beach since Byers study in 2002 with *Nuttallia* concentrated around 1.5 meters above MLLW. Leukoma and Ruditapes will be more concentrated lower in the intertidal at 0 meters above MLLW.

Alternative: All three species will be equally distributed across tidal elevations.

Reasoning: Mirrors Byers 2002 study.

Trevan, Chase, Marco (Peer revision)

Methods

Five total transect lines, represented by the red lines in the Figure

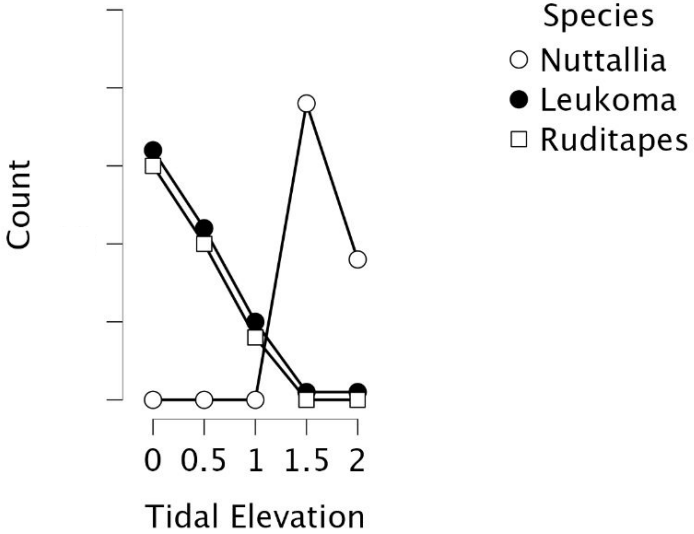
Transects consisted of five quadrats with an area of 0.25 square meters from 0-2 meters above MLLW

Each quadrat hole was 20 centimeters deep

Nuttallia, Leukoma, and Ruditapes present were recorded.

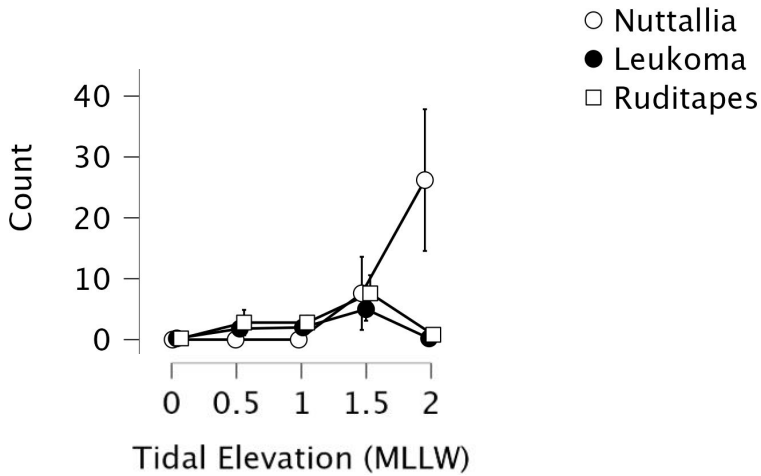
Clams were placed back into holes, with dugout sediment placed on top

Expected Results



Highest concentration of *Nuttallia* found at 1.5 meters above MLLW. The highest concentration of *Leukoma* and *Ruditapes* will be 0 meters above MLLW and concentrations will taper higher in the intertidal.

Our Results



- Significantly more *Ruditapes* and *Leukoma* than *Nuttallia* at 0.5 and 1 meters above MLLW
- Significantly more *Nuttallia* than *Ruditapes* or *Leukoma* at 2 meters above MLLW
- Only two clams found at 0 meters above MLLW, a *Ruditapes* and a *Leukoma*

Implications

Conclusion(s) in a nutshell

Significantly more *Nuttallia* found at 2 meters above MLLW suggesting that the invasive clam is moving higher in the intertidal (compared to Byers' study)

Future:

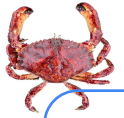
•How does seasonality affect the distribution of *Nuttallia* at Argyle Beach?

•How competitive are *Nuttallia* at Argyle Beach?

-What measures of biotic resistance influence invasion the most at argyle?

•Are native clams increasing in population at Argyle Beach?

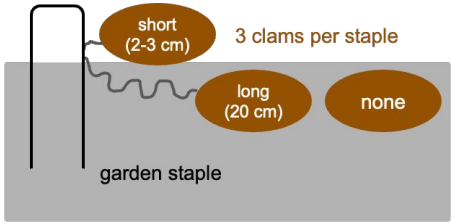
Pilot studies (~5 days):



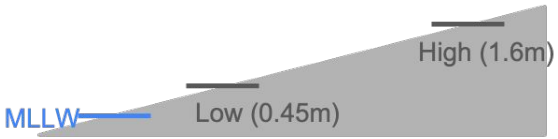
How secure are labels and tethers?
Sharpie on *Nuttallia* ✓
Tethers on *Leukoma*
✗

Which clams are easiest to open?
***Nuttallia* hardest**

Do tethers attract/ deter crabs?
No 😅



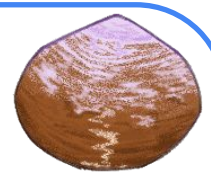
Where are clams distributed now?
***Nuttallia* higher**



Which clams do red rock crabs prefer?
Nuttallia

Compelling questions

1. Is biotic resistance to varnish clams (via predation) as intense today?

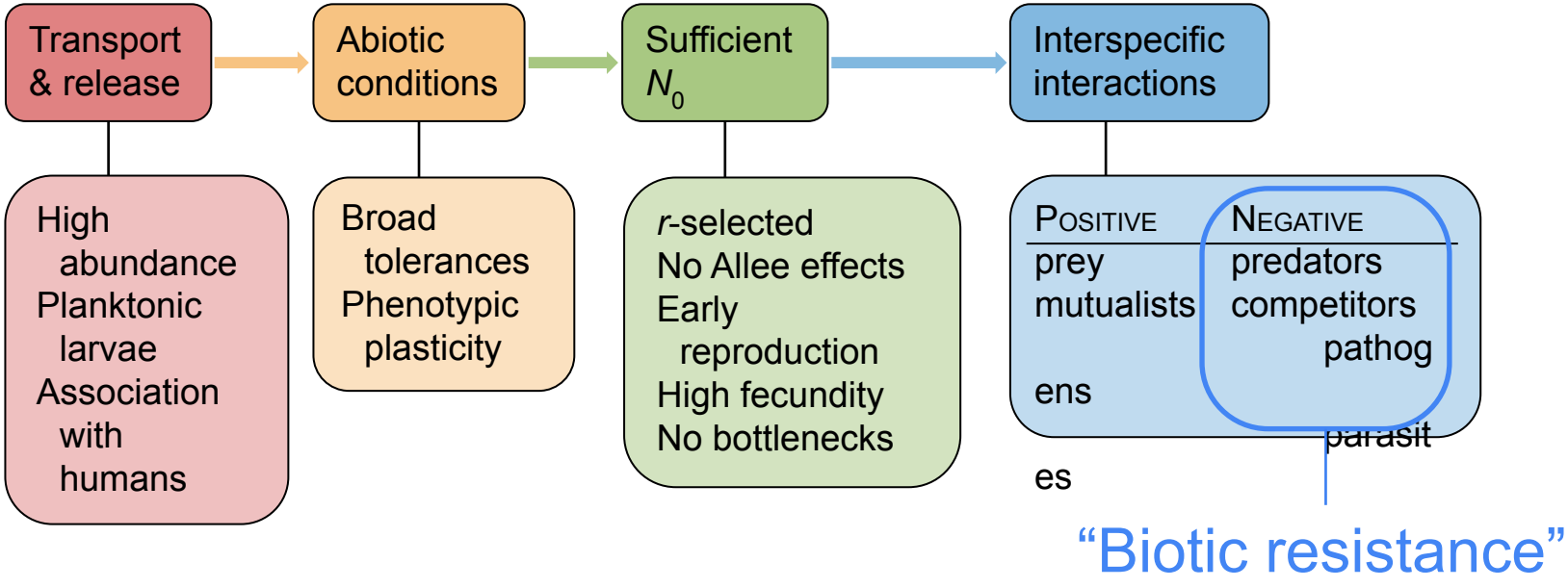


2. How intense is biotic resistance to the Manila clam?

3. How does predation intensity compare on native littleneck clam?

4. Will predation intensity change when green crabs arrive?

Which bioinvasions succeed?



After Carlton REF, Blackburn REF, Geburzi & McCarthy 2018