The plasticity of estuarine arthropods: how arthropods from various biomes respond to elevated pCO_2 levels

Tait Algayer[1,3], Toni Sleugh[2], Dr. R. Christopher Chambers[3]

[1]The College of New Jersey,[2] Iowa State University, [3]Howard Marine Sciences Laboratory, NOAA Fisheries Service

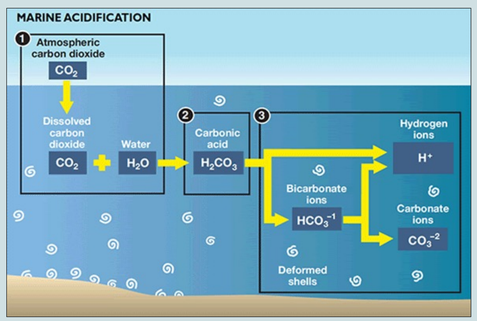
Introduction

Ocean acidification (OA) poses a threat to marine biomes and their inhabitants, particularly calcifying organisms. Relatively little is known about the functional responses of calcifying organisms, such as arthropods, to OA. Recent studies have demonstrated significant impairments to physiological mechanisms of arthropods upon exposure to elevated CO_2 levels. Due to the variety of biomes that arthropods inhabit, assessing how OA affects this taxon is challenging. This meta-analysis examined physiological and behavioral responses of marine arthropods to predicted future ocean conditions by reviewing extant studies that experimentally manipulate CO_2 concentrations.

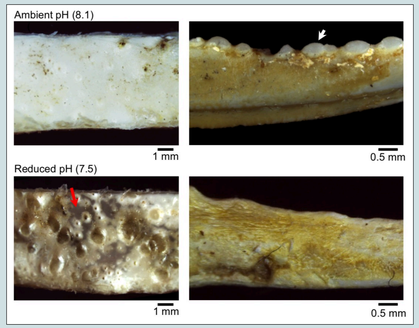
Hypothesis

The magnitude of CO_2 effects on physiology, behavior, and survivability will increase with severity of acidification, and that significant associations will arise between the pattern of CO_2 impacts and biome of the examined taxa.

Mechanism & Impact of Ocean Acidification



Mechanism by which atmospheric carbon dioxide is absorbed by the ocean. Carbon dioxide is released into the atmosphere when hydrocarbon fuels (i.e. wood, coal, natural gas, gasoline, and oil) are burned.
Image: UK Ocean Acidification research program



Visible erosion (e.g. the darkened region marked by the red arrow, lower left) observed in Tanner crab claws after a 2 year exposure to reduced pH (7.5) This erosion was not observed in crabs held at ambient pH (8.1).
Image: Dickinson et al. (2021)

Selection Criteria and Data Quantification

This meta-analysis included 106 studies that examined how survival, growth, behavior, and metabolic processes of marine arthropods are affected by elevated CO_2 levels. All studies recorded acidification in µatm, controlled treatment levels in a laboratory setting, and acidified water via CO_2 bubbling.

Response variable categories were defined by the following metrics:

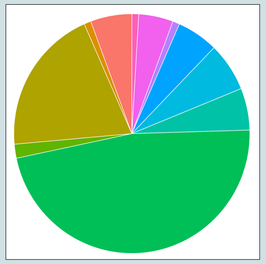
- **Metabolic Processes:** Respiration rate, oxygen consumption, hemolymph pH, heart rate
- **Growth:** Δ mass, wet mass, dry mass, carapace length/width, total length/width
- **Behavior:** Resource efficiency, righting response, time spent active, swimming speed
- **Survival:** Survival rate or mortality rate, longevity, temporal average mortality

Data values were extracted from images of published figures by using values as reported in the text or by using an online freeware (WebPlotDigitizer v. 4.3, Rohatgi) to extract data directly from figures.

Statistical Methods

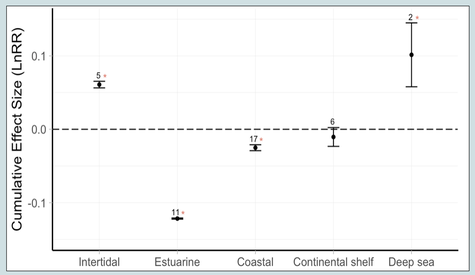
For each treatment level, magnitude of the response to elevated CO_2 was quantified by using the mean and standard deviation to calculate the log-transformed response ratio and the variance of the response ratio. Response ratios were averaged by finding the cumulative effect size and significance was determined using a 95% confidence interval.

Represented Orders



Color	Order	%
	Decapoda	47.17%
	Calanoida	19.81%
	Harpacticoida	6.60%
	Amphipoda	5.66%
	Euphausiacea	5.66%
	Isopoda	5.66%
	Sessilia	4.72%
	Cyclopoida	1.89%
	Anomopoda	0.94%
	Mysida	0.94%
	Stomatopoda	0.94%

Metabolic Processes

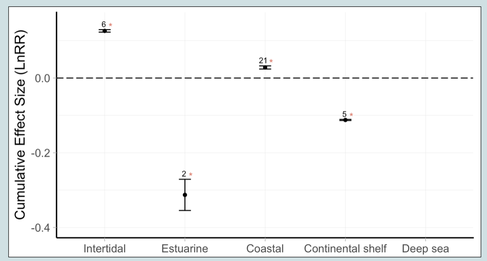


*Negative values indicate a deleterious effect of elevated pCO_2 levels and positive values indicate increases in functioning upon exposure to increased pCO_2 levels . The number above error bars denotes the number of data points used to calculate the mean and the asterisk denotes a significant difference from zero. Error bars represent 95% confidence intervals.

Key Points

- Estuarine & Coastal experience reductions in metabolic processes
- Intertidal & Deep sea experience increases
- Estuarine arthropods are the most affected

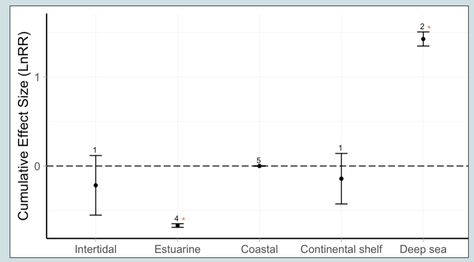
Growth



Key Points

- Estuarine & Continental Shelf arthropods experience reductions in growth
- Intertidal & Coastal arthropods experience increases
- All biomes are significantly affected

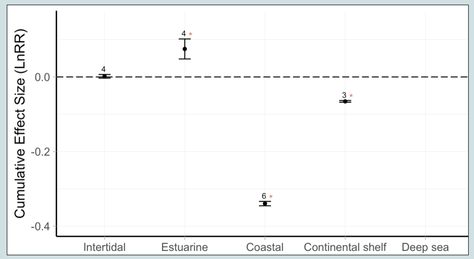
Behavior



Key Points

- Estuarine arthropods experience reductions in behavioral functioning
- Deep sea arthropods experience increases
- All other biomes are insignificantly affected

Survival



Key Points

- Estuarine arthropods experience increases in survival
- Coastal arthropods experience reduction
- Continental Shelf arthropods experience reductions

Summary and Implications of Findings

- Estuarine arthropods show reduced sublethal traits in response to OA, suggesting expression of plasticity that downregulates metabolism, growth, and behavior to conserve survival when exposed to environmental stress
- Coastal arthropods experience a decrease in survival while estuarine arthropods experience an increase, suggesting that this compensatory mechanism is unique to estuarine arthropods
- Intertidal arthropods did not experience any reductions in physiological or behavioral functioning, indicating high resilience in response to elevated pCO_2 levels
- Continental shelf arthropods showed decreases in survival and growth, implying relatively high susceptibly to OA

Acknowledgments

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References

Dickinson, G. H., Bejerano, S., Salvador, T., Makdisi, C., Patel, S., Long, W. C., ... & Aronson, R. B. (2021). Ocean acidification alters properties of the exoskeleton in adult Tanner crabs, Chionoecetes bairdi. *Journal of Experimental Biology*, *224*(3)