***LITTORINA LITTOREA* INFECTION BY *CRYPTOCOTYLE LINGUA* AT NAHANT, MA: AN INVESTIGATION OF POSSIBLE BEHAVIOR CHANGES**

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Abstract *Littorina littorea* is one of the most abundant gastropod species along the New England rocky intertidal. A common parasite found in *L. littorea* is the trematode, *Cryptocotyle lingua*. This infection has been documented for hundreds of years, however its impact may become more prominent as climate change continues and pollution increases. The parasite infection effects *L. littorea* digestion, reproduction, and longevity. Infected snails were only found on a rock formation on which sea gulls congregated. *L. littorea* were collected based on their location above the edge of the open water at low tide to determine where the highest prevalence of infection exists. The data suggest that infection by *C. lingua* causes a behavioral change in *L. littorea* forcing them to move down the tidal zones to open water. This behavioral change could be evolutionarily beneficial to the trematode as it would help ensure contact with a fish, the next host in its lifecycle.

Key Words: behavior change*, Cryptocotyle lingua, Littorina littorea,* parasitism

Introduction

Parasites influence host mortality, fecundity, growth, nutritional status, energetic requirements and behavior of host populations. The majority of gastropod parasites are digenean trematodes (Robson and Williams 1970). Along the North Atlantic rocky intertidal zone, there are five trematodes that infect *L. littorea*, the most common species is *Cryptocotyle lingua* (Robson and Williams 1970). Infection rates vary enormously along the New England rocky intertidal from a prevalence of 0.006 to 0.47 (Beyers et al. 2008). Trematode predominance is largely determined by gull abundance at the study site (Beyers et al. 2008).

L. littorea is one the most abundant gastropod along the northwestern Atlantic Coast, therefore, changes to their population structure affect the entire coastal community. *L. littorea* infected by *C. lingua* will sustain extensive damage to its digestive system, lifespan, and reproduction mechanisms (Wood et al. 2007). Infected *L. littorea* have lowered heat tolerance than uninfected L. littorea, which may make the infection more lethal with rising global temperatures (McDaniel 1969). In addition, higher temperatures, higher salinity, and lower wave energy are preferable for the trematode's lifecycle (Pietrock and Marcogliese 2003). As these trends continue, trematode infection will become increasingly predominant, which will have repercussions for the entire ecosystem.

This study focused on *L. littorea populations* on the coast of Nahant, Massachusetts. The purpose was to determine the infection rate of this area of the rocky intertidal. This study also looked at the importance of seabird resting locations on the prevalence of infection in *L. littorea*. Additionally, I hypothesized that the *L. littorea* behavior would be altered to remain in the lower tidal pools or in open water so that the *C. lingua* could be passed to fish, the next host in its lifecycle.

Materials and Methods

Because of it's ability to thrive in a large range of conditions, *Littorina littorea* is one of the most abundant gastropod along the New England rocky intertidal. They can be found in the high intertidal zone down to 180 feet below sea level. *L. littorea* live along shores that are sheltered, shores that have high wave exposure and can even be found in polluted estuaries (Moore 1937). *L. littorea* feed on diatoms *Enteromorpha, Ulva, and Porphyra.* The snail has a thick shell that is whorled and pointed and has an average width of 16-38mm. *L. littorea* are hosts to at least five parasitic trematode species, however they are usually dominated by *C. lingua* (Beyers et al. 2008)

L. littorea generally has a whitish colored foot, however, coloration changes with infection status (Fig. 1; Wiley and Gross 1957). This method of identifying infection status was originally developed by Willey and Gross in 1957 and has an accuracy of about 90% (Wood et al. 2007). Another method to determine infection status is isolation, a time consuming process that involves waiting for the mature trematodes to emerge from the snail. The only definitive method to determine infection status is dissection of the snails.

Figure 1: Images of *Littorina littorea* collected at Nahant, MA. The snails are attached to Petri dishes to demonstrate foot color. The snail on the left is uninfected, while the snail on the right, with a darkened foot color, is infected by *Cryptocotyle lingua.*

Cryptocotyle lingua lifecycle is dependent on three different hosts. Adults are found in the intestine of fish eating birds and mammals (Stunkard 1930). The eggs are excreted with waste into the ocean where they settle on the algae consumed by *L. littorea* (Davies and Knowles 2001)*.* The larval stage occurs in the intestines of the snail until it becomes free swimming during, the cercaria stage (Stunkard 1930). The free-swimming form of *C. lingua* then attaches to the scales of fish that may eventually be eaten by a gull, permitting the lifecycle to continue. *C. lingua,* also known as Black Spot, gets its common name from the appearance it gives its fish host when it becomes encysted (Køie 1977).

Infection by *C. lingua* has serious implications for *L. littorea* as it greatly reduces its ability to digest food, reproduce, and survive (Wood et al. 2007). The trematode resides in the gonad of the snail host, however, the infection usually causes considerable damage to the digestive tract as well. These damages cause the snail to discontinue reproducing and to consume less algae (Wood et all. 2007). After the initial infection, snails generally remain infected for the duration of their life (Køie 1977). As the infection is not short time, infection rates are likely to have a large impact on the entire ecosystem.

This study was conducted at Northeastern University's Marine Science Center located on the East Point peninsula in Nahant, Massachusetts (42.42, 70.91). The property is five miles from the entrance to the Boston Harbor. At this location there was one area of intertidal that jut out into the ocean where gulls congregated on. This area could only be accessed during low tide and was the area where the snails used for this study were collected.

To determine if parasite infection was correlated with changes in foot color, *L. littorea* were haphazardly collected and brought back to the laboratory. They were then placed in Petri dishes or other clear-bottomed containers so that foot color could be seen and recorded. *L. littorea* with various shades of foot coloration were dissected under a dissection microscope to determine infection status. A more powerful microscope was then used to ensure that the parasite was *C. lingua.* From these dissections, a color scale was generated indicating which shade of orange indicated a positive infection status. This preliminary step ensured dissection was not needed for the remainder of the study.

After infection coloration was determined, *L. littorea* were collected based on their height from open water at low tide. Because no infected snails were found along the coast in front of Northeastern University's Marine Science Center, the rest of the observations were taken on the rock where the gulls were present. This rock is about a thirty minute walk away and can be seen from the coast in front of Northeastern University's Marine Science Center. Snails were collected at four different height categories: edge of open water, low intertidal tide pool, mid-intertidal tide pool, and high intertidal tide pool. Infection statuses were determined in the field by using clear-bottomed containers to observe foot color and the color scale made in the laboratory. Ambiguous specimens were excluded from analysis. The rate of infection in each category was then compared.

Results and Discussion

A total of 258 *L. littorea* were examined during this study to determine the extent of infection at Nahant. For snails collected near seabird aggregations, 7.36% of these specimens were infected by the trematode *C. lingua*. This data was collected only on the rock were the seabirds were present; therefore the infection status for the entire area would be drastically lower. Although this calculation was not determined because of the focus on collection on the island, it is estimated to be around the calculated infection rates of nearby locations. In 2007, Beyers et al. determined the infection rate in Plymouth, MA to be 0.188 and to be 0.096 in Gloucester, MA. Beyers et al. also concluded that islands along the New England coast were more likely to have higher infection rates than along the mainland due to their higher bird population. The island characteristics of the rock may be the reason why the sea birds aggregate here, increasing the infection rate of the area.

There was a higher percentage of *L. littorea* infected near the open water and low intertidal tide pools than in mid- or high intertidal tidepools (Fig. 2). This result is notable because the majority of guano was observed in and around the high intertidal tide pool. The higher percentage of infection in the lower intertidal may be an indication that the behavior of *L. littorea* has been altered. This behavioral change would be evolutionarily beneficial to *C. lingua* as it can better find its way to a fish. Although there are no formal findings about altered *L. littorea* behavior due to infection by *C. lingua,* there have been other studies that have provided similar data. An experimental study could be done to determine if behavioral change by *C. lingua* is the reason for this pattern or if it just coincides with other factors.

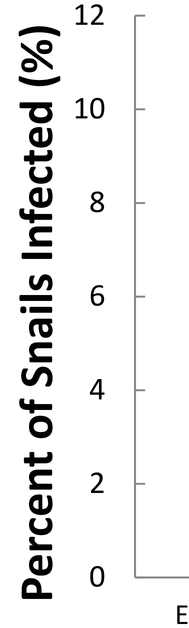

Figure 2: Percent of snails infected at various heights on rock with sea birds at East Point, Nahant, MA. A significantly lower percentage of snails were infected on the edge of the open water than in the other locations, suggesting a possible behavior change.

The infection rate could be higher closer to the open water because this could be where *C. lingua* eggs settle if the tide goes above the rock, washing the guano away. Another explanation for these findings is that the larger snails, which have had more opportunities to become infected, prefer to settle to the lower intertidal tide pools. In order to determine that the infection by *C. lingua* is the reason for the lower settlement choice, infected and uninfected snails would need to be isolated with all other variables removed or controlled.

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