Carcinus maenas: An optimal forager?

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Introduction

We examined the foraging success and behavior(s) of the invasive green crab (*Carcinus maenas*) with hard clams (*Mercenaria mercenaria*) in a rippled bed in a racetrack flume. The immediate goal was to determine the effects of habitat heterogeneity (bottom topography and roughness) on crab behavior, feeding success, and consumption rate.

Ripples are formed on the bottom of sand beds due to sediment displacement by waves or water currents and are prevalent in coastal areas[1]. In areas of ripple troughs or in low flow, it is believed that crabs rely chiefly on chemical cues to locate their prey[2]. The distribution and concentration of chemical cues are affected by flow speed, bed roughness, and turbulence regime[3,4]. While searching for food in a heterogeneous environment, Clark et al. (2000) predicted that predators should forage for food in patches providing the most energy. Crabs foraging in areas with no coverage have greater foraging success and therefore receive more energy than they would in areas with refuges for clams[5]. Predators have to decide when they have reduced their energy source within a certain patch and at what point they should move on to find another one[2]. These questions are the basis for optimal foraging theory.

Objectives and Questions

Do green crabs exhibit foraging behaviors consistent with the optimal foraging theory while searching for patches of hard clams in a heterogeneous rippled bed? Here we hold patch shape, size, prey density, and distance between patches constant to test the following null hypotheses:

1. Crabs will spend an equal amount of time foraging for clams (time spent prior to eating from a patch), among ripple crests, troughs with no shell hash, and troughs with shell hash.

2. Foraging success (consumption of clams) and consumption rates will be the same between troughs with no shell hash and troughs with shell hash.

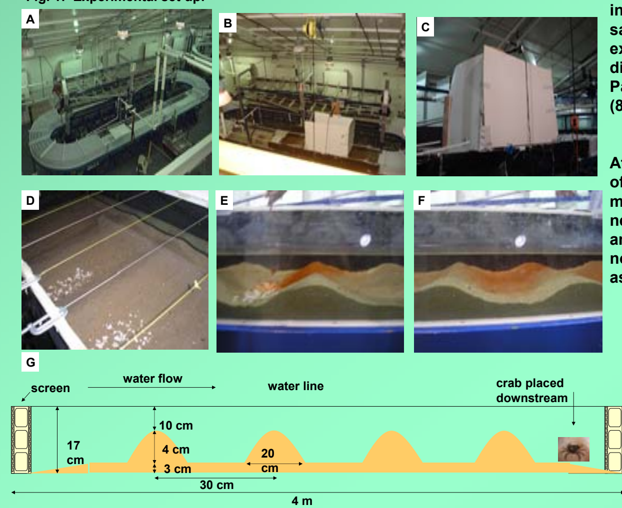
3. When presented with two patches in troughs with no shell hash or troughs without shell hash crabs will not move equally between the two patches.

Alternatively, the green crab will exhibit foraging behavior consistent with the optimal foraging theory; e.g., crabs will forage most in the habitat where the patches are located. It is also expected that the crabs will consume more clams from the sandy trough habitat than from the trough with shell hash. When a crab is presented with two patches of clams in a sandy trough habitat or two patches in a trough with shell hash, it is expected that the crabs will spend an equal amount of time moving between and consuming clams in each patch.

Materials and Methods

Experiments were conducted in racetrack flume at the Institute of Marine and Coastal Sciences (IMCS), Rutgers University. Flow was driven by a set of paddles located in the return channel of the flume. (Fig. 1A). The free stream velocity was set at $8\ cm\ s^{-1}$, comparable to mean flow at LEO-15. The flume was filled with seawater to a depth of 17 cm, maintained at 20°C, with a salinity of 31 ±2. To record crab behavior, a camera was set up 117.5 cm above the bottom of the flume. Experiments were conducted in dim light to simulate the natural darkness of the crab's environment. Foam board and black plastic were placed around the arena to reduce light and avoid stimulating the crabs with outside variables (Figs. B & C). Green crabs (carapace length 40-50 mm) were collected at the Rutgers University Marine Field Station (RUMFS), Tuckerton, NJ. Hard clams (length 4-6 mm) were ordered from Oyster House, South Carolina.

Fig. 1: Experimental set up.



Crabs were starved for at least 24 h. Prior to each trial individuals were tested for hunger by exposing them to a prey sample. Crabs that immediately ate were used in the experiment. Two patches containing 50 clams each (patch diameter 7 cm) located 30 cm apart were seeded by hand. Patches were placed in two ripple troughs with no shell hash (8 trials) or two troughs containing shell hash (9 trials).

At the initiation of each trial the crab was placed downstream of the clam patches and behavior was video-recorded for 120 min. Following this, patches were collected using a fish tank net and counted. Videos were analyzed by calculating the amount of time each crab spent in ripple crests, troughs with no shell hash, troughs with shell hash, skirting the perimeter, as well as eating in either patch.

In the flume a rippled bed (4 crests, 3 troughs) was set up using medium to coarse sand from LEO-15, Sta. 9. The sand was sieved to remove large shell debris. Shell hash was then added to half of each ripple trough to achieve thirty percent coverage. The hash was switched to the other side of the trough periodically to rule out crabs favoring one side of the arena. Screens were placed at either end of the arena to keep crabs from moving to the paddles of the flume. (Fig. 1 D & G). Red dye experiments were conducted to examine flow (Fig. 1E & F).

Results

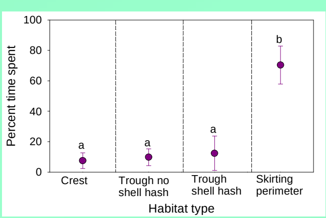


Fig. 2: Percentage of time spent by crabs in each habitat ± 95% confidence intervals (n=12); a and b indicate significant differences among habitats (Mann-Whitney non-parametric test: α=0.05, $p<0.0001$).

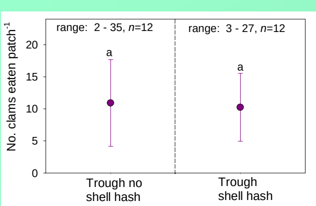


Fig. 3: Mean number of clams consumed in each patch for patches located in troughs with no shell hash and with shell hash ± 95% confidence intervals; a indicates no significant difference between habitats (Mann-Whitney non-parametric test: α=0.05).

Fig. 4: Mean consumption rate in each patch for patches located in troughs with no shell hash and with shell hash ± 95% confidence intervals (n=23); a indicates no significant difference between habitats (Mann-Whitney non-parametric test: α=0.05).

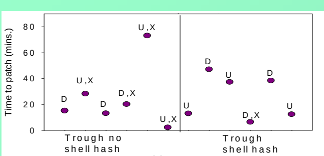


Fig. 5: Time interval before crabs reached a patch and ate clams (n=12). Direction of approach: D=move with flow to a patch, U=move against flow to a patch, X=move crossflow to a patch.

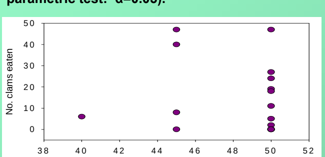


Fig. 6: Number of clams eaten versus size (length) of the crab (n=18).

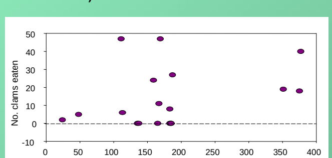


Fig. 7: Number of clams eaten versus period of starvation (n=18).

Significance

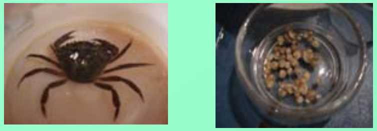


Fig. 3: Pictures of *Carcinus maenas* (left) and *Mercenaria mercenaria* (right).

The European green crab, an invasive species, is a predator on bivalves, gastropods, and other infaunal species. It is important to study its foraging behavior since it can have large ecological and economical effects on shellfish resources. It is useful to study the green crab's predatory behavior in order to devise plans to manage the populations and to reduce their impact on commercial bivalves in mariculture operations.

Conclusions

- Crabs spent an equal amount of time foraging for clams among ripple crests, troughs with no shell hash, and troughs with shell hash.
- Foraging success and consumption rate was the same in troughs with no shell hash and troughs with shell hash.
- Crabs did not spend an equal amount of time moving between clam patches in the two trough habitats.

Discussion

In these experiments, crabs showed an affinity for the boundaries of the experimental arena, and it appeared that neither flow direction, bottom topography, the presence or absence of shell hash, or chemical cues emanating from clam patches affected searching and feeding behavior. Based on optimal foraging theory, we expected crabs to eat fewer clams from troughs with shell hash as this habitat was considered to be suboptimal for two reasons: crabs might expend more energy moving shell hash to find clams and the increased turbulence associated with the hash might disrupt the chemical cue. It did not appear that shell hash impeded their ability to find or eat food. Since green crabs approached patches equally from downstream and upstream directions, they probably did not receive a chemical cue at a distance. Moreover, when individual crabs were presented with two patches, they did not move equally between them, and when foraging for food, crabs searched equally among all three habitats. Optimal foraging theory suggests that it is a greater cost for crabs to deplete the first patch they find rather than use energy to find a second patch. The green crabs either ate from the first patch found and then moved to the second patch, or did not find a second patch at all. No crabs completely depleted a patch and because they constantly explored all available habitats, their behavior may be consistent with optimal foraging theory.

Literature Cited

[1]Traykovski P. et al. (1999). *Journal of Geophysical Research* 104; [2]Clark M.E. et al. (2000). *Ecography* 23; [3]Finelli C.M. et al. (2000). *Ecology* 81; [4]Zimmer R.K. et al. (1999). *Ecology* 80; [5]Sponaugle S., Lawton P. (1990). *Marine Ecology Progress Series* 67

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