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EPIDEMIOLOGY OF GASTROINTESTINAL PARASITE INFECTIONS IN A WILD
HERBIVORE

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ABSTRACT

Host mediated-effects and parasite density-dependence can greatly impact the rate of growth and fecundity of parasitic helminths in a seasonal environment. Trends in nematode development and fecundity can provide quantitative data regarding infection dynamics, host immunity, and regional climatic conditions over time. The purpose of this study was to examine the development and fecundity of the gastrointestinal nematode *Trichostrongylus retortaeformis (TR)* in wild European rabbit (Oryctolagus cuniculus) and make predictions on the processes affecting parasite dynamics of infection. Nematode length and number of eggs in uterus were quantified using a digitalized system of a camera connected to a microscope and a computer; two years of monthly data were processed.

A number of clear patterns were observed in this study. First, there was a positive linear relationship between the numbers of eggs *in utero* and nematode length. Secondly, a distinct exponential decrease was noted when comparing the lengths and the number of eggs present in the nematodes with host age. Finally, the number of eggs steadily increased throughout the spring and summer peaking in June and then continued to steadily decrease in the fall and winter. The peak correlates to when the offspring are born. These trends appear to be directly attributed to host immune responses; however, parasite density dependent processed may have also contributed to the pattern observed. Further research using laboratory rabbits is needed to reveal more clearly how parasite density-dependent constraints, host-mediated effects and the seasonal environment impact the course of an infection.

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INTRODUCTION

Previous studies have clearly shown that host-mediated effects, parasite density-dependent processes and environmental factors affect the epidemiology of gastrointestinal parasite infections of wild herbivores. However, it is difficult to discern the precise role each plays in parasite growth and fecundity. One simple way to evaluate the factors that affect a parasite such as the gastrointestinal helminth *Trichostrongylus retortaeformis* common in the European rabbit (Oryctolagus cuniculus) is to first measure its establishment and development within a host. This is done by recording the number of infective lavae that infect and colonize the host and the length of the adult stage. Second, one must assess the parasite's fitness by recording the number of eggs *in utero* (Chylinski *et al*. 2008).

Host-mediated responses can affect parasites in two major ways: indirectly, by altering parasite density-dependent constraints (for example food or space) or directly by attaching the parasite with way of an immune response. Parasite-density dependent factors involve the competition among parasitic worms for resources within the host organism (Viney, 2002). Acquired immunity negatively affects nematode fitness by specifically attacking the parasite or by adding stress to the system, like altering food quality or resources. This can result in a reduction of the total parasite population, adult body length, number of eggs *in utero* and their location within the host (Moqbel and McLaren, 1980; Petarson and Viney, 2002; Wilkes *et al.* 2007).

Environmental factors such as seasonality also play a central role in the maturation of the free-living stages of parasitic nematodes. Monthly changes in weather, temperature and rainfall, greatly affect parasite development, for example below 5°C the free-living stages of *T. retortaeformis* are inactive (Cattadori *et al.* 2005). Furthermore, for development and

subsequent infection to occur free-living stages need to be exposed to a warm and moist environment. This leads to seasonal variation in the quantity of infective stages ready to infect a susceptible host (Soulsby 1982).

Trichostrongylus retortaeformis (the parasite used in this study) experiences a direct life cycle. Fertile female worms shed their eggs through the host's (*Oryctolagus cuniculus*) feces. The eggs then hatch and develop into an infective larval stage (L3). Transmission results when the free-living rabbits eat infectious larvae that have migrated to vegetation in the pastures. The helminths then establish within the mucosa of the small intestine and continue to develop into mature adults (Iason and Boag, 1988). It takes about two weeks for the female parasites to establish, shed eggs and start the cycle all over again (Audebert *et al.* 2003).

The goal of this study was to better understand the development and fecundity of *T. retortaeformis* in its common host by taking monthly specimens of adult nematodes from a population of free-living European rabbits sampled throughout 2009 and 2010 (samples were not recovered for January 2010). A subsequent investigation into the effects of host-characteristics, parasite intensity and seasonality was conducted. Previous studies have found that a strong seasonal variability in the abundance of both host and parasites exists. They have also shown that the magnitude of parasite infections increases with host age reaching an apex within juveniles prior to a decline in older adult hosts; host age classes are defined as follows: kittens (110-750g), juveniles (751-1300g) and adults (1300g or more) (Cattadori *et al.* 2005). Overall, it is suggested that parasite growth and fecundity can be best explained by a three-fold of processes: host-mediated, parasite density-dependent and environmental effects. In the case of host-mediated effects, it can be hypothesized that *T. retortaeformis* will be the longest and will have the highest number of eggs in kitten *O. cuniculus* when host constrains are at the lowest. In

regards to parasite-density effects, it can be predicted that as female *T. retortaeformis* length increases due to less competition, so will the number of eggs *in utero*. Lastly, when considering environmental effects, it can be hypothesized that *T. retortaeformis* will be the shortest and will have the least number of eggs during the winter months when climatic conditions are unfavorable for infection and naïve hosts are at their lowest numbers.

MATERIALS AND METHODS

The System.

The system used in this study was focused around the common gastrointestinal nematode *T. retortaeformis* found in free-living European rabbits (*Oryctolagus cuniculus*). *Trichostrongylus retortaeformis* matured to adulthood within the small intestine and their eggs were shed into the pastures via infected rabbit's feces. New infection occurred when third-stage larva were subsequently consumed by the rabbits. It took the helminth population two weeks to establish and mature to adulthood within the host's small intestine (Chylinski *et al*. 2008). Rabbits are the common host of this nematode which often persists in the host as a chronic long-lasting infection. *Oryctolagus cuniculus* are social animals that live together in communities feeding on vegetation within their warrens. In Scotland they experience a seasonal breeding pattern spanning from late winter to late summer (Cattadori *et al*. 2005).

Nematode Collection.

Every month from January of 2009 to December of 2010 with the exception of January 2010 samples of *T. retortaeformis* were obtained from a population of free living rabbits that were sampled with a .22 rifle in Perthshire, Scotland. *T. retortaeformis* specimens were extracted from the small intestines and intensity of infection estimated for each rabbit. A subsample of randomly collected specimens was stored in 0.4% formalin and the vial was labeled with the rabbit's identification number and cull date. The samples were then mailed to 508 Mueller laboratory for processing. Host characteristics, including age, sex, weight, breeding status, were collected and archived in a master excel file.

Methods of Counting.

For every vial the nematodes were placed into a petri dish. Five females were then randomly

selected and the number of eggs in the uterus was counted using a LEICA MZ95 microscope at 6

times magnification. The eggs are easy to count as they are clearly distinguishable and regularly

aligned along the uterus. However, special care was taken to not misidentify fat or undigested

food as eggs. The egg number was recorded into a notebook and later entered into a computer

file, the females were then set aside for digitilization.

Digitilization and Measurement.

An additional five males were randomly selected from the sample. The five females and the

fives males were then carefully arranged so that all five nematodes of each sex could be viewed

under the microscope at 0.8 magnification. One picture of the female nematodes and one picture

of the male nematodes was taken using a camera-microscope system connected to a

computer. The program (INFINITY CAPTURE, Lumenera Corporation, Canada) was used to

save and archive the images.   Nematode length from head to tail was then measured using the

program Image J (National Institue of Mental Health, Bethseda, Maryland). The samples were

then returned to their respective vials and stored in 508 Mueller lab.
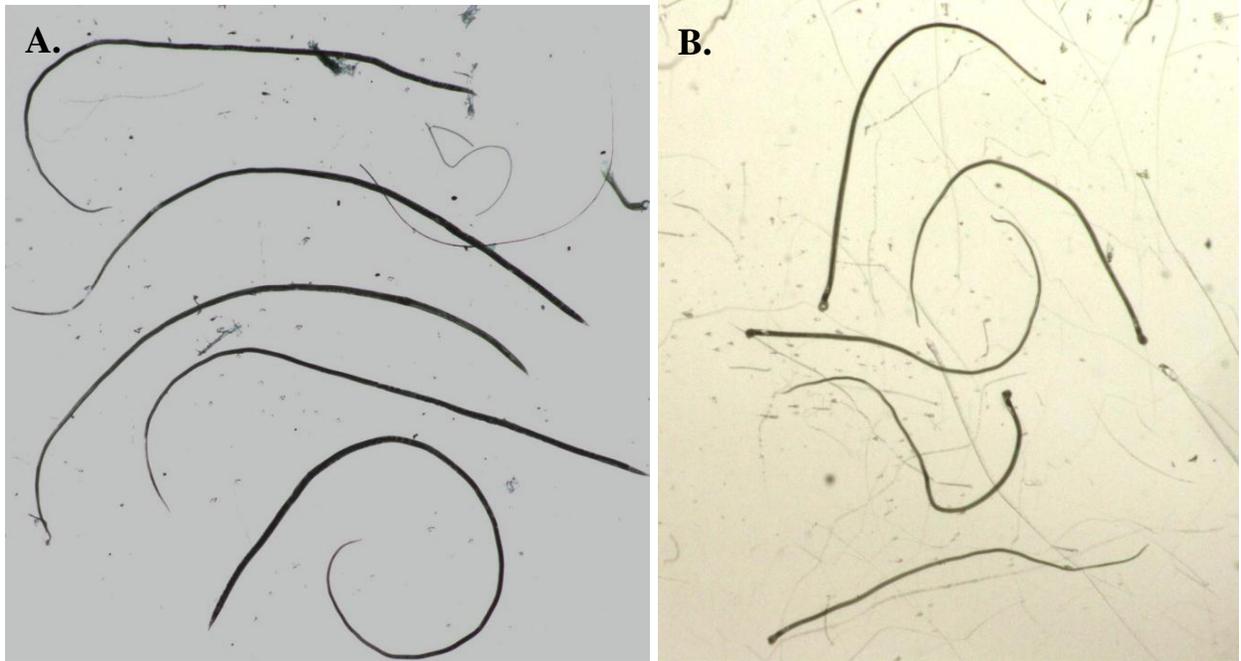
Figure 1. (A) Adult female *T. retortaeformis.* (B) Adult male *T. retortaeformis*
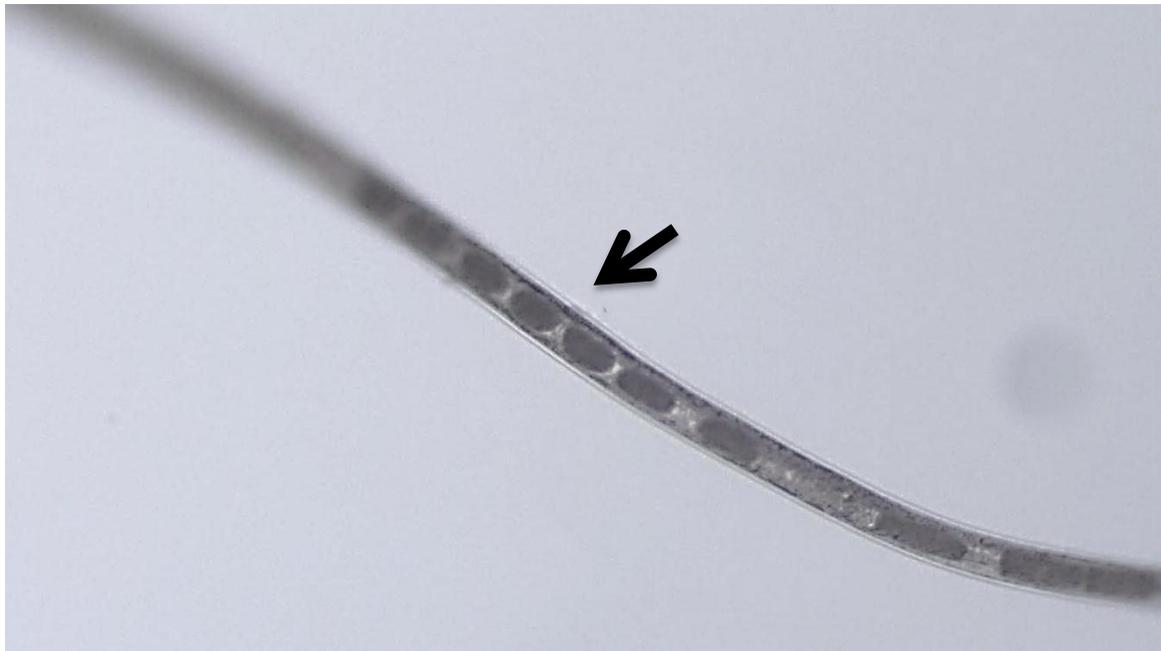
**Figure 2.** Arrow indicates eggs *in utero* of an adult female *T. retortaeformis* at 8.0 times magnification.

Statistical Analysis

Nematode length and number of eggs *in utero* were entered into Microsoft Excel and matched with the rabbit they were collected from. Average monthly lengths for both males and females and average monthly number of eggs *in utero* were calculated. Total nematode lengths and number of eggs *in utero* as well as the relationship between these two variables, and the intensity of infection were tabulated. In addition, length and eggs in uterus were examined in relation to host age (kitten, juvenile, adult)

Weather Data

Climatic data was attained from the Mylnefield climatic station, which was located 7 km from the study are in which the research was conducted. The station recorded daily values of the minimum and maximum environmental temperatures as well as grass and soil temperatures, total snow and rain accumulations and sun hours (Cattadori *et al,* 2005). Data has been archived since 1980.
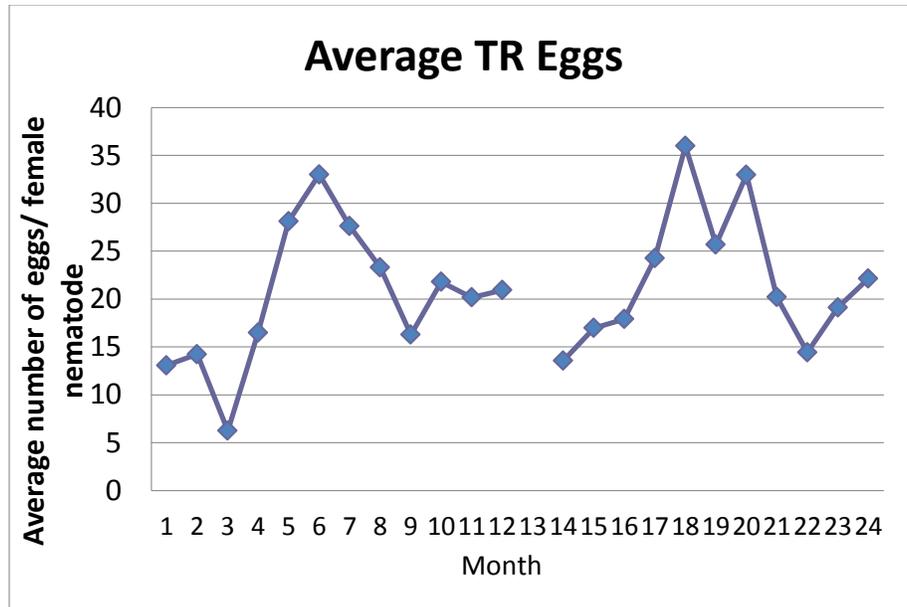
RESULTS
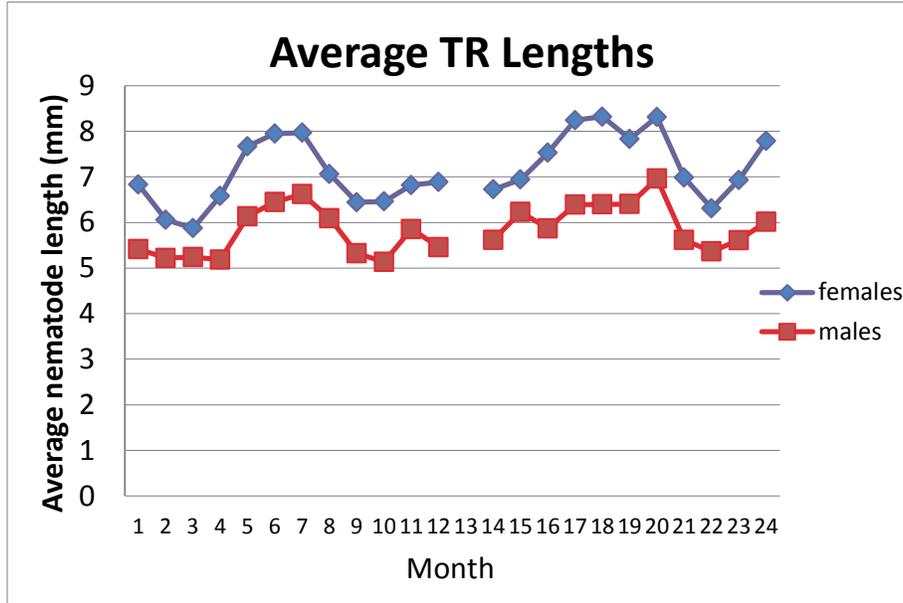
Figure 3. Average *T. retortaeformis* length vs. month. There was a clear cyclic seasonal pattern between TR length and month of collection from January 2009 (1) to December 2010 (24). Female TR were longer than male TR.

Female *T. retortaeformis* nematodes were significantly longer than male *T. retortaeformis* (Fig. 3). A sample of 1894 female nematodes had an average length of 7.287 ± 0.030 mm and a sample of 1746 male nematodes had an average length of 5.954 ± 0.025 mm. The longest female was 11.802mm (sampled from PIT9 on June 9th, 2010) and the longest male nematode was 9.054mm (sampled from PIT 2 on July 19th, 2009), suggesting that fertility linearly increases with body length.

There was a distinct seasonal pattern between *T. retortaeformis* average length and month of collection (Fig. 3). Average f emale *T. retortaeformis* length gradually increased throughout the spring months until reaching a peak in July of 2009 (7.964mm) where it then began to slowly decline until reaching a minimum length in September of 2009 (6.44mm). The average length then began to gradually increase throughout the late fall and winter months and once again

reached a peak in the late spring and early summer months of 2010. The same trend held true

with male *T. retortaeformis average* length with a peaks in July 2009 (6.618mm) and August

2010 (6.961mm) and minimun lengths in October 2009 (5.132mm) and October 2010

(5.363mm).

Figure 4. Average *T. retortaeformis* eggs per female vs. month. There was a distinct recuring seasonal pattern between number of TR eggs and month of collection from January 2009 (1) to December 2010 (24).

Similarily, results showed that there was a strong seasonal correlation between the

number of *T. retortaeformis* eggs *in utero* and the month the sample was obtained. Over the two

year period, an average of 22.777 ± 0.295 eggs was present *in utero*. The maximum number of

eggs counted was 74 in a helminth (length: 10.308mm) collected on the second of August 2010

(PIT3.2.8.10). The average number of eggs steadily increased throughout the spring and summer

peaking in June 2009 with 33.0177 eggs and then continued to steadily decrease in the fall and

winter. This same trend was observed in 2010 with a peak of 35.980 eggs in June.

Overall, nematode length and number of eggs in uterus correlate well with the rabbit breeding mainly occurring between April and July, supporting the hypothesis that the arrival of susceptible offspring affects the dynamics of nematode infection as well as parasite development and fertility (Cattadori et al. 2005, Chylinski et al. 2008).

Although this deviates from the overall annual cycle of *T. retortaeformis* length and egg number, March of 2009 had the shortest average female nematode length, 5.871mm, and the least number of eggs, 6.25 (fig. 4). In comparison, March 2010 had an average female nematode length of 6.939mm and an average number of eggs of 16.975: these values are characteristic of the overall patterns observed. The pattern observed in March 2009 may have been caused by a much smaller sample set (20 nematodes) than the other months (up to 124 nematodes).
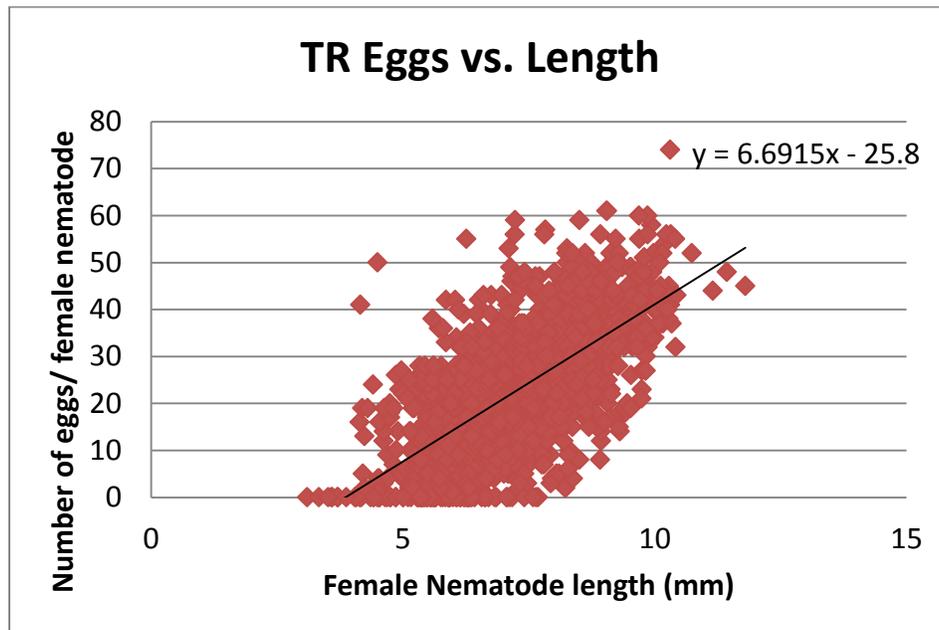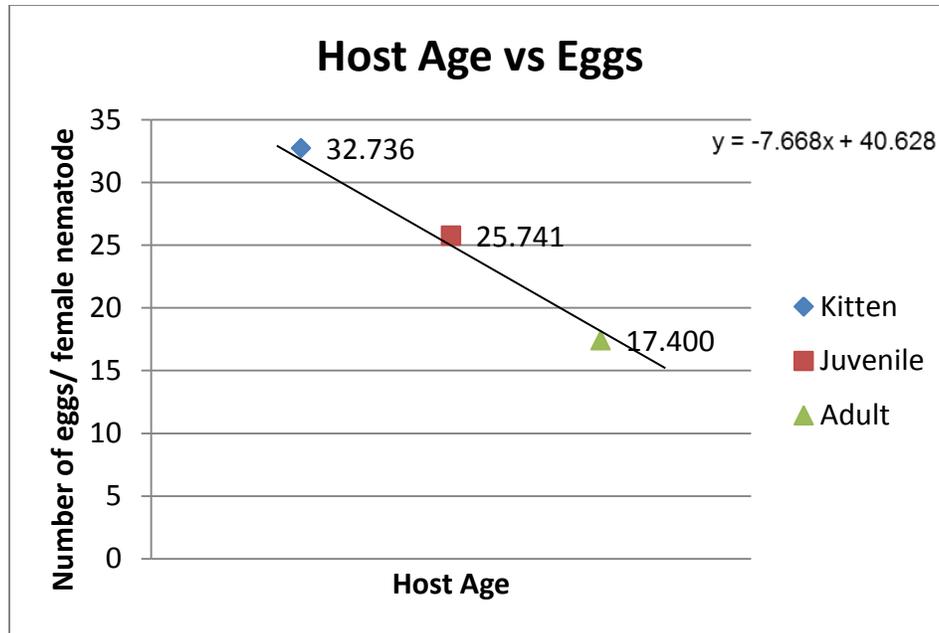

Figure 5. *T. retortaeformis* eggs per female vs. length. There was a positive linear relationship between the length of TR adult females and the number of eggs *in utero* from rabbits sampled from January 2009 to December 2010. Regression line: y= 6.6915x – 25.8

Results showed that there was a direct positive linear correlation between the number of eggs *in utero* and female *T. retortaeformis* length (Fig. 5). The number of eggs *in utero* increased at a rate of 6.6915 eggs per millimeter of *T. retortaeformis* length (regression line: y= 6.6915x − 25.8). June 2010 had the highest number of eggs *in utero,* 35.980, and the longest average nematode length, 8.318mm.
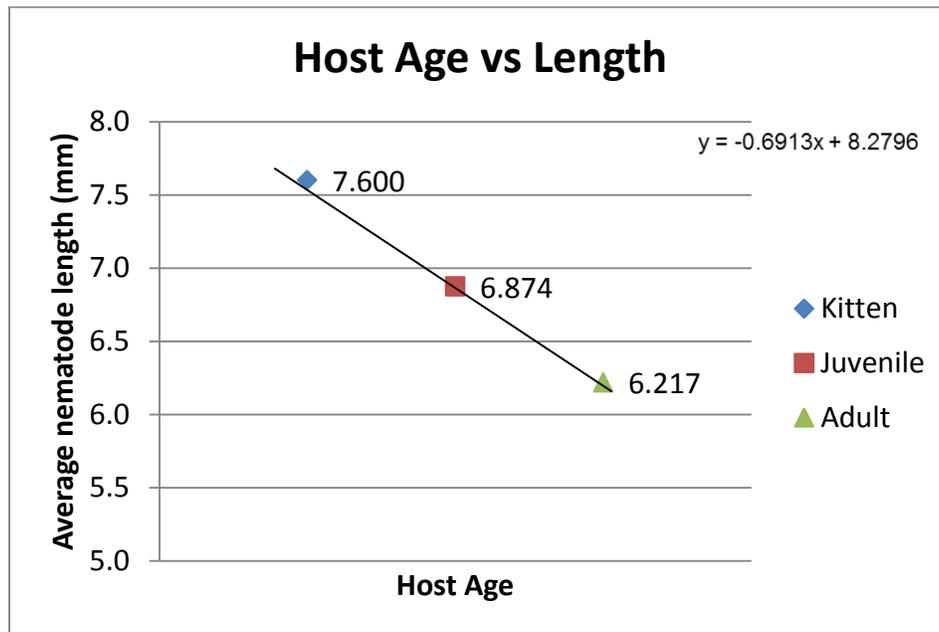
Figure 6. Average *T. retortaeformis* length vs. host age . There was a strong negative linear relationship between host age and TR length. Regression line: y= 0.6913x + 8.2796

Results also showed that there was a distinct decrease in *T. retortaeformis* length with host age (Fig. 6). The average nematode length from samples obtained from kittens, juveniles, and adult rabbits was 7.600mm, 6.874mm, and 6.217, respectively. This corresponds to an average decrease in length of 0.6913mm per increase in host age group (regression line: y=-0.6913x + 8.2796).

Host Age vs Eggs

32.736

25.741

17.400

y = -7.668x + 40.628

Number of eggs/ female nematode

Host Age

◆ Kitten
■ Juvenile
▲ Adult

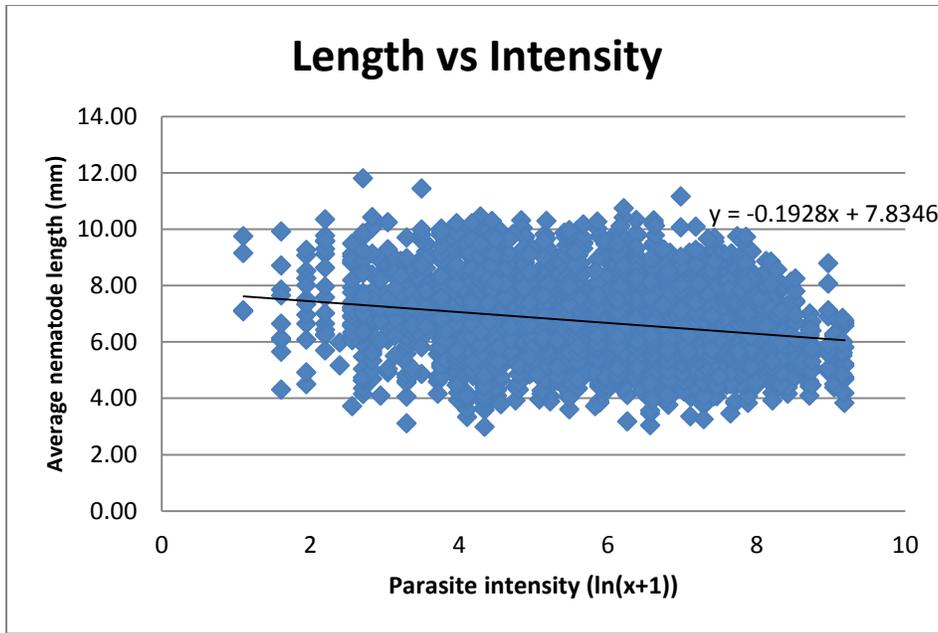**Figure 7. Average *T. retortaeformis* eggs per female vs. host age .** There was a strong negative linear relationship between host age and the number of TR eggs present *in utero*. Regression line: y= -7.668x + 40.628

Similarly, there was a linear exponential decrease between number of *T. retortaeformis* eggs *in utero* and host age (fig. 7). The average number of nematode eggs *in utero* from samples obtained kittens, juveniles, and adults was: 32.736, 25.741, and 17.400, respectively. This corresponds to an average decrease in egg number of 7.668 eggs per increase in host age group (regression line: y= -7.688x + 40.628). This suggests that acquired immunity is particularily influential when it comes to parasite infections.

Figure 8. *T. retortaeformis* **length vs. intensity of infection .** There was a weak negative linear relationship between the intensity of infection and nematode length.   Regression line: y = -0.1928x + 7.8346
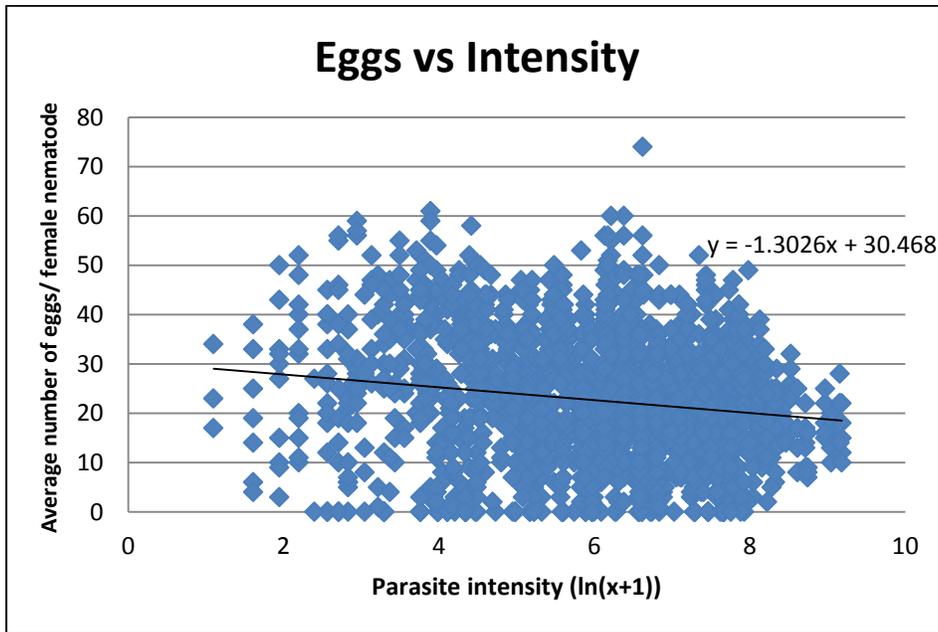
Figure 9. *T. retortaeformis* **eggs per female vs. intensity of infection .** There was a slight negative linear relationship between the intensity of infection and host age and the number of TR eggs present *in utero*. Regression line: y = -1.3026x + 30.468

Although there was noticible variability among the data, there was a weak but robust negative linear relationship between the intensity of infection and nematode length of both males and females (regression line: y = -0.1928x + 7.8346; Fig 8). In line with this result, there was also a negative linear relationship between the intensity of infection and the number of eggs *in utero*(regression line: y = -1.3026x + 30.468, Fig. 9), suggesting that density-dependent constraints play a smaller role in *T. retortaeformis* development and fecundity.

DISCUSSION

In this study I explored the dynamics of infection of the gastrointestinal nematode *T. retortaeformis* in its common host the European rabbit, looking for mechanisms that can affect the development and fecundity of this parasite. This was accomplished by counting the number of eggs *in utero* and measuring the body lengths of male and female nematodes collected monthly between 2009 and 2010 from the intestines of a free-living population of European rabbits (*O. cuniculus)* in Perthshire, Scotland.

In the wild the European rabbit experiences a distinct seasonal pattern of reproduction (Boyd, 1986). In the Northern Hemisphere the months in which the most offspring are born are April, May and June (Boyd, 1987). Individuals live in family groups in well-structured borrows. Newborns spend the first three weeks with the mothers lactating; subsequently, they emerge from the borrow and start feeding on the nematode contaminated pasture where they get rapidly become infected with *T. retortaeformis.* Previous studies confirmed that rabbits develop an acquire immune response to *T. retortaeformis* infections where individuals can clear or reduce the burden within a few weeks, depending of the force of infection (Cattadori *et al.* 2005, Murphy et al. 2011). Therefore, during the breeding months there are the greatest number of naïve newborns who have yet to develop acquired immunity to fight this infection . As a result, one would expect to see an increase in the length and number of eggs of *T. retortaeformis* during the summer months and a decrease during the fall and winter months if host-mediated effects directly influence nematode dynamics. Moreover, in the naïve offspring, there should be a slight time delay between the full development of the nematodes to adult size and complete fertility and the development of an active immune response that can successfully control the infection. After ingestion, it takes *T. retortaeformis* around two weeks to develop into mature

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adults from their infective third larval stage and, in naïve hosts, about 3 weeks to develop a robust antibody response and eosinophilia required for parasite clearance (Audebert 2002, Murphy et al. 2011).

These observations support my prediction that in the case of host-mediated effects, *T. retortaeformis* will be the longest and will have the most number of eggs in kitten *O. cuniculus.* Figure 6 and figure 7 show that both *T. retortaeformis* length (males and females) and the number of eggs *in utero* decreased as the host age increased. *T. retortaeformis* in kitten hosts were an average of 7.600mm long and had an average of 32.736 eggs *in utero*; whereas, *T. retortaeformis* in adult hosts were an average of 6.217mm in length and had an average of 32.736 eggs *in utero*. This same pattern was observed in a previous study by Chylinski *et al* (2008) . The kitten hosts have yet to develop an acquired immunity due to their young age and in general they have weaker immmune systems, which causes less stress for the nematodes and permits them to grow longer and be more fecund. Moreover, it is likely that the juvenile and adult host rabbits have been repeatedly infected by *T. retortaeformis* throughout their lifetime and have built up an immune response againt the parasitic *T. retortaeformis* (Cattadori *et al,* 2005). Therefore, the immune-driven pressure on the *T. retortaeformis* that have established in juvenile and adult hosts is greater and consequently appears to make *T. retortaeformis* shorter and less viable. Indeed, previous studies confirmed that *T. retortaeformis* stimulates a strong acquired immune response in the European rabbit (Cattadori *et al,* 2008, Murphy et al. 2011).

Because the samples in this study were taken from a seasonal system, it was important to explore if the weather impacted parasitic infections. The infective free-living larvae require a warm and moist environment to survive, which suggests that temperature is a major factor in the development of nematode free living stages (Soulsby 1982). During the winter months, free-

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living *T. retortaeformis* is in an inactive state; therefore, *T. retortaeformis* recovered from hosts

during these months had not been recently ingested. They had most likely entered the host

during warmers months and passed into a state of arrested development (Cattadori *et al,* 2005).

Later, when the parasites had become metabobilcally active again, they were living in more

mature hosts, an environment that is less conducive to *T. retortaeformis* development because

their hosts were more adept at fighting infection due to the development of an acquired

immunity. When taking environmental effects into consideration, it was predicted that *T.*

retortaeformis will be the shortest and will have the least number of eggs during the winter

months. This can once again be attributed to the host's seasonal breeding pattern: during the

winter there are no or very few susceptible newborns. Figure 3 and figure 4 show that the

environment which influences the hosts' breeding season does impact *T. retortaeformis*

development by depicting a distinct repeated seasonal pattern between both *T. retortaeformis*

length and month of collection and the number of *T. retortaeformis* eggs *in utero* and month of

collection.   The average number of eggs and nematode lengths steadily increased throughout

the spring and summer peaking in June 2009 and again in June 2010. It then continued to

steadily decrease throughout the fall and winter months, which corresponds to the maturing of

the major proportion of the host population and its immune system. Most importantly, this cycle

of nematode length and number of eggs correspond to when the new offspring are born and to

climatic conditions that are ideal for free-living infective larvae, which implies that host-

mediated responses, especially that of acquired immunity are especially important (Chylinski *et*

al, 2008).

When the intensity of an infection increases, there is greater competition among the

parasite population for resources and space and this can lead to a decrease in nematode length

and fecundity (Schmidt *et al*, 2009*)*. I predicted that in regards to parasite-density effects, as female *T. retortaeformis* length increases due to less competition, so will the number of eggs *in utero.* Figure 8 and figure 9 show a negative trend when comparing the intensity of infection to nematode length (male and female) and to the number of eggs *in utero.* This negative relationship supports a density-dependent regulation of nematode development and fecundity in addition to an immune mediated host response: the parasites that were burdened with the most density dependent constraints were the shortest and least fertile. Furthermore, as displayed in figure 5, there was a very strong positive relationship between the length of adult female *T. retortaeformis* and the number of eggs *in utero,* suggesting that nematode length is directly related to nematode development (this pattern was also noted in an epidemiological study carried out by Chylinski in 2008). Shorter nematodes may have either experienced slowed development due to a lack of environmental resources that resulted in a decrease of their capability to make eggs implying that female fecundity is primarily controlled by nematode length. Yet at the same time we know that immunity has a strong control over parasite intensity so while development and fecundity may have been affected by parasite intensity host immunity may have played the major role in affecting both parasite abundance and life history traits.

Furthermore, it has been previously noted that in very old hosts it is common for nematode body length and number of eggs *in utero* to increase. This further promotes the concept that density-dependent factors also impact nematode development and fertility in addition to a host-mediated immune response.   Mature hosts have the ability to clear or greatly reduce infections, which results in a great decrease in the intensity of the infection (Chylinski *et al,* 2008).   Consequently, the density-dependent pressures experienced by the surviving nematodes are much lower and while they are still negatively impacted by the host's immune

response they are able to overcome it to some extent and grow larger and more fecund due to an increase in environmental resources.

Lastly, the results from this study suggest that the environment may also influence the intensity of infection. According to climate data June is a fairly dry month (for example the total rainfall for June 2009 was 44.3mm; whereas, that of July was 144.3mm). Moreover, June of 2010 was particularly dry with a total rainfall of 23.2mm, which is significantly lower than the thirty year monthly average. Dry fields present conditions that are unfavorable to free-living parasites. One possible contributing factor to the statistic that June had the longest, most fecund nematodes is that there were less viable infective larvae in the field due to these dry conditions, resulting in the rabbits consuming fewer parasites. This may have led to a parasite infection that was less intense in comparison to more wet months. Thus, the parasites that did manage to establish themselves within a host had less competition and as a result were longer and more fertile.

There were some clear limitations to this study which made it difficult to tell what outside force has the greatest impact on the course of the infection and overall nematode development and fecundity. During the summer months one would expect to see larger and more fertile nematodes because of the naïve immune responses of the new-born offspring. However, at the same time during the summer months Scotland experiences its warmest temperatures and a fair amount of rainfall, which are the ideal conditions for *T. retortaeformis* development. Perhaps a similar study conducted in the laboratory could provide more conclusive data on how exactly host-mediated responses and parasite density-dependent parameters impact the fecundity and development of *T. retortaeformis* because the variable seasonal environment can be eliminated. Another factor that should be considered is that the

majority of the rabbits were not only just infected with *T. retortaeformis*. In addition, most rabbits were infected with other nematodes including *Graphidium strigosum.* In order to best understand *T. retortaeformis* epidemiology, it would be helpful to conduct this same study in the laboratory where *T. retortaeformis* was the sole parasite because in a previous study it was found that co-infections did affect *T. retortaeformis (Cattadori et al, 2008).* Having a single infection would eliminate any error that could have been encountered due to the host's immune system in an attempt to clear multiple infections and would show how the host adapts to fight *T. retortaeformis* specifically.

One important element that was not thoroughly explored in this study was the impact of arrested development. Arrested development or hypobiosis is a period of metabolic depression that permits parasites to stay alive until harsh conditions, such as extreme weather or overcrowded living spaces, are removed (Nisbet et al, 2004).   Hypobiosis can be induced by two factors that were investigated in this study: host immunity and environmental changes (seasonality). Therefore, the further study of arrested development could provide more insight to the results we gathered regarding these effects (Michel, 1974; Schad 1977).   An additional phenomenon that would be interesting to investigate is anhydrobiosis. Anhydrobiosis is another adaptation involving the complete or partial desiccation and commencement of all metabolic activity for a given time period that some species of trichostrongyle nematodes have developed to survive extreme weather conditions during their free-living infective state (Lettini *et al*, 2006). It would be interesting to see if *T. retortaeformis* have the ability to undergo anhydrobiosis because it may help explain the patterns cyclic observed and provide additional understanding as to how a seasonal environment impacts *T. retortaeformis* development.

This study was important because it provided information about host immunity, population dynamics, and local climatic conditions over time. This information can help us better understand how several external forces, host-mediated, parasite density-dependent and environmental effects, interact to affect the course of an infection. Moreover, the results from this study provided a number of clear patterns regarding *T. retortaeformis* development and fecundity and insight on the mechanisms that impact this nematode. The data indicates that density-dependent effects may have contributed to the dynamics of infection especially at high levels of parasite intensities but it appears that host-mediated effects specifically the hosts development of an acquired immunity is the major player when it comes to nematode infections.

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VITA

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EDUCATION

Schreyer Honor College at the Pennsylvania State University, University Park, PA
Bachelors of Science in Biology: Vertebrate Physiology Option with Honors
Bachelors of Science in Spanish: Applied Option
Anticipated Graduation: May 2011
Thesis Title: "Epidemiology of Gastrointestinal Parasite Infections in a Wild Herbivore"
Thesis Supervisor: Dr. Isabella Cattadori

UNDERGRADUATE RESEARCH EXPERIENCE

January 2010- Present: The Department of Biology, Dr. Isabella Cattadori
The Pennsylvania State University, University Park
- Studied the host-parasite interactions in laboratory and free-living rabbits through microscopic identification and quantification of the intestinal nematode, *Trichostrongylus retortaeformis*
- Assisted in determining fecundity of the intestinal nematode, *Graphidium strigosum*

VOLUNTEER/ COMMUNITY SERVICE

The Department of Biology, Biology Tutor

Sept. 2008- Dec. 2009

Mount Nittany Medical Center, Occupational and Physical Therapy Volunteer
Nov. 2009- May 2010

CS Clase de Salud, Volunteer
May 2010- July 2010

Relay for Life, Team Member
Mar. 2011- Apr. 2011

ORGANIZATIONS & LEADERSHIP

Penn State Spanish Club
Member, Fall 2008- Fall 2010

Penn State Student Red Cross Club
Active Member, Fall 2008- Present
On-Site Coordinator, Spring 2010- Present
- Managed and delegated tasks to student volunteers
On-Site Coordinator Chair, Spring 2010- Present
- Recruited and trained new on-site coordinators
- Scheduled on-site coordinators for all Penn State blood drives

Alpha Epsilon Delta – Premedical Honors Fraternity
Member, Spring 2009- Present