Ocean acidification impairs the ability of American lobsters (*Homarus americanus*) to respond to food odors

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Background

- The nearshore Gulf of Maine is warming faster than the majority of the world's oceans, and is likely to experience heightened coastal ocean acidification (COA) as well [1].
- The consequences of COA could be profound for many fished species, including the American lobster (*Homarus americanus*) [2].
- Research on the effects of COA on lobsters has primarily focused on larval development and shell formation [3,4], yet acidification can also alter behaviors mediated by chemical cues [5,6].
- The objective of this study was to determine if the responses of lobsters to food odors would be altered when the pH is reduced by adding CO_2 to seawater.

Methods

- We conducted three experiments to measure the responses of juvenile lobsters (24-60 mm carapace length) to herring bait under ambient and lowered pH conditions (Table 1).
- A GLA PRO CO_2 controller was used to create acidified (low pH) conditions by bubbling CO_2 into raw seawater in a mixing container prior to allowing it to flow into the experimental arena.
- **Experiment 1** tested the effect of pH on lobster response times.
- **Experiment 2** also tested response times, but the response times were measured for each lobster under both ambient and acidified conditions, in random order, with two weeks between trials.
- **Experiment 3** tested bait handling time using a HOBO Pendant G accelerometer datalogger that was placed in the bait container (Fig. 1).

Table 1. Details of each of the three experiments.

Experiment	# of lobsters	Acidified pH	Ambient pH	Temperature (°C)	Salinity (psu)
1	23	6.2-6.5	8.0-8.2	13-19	30-33
2	8	6.6-7.3	7.8-8.2	15-22	30-36
3	5	7.2-7.6	7.8-8.1	12-18	30-32

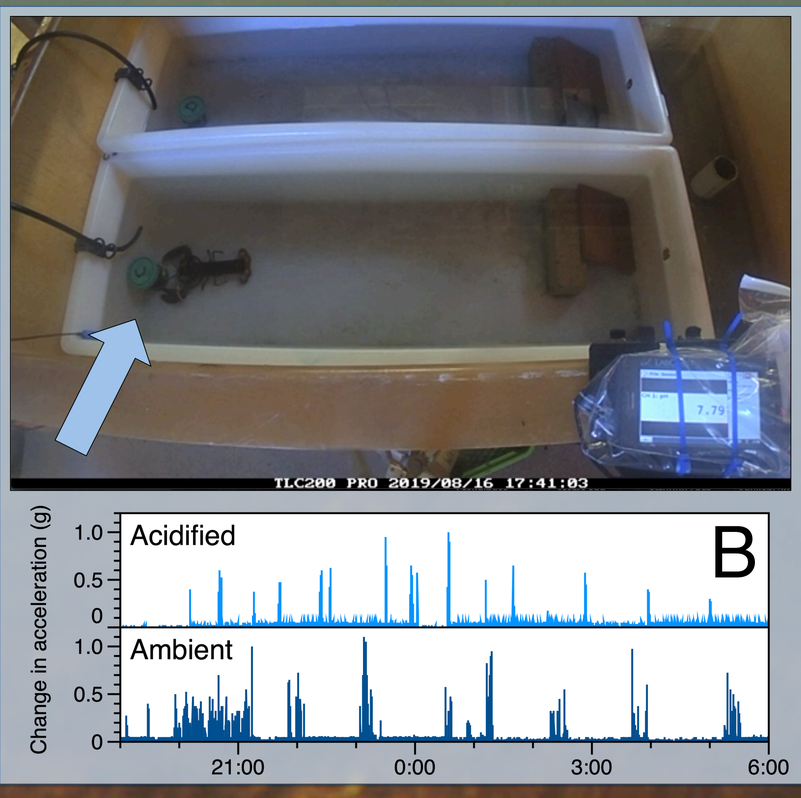

Figure 1. A: Setup for Experiment 3. In the bottom test arena a lobster is interacting with the bait container that also has an accelerometer in it (arrow), while the lobster in the top arena has yet to leave its shelter.
B: Example showing accelerometer output from runs with the same lobster under acidified and ambient conditions. Each tick mark on the x-axis represents one hour. Note fewer "spikes" in acidified conditions, especially shortly after adding the bait container, indicating less handling.

Literature cited

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Results

Acidification delays response to food odors

- Lobsters took longer to react to the addition of food (herring bait) under acidified conditions in all three experiments (Figs. 2, 3). In Experiment 2, lobsters first tested under acidified conditions were faster to reach the bait when tested again under ambient conditions, indicating that acidified conditions did not permanently affect olfactory abilities.

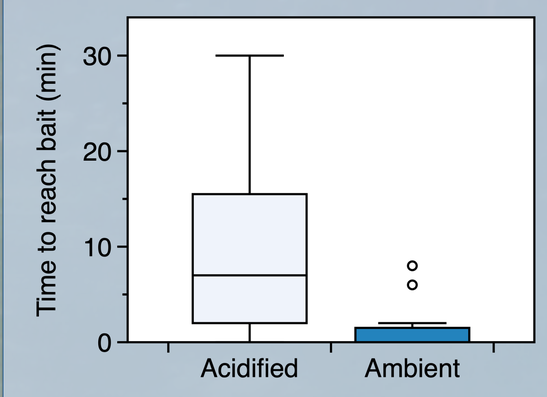

Figure 2. Time taken to reach the bait in Experiment 1**.** Whiskers represent interquartile range and dots are outliers. Lobsters took significantly longer to seek out bait in acidified seawater than in ambient seawater (paired t-test, t = 4.079, df = 22, p = 0.005).

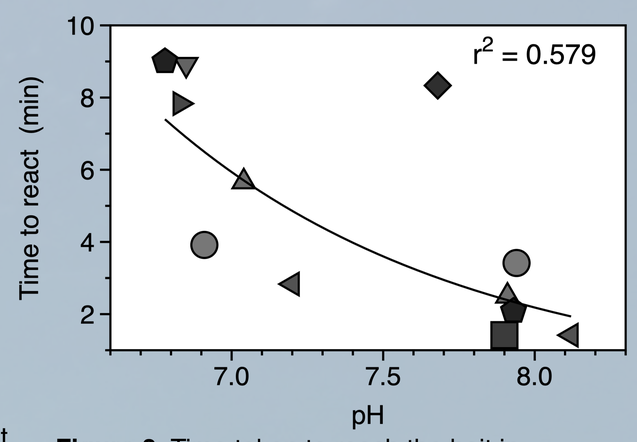

Figure 3. Time taken to reach the bait in Experiment 2**.** Each different symbol represents an individual lobster. The trendline represents a logarithmic fit.

Acidification does not reduce time spent handling food items

- There was no effect of pH on the overall time spent handling the bait in Experiment 3, but there was an interactive effect between pH and time since bait addition (Fig. 4). Overall activity levels were not changed by acidification (Fig. 5).

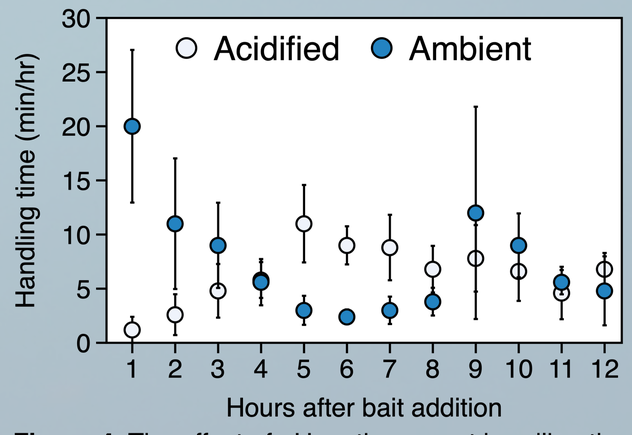

Figure 4. The effect of pH on time spent handling the bait container in the 12 hours after bait addition, as measured by an accelerometer in the container. There was no effect of pH on overall handling time (split plot ANOVA, $F_{1,8}$ = 0.70, p = 0.798), nor was there an effect of hour ($F_{11,88}$ = 0.334, p = 0.976). There was a significant interaction between pH and hour ($F_{11,88}$ = 4.452, p < 0.001)

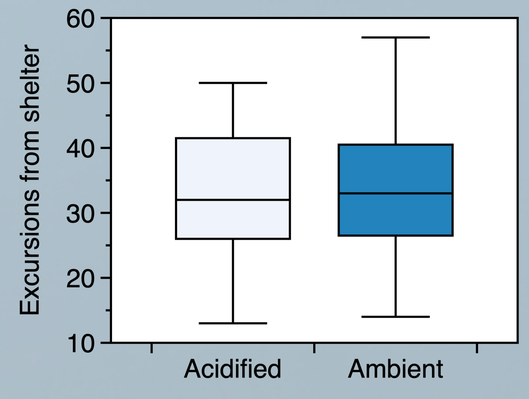

Figure 5. The number of excursions lobsters made from their shelters over the course of the first 12 hours after bait addition in each treatment. Whiskers represent interquartile range. There was no effect of pH on activity (paired t-test, t = 0.365, df = 6, p = 0.73)

Discussion

- The delayed responses to food odors are indicative of impaired olfaction. Lobsters remained active in acidified conditions, but were less able to localize the odor source. However, when the bait was encountered, it remained attractive, potentially due to different chemoreceptors for distance and contact sensing.
- The delayed responses are consistent with data from other decapod species [7,8], indicating that sensory impairment deserves consideration as a major impact of COA.

Effects on foraging and fisheries

- Olfaction is vital to lobsters for foraging. A reduction in olfactory abilities may lead to both decreased lobster foraging success, and decreases in fishery catch rates, as trap baits become less effective. Alternative baits that may perform better in acidified conditions may be able to help and should be further investigated.
- In contrast with these results, other marine decapods show reductions in food handling time in acidified conditions [8,9]. Further work should be done to clarify how and why lobster chemoreception may be affected differently by COA than other decapods.

Implications for lobster populations

- Lobsters are highly mobile and will move to areas where they find more favorable water conditions [10]. Therefore, an aversion to acidified areas could lead to shifts in their distribution along the coast.
- Lobster mating relies on chemoreception of pheromone cues. If acidification reduces perception of pheromones similarly to baits, this may cause reproductive failure.