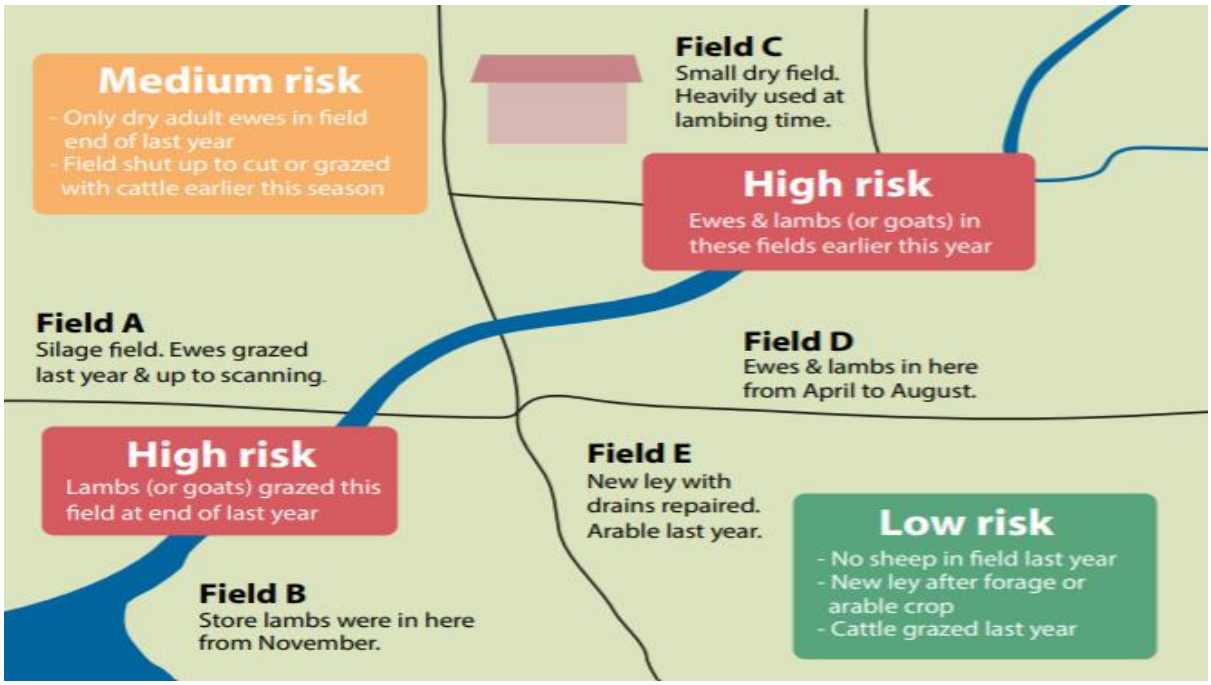
Pasture-based risk assessment & pasture mapping

A logical extension of the retrospective low/medium/high pasture risk (lamb strategies) is for the farmer to keep grazing records and map estimated contamination levels for each pasture or paddock. These maps can be updated at intervals throughout the year and used to make more informed grazing choices. For example, to evade nematode infection, farmers can choose to graze one of the fields with the lowest level of contamination. An example is shown below:



In contrast, farmers can identify 'dirty' fields with higher levels of contamination to turn out sheep that have had quarantine treatments ensuring rapid reinfection and dilution of any eggs from surviving worms.

Farms regularly monitoring FECs can further refine this process. For example, fields grazed for a short period of time by sheep with high FECs may warrant a higher contamination level than fields grazed for a longer period by sheep with very low FECs. This is especially useful when planning evasive control strategies for *Nematodirus* to identify safe grazing. For example, fields not grazed by young lambs the previous spring are generally considered safer grazing for young lambs with respect to *Nematodirus*, but this might not be the case if the land was grazed by older lambs shedding significant numbers of *Nematodirus* eggs the previous year.

Flock health planning: HACCP and GAME

Good flock health planning is central to good parasite management. Hazard Analysis and Critical Control Point (HACCP) principles can be applied to flock health planning to monitor and manage parasitic gastroenteritis (PGE) in sheep (see Gascoigne et al., 2018, Controlling nematode infections in sheep: application of HACCP. In Practice, 40, pp. 334-347).

The hazards of parasitic infection are the measurable impacts of disease, such as loss of condition, reduced daily liveweight gain, reduced milk yield and death. Critical control points are times in the flock calendar where these hazards can be eliminated, prevented or reduced to acceptable levels by taking corrective action. For example, the hazard of reduced daily liveweight gain in lambs after weaning can be reduced by taking corrective actions at the critical control point of weaning.

Corrective actions at critical control points refer to the many parasite control actions highlighted throughout this manual. To help identify appropriate actions at each point, a "GAME" approach was devised based on the founding SCOPS principles.

- **G** – General Health and Genetics including nutrition and selective breeding.
- **A** – Avoidance (pasture-based risk assessment)
- **M** – Monitoring (including weighing, conducting faecal egg counts and monitoring risk and forecasts).
- **E** – Effective and efficacious treatment following the SCOPS principles.

A key feature of the HACCP and GAME approach is that, providing monitoring systems are put in place, progress can be monitored from year to year and the flock health plan can be adjusted accordingly. Crucially**, this method places anthelmintic treatment as the final option that should be considered for sustainable parasite control**, focusing first on gains that can be made by forward planning, manipulating nutrition, selecting for resistant/resilient stock, avoiding infection, and monitoring infection and risk to inform treatment choices.

HACCP application to a flock health calendar can be seen in the table below. Gastrointestinal nematode infection, resulting in reduced weight gain, as identified as a hazard, and the production system, with key management events, was defined on the calendar. A system for record keeping and monitoring was put in place. Critical control points (CCPs) (green boxes) were identified; these are points at which the hazard can be eliminated, prevented or reduced to acceptable levels. For each CCP, corrective actions are identified using the GAME strategy. Finally, options to verify control (orange boxes) throughout the year and at the end of the year were identified and put in place

HACCP analysis applied to Flock Health Plan with respect to typical flock producing finished lambs

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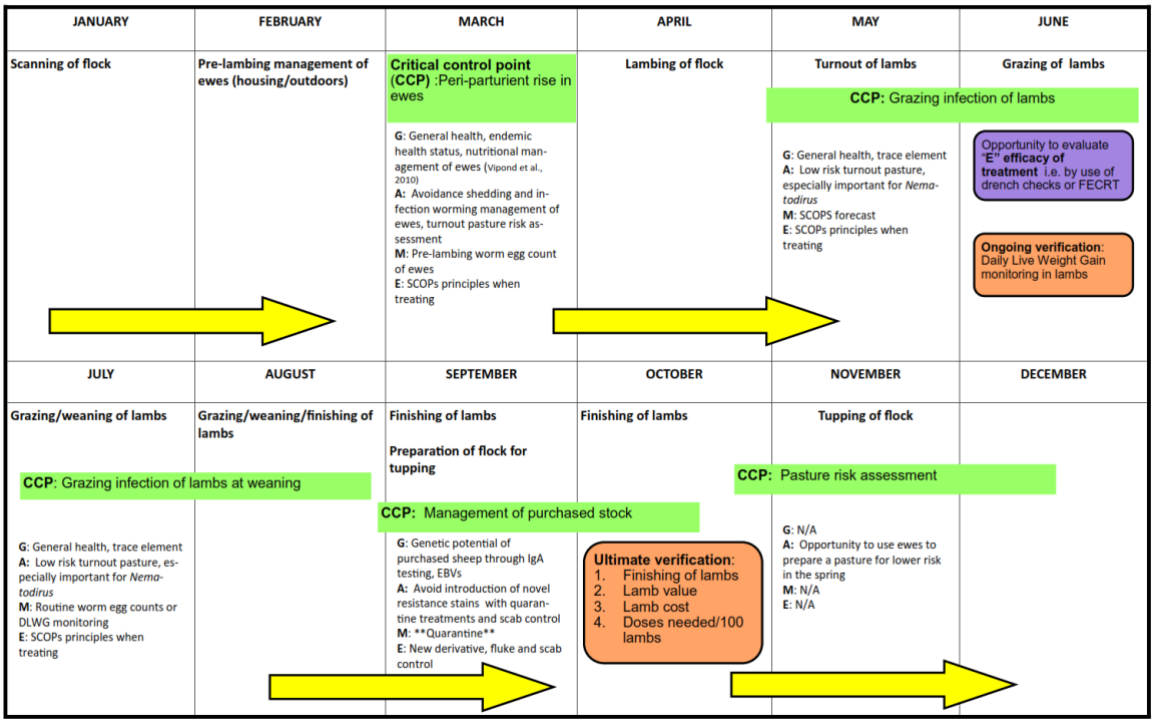

Gascoigne, E., Morgan, E. R., Lovatt, F., & Rose Vineer, H. (2018). Controlling nematode infections in sheep: Application of HACCP. In Practice, 40, 334-347. doi:10.1136/inp.k3858

Additional risk factors

Rainfall and temperature

As the life cycle of nematodes and fluke are partly completed outside of the host, and the life cycle of fluke involves an invertebrate intermediate host (a snail), weather can play an important role in modifying the seasonal patterns of infection. The range of conditions that each parasite can tolerate also varies. Knowledge of these variations and requirements can be helpful to forecast infection risk, plan grazing strategies to avoid infection, and when tracking pasture contamination.

Temperature effects on development

For all parasite species, development speeds up as temperatures increase, and they are able to complete their life cycle much quicker in peak summer than in early spring or late autumn.
The minimum temperature required for *Haemonchus* eggs to hatch and develop to infective larvae is around 9℃ or around 4℃ for *Teladorsagia.* This means that most eggs shed by infected animals over winter die before they are able to hatch and develop to infective larvae (eggs in dung kept refrigerated in the lab usually start to die after a week or so). Most of the infective larvae that accumulate on pasture are either larvae that have survived over winter on pasture, or larvae that develop from eggs deposited by ewes around lambing and later by lambs.

Nematodirus is unique in that the infective larvae develop within the egg (usually deposited by lambs over spring and summer). The majority of these eggs will need a period of chilling (i.e. need to be exposed to cold temperatures over winter) before hatching once they have spent sufficient time between around 11-17℃. Nematodirosis is therefore associated with spring lamb infections, and the approximate date that eggs will hatch can be estimated using recent weather data. A small proportion of eggs don't require chilling, however, and can hatch in autumn once temperatures start dipping below 17℃ again which can lead to autumn disease on some farms.

Temperature effects on survival

Although parasites tend to develop quicker as temperatures increase, they will also die quicker. In addition, different species can tolerate cold weather to varying degrees and it is not necessarily true that a cold winter will "clean up" pasture. Although their numbers (i.e. contamination levels) will decrease, infective nematode larvae are able to survive on pasture over winter in the UK. Contrary to previous beliefs, field studies conducted in Southwest England and Scotland have shown that *Haemonchus* larvae can survive in large numbers on pasture over winter, even when exposed to occasional sub-zero temperatures. *Nematodirus* eggs can also survive on pasture over winter.

Rainfall and moisture requirements

Nematode infective larvae need moisture to migrate out of the dung and onto pasture – larvae rapidly migrate out of dung in the hours following rainfall. In dry years, the levels of infective larvae on the pasture are lower as the larvae are less able to escape the dung. But once it rains, there tends to be a huge increase in pasture infectivity as the L3 larvae emerge from the dung. It is common, therefore, to see heavy worm burdens in the autumn and winter following a dry summer. During hot, dry weather where dung has accumulated on pasture, farmers may wish to move their sheep on to pasture with lower contamination levels prior to forecast rain.

Previous exposure

Lambs will normally develop immunity to gastrointestinal nematodes by the time they are 5-6 months old. However, this is an acquired immunity, dependent on sufficient exposure to the parasites and not as strong as in adult ewes. Lambs kept on clean grazing, or kept indoors for long periods of their early life, may remain naïve to parasite challenge and succumb to PGE when subsequently exposed, irrespective of their age. For example, pedigree ram lambs that have been pushed hard on concentrates and wormed regularly so they have had little exposure worms before being put out to work on a commercial farm. This can also be an issue for hill lambs when they are moved down from low challenge hill grazing to heavily infected lowland farms.

Concurrent disease

The ability of sheep to withstand a challenge from parasites will be impaired by concurrent disease. Of particular note is the effect of coccidiosis on *Nematodirus* and vice versa, which increases the severity of infection. This will also apply to disease caused by nutritional deficiencies (for example cobalt deficiency is implicated in the inability to withstand parasite challenges) or previous damage to the gastro-intestinal tract due to other parasitic disease.