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Modelling the risk of specific parasites to UK sheep under predicted climate change

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Interim Summary Report

Planned work – horizon scanning

1. Key points

- *Haemonchus contortus* is a voracious blood-feeding parasite that can cause disease and death in sheep flocks.
- The larvae can be found on pasture, and sheep become infected while grazing.
- How the resulting disease (haemonchosis) develops depends to a large extent on the climate, especially temperature and rainfall.
- Our modelling work suggests that projected climate change in the UK is likely to lead to the parasite being more common on pastures in the UK and, therefore, posing a greater health risk to sheep and goats.
- Recent surveys show that *Haemonchus* is already becoming more common in the UK, and reports of clinical haemonchosis are increasing.
- Modelling climatic changes and how they impact on *Haemonchus* will make it easier to detect and forecast haemonchosis risk.
- In the broader context of a sustainable and profitable sheep industry, improving animal health through parasite control will improve efficiency and animal welfare, reduce its environmental impact and increase farm profits.

2. Executive summary

Haemonchus contortus is a blood-feeding parasitic worm that affects the health, welfare and productivity of sheep. Historically it was only viewed as a serious problem for sheep producers in tropical and sub-tropical parts of the Southern Hemisphere, for example, Australia, South Africa and South America. Recent surveys in northern Europe, including the UK, have shown that the parasite is becoming more common and causing more health risk to sheep. One possible explanation for this is a changing climate, in particular warmer and wetter seasons. To explore the potential short-to-medium term risks of increased clinical disease (haemonchosis) associated with this parasite, we have developed a model to look at possible future risk. The model has been used to investigate how the parasite would survive and develop on pasture under likely mean daily temperature and precipitation, based on the three greenhouse gas emissions scenarios underpinning the UK Met Office climate projections (UKCP09). Under all three emissions scenarios, the rate of development of *Haemonchus* on pasture is expected to increase. In Scotland, this is likely to be highest in the West of Scotland in spring and autumn, and across the central belt throughout late spring and summer.

3. Background

Haemonchus contortus, also known as the 'Barber's Pole' worm, is a dangerous blood-feeding parasite that infects small ruminants, mostly sheep. The parasite has a simple, direct life-cycle that has both a free-living phase (on pasture) and parasitic phase (in the host animal). Sheep and goats become infected by eating grass and other vegetation contaminated with infectious *Haemonchus* larvae. The larvae can develop into egg-laying adults within the host animal in as little as 2-3 weeks. *Haemonchus* is a voracious blood-feeder, each adult worm can take around 0.05ml of blood a day from an infected animal. Even a moderate infection, with fewer than 7000 adult worms, can take the equivalent of a standard can of Coke (330ml) of blood per day, a serious blood loss that can result in haemorrhagic anaemia. The female parasites are prolific egg layers, often producing 7000–10,000 eggs each per day and, as a result, can contaminate pastures rapidly. Under tropical conditions, eggs can develop to become infective stages within a short period of time (3-5 days). Under cooler, temperate conditions, it may take weeks or even months. As a result, the threat *Haemonchus* poses is significantly different in tropical and temperate regions.

Haemonchus is endemic in many regions of the world, and is the scourge of the livestock industry in the southern hemisphere, most notably, Australia, South Africa and South America. Such is the concern about haemonchosis decimating sheep flocks in Australia, that the industry employs regional parasite control officers and has set up a specific regional forecasting system, known as 'WormBoss' (http://www. wormboss.com.au/). This provides producers with advanced warning of *Haemonchus* outbreaks and gives them time to implement specific diagnostic testing and/or appropriate drug treatments. A similar risk forecast, based on predicting the optimal climatic conditions for mass egg hatching, has recently been developed for the sheep parasite, *Nematodirus battus* in the UK, as part of the EU-GLOWORM project [www.gloworm.eu]. The forecast, in the form of real-time regional risk maps, is hosted on the industry-led Sustainable Control of Parasites in Sheep (SCOPS) website [www.scops.org]. We aim to develop and validate our *Haemonchus* model to be used in a similar way.

Historically, there was little concern about *Haemonchus* in temperate regions in the Northern hemisphere. The cooler climates in such regions mean that only one annual infection cycle may occur, and the larvae ingested in late autumn would often not develop in the host until the following year. This inhibition in development (also known as hypobiosis), is one mechanism that the parasite uses to survive otherwise difficult Northern (or temperate) conditions. However, recent surveys have found a high prevalance of *Haemonchus* in Swedish and Swiss sheep flocks (Hoglund et al, 2009; Murri et al., 2014, respectively) and also within the UK sheep sector (Burgess et al., 2012).

Reports of clinical haemonchosis have risen in the UK over the past 10 years, with the most likely explanation being recent climatic changes (van Dijk et al, 2008; Kenyon et al., 2009; van Dijk et al., 2013). Assessment of historical meteorological trends (1961 – 2004) has shown an increase in average air temperature and precipitation, a decrease in ground frost and an overall increase in growing/grazing days (Barnett et al, SNIFFER handbook 2006). Such changes effectively contribute to an extended parasite season, allowing for increased larval survival on pasture and a greater opportunity for grazing animals to become infected.

Whilst cases of clinical haemonchosis are still relatively rare in the UK, the parasite itself is surprisingly common. During a survey in 2008-2011, it was found on around 50% of UK sheep farms, including some 30% of farms in Scotland (Burgess et al., 2012). Heavy infections are now occurring sporadically in newly affected areas and pathological haemonchosis cases are already becoming a problem for farmers, especially in the south-east of England. So, how much does the climate of the UK, and Scotland in particular, have to change for this dangerous parasite to become a serious threat to the sheep industry? Also, based on projections and established models of

Haemonchus epidemiology, can we make predictions about haemonchosis risk in the short-to-medium term? Our model was set up to address these questions.

4. Predicting risk

In order to consider the effects of climate change on the life-cycle and epidemiology of a helminth parasite, it is important to examine the effects on the free-living stages. As mentioned above, *Haemonchus* has a life-cycle that includes a phase from egg to infectious third larval stage on pasture. The rate at which the parasite develops depends on the temperature and moisture. In order to investigate the effect of climate change on the likely risk of *Haemonchus* across Scotland, we examined the rate of development of the larval stages on pasture under the likely mean daily temperature and precipitation, based on UK Met Office climate projections (UKCP09), under low, medium and high emissions scenarios (http://ukclimateprojections. metoffice.gov.uk/).

The specific model used was that proposed by Onyia (1985). Specifically, it is assumed that no larval development occurs at temperatures below 9^{o}C. According to this model, between 9^{o}C and about 25^{o}C, development occurs at a rate that is non-linearly influenced by the daily temperature. Above 25^{o}C, the rate is fixed, such that development is complete within 4 days. In addition, we include a restriction that development only occurs when the average daily precipitation is above 3mm per day.

The UKCP09 predictions are available for 25km square land parcels across the whole of the UK. For each parcel of land and under each scenario, and for each month of the year, we estimated the rate of development of *Haemonchus* larvae. For comparative purposes, we plotted these results on maps of the UK, using a scale representing the range of values across the UK predicted for the reference year (1961-1990). These monthly risk maps, for each emissions scenario, can be produced for the decades 2020 to 2080 based on the UKCP09 projections.

The UKCP09 results are produced as a probabilistic prediction. There is a distribution of mean temperatures available for each emission scenario and time point. We integrated over the probability distribution to estimate the mean or expected rate of development. Under all three emission scenarios, the rate of development of *Haemonchus* on pasture is expected to increase in the future. In Scotland, this is likely to be highest in the West of Scotland in spring and autumn, and across the central belt throughout late spring and summer (see Fig.1).

Further development of this predictive model will include sheep grazing density data, as this will affect the level of pasture contamination. Furthermore, we will include a within-host delay to investigate the possibility of multiple *Haemonchus* generations within a single grazing year. This will be combined with estimates of the grazing duration under various climate predictions to further inform the risk of haemonchosis in relation to predicted climate change.

5. Key findings

- *Haemonchus* is the single most important gastrointestinal nematode parasite of small ruminants globally.
- The epidemiology of haemonchosis is driven, to a large extent, by the prevailing climatic conditions, especially temperature and rainfall.
- *Haemonchus* is becoming more common in UK sheep and goats and reports of clinical haemonchosis are increasing.
- Changing climatic conditions across the UK may be expected to be more favourable for *Haemonchus* development on pasture in the future.

- Modelling climatic changes and their impact on *Haemonchus* development will improve detection and forecasting of haemonchosis risk in the future.

6. Policy implications

The increasing prevalence of *Haemonchus* and more frequent reports of clinical haemonchosis are warning signs of a new challenge to the sheep industry in Scotland. Our modelling work to date indicates that projected climate change is likely to lead to more rapid development of *Haemonchus* on pasture, increasing the risk of clinical haemonchosis. This confluence of observed and predicted trends reinforces the need for enhanced surveillance and preparedness, in combination with effective quarantine and drug treatment of bought-in stock. In the broader context of a sustainable and profitable sheep industry, improving animal health through parasite control will improve the biological efficiency of small ruminant production, improve animal welfare, reduce its environmental impact and increase farm profits.

7. Knowledge gaps

- *Haemonchus* eggs are common in UK sheep faecal samples, but we do not know how common or viable the resultant larval stages are on pasture, especially the over-wintering survival of eggs shed in the autumn – ongoing field studies are attempting to address this knowledge gap.

- *Haemonchus* is known to evade adverse winter conditions by entering a state of arrested development (or hypobiosis) within the host, resuming development in spring when conditions are more favourable (Sargison et al., 2007; Waller et al., 2004). We do not fully understand what triggers developmental arrest and this has important implications for when (or if) clinical disease will result.

- Increased stocking density on pasture may lead to increased pasture contamination and, therefore, higher infection rates but may also lead to changes in sward structure and, hence, less favourable conditions for parasite development and survival. We do not know the balance between these opposing pressures on *Haemonchus* population densities.

- Will increased length of grazing season lead to increased reliance on chemoprophylaxis, which will inevitably increase the selection pressure for development of anthelmintic resistance and lead to further pasture contamination?

- Previous models of parasite development highlight nonlinearities in host-parasite interaction, leading to non-linear responses in parasite burdens as a function of free-living stage development rates (e.g. Roberts & Grenfell, 1991; Fox et al, 2013). The link shown in this work between climate and development rates may, therefore, lead to sudden changes in risk/impact as climate changes.

- We do not fully understand the relationship between *Haemonchus* larval development rate and the onset of clinical disease, nor what thresholds may represent 'tipping points' for widespread outbreaks of haemonchosis.

- What impact will CAP reform have on population structure of sheep farms in future? This will also have implications for farm management, disease surveillance and sustainable parasite control.

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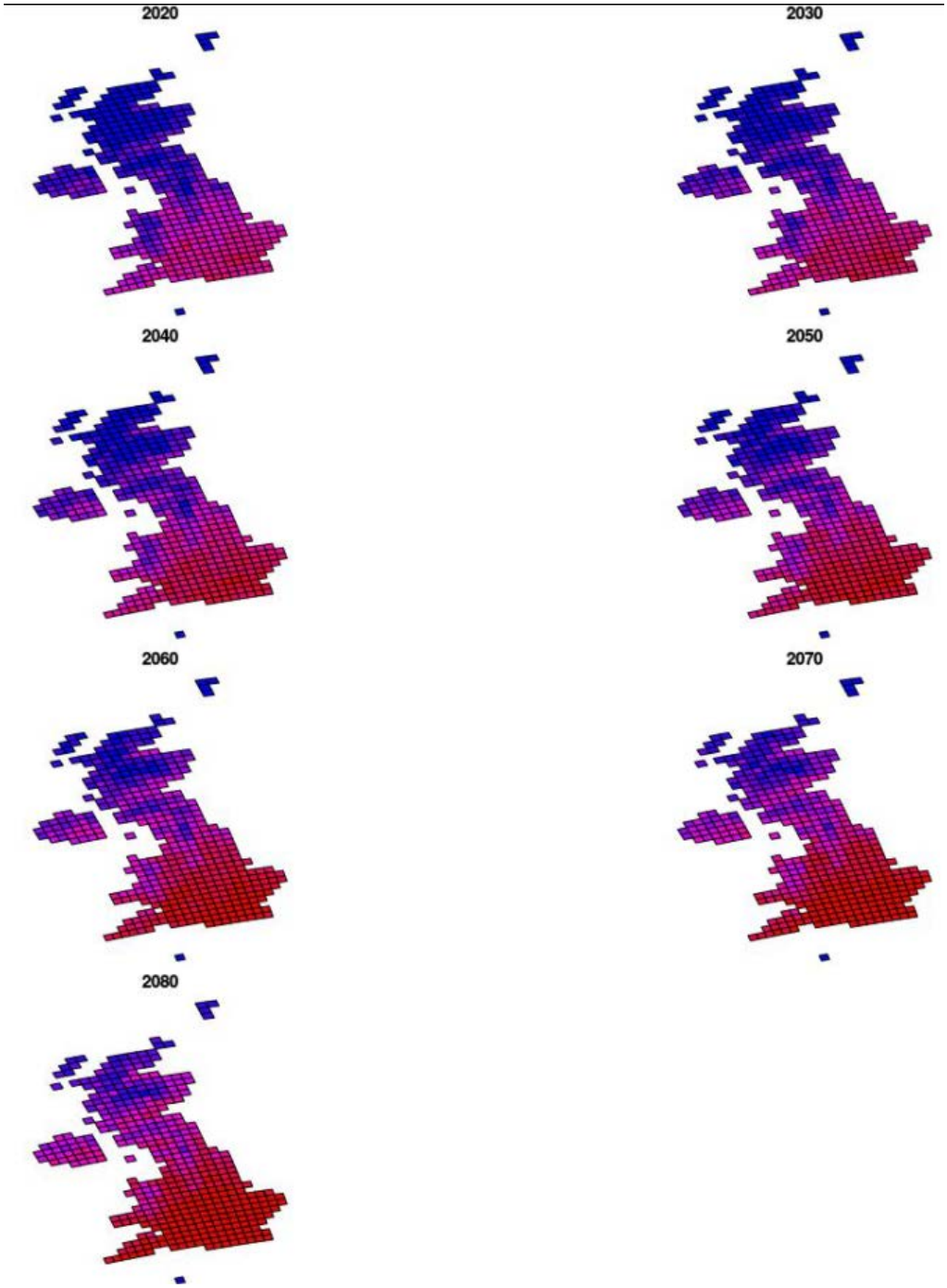
Fig.1. Forward projections of the rate of development of *Haemonchus* in its peak month (July) across the UK, based on the medium emission scenario from UKCP09.Blue = slow development; Magenta = moderate rates; Red = rapid development.



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