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Internal parasites in American bison

Gaël Misselyn

Promotor :
Meulemans Godelieve

Bachelor paper executed to obtain the degree of
Bachelor in agro- and biotechnology
Specialization: Animal care
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Abstract

This paper discusses the study of internal parasites in the American bison. Different bison types are mentioned, including the American bison and the European bison. Gastrointestinal tract and diet are relevant to the study as parasite activity influences these. Nematodes, cestodes and protozoa are the three main groups of internal parasites in bison, the most common parasites are discussed. To determine the intestinal parasitic load in bison, a fecal egg count study was executed for the bison herd at the Cochrane Ecological Institute by using several egg counting methods. For the whole study, the McMaster fecal counting method was used. To give an idea of the parasite infection in bison held in different conditions, samples of a bison herd in the Blood Indian Reserve were taken as well. This led to interesting results. The types of parasites that were mostly determined were Strongylids. *Nematodirus* eggs were found as well in the herd at the Blood Indian Reserve.

Foreword

Seen the fact that I’m very interested in microscope work, I was excited when Ken Weagle proposed this subject to me. Not having any help from a vet, he helped me realizing this study, he coached me throughout it and made sure I had all the materials needed. I want to thank him for coaching me and for giving me this personal project. I am thankful that Ken Weagle and Clio Smeeton gave me this amazing opportunity, the access to their massive library helped me out tremendously. Thanks to Mike Curtis I was able to collect all the samples needed for the research. He also taught me a lot about bison behaviour. Godelieve Meulemans was my promotor, she guided me throughout the writing process of this paper, which is why I want to thank her.

Contents

1 Introduction

Internal parasites have an influence on living beings. The start of this research was given because of a very skinny bison at the Cochrane Ecological Institute. She lost a lot of weight over winter, even though she was being fed like the others. Internal parasites could be a cause for that, this is why the research was set up. Unfortunately, this bison died before the study started, so samples of her weren't included.

First, a little background between the different types of bison is given, including the American bison and the European bison. Secondly, there is a short description of the gastro-intestinal tract and diet, since they are involved in intestinal parasitosis. The three most important groups of internal parasites in ruminants are then clarified, these concern the nematodes, the cestodes and the protozoa. After that, the study is elaborated. The aim of this study was to estimate the degree of the bison herd's internal parasitosis through fecal egg counting methods. Additional samples were taken from another bison herd, this gives an idea of the parasite infection in a herd held in different conditions. In a preliminary study, two different fecal egg counting methods were tested, the modified Wisconsin sugar flotation method and the McMaster fecal egg counting method. Due to easier counting, the McMaster fecal egg counting method was used for further research.

2 Taxonomy

Kingdom: Animalia
Phylum: Chordata
Class: Mammalia
Order: Cetartiodactyla: even-toed hoofed or ungulated animals
Family: Bovidae: including: cattle, water buffalo, oxen, antelopes, goats, sheep etc.
Genus: *Bison*

Table 1: Bison species and subspecies

Species	**Subspecies**
Bison antiquus / Ancient bison †	/
Bison bison / American bison	*Bison b. athabascae* / American wood bison *Bison b. bison* / American plains bison
Bison bonasus / European bison	*Bison b. bonasus* / Lowland bison *Bison b. caucasicus* † *Bison b. hungarorum* †
Bison latifrons / Long-horned bison †	/
Bison priscus / Steppe bison †	/

(San Diego Zoo, 2009; Gates & Aune, 2008).

3 Breeds

3.1 The American bison / *Bison bison*

Bison bison, also named the American buffalo, is North America's heaviest terrestrial, native mammal (Forsyth, 2006). There are two subspecies, the wood bison and the plains bison (Naughton, 2012). It is listed as 'near threatened', since presently there are only five small populations which rely on an ongoing conservation program. During the 19th century there was severe overhunting, which caused the population numbers to drop drastically. Nowadays 97% of the whole population is managed for private captive commercial breeding. The wild free- and semi-free-ranging herds are estimated to consist of 11250 individuals (Gates & Aune, 2008). These non-territorial species are nomadic, they live in small herds and have a certain home range. Throughout the different seasons they can travel from 40 km to 240 km depending on the habitat type (San Diego Zoo, 2009). Their habitat range extends from northern Mexico to Alaska (Gates & Aune, 2008).

The American bison's habitats are North America's prairies (Bartoli & Boitani, 1983). The soil is very rich in the prairies of the United States and Canada, so it is perfect to nourish themselves with the grasses growing on it. Nowadays the land has become more urbanized and industrialized, this is why lots of the original prairies have vanished (Curry-Lindahl, 1981). Still, bison have an enormous effect on the grassland quality. During spring the bison's wallows become temporary puddles, in which aquatic organisms live. On the land, where prairie dogs are foraging, bison eat the plants avoided by these rodents. Bison dungs and hoof prints ensure the growth of grass eaten by the prairie dogs. The fact that the soil nutrients are recycled in the dungs and absorbed back in the ground is believed to be tremendously valuable to maintain the rich soils of the prairies (Forsyth, 2006).

Figure 1: The American bison in its natural habitat

These robust animals are mostly different shades of brown, occasionally there's an albino, but this is rarely seen (Naughton, 2012). The pelage is rough and longer on the head, the shoulders, the neck and the front legs (Bartoli & Boitani, 1983). The sides are covered with scabby hair (Forsyth, 2006). On the head, the hair is curly and thick (Bartoli & Boitani, 1983). Their coat explains their adaptation to the extreme weather conditions, which is outstanding. When a blizzard comes up, they lower their heads facing it. Bison have much more hair in the front of their bodies, so that way they will keep warm (Curry-Lindahl, 1981). The low-carried head is massive, the nostrils are big and the tongue is slate-blue (Forsyth, 2006). The fact that their head is so huge helps them find food during winter. If there's a deep layer of snow covering their food supply, they will dig their snouts into it, using side to side motions with the head to push it away. This way they get access to the grass deep beneath the snow. This method doesn't work for melted and refrozen snow. As the ice covers the food supply, this is one of the only threatening winter conditions to bison's survival (Curry-Lindahl, 1981). Under the chin, the hair forms a beard. Both males and females have short, upward pointing, black horns, even though the males' horns are bigger (Bartoli & Boitani, 1983). These slender horns are unbranched and have a bony core (Patten, 1981). The horn sheath is not shed, during full life length it continues to grow (Naughton, 2012). Bison's eyelashes are much shorter than those of cattle, this prevents the ice from accumulating on them (San Diego Zoo, 2009). There is definite sex dimorphism, in general the males are bigger and heavier than the females (Naughton, 2012). Males have a broader, muscled neck, the hump is much more prominent and their pelage is longer (San Diego Zoo, 2009). Overall, males are 225 to 335 cm long with a weight varying from 680 to 1180 kg. Females have a total length between 220 and 285 cm. Their weight varies from 390 to 640 kg (Smith, 1993). The rope like tail has a length varying from 30 to 90 cm, it ends in a tuft (Forsyth, 2006). Most of the ruminants lack upper incisors, instead, they have a dental pad. The lower jaw has a gap that separates incisors and premolars, this is called the diastema (Rouge, 2017). Bison's permanent dental formula consists of 32 teeth. The upper jaw has zero incisors, zero canines, three premolars and three molars. The lower jaw has three incisors, one canine, three premolars and three molars (Naughton, 2012).

Gestation in the American bison takes 270 to 285 days. Mid-April to June most calves are born, which weigh about 15 to 25 kg (Naughton, 2012). This species is precocial, so 30 minutes after birth the calves walk around (Forsyth, 2006). Each bison produces a single calf (twins, however, do occur), it takes three years before the calves are fully mature (Bartoli & Boitani, 1983). The calves pelage is usually much lighter than the adult individuals coat. (San Diego Zoo, 2009).

Despite their size, bison have a few predators, namely grizzly bear, grey wolf and puma. Wolves are the main predators, they mostly prey on calves or old, weak animals. A lone healthy adult is difficult to kill, even with a whole wolf pack (Forsyth, 2006).

3.1.1 Wood bison / *Bison bison athabascae*

Figure 2: Wood bison

Wood bison live more up in North America. Their habitat range stretches from central Alberta to Alaska. Nowadays their range is restricted, mainly because of reportable disease management policies (Gates & Aune, 2008). Reportable diseases have to be eradicated, for domestic animals, the protocols are well developed. When these protocols apply to wildlife, it is very difficult to match these with conservation goals (Gates et al., 2010). Inhabited Western boreal parklands and woodlands are the best environment for this subspecies (San Diego Zoo, 2009). An estimated 11000 wood bison live in eleven conservation herds. Ten wild herds are known to live in their natural habitat in Canada (Gates & Aune, 2008).

Wood bison tend to have a darker pelage and are usually larger than plains bison. The highest point of the shoulder hump is located forward to the front legs. The hair colour is brown to black on the forequarters, the hindquarters are dark brown. Males are between 245 and 386 cm long, with an average weight of 880 kg. The weight ranges from 642 to 1179 kg. The shoulder's highest point varies from 168 to 201 cm. Females have a total length of 265 to 333 cm. They weigh from 493 to 567 kg with an average of 525 kg. The shoulder height is 155 to 172 cm (Naughton, 2012).

3.1.2 Plains bison / *Bison bison bison*

Figure 3: Plains bison

This subspecies is found from northern Mexico to central Alberta. Currently, the range is restricted because of land use and wildlife management policies (Gates & Aune, 2008). Their habitat is mainly open grasslands (San Diego Zoo, 2009). Roughly 19000 individuals of this species live in 54 conservation herds. Six herds are wild, two of them appearing in Canada, three in the US and one in Mexico (Gates & Aune, 2008).

The hair is generally shorter than that of wood Bison. Most hair is seen on the back of the lower part of the legs, along the bottom of the neck, between the horns, in the beard and in the cape. There is a clear colour difference between the longer hair on the forequarters and the shorter hair on the hindquarters. The highest point of the shoulder hump is over or behind the front legs. Males have a total length between 304 and 390 cm. They weigh 544 to 1090 kg, with an average of 769 kg. The shoulder height is between 152 and 179 cm. Females measure 213 to 318 cm in total. Their weight ranges from 390 to 605 kg, with an average of 425 kg. The height at the shoulder is from 140 to 157 cm (Naughton, 2012).

3.2 The European bison / *Bison bonasus*

Figure 4: European bison

The European bison, also called wisent, is listed as ‘vulnerable’, even though the population numbers are slowly increasing. This IUCN Red List status is the result of severe population losses between 1990 and 2000. During this period wisent were threatened by agricultural activity, forest logging and unlimited hunting and poaching. Furthermore, in the early 90’s a massive population of deer dramatically reduced food resource which was harmful to the bison (Olech, 2008). European bison’s habitat are the forests of Central and Northern Europe (Bartoli & Boitani, 1983). Two populations occur in the Bialowieza forest in Belarus and Poland. After World War II, the international borders divided the populations. This resulted in two genetic lines, namely the lowland line and the lowland-Caucasian line (Hendricks, 2013). The optimal forest composition is mosaic-like positioned deciduous or mixed trees with 20% grassland. Occasionally they forage in coniferous forests due to their food flexibility. Wisent have played an invaluable role in the composition of the prehistoric European broad-leaf forest and forested steppe ecosystems (Olech, 2008).

The dark brown or black fur is dense and longer than the American Bison’s hair. On the neck it almost forms a mane. Horns are seen in both sexes, they are curved pointing upwards (Bartoli & Boitani, 1983). The full length (head and body) can vary between 2,5m to 3m. The shoulder height at the hump can be up to 2m. Their weight varies from 800 to 1000 kg (Bartoli & Boitani, 1983). In the wild, their lifespan is an average of 19 years. In captivity they mostly live longer, with an average lifespan of 24 years. After a gestation of nine months, the females seclude themselves from the herd to give birth to a single calf (Hendricks, 2013).

4 Gastro-intestinal tract

The bison is a ruminant species, this means that they have a four-chambered stomach (San Diego Zoo, 2009). This complex, multi-compartment gut is made to digest bulky, low-nutrient diets. The first one of these chambers is the rumen or paunch, this one occupies the whole left side of the animal. It's the largest stomach of the four, its main functions are storing, soaking, mixing and fermenting food (Regents of the University of Minnesota, 2017). This enormous stomach takes in unchewed, fresh and sturdy plants along with the saliva, which maintains the acidity level in the gut to acceptable values. In the rumen the meal is edited by digestive enzymes, which break up the lignin and cellulose. After a couple of hours, the mass is regurgitated thanks to a bidirectionally functioning oesophagus, this is when ruminants chew their cud. Usually, they forage for a certain period, then the animal is resting and ruminates (Forsyth, 2006). Rumination can take up to 35 to 40 percent of the day, depending on the feed. When finely ground rations are fed the rumination time decreases, when long hay is fed the rumination time increases. The rumination helps reducing particle size, because ruminants spend very little time on chewing when eating. Another advantage of rumination is the resalivation of the food bolus. Consequently to these actions, the rumen microbes have an easier time digesting the feed (Regents of the University of Minnesota, 2017). After the nutrients are absorbed from the digested vegetation, the food bolus continues its journey through the following stomachs (Forsyth, 2006). The second stomach is the reticulum, the inside resembles a honeycomb. This one is not completely separated from the rumen, only a small fold of tissue separates them. The reticulum filters dense feed. The third stomach is the omasum, the inside resembles the pages of a book, it absorbs water and nutrients. Another function is reducing the particle sizes. The last stomach, called the abomasum has glandular lining which secretes enzymes. This one is called the real stomach because it is comparable to non-ruminant's stomach (Regents of the University of Minnesota, 2017). After going through all of the stomachs, the food bolus passes through the small intestine. In the caecum there's a last fermentation process, the caecum is located on the transition from the small intestine to the large intestine. Thanks to this complex digestive process, ruminants are capable of extracting most of the nutrients and the extra vitamins constituted by the intestinal bacteria. Another advantage of Artiodactyls is the fact that they are capable of recycling nitrogen wastes. When proteins are broken down, urea is formed, this circulates in the blood. When the rumen recycles the urea from the blood, gut bacteria use the nitrogen produced by urea. This provides the host ruminant with amino acids, nucleic acids and ammonia, making the digestion work more efficiently. The complete process of digesting a food bolus can take up to four days to pass through the whole gastro-intestinal tract (Forsyth, 2006).

Bison are extremely efficient in their food-intake and digestion. Their very structured rumen makes it possible to retain food in their digestive tract for a longer time than

cattle do. The total tract retention time can be up to 10 hours longer in bison. This gives them more time to digest forages with high fiber levels, such as sedges and grasses. Per feeding, bison consume large quantities of food, feeding only four to nine times a day (Feist, 2000).

The dungs produced by bison are comparable to cattle's feces. Depending on the feed, the consistency of the droppings are variable. When a succulent diet is consumed, a 30 cm diameter flat patty is seen. Whenever a dry diet is consumed, the feces will be layered and cylindrical (Forsyth, 2006). During winter times, intake of snow and ice are reduced to a minimum. This allows the animal to keep more of its body heat since it doesn't have to heat up the water to produce urine (Forsyth, 2006).

5 Diet

These grazer's diet mostly consist of graminoids such as grasses and sedges, they use the grassland and meadow very efficiently in comparison to cattle. A big variety of vegetation can be digested because of its ability to extract nutrients from fibrous vegetations (Curry-Lindahl, 1981). Out of low protein, highly fibrous plants bison can extract much more nutrition, contrary to cattle (San Diego Zoo, 2009). Summer and fall bring a wide diversity of various plants, leaves, grasses and sedges (IUCN, 2016). During winter lichens and mosses are added to the diet (San Diego Zoo, 2009).

The energy metabolism varies over the seasons, during winter the energy intake is noticeably lower than during summer. The reason for this decrease in food intake is the fact that activity and acclimatization are reduced (Gates et al., 2010). During winter, the metabolism is at maintenance level, this is regulated by melatonin levels in the brain. When at maintenance level, the metabolism doesn't require a lot of energy (Feist, 2000). Bison are extremely well adapted to extreme temperatures. Little energy is lost thanks to the greatly insulating capacity of the pelage (Gates et al., 2010). Therefore, bison are seasonal ruminants. The metabolic rate, dry matter intake and body weight fluctuations are related to the seasons. Day length, hormone fluctuations and forage quality are also parameters that influence the metabolic rate (Feist, 2000).

Bison have a nomadic foraging strategy, they move between different foraging patches along distinct trails. When moving, they travel in a single file. Primitively, bison roamed randomly until they found appropriate grazing conditions. They grazed at these places until need for water forced them to travel further. Bison seek highly nutritious forages, in which they graze extremely efficiently to satisfy their nutritional needs (Gates et al., 2010). Generally, they tend to show more interest for the fresh shoots. These are often easier to digest and richer in protein (Bergmann

et al., 2015). Therefore, bison should have access to very large areas with the presence of various choice in abundance and quality of the forage. Originally, non-captive bison travelled from summer to winter ranges, moving from North to South. Bison also moved from East to West during winter, from the prairies to the foothills of the Rocky Mountains. They used to spend the summer at higher elevation, whereas the winter was spent at lower elevation (Gates et al., 2010). Over the seasons, there's variation is the bison's diet. This is probably due to changes in the nutritional values of plants (Bergmann et al., 2015).

6 Internal parasites

6.1 Introduction

Numerous problems are caused by the presence of parasites. It seems that wildlife has adapted to their presence, but not to the adverse effects. Parasites can cause both clinical and subclinical conditions in the animals. In case of clinical parasitism, the animal is showing visible symptoms. Subclinical conditions are very hard to measure, the animal doesn't show clear signs of illness. Parasitism has a significant effect in wild ruminants. It's known that forage intake, feed efficiency and growth rates are reduced in case of high parasite burdens. During severe winters or drought parasitism can aggravate the effects of malnutrition and food availability. This can lead to pathogenic infections and even death. Most of the infections happen from early spring to late fall. After severe winters, parasitic larvae become active as the temperatures get warmer. Most of the infections take place near water since moisture is key to their development and movement. Control of parasites in wildlife is difficult since handling the animals for treatment is an issue (Bliss, s.a.).

Occuring parasites in bison are protozoa, trematodes, cestodes, nematodes and artropodes (Eljaki et al., 2016). The main internal parasites in hoofed wildlife can be divided in three major groups. The first one is the most important one, nematodes include stomach, intestinal and lung-worms. Another group is the cestodes, tapeworms belong to this group. The last group, the protozoa, include coccidia and giardia (Bliss, s.a.). Bison are highly sensitive to infection by trichostrongyle species that are strongly adapted for both ovine and bovine (Eljaki et al., 2016).

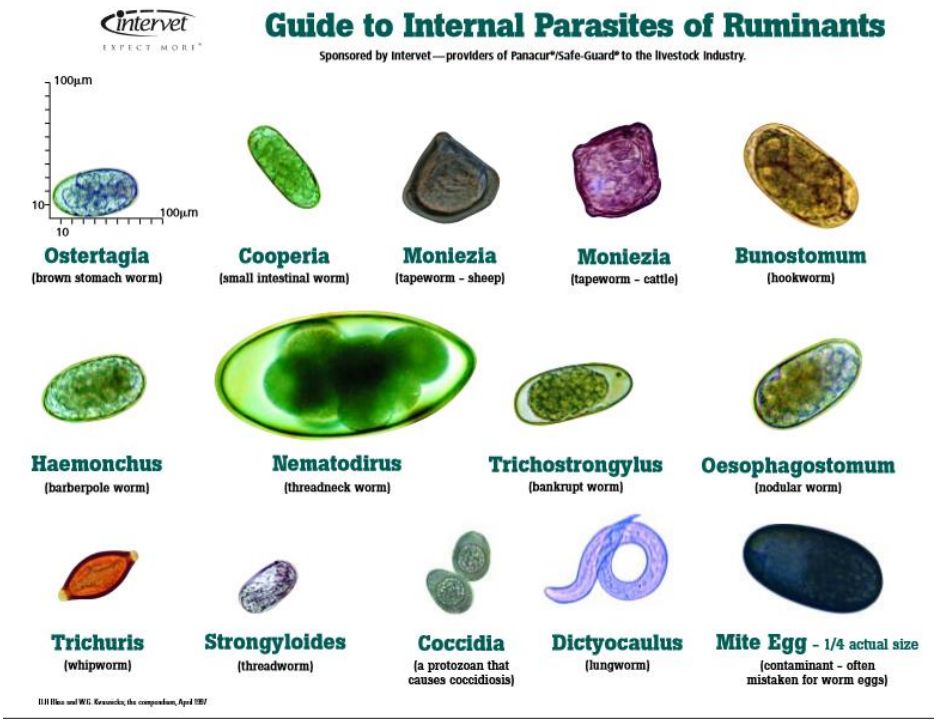

Figure 5: Comparison between the different internal parasites of ruminants

6.2 Nematodes

Nematodes have a direct life cycle, which begins in the gastro-intestinal tract of the host animal, this is where the adult parasites live. The adults lay eggs, which pass out in the feces. When the feces are in the environment, the eggs embryonate into infective larvae. The larvae undergo three larval stages before they are infective. The first molt is from a L1 to a L2 larva. The second molt to a L3 larva is where the larva becomes infective, in this stage the larvae are very mobile. Most infections happen in the early morning or in the late evening as the infective larvae follow moisture trails from the feces onto the vegetation. At these times dew is on the plants, most animals are grazing then. There are seasonal influences on the development of the eggs and larvae outside the animal, ideal weather conditions are warmth and moisture. Once the larvae have reached an infectious stage, they can survive up to several years in severe weather conditions (Bliss, s.a.).

6.2.1 *Bunostomum* spp.

Bunostomum or hookworm is found in the small intestine. This one is mostly found in regions with warm and humid weather conditions. Infection happens mostly through larval penetration through the skin contrarily to oral ingestion (Junquera, 2017). The latter mostly happens with animals held in poor conditions. Male adult worms can be 15 mm long, while the females can be 25 mm long. They have well-developed capsules, with those they attach to the mucosa (Fox, 2016). The color of the worms is greyish to whitish (Junquera, 2017). Its eggs are medium-sized with

an average length of 100 µm. There are four to eight blastomeres and sometimes the walls are thick and rectangular (Bliss & Kvasnicka, 1997).

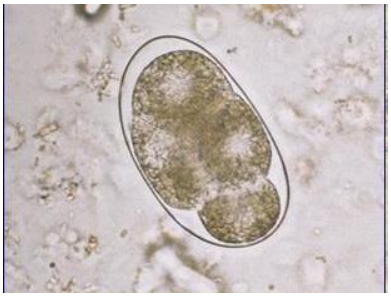

Figure 6: *Bunostomum* oocyst

Consequences of infection are anemia and rapid weight loss. Occasionally, diarrhea and constipation do occur. Mild hypoproteinemic edema can be present. In the intestine, the mucosa appears to be congested and swollen, with small hemorrhagic points where the worms were attached (Fox, 2016).

6.2.2 *Capillaria bovis*

Capillaria parasites are found in the small intestine. Male adults are eight to nine mm while females measure up to 12 mm. The worms are very fine and have a whitish color. (Taylor et al., 2016). The eggs can be recognized by the bipolar plugs. These are smaller than the very similar eggs of *Trichuris* because of the bipolar plugs. A clinical infection is considered insignificant for this parasite (Faculty of Tropical AgriSciences, 2017). Little information is known about this parasite.

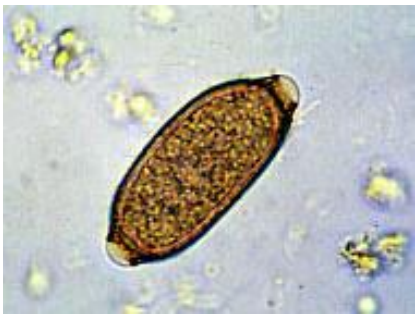

Figure 7: *Capillaria bovis* oocyst

6.2.3 *Chabertia ovina*

These worms are found in the large intestine of ruminants, specifically the colon. Usually they are more common in sheep and goats, but occasionally they do occur in other ruminants (Taylor et al., 2016). Prevalence is more frequent in areas with a temperate climate (Junquera, 2017). Adults are 15 to 20 mm long, females are longer than males (Taylor et al., 2016). Eggs have an oval shape with a thin shell, it contains more than 16 cells (Junquera, 2017).

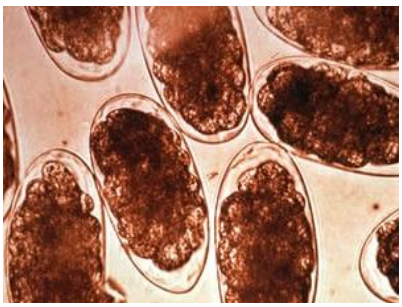

Figure 8: *Chabertia ovina* oocysts

Mostly, this parasite is not harmful. It does aggravate damage caused by other parasite species. In the gut, various ulcers are caused by the attachment of the worm to the mucosa. Clinical signs are mucous or hemorrhagic diarrhea, anemia, weight loss. In severe cases, the animals can die. In bison, this parasite does not seem to be pathogenic (Junquera, 2017).

6.2.4 *Cooperia* spp.

This type of intestinal parasite is a small worm causing mucosal damage in the small intestine (Fox, 2016). Most of the infections happen in areas with warm and humid weather (Junquera, 2017). Adult individuals are five to eight mm long, they are red and coiled (Fox, 2016). Its medium-sized, cylindrical eggs can be 75 to 85 µm long. The sides are parallel, it has numerous blastomeres which are hard to distinguish (Bliss & Kvasnicka, 1997).

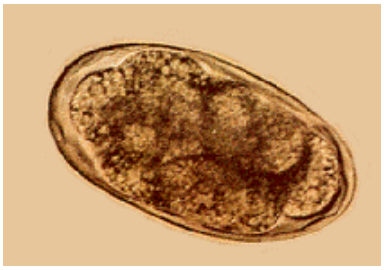

Figure 9: *Cooperia* oocyst

Diarrhea, anorexia, emaciation, weight loss, slowed growth and poor productivity are caused by these worms (Fox, 2016). When these worms are present in high numbers, they are particularly harmful for young animals, these become anemic after infection (Junquera, 2017).

6.2.5 *Dictyocaulus* spp.

Lungworms are mainly found in regions with temperate or cold climate. Adults occur in the trachea, bronchi and bronchioles. The larvae migrate to various organs including the gut. Adults are medium-sized with a length up to 8 cm. Females are longer than males. All adults have a whitish or grayish color. The eggs are recognized because of the ovoid shape which contains a fully developed L1 larva (Junquera, 2017). Lungworm L1 larvae are found in the feces, which have a

flattened head with blunt pointed tail end (Bliss & Kvasnicka, 1997). The diagnose is made by use of the Baermann method (Taylor et al., 2016).

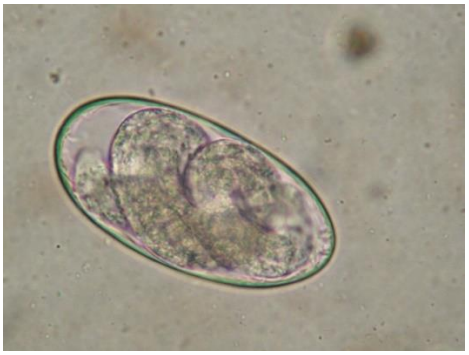

Figure 10: *Dictyocaulus* oocyst

Reduced appetite, weight and milk production is caused by this worm (Bliss & Kvasnicka, 1997). Heavy coughing, difficult breathing and nasal discharge are also effects caused by lungworm (Junquera, 2017). The identification of the worm can be done by taking rectal samples of the feces (Bliss & Kvasnicka, 1997).

6.2.6 *Haemonchus* spp.

The barberpole worm is a so-called twisted stomach worm, occurring in the abomasum. These are voracious bloodsuckers and more prevalent in tropical regions (Junquera, 2017). These big worms can be two to three cm long (Taylor et al., 2016). The oocysts are large and round, the blastomeres are easily seen. The length of the oocysts is average 85 µm (Bliss & Kvasnicka, 1997).

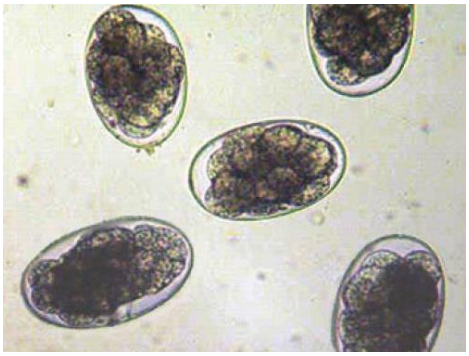

Figure 11: *Haemonchus contortus* oocysts

The barber pole worm mainly causes anemia in variable degrees. In goats and sheep death is commonly seen (Bliss & Kvasnicka, 1997). Other possible effects are intermittent periods of constipation. Hypoproteinemia and edema are also effects, the edema mostly appearing under the lower jaw or along the ventral abdomen. Other signs may be progressive weight loss, weakness, rough coat and anorexia (Fox, 2016). In case of heavy infections, the host dies. Even when the infection is medium, the host is significantly weaker (Junquera, 2017).

6.2.7 *Nematodirus* spp.

Nematodirus or threadneck worm is found in the small intestines and causes mucosal damage. Regions with temperate climate are optimal for these worms (Junquera, 2017). Adult males can be 12 mm long, females are 18 to 25 mm long (Fox, 2016). Their color is whitish (Junquera, 2017). Its eggs are large, looking like an American football with basketballs inside. Two to eight blastomeres are inside a fluid-filled cavity. Its length is approximately 200 µm (Bliss & Kvasnicka, 1997).

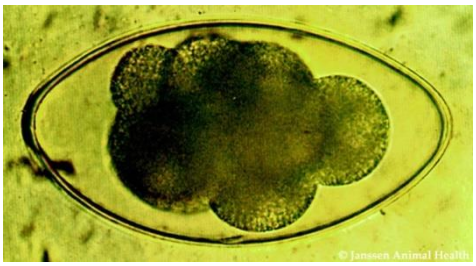

Figure 12: *Nematodirus filicollis* oocyst

This parasite causes diarrhea, slowed growth, anorexia and sometimes emaciation and death in sheep and young cattle (Bliss & Kvasnicka, 1997). The mucosa in the infected tissues may be thick and edematous (Fox, 2016).

6.2.8 *Oesophagostomum* spp.

The nodular worm is located in the large intestine and causes severe damage to its host (FAO, 2017). This worm is mainly found in areas where the climate is tropical or subtropical (Junquera, 2017). The whitish adult worms can be 12 to 15 mm long, with a dorsally bent head (Fox, 2016). Its medium-sized to large eggs have 16 to 32 blastomeres, these are easier to see than those of *Haemonchus* (Bliss & Kvasnicka, 1997).

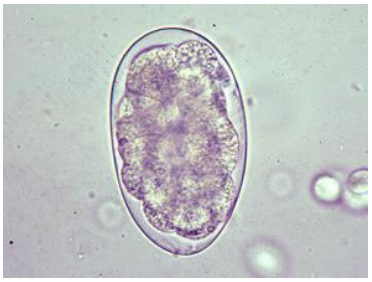

Figure 13: *Oesophagostomum* oocyst

Oesophagostomum causes leakage of protein from the mucosa into the intestinal lumen, causing hypoproteinemia. The larvae escape from the abomasum and migrate to the intestine. The anemia is caused by hemorrhage into the lumen of the gut. The larvae cause swellings or nodules in the intestinal wall of their hosts . Severe, dark, constant, smelly diarrhea is a consequence of infection. Other signs are anorexia, weight loss, reduced growth and death. In older animals, nodules enclosing larval worms are seen. These can be palpated through the rectum (Fox, 2016).

6.2.9 *Ostertagia* spp.

Ostertagia worms, or so-called brown stomach worms, are present on the surface of the mucosa in the abomasum (Taylor et al., 2016). These are large in numbers in areas with temperate and cool climate (Junquera, 2017). An adult of this medium stomach worm can be from six to nine mm long with a brownish color (Fox, 2016). The eggs are medium-sized, looking like a standard Strongylid egg. The walls of the eggs are barrel-shaped with an inside well-filled with a large number of blastomeres (Bliss & Kvasnicka, 1997).

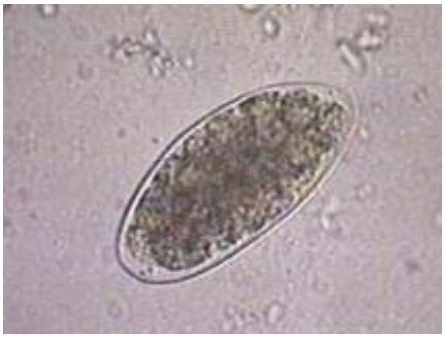

Figure 14: *Ostertagia ostertagi* oocyst

This worm suppresses appetite, causes weight loss and a poor body condition (Bliss & Kvasnicka, 1997). A profuse and persistent watery diarrhea is typical for this infection. Hypoproteinemia and edema are rather rare, but do occur. Other signs are weight loss, weakness, rough coat and anorexia. Common lesions seen in the abomasum are small, umbilicated nodules, sometimes the gastric pH rises to six or seven (Fox, 2016).

6.2.10 *Strongyloides* spp.

Threadworm is found in the small intestine, causing mucosal damage. They are particularly common in warm and moist climates. The infection happens through ingestion or when they migrate through the skin (Junquera, 2017). Only the female individuals of this parasite are found in the intestine, these are 3,5 to 6 mm long. Infective larvae can even be transmitted through the colostrum (Fox, 2016). Adult worms are small measuring one to six mm, they are almost transparent (Junquera, 2017). The egg is small with a thin shell, it contains a L1 larva which can be seen by light microscopy under low power. Its approximate length is 40 to 65 µm (Bliss & Kvasnicka, 1997).

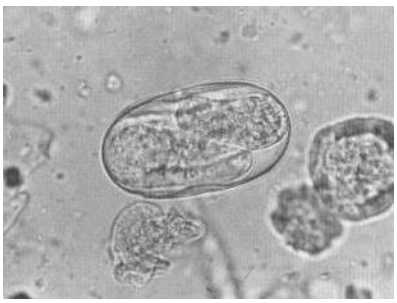

Figure 15: *Strongyloides papillosus oocyst*

Mostly, young calves show signs of infection. These include intermittent diarrhea, appetite and weight loss, with occasionally blood and mucus in the feces (Fox, 2016).

6.2.11 *Toxocara vitulorum*

This parasite is a long and thick roundworm found in the small intestine (Junquera, 2017). Mostly, *Toxocara vitulorum* is found in tropical and subtropical climates. It is not clinically pathogenic in calves older than six months or adults. The larvae hatch and migrate to muscles, liver, kidneys and other viscera after they are ingested by the older hosts. This migratory movement can cause serious damage to the organs. In pregnant females, one to eight days before parturition, the dormant larvae become active. This is when they migrate to the mammary glands, where they enter the colostrum and the milk. This way, the calves are infected (Woodbury et al., 2014). Adult worms can be up to 30 cm long and 7 mm thick. Males are smaller than females. These worms are whitish with a translucent aspect. The eggs are formed like a sphere, they have an alveolated and thick membrane which contains a single cell (Junquera, 2017).

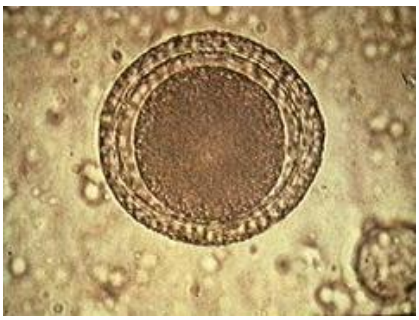

Figure 16: *Toxocara vitulorum* oocyst

When present in high numbers, the worms can obstruct or perforate the gut (Junquera, 2017). This is why extremely infected bison calves can die from heavy worm burdens. In case of a milder infection, effects are ill-thrift, poor weight gain and secondary health issues (Woodbury et al., 2014). Other symptoms are putrid diarrhea, colic, enteritis and loss of appetite (Junquera, 2017).

6.2.12 *Trichostrongylus* spp.

Trichostrongylus, also called the small stomach worm or the bankrupt worm, can reach 5 mm long adult size. Females are slightly bigger than males, reaching sizes of 6 mm (Fox, 2016). Their color is brownish to reddish (Junquera, 2017). Its eggs are medium-sized with parallel sides, inside there are numerous blastomeres, which are difficult to distinguish through the microscope (Bliss & Kvasnicka, 1997).

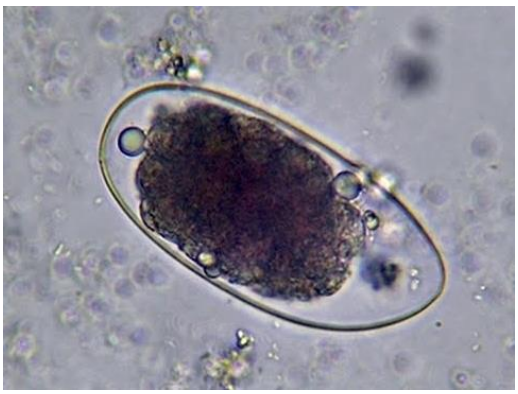

Figure 17: *Trichostrongylus* oocyst

This parasite causes profuse, persistent watery diarrhea and slowed growth (Bliss & Kvasnicka, 1997). There is often hypoproteinemia and edema, particularly on the lower jaw and sometimes along the ventral abdomen. Even subclinical conditions can lead to death. Other variable signs are weight loss, rough pelage and anorexia. At necropsy, congestion and superficial erosions can be seen on the mucosa of the abomasum. Occasionally, these are covered with a fibrinecrotic exsudate (Fox, 2016).

6.2.13 *Trichuris* spp.

Trichuris or whipworm occurs in the cecum, where it feeds on blood. Mostly, they occur in areas with tropical or subtropical climate. Adults are three to eight cm long with a whitish to yellowish color (Junquera, 2017). Its eggs are shaped like American footballs with two protruding polar caps and a double, thick shell. The average length of the eggs is 75 µm (Bliss & Kvasnicka, 1997).

Figure 18: *Trichuris* oocyst

This infection is the most common in calves, with small numbers (Fox, 2016). This parasite causes reduced appetite and slowed growth (Bliss & Kvasnicka, 1997). Signs of heavy infection may be dark feces, anemia and anorexia (Fox, 2016).

6.3 Cestodes

6.3.1 *Moniezia* spp.

Tapeworm occurs in the small intestine of ruminants. It has an indirect life cycle in which oribatid mites are intermediate hosts and ruminants are the final hosts. Oribatid mites are also called moss mites or beetle mites. The fully embryonated eggs are passed in the feces or released from chains of ripe proglottids voided by their hosts around the pastures where they graze. None of these are able to survive over winter on pastures. When the eggs are ingested by the oribatid mites, they hatch and develop to cysticercoids in the mites gut. Inside the mites, these cysticercoids can survive for months. The mites crawl over the soil and grass in search of food at the same time as ruminants are grazing. This is when the contaminated mites are ingested by the final hosts, infecting them. When the mites are digested, the cysticercoids are released into the gut. Adults can be up to 10 cm (Junquera, 2017). Its eggs are quadrangular and somewhat irregular with a length of 80 µm. These contain a circular or pear-shaped apparatus at one end (Bliss & Kvasnicka, 1997).

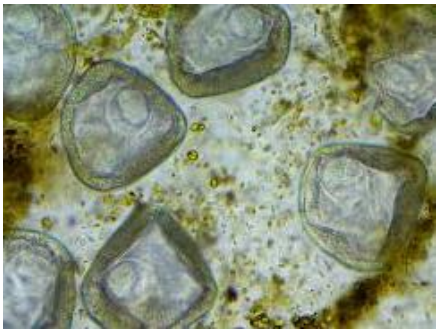

Figure 19: *Monezia benedeni* oocysts

This worm causes blockages in the small intestines of young individuals and loss of nutrients (Bliss & Kvasnicka, 1997). They are considered non-pathogenic in calves (Fox, 2016).

6.4 Protozoa

6.4.1 *Eimeria* spp.

Eimeria has a direct life-cycle like nematodes (Eljaki, 2016). Coccidiosis most commonly affects young individuals, mostly during wet weather conditions (Constable, 2016). Approximately, the length of these protozoa eggs can vary between 16 to 47 µm (Bliss & Kvasnicka, 1997).

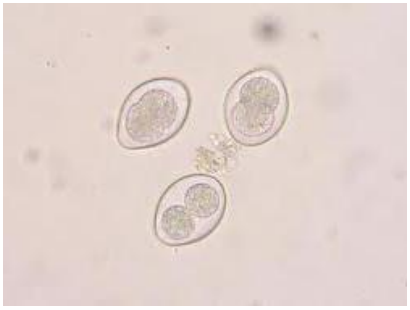

Figure 20: *Eimeria coccidia* oocysts

Signs of infection are apathetic calves with feces stuck to the perineal areas. In adults, feed efficiency is lowered. Clinical coccidiosis is recognizable due to watery feces, possibly with blood. This is a self-limiting disease which spontaneously disappears when the multiplication stage had passed (Constable, 2016). The clinical significance in bison is little known (Eljaki, 2016).

7 Faecal parasite study

7.1 Goal

The goal in this study was to identify all parasite eggs found in the dung samples of bison herds. Two herds have been examined, the Cochrane Ecological Institute's herd and Dan Fox's herd.

7.2 Material and methods

7.2.1 Description of the examined herds

7.2.1.1 Cochrane Ecological Institute's herd

This herd is located in Cochrane on the property of the CEI, this is a town situated on the foothills of the Rocky Mountains. Originally, the CEI herd consisted of nine individuals. Unfortunately, Old Girl died of an unknown reason at an approximate age of 18 before the research was started. She was very skinny, which was the initial reason for conducting this test. No autopsy was executed, her carcass was left in the bison enclosure for other animals to feed on. Big Bull is the biggest and oldest male, he is 18 years old and he is considered the leader of the herd. Daisy is a cow, approximately the same age as Big Bull, she is pregnant. There are two heifers, which are both pregnant. There is one two-year old bull. The remaining herd members are two yearlings. Samples were taken on the 27th of March, the 11th of April and the 21st of April. When the last samples were taken from the herd, three calves were born. Unfortunately, samples weren't collected from these calves.

Figure 21: Big Bull

Figure 22: Old Girl

The bison at the CEI are free-ranging in an enclosure of 48 hectares. This enclosure includes numerous types of vegetation like grasses, sedges, spruce tree, poplar trees, etc. There are several ponds in the enclosure. Over winter their diet was supplemented with bread and hay. Bread was given every day, the amount

depended on what was given by the bakery. Every ten days a hay bale weighing 680 kilograms was given. When the snow was gone, the bison weren't fed these supplements anymore. This year, it was at the end of April. Other than that, they had access to the whole area where they could forage whenever they want.

7.2.1.2 Dan Fox's herd

Dan Fox's pasture is located in the Blood Indian Reserve in the South of Alberta. Dan has a big herd of 23 animals, all aged from eight to eleven years old. This big herd is free-ranging in a big pasture. He also just bought five young bison calves from a vendor in Saskatchewan, which are kept in a corral. These are younger than one year old. Both groups are kept separately. The samples from Dan's big herd and the calves were interpreted separately. Samples from both groups were taken on the 4th of April.

Figure 23: Dan's big herd

Figure 24: The Saskatchewan calves

The big herd's total enclosure measures about 85 hectares and is divided in three smaller enclosures and a holding pen. Because of the divide in pastures, a rotational grazing system is applied. The vegetation in here is mainly grass and there is an open landscape. During winter the bison are supplemented with an alfalfa hay bales or oats. Every six months a new mineral stone is provided.

7.2.2 Fecal collection

7.2.2.1 Material

- Ziplock bags
- Permanent marker

7.2.2.2 Method

The bison examined in this study were not used to being handled, this is why fecal samples were not be collected out of the rectum. Therefore, fresh droppings were collected in their enclosure. The resealable bags were inverted like a glove to

collect the manure. Golf-ball sized samples were picked up, then the bags carefully re-inverted. Each sample bag was labeled with a number, a date and the group of animals from which the samples were taken from. All the samples were stored in a 3°C refrigerator as soon as possible. The samples can stay in the fridge for maximum a week. When many samples are collected at the same time, it is highly recommended to bring a cooler with ice (Zajac, 2014). Refrigeration suppresses parasite egg development. Freezing causes egg destruction (Midamerica Agricultural Research, 2017).

Figure 25: Me taking samples in the bison enclosure

7.2.3 Modified Wisconsin sugar flotation method

This procedure is the most sensitive method for fecal testing in all animal species. It's an effective technique for worm egg counting in animals with a low worm egg output. For bison three grams of manure was tested, all eggs in this sample were identified and counted (Midamerica Agricultural Research, 2017).

7.2.3.1 Material

- Scale (weighing in 0.1 gram)
- Plastic cups
- 455 grams of sugar
- 355 ml of hot distilled water
- Mason jar
- 10ml syringe to measure flotation solution
- Plastic knives for stirring
- Tea strainer
- Centrifuge
- Centrifuge tubes
- Microscope slides
- Cover slips
- Monocular microscope

- External light source for microscope

7.2.3.2 Method

Since this method is based on flotation, first a sugar flotation solution was made. A pan with 355 ml of distilled water was heated. Then, 455 grams of sugar was added to the distilled water. The mixture was stirred until all sugar was dissolved (Midamerica Agricultural Research, 2017). The solution was poured into a mason jar and kept in the fridge to cool down. This flotation fluid has a higher gravity than the eggs, which makes it possible for the eggs to float to the surface. This way, they can be examined under the microscope (Taylor et al., 2016).

Three grams of manure was measured into a plastic cup. Fifteen milliliters of the sugar solution was added to the manure. The content of the cup was stirred well with a plastic knife, to obtain a homogenic mixture. The concoction was strained in the tea-strainer to take out the big lumps. The remaining fluid was poured into a centrifuge tube and placed in the centrifuge. The centrifuge was switched on at a speed of 900 rpm for six minutes. After this the tubes were placed in a rack, topping them up with the flotation solution until a meniscus formed on top of it. A cover slip was placed on the meniscus, setting for four minutes. This allows the parasite eggs to float to the surface and stick to the cover slip. The cover slip was placed on a microscope slide, then the preparation was examined under the microscope (Midamerica Agricultural Research, 2017). Parasite eggs were identified using existing pictures of them.

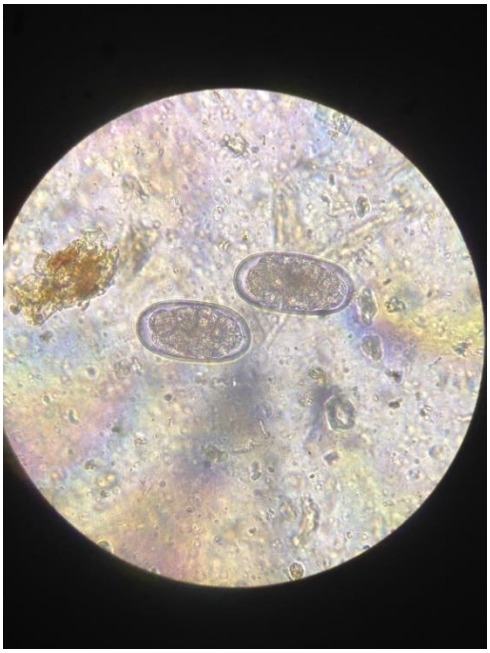

Figure 26: Strongyle-type eggs found using the modified Wisconsin sugar flotation method

Figure 27: The materials needed to start the Modified Wisconsin sugar flotation method

Figure 28: Left: stirred mixture. Right: unstirred mixture

Figure 29: Strained mixture

Figure 30: Tubes in the centrifuge

Figure 31: A meniscus forms

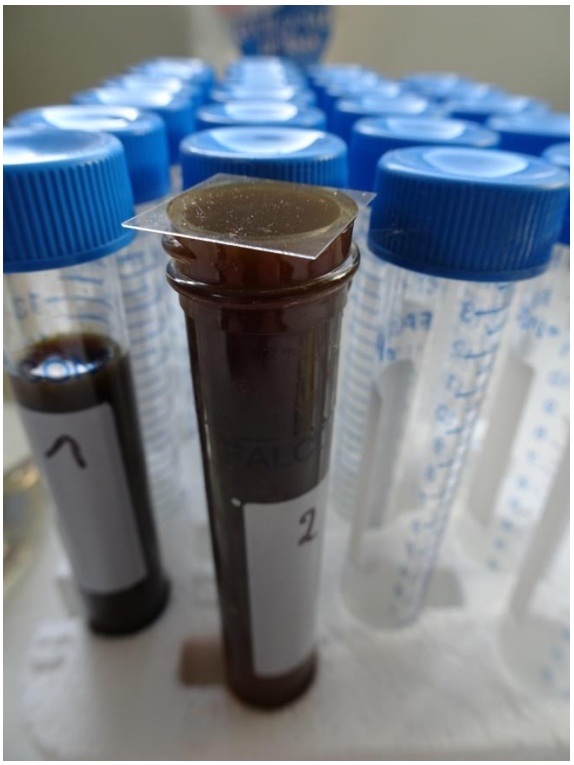

Figure 32: A cover slip is placed on the meniscus

7.2.4 Modified McMaster test

This technique is based on flotation: manure and flotation fluid are measured and mixed and only a small amount of the total mixture is used for the test. Due the difference in density between parasite eggs and debris, the eggs will float to the surface of the counting chamber. This way, the eggs can easily be identified and counted under the microscope. The McMaster microscope slide has two chambers with a grid, which makes the counting of the eggs easier. After counting all the eggs in the slide, a calculation determines the number of eggs per gram in the dungs (Zajac, 2014). Due to easier reading and counting of the eggs, the McMaster method was used to obtain all results of this research. The eggs counted in this test were all Strongylids except if mentioned differently, these are several nematode worms. It requires a trained eye to distinguish different Strongylids. The eyepiece of the microscope had a magnification of 15X while the objective had a magnification of 10X. Together this forms a total magnification of 150X.

7.2.4.1 Material

- Scale (weighing in 0.1 gram)
- Plastic cups
- 455 grams of sugar
- 355 ml of hot distilled water
- Mason jar
- 10ml syringe to measure flotation solution
- Plastic knives for stirring
- Tea strainer
- 2-chamber McMaster slides
- 5ml syringe for filling McMaster slides
- Monocular microscope
- External light source for microscope

7.2.4.2 Method

This method is also based on flotation, a sugar flotation solution was made first. A pan with 355 ml of distilled water was heated. Then, 455 grams of sugar was added to the distilled water. The mixture was stirred until all sugar was dissolved (Midamerica Agricultural Research, 2017). The solution was poured into a mason jar and kept in the fridge to cool down. This flotation fluid has a higher gravity than the eggs, which makes it possible for the eggs to float to the surface. This way, they can be examined under the microscope (Taylor et al., 2016).

An amount of two grams of manure was measured into a plastic cup. A weight deviation of 0,1 grams is acceptable. Then, 28 ml of flotation solution was added to the cup. The mixture was stirred well with a plastic knife before straining it into another cup. When given a last stir, The fluid was sucked up with a five ml syringe and put into the McMaster slides. The slides can be read after five minutes, this

allows the eggs to float to the surface. The microscope was focused on the lines of the McMaster slide, this was where the eggs could be found. All eggs in both chambers were counted. For this method the counting always started in the left top corner of the left chamber. By doing this consequently, no chambers were forgotten. When done reading the slides, all eggs were counted together and multiplied with factor 50. This gives an average number of eggs per gram feces (Zajac, 2014). Parasite eggs were identified using existing pictures of them.

Figure 33: All materials needed to execute the McMaster egg counting method

Figure 34: Two grams of manure is measured into a plastic cup

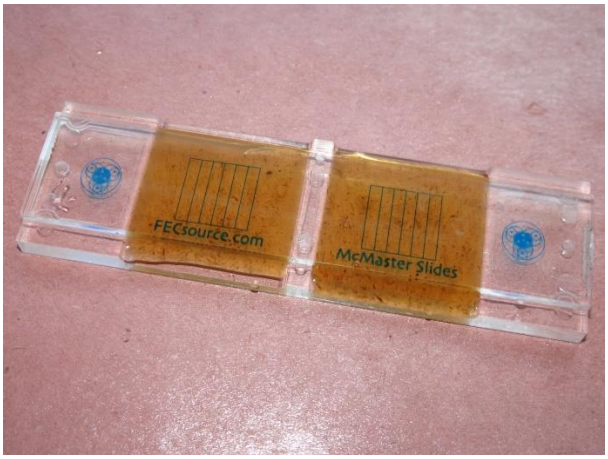

Figure 35: A filled McMaster slide

Figure 36: The monocular microscope with an external light source

7.3 Results

7.3.1 Cochrane Ecological Institute's herd

The first samples were collected the 27th of March, nine samples were taken. There was certitude about the provenance of two samples. Unfortunately the other samples couldn't be related to specific individuals. Because provenance of the samples was very hard to tell, all the samples represent the whole herd instead of an age-class. All samples were examined separately. The range of the EPG's in the first sampling was 50 EPG to 350 EPG. The average was 133 EPG. The median in

this take was 100 EPG. The standard deviation was 106. Strongylid-type parasites were the only ones found in these samples.

The second samples were taken on the 11th of April, two weeks after the first take. At this point 15 samples were collected. All samples were examined separately. The results ranged from 0 EPG to 500 EPG. The average was 187 EPG, this was higher than the first sample-taking. The median was 150 EPG and the standard deviation was 130. Strongylid-type parasites were the only ones found in these samples.

The third samples were taken on the 21st of April, ten days after the last take. Sixteen samples were taken on this date. All samples were examined separately. The range was from 50 EPG to 900 EPG, with an average of 244 EPG. This average was significantly higher than the previous sample-takings. The median was 150 EPG and the standard deviation was 243. Strongylid-type parasites were the only ones found in these samples.

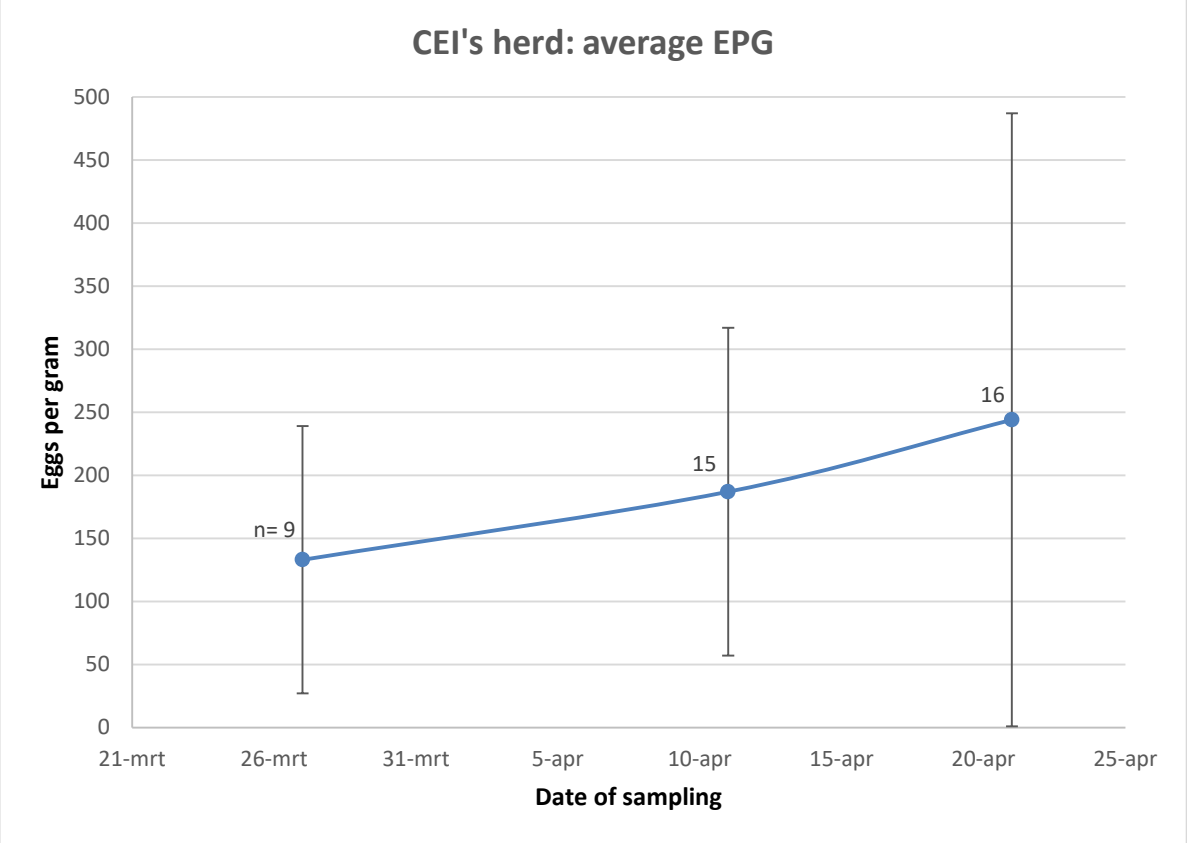

Chart 1: CEI's herd: average EPG with standard deviation

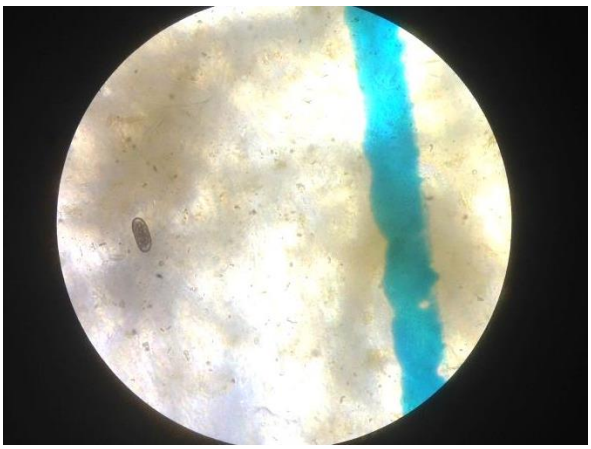

Figure 37: A strongylid-type egg found in the feces of the CEI's herd (150X)

7.3.2 Dan Fox's herd

From the big herd, 22 samples were taken. All samples were examined separately. These ranged from 0 EPG to 100 EPG. This brought it to an average of 34 EPG. The median was 50 EPG.

Seven samples were taken from the Saskatchewan calves. All samples were examined separately. The lowest burden was 100 EPG, while the highest was 500 EPG. The average was 314 EPG. The median was 350 EPG. Mainly Strongylid eggs were found, except for two of the samples, where one *Nematodirus* egg was found.

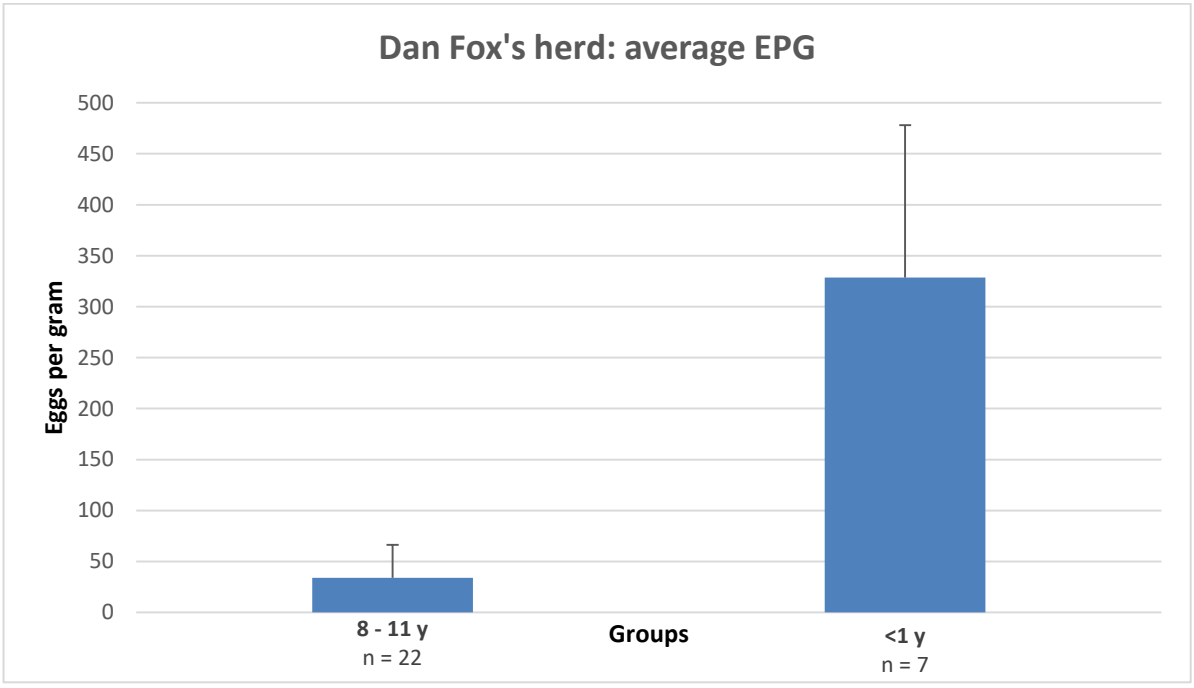

Chart 2: Dan Fox's herd: Average EPG with standard deviation

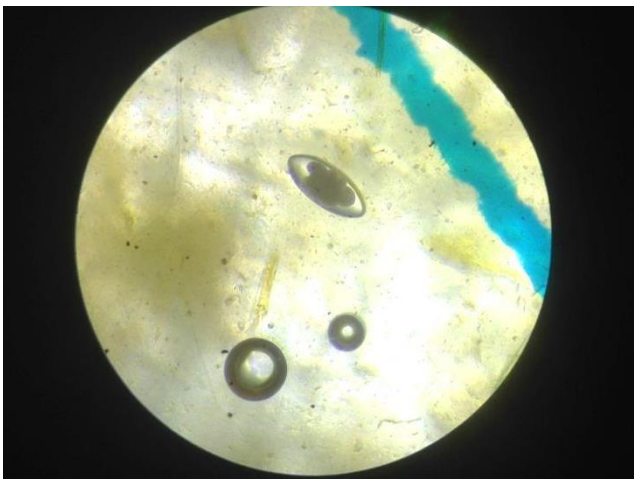

Figure 38: A *Nematodirus* egg found in the feces of Dan Fox's calves (150X)

To assess if there was a significant difference between the faecal eggs counts of the big herd and the calves, a T-test was conducted. The T-test showed that there was a significant difference between the two groups because the results are smaller than the hypothesis of p=0,005.

Table 2: T-test: two samplings with different variances

	Variable 1 Big herd	*Variable 2 Calves*
Average	34,09090909	328,5714286
Variance	1044,372294	22380,95238
Observations	22	7
Estimate of deviation between averages	0	
Degrees of freedom	6	
T- statistical data	-5,16970694	
P(T<=t) unilateral	0,001037507	
Critical zone of T-test: unilateral	1,943180281	
P(T<=t) bilateral	0,002075013	
Critical zone of T-test: bilateral	2,446911851	

7.4 Discussion

Because of a difference in the herd composition and a difference in the dates the samples were taken, it is irrelevant to compare both herds. However, it gives an idea of the amount of parasite eggs found in a different herd than the CEI's one. For the CEI's herd, it is clear that there's an increasing tendency in the numbers of eggs per gram. This can be due to the spring coming up, temperatures are rising and the water is melting. This provides the two most important factors for the parasites to be infectious. When the last samples were taken, the cows had calved. These samples had a significant rise in parasite egg levels. This can be due to a decrease in postpartum immunity, also called the periparturient relaxation of immunity (PPRI).

This means that the egg output will rise due to a relaxation of immunity around the time of calving, traditionally in the spring months (Peregrine, 2006). Concerning Dan Fox's herd, it is clear to see that the calves are more infected than the big herd. A reason for these higher egg levels could be that the calves still have to develop immunity. And the fact that they are kept in a corral which increases the infection pressure. All CEI's bison are free-ranging and is just a small herd, this decreases the infection pressure. Dan Fox's herd is bigger, but these are also free-ranging on a big pasture, which also lowers the infection pressure.

There is uncertainty about the first sample of Dan Fox's big herd. Possibly, two *Monezia benedeni* eggs were found. The size and the shape of the eggs are right, but the inner structures are too vague to make a clear diagnose. Additional to this, no *Monezia* eggs were found in the rest of the herd. Therefore, these eggs weren't included in the total EPG for that particular sample. Nonetheless, they were included in the results in the appendix.

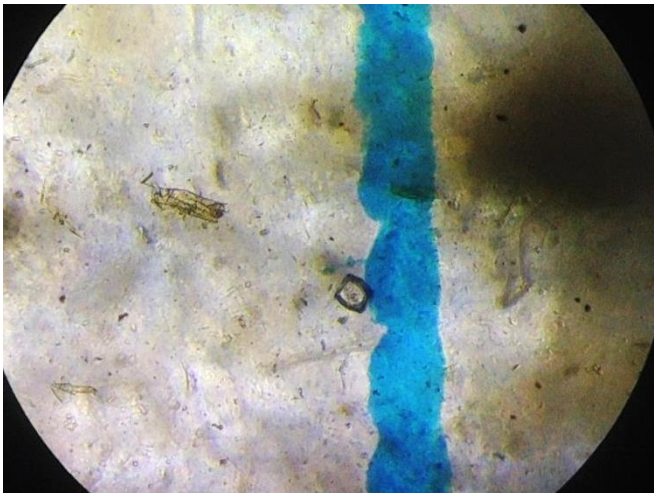

Figure 39: Possible *Monezia benedeni* oocyst (150X)

The McMaster fecal egg counting method is not really specific at low egg rates. The modified Wisconsin sugar flotation method is a more sensitive test, but requires a trained eye to count all the eggs and to distinguish them. Due to a lack of experience, it is possible that certain parasite eggs have been overlooked. Different Strongylid eggs are very difficult to tell apart. If more details about the specific type of Strongylids want to be known, a second test can be performed by an experienced person in this field.

There are several things that can be improved on the manner of research. It is possible that some of the fecal samples weren't fresh enough. The samples were always collected from the ground. Unfortunately, few fecal samples could be related to certain individuals or age groups. A solution could be to spend more time on observation of the animals. Whenever an animal decides to defecate, there is certitude about the provenance of the fecal sample. There's a possibility that certain samples were frozen during the night and thawed which made them look fresh. This

could affect the number of eggs in the sample. Not all of the samples taken on the same day were examined the same day. Sometimes the samples were subdivided over different days for examination.

Results of the fecal eggs counts can be interpreted as follows. If ruminants have egg counts excessing 1000 EPG, it is regarded as a heavy infection. Moderate infections show egg counts around 500 EPG. Nonetheless, a low EPG does not always imply very low infections. It is possible that the animal is newly infected (Taylor et al., 2016). For the CEI's herd and Dan's Saskatchewan calves it would be recommended to conduct a parasite control program.

7.5 Conclusion

This study has shown a rough image of the parasite infection in both herds. If more details want to be known about the specific parasites in the samples, a second examination by a veterinary is advised.

A treatment can be started for the CEI's herd and Dan's Saskatchewan calves. Because of the inability to handle bison for treatment, another way of giving medical care is considered. A product that is approved for the use in wildlife is fenbendazole (SafeGuard®). Pellets containing fenbendazole are given in a dosage of 7,5mg/kg. This should be fed over a period of three to five days. Given the fact that these bison are free-ranging and the medication should be fed free choice, intake is hard to monitor. Fortunately, the safety ratings for fenbendazole are extremely high, when consuming more than 100 times the suggested dose, no unfavorable reactions are registered. Another advantage of fenbendazole is the fact that no negative reactions occur when other animals species such as wild turkeys, squirrels and rodents consume it accidentally. A cumulative dose effect makes sure that the animals absorb an adequate amount of product to destroy the parasites. After deworming the herd, bison should be monitored to see if the number of parasites decreases (Bliss, s.a.).

8 Final word

During this study I learned to work more independently and to be confident and critical about my work. Ken helped me getting on the right track. We tested different methods of fecal egg counting, after which I continued the research on my own. If I needed a second opinion I could turn to Ken. I learned to work with materials I'm not familiar with. My experience is that not everything goes like desired, but a solution can always be found. My knowledge is certainly expanded by conducting this research, even though there is still a lot of space for improvement.

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Appendix

I. Results McMaster method CEI herd take 1: strongyle-typed eggs

CEI HERD take 1 (27/03/2017)				
Number	**Chamber 1**	**Chamber 2**	**Total**	**EPG**
1)	I	0	1	50 EPG
2)	0	III	3	150 EPG
3)	IV	I	5	250 EPG
4)	0	I	1	50 EPG
5)	IV	III	7	350 EPG
6)	0	III	3	150 EPG
7)	I	0	1	50 EPG
8)	0	I	1	50 EPG
9)	I	I	2	100 EPG

II. Results McMaster method CEI herd take 2: strongyle-typed eggs

CEI HERD take 2 (11/4/2017)				
Number	**Chamber 1**	**Chamber 2**	**Total**	**EPG**
1)	III	IV	7	350 EPG
2)	I	II	3	150 EPG
3)	IV	0	4	200 EPG
4)	I	III	4	200 EPG
5)	0	II	2	100 EPG
6)	III	I	4	200 EPG
7)	I	I	2	100 EPG
8)	0	0	0	0 EPG
9)	I	I	2	100 EPG
10)	I	I	2	100 EPG
11)	I	0	1	50 EPG
12)	III	0	3	150 EPG
13)	II	IV	6	300 EPG
14)	IV	VI	10	500 EPG
15)	III	III	6	300 EPG

III. Results McMaster method CEI herd take 3: strongyle-typed eggs

CEI HERD take 3 (21/4/2017)				
Number	**Chamber 1**	**Chamber 2**	**Total**	**EPG**
1)	III	0	3	150 EPG
2)	I	I	2	100 EPG
3)	II	I	3	150 EPG
4)	I	I	2	100 EPG
5)	0	I	1	50 EPG

6)	II	I	3	150 EPG
7)	I	I	2	100 EPG
8)	II	IV	6	300 EPG
9)	0	I	1	50 EPG
10)	III	I	4	200 EPG
11)	IX	IX	18	900 EPG
12)	III	I	4	200 EPG
13)	III	IX	12	600 EPG
14)	V	VII	12	600 EPG
15)	II	I	3	150 EPG
16)	0	II	2	100 EPG

IV. Results McMaster method Dan Fox's herd: strongyle-typed eggs (except if mentioned differently)

DAN'S HERD 8-11y (4/4/2017)				
Number	**Chamber 1**	**Chamber 2**	**Total**	**EPG**
1)	0 I monezia	0 I monezia	0	0 EPG
2)	0	I	1	50 EPG
3)	I	0	1	50 EPG
4)	I	0	1	50 EPG
5)	0	0	0	0 EPG
6)	0	I	1	50 EPG
7)	0	0	0	0 EPG
8)	0	0	0	0 EPG
9)	0	0	0	0 EPG
10)	0	0	0	0 EPG
11)	I	0	1	50 EPG
12)	0	0	0	0 EPG
13)	II	0	2	100 EPG
14)	0	I	1	50 EPG
15)	0	I	1	50 EPG
16)	0	I	1	50 EPG
17)	0	I	1	50 EPG
18)	0	0	0	0 EPG
19)	0	I	0	50 EPG
20)	0	0	0	0 EPG
21)	0	I	1	50 EPG
22)	II	0	2	100 EPG

V. Results McMaster method Dan Fox's Saskatchewan calves: nematodes (all strongyle-typed eggs except if mentioned differently)

DAN'S SASKATCHEWAN CALVES <1y (4/4/2017)				
Number	**Chamber 1**	**Chamber 2**	**Total**	**EPG**
1)	IV	VI	10	500 EPG
2)	IV I *Nematodirus*	II	7	350 EPG
3)	V	IV	9	450 EPG
4)	IV	IV	8	400 EPG
5)	I	I	2	100 EPG
6)	II	I *Nematodirus*	3	150 EPG
7)	IV	III	7	350 EPG