Determining the optimum timing for treatment of gastrointestinal nematodes with tree fodder through mathematical modelling

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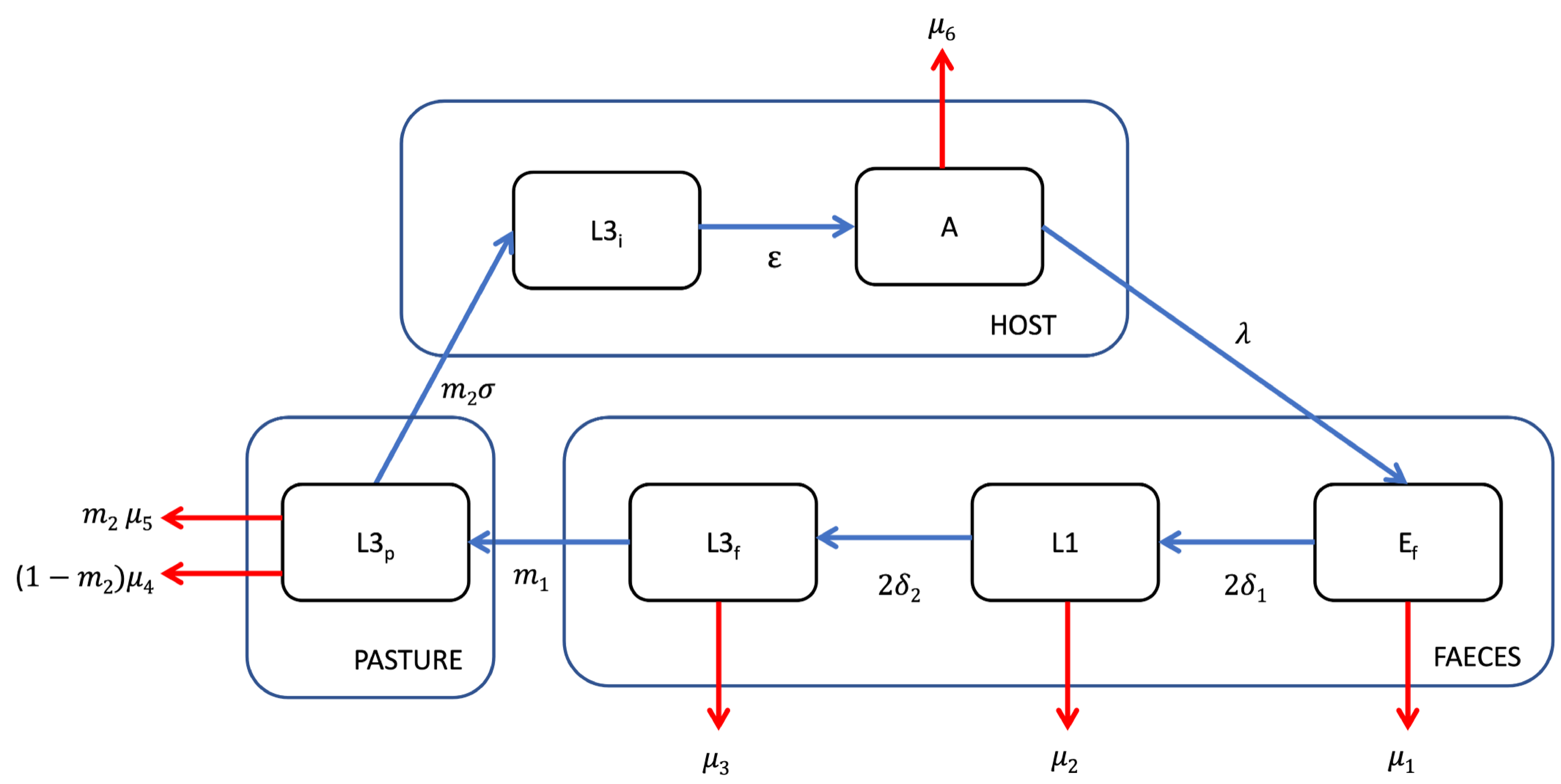
INTRODUCTION

Increasing levels of anthelmintic resistance has led to amplified interest in alternative control methods for gastrointestinal nematode (GIN) infections of livestock.

Feeding tree fodder can affect parasite transmission simply by reducing the amount of larvae covered grass animals eat (**displacement**). Additionally, some trees contain high levels of plant secondary metabolites such as condensed **tannins** which have direct effects against multiple stages of the parasite lifecycle. However they are a limited resource so the timing of their use must be optimised. This can be done through the use of parasite transmission models. This study simulated treatment for the displacement and tannin effects in different months of the year in different geographic locations to determine when these can be most effectively utilised.



The GLOWORM-FL model framework is commonly used to look at effects of weather and climate on transmission dynamics but does not include the parasitic stages. The model was extended here to include the host compartment and allow feeding through of larvae, enabling the effects of treatment on the whole lifecycle to be simulated.

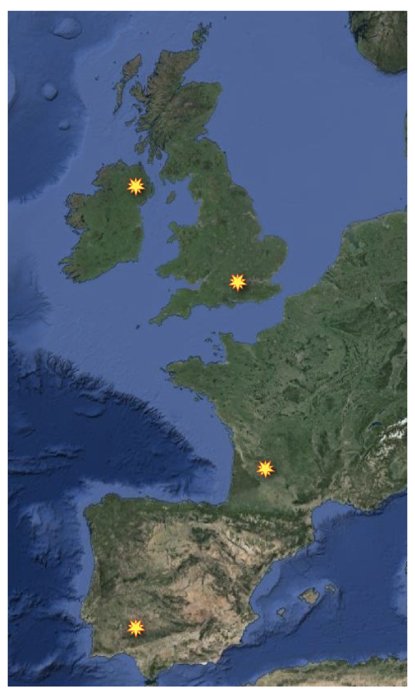
METHODS

	Haemonchus	Teladorsagia
Adult mortality (μ_6)	0.021	0.0307
Establishment (ε)	-log(1-0.24)/15	-log(1-0.21)/14
Egg production (λ)	log(1296/2)	log(240/2)
Stocking density / hectare	7	
DMI intake kg/ sheep / day	4.9	

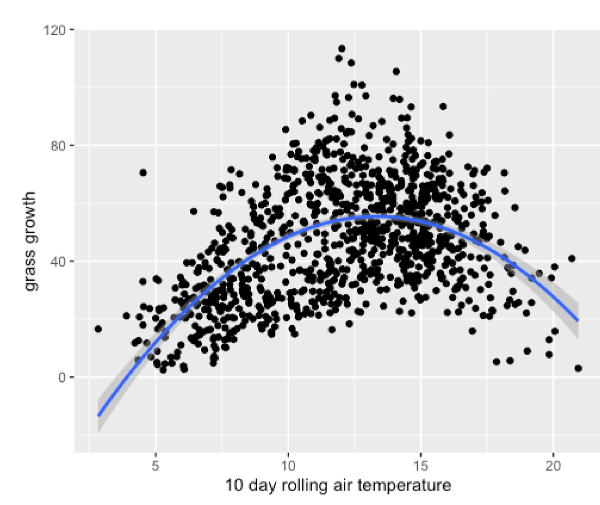
Parameters values for the parasitic stages of the lifecycle were sourced from the literature. All parameter values for the free-living stages were taken from the GLOWORM-FL framework.

	Haemonchus mean value (IQR)	Teladorsagia mean value (IQR)
Larval motility ($m1$)	0.67 (0.37 - 0.85) n = 46	0.48 (0.42 - 0.54) n=2
Adult mortality (μ_6)	1.93 (1.75 - 2.24) n = 15	
Egg hatching (δ_1)	0.62 (0.39 - 0.90) n = 40	0.25 (0.005 - 0.35) n=6
Development L1 – L3 (δ_2)	0.43 (0.30 - 0.58) n = 14	
Egg production (λ)	0.63 (0.56 - 0.79) n = 4	0.86 (0.82 - 0.91) n=2
Ingestion (σ)	0.3	0.3

Data were compiled from *in vivo* and *in vitro* studies on the effects of tree leaf tannins on *Haemonchus* and *Teladorsagia* and the relative effect size calculated to provide multipliers for the model parameters. Insufficient data were available for adult mortality of *Teladorsagia* so the value for *Haemonchus* was used as proxy. For larval development of *Teladorsagia* the egg hatch rate was used.
The level of inclusion of tree leaf fodder, and thus the displacement effect, was set to 30% DMI



The model was run using weather data from four locations on a North - South gradient across western Europe for each year between 1970 and 2022 to assess for spatio-temporal variations in the predictions



Grass growth and temperature data were provided by GrassCheck GB and NI, and a quadratic model fitted. This was used to to estimate grass availability throughout the year

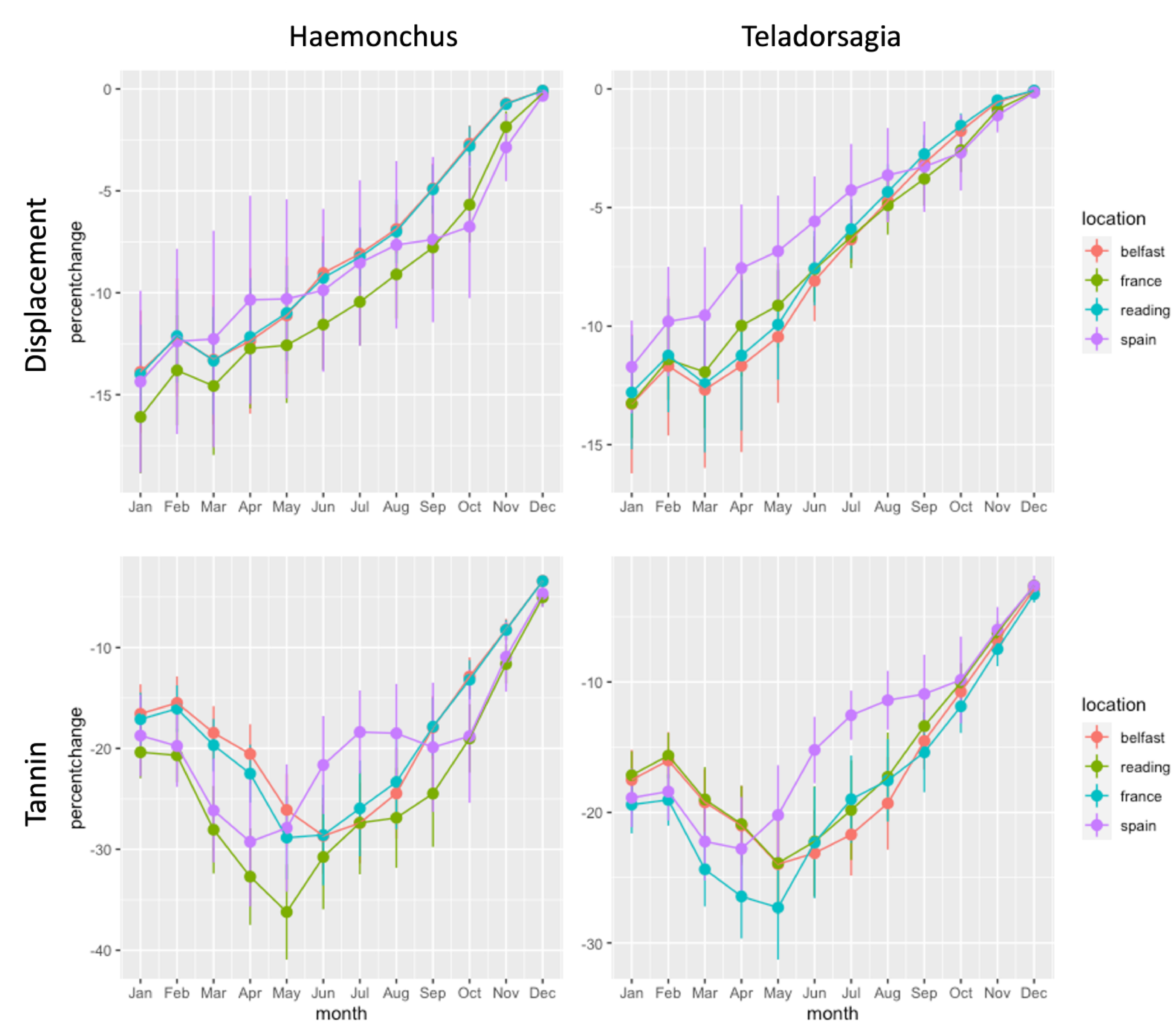
CONCLUSION

The level of effect induced by displacement only is highest at the beginning of the year with a linear decrease throughout. Therefore the optimum time to feed low-tannin fodder is early in the year to reduce parasite build-up on pasture.

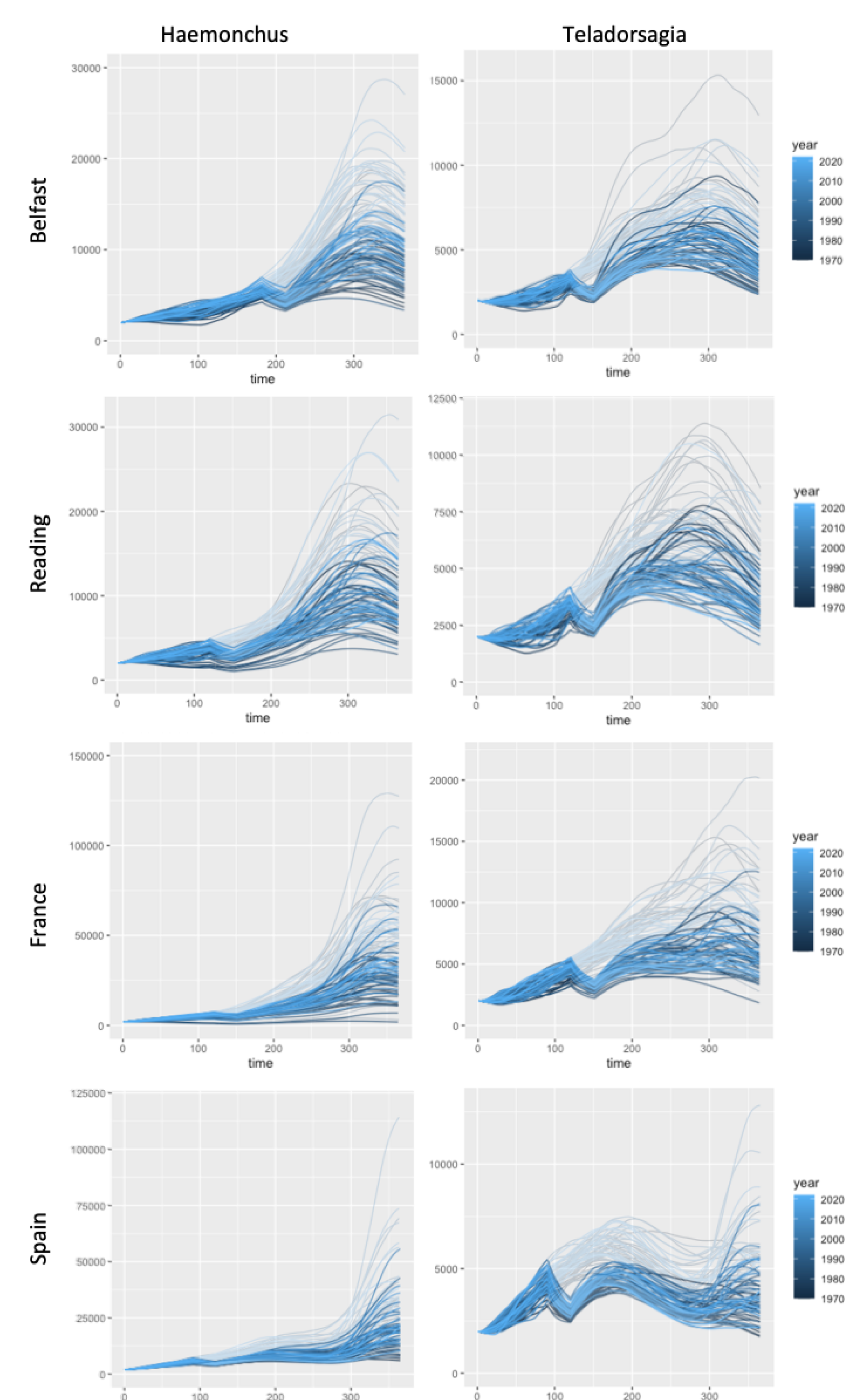
The effect of tannin peaks in the late-spring/early summer during the rise in parasite burdens but prior to the peak levels. The exact timing differs between years and locations. This supports the use of mathematical models as a tool to increase efficiency of use of tree leaves as an alternative or supplementary control method.

RESULTS

All results shown are for adult parasite burden within the hosts



The average percentage change in adult worm burden induced by treatment in each month in each location for the two types of treatment, with 95% confidence intervals. Differences between worm species and geographic locations are evident for tannin treatment but not for displacement.



The effect of tannin treatment on adult worm burden for the most common optimum month of treatment in each location as compared to the baseline burden when no treatment is given (faded lines). Each year is represented by an individual line to show the level of interannual variation.

The best month for treatment differed between years. The following shows how many times in the 53 modelled years each month was the optimal month for tannin treatment The month highlighted in bold is shown in the graph:

Belfast Haemonchus:
- **Jun** - 25
- Jul - 18
- May - 8
- Aug - 2

Belfast Teladorsagia:
- **May** - 28
- Jun - 12
- Jul - 12

Reading Haemonchus
- **Jun** - 23
- May - 20
- Jul - 5
- Aug - 5

Reading Teladorsagia:
- **May** - 29
- Jun - 15
- Apr - 6
- Jul - 3

France Haemonchus
- **May** - 33
- Apr - 10
- Jun - 5
- Jul - 3
- Mar - 1
- Aug - 1

France Teladorsagia
- **May** - 30
- April - 14
- Mar - 5
- Jun - 2
- Jan - 1
- Jul - 1

Spain Haemonchus
- **Apr** - 24
- May - 17
- Mar - 9
- Sep - 2
- Jun - 1

Spain Teladorsagia
- **Apr** - 22
- Mar - 17
- May - 8
- Jan - 6

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