Influence of Microplastics on *Emerita analoga* Temperature

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Abstract

The growing amount of microplastics in marine coastal areas and the impact of this debris on the physiology and health of organisms is a global concern. Pacific mole crabs *(Emerita analoga)* are one of the most important species of the macrofauna community in the North American West coast intertidal ecosystems. It is still unknown how microplastic presence affects the temperature of these burrowing organisms found in the foreshore. We examined the effect of microplastics (polypropylene pellets) on the body temperature of large and small burrowing Pacific mole crabs using infrared thermographic technology (IRT) both at the surface (Treatment #1) and while borrowing (Treatment #2). There was greater overall temperature change of the mole crabs in the sand substrate compared to the substrate with sand and propylene pellets (7.2°C/g, 6.6°C/g respectively). Increasing global temperatures signal a need to understand how organisms will react to spikes in heat; particularly those that rely on outside sources for their thermal regulation. Understanding how *Emerita analoga* is impacted by microplastic pollution helps us predict how they and other intertidal marine invertebrates will cope with both their own thermal physiology and climate change.

Introduction

With no end in sight to human pollution and consumption of plastics, intertidal ecosystems face a soaring amount of plastic in their habitats. By 2014, an estimated 236,000 tons of microplastics had already accumulated in marine habitats (van Sebille et al., 2015). Specifically, a growing number of microplastics are appearing in sediment and the water column, and are being ingested by marine invertebrates (Horn et al., 2020; Gao et al., 2022). *Emerita analoga*, or Pacific mole crabs, are ubiquitous on the California coast (Lastra 2002), and filter feed in the top layer of sand, exposing them to washed up and littered plastics (Horn 2018). Across 38 beaches in California, Horn (2018) found mole crabs had ingested plastic. A study by Horn et. al. (2020) revealed that exposure to Polypropylene Plastic significantly increases mortality rate in adult mole crabs. Higher presence of microplastic was associated with a higher variability in embryonic development (Horn 2020) and a decreased rate of heat flow and average temperature of sand (Gao et al., 2022). Mole crabs are ectothermic, (body temperature depends on external sources), so environmental factors such as radiation and the type of substrate greatly influence how they interact with their thermal environment (Britannica 2019). Moreso, thermal properties between sand and plastic vary greatly (Hamdhan et al., 2010; Professional Plastics). Considering the ever-increasing amount of microplastics interacting with intertidal ecosystems, we investigated how microplastic presence in sand affects the temperature of burrowing Pacific mole crabs.

Results

Treatment #1
(0-5min - Surface Heat Intake)
Although these results weren't statistically significant (unpaired T-test; $p=0.054$; $t=2.10$), mole crabs were on average 2.2°C/g higher when placed next to sand & plastic versus sand.

Treatment #2
(5-15min - Substrate Heat Intake)
Mole crabs in sand changed on average 2.8°C/g more than those in sand & plastic (unpaired T-test; $p=0.021$; $t=2.61$).

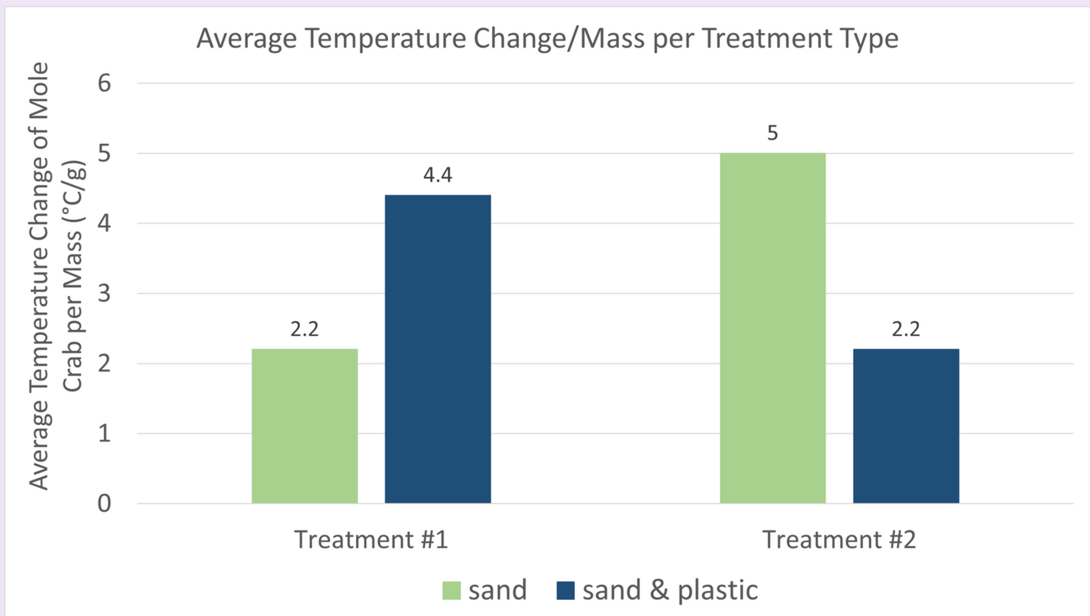

Figure 2. Average change in mole crab temperature (°C/gram) during different treatments (n=8; 0.54-1.09 g).

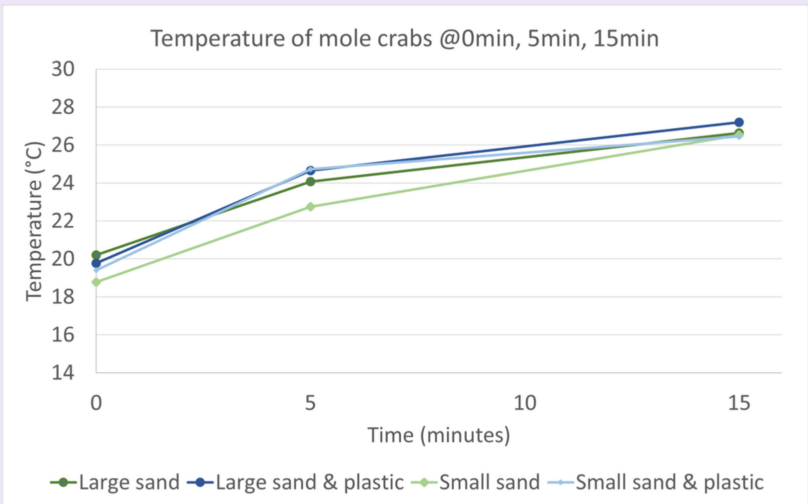

Figure 3. Average mole crab temperature (°C) in different substrates (n=8). Large: 0.91-1.09g, small: 0.54-0.57g.

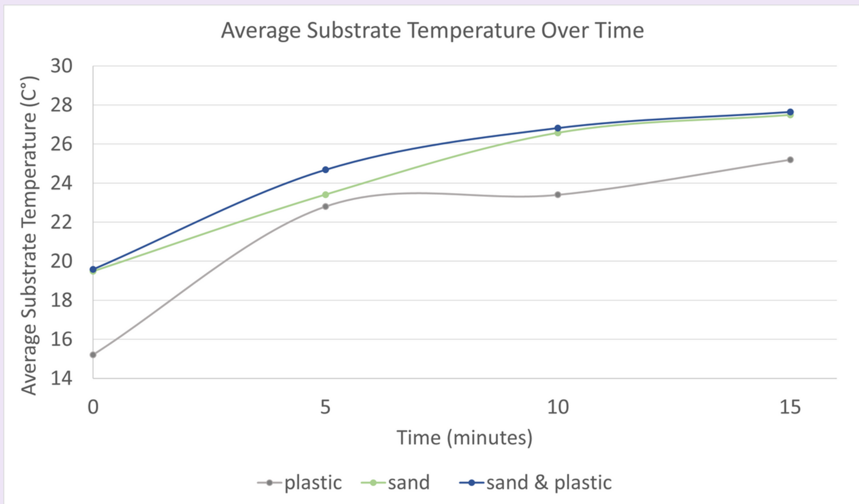

Figure 4. Average temperature (°C) of substrate surface at 5 minute intervals (n=8 for sand and sand & plastic, n=1 for plastic nurdles).

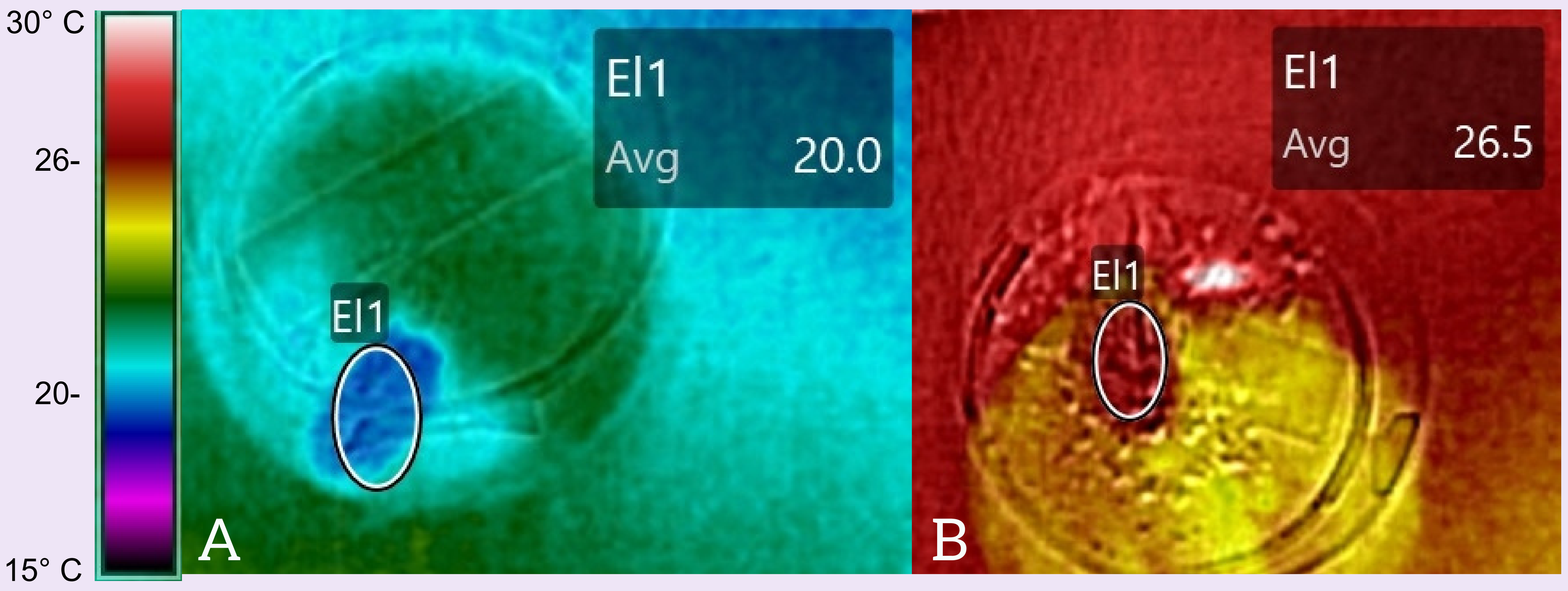

Figure 5. Thermal images of mole crab (0.91g) before (A) and after (B) burrowing in the sand substrate for 10 minutes during Treatment #2.

Materials and Methods

Figure 1. Filter feeding *E. analoga*. @Nicole Yen

- Mole crabs (n=20) were collected at Marine Street Beach (32.837N 117.282W) and kept at Scripps Institution of Oceanography.
- Mole crabs were dry-blotted, weighed and categorized into large (n=4, 0.91-1.09g), and small (n=4, 0.54-0.57g) groups.
- Containers were filled with either 200 mL of Quikrete play sand, composed of crystalline silica (labeled sand) or 180 mL of play sand and 20 mL of Poly-Fil nurdles (pre-production plastic pellets made of polypropylene; labeled sand & plastic).
- Treatment #1 - Mole crabs were set in petri dishes directly next to the container (29.7 x 19.3 x 20.3 cm) under a 50W heat lamp for 5 minutes.
- Treatment #2 - Mole crabs were transferred directly to container with tweezers and allowed to burrow under the sand for 10 minutes (Sand was kept just wet enough to allow for burrowing behaviors).
- Temperature measurements were recorded using a FLIR C5 camera at initial time (t=0 min) and at 5 minute intervals, for a total duration of 15 mins for the substrate (Treatment #1 at 0, 5 minutes; Treatment #2 at 15 minutes)/
- Trials were repeated twice for each Treatment, alternating each mole crab between Treatments (n=8; trials=16).
- Data analyses was conducted using FLIR tools: the rectangle measurement tool was used for average substrate temperature while the oval measurement tool was used for average crabs temperatures.

Discussion

Interpreting Data

- There was greater overall temperature change of the mole crabs in the sand substrate compared to the substrate with sand and polypropylene pellets (7.2°C/g, 6.6°C/g respectively).
- We saw a significantly greater average difference in crab temperatures/mass burrowed in plain sand during Treatment #2 ($p=0.021$). This can be partially supported by the differences between the thermal conductivity of polypropylene (0.1-0.3 W/m·K, Professional Plastics) and sand (3.34 W/m·K, Hamdhan et al., 2010) and the difference in temperature change during treatment #1 affecting the heat intake of the mole crabs during treatment #2.

Conclusion

- Microplastics in sandy shore habitats may affect *E. analoga* ability to uptake heat and possibly even their thermoregulatory abilities.
- Our findings suggest that crabs conformed to the temperature around themselves in sand more than plastic, displaying that plastic in mole crab substrate potentially protects them from increasing to deadly temperatures caused by climate change. A study by Suresh (2020) found 100% mortality in mole crabs at 35°C after 1240 minutes of exposure, but only after 4 minutes at 38°C. In our study, the surface temperature of substrate was 28.4°C at the highest.
- We cannot make any definitive claims about the impact of plastic on the thermal regulation of mole crabs; however, plastic poses many different issues. Marine invertebrates have been found to ingest microplastics, which decrease their life span by ~5.5 d ±2.1 SE days (Horn, 2020).
- Decreased heat flow and ultimate sand temperature caused by microplastics may affect nestling sea turtles, whose sex determination depends on the temperature of sand (Gao et al., 2022).
- Plastic also affects substrate permeability, which may impact the microbial life in the sand, changing their rates of carbon and nitrogen cycling (Gao et al., 2022).
- The compounding impacts of microplastics in mole crab habitats may outweigh the potential thermal protection mole crabs would receive from the plastic—and ultimately impact all intertidal life, the environment, and human health (Gao et al., 2022).
- The effects of bioaccumulation starting from mole crabs to the predators that prey on mole crabs and so forth is also detrimental to the ecosystems. The plastic will accumulate in organisms as the food chain progresses, leading to the same effects in other animals through a non direct source (Miller et al.,2020).

Limitations

- Small sample size.
- Discrepancy in FLIR images due to camera tilt and measurement capabilities.
- The depth to which the mole crab burrowed.
- Position of mole crab under the heat lamp.
- 2 of our sample crabs were not brooding, while 6 were.
- Mole crabs were housed with other organisms.

Figure 6. *Emerita analoga*. OuterBanks. https://www.outerbanks.com/sand-crabs.html

Future Directions

- Remove conduction variables (heat from hand).
- Test different plastic types with different thermal conductivity rates.
- Collect mole crabs from different coasts to compare the differences of how microplastic pollution affects different intertidal areas.
- How interactions with mole crabs that ingested microplastics affect other organisms, such as predators.
- Finding the difference in temperature change in brooding mole crabs and non brooding mole crabs.
- Using our research as a different variable when focusing on the effects of microplastics on sandy beaches, and to further understand the increased mortality rate of mole crabs.

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