Introduction

Gastro-intestinal nematode (GIN) infections have become an increasingly greater challenge to small ruminant health and well being in the Midwest region of the USA in recent years yet there has been little documentation of neither the population dynamics of the major GIN species nor evaluation of risk factors for infection in this region. Understanding the GIN population structure and risk factors for infection are important in developing effective integrated control programs as they dictate the choice of GIN infection control strategy.

GIN population structure in large commercial sheep flocks

During 2011 or 2012, we evaluated the GIN population structure throughout the year on 4 large sheep flocks (>500 ewes) representing a diversity of climate and sheep farm management system within Michigan. All of these flocks grazed adult ewes for the majority of summer but they varied in the frequency and distribution of lambing periods during the year and also in feeding system as some farms fed a total mixed ration in confinement for extended periods while others were entirely pasture-based with minimal concentrate feeding and outdoor housing of ewes for the vast majority of the year. GIN larval population composition in these flocks was determined by counting L3 larvae cultured in the laboratory obtained from replicates (n≥3) of composite samples of feces (10-25 individual sheep fecal samples pooled to make a single composite).

Figure 1. GIN population dynamics in 4 large sheep flocks in Michigan according to season.
Haemonchus contortus dominated the GIN population in all 4 flocks throughout the year (Figure 1). Caution should be exercised in extrapolating this finding to the entire region as it is possible that a different population structure may exist if a broader range of flock size were examined. However in the large flocks examined it was striking how consistently Haemonchus dominated the GIN population in these flocks representing a large number of ewes (approximately 3600 ewes). These flocks ranged in location from the far North to the far South of Michigan’s lower peninsula thus representing a pasture growing season varying by an estimated 4-6 weeks.

**Haemonchus contortus development and lifecycle basics**

Haemonchus clearly thrives in warm, humid environments which present optimal egg hatching and larval development conditions. In Michigan, there is great diversity in climate given the range of latitude (42nd-46th parallels) and proximity to the one of 4 great lakes, however despite this diversity in microclimate; there are significant stretches of warm, humid weather in all that are conducive to Haemonchus development. The extent and duration of cold during a Michigan winter (in all microclimates) kills the vast majority of the free-living, terrestrial population of Haemonchus as confirmed by studies performed on the Michigan Agriculture Experiment Station in the 1940’s. However while the free living population is decimated, the population living within the animal survives by entering a state of arrested development or hypobiosis allowing survival to the following spring. This arrest wanes markedly at birth (Figure 2) and is often referred to as the periparturient rise is fecal egg count, which in many flocks/herds is coincident with warm spring weather thus quickly repopulating pastures and propagating a year round life cycle even in cold, frozen climates.

![Figure 2. The periparturient rise in fecal egg count in ewes (n=47) housed indoors giving birth to an average of 1.87 lambs per ewe.](image)

Egg hatching, larval development and larval survival dynamics are difficult to model as they are modulated by temperature and humidity. The length of pasture infectivity following a single, discrete grazing bout therefore can vary widely with egg to infective larval progression as rapid
as 2-3 days under ideal conditions and the length of time required to reduce larval population to <20% of peak varying from an estimated 30-90 days. This variation makes it extremely difficult to prescribe a standard grazing management scheme to minimize animal re-infection following a grazing bout. In fact, rotational grazing practices designed to optimize pasture utilization and animal nutrition by keeping rotation lengths in the 18-35 day range, are commonly far too short to allow pasture larval population and therefore pasture infectivity to decrease appreciably. An effective strategy to lower pasture infectivity while maintaining a high level of forage utilization and quality is to alternate small ruminant grazing bouts with a machine harvest of forage or by harvest with a different species that does not share the same parasite host range (i.e. cattle).

**Haemonchus infection risk and population distribution**

Haemonchus infections progress rapidly in sub populations of animals with susceptibility likely explained by variation in immunity to the organism. Young animals previously naïve to Haemonchus infection are especially vulnerable as are animals in certain physiological states (i.e. lactation, especially lactating animals in pronounced negative energy balance; i.e. chronic diseases including maedi visna/ovine progressive pneumonia and Johnes disease). Adult, non lactating animals are clearly more resilient to infection and can often resist significant infection even on highly contaminated ground. This is not universal however as there are individuals within all populations that exhibit greater susceptibility regardless of physiologic state or age. Variation in susceptibility clearly has a genetic basis as well with genetics explaining 35-45% of the variation in fecal egg counts in studied populations. The large variation observed in susceptibility by genetics, age and physiological state collectively manifest as a highly over dispersed distribution of infection within a population as shown in Figure 3. All populations of small ruminants exhibit this distribution with variation only in the mean level of infection. This infection distribution pattern has important implication for control as only 33% of any given population accounting for 80% of the eggs deposited on a pasture at any given time.

![Figure 3. Distribution of fecal egg output within a given population of ewes (n=147).](image-url)
Infection monitoring schemes

The highly dispersed nature of infection within a population provides opportunity for selective infection treatment. Selective treatment has distinct advantages in parasite management as it allows maintenance of a refugia population of parasites that are less exposed to anthelmintics in animals that can resist infection. Selective treatment however requires an effective infection monitoring program. The FAMACHA system is a monitoring scheme developed in South Africa that compares the color of the lower conjunctiva to a color chart providing a convenient, inexpensive read-out of red blood cell count. This system is well suited to parasite populations that are dominated by Haemonchus and less effective in others. FAMACHA score provided good predictive power of hematocrit in a population of naturally infected lambs grazing in the Upper Peninsula of Michigan (Figure 4).

![Figure 4](attachment:image.png)

Figure 4. FAMACHA score as a predictor of red blood cell count (hematocrit, %) in a population of 100 growing lambs on a farm in the Upper Peninsula of Michigan. FAMACHA scores are categorical from 1 (red) to 5 (pale pink).

Summary

The dominance of *Haemonchus contortus* in GIN infections in large sheep flocks in Michigan combined with its severe pathogenicity make it a central target of parasite management control measures in this region. Knowledge of the risk factors for infection (age, physiological state, genetics) and distribution of infection within a population are important factors to consider in developing a sustainable control program. The FAMACHA system offers promise a simple and elegant monitoring tool in many circumstances but may have limits in efficacy and feasibility in large flocks/herds of lactating and nursing small ruminants.