Sea Star Regeneration

Advanced Invertebrate Zoology

Spring 2013

Julie Schram

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Advantages of regeneration

- Recovery from autotomy
- Repair tissue damage – wounding
- Asexual reproduction?

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http://www.pcog.org/21076/high-five-for-the-starfish/

Disadvantages of regeneration

- Loss of investment
- Decreased ability to obtain nutrients
- Allocation of nutrients to regeneration of lost body compartments

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Degree & Position of Autotomy

Location of “catch connective tissue”

Ability to reduce body fluid loss

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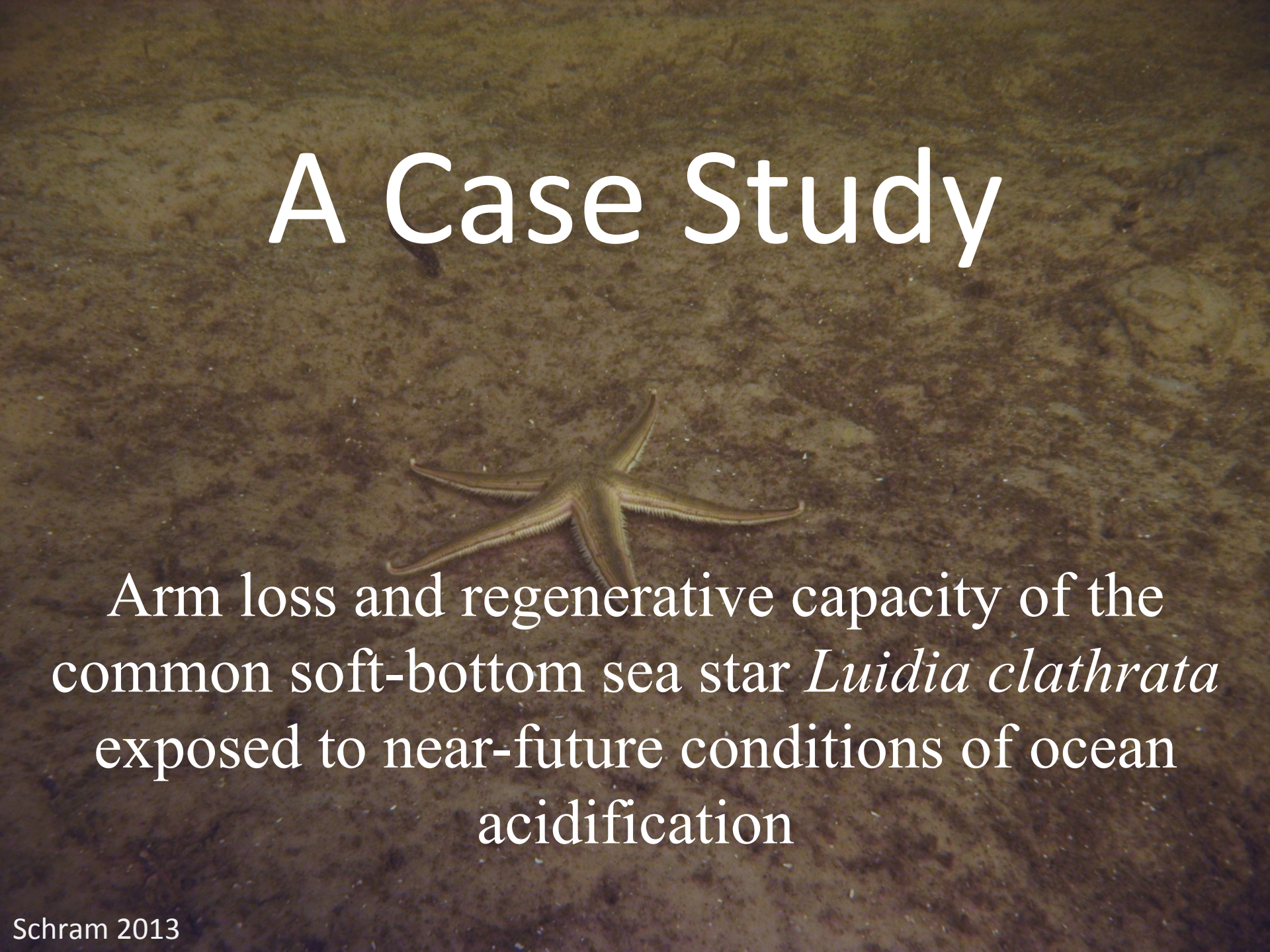
A Case Study



Arm loss and regenerative capacity of the common soft-bottom sea star *Luidia clathrata* exposed to near-future conditions of ocean acidification

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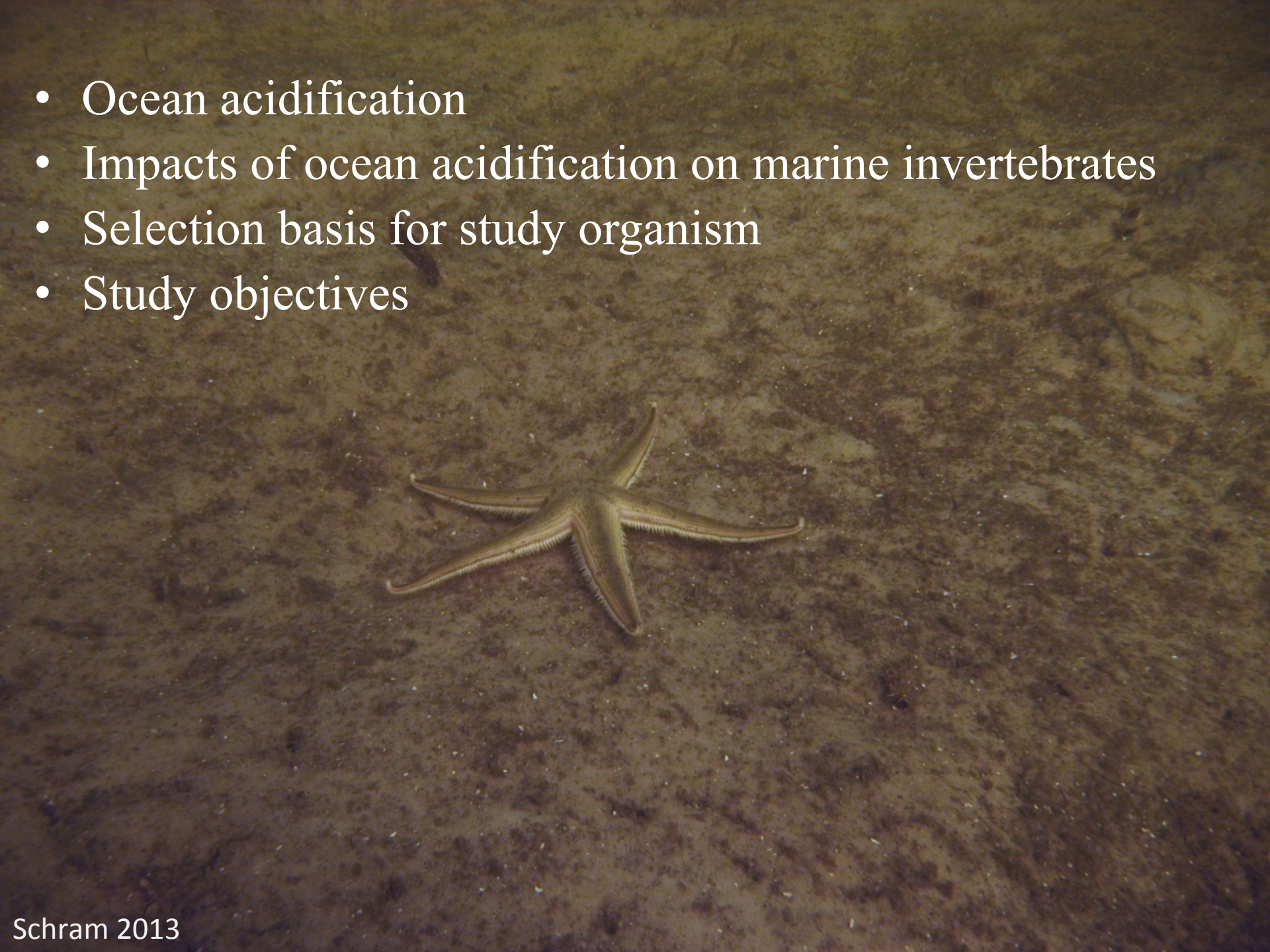
- Ocean acidification
- Impacts of ocean acidification on marine invertebrates
- Selection basis for study organism
- Study objectives



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What is Ocean Acidification?

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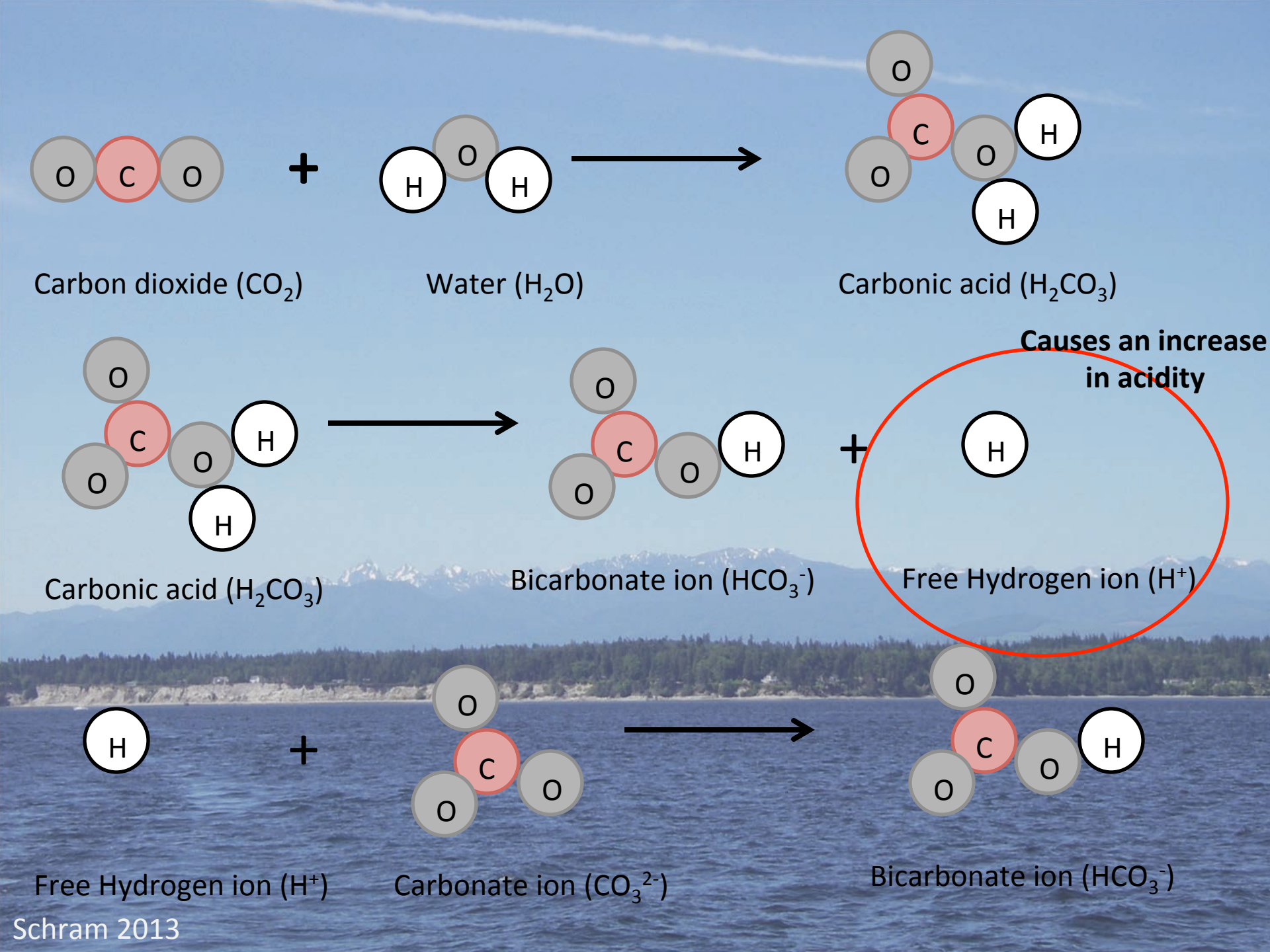
O C O
+
H O H
O C O H O H
Carbon dioxide (CO_2)
Water (H_2O)
Carbonic acid (H_2CO_3)
Causes an increase in acidity
O C O H O H
O C O H
+
H
Carbonic acid (H_2CO_3)
Bicarbonate ion (HCO_3^-)
Free Hydrogen ion (H^+)
H
+
O C O O
O C O H O
Free Hydrogen ion (H^+)
Carbonate ion (CO_3^{2-})
Bicarbonate ion (HCO_3^-)

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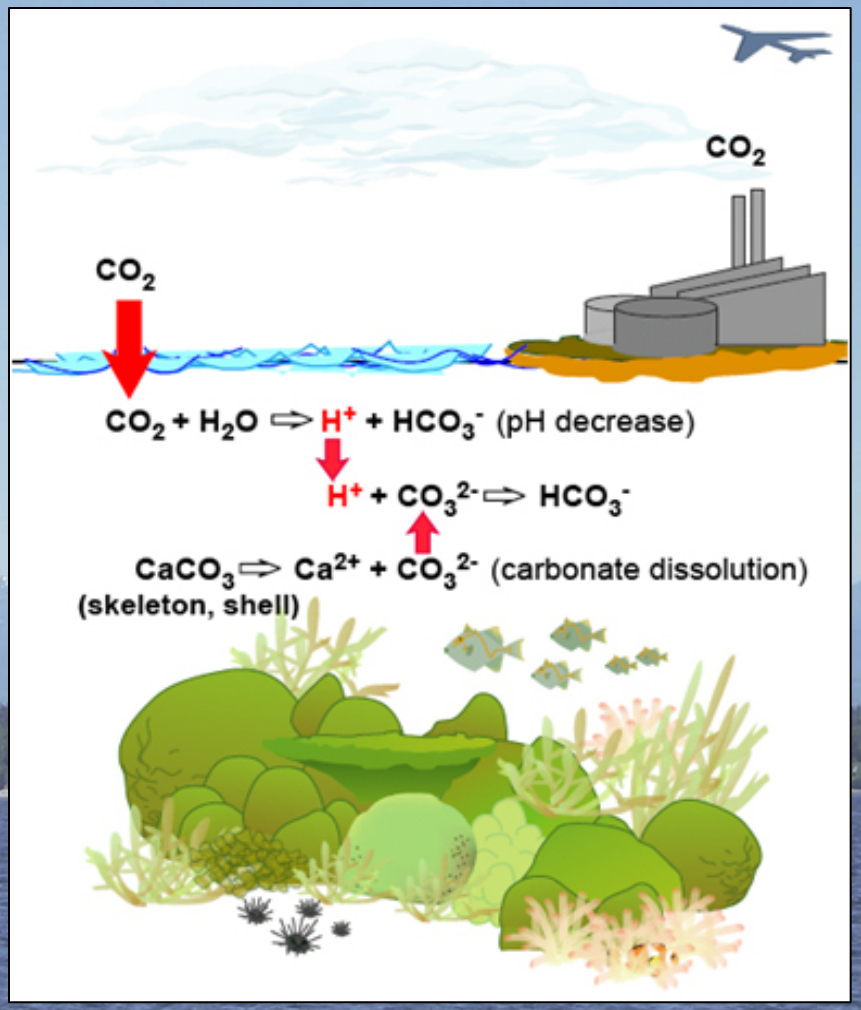
3 pathways of Ocean Acidification

- Increased pCO_2
- Decreased pH
- Decreased carbonate ion (CO_3^{2-}) concentration



www.aical-sesoko.jp/en/project

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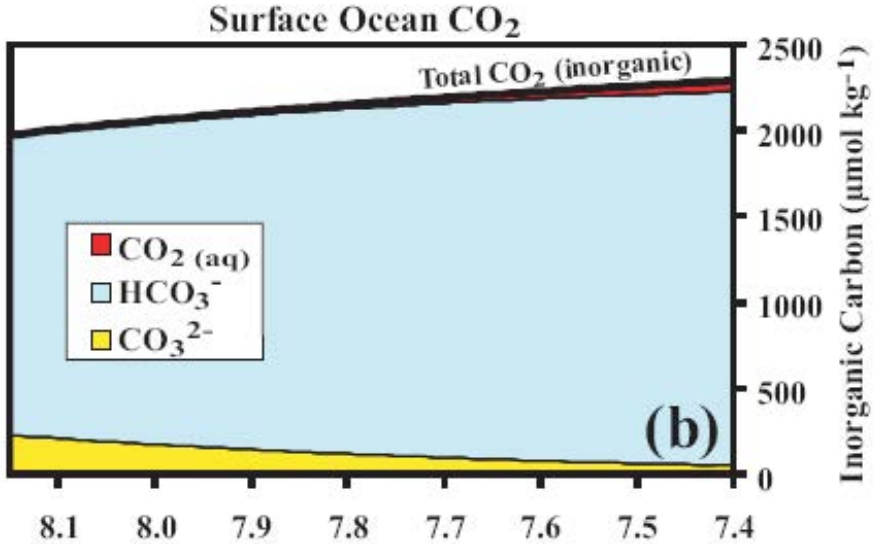
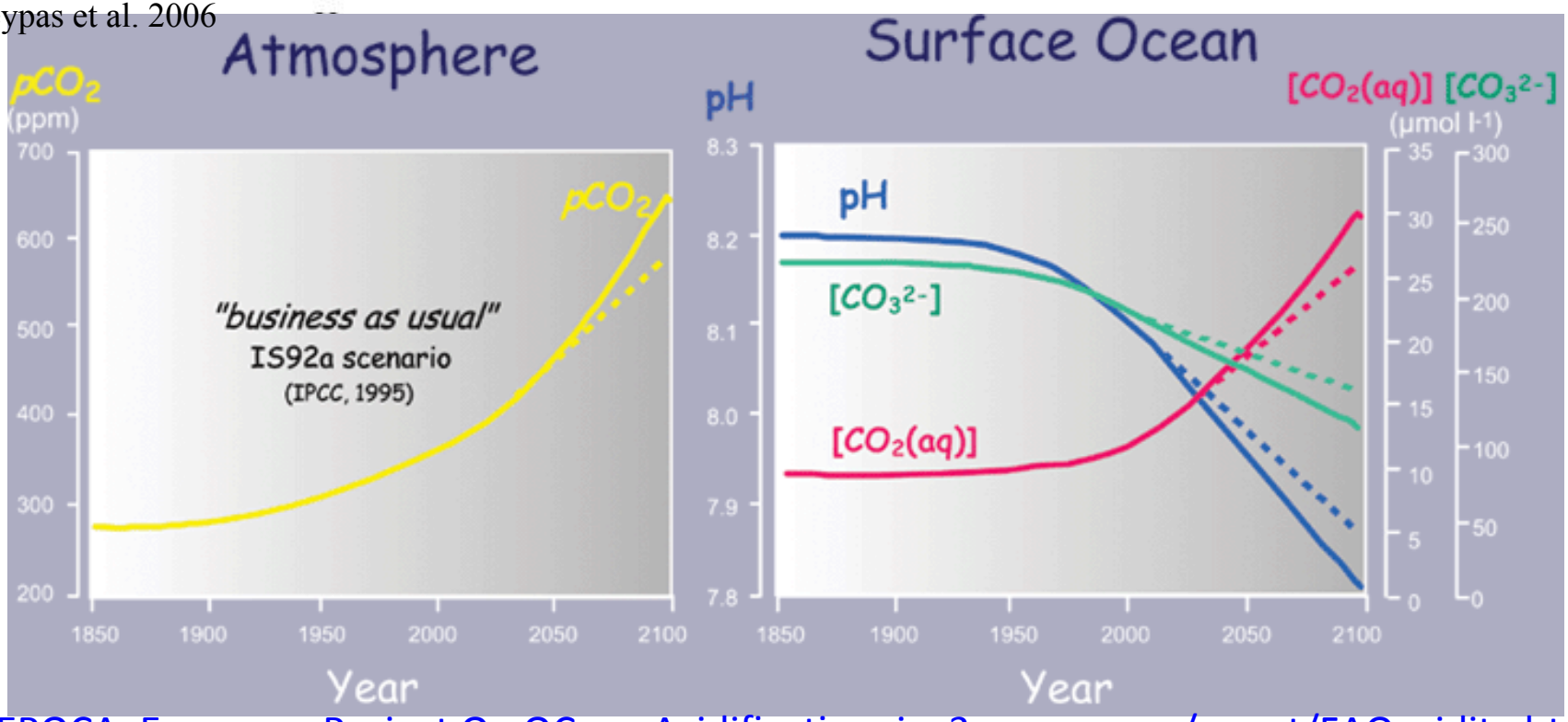
Shifting balance of carbon species present in the world's oceans



Kleypas et al. 2006



EPOCA, European Project On OCean Acidification: ioc3.unesco.org/oanet/FAQacidity.html

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Why sea stars?
Why *Luidia clathrata*?

- High regenerative capacity
  - Regenerate often
  - Regenerate quickly
- Body wall with Mg-Calcite ossicles
- Discrete body components
- Measurable behaviors
- Widespread distribution and ecologically important

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Geographic Range of *Luidia clathrata*

http://www.aquamaps.org/receive.php#

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Study Objectives

How do carbon chemistry changes associated with ocean acidification affect:

- Whole body growth
- Arm regeneration
  - Growth rate
  - Final length
  - Biochemical composition of arm components (body wall and pyloric caeca)
- Behavior
  - Righting response

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Collection

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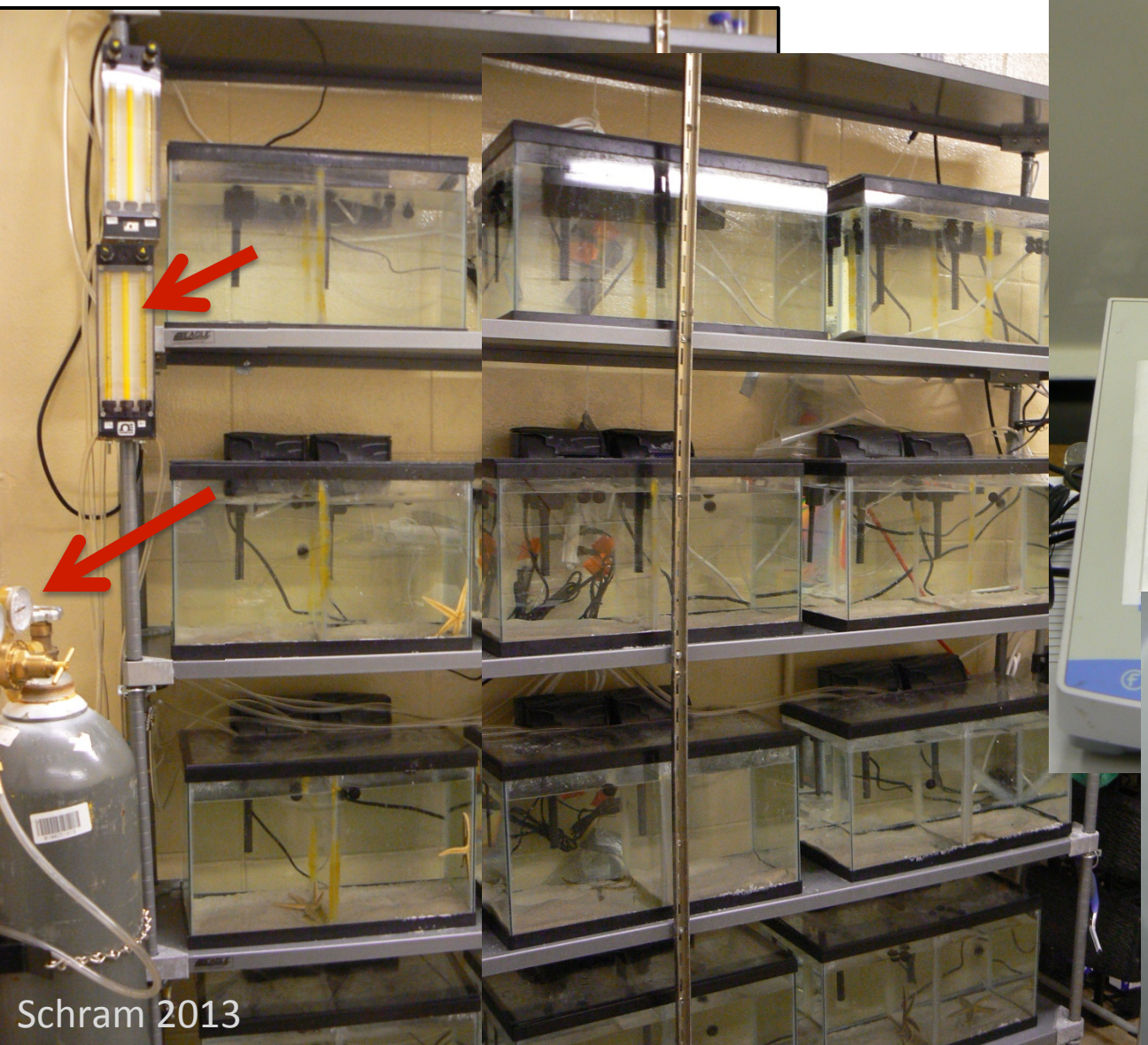
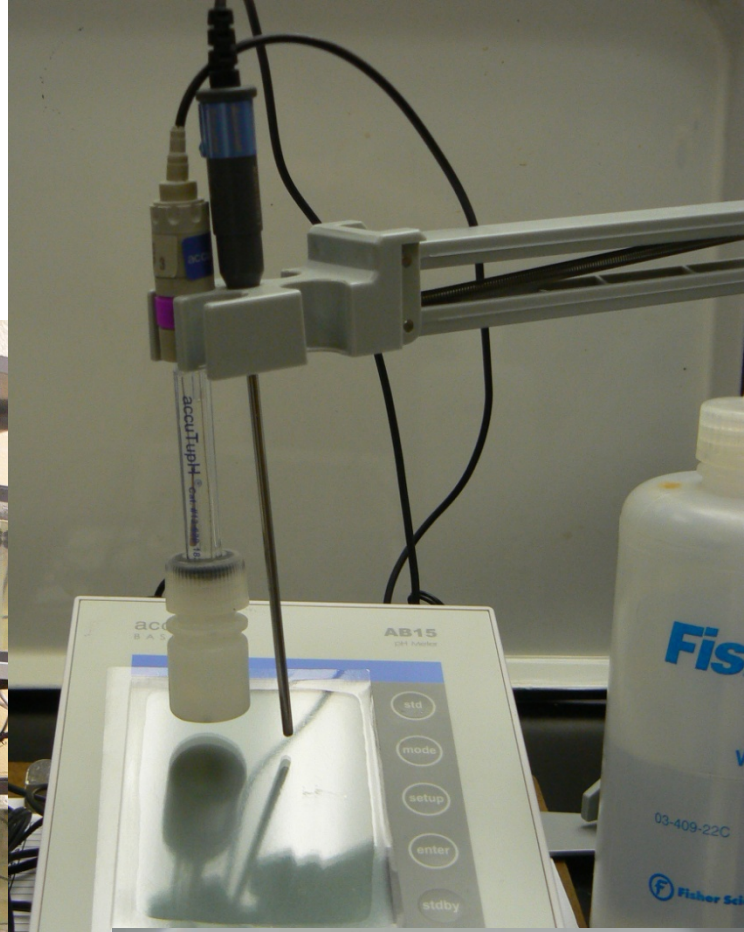
Experimental Set-up





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Arm removal

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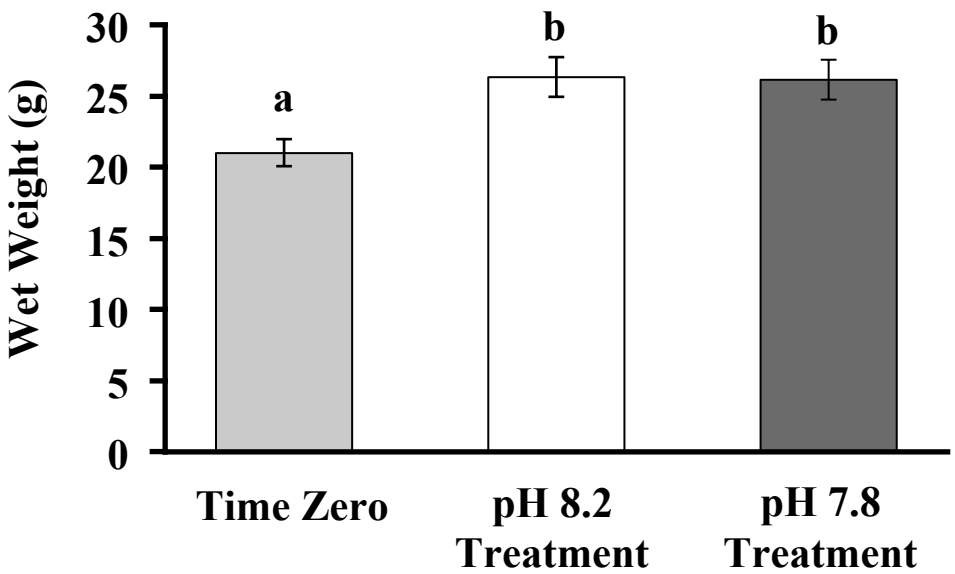
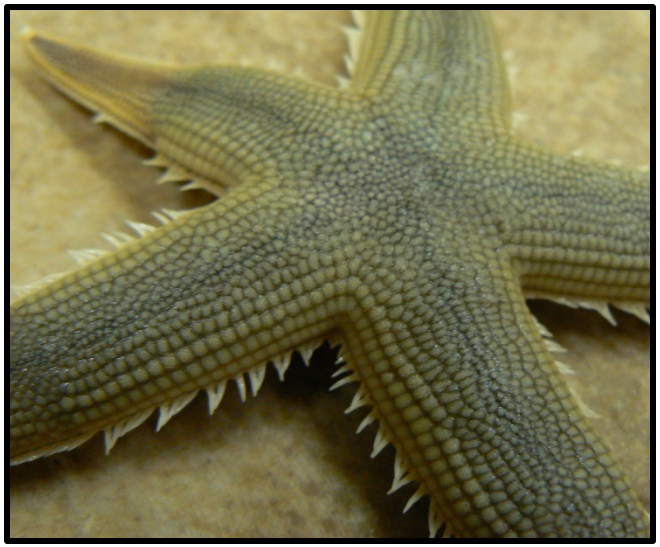
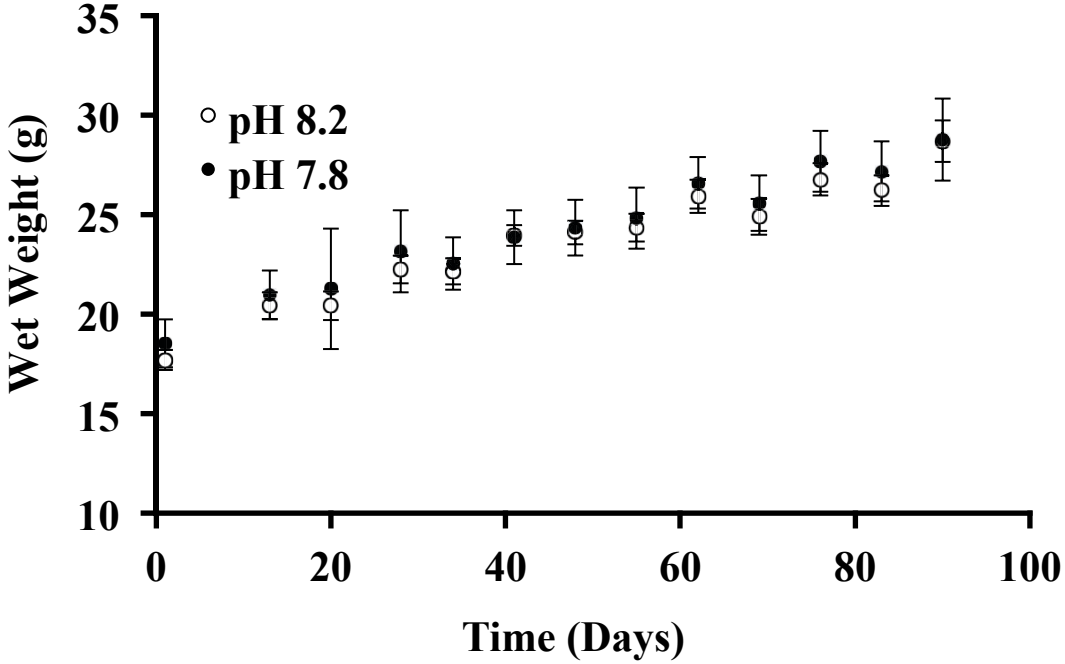
Whole Animal Growth







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Arm Regeneration

- Regenerated arm lengths measured weekly
  - New growth of both regenerating arms recorded

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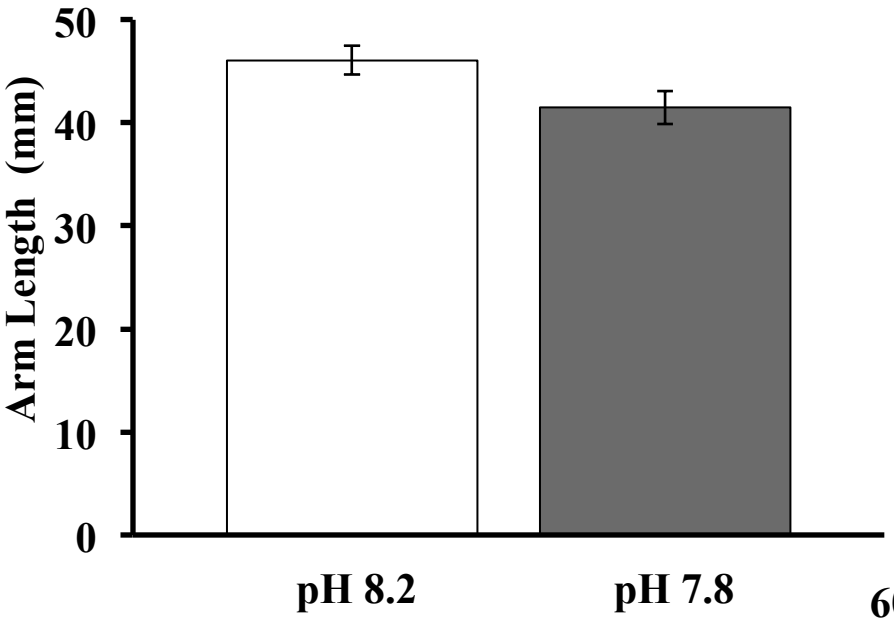
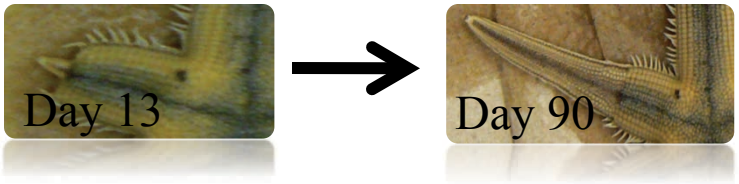
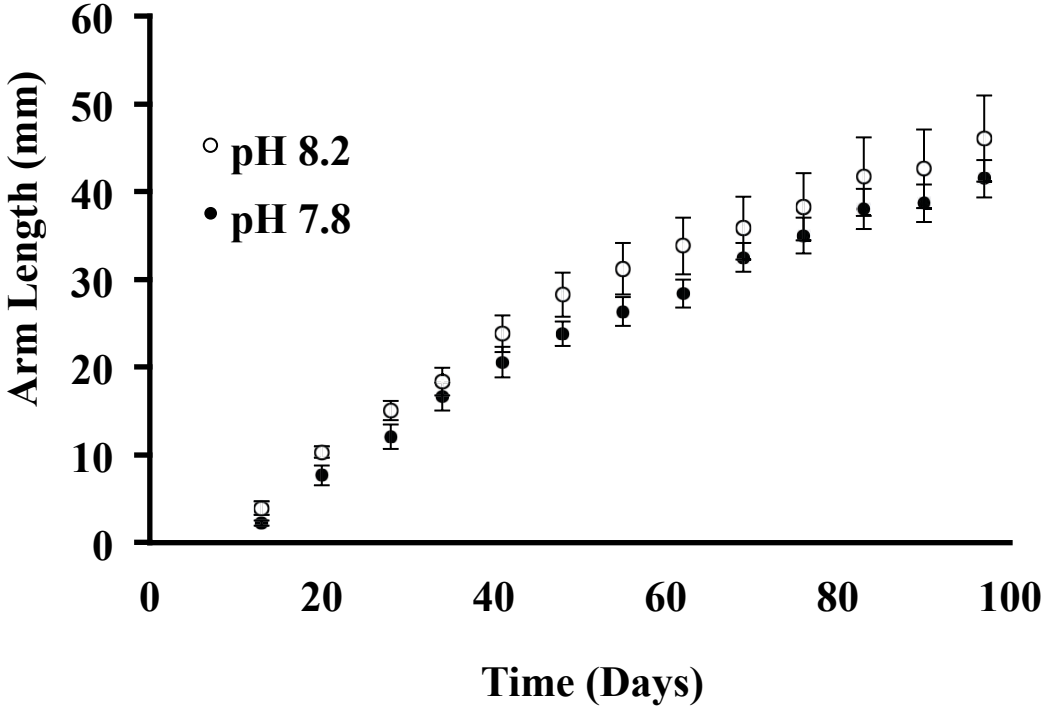
Regenerated Arm Lengths







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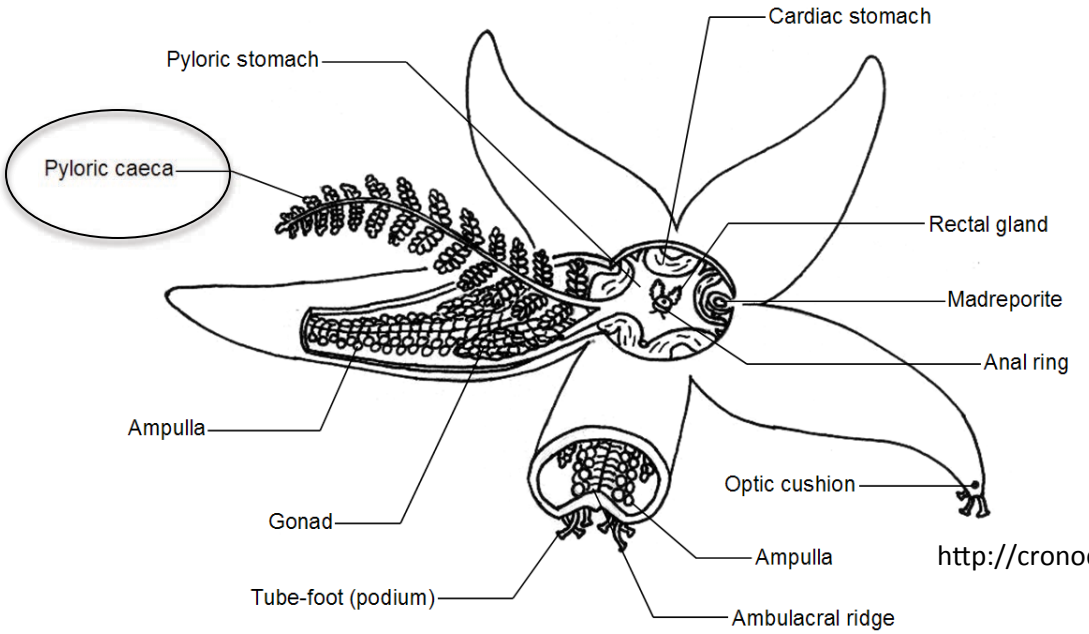
Individual Arm Pyloric Caecal Index

- Pyloric caeca = nutrient storage organ
- IAPC Index = $\frac{\text{wet wt pyloric caeca}}{\text{wet wt of entire arm}} \times 100$



http://cronodon.com/BioTech/Asteroids.html

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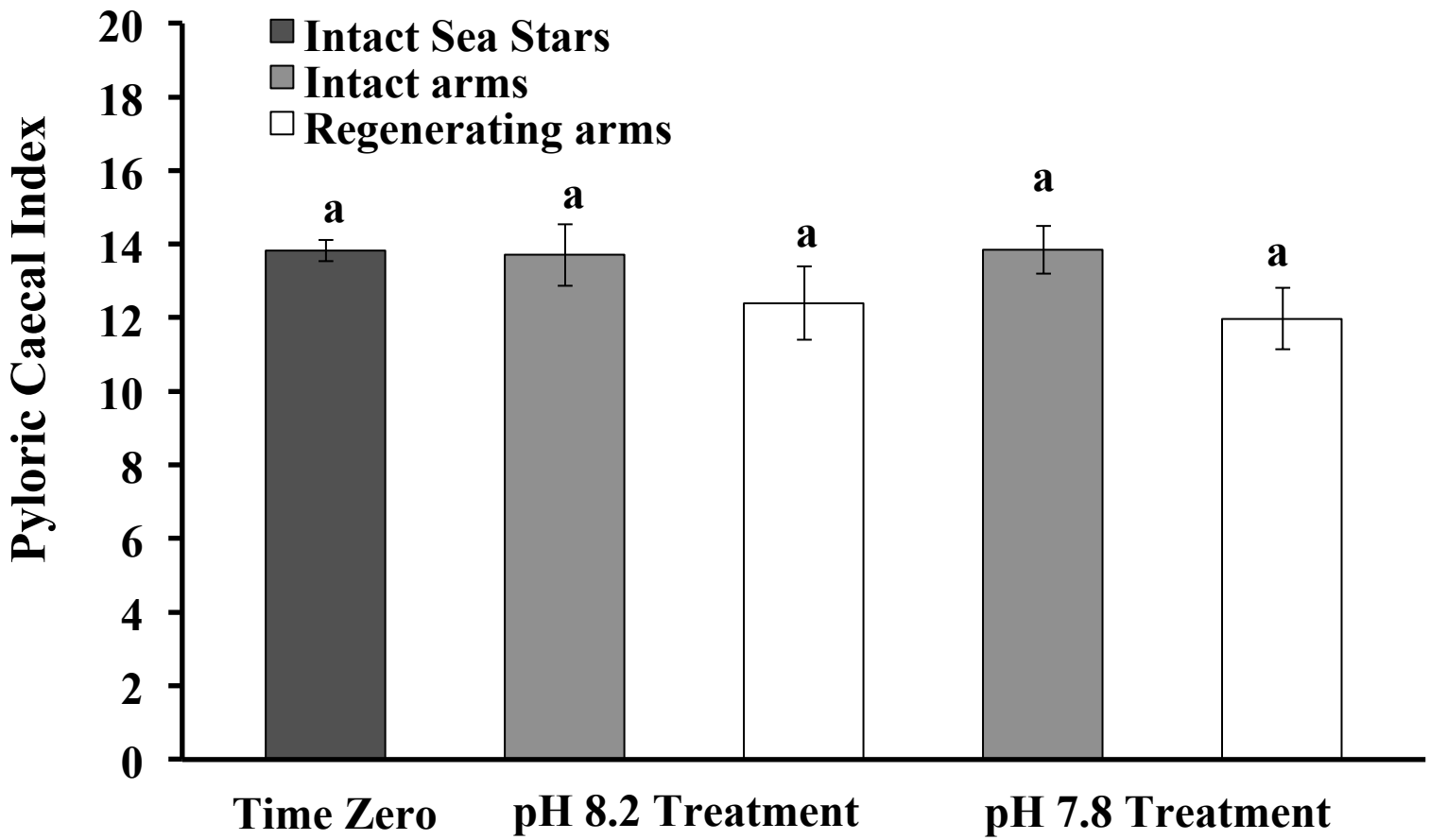
Individual Arm Pyloric Caeca Index



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Biochemical Analysis Methodology

Analyze body tissue components:

- **Soluble protein** ~ Bradford (1976) Spectrophotometric
- **Insoluble protein** ~ Lawrence et al. (1984) Subtraction
- **Soluble carbohydrate** ~ DuBois (1956) Spectrophotometric
- **Lipid** ~ Folch (1957) Gravimetric
- **Ash** ~ Paine (1966) Gravimetric

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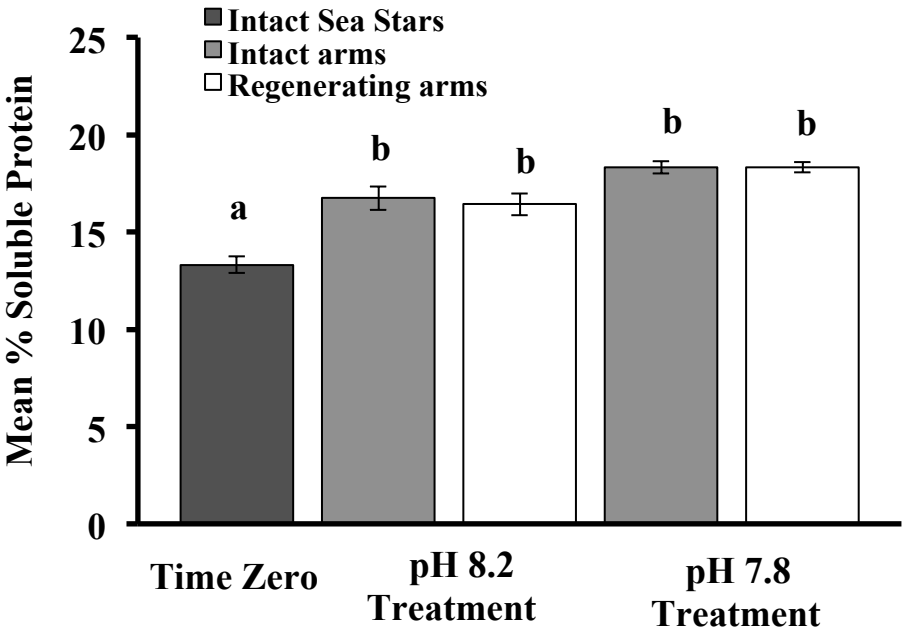
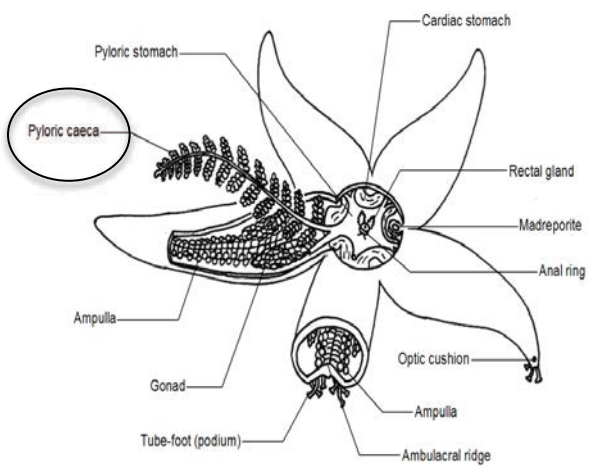
Pyloric Caeca





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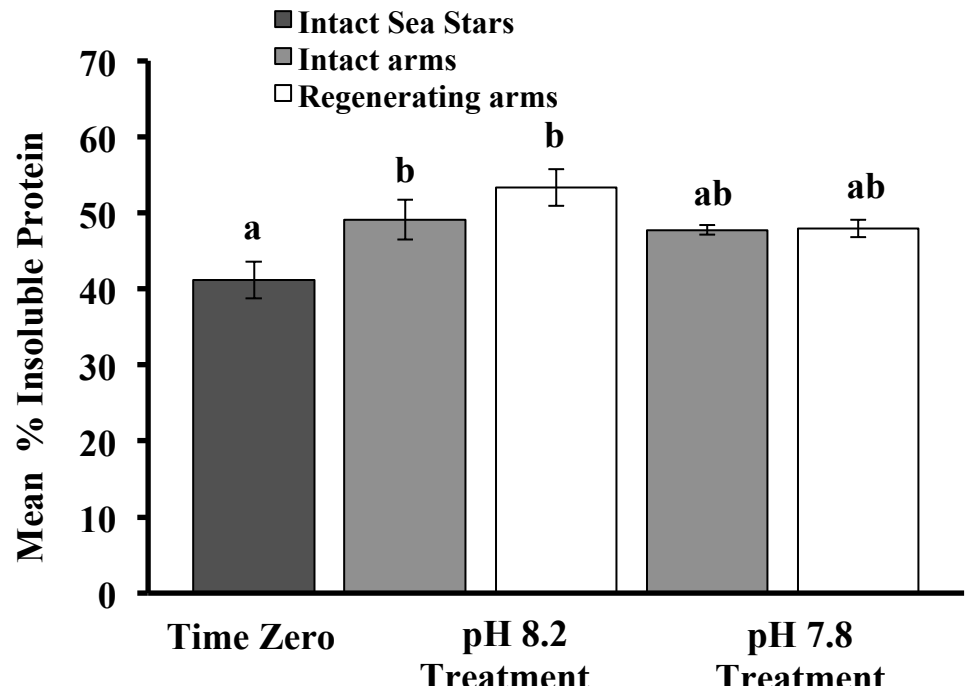

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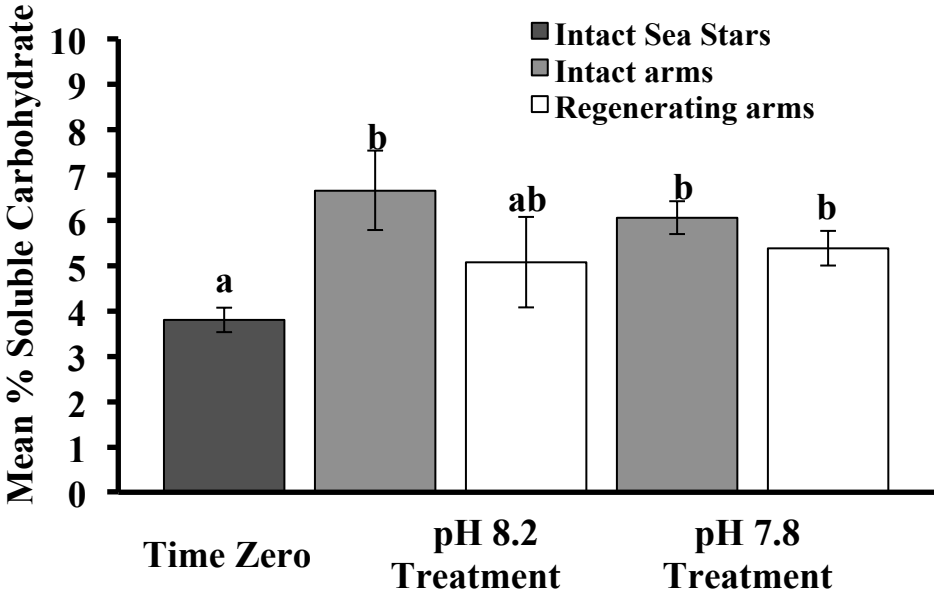
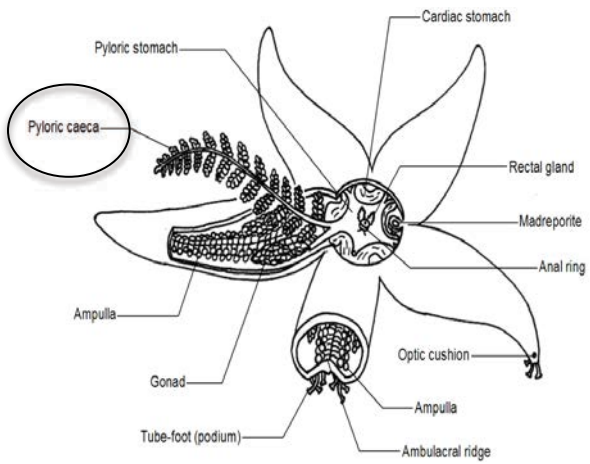
Pyloric Caeca





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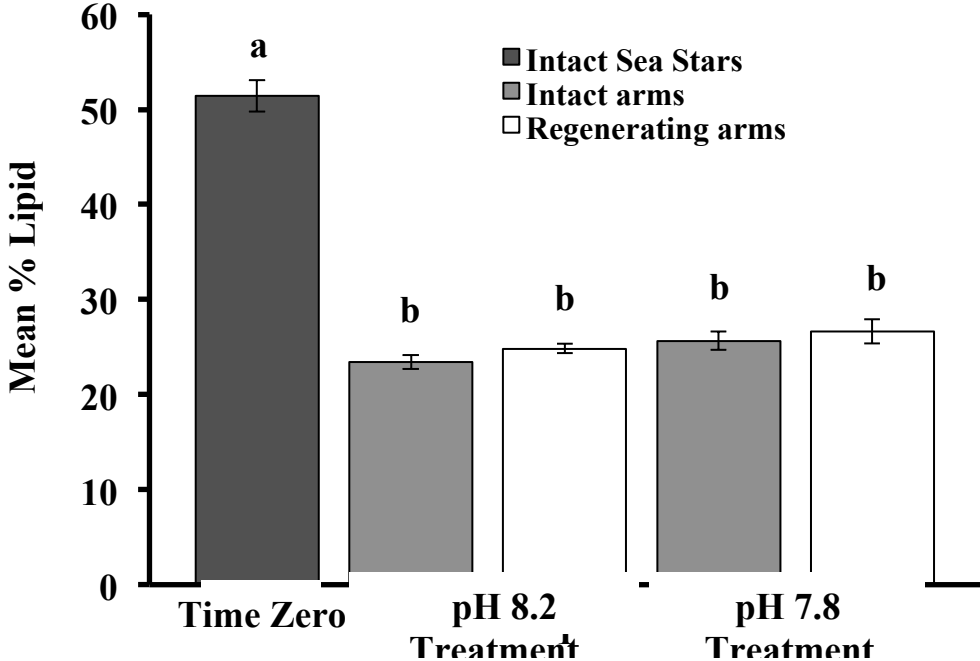

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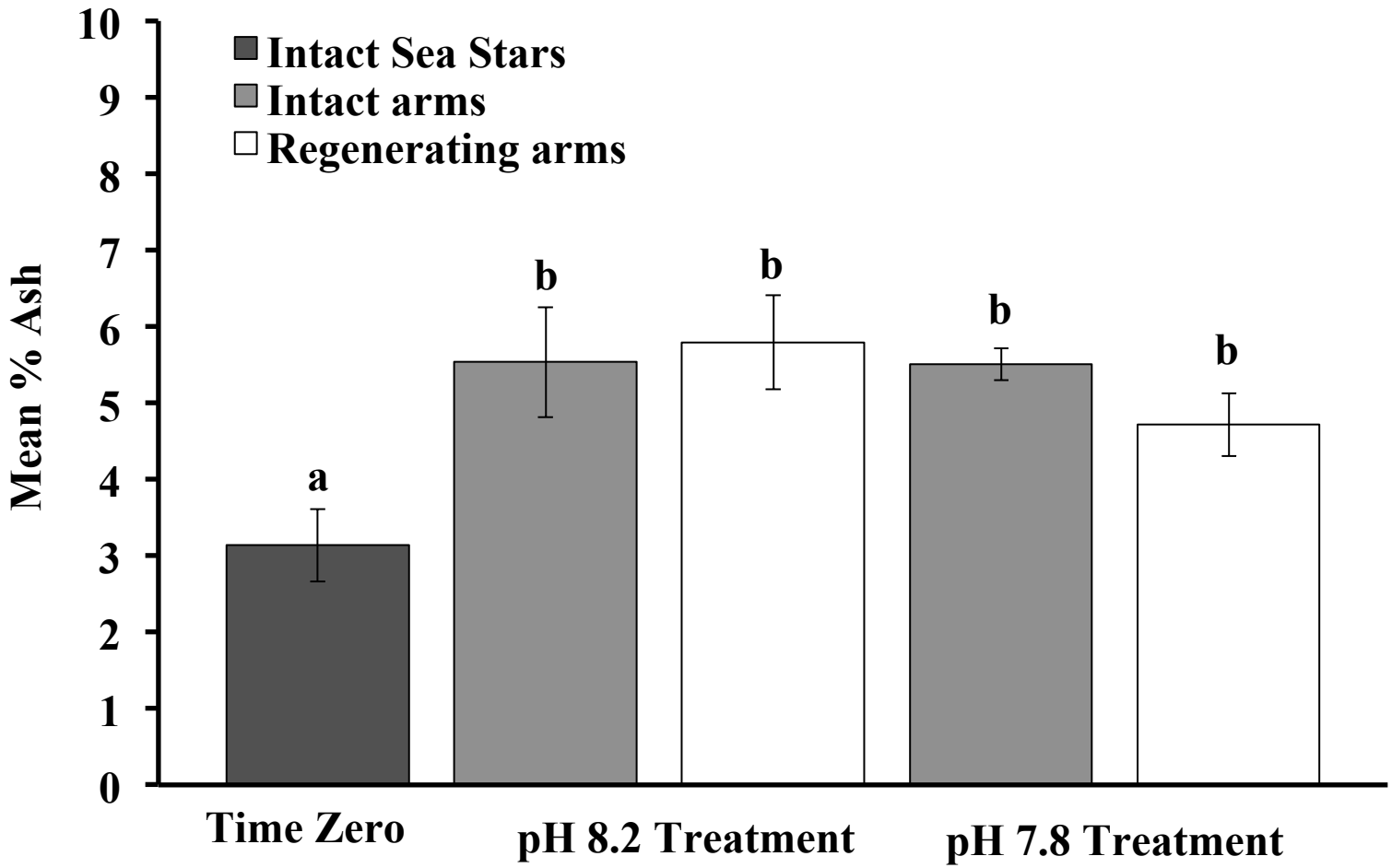
Pyloric Caeca - Ash



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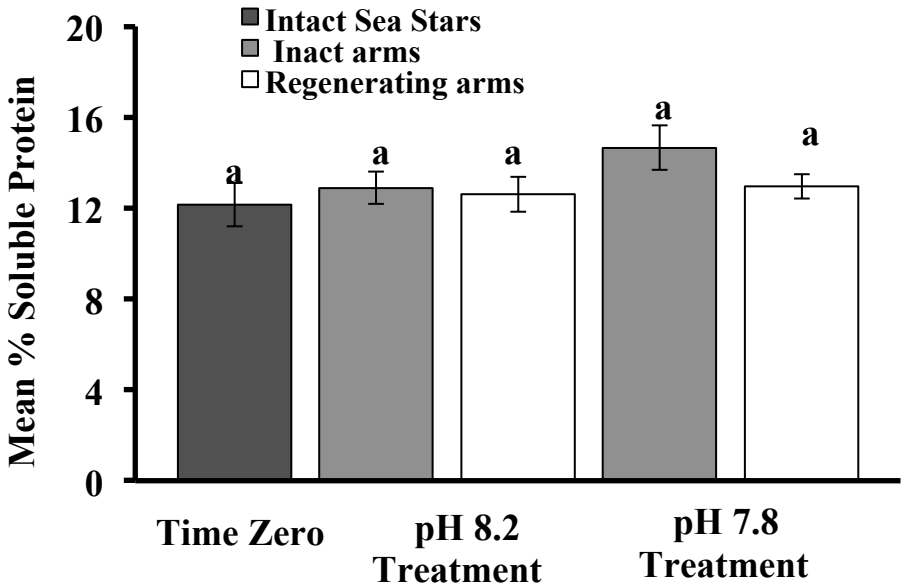
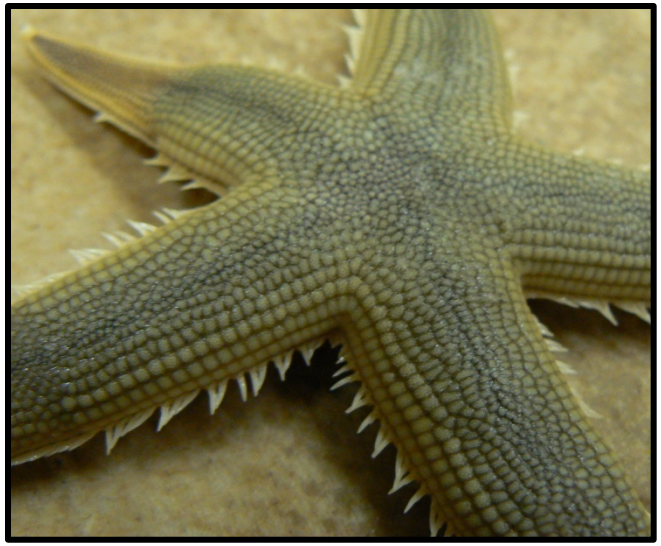
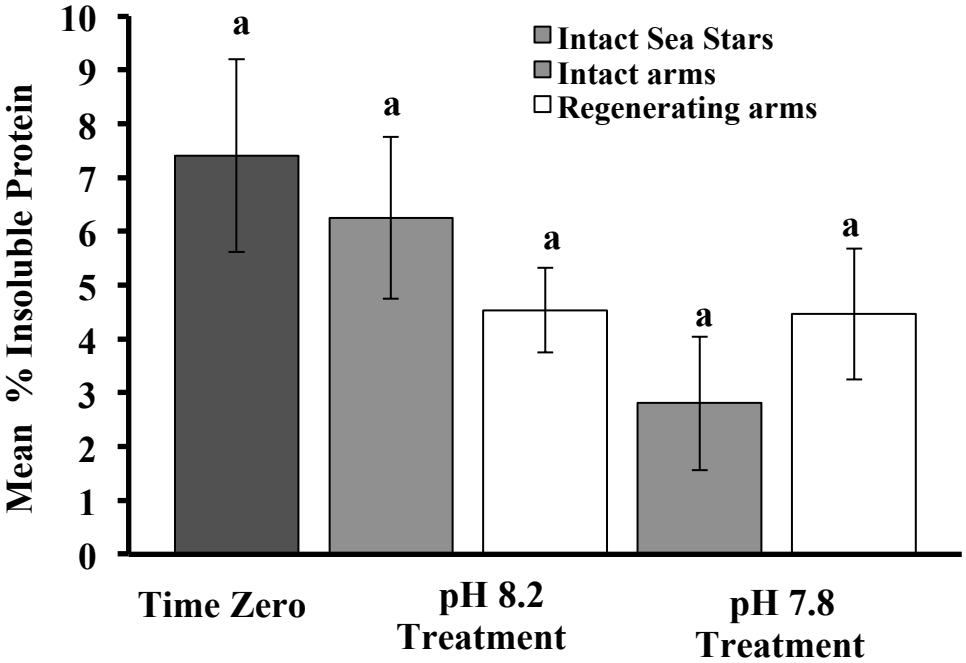


Body Wall





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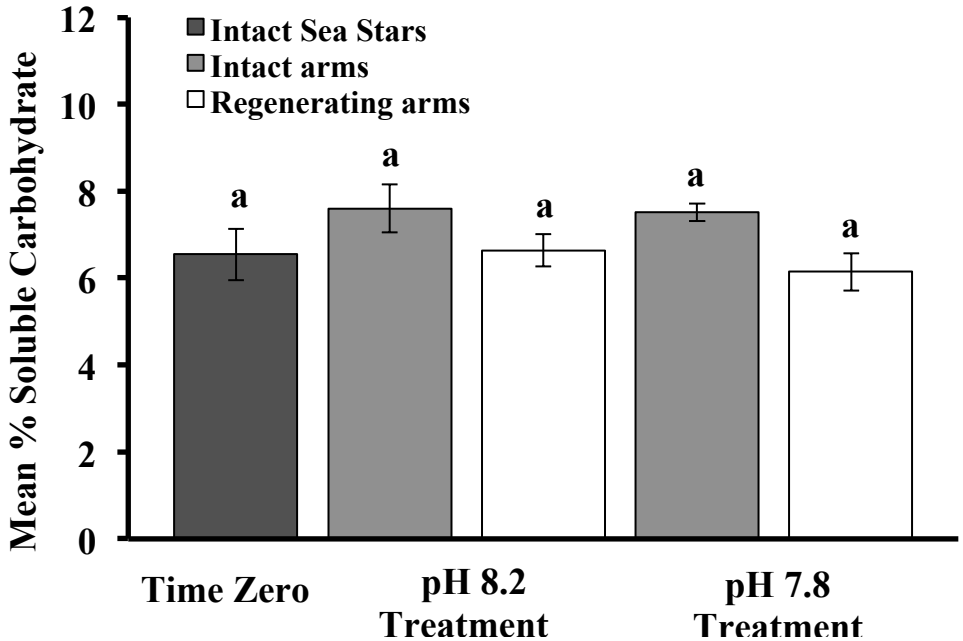
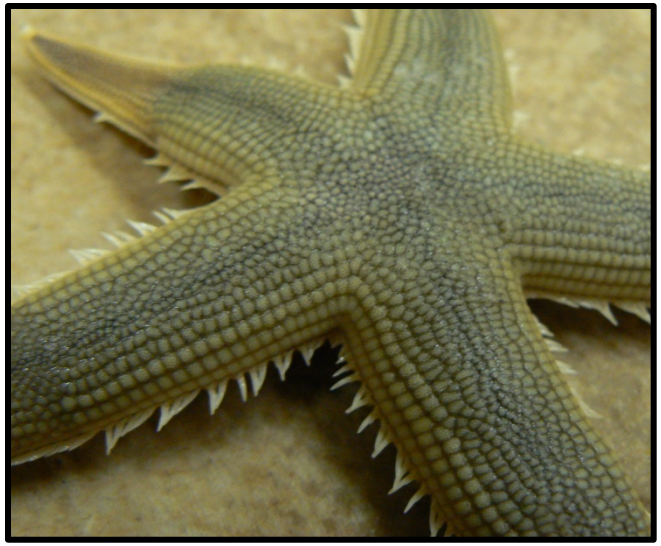
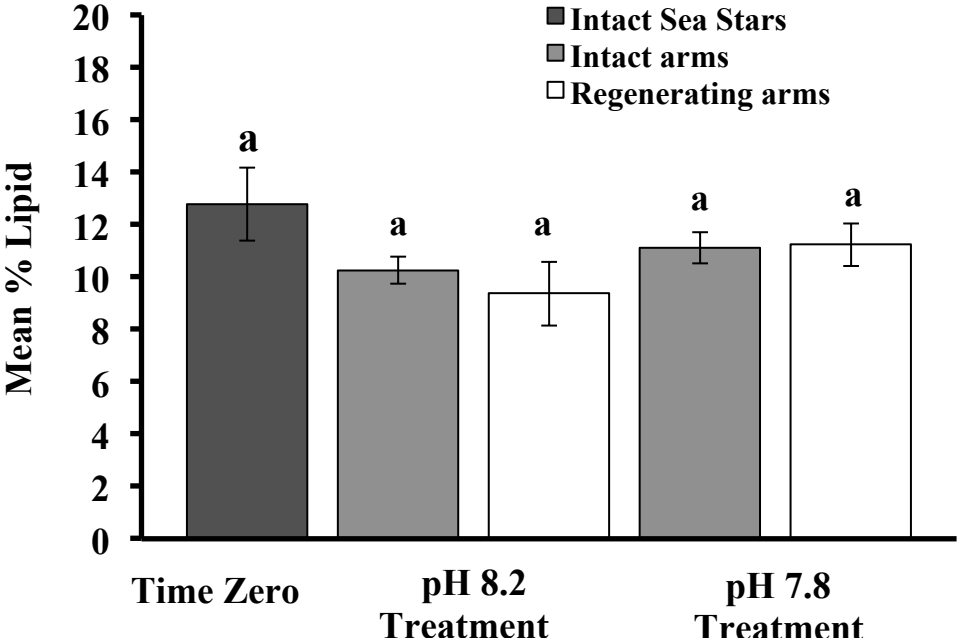


Body Wall





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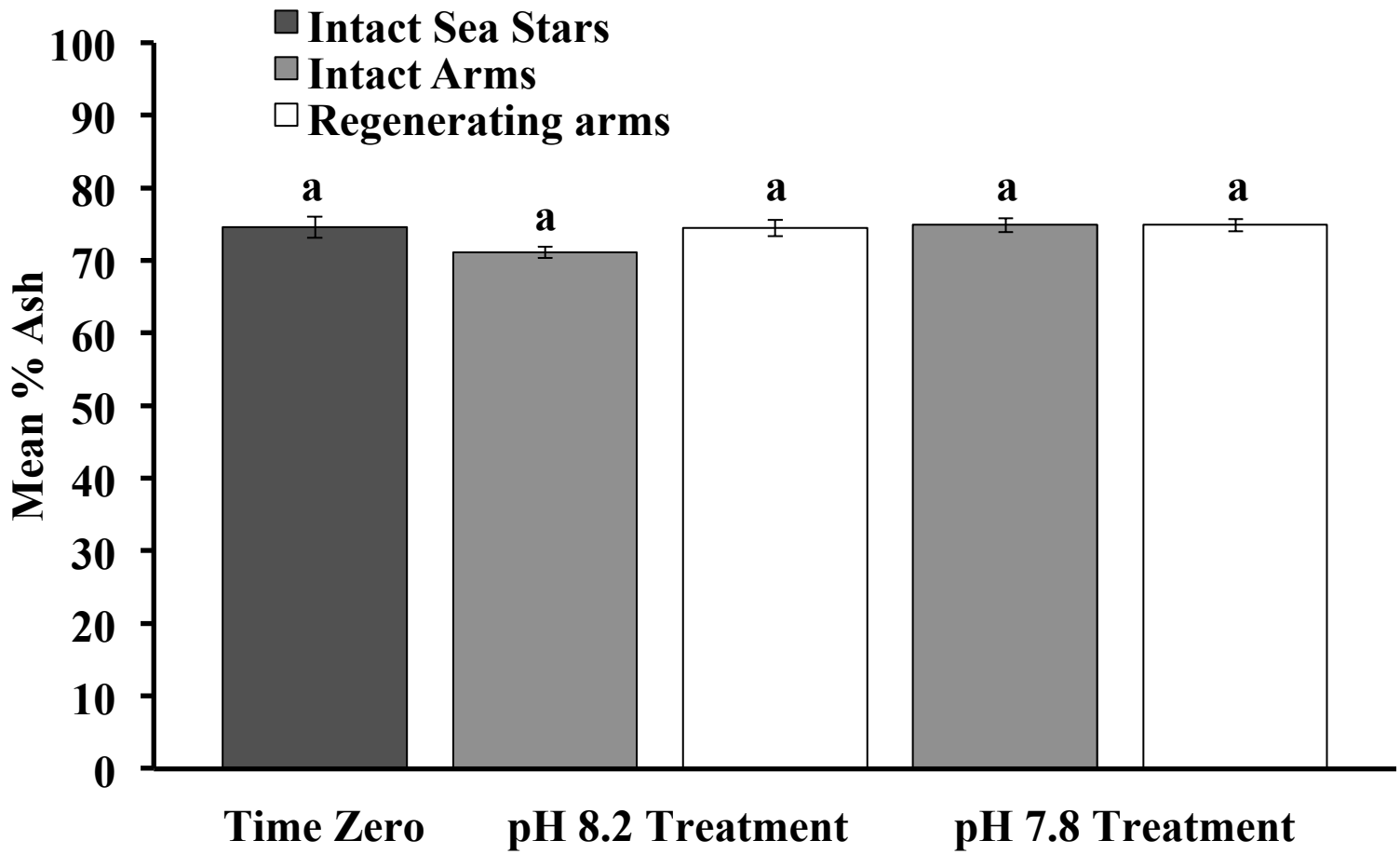
Body Wall - Ash



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Behavior

- Post-feeding ~ observed activity associated with feeding for 10 minutes after food was placed in aquaria (when fed every other day)
  - Number of climbing attempts
  - Time spent buried
  - Presence/absence of climbing behavior
  - Substrate active – active movement on substrate
  - Observe and record righting time
- Righting response ~ a measure of organismal stress

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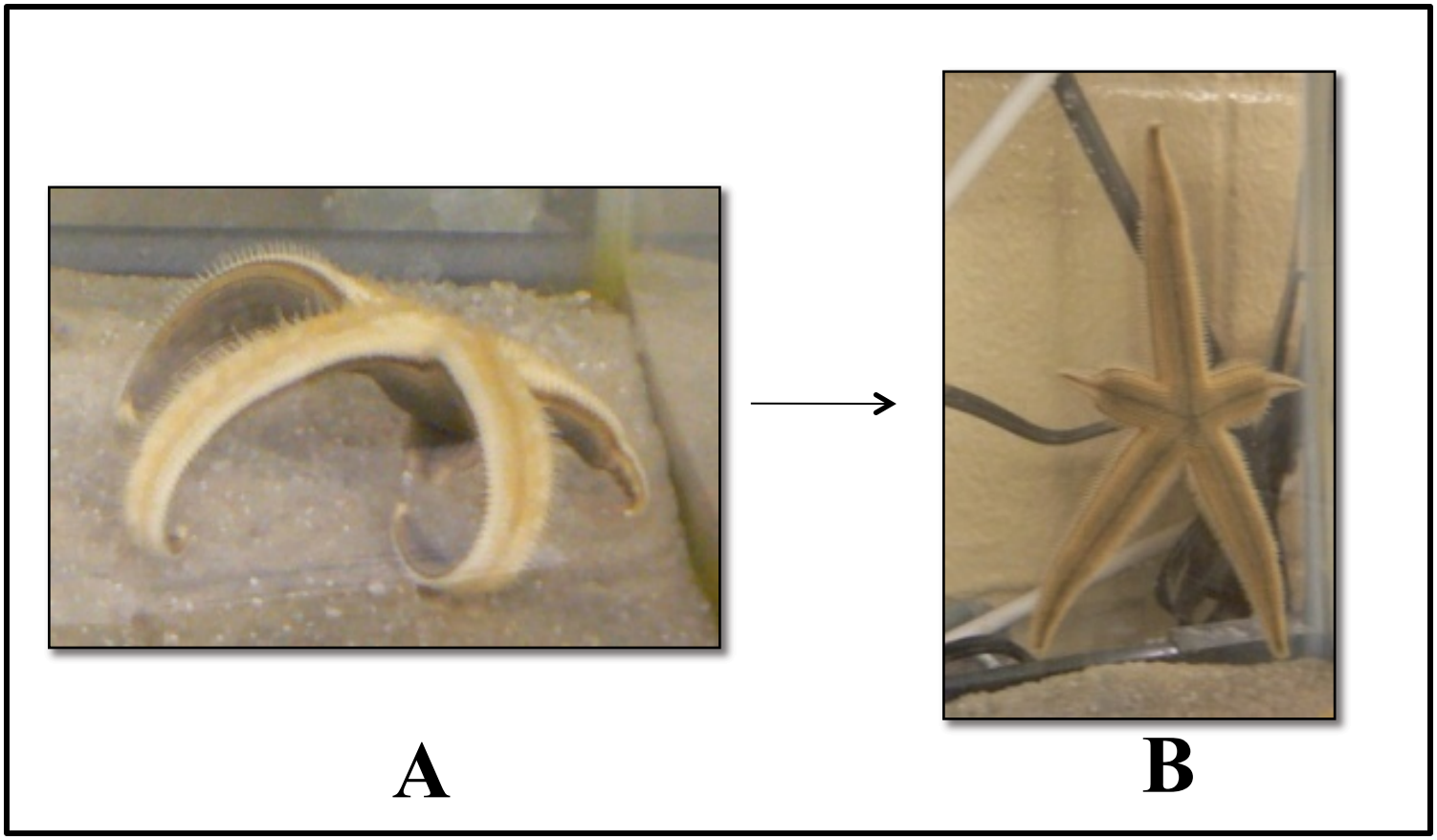
Determining Righting Activity Coefficient (RAC)



RAC = 1000 divided by the time to right (in seconds)

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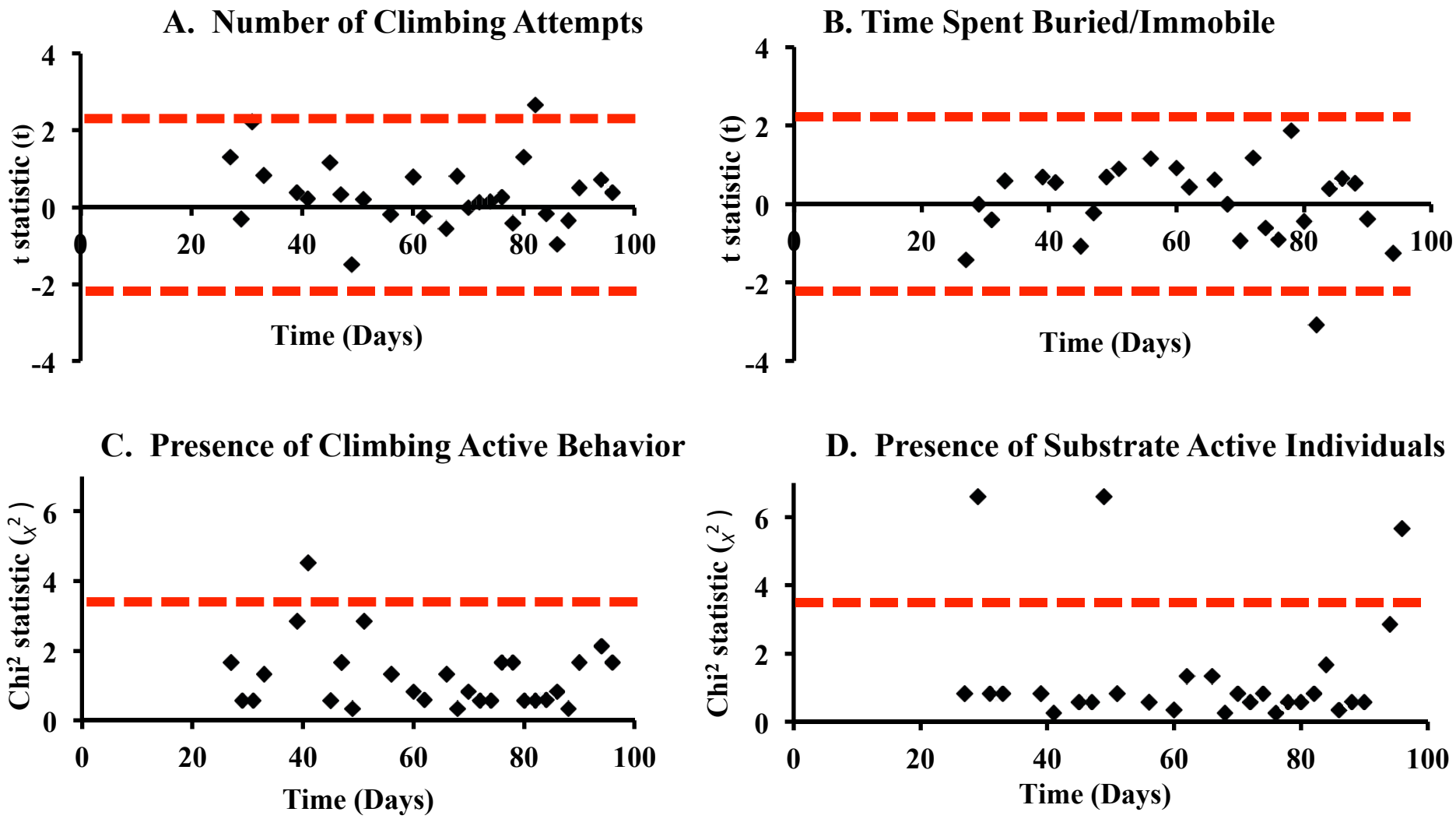
Post-Feeding Behaviors



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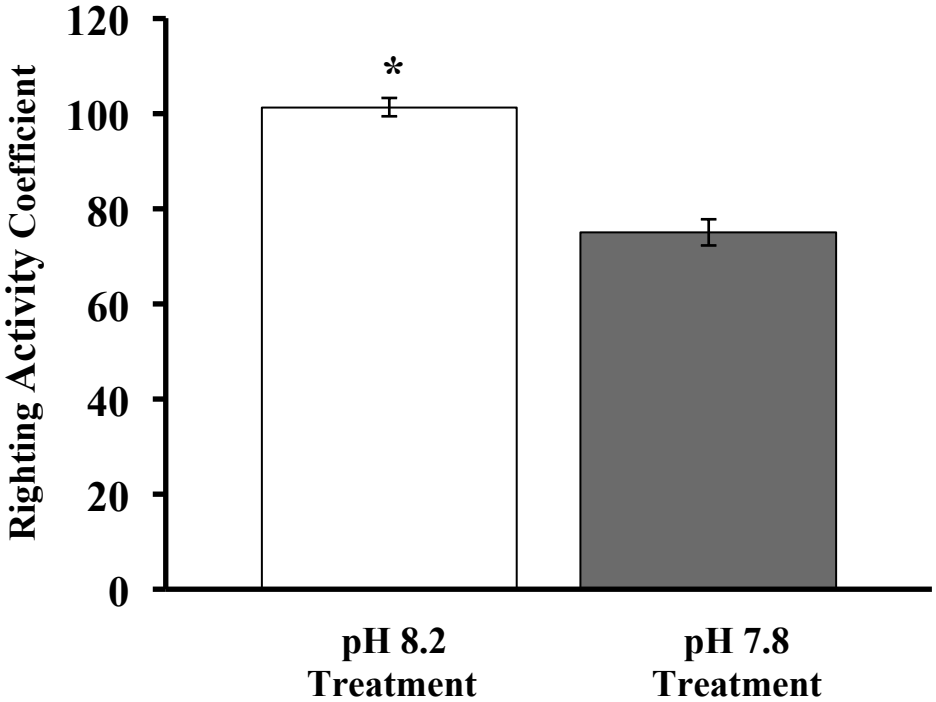
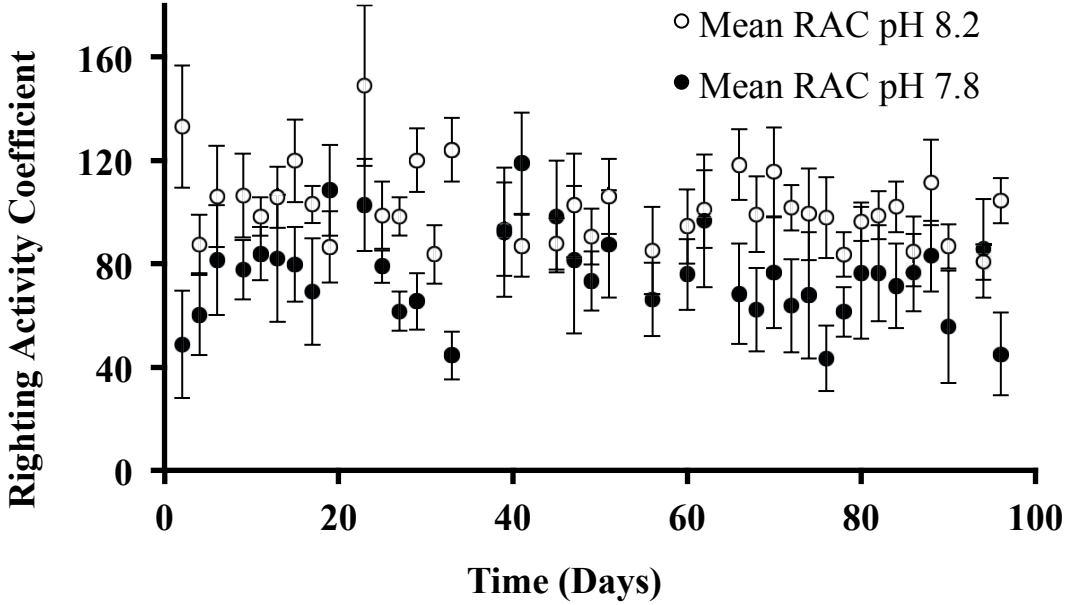
Post-Feeding Righting Activity Coefficient (RAC)





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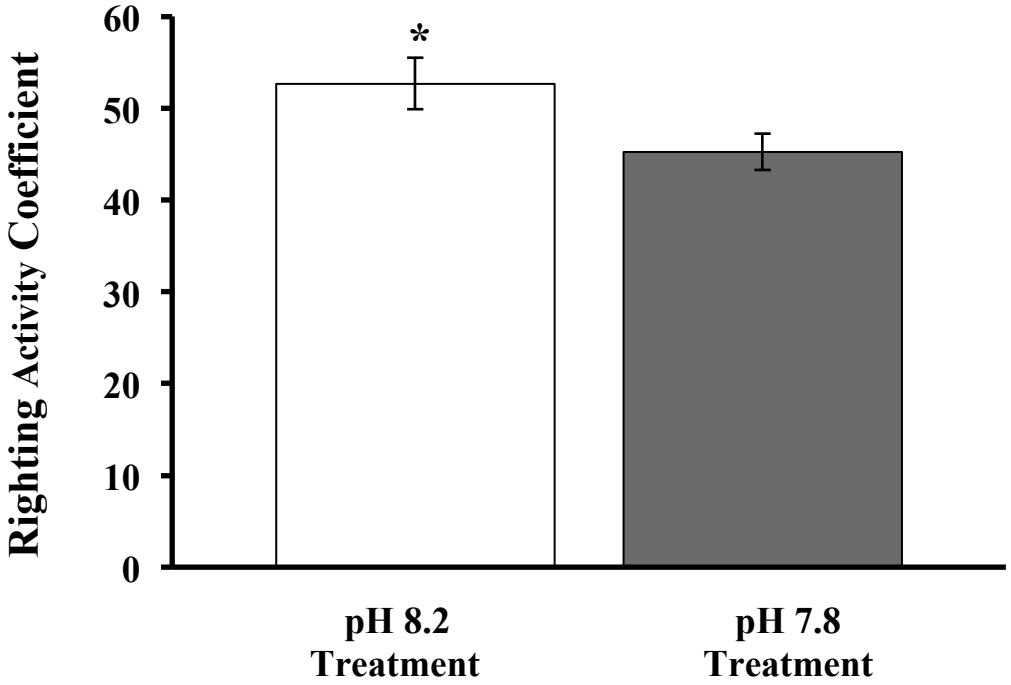
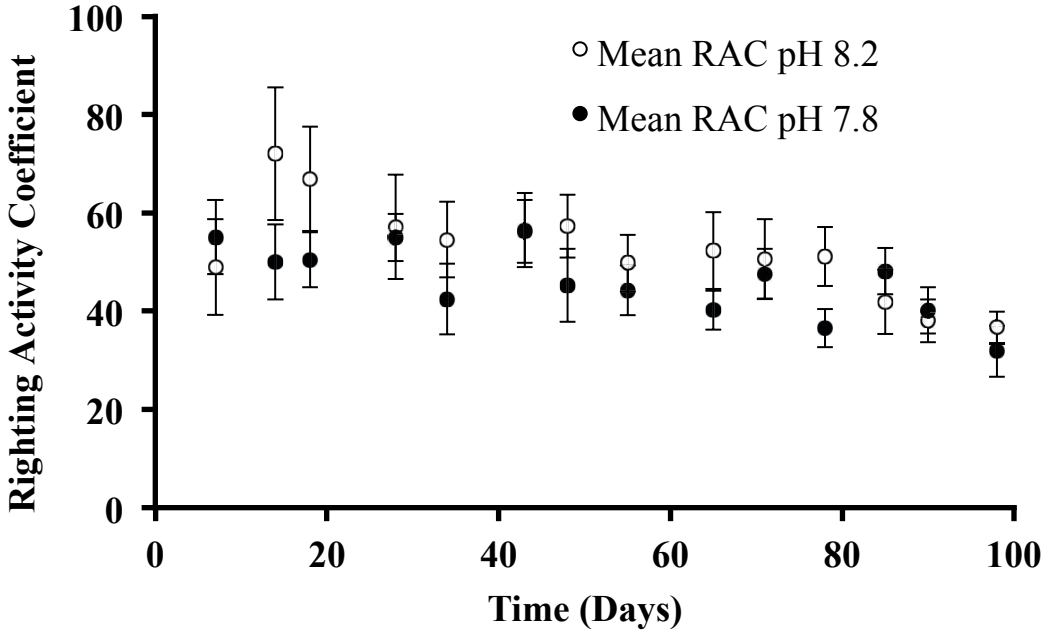
Righting Activity Coefficient (RAC)





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In both pH treatments:

- Sea stars on a sub-satiation formulated diet rapidly regenerated their excised arms

- Nutrient reserves were allocated to the body wall prior to nutrient storage

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Reduced seawater pH had no impact on:

- Rate of arm regeneration
- Pyloric caecal indices

- Biochemical composition of body components
- Most post-feeding behaviors

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Reduced seawater pH had an impact on:

- Final regenerated arm length

- Post-feeding righting response
- Non-feeding related righting response

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Take Home Message!

Despite ocean acidification only modestly impacting regenerative capacity, its impacts on some behaviors may be important to consider in marine invertebrates.

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Research Acknowledgments

My Committee

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