In the Hot Seat: Effects of Climate Change on Competitive Behaviors of Invasive Predatory Crabs in the NE Rocky Intertidal

Catherine Park AEMES ‘23[1,2], Gladys Batista AEMES ‘24, Jamie Rambin AEMES ‘24, Paulette Peckol[1,3]
Environmental Science & Policy Program[1]; Statistical & Data Sciences[2] , Biological Sciences[3]; Smith College

Introduction

Global warming and concomitant increasing seawater temperatures are having dramatic effects on marine communities on a worldwide scale. The Gulf of Maine is one of the most rapidly warming regions, with ocean temperatures increasing at greater rates than global averages, and several foundational intertidal invertebrates are declining as a result (Pershing et al. 2015; Petraitis and Dudgeon 2020). New England intertidal communities serve as early warning systems for climate change because organisms in these habitats are often exposed to temperatures above their thermal limits during low tides (Helmuth et al. 2006).

Both competitive and trophic level interactions shape the behavior and activities of organisms occurring in intertidal habitats. *Hemigrapsus sanguineus* and *Carcinus maenas* are invasive crab species that prey on *Mytilus edulis* (Figs. 1 & 2). These crab species have similar food and habitat preferences, and anecdotal evidence suggests that *H. sanguineus* has largely replaced *C. maenas* in southern New England. Both species are strongly affected by seawater temperatures and their interactions might affect future trophic dynamics. In this study, we investigated whether elevated temperatures affect competition between *H. sanguineus* and *C. maenas*, specifically in their habitat choice and food acquisition.

Fig. 1: *Hemigrapsus sanguineus* (Asian Shore Crab)

Fig. 2: *Carcinus maenas* (European Green Crab)

Methods

Field collections of *H. sanguineus* and *C. maenas* were returned to the lab for acclimation at the experimental temperatures of 15°C and 22°C (1-2 weeks). We used rectangular aquaria with a layer of sand, pebbles, and shells to simulate their natural habitat. Either food (*M. edulis*) or constructed habitat was provided in the center of the aquaria (Fig. 3). Before each experiment, we acclimated crabs for 10 minutes in opaque containers that allowed for aeration; these containers were then removed for a 30-min experimental period. We conducted trials in which crab release times were staggered (one was released 10 minutes earlier) and trials with two individuals of the same species against one individual of the other species (Baillie and Grabowski 2018). Activity observations were tallied every 5 minutes, primarily focusing on any fights occurring between the crabs, burrowing, feeding or seeking habitat (Table 1). All data analyses were performed with R (Version 4.1.1 R Core Team 2021, Wickham et al. 2019).

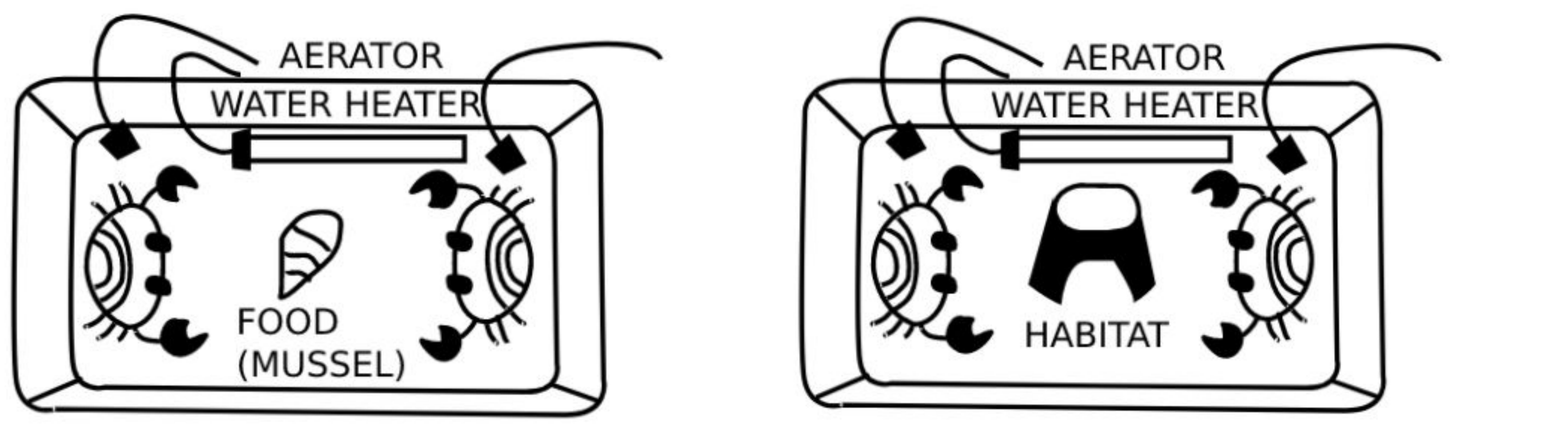

Fig. 3: Diagram of aquaria for interspecific behavioral trials with food (a) or habitat (b).

Table 1. Description of behaviors observed in *C. maenas* and *H. sanguineus* during experimental trials.

Type of Behavior	Description
Initiate Fight	Observed crab approached the other crab and aggressively pushed/snapped at it or attempted to get on top of it.
Initiate Food/Habitat	Observed crab approached the provided food (*M. edulis*) or habitat and consumed/interacted with it.
Burrow	Observed crab is visibly deep in the layer of sand and unmoving.
Won Food/Habitat	Observed crab was the last one to have successfully interacted with food or habitat without interference from the other crab(s)

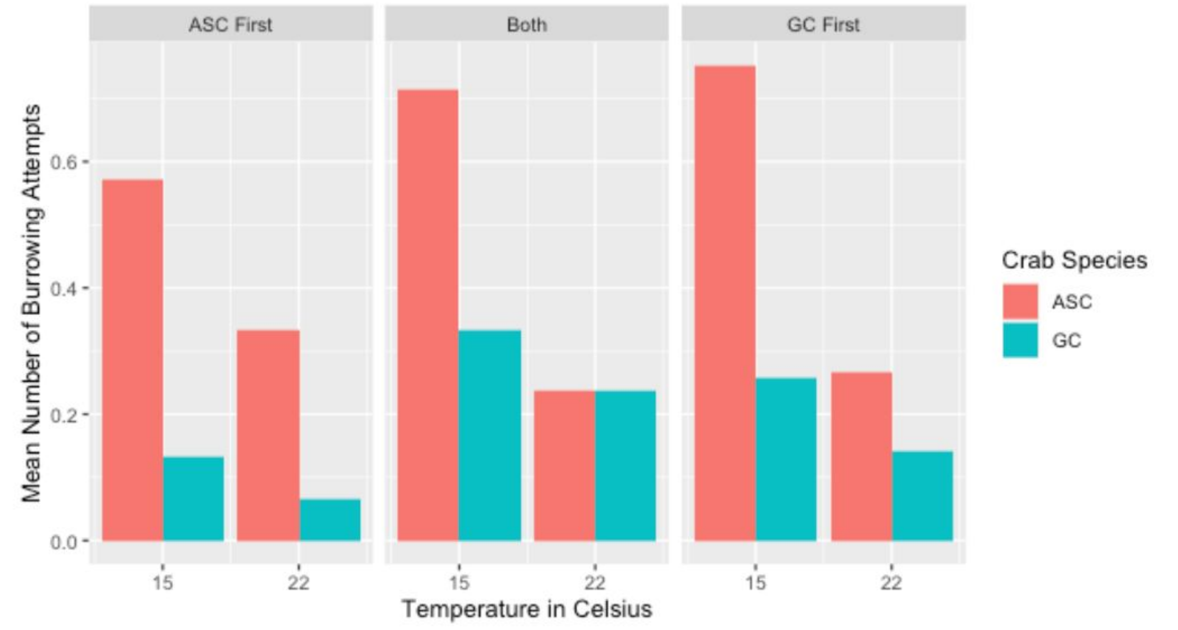

Fig. 4: Mean number of burrowing attempts by *H. sanguineus* (Asian Shore Crab = ASC) and *C. maenas* (Green Crab = GC) when held at two temperatures (15°C and 22°C) for different release times.

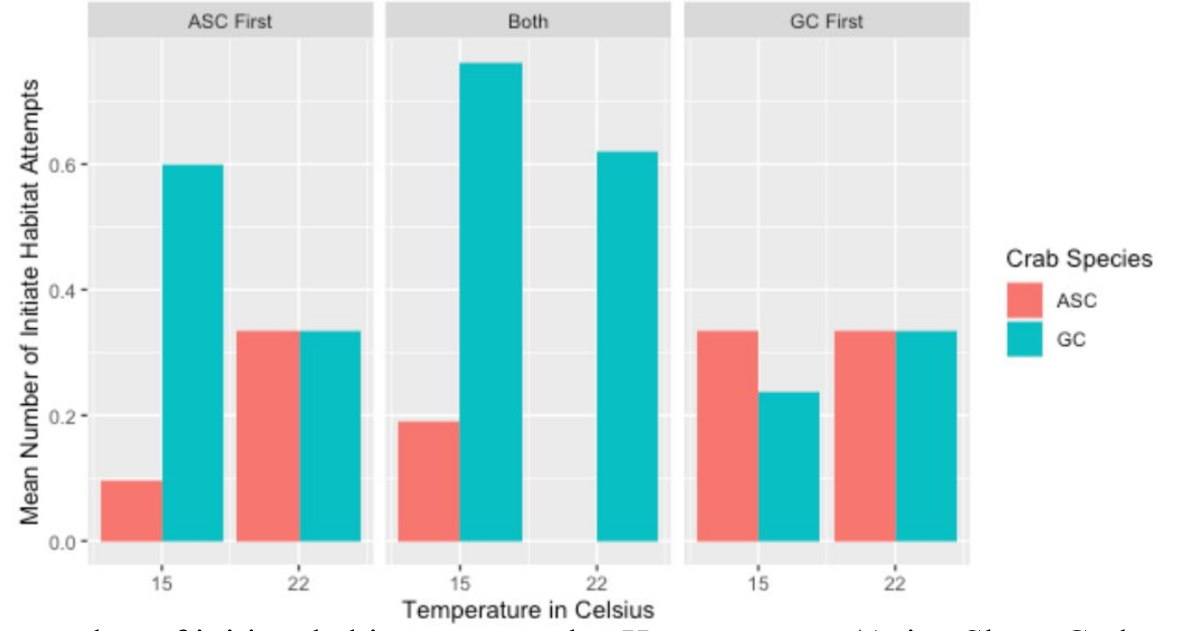

Fig. 5: Mean number of initiate habitat attempts by *H. sanguineus* (Asian Shore Crab = ASC) and *C. maenas* (Green Crab = GC) when held at two temperatures (15°C and 22°C) for different release times.

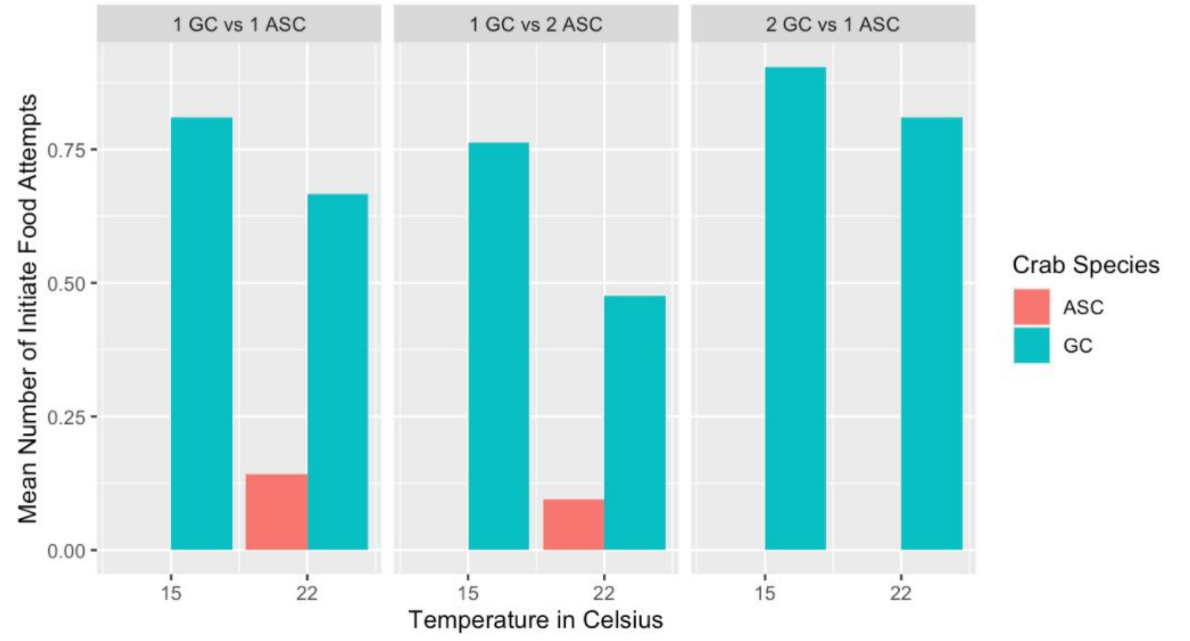

Fig. 6: Mean number of initiate food attempts by *H. sanguineus* (Asian Shore Crab = ASC) and *C. maenas* (Green Crab = GC) when held at two temperatures (15°C and 22°C) for when two crabs of one species interacted with one crab of the other species.

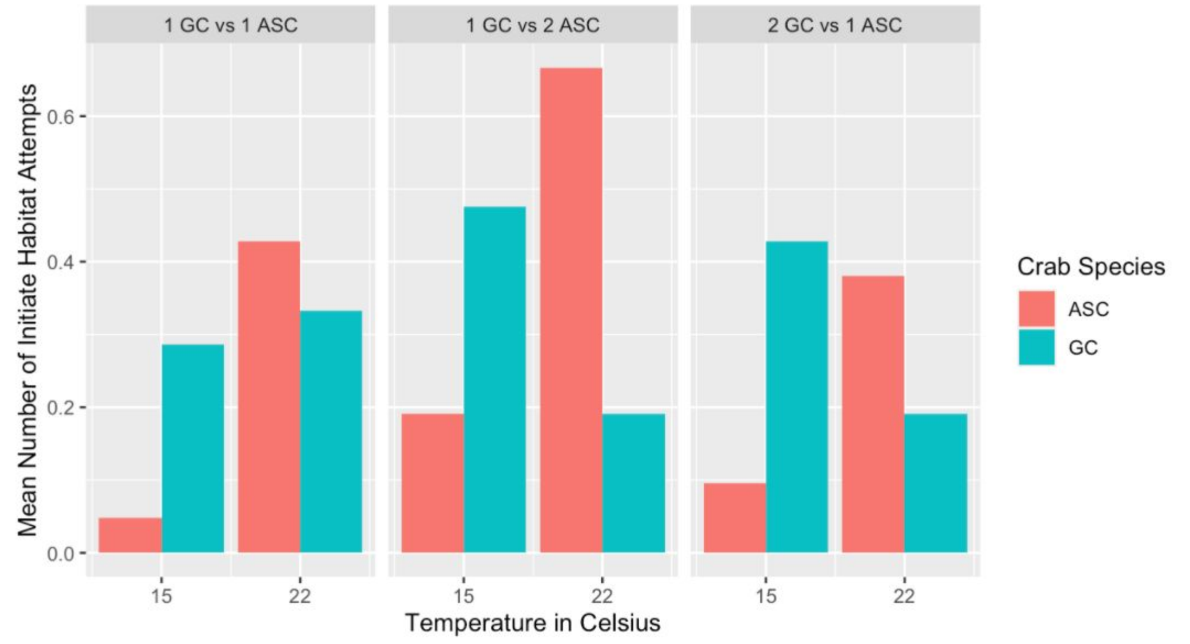

Fig. 7: Mean number of initiate habitat attempts by *H. sanguineus* (Asian Shore Crab = ASC) and *C. maenas* (Green Crab = GC) when held at two temperatures (15°C and 22°C) for when two crabs of one species interacted with one crab of the other species.

Results & Discussion

This study investigated how elevated temperatures may affect competition between *H. sanguineus* and *C. maenas*. Overall, we found that *C. maenas* surpassed *H. sanguineus* in acquiring provided resources at both experimental temperatures. For the staggered release-time experiments, behavioral patterns from both crab species were consistent. *H. sanguineus* preferred to burrow at much greater rates than *C. maenas*; however, both species reduced their burrowing activity as temperatures increased to 22°C (Fig. 4). There was a notable reduction of activity by *C. maenas* for seeking food when under 22°C compared with 15°C. When seeking habitat, *C. maenas* interacted with the provided shelter more often when *H. sanguineus* was released first and when both crabs were released at the same time (Fig. 5). Interestingly, Jensen et al. (2002) found that when *C. maenas* naturally co-occurs with *H. sanguineus*, it often avoids interaction, while *C. maenas* without prior experience with *H. sanguineus* may be more aggressive, but will often fail in retrieving the desired resource (Jensen et al. 2002). Likely, the interactions between these invasive crabs will evolve as they continue to spread along the western Atlantic shoreline.

For the multiple vs. individual trials, we found that *C. maenas* pursued and won food more often than *H. sanguineus* (Fig. 6), regardless of the number of individuals released. Notably, *C. maenas* had higher activity than *H. sanguineus* across all multiple vs. individual habitat trials. While there was a reduction in activity for *C. maenas* as temperatures increased, *H. sanguineus* showed the opposite trend (Fig. 7). Thus, while in the short-term *C. maenas* can outcompete *H. sanguineus*, continued increased temperatures may cause *C. maenas* to suffer from more long-term consequences of climate change. Howard et al. (2022) studied competition of British Columbia populations of the invasive *C. maenas* and the native rock crab, *Metacarcinus gracilis*, and found that overall feeding rates of *C. maenas* were almost double those of the native crab species at elevated temperatures. The response of the invasive crabs to temperature increases found in our study may reflect their contrasting native habitats; *H. sanguineus* and *C. maenas* are from warmer and cooler regions, respectively (Fig. 8) (Lohrer 2008; Delaney 2008).

In conclusion, with warming conditions along the New England shores, our results suggest that *C. maenas* may experience a reduced level of activity when seeking shelter and foraging for food, while *H. sanguineus* may remain more tolerant of climate change. These differences may have significant impacts on their prey populations and potentially result in trophic cascades.

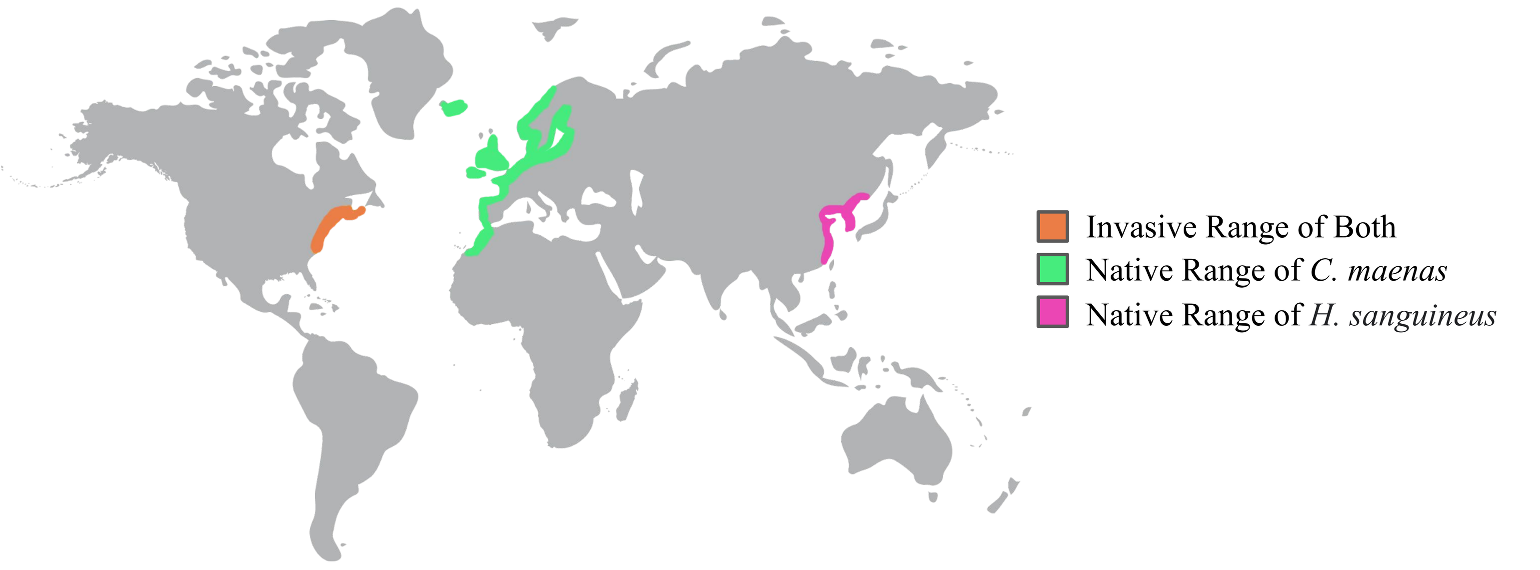

Fig. 8: Native and invasive ranges of *C. maenas* and *H. sanguineus*.

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