



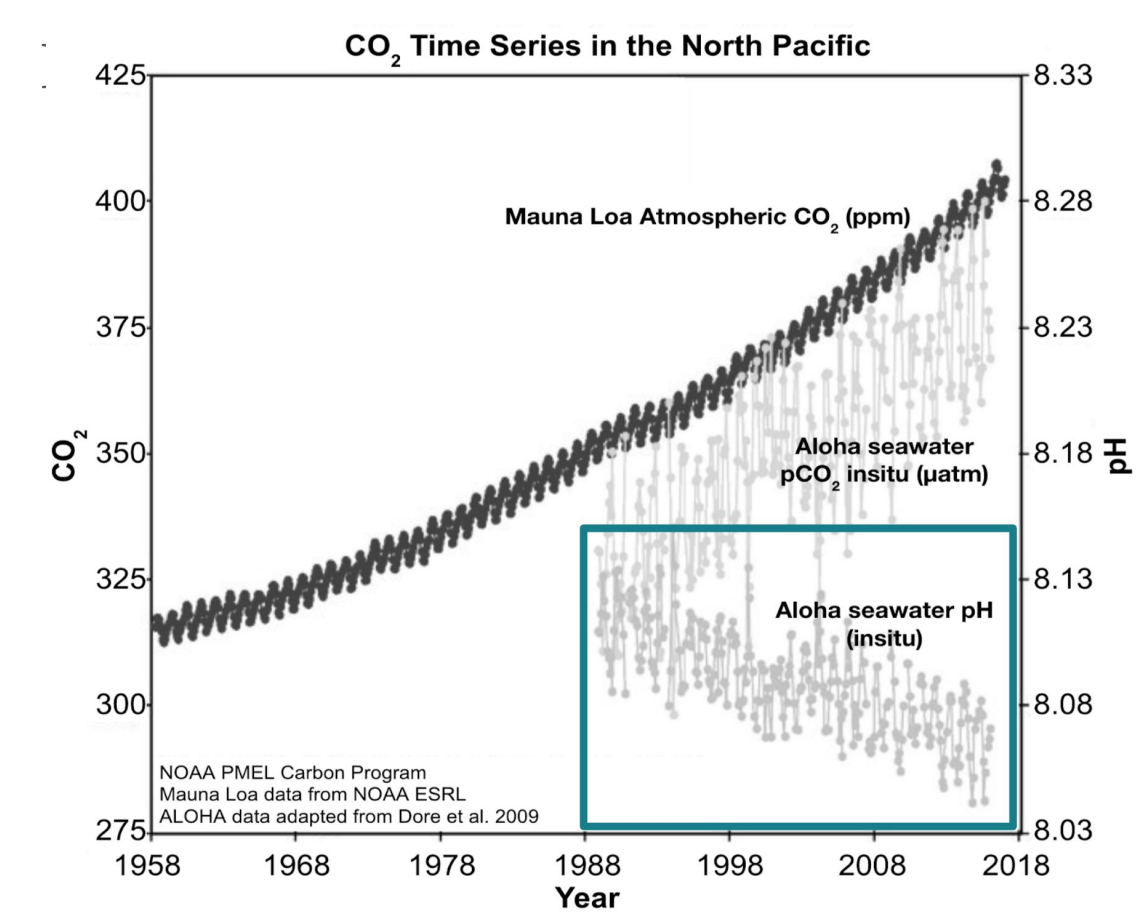
Reduced success of urchin fertilization under low pH conditions

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Abstract

The oceans serve as an important carbon sink, but rising amounts of dissolved carbon are reducing their pH. Projections anticipate a decrease in mean surface pH from 8.07 to 7.67 by 2100, and some regions are already experiencing pH fluctuations with lows below 7.15 units. Studies have demonstrated *Strongylocentrotus purpuratus* urchins to be evolving in response to acidifying conditions, but successful spawning amongst this species may be inhibited by more acidic seawater. To determine the effect of reduced pH on fertilization success, we simulated spawning by mixing collected gametes in seawater solutions of decreasing pH and assessed eggs for fertilization using a compound microscope. We found that mean percent fertilization decreased significantly from pH 8.06 (M=98%, SD=1.81) to pH 7.00 (M=84%, SD=12.33) seawater; $t(8)=-2.52$, $p=.026$. Natural pH fluctuations combined with ocean acidification could bring pH levels below 7.00 in the near future, possibly inhibiting the success of *S. purpuratus* reproduction. The resultant decline in urchin populations would have negative consequences for the Pacific kelp forests in which this species lives and could disrupt these fragile ecosystems.

Introduction



As more carbon is released into the atmosphere and dissolved into the ocean, the water becomes more acidic: current projections anticipate that the ocean's average pH will decrease from the current 8.07 to 7.67 by 2100.¹ NOAA buoys off the coast of Oregon have already measured pH levels as low as 7.15 - these lows will continue to decrease as more carbon dissolves in the ocean.² *Strongylocentrotus purpuratus* urchins have begun evolving to adapt to their acidifying environment, modifying the pathways by which they build skeletons and regulate ions.³ However, because urchins spawn to reproduce, these mechanisms will not protect gametes from acidic conditions, which may inhibit successful fertilization.

Methods

- Two male and four female *S. purpuratus* urchins were made to spawn by injecting each with 1 mL of .5M KCl and shaking.
- Gametes were collected and sperm and eggs were mixed in solutions of seawater and acetic acid (pH values 8.06, 7.75, 7.50, 7.25, 7.00).
- After ten minutes, eggs were observed at 10x magnification with a compound microscope and thirty eggs were assessed for fertilization.
- Five trials were conducted for each pH value.

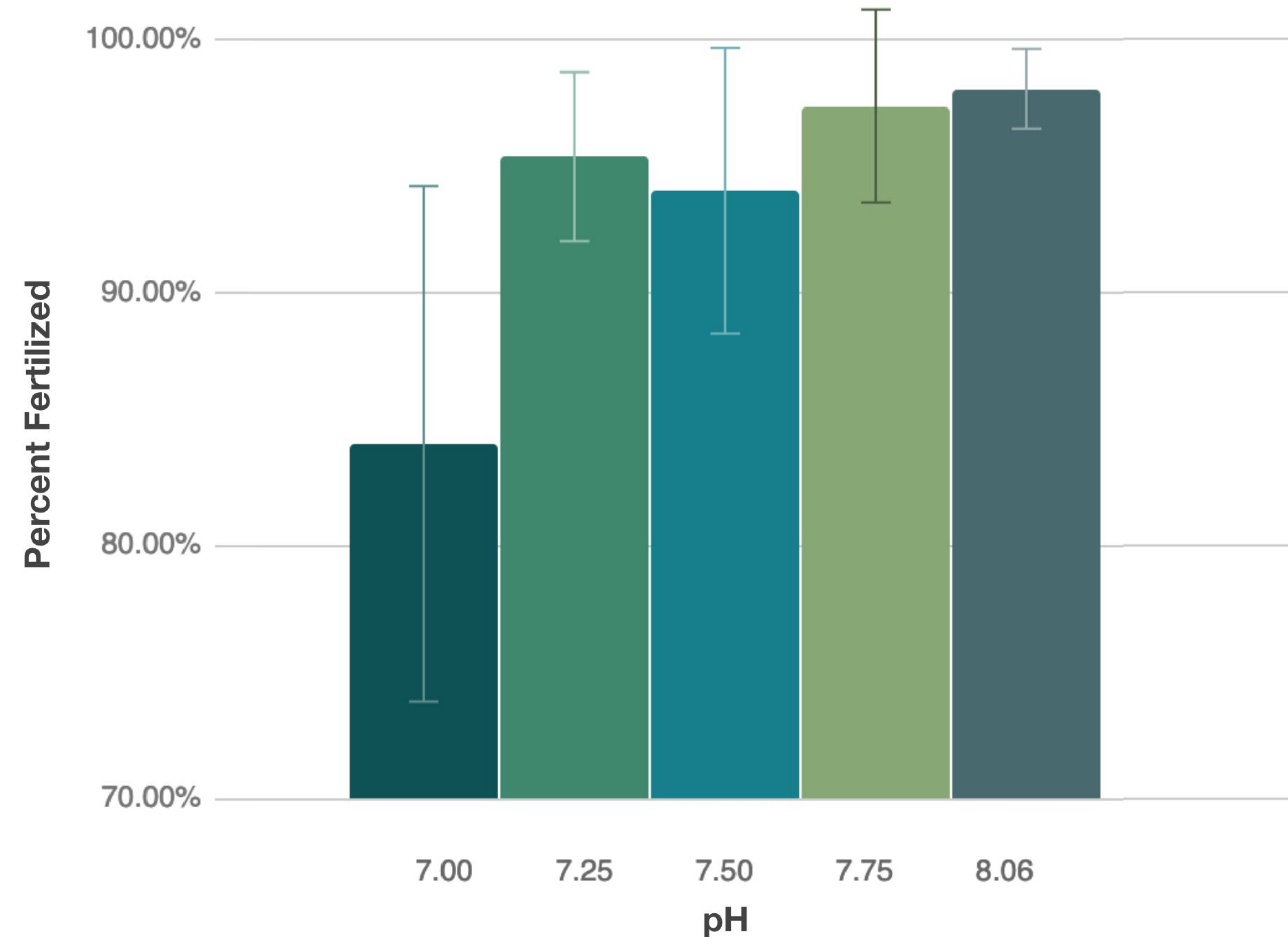
Fertilized and unfertilized urchin eggs



Results

Mean percent fertilization decreased significantly from pH 8.06 (M=98%, SD=1.81) to pH 7.00 (M=84%, SD=12.33) seawater; $t(8)=-2.52$, $p=.026$. The decreased fertilization success in higher pH seawater solutions was statistically insignificant.

Percent of urchin eggs fertilized in acidified seawater



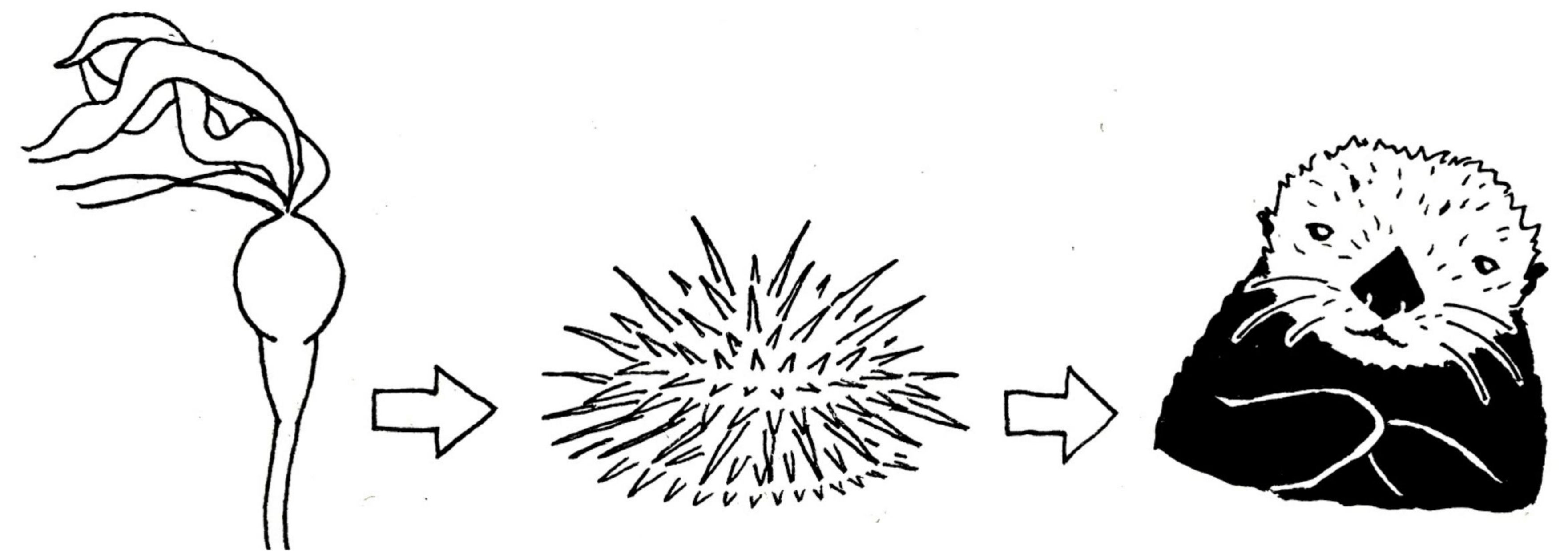
Mean percent fertilization at decreased pH; error bars = 95% CI

Proposed Mechanisms of pH-Based Inhibition

- Male urchin gonads are relatively acidic (pH 7.2) to inhibit dynein activity; spawning introduces sperm to a high pH environment in which they can respire.⁵ If pH is low, sperm may be incapable of swimming.
- The acrosome reaction requires H⁺ efflux to raise pH; if extracellular pH is reduced this may be inhibited.⁵

Discussion

- The predicted 0.7 unit reduction in current surface pH could result in seawater pH lows beneath 7.00.⁶
- This decreasing pH may lead to a reduction in successful fertilization amongst purple urchin populations.
- Reduced reproductive success could lead to population decline.



Pacific kelp forest trophic cascade

Implications

- *S. purpuratus* urchins play a significant role as grazers in kelp forests; their decline could affect these ecosystems.
- In Ireland, urchin population decline resulted in algal blooms that cause both anoxic and hypoxic conditions.⁷
- In the Caribbean, biodiversity greatly decreased after urchin population decline.⁸

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