INTRODUCTION

Parasites have complex life cycles in which they utilize multiple hosts in different environments, which proved to be a very difficult matter due to the low probability of being transmitted to the next host. Some parasites are known to manipulate host life history, morphology, and even behavior in order to reduce host fitness to facilitate their movement into their next host (Bernot 2003). Altering host behavior is indicative of a few adaptive strategies that have been selected for in parasites, including the idea that parasites do not completely kill their host so they can be transmitted to the next host and continue their life cycle (Bernot 2003). By manipulating host behavior, parasites could make their current hosts more vulnerable to predation by their next hosts (Bakker et al. 1997).

As parasites move between their hosts, infection rates could vary greatly such that some individual hosts might contain few parasites while others were more heavily infected. The density dependent effects of parasite loads on their hosts are currently unknown (Brown et al. 2003). Some scientists believed higher parasite densities manipulated host behavior to a greater degree while others speculated that higher parasite densities led to more competition between parasites, leading to a trade off between infrapopulation competition and manipulation of host behavior (Brown et al. 2003). From his study, Brown (2003) concluded that competition among the host's parasites or negative interference by those parasites influenced host fitness especially as parasite load increases; thus, heavily infected crayfish have reduced fitness due to the sheer presence of parasites. This is because parasites exploit host nutrition when it would otherwise go toward host growth and development.

The crayfish *Orconectes virilis* are known to contain the parasitic trematodes of the genus *Microphallus*. The parasites' asexual stage, the metacercariae, live in crayfish livers where they feed off host tissue (Stunkard 1951). Crayfish, the parasite's second intermediate host, obtain the parasite through the consumption of infected snails, which are the parasite's first intermediate host (Caveny and Etges 1971). *Microphallus* is transmitted to fish or birds, the definitive hosts, when they consume infected crayfish (Caveny and Etges 1971). In the definitive host, trematode metacercariae mature into adult worms whose eggs are released in the definitive host feces, which are consumed by snails; thus, continuing the *Microphallus* life cycle (Stunkard 1968).

In this study, I tested the movement fitness in *Orconectes virilis* and measured the parasite loads in their livers to examine the relationship between the two variables. In order for parasites to continue their life cycle, parasites alter host behavior and fitness to make their hosts more susceptible to predation (Brown et al. 2003); therefore, I hypothesized that crayfish with parasites present in their livers would have decreased movement fitness compared to crayfish without parasites. Furthermore, among parasitized crayfish, individuals with higher infection rates would have even lower movement fitness than less parasitized crayfish.

METHODS

I collected 40 crayfish of the species *Orconectes virilis* from North Fishtail Bay in Douglas Lake and Maple Bay in Burt Lake, which are both located in Pellston, Michigan near the University of Michigan Biological Station. Crayfish were collected between the hours of 22:00 and 0:00 when crayfish were most active (Stunkard 1951). Within a couple days of capture, I recorded the mass (in grams) of each crayfish and measured their carapace lengths (in millimeters) starting from the tip of the rostrum to the end of the carapace (Keller, personal communication). At the University of Michigan Biological Station's Stream Lab, I determined crayfish movement fitness by observing the current flow the crayfish could withstand. I tested this by submerging the crayfish in approximately 10 centimeters of water in a flume containing a centimeter deep layer of gravel, and placing the crayfish at the end of the flume opposite the flow of water. Beginning with a flow at approximately 900 rpm and waiting for the crayfish to begin walking upstream against the current, I slowly increased the current until the crayfish was unable to move against the current for a full 5 seconds. Then, I recorded the strength of the flow at which the crayfish could no longer advance, and I repeated this test for each crayfish. Next, I killed the crayfish with jars saturated with ethyl acetate. I waited approximately 5 minutes to ensure that the crayfish were dead, then took the crayfish out of the kill jars and dissected them, extracted the liver, and compressed the liver between two glass plates and counted the number of metacercariae in the liver to document its parasite load. I used linear regression to examine the relationships between current and parasite load, carapace length and parasite load, and mass and parasite load. I also used an independent samples t-test to compare parasite loads between crayfish from Douglas Lake and Burt Lake, and current between crayfish from Douglas Lake and Burt Lake.

RESULTS

My results showed significant differences in parasite load between crayfish in Burt Lake and Douglas Lake (t-test; *N*=40; $p<0.001$). Crayfish in Burt Lake had higher infection rates than crayfish from Douglas Lake (Figure 1). There were also significant differences in the current crayfish could withstand between crayfish from Burt Lake and those from Douglas Lake (t-test; *N*=40; $p<0.001$). Current scores were higher in Douglas Lake crayfish than those from Burt Lake (Figure 1). As crayfish parasite load increased, there was a significant decrease in the current that crayfish could withstand (Figure 2; $R^2=0.214$; *N*=40; $p=0.003$). Based on results from linear regression, there was a significant relationship between carapace length and current ($R^2=0.182$; *N*=40; $p=0.006$). As carapace length increased there was a decrease in the current that crayfish could withstand (Figure 3). There was a significant correlation between carapace length and parasite load ($R^2=0.332$; $N=40$; $p<0.001$). Crayfish with larger carapace length exhibited higher parasite loads (Figure 4). Results also showed a significant relationship between mass and parasite load ($R^2=0.203$; $N=40$; $p=0.004$). Similarly, crayfish with higher mass contained higher parasite loads (Figure 5).

DISCUSSION

. Based on the results, it was interesting to see that crayfish from Burt Lake were significantly more parasitized than those from Douglas Lake (Figure 1), indicating that *Microphallus* parasites were more prevalent in Burt Lake. This might be due to recent zebra mussel invasion in Douglas Lake eradicating the snail population (Hollandsworth et al. 2006), the parasite's intermediate host, which would explain the low infection rates found in Douglas Lake crayfish. Due to the drastic differences in parasite load between crayfish from Burt Lake and those from Douglas Lake, there were significant differences in how strong a current the crayfish could withstand (Figure 1). Highly parasitized crayfish could only withstand weaker currents. Therefore, my results supported my hypothesis that high parasite loads decreased crayfish movement fitness. This was consistent with Moller (2005) that animals affected by parasitism experience negative effects on their overall fitness. Additionally, parasitism induced stress on an animal, which negatively affected their fitness (Leung et al. 2000). By affecting fitness, it reduced crayfish's antipredator behavior; thereby, making themselves vulnerable to predation by *Microphallus'* definitive hosts (Bakker et al. 1997). In manipulating host fitness, parasites were able to facilitate themselves in continuing their life cycle.

The results illustrated that crayfish with larger carapace length withstood lower current flow, which could be due to the idea that animals evolved morphological adaptations to reduce drag from current flow by having low surface area to volume ratio (Stazner and Holm 1989); thus, larger crayfish have larger surface area to volume ratios, meaning they could only withstand weaker currents. In contrast, crayfish with smaller surface area to volume ratios were able to withstand stronger currents.

However, there was also a correlation with larger crayfish in both carapace length and mass and higher parasite load. This could be based on the general trend that larger crayfish were older (Pung et al. 2002) and have had more time to obtain parasites and that larger crayfish were more capable of holding a greater parasite load because they have larger livers that have the capacity to hold more parasites.

In conclusion, parasites were more prevalent in Burt Lake giving those crayfish higher parasite loads than those in Douglas Lake. Almost no crayfish in Douglas Lake were parasitized, allowing them to have higher movement fitness by being able to withstand stronger currents. Finally, crayfish with larger carapace lengths and greater mass have higher parasite loads, which decreased their movement fitness.

ACKNOWLEDGEMENTS

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FIGURES

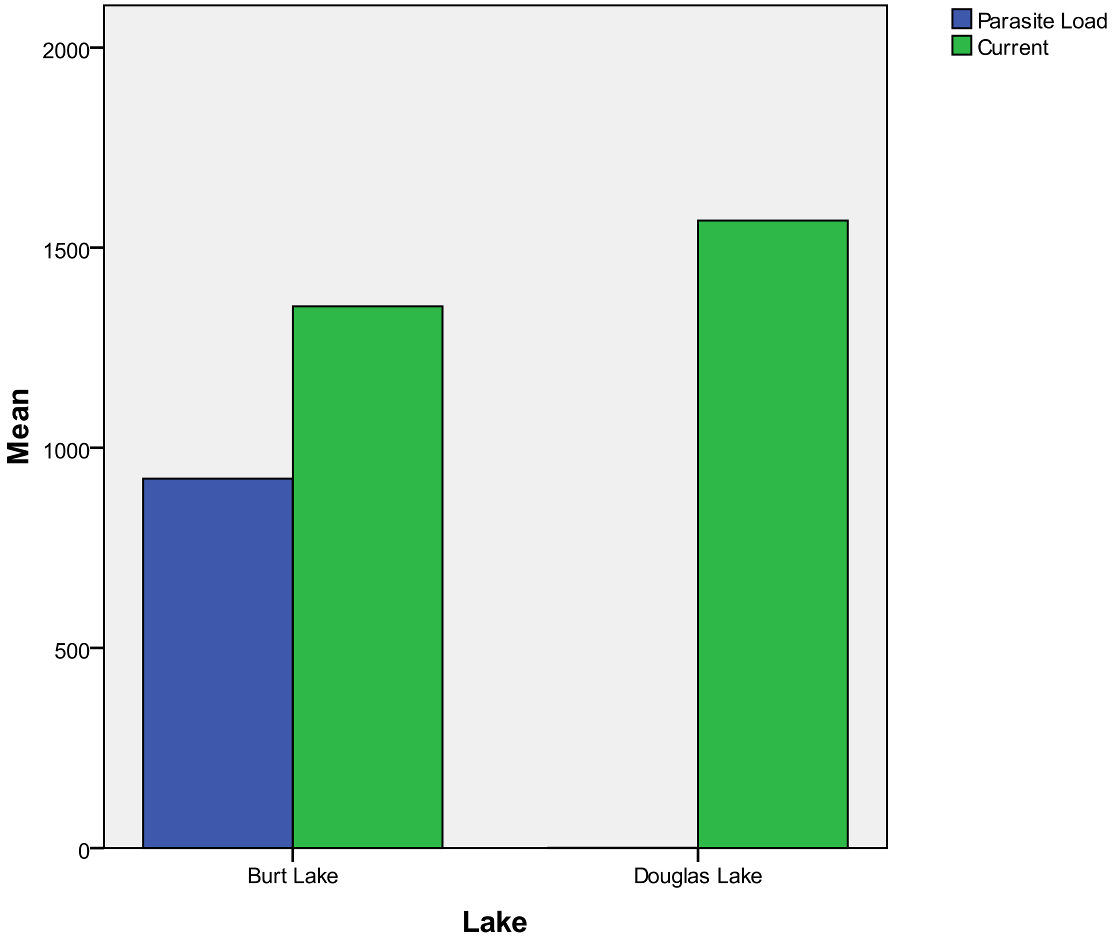

Figure 1: Comparisons of crayfish from Burt Lake and Douglas Lake and parasite load and current. There is a significant difference between parasite load in crayfish at different locations (t=4.87; *N*=40; p<0.001). Crayfish from Burt Lake had significantly heavier parasite loads than those from Douglas Lake. Burt Lake crayfish could withstand significantly lower currents than crayfish from Douglas Lake (t-test; *N*=40; p<0.001).

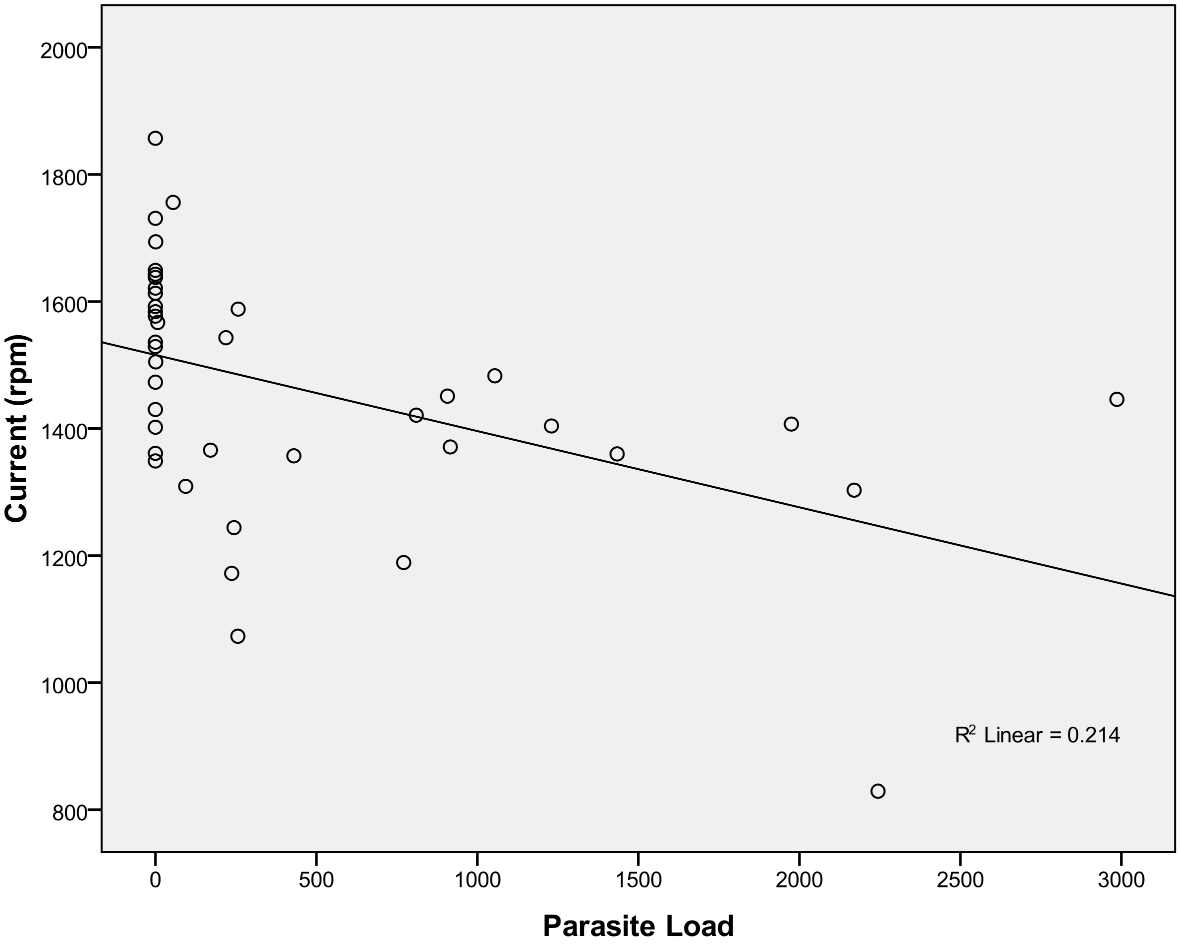

Figure 2: Linear Regression of current and parasite load. There was a significant relationship between parasite load and current (R^2=0.214; *N*=40; p=0.003). As crayfish become more parasitized they could only withstand weaker currents.

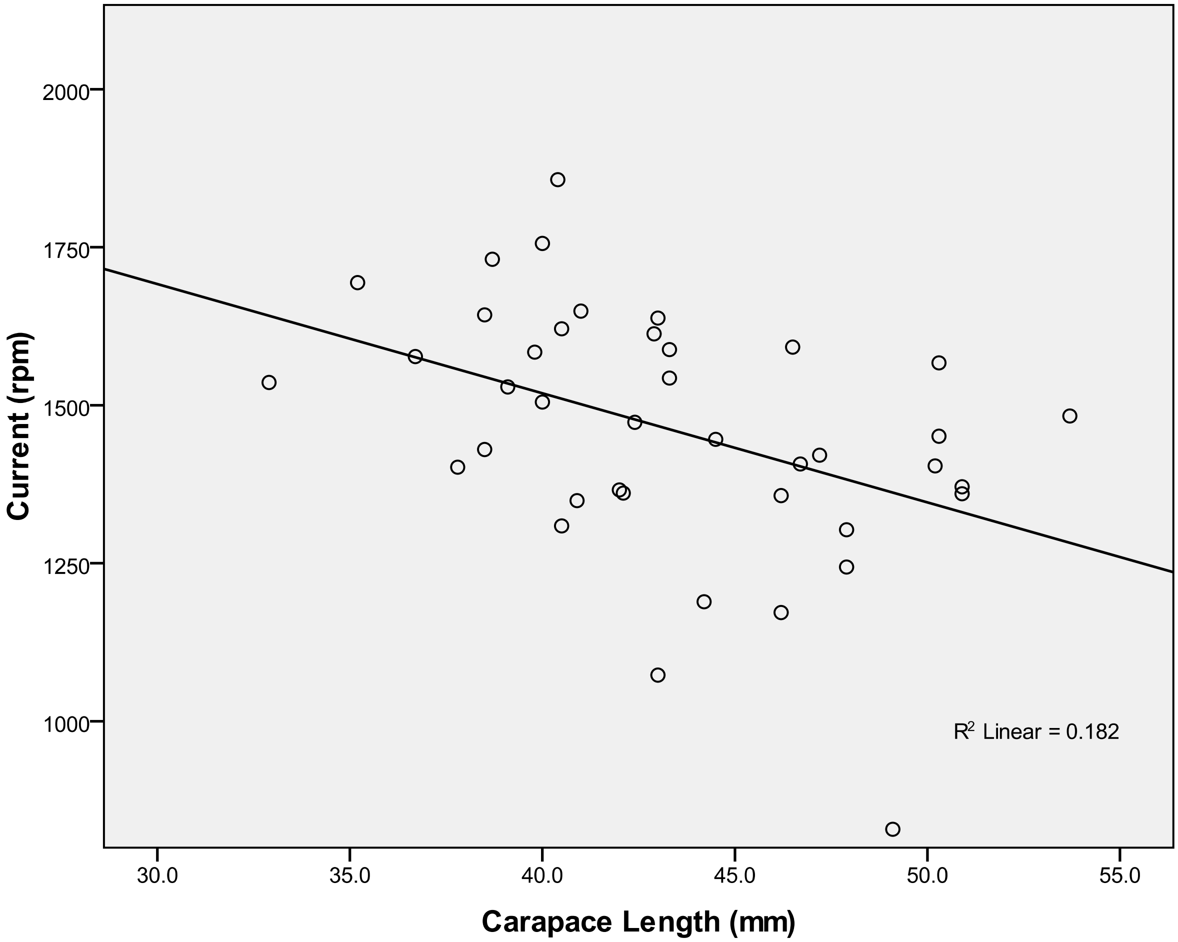

Figure 3: Linear Regression of current and carapace length. The general trend shows the larger the carapace length and lower the current crayfish can withstand. Statistical data supports this decreasing trend (R^2=0.182; *N*=40; p=0.006).

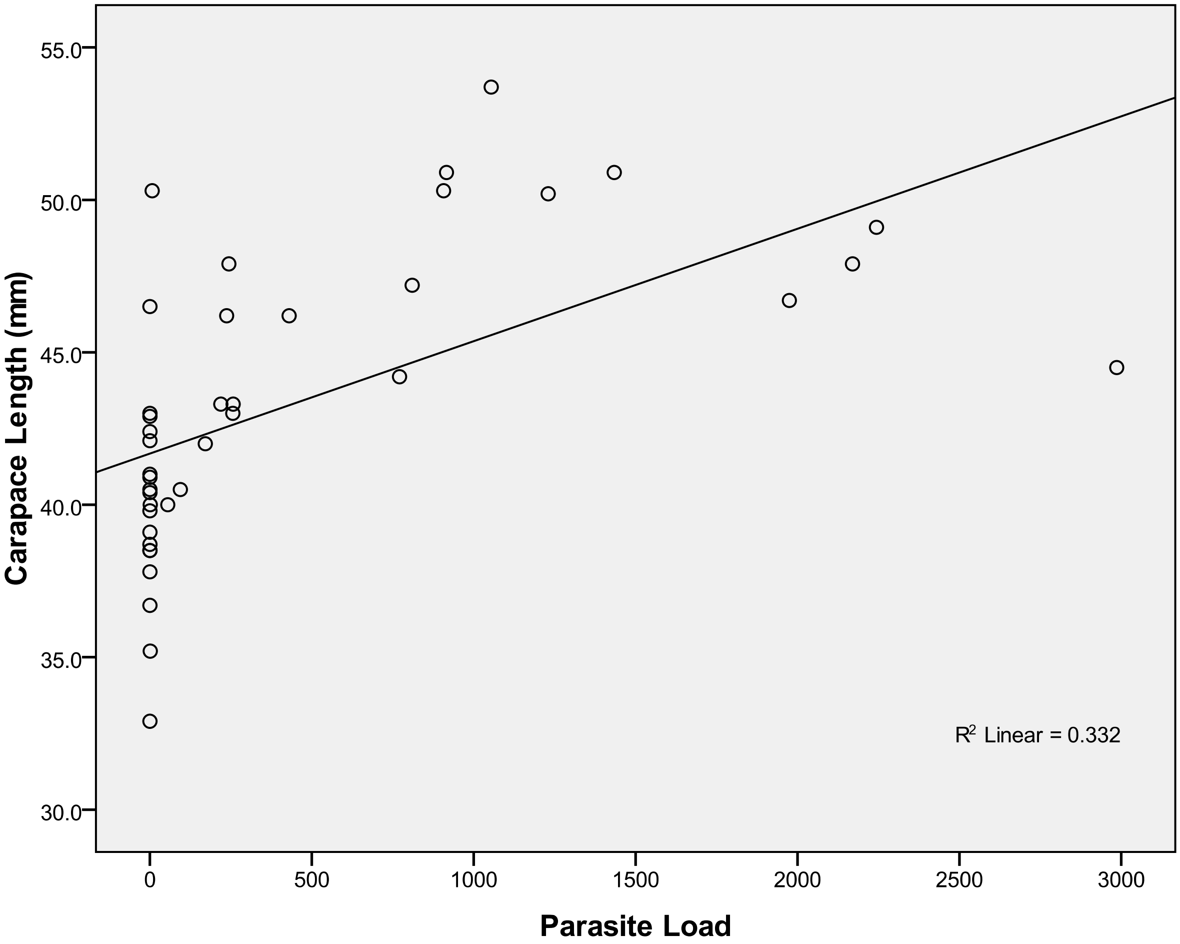

Figure 4: Linear Regression between crayfish carapace length and parasite load. There is an increasing trend where the greater the carapace length the greater the parasite load, showing great significance (R^2=0.332; *N*=40; p<0.001).

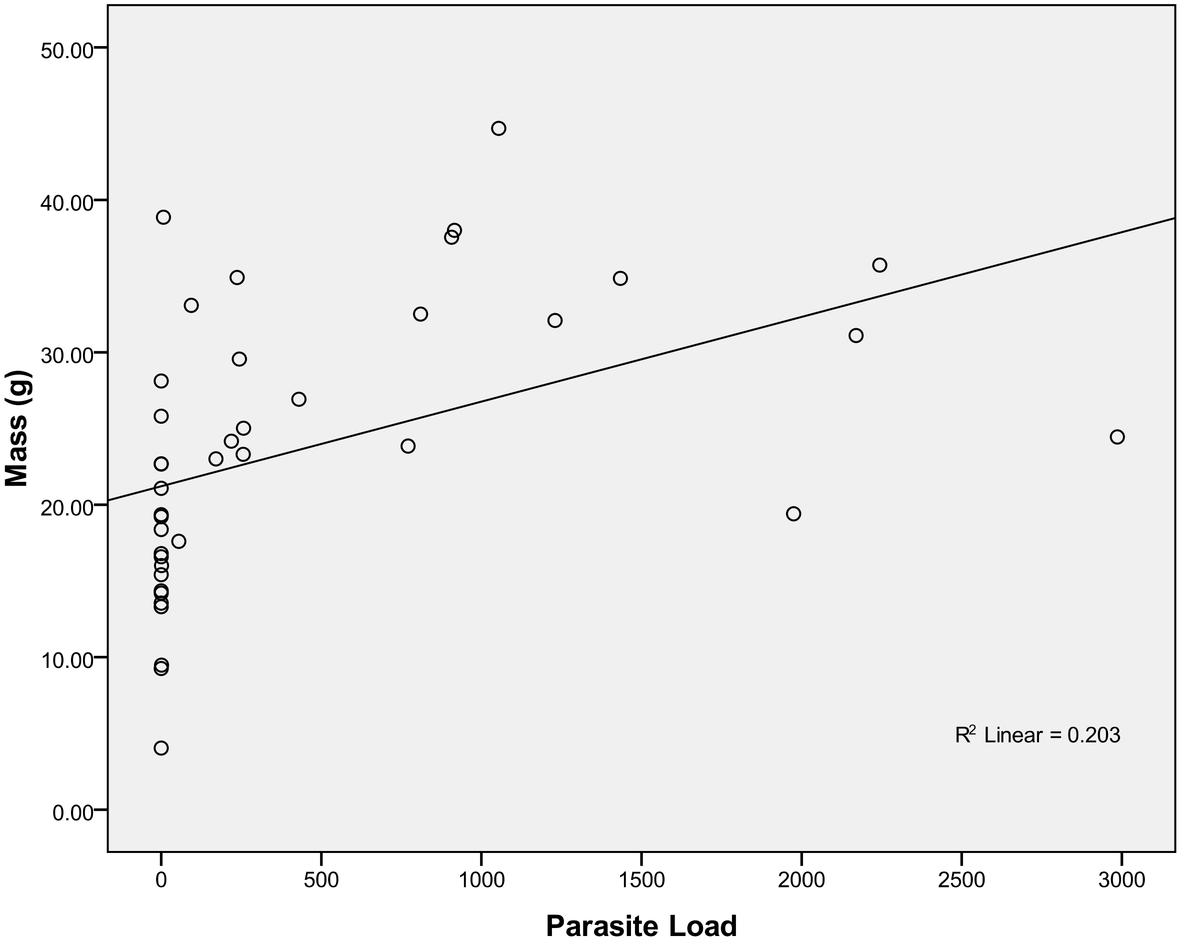

Figure 5: Linear Regression between crayfish mass and parasite load. The graph illustrates a significant increase where heavier crayfish hold a greater amount of parasites (R^2=0.203; *N*=40; p=0.004).