# Epidemiology of the Barberpole worm (Haemonchus contortus) in sheep in Nova Scotia

FINAL REPORT

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**Summary**
We analysed faecal samples from lambs, mature ewes and rams, goats and llamas from May 1 to October 31, 2013. These were provided by producers (over 2,150 samples) or collected at the Atlantic Stock Yards (over 300 samples). We also carried out faecal egg count reduction tests for 8 producers to estimate the efficacy of one or more anthelmintics. We cultured faecal samples to identify L3 larvae of *Haemonchus contortus, Teladorsagia* circumcincta and *Trichostrongylus spp*, which cannot be identified as eggs; other species (*Nematodirus battus*, *Nematodirus* sp., *Strongyloides papillosus* and *Trichuris ovis*) were identified as eggs and recorded separately.

Five producers gave samples on 6 or more occasions. These showed a consistent pattern, with FECs rising rapidly through July (flocks lambing in February-March) or August (lambing in June). Ewe FECs remained high for 2-3 months after lambing.

Atlantic Stock Yards sampling suggested that half the lambs consigned from July to September are barn-raised. Some lambs with high FECs and signs of haemonchosis were seen in late summer and fall.

Resistance to one or both available anthelmintics was seen in 7 of 8 participating farms. Efficacies of 30-77% were recorded for avermectins and 60-70% for benzimidazoles. Levamisole or pyrantel were effective, and preliminary observations show that closantel is also effective against *Haemonchus*.

Most larvae in cultures were *Haemonchus* (>90%); 4 other species (<10%) were recorded on Farm 1. On two other farms, only *Haemonchus* were found. After dosing with an avermectin or a benzimidazole, only *Haemonchus* was still seen in samples from Farm 1. No *Haemonchus* were seen after dosing with levamisole or closantel, although 4 other species were recovered after closantel use.

*Nematodirus battus* was very common, on 24 of 25 farms with FECs >50 epg in lambs. Eggs were seen about 1 week earlier than other GINs, with peak counts in June and a decline through July. *Nematodirus* spp. was uncommon, and mainly seen in late summer. *Trichuris* and *Strongyloides* were seen mainly in spring or early summer.

We conclude that resistance to the two available classes of anthelmintics is probably widespread, and *Haemonchus* is a serious problem for the sheep industry in this region.

## Introduction

*Haemonchus contortus* is a nematode parasitic in the abomasum of sheep and other small ruminants. It is characteristically a warm climate species, and so, until recently, has not been considered a serious problem in northern regions of North America and northern Europe (Kaplan & Vidyashankar 2012). In cold winter climates this parasite does not survive to any extent overwinter on pasture (Menzies et al. 2012), and short summer grazing periods mean that parasite populations have not built up to dangerous levels. It has posed a problem in Nova Scotia only occasionally in hot; dry summers when sheep have spent considerable periods of time congregating around water sources in a restricted area (E. Semple, personal communication). However, within the last 4-5 years this parasite has become far more prevalent, and has emerged as a serious pathogen of grazing small ruminants in this region, as well as in southern Ontario (Falzon et al., 2013), Britain (Abbott et al., 2012) and other northern climate areas (Domke et al. 2012a; Manninen 2008). There is also growing concern that, worldwide, this species is rapidly developing resistance to anthelmintics (Kaplan & Vidyashankar, 2012), and that this is occurring rapidly in countries where winter climates prevent larvae overwintering in the soil (Waller et al. 2004; Falzon et al., 2013; Domke et al, 2012 a, b).

While there is considerable information on the epidemiology of *Haemonchus* in countries where it has long been a major pathogen, there is relatively little information in Canada. Most Canadian studies have been carried out in southern Ontario, and virtually no information is available for any of the Atlantic Provinces. Many Nova Scotian producers have faced sudden losses of lambs, and even mature ewes in the last few years, and are not sure how the problem can be managed; some have turned to raising lambs in confinement, or have left the industry. The purpose of this study, therefore, has been to document how widespread *Haemonchus* is in Nova Scotia, to demonstrate the pattern of seasonal changes through one grazing season, and to investigate whether resistance to either or both of the available classes of anthelmintics is emerging on local farms.

Whereas *Haemonchus contortus* is a subtropical species that is becoming more prevalent in colder climates, *Nematodirus battus* is an arctic species that seems to be extending its range south (van Dijk & Morgan 2010). It has been associated with early spring disease outbreaks in Britain (Abbott et al 2012), but is seldom considered significant in Canada (Menzies et al., 2012). It is relatively easy to identify, however, and since it is a major pathogen on British farms, a secondary objective during this study was to determine whether *Nematodirus battus* is also prevalent on farms in this region.

**Biology of *Haemonchus***

The most important nematodes parasitic in small ruminants belong to the family Trichostrongylidae; this includes not only *Haemonchus* but also the brown stomach worm, *Teladorsagia circumcincta* and the stomach hair worm and black scour worm, *Trichstrongylus* spp. (Menzies et al. 2012). All have similar direct life cycles, with larval development occurring in faecal deposits and adjacent soil (Figure 1).

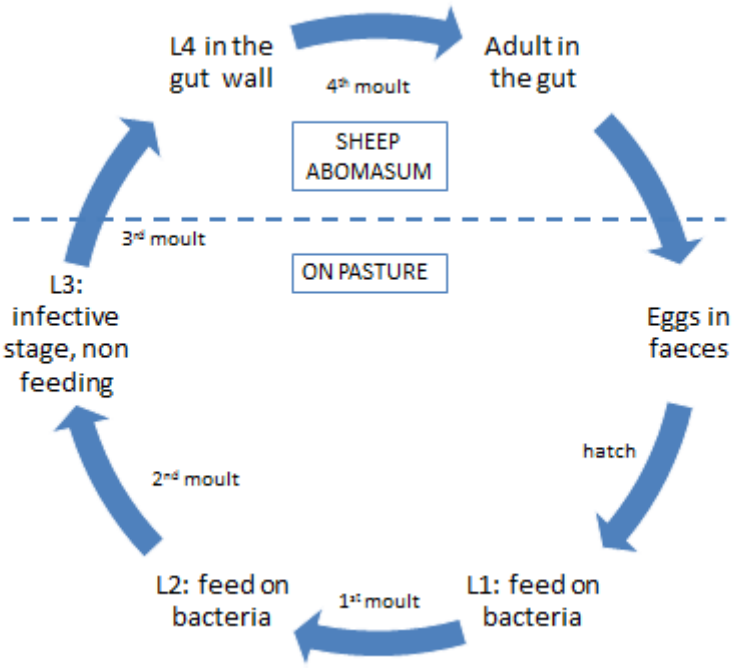


Figure 1: Life cycle of trichostrongyle nematodes

Four larval (or juvenile) stages occur, and the larval cuticle is moulted between each stage. The third stage is infective, and is enclosed in a sheath formed from the retained cuticle of the second larval stage; thus it is non-feeding and its persistence on pasture depends on its stored food reserves. Climate conditions during the grazing season strongly influence the length of time infective larvae can survive on pasture.

Infective larvae move to a limited extent between faecal pellets, the surrounding soil and herbage. A water film is necessary for movement, which can limit exposure to the larvae in hot, dry conditions, at least when there is no dew on the grass Abbott et al. 2012; Menzies et al. 2012). However, typical seasonal conditions in Nova Scotia over the last few years have been suitable for a buildup of high worm burdens of *Haemonchus*.

The infective larvae, when eaten along with pasture plants, cast off the sheath as they pass through the forestomach chambers, and moult to the fourth larval stage and subsequently to the adult. The prepatent period (the time from ingestion of larvae to the appearance of eggs in the faeces) is approximately 16-21 days Menzies 2012).

Adult *Haemonchus* in the abomasum feed on blood, puncturing the mucosa with a single large tooth. Blood loss, through feeding and through haemorrhage from the punctures, is approximately 0.05 ml per worm, but heavy infections are common and anaemia can be severe and rapidly life-threatening. Adults also have high fecundity, with reports of 10,000 eggs per female worm per day or even more (Pritchard 2001; Abbott 2012). High levels of pasture contamination with infective larvae can result in early summer, and lambs can acquire heavy worm burdens very rapidly on such pastures.

An effective immune response develops slowly in lambs or in yearlings if they are in their first grazing season (Douch & Morum 1993; Menzies et al., 2012), and requires continuous exposure to infective larvae for 3-4 months; thus lambs remain susceptible throughout the summer under most management conditions, but by fall

often show reduced output of eggs in the faeces. Mature sheep are generally capable of mounting an effective response, so that they produce few or no eggs and do not show signs of disease. Yearlings and two or three year old animals may, however, still show a higher susceptibility, particularly during and after lambing (Menzies et al., 2012).

Most gastrointestinal nematodes in ruminants have two strategies for overwinter survival. They can survive freezing, so can overwinter in the soil and become active once soil temperatures rise in the spring; however, if they have been ingested by ewes or lambs during the fall, they can undergo a period of dormancy (larval arrest, or hypobiosis) in the gut wall. Around the time of lambing (the periparturient period), the immune response is weaker, and the larvae emerge from arrest, resume development, and produce eggs that can contaminate pastures heavily in spring. This periparturient egg rise (PPER) occurs from about two weeks before lambing to six or more weeks after lambing, during lactation (Menzies et al. 2012) In spring, therefore, lambs are exposed to infective larvae that have overwintered in ewes as well as those that have overwintered on pasture. However, *Haemonchus* is not well adapted to cold winter climates, and any L3 larvae that do survive on pasture are poorly infective (Menzies et al., 2012). Therefore, infective larvae are overwhelmingly those from the PPER. This is a major factor in the rapid increase in resistance to anthelmintics shown by *Haemonchus* in regions with cold winters, including Canada (Menzies et al., 2012; Falzon et al. 2013) and Scandinavia (Waller et al. 2004; Domke et al. 2012).

The PPER has two consequences. Ewes that pick up large numbers of larvae in the fall can themselves become severely affected when the larvae emerge and mature, particularly young ewes and those raising multiple lambs. Sudden death is increasingly common a few weeks after lambing. In addition, it is common practice to worm all ewes when they are housed during the winter; since this means that effectively all the worms in the population may be exposed to the anthelmintic used, this practice is strongly selective for resistant worms. The only source of infective larvae in spring will be from worms that have survived anthelmintic treatment. Only two classes of anthelmintics have been in use in Canada for approximately ten years, and there is evidence that resistance of *Haemonchu*s to one or both is increasing, and is now common in Ontario (Falzon et al. 2013).

**Previous Studies**

Studies in southern Ontario and Quebec in 2007-8 found little or no evidence of resistant *Haemonchus*; however, more recently resistance has been demonstrated in over 80% of sampled farms in Ontario (Mederos et al. 2010; Falzon et al. 2013).

In Nova Scotia, there is very little information on parasite populations in small ruminants. However, a survey was carried out through the summer of 1997, with funding from Agriculture Canada, to follow worm burdens in a group of lambs on three farms (Maal-Bared, 1998; G. Jones & Y. Papadopoulos, unpublished observations). One of these farms, belonging to the author, was sampled again during the summer of 2012, in an unfunded study by Saint Mary's University students G. Jones, K. Hipwell & R. Betts, unpublished observations). This survey, though very limited, showed a major change in FECs between these two summers (Figure 2). In 1997 FECs increased during August and peaked in early September then declined. Maximum intensity of infection was almost 1000 epg. In 2012 FECs increased through July, August and early September, and remained high into October. Maximum intensity of infection was approximately 4000 epg, and was still close to this level in early October.

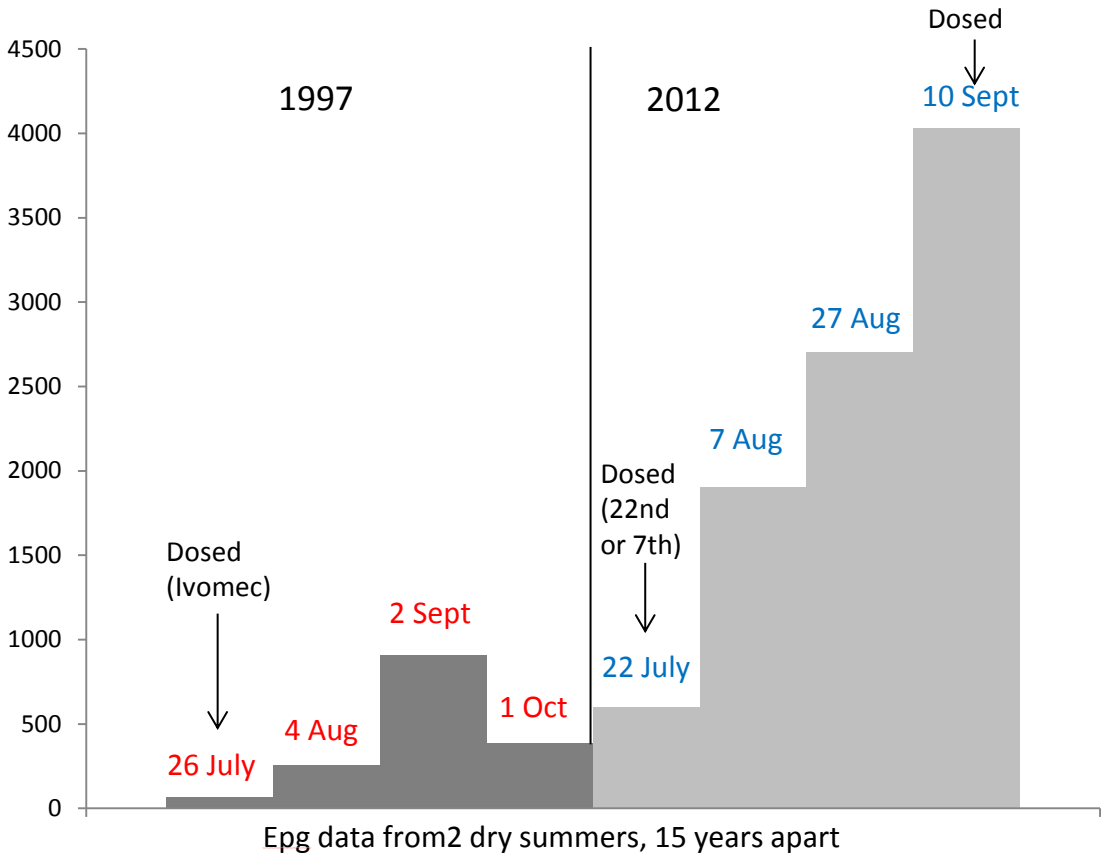


Figure 2: FECs from Farm 1 surveyed in two different seasons

In 2012 a single faecal egg count reduction test was performed on this farm, to investigate the efficacy of one anthelmintic, Valbazen (the BZ albendazole) that had been used frequently for a number of years. This test indicated an efficacy of only about 70%, well below the >95% reduction seen where there is no resistance. During August 2012 a number of producers throughout the province reported losing significant numbers of lambs, and severe loss of condition in surviving lambs after dosing.

These observations indicated that problems of parasitism, especially *Haemonchus*, are now sufficiently severe that a larger scale study would be helpful to inform producers of the need to monitor for haemonchosis and to investigate potential anthelmintic resistance.

**Methods**
Samples were collected for this project from both participating producers and from regular visits to the Atlantic Stock Yards (ASY) in Murray Siding, N.S. We invited producers to submit samples through direct contact with those who had attended one of two parasite workshops in the previous fall, through contacts during collection at ASY, and through advertising on the SPANS website and the NSFA e-news site. Over 40 producers responded with samples; five farms provided multiple (6 or more) samples throughout the study period while the remainder provided one or a few. Most samples were submitted from lambs, with fewer from mature sheep; a few samples from goats and three from llamas were also analysed.

The majority of producers submitted samples to us in person or through the co-operation of Holly Hines at Dalhousie Agricultural Campus, Cathy Vallis at Atlantic Woolgrowers, and the Pathology Laboratory in Truro. Where necessary, a student (Danielle Thibault) travelled to the producer's farm to assist in collection.

Sample collection at ASY was carried out by Danielle Thibault, weekly from July to September, and by Kelsey Brydon during October. Lambs were randomly sampled in the pens, and no attempt was made to identify the farm of origin unless specifically requested by their consignor. Ewes and goats were also sampled when time permitted. In October, numbers of lambs from islands off the South Shore are transported to ASY. Since these lambs are likely to have had minimal worming, they were identified at sampling as island lambs, but not traced to a specific island or producer.

During the annual PSBANS Fall Sale in Truro, a booth was set up to receive any samples provided, and to collect samples from consigned animals at the request of the consignor.

**Sample Collection and Analysis**
Faecal samples were collected rectally using disposable gloves wherever possible, or were picked up as fresh deposits from the ground, with minimal contamination from bedding, soil or plant material (Gibbons et al, accessed 2013). They were labelled and transferred to a cooler with ice packs and kept refrigerated until analysis.

Faecal egg counts (FECs) were performed according to standard parasitological methods (MAFF 1986; Coles et al. 2006; Gibbons et al., accessed 2013) using a modified McMaster technique with a detection limit of 50 eggs/gram (epg). Analyses were carried out at Saint Mary's University, Department of Biology, in Halifax.

For each analysis, 3 grams of faeces were suspended in 45 ml of saturated salt solution (400 gm/l), filtered through a metal tea strainer to remove large debris and stirred thoroughly. Both chambers of a McMaster counting slide (Chalex Corporation, USA) were quickly filled by pipette from this suspension, and the slide left for at least 5 minutes for eggs and debris to separate. The eggs from both chambers were counted, and the total multiplied by 50 to estimate epg. Samples were counted as soon as possible after collection, or stored for up to 3 weeks in the refrigerator if necessary.

Eggs can only be reliably identified for a few species of nematodes. Those that are identifiable were recorded separately; this included *Trichuris ovis, Strongyloides papillosus, Nematodirus battus and Nematodirus spp.* All others, including *Haemonchus,* were grouped as gastrointestinal nematodes (GIN).

**Faecal Egg Count Reduction Tests (FECRTs)**
Eight producers sent samples before and one or two weeks after worming with one or more anthelmintics. These were analysed as above, and the efficacy (% reduction in FEC) calculated for each anthelmintic. Most participants tested one or two anthelmintic classes together with a control group that was left untreated; one tested three anthelmintics, and two did not use a control group.

An Emergency Drug Release (EDR) was granted to permit the veterinarian to import a single sample of closantel, an anthelmintic specifically effective against *Haemonchus,* and a limited efficacy trial was performed on 4 farms. The anthelmintic was not available until October, and analysis is still underway for two of these farms.

**Larval Identification**
A limited number of faecal samples collected before and after treatment with anthelmintics, were also used to set up faecal cultures. These samples were not refrigerated for more than 1-2 days, since *Haemonchus* has poor cold tolerance. Faecal samples were maintained at room temperature for 1-2 weeks and L3 larvae then extracted using a Baermann funnel (Gibbons et al. accessed 2013). The cultures were moistened if necessary, or mixed with vermiculite if too loose.

Larvae were collected by draining the funnel into a petri dish. This was scanned using an inverted microscope for the presence of larvae, and a sample transferred to a microscope slide. A drop of Gram's iodine was added to kill and stain the larvae, which were then identified by comparison with published keys (Gibbons et al. accessed 2013; MAFF 1986; van Wyk et al. 2004).

**Statistical Analysis**
**Surveys and Seasonal Dynamics**
For each farm and the ASY samples, we recorded data as follows:

- Prevalence: proportion or percentage infected
- Mean intensity: average (arithmetic mean) FEC per infected animal
- Range: maximum and minimum counts in the sampled group

For the five farms that gave samples on 6 or more occasions, we also calculated the average FEC (mean ± standard deviation) for early, mid-month or late periods each month (day 1-10, 11-20, 21-30/31) from May to August.

**FECRTs**
Anthelmintic efficacy can be calculated in several ways (Dash et al. 1988; Martin et al. 1989; Falzon et al. 2013).

- $T_1$: count in treated group before dosing
- $T_2$: count in treated group after dosing
- $C_1$: count in control group before dosing
- $C_2$: count in control group after dosing

If no control group was included we calculated the FECR as $100(1-T_2/T_1)$

If a control group was included we calculated the FECR as $100(1-T_2/C_2)$

If counts in the control group are rising rapidly or falling an additional correction can be made (Dash 1988); we calculated the FECR at these times also as $100(1-T_2/T_1 \times C_1/C_2)$. We compared these formulae to check for bias in the calculations.

We based these calculations on arithmetic means for the whole group (i.e. including zero counts), not on mean intensity which is a statistic appropriate to ecological investigations, in this case broad surveys and seasonal dynamics. Between-group comparisons can be based on arithmetic or geometric (log transformed data+25) means but arithmetic means are less likely to overstate efficacy at % reductions close to 90% (Dash 1988).

**Observations**
Forty-seven producers provided samples between May 1 and October 31; of these, five submitted 6 or more samples. These gave useful information on the seasonal dynamics and risk period for *Haemonchus.* In addition, samples were collected at ASY from July 4 to September 12, and again on October 3 and October 31; thirteen animals were also sampled at the annual Sheep Sale on August 31. Approximately 2,150 samples were analysed from these submissions, plus approximately 300 from sale consignments. Faecal egg count reduction tests were conducted on 8 farms, with partial data from several others.

**The Typical Pattern**
One farm provided samples on 19 separate occasions, with minimal use of anthelmintics. Data from this farm (Farm 1) were used as an example, and a baseline study to compare with other, more limited samples. This farm uses set stocking with a low stocking density, and lambs in late February-mid March, with a smaller group lambing in late April. The ewes and lambs from early lambing were turned out on April 29, and ewe lambs continued to run with the ewes until September 21. Lambs were wormed in July, for a FECRT, and not wormed again unless showing signs of parasitism, or for additional FECRTs. The ewes were only wormed if they were showing signs of haemonchosis, notably a high FAMACHA score (Kaplan et al 2004), on July 7, or occasionally, with evidence of bottle jaw, in June or July.

The results from this flock are shown in Figure 3. Ewe FECs were high through May and much of June, but then dropped rapidly. A subsequent apparent rise in July was associated with unusually high counts in two ewes with bottle jaw; apart from these, ewe counts remained low through the summer and fall.
Lamb counts did not begin to rise until late June, but increased rapidly through July. Three groups of lambs were treated with anthelmintics on July 10 for FECRTs; these are not included in the July 24 FEC. Lambs in the control group were wormed on July 24. After this worming the counts dropped, but they were rising again by mid-August. At this time only lambs with high counts were wormed. This partial flock treatment resulted in a drop in mean intensity of infection for the whole flock.

Subsequently, in a group of 12 ewe lambs that had remained on pasture with the ewes and had not been dosed, unless anaemic, since July 24, mean intensity was still 3100 epg on October 11 and declined only to 2900 epg by October 25. A second group of 15 ewe lambs was treated with closantel on October 11 for an additional FECRT.

Prevalence increased from 20% on June 12 and June 17 to 100% throughout July and August, declining only to 90% in September and October.

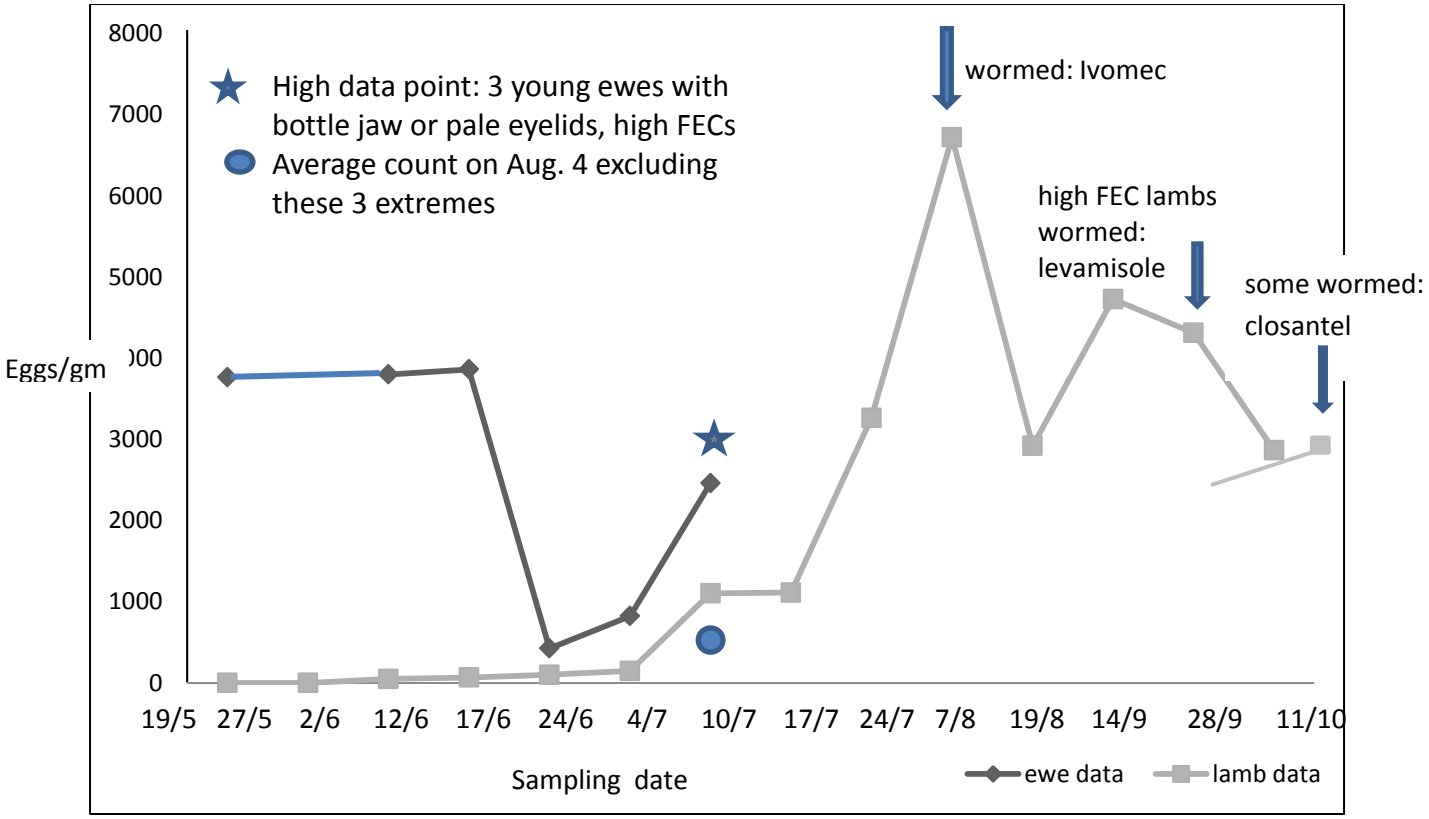


Figure 3: Seasonal variation in FECs; ewes and lambs from Farm 1

These results are comparable to those from the other farms that submitted multiple samples (Figure 4, 5). There is considerable variation in epg,s among the flocks, particularly from mid-July onwards, which reflects different management practices, especially frequency of worming. The pattern of infection, however is the same. Fewer samples were received during September and October from these farms, so these data are only analysed to the end of August. Prevalences were typically 100% in July and August, except for the late lambing flock.

Four of the five farms practiced set stocking or limited rotations, e.g. alternating between two fields, and were lambing in a similar time frame (Figure 4). Ewe FECs for these four farms followed the same general pattern as in Farm 1, although fewer samples were available and consequently variance was much higher (Figure 4). The PPER even in early lambing flocks is still evident when animals are turned out, which can result in rapid contamination of the pastures at the start of the pasture season.

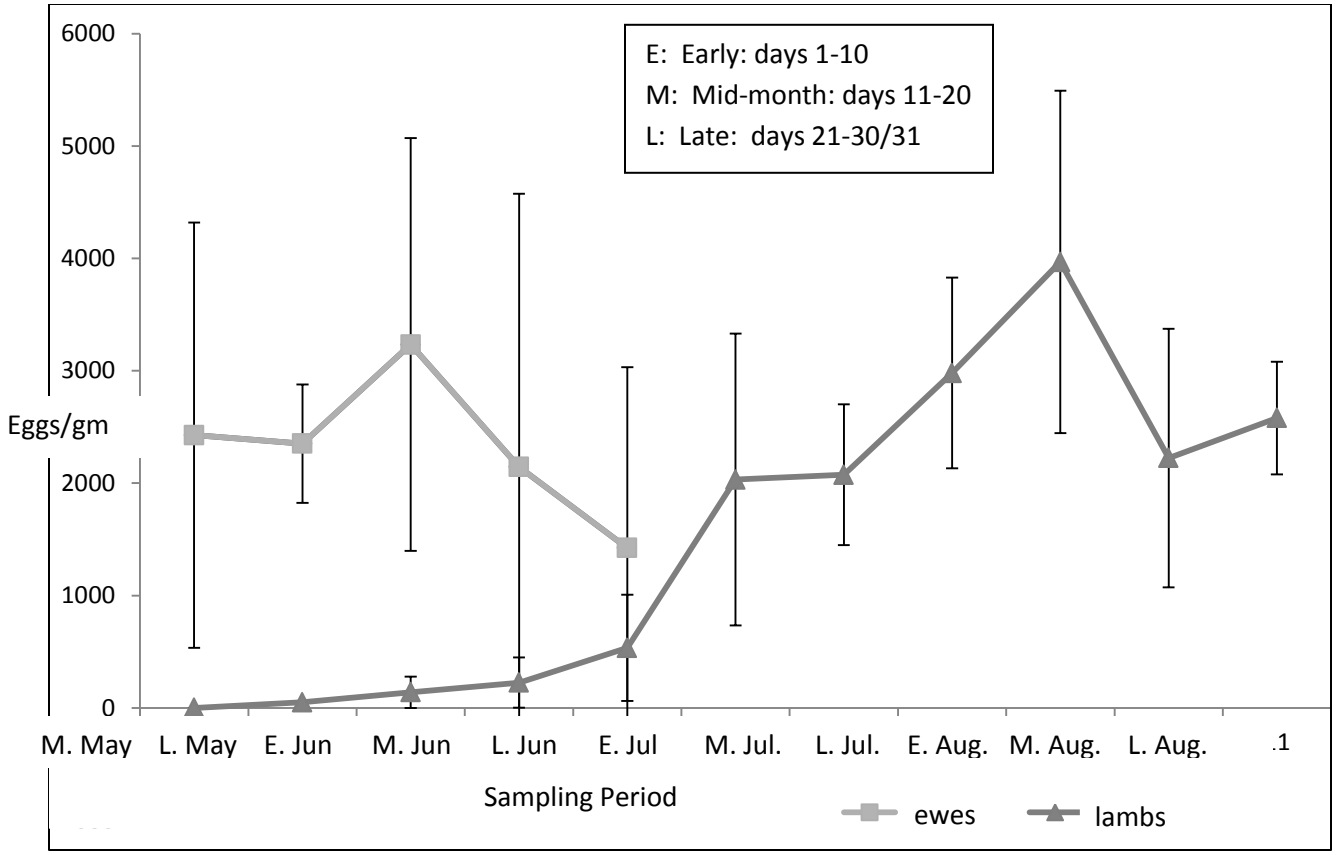


Figure 4: FECs for four flocks lambing in February-March (mean intensity ± S.D.). Ewe FECs show very high variabilit because only 2 or 3 farms were sampled in each sampling period

One farm lambed later, from June 10, and rotated through one large field with portable electric fencing to make variable paddocks. Fig. 5 shows a summary of the data from this flock; the rapid increase in FECs occurred in August, a month later than for early lambing flocks.

Samples analysed in September were mainly provided during the PSBANS annual Fall Sale, and included two submissions from New Brunswick and 5 from Prince Edward Island.

A summary of data for the remaining producers (those submitting samples on 1-4 occasions through the sampling period) is given in Table 1. These data confirm the general pattern shown in Figure 3. Lamb FECs rise during the first half of July and remain high into the fall. However, in most cases information on pasture management and worming practices was not provided.

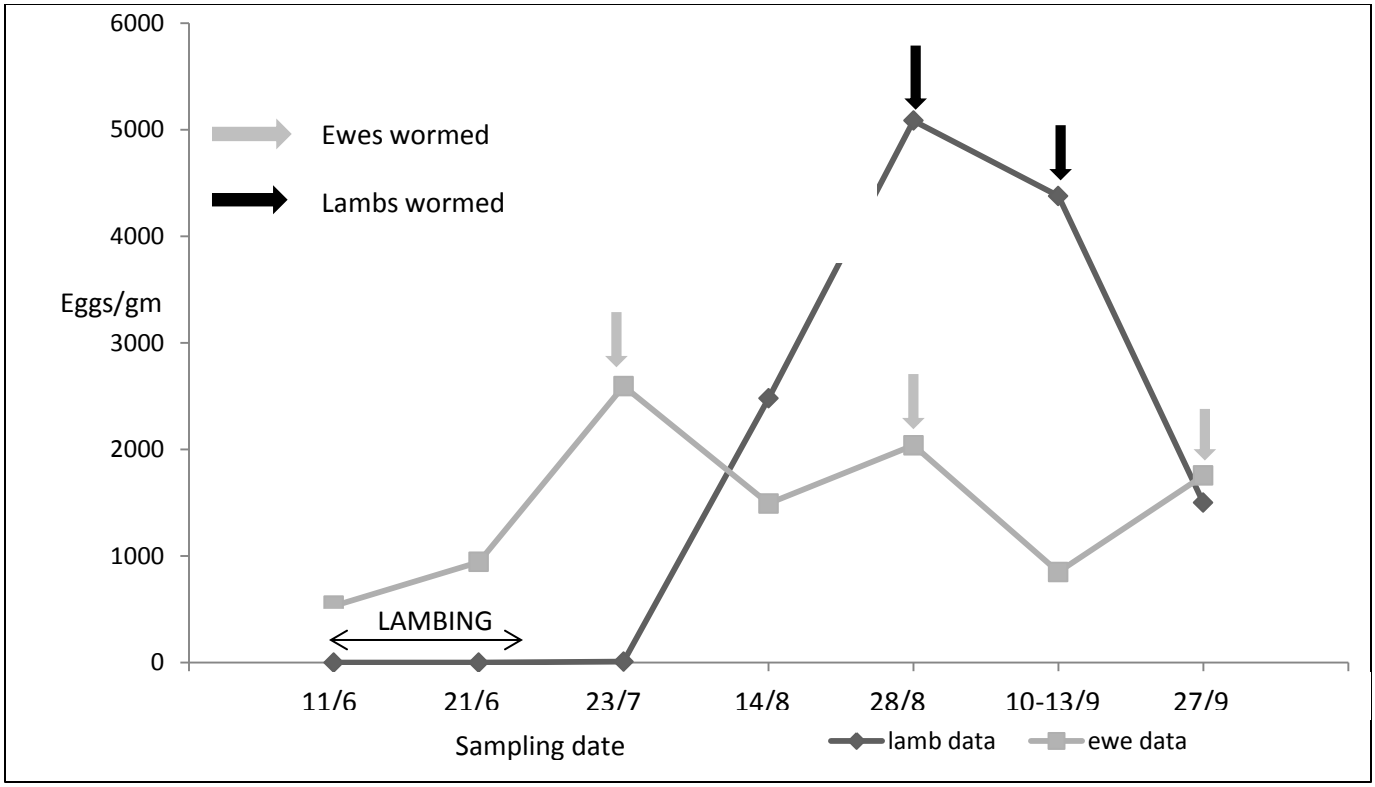

Figure 5: FECs in a late lambing flock

Table 1: FECs in lambs and mature sheep: random samples submitted by producers. This does not include data from animals of unknown or mixed ages, or from goats and llamas.

| | LAMBS | | | EWES/RAMS | | |
|---|---|---|---|---|---|---|
| Month | No. of farms | Prevalence (%) | Mean intensity | No. of farms | Prevalence (%) | Mean intensity |
| May | 1 | 0 | 0 | 2 | 1 | 1540-3670 |
| June 1-15 | 2 | 0-0.1 | 0-50 | 6 | 0.1-1 | 50-6005 |
| June 16-30 | 3 | 0-1 | 0-550 | 3 | 0.1-1 | 50-1768 |
| July 1-15 | 3 | 0-1 | 0-2950 | 3 | 0.7-1 | 233-13,050 |
| July 16-31 | 3 | 0.9-1 | 2919-3217 | 1 | 0.8 | 1000 |
| August 1-15 | 3 | 0.3-0.9 | 2125-5500 | 3 | 0.4-1 | 238-2140 |
| August 16-31 | 10 | 0.1-1 | 50-4817 | 8 | 0-1 | 0-2750 |
| September | 4 | 0.9-1 | 1599-51,200 | 1 | 0.5 | 217 |
| October | 4 | 0.3-1 | 50-2525 | 2 | 1 | 250-363 |

Samples from ASY also confirm this seasonal pattern (Table 2). However, prevalence varied from 0.2 to 1 (20 – 100%), averaging about 50%. About half the lambs consigned had zero counts.

Individual lambs with high or extreme counts were seen particularly from mid-August, notably one lamb with a FEC of 69,100 epg and signs of severe haemonchosis. Many or all lambs consigned on October 31 were from an unidentified island or islands; prevalence and worm burdens were high in these samples, even at the end of October (Table 2).

Table 2: FECs in lambs and mature sheep sampled at the Atlantic Stock Yards

| | | LAMBS | | |
|---|---|---|---|---|
| Date | N | Prevalence | Mean Intensity | Range |
| Jul-04 | 9 | 0.45 | 88 | 0-200 |
| Jul-11 | 10 | 0.5 | 610 | 0-1050 |
| Jul-18 | 20 | 0.45 | 1906 | 0-8250 |
| Jul-25 | 9 | 0.2 | 1900 | 0-3600 |
| Aug-01 | 26 | 0.8 | 2248 | 0-7950 |
| Aug-08 | 3 | 0.3 | 2200 | 0-2200 |
| Aug-15 | 30 | 0.6 | 8186 | 0-69,100 |
| Aug-22 | 17 | 0.8 | 5318 | 0-19,950 |
| Sep-12 | 24 | 0.5 | 1850 | 0-10,400 |
| Oct-08 | 86 | 0.8 | 1064 | 0-17,700 |
| Oct. 31 | 60 | 1 | 12,012 | 150-52,300 |
| | | MATURE SHEEP | | |
| | N | Prevalence | Mean Intensity | Range |
| Jul-04 | 9 | 0 | 0 | 0 |
| Jul-11 | 1 | 0 | 0 | 0 |
| Jul-18 | 1 | 0 | 0 | 0 |
| Jul-25 | 27 | 0.8 | 1474 | 0-6700 |
| Aug-01 | 4 | 0.5 | 1150 | 0-2550 |
| Aug-08 | 6 | 1 | 1867 | 100-7400 |

**Anthelmintic Resistance**

Eight producers sent samples in July or August, before and after worming, to test for anthelmintic efficacy. These results are summarised in Table 3.

Reduced efficacy for one or both routinely available classes of AH was evident in 7 of these farms. Levamisole was still highly effective, as was pyrantel (Strongid). However levamisole does not have a persistent effect, and on two farms counts after 4 weeks were similar to those with less effective AH's (Figure 6).

For 3 farms, faecal cultures after treatment with AV or BZ contained only *Haemonchus.* Since levamisole and pyrantel were highly effective, no larvae were recovered from cultures. Faecal cultures from samples collected from the ground were contaminated with large numbers of freeliving nematodes. On Farm 1, pretreatment cultures contained at least 4 species of GIN (*Teladorsagia, Trichostrongylus, Strongyloides* and an unidentified species, possibly *Oesophagostomum* or *Chabertia)* in addition to *Haemonchus*, although *Haemonchus* comprised over 90% of the samples.

Table 3: Summary of FECRT results for eight participating farms (% reduction in FECs). Post- treatment counts were made after 7 days for Levamisole or 14 days for AVs, Strongid or BZs

| Farm | AV group | BZ group | Levamisole or Strongid | Note |
|---|---|---|---|---|
| 1 | 30 | 64 | 100 | |
| 2 | 38 | - | 95 | |
| 3 | 56 | - | 91 | 1 high Lev count - missed dose? |
| 4 | - | 44% incr. | 98 | |
| 5 | - | - | 99.5 | |
| 6 | - | 63 | 97 | |
| 7 | 77 | - | - | Alternated dosing ewes and lambs |
| 8 | 97 | 100 | - | Lambs on clean grazing |

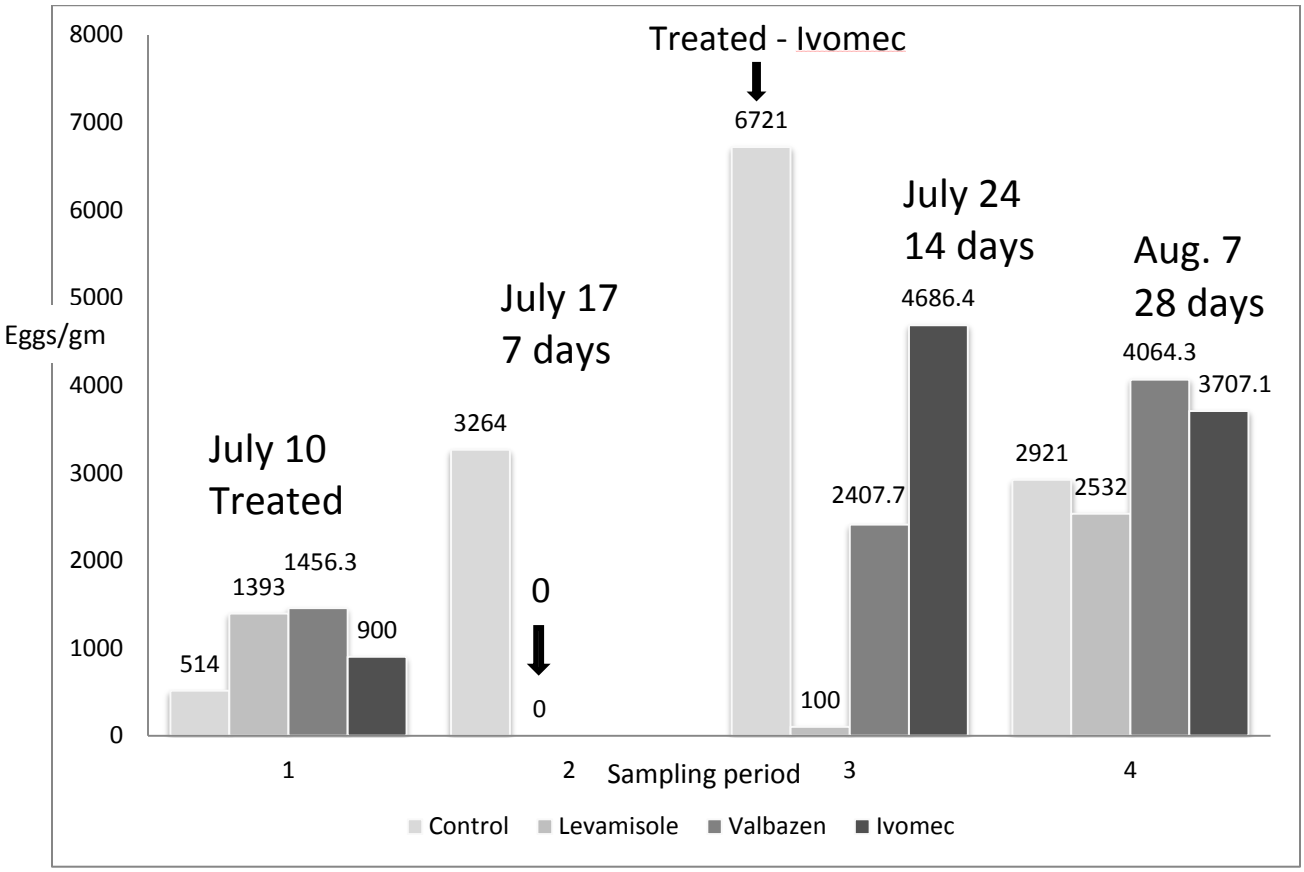


Figure 6: Comparison of efficacy for three AHs 1, 2 and 4 weeks after dosing, on Farm 1

Farm 1 tested an AV (Ivomec) again at twice the recommended dose per kg body weight. By doubling the dose, efficacy increased from 30% to over 70% although this was a small sample of 8 lambs. Individual FECRs ranged from 59% to 90% when the same lambs were compared before and after treatment.

Only two farms have tested closantel to date; two others are being counted and one is delayed due to unforeseen circumstances. The results suggest this AH is highly effective (Table 4).

Table 4: Efficacy of closantel on two farms. Efficacies were calculated with 2 FECRT formulae since C1 and T1 mean epgs were not similar in Farm 1 and control counts were declining in both farms.

| | Control | Control | Closantel | Closantel | Efficacy | Efficacy |
|---|---|---|---|---|---|---|
| Farm | C1 | C2 | T1 | T2 | 100(1-T2/C2) | 100(1-T2/T1xC1/C2) |
| 1 | 3100 | 2690 | 4013 | 823 | 69% | 76% |
| 2 | 2054 | 1465 | 2894 | 50 | 97% | 96% |

Since these tests were carried out in October, when lamb immunity is more effective, these efficacies may be less accurate than those estimated in summer. Larval identification from post-treatment cultures is preliminary: four species (*Teladorsagia*, *Trichostrongylus, Strongyloides* and unidentified larvae (possibly *Oesophagostomum* or *Chabertia*) have been observed but *Haemonchus* has not been verified.

**Selection for Low FECs**

Farm 1 recorded lamb weights and FECs from late July to October 2012 to identify ram lambs with consistently low FECs as well as lambs with consistently high counts which were culled. Lambs with low FECs were retained, and resampled in 2013 when turned out as yearlings (Table5). Rams showed a faster immune response as yearlings and those with lowest counts in this group as lambs also had low counts in 2013.

Table 5: Yearling Ram Data: 2012, 2013 (eggs/gm faeces and Famacha score)

| | 2012 | | | | 2013 | | |
|---|---|---|---|---|---|---|---|
| Ram ID | 22/7(or 30/7) | 7/8 | 27/8 | 10/9 ( or 4/10) | 14/5 | 17/6 | 19/8 |
| 27Z | 100 Iv | 800 | 1000 | 2600 Iv F3 | 50 | 100 | 150 |
| 31Z | 300 V | 1000 | 3600 Iv | 2550 - F3 | 1100 | 5900 | 400 |
| 38Z | 550 V | 250 | 2650 | 2300 Iv F3 | 150 | - | 50 |
| 39Z | 1100 V | 4750 | - | 2800 Iv F4 | 300 | 450 | 50 |
| 53Z | - V | - | 900 | 2200 Iv F2 | 1450 | 3350 | 550 |
| 58Z | 1300 Iv | 9500 | 2700 | 3250 Iv F3.5 | 50 | 6100 | 900 |
| 61Z | 250 Iv | 550 | - | 700 Iv F3 | - | - | 600 |
| 66Z | 5250 V | 1650 | 750 | 650 Iv F2 | 350 | 2450 | 750 |
| 68Z | 2100 V | 6700 | 2450 | 1450 Iv F3.5 | 150 | - | 100 |
| 88Z | - | - | - | 0 Iv F2 | 100 | 600 | 200 |
| *Mean intensity* | *1369* | *3150* | *2475* | *2055* | *411* | *2707* | *375* |

- Iv: Ivomec drench
- V: Valbazen drench
- F: Famacha score for anaemia ( 1 – 5: 1=red, 5=white)
- -: not sampled or not dosed

**Nematodirus battus**

*Nematodirus battus* was recorded on 24 of 36 farms providing lamb samples, but on 11 of these FECs were 0 or <50 epg; *N. battus* was present in 24 of 25 farms with lamb FECs >50 epg . This suggests a prevalence of 96%.

*N. battus* was the first nematode recorded in lambs, about 3-4 weeks after turnout at the beginning of May. FECs increased through May and June, but decreased in July and were sporadic thereafter Figure 7). Counts on Farm 1 and 2 reached levels in some lambs that are associated with scouring and weight loss in Europe (>300 epg: Abbott et al. 2012), but no evidence of this was seen (producer observations). Maximum FECs of 550 epg were found on June 24 and July 4 in Farm 1, and 850-950 epg on May 27 and June 16 in Farm 2.

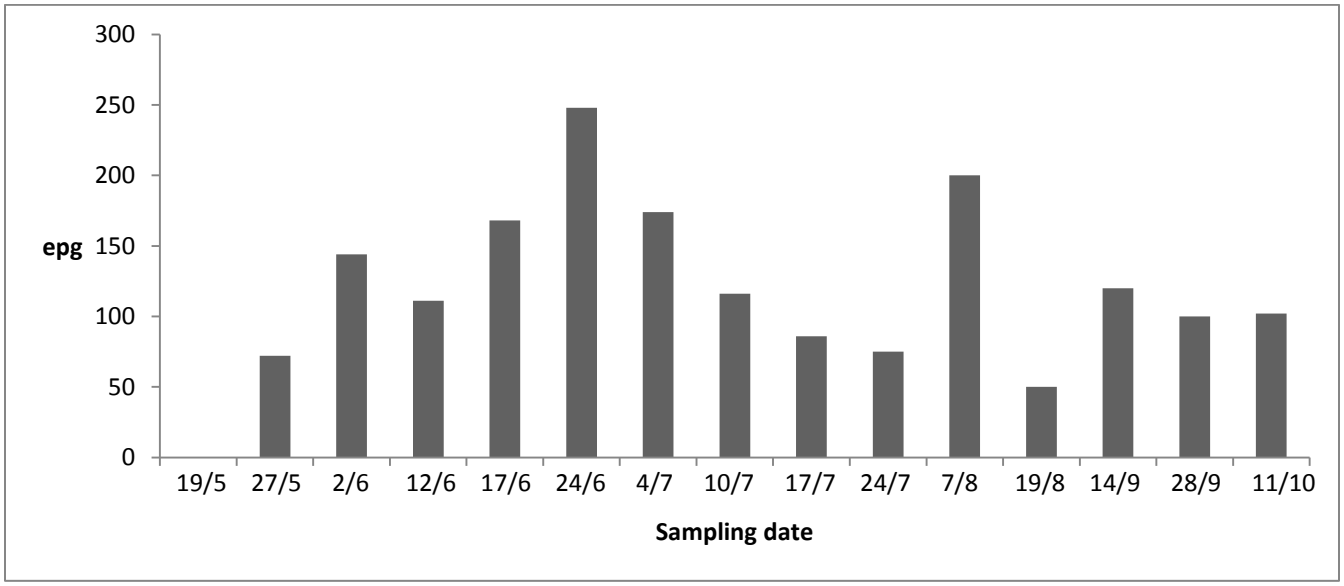

Figure 7. Mean intensity of *Nematodirus battus* on Farm 1

A second species, *Nematodirus* sp. (possibly *N. filicollis*) was less common, occurring on 20% of farms with lamb FECs > 50 epg. It was first recorded in early July, and occasionally thereafter. Counts were generally <200 epg for *N. battus* and < 100 epg for *Nematodirus* sp. in random samples from producers and from ASY. Both species were found in late October samples from island lambs. In these lambs, *N. battus* had a prevalence of 0.6 (60%) and mean intensity of 409 epg (range 0 – 2400 epg). *Nematodirus* sp. Had a prevalence of 0.4 (40%) and mean intensity of 107 epg (range 0 – 750 epg). GIN FECs were also high in these lambs (Table 2).

**Case Studies**

Two incidental observations demonstrated the rapid buildup of *Haemonchus* larvae on pasture:

- Farm 1 lent 2 ewe lambs for 4-H. They went from the lambing barn to a beef farm with no history of sheep or goats and had never shared pasture with adult sheep. They had a ¼ acre paddock through the summer. One other lamb, from the home pasture, shared this paddock for 10 days from July 4; on this date the lamb mean intensity was 1100 epg. There was no further contact with ewes or lambs. By mid-September both lambs were anaemic (FAMACHA score 4) and one had a FEC >33,000 epg.

- In a late lambing flock (May or June) all ewes were treated with levamisole on July 1 and the flock turned onto clean pasture not previously grazed by sheep. Lambs were not treated but had a prevalence of 30% and mean intensity of 117 epg. In the first week of September several lambs died suddenly and others were anaemic. One lamb had a FEC >50,000 epg.

## Discussion

*Haemonchus* has become the most serious parasite affecting small ruminants throughout the world (Kaplan & Vidyashankar 2012). Although it is primarily a warm climate species ( Kaplan & Vidyashankar 2012; Taylor 2012) it has become more prevalent in northern climates, including Ontario (Falzon et al., 2013), the U.S. (Kaplan & Vidyashankar 2012) and Scandinavia (Waller et al. 2004; Domke et al. 2012, 2013; Manninen & Oksanen 2010). In these regions, increased prevalence is probably correlated with milder spring and fall conditions (Sargison 2012). High fecundity results in a fast buildup of pasture contamination, as shown in the comparison of 1997 and 2012 data and the case studies in this study. The difference in mean intensity of infection between these two years is a reflection of the fecundity of female *Haemonchus,* which can produce 10.000 eggs/day (Abbott et al. 2012). In 1997, and traditionally (Mederos et al. 2010), the main sign of GIN parasitism was scouring and loss of condition in late summer-early fall. Anaemia was seldom seen (E. Semple, personal communication). No information has been found on *Haemonchus* in Canadian sheep between 1973 and 2008 (Mederos et al, 2010).

In Nova Scotia *Haemonchus* has become a problem that could threaten the economic sustainability of pasture production of small ruminants. The results of this study agree with those of other regions with similar winter climates (Falzon et al. 2013; Domke et al. 2012, 2013). In southern Ontario 88% of farms sampled had drench failure, and high levels of resistance were recorded to ivermectin and/or fenbendazole (Falzon et al. 2013). One farm sampled also had some resistance to levamisole, although this AH has not been marketed in Canada for about 10 years.

*Haemonchus* has very poor overwinter survival on pasture (Menzies et al. 2012), but undergoes arrested development in the gut wall when ingested in late fall (Menzies et al. 2013; Taylor 2012).The relaxation of immunity that occurs in late pregnancy and lactation allows larvae to resume development, and this periparturient egg rise (PPER) is the source of pasture contamination in the spring (Menzies et al. 2012). A number of Nova Scotian producers have had cases of bottle jaw or losses of ewes several weeks after lambing from heavy worm burdens (producer observations). It is common practice to dose ewes when housed in winter to prevent the PPER, but this exerts a strong selective pressure for resistance because only resistant worms will be left to contaminate pastures in the spring (Troell et al. 2006; Menzies et al. 2012; Taylor 2012). Similarly, dosing all animals and moving immediately to clean pasture gives resistant worms a competitive advantage (Sargison 2012).

## Seasonal Dynamics

Our observations in Nova Scotia, and limited samples from New Brunswick and PEI, agree with those from other published studies. The first FECs were recorded from early June, about 30 – 35 days after turnout. At this time of year soil temperatures are too cold for rapid development of *Haemonchus* to the L3. Development can take less than a week at 25$^{O}$C, but 2 months in cool conditions (Menzies et al. 2012). These early FECs are probably from more winter-hardy species such as *Teladorsagia*, and it would be useful to recover larvae from herbage early in the season to determine when *Haemonchus* first appears. By early July, however, counts were beginning to rise rapidly, and this suggests that *Haemonchus* has become established. Typically, the first submissions to the Pathology Laboratory in Truro for GIN parasitism in lambs are in mid-July (G. Spearman, personal communication). Larval cultures in July were dominated by *Haemonchus.*

Sampling at ASY showed that many producers are raising market lambs in the barn or in drylot. This is effective in preventing parasite problems, but can have extra costs in labour and feed. It will also not prevent parasitism if replacement ewe lambs are sent to pasture for the first time as yearlings, although an immune response develops more rapidly in older animals (Douch & Morum 1993; Stear et al. 2000).

It is apparent from comments and conversations at ASY that many producers do not yet realise how widespread and severe problems of haemonchosis can be (D. Thibault, C. Vallis, and personal communications). Occasional lambs were consigned with signs of severe haemonchosis.

Lambs consigned from unidentified island pastures in late October had a high prevalence and intensity of infection, with extreme FECs over 50,000 epg and 2400 epg of *Nematodirus battus*. This is potentially a

concern, since these animals may not be readily gathered for monitoring and treatment and AH use may be minimal. Further study of this management system would be helpful.

**FECRTs**

Only one out of eight farms showed high AH efficacy with routinely used drugs; although a small sample, this is similar to observations in Ontario (Falzon et al. 2012). Ivermectins (AV) in particular showed low efficacy on some farms. Resistance can arise through gene flow (introduced animals), repeated AH use at suboptimal dose (underestimating weights or poor drench technique), or whole-flock dosing when animals cannot pick up larvae which were not exposed to the AH (in winter housing, or moving to clean grazing immediately after dosing)(Sargison 2012). Resistance will develop more rapidly if one or a few genes are involved and if the alleles are dominant (AVs), incompletely dominant or recessive (BZs) or autosomal recessive (levamisole) (Dobson et al 1996). It was predictable in hindsight that ivermectins, especially used on all ewes in winter housing, would rapidly lose efficacy in cold winter regions.

Levamisole is still highly effective, since it has not been available in Canada for 10 years (Falzon et al. 2012). This AH can be obtained to a veterinarian from a veterinary compounding pharmacy; but when compounded it does not have a specified withdrawal time (E. Semple, personal communication). It is not effective against arrested larvae (sheepandgoat.com). Strongid T (pyrantel), formulated for horses, was used by one producer; while also effective, it is seldom used in livestock (Menzies et al. 2012) and no withdrawal time is available. It does not kill larvae (sheepandgoat.com). No other record of its use in sheep was found in the literature.

Choices of AH in Canada are more limited than in many countries with larger sheep industries (Abbott 2012). Closantel (Flukiver$^{TM}$; Elanco, U.K.) is an AH used for many years against liver fluke in Britain, but it is also effective as a narrow spectrum AH against *Haemonchus* (Abbott 2012). It may be preferable to use a narrow spectrum product where only one species is the main problem because this will not select for resistance in non-target species (Abbott 2012). The results with closantel in this study are very preliminary, with two of four farms analysed so far, but are encouraging. When *Haemonchus* is not the only GIN present, however, efficacies below 95% will not necessarily indicate AH resistance. On one farm, only one lamb had a FEC >0 when resampled 2 weeks after dosing, which perhaps indicates a missed dose, or metabolic effects or reduced bioavailability of the drug in this lamb rather than resistance (Falzon 2012). On the other farm, apparent resistance (<95% reduction) is probably due to the presence of several non-target species, although further culturing would be useful from these animals. Closantel has a long withdrawal time (6 weeks: Abbott et al 2012), and if this AH were to be more widely available this must be taken into account when dosing lambs close to market weight.

If these FECRT results are typical for many small farms in the province, reliance on AHs alone will not be enough to control *Haemonchus*. Other strategies, such as early weaning onto clean grazing, targeted dosing, protein supplementation and liveweight monitoring (Hoste & Torres-Acoste 2011; Bisset & Morris, 1996; Kenyon & Jackson 2012) are essential. Evidence from other countries suggests that this will not be simple (Patten et al. 2011; McMahon et al. 2013; van Wyk et al. 2008; Hostes & Torres-Acoste 2011; Woodgate & Love 2012). One response is to leave a proportion of the flock untreated (Menzies et al. 2012) or to target treatment to identified at-risk individuals (Kenyon & Jackson 2012).

**Selection for Low FECs**

There is considerable interest in genetic selection for sheep resistant to GINs, especially *Haemonchus* (Jackson & Miller 2006; Karlsson & Greeff 2012; Kelly et al. 2013). Both resistance (an effective immune response) and resilience ( the ability to withstand worm burdens without developing disease) are under genetic control (Jackson & Miller 2006; Bisset &Morris 1996; Kelly et al. 2013).Identification of superior animals, based on FECs, is incorporated into some genetic evaluation programmes, such as Lambplan in Australia (sheepgenetics.org.au) and Signet in Britain (signetfbc.co.uk).

It is possible to select for low FECs in lambs when they have been exposed to larval challenge for 3-4 months, and this is more reliable if repeated FECs are estimated from each animal (Bishop et al. 2006). Lambs with low counts also have low counts as yearlings and show a faster response at this age (Douch & Morum 1993). However, unless time and facilities allow FECs from many animals to be followed, improvements may be slow.

Selection for resilience, based on the ability to maintain weight gain and other production parameters in spite of the worm burden, may be a practical alternative for many farmers (Hoste & Torres-Acosta 2011).

**Other Nematodes**

While the predominant nematode recorded was *Haemonchus,* other species were also identified as eggs or larvae. Most of these (*Trichuris ovis, Strongyloides papillosus, Nematodirus* sp. and an unidentified species which may be *Chabertia* or *Oesophagostomum* ) are of low pathogenicity or usually found in low numbers (Abbott et al. 2012; Menzies et al. 2012). However, *Teladorsagia* and *Trichostrongylus* spp. are the main pathogens, causing scouring, inappetance and loss of condition, when *Haemonchus* is less prevalent in temperate regions (Abbott 2012). Scouring is well known as a symptom of GIN parasitism in late summer, but the presence of large numbers of *Haemonchus* obscures this, and instead faecal pellets tend to be dry and hard in haemonchosis. This can cause a mistaken impression that GINs are not a problem when scouring does not occur (producer observations).

Nematodirus battus was first described in Britain (Crofton & Thomas 1951), and later in Europe and North America (Rickard 1987). The first record in Canada was from the Maritimes (Smith & Hines 1987; Smith & McIntosh 1988). It appears to be an arctic species now adapting to milder climates (van Dijk & Morgan 2010).

The life cycle of *N. battus* differs from that of other GINs: eggs usually only hatch after winter chilling when temperatures rise above 10-11$^{O}$C (van Dijk & Morgan 2008). This can result in mass hatching in spring, and outbreaks of scouring in young lambs are well known in Britain (Abbott 2012). There is evidence of adaptation to longer pasture seasons in southern Britain, where a proportion of larvae now hatch in the same summer without chilling. This can lead to disease outbreaks in the fall (Abbott 2012) and may be a bet-hedging strategy against unpredictable changing climates (van Dijk & Morgan 2008).

This species is not considered an important pathogen in Canada (Menzies 2012), although three producers in Nova Scotia were familiar with nematodirosis and its potential to cause problems should not be overlooked. Calves can also harbour *N. battus* and contaminate pastures to levels causing disease in young lambs in Britain (Coop et al. 1991).

Little attention has been paid to this nematode since it was described from lambs with severe scouring on two PEI farms in June-July 1986 (Smith & Hines 2987). However, it is clearly widespread and in several flocks some individual FECs were at levels (>300 epg) associated with disease in Britain (Abbott 2012). No scouring was reported even in these lambs and it is still not clear whether this species has clinical significance at the individual or flock level.

**Options for Producers**

Management practices can limit parasitism; these can include reduced stocking density, early weaning onto clean grazing, finishing on aftermath or stockpiled forage, protein supplementation and bioactive forage as well as a potential long-term focus on genetic selection for resistance or resilience (Jackson & Miller 2006; Menzies 2012, Hoste & Torres-Acosta 2011.) However, this will not be simple. These approaches cannot achieve the same control as a highly effective AH (Ketzis et al. 2006). Educational programmes have had some success (McMahon et al. 2013; Whitley et al. 2013), particularly in promoting monitoring (FAMACHA, weight gain, FECs). A wider availability of low cost FECRTs could be very helpful to producers in slowing the development of AH resistance and preserving the efficacy of any new AH. Both levasmisole and closantel are very promising AHs if they become available, and with careful use they could be useful components in a parasite management program.

The experience of the last decade, and particularly the last 3-4 years, shows that AH resistance can develop rapidly. Once resistance is established, it is unlikely that there will be any reversion to susceptibility (Sargison 2012), and so it is essential that strategies are developed to protect the AHs we have and minimise the onset of resistance as far as possible if any new AHs are approved for use in Canada.

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