An evaluation of UK sheep farmers' attitudes and behaviours towards sustainable roundworm control

Corin Malcolm Jack

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DECLARATION

I declare that the work presented in this thesis is my own work unless otherwise stated and has not been submitted for any other degree or professional qualification.

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Corin Malcolm Jack

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ABSTRACT

One of the major constraints limiting the efficiency of sheep production is the control of gastrointestinal nematode parasites. Parasite control by strategic use of anthelmintics is threatened by the emergence of nematode populations that are resistant to the drugs available. It is therefore increasingly apparent that steps toward maintaining sustainable productivity in the growing face of anthelmintic resistance (AR) is required by farmers. To facilitate the uptake of sustainable approaches to parasite management, a comprehensive understanding of the various factors that may influence farmers' decision-making processes is required.

In order to establish which factors are influential, and determine their impact on farmers' roundworm control behaviours, both qualitative and quantitative research methods were used including focus groups as well as attitudinal and behavioural questionnaires.

A retrospective analysis was initially conducted of historical surveys designed to identify farm specific characteristics and parasite management practices including anthelmintic usage. The objectives of the analysis were to identify factors associated with uptake of best practice advice including farm characteristics and information sourcing. In addition, the implementation of sustainable roundworm control practices was investigated using two surveys conducted in 2000 and 2010. Logistic regression models were applied for univariable and multivariable analysis of dependent and independent variables.

The next step was to conduct a series of focus groups in different geographic regions of Scotland. The main purposes were to explore sheep farmers' attitudes towards different aspects of roundworm management, as well as to identify potential motivators and barriers to uptake of sustainable parasite control practices. The findings aided in the development of an attitudinal questionnaire used to canvass opinions representative on a national level.

The concluding study involved a telephone survey of 400 Scottish sheep farmers, designed to elicit attitudes regarding roundworm control, AR and sustainable roundworm control practices. A quantitative statistical analysis technique (Structural Equation Modelling) was then used to test the relationships between socio-psychological factors and the uptake of sustainable roundworm control practices.

The analysis of historical questionnaire data demonstrated evidence of a shift towards the use of practices to reduce the rate of AR development, most notably a decline in the practice of 'dose and move' as well as an overall reduction in treatment frequency. Statistical analysis identified significant associations between farm characteristics and specific treatment strategies. For example, larger farms were more likely to adopt a set treatment regimen (P=0.036), compared with smaller farms, which were more likely to treat based on clinical signs of infection (P=0.021). Sourcing of roundworm control information primarily from veterinarians was most associated with treatment timings with no parallels between time points.

From the qualitative focus group studies conducted we identified four overarching themes impacting on sheep producers' attitudes to roundworm control and best practice advice. These themes comprised: a lack of perceived need to change, the complexity of advice, the ease of implementation of recommended practices and the effectiveness of extension approaches. Additionally, the most important and implementable guidelines identified by sheep farmers were: 'working out a roundworm control strategy with an advisor' and 'administering anthelmintics effectively' with regard to correct drenching practice i.e. appropriate dosing, administration and drug storage procedures. These findings exhibited similarities with veterinarians' rankings with also, 'testing for AR', 'preserving susceptible parasites' and 'reducing dependence on anthelmintics' receiving the lowest rankings for importance and implementability.

The quantitative analysis from the attitudinal/behavioural questionnaire identified eleven factors with significant influences on the adoption of sustainable roundworm control practices. The key influences on overall adoption were farmers' baseline understanding about roundworm control and self-reported confirmation of anthelmintic resistance in their flock. Additional positive influences included, positive attitudes to veterinary services, enterprise type and perceived risk of AR. Factors that were shown to have the greatest relative effects on individual parasite control practices included; the perceived resource requirements for implementing a quarantine strategy, farmers' AR suspicions for instigating AR testing and the confirmation of AR for adopting faecal egg count monitoring.

The findings have highlighted several factors which can influence sheep farmers' decisions to reject or adopt recommended roundworm control practices. It is evident that the perceived complexity, lack of need and practicality of the current recommendations necessitates changes to how extension is designed and disseminated to farmers. The findings also suggest that improving farmers' acceptance and uptake of diagnostic testing and improving underlying knowledge and awareness about nematode control is a significant target to influencing adoption of best practice behaviours. The importance of veterinarians as highly-trusted information resources validates the need for further engagement with veterinarians concerning sustainable parasite control approaches, to facilitate collaboration with farmers. The need for interaction between farmers and their advisors is key to resolving the issues raised to enable the necessary explanation, justification and execution of recommended practices to suit farmers' needs and farming conditions.

LAY SUMMARY

Introduction

One of the major factors limiting the efficiency and profitability of sheep production is the control of parasitic intestinal roundworms. Roundworm control by strategic use of chemical treatments is threatened by the emergence of populations that are resistant to the available drugs. It is therefore increasingly apparent that steps toward maintaining productivity in the growing face of drug resistance is required by farmers. To improve the uptake of sustainable approaches to parasite management, a full understanding of the various factors that may influence farmers' decision making processes is required.

Materials and Methods

In order to understand which factors are influential, and determine their impact on farmers' roundworm control behaviours, research methods included the use of focus group discussions as well as questionnaires measuring attitudes and behaviours were undertaken.

An analysis was initially conducted of historical surveys designed to identify farm specific characteristics and parasite management practices including treatment usage. The objectives of the analysis were to identify factors associated with uptake of best practice advice including farm characteristics and information sourcing. In addition, the implementation of recommended parasite control practices was investigated using two surveys carried out in 2000 and 2010. Statistical analysis methods were used to determine the relationships between a single demographic characteristic e.g. farm size and a roundworm control strategy e.g. number of treatments per year. Analysis was also used to assess the relationships between multiple variables, using recommended practices as the outcome.

The next step was to conduct a series of roundtable discussions in different geographic regions of Scotland. The main purposes were to explore sheep farmers' attitudes towards different aspects of roundworm management, as well as to identify potential motivators and barriers to uptake of sustainable parasite control practices. The findings aided in the development of an attitudinal questionnaire used to measure opinions representative on a national level.

The concluding study involved a telephone survey of 400 Scottish sheep farmers, designed to measure attitudes regarding roundworm control, drug resistance and sustainable roundworm control practices. A statistical modelling technique (structural equation modelling) was then used to analyse the data to test the relationships between social-psychological factors and the uptake of sustainable roundworm control practices.

Results

The analysis of historical questionnaire data demonstrated evidence of a shift towards the use of practices to reduce the rate of drug resistance development, most notably a decline in the practice of 'dose and move' as well as an overall reduction in treatment usage. Statistical analysis identified significant associations between farm characteristics and specific treatment strategies. For example, larger farms were more likely to adopt a set treatment regime (P=0.036), compared to smaller farms, which were more likely to treat based on visible signs of parasite disease (P=0.021). Sourcing of roundworm control information primarily from veterinarians was most associated with treatment timings with no differences between time points.

From the focus group studies, we identified four main themes impacting on sheep producers' attitudes to parasite control and best practice advice. These themes comprised of: a lack of perceived need to change, the complexity of advice, the implementability of recommended practices and the effectiveness of extension approaches. Additionally, the most important and implementable practices identified by sheep farmers were: 'Working out a roundworm control strategy with an advisor' and 'administering anthelmintics effectively'. These findings exhibited similarities with veterinarians' rankings with also, 'testing for drug resistance', 'preserving susceptible parasites' and 'reducing dependence on anthelmintics' receiving the lowest rankings for importance and implementability.

The statistical modelling analysis for the attitudinal and behavioural questionnaire identified eleven factors with significant influences on the adoption of sustainable roundworm control practices. The key influences on overall adoption were farmer's base line understanding about roundworm control and confirmation about lack of drug efficacy in their flock. Additional positive influences included positive attitudes to veterinary services, enterprise type and perceived risk of drug resistance. Factors that were shown to have the greatest relative effects on individual parasite control practices included; the perceived resource requirements for implementing a quarantine strategy, farmers drug resistance suspicions for prompting testing and the confirmation of drug resistance for adopting faecal egg count monitoring.

Discussion

The findings have highlighted several factors which can influence sheep farmers' decisions to reject or adopt recommended roundworm control practices. It is evident that the perceived complexity, lack of need and practicality of the current recommendations necessitates changes to how extension is designed and disseminated to farmers. The findings also suggest that improving farmers' acceptance and uptake of diagnostic testing and improving underlying knowledge and awareness about roundworm control is a significant target to influencing adoption of best practice behaviours. The importance of veterinarians as a highly-trusted information resource validates the need to improve engagement of veterinarians concerning sustainable parasite control approaches to facilitate collaboration with farmers. The need for interaction between farmers and their advisors is key to resolving the issues raised to enable the necessary explanation, justification and execution of recommended practices to suit farmers' needs and farming conditions.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ABBREVIATIONS

1-BZ	Benzimadazole
2-LV	Levamisole
3-ML	Macrocyclic lactone
4-AD	Amino-acetonitrile derivatives
5-SI	Spiroindoles
ABZ	Albendazole
AR	Anthelmintic resistance
ARS	Audience response system
CAP	Common agricultural policy
DOI	Diffusion of innovation
FEC	Faecal egg count
FECRT	Faecal egg count reduction test
GIT	Gastro-intestinal tract
GIN	Gastro-intestinal nematodes
HBM	Health belief model
L_1	First stage larvae
L_2	Second stage larvae
L_3	Third stage larvae
L_4	Fourth stage larvae
L_5	Fifth stage larvae
MVM	Mark Veterinary Manual
$^{\circ}C$	Degrees Celsius
PBC	Perceived behavioural control

PGE	Parasitic gastroenteritis
PPP	Pre-patent period
PPRI	Peri-parturient relaxation of immunity
R_0	Basic reproduction number
SCOPS	Sustainable control of parasites in sheep
TPB	Theory of planned behaviour
TRA	Theory of reasoned action

GLOSSARY

Agricultural Extension A service or system which assists farmers through educational procedures, in improving farming methods and techniques, increasing production efficiency and income, bettering their levels of living, and lifting the social and educational standards of rural life (Maunder, 1972).

Anthelmintic Resistance A heritable reduction in the sensitivity of a parasite population to the action of a drug (Conder and Campbell, 1995)

Beta Coefficient (β values) Standardisation regression coefficient that allows a direct comparison between coefficients as their relative explanatory power of the dependent variable (Hair et al, 2006).

Collinearity Expression of relationship between two (collinearity) or more (multi-collinearity) independent variables (Hair et al, 2006).

Endogenous variables A variable that is influenced by other variables in a system.

Exogenous variables A variable that is not affected by other variables in a system.

Suitably Qualified Person (SQP) an individual who is entitled to prescribe and/or supply certain veterinary medicines under the Veterinary Medicines Regulations (AMTRA, 2017).

Factor Represent an underlying dimension (constructs) that summarize or account for the original set of observed variables (Hair et al, 2006).

Factor Analysis (FA) **A**n interdependence technique whose primary purpose is to define the underlying structure among the variables in the analysis (Hair et al, 2006).

Goodness-of-fit (GOF) Measure indicating how well a specified model reproduces the covariance matrix among the indicator variables (Hair et al, 2006).

Faecal egg count (FEC) A test performed to count the number of worm eggs per gram of faeces. FEC's are used to monitor worm burden as well as to test anthelmintic treatment efficacy.

Faecal egg count reduction test (FECRT) The gold standard method of determining resistance status in a parasite population. For each anthelmintic treatment tested, animals are allocated into a treatment group and an untreated (control) group and faecal egg count tests are conducted pre-and post-treatment in order to assess the reduction in faecal egg count.

Goodness of fit (GFI) Measure indicating how well a specific model reproduces the covariance matrix among the indicator variables (Hair et al, 2006).

Health Belief Model (HBM) Developed by Rosenstock et al (1971), this model proposed to predict and explain the adoption of preventive health behaviours. The model consists of the following behaviour predicting factors: modifying variables, perceived threat, perceived benefits and barriers, self-efficacy and cues to action.

Helminths A worm, often parasitic, characterized by elongated, flat or round bodies. Helminths include members of the following taxa: monogeneans, cestodes (tapeworms), nematodes (roundworms), and trematodes (flukes).

Incremental Fit Index (IFI) Group of goodness-of-fit indices that assesses how well as specified model fits relative to some alternative baseline model (Hair et al, 2006).

Logistic regression Form of regression in which the dependent variable is a non-parametric, dichotomous (binary) variable (Hair et al, 2006).

Structural Equation Modelling (SEM) Multivariate technique combing aspects of factor analysis and multiple regression that enables the researcher to simultaneously examine a series of interrelated dependence relationships among the measured variables and latent constructs as well as between several latent constructs (Hair et al, 2006).

Sustainable Control of Parasites in Sheep (SCOPS) SCOPS is an industry led group that was formed to develop sustainable strategies for parasite control in sheep, facilitate and oversee the delivery of these recommendations to the industry and ensure that new research and development is incorporated to refine and improve advice given to the sheep industry.

Theory of Planned Behaviour A model proposed by Ajzen at al (1991) to predict an individual's behavioural intentions and behaviour. The model consists of the following behaviour predicting factors: attitudes, social normative beliefs and perceived behavioural control.

CHAPTER 1: GENERAL INTRODUCTION

The aim of the general introduction chapter is to firstly present the many facets of the sheep farming industry including its importance to the rural economy and farming culture, as well as for wider society. Over many years the role of sheep within the farming industry has changed substantially from a thriving supplier of numerous valuable commodities (e.g. meat, wool, skins, and milk) with many downstream business markets, to a primarily lamb-meat based production market. The contributing factors leading to these changes in UK sheep farming included events starting with the industrial revolution, along with agricultural subsidy reforms and the devastating foot-and-mouth disease outbreaks. The result of these events has had both emotive and financial repercussions on the sheep farming industry and since its peak in the 1990's the UK national flock has seen a prominent decline.

The subsequent sub sections focus on gastrointestinal nematodes (GIN) recognised as one of greatest production limiting diseases affecting sheep health, welfare and production. The successes of GIN as a disease entity are discussed as well as the control strategies utilised by farmers, including anthelmintic use and the development and dissemination of resistance to the available compounds The latest industry recommendations (e.g. SCOPS) on sustainable roundworm control and strategies to reduce the selection pressures for resistance on farms is subsequently highlighted.

The concluding sections outlines the history of agricultural extension in relation to the traditional and modern extension methods used in knowledge transfer/exchange to the farming community. The final sections summarise the development of social and psychological concepts and behavioural models used to understand decision-making processes and subsequent behaviour. The use of such models within the agricultural context is also discussed.

1.1 THE UK SHEEP FARMING INDUSTRY

Within the agricultural industry, the sheep farming sector has made major contributions to the economic, cultural and environmental landscape worldwide and notably within the United Kingdom. In fact, among European member states the UK is the greatest sheep meat producer contributing 27% of the total EU output (Marquer et al, 2015). In monetary terms, the revenue generated from UK outputs from sheep production amounted to approximately 1.1 billion pounds (National Statistics, 2016b). In Scotland alone, the revenue produced from finished sheep and lamb outputs equalled 190 million pounds (Scottish Government, 2016). Studies that have assessed the multiplier effects from the different agricultural sectors i.e. the return from investment, have estimated income and employment multiplier ratios of 2.2 and 1.6. This equates to an additional 54% return for every pound invested, and a 34% return in full time employment for the wider economy (Doyle, 2000). In the less favoured areas of Scotland, the estimated output multiplier from sheep farms is estimated at 1.7, which is a 41% return to the wider economy (Schwarz et al., 2006). The main products yielded from sheep production comprise wool, skins, milk and meat, which have all seen significant changes regarding their function, demand and ultimate value. In the UK, these changes were most apparent within the textile industries where wool production was the primary sheep commodity up until the 18^{th} century (Scott, 1978). Following the industrial revolution, the decline in wool production was superseded by an increasing demand for meat production to sustain the growing population. This shift lead to the development of sheep breeds for the purpose of the lamb meat market.

In comparison with other livestock production systems the maintenance of sheep is relatively minimal with grass often forming the principal component of the diet, and with little requirement for supplementary feeding. This resource of grazing for livestock is a particular feature of the UK's agricultural land use, as it accounts for 71% of the 17 million hectares utilised for agriculture (National Statistics, 2015). The three classifications of grassland, i.e. temporary, permanent and rough grazing, are adapted to different conditions and have varying effects on animal production potential (Scott, 1978). These differences are due to the range of factors (e.g. topography, climate and soil quality) influencing the flora that are able to inhabit these areas. Sheep breeds that exhibited traits favourable to each of the different conditions have arisen in order to utilize areas of less fertile land, which would otherwise be unproductive for other species. The UK sheep industry as a result can be characterized as a three-tier stratified system based on the following terrains i.e. hill, upland and lowland. The hill and upland systems in particular are limited in their scope for crop production due to the elevated topography, poor soil quality and harsh climate, consequently sheep production plays a more prominent role in these systems. In contrast, the lowland systems can be characterized by an improvement in soil quality and climatic conditions which are more conducive to a range of farming enterprises including crops and livestock (Scott, 1978).

The UK stratified structure also serves a useful purpose for cross breeding, with the hill and upland breeds acting as a reservoir for breeding stock, in order to produce hybrid progenies with inherited traits from both breeds (Scott, 1978). For instance, purebred hill ewes that are characteristically hardy with strong maternal instincts are drafted onto upland conditions where they are mated with a long woollen breed ram.

The resulting ewe lamb hybrids known as mules are then sold onto lowland farms where they are crossed with meaty terminal sires to produce finished lambs or replacement terminal sires (Sargison, 2009; Rodriguez-Ledesma et al., 2011).

1.2 SOCIAL CONTRIBUTION OF SHEEP FARMING

The farming community provide a distinct subculture within rural society. This is likely due to a strong sense of identity and common purpose within farming communities (National Research Council, 2002; Setten, 2005), which is reflected by the types of social activities associated with farming, such as weekly livestock markets, agricultural shows and young farmers' meetings (National Federation of Young Farmers' Clubs, 2017; National Museum Australia, 2017). Such events as well as developing social cohesion amongst the farming community also play a large role in the social networking within rural communities (Environment, 2011). The events also provide opportunities for farmers to gather in otherwise isolated settings, which is a large concern for farmers' wellbeing. Another social benefit from farming from a public standpoint is the desire for the countryside to be managed in order to preserve the aesthetic appeal of the land (Scottish Government, 2002). The strong connection between rural communities and the landscape is shaped by agriculture and acts as the backdrop to rural life, and is an important pull for the counter-urbanization movement of people from urban to rural areas, in addition to providing an important income source from tourism. The management of the landscape by grazing livestock on hills and moorland enables people to take part in recreational activities such as hiking, walking and climbing as well as sporting pursuits such grouse shooting and deer stalking which add additional attraction for visitors (Young, 2013; The National Sheep Association, 2016).

With regard to specific circumstances of social contribution, there are features that are beneficial at both the individual farm level as well as within the wider public context. Regarding the first aspect, the individual family farm lies at the heart of preserving both the farming business as well as the farming culture through intergenerational teaching and guidance. As Gray (1998) suggests, in a sense the flock possesses the characteristics embodied by the skills and expertise of the farmers and farm staff to select breeding stock that will produce profitable lambs tailored to the demands of the market. This aspect of improving the genetic lines of the breeding flock through careful selection is an important aspect of sheep farming and is a process that is valued and hoped to continue through successive generations. The sustaining of the knowledge, skills and practices associated with sheep farming provides the main basis for the maintenance of the social fabric in less favoured areas, which is particularly pertinent in the context of Scottish agriculture (The National Sheep Association, 2016). The inhabitation of the less favoured areas by sheep producers also provides a number of benefits to local communities through providing supplies for downstream businesses such as hotels, restaurants, butchers, textile shops as well as providing labour opportunities and supporting upstream businesses such as agricultural suppliers and local veterinary services.

1.3 THE DECLINE OF THE NATIONAL SHEEP FLOCK

Since the UK sheep flock reached its peak in the 1990's with over 18 million breeding ewes, the size and structure of the industry has changed with currently approximately 14.6 million breeding ewes (National Statistics, 2016a). A variety of factors are considered to have influenced the fall in the national sheep population, which will be discussed further.

The principle concerns for the sheep farming industry is the income generated from production as well as from government subsidy. The Common Agricultural Policy (CAP) was set up to fulfil a number of requirements for food producers and consumers. The main objectives of CAP were to increase overall agricultural productivity in the post war era, in order to safeguard food security within Europe, along with providing suitable living standards for farmers and farming communities (Hird et al., 2013). Since the CAP was introduced in the late 1950's, a number of reforms have occurred which has seen a shift in how subsidies are allocated to farmers. Initially sheep farmers received direct support for the price that they received for finished lambs. This then evolved to a headage payment based on the ewe numbers and more recently to a land-area based system (Thompson, 2009).

In 2000, the CAP was divided into two main pillars: production support (as previously discussed) and rural development. The latter proposes measures towards more 'greener' farming approaches, such as by improving biodiversity through land conservation as well as improving animal welfare standards. Other aspects of the reform include encouraging younger farmers to go into farming, as well as promoting diversification. This restructuring of the industry towards rural development is likely to make considerable changes to agricultural land use, with competing opportunities for farmers from sectors such as forestry and tourism. Indeed, the reliance from off-farm incomes is demonstrated from surveys which have shown that approximately 42% of the average overall income from specialist sheep farms in Scotland is created from off farm activities (Scottish Government, 2013). This requirement for alternative incomes is further demonstrated in the northernmost regions of Scotland (namely Caithness and Sutherland) where surveys have suggested that 80% of the total income generated is from non-agricultural sources (Bergmann et al., 2006). This is despite the fact that agriculture has a larger economic importance in these areas, above the national average (Bergmann et al., 2006). The retargeting of support towards rural development programmes could mean certain sectors will notice wider support gaps, which will mean the total amount of subsidy payable to many individual farmers will be lower than previously received (Agriculture and Horticulture Development Board, 2013).

Outside the influence of government policy, an event that has had a significant impact on the UK sheep industry was the outbreak of foot and mouth disease in 2001. The outbreak affected the sheep sector in a number of ways including the loss of an estimated 3.5 million sheep, losses from trade restrictions and over 25% drop in sheep and goat production in the UK compared with the previous year (Canali and Consortium, 2006). The event also resulted in added social repercussions for farmers in terms of distress caused from the prolonged event itself, the aftermath of movement restrictions and the loss of often irreplaceable bloodlines (Mort et al., 2008). The disease outbreak also raises issues around the inadequacies of both exotic and endemic disease control (Sargison, 2009).

The challenges that face many sheep producers demonstrate the sensitivity of the industry to policy change which can have significant knock-on effects for those farmers heavily reliant on subsidization, including reducing workforce as well as flock size. The risks from disease also pose important threats to farm businesses irrespective of scale. These changes will invariably affect the degree of sheep farmers' contributions to the industry and to the rural communities around them. Many of these impositions are outwith the control of most individuals, nevertheless sheep farmers need to consider ways to improve their production efficiency through an evaluation of production limiting issues. The maintenance of a healthy flock is an essential part of sustainable animal production, which is largely dependent on investment in disease diagnosis, control, and management. The requirement to identify and address the key constraints on productivity is critical to the economic sustainability of the sheep farming industry, especially if smaller to medium sized farms are to survive in the long-term future.

1.4 GASTROINTESTINAL NEMATODES

Among the many potential infectious agents affecting sheep farming, gastrointestinal nematodes (GIN) are recognized as one of the major global disease pathogens affecting sheep health, welfare and production. The nematode phylum (*Nematoda*) form a subclass of helminth parasites, distinct from other common closely related endoparasites such as cestodes (e.g. tapeworm) or trematodes (e.g. fluke). As such nematodes, also referred to as roundworms, have unique morphological features including a small, slender cylindrical shape, as well as a complete alimentary digestive tract. The nematode phylum is also the most diverse, with in excess of 70 species isolated from small ruminants (Taylor, 2010). In particular, The Trichostrongylidae family of nematodes contains the majority of parasite species known to cause disease in small ruminants in the UK and elsewhere, which include *Haemonchus contortus, Teladorsagia circumcincta* and *Trichostrongylus* species (Boag and Thomas, 1975).

1.4.1 Life cycle

For the aforementioned parasite genera, the same general life cycle applies as illustrated in Figure 1 and detailed as follows. The first three larval stages (L_1 to L_3) occur in the environment, which is referred to as the free-living phase. Following mating, adult female worms lay eggs within infected animals, which are passed out within faeces onto pasture. Eggs undergo embryonation, development and hatching into first stage larvae (L_1). The L_1 feed on bacteria present in the faeces until they moult into second stage larvae (L_2). A repeat of this process occurs between L_2 and L_3 stages, however the L_2 cuticle is retained to enclose the L_3 within a protective and impermeable sheath. The L_3 stage, which is also known as the infective stage larvae, is unable to feed and therefore relies on food stores within its intestinal cells to survive. The ensheathed larvae migrate from the faeces towards the soil and herbage layers (Soulsby, 1982).

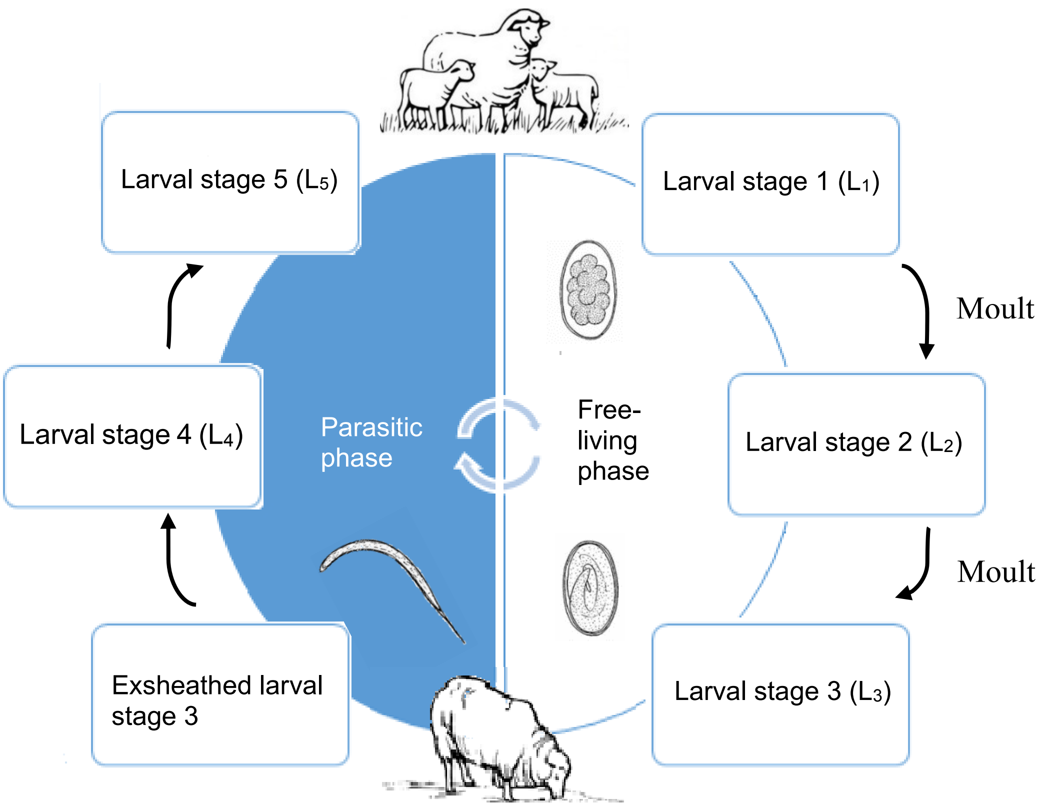


Figure 1 - The basic life-cycle of nematode parasites (adapted from Bartley, 2008)

The larvae then undergo vertical migration up grass at a climate dependent rate, pending ingestion to start the parasitic phase of their life cycle. If the L_3 expend their internal food reserves before they can be ingested they will die. Other associated factors considered to influence larvae mortality rates include moisture levels, temperature and ultraviolet intensity (Rose et al., 2015).

Once L_3 are ingested they target species-specific sites within the gastrointestinal tract (GIT), larvae will exsheath proximally to their predilection site. Once the larvae have migrated to their predilection site they will continue development to L_4 and L_5 stages prior to reaching full maturity. The pre-patent period (PPP) i.e. time from ingestion of

L_3 to producing eggs, is species dependent and may vary between 14 and 42 days' post infection (Soulsby, 1982)

1.5 EPIDEMIOLOGY

The main aspects that have been proposed to dictate the success of an infectious agent include the abilities to establish, persist and spread within a population (Anderson et al., 1986). The numerous biological mechanisms which have contributed to the successes of GIN's as an infectious disease entity will be discussed.

1.5.1 Establishment

The ability for a parasite to infect a host depends on a number of host and parasite specific factors. First, the host specificity of the parasite species determines whether the parasite can infect the host or are alternatively rejected and expelled. The ability for parasites to infect multiple different hosts characterizes the degree of host specificity i.e. from a more generalist host range to a higher host specificity (Poulin et al., 2006). In regards to GIN of ruminants, the specificity is typically high between host species such as sheep and cattle. However, some species are known to infect multiple hosts such as *Haemonchus contortus, Trichostrongylus axei* and *Cooperia spp.* (Roberts, 1942; Borgsteede, 1981).

Once an L_3 is ingested by a suitable host, its survival and further development is dependent on a number of factors influencing the susceptibility or resistance of the host to infection. The primary influence of host susceptibility is the immune status of the individual, which is associated with a range of factors including age, breed, exposure to parasite challenge and physiological factors such as stress, nutrition and reproductive status (Australian Wool Innovation and University of Sydney, 2003).

The transition from an initial innate (non-specific) immune response to a more adaptive (targeted) immune response relies on the exposure of animals to GIN challenge. Consequently, younger immunologically naïve animals are particularly prone to infection in comparison with older grazing animals, which are gradually able to develop their adaptive immune responses. This process requires repeated or continuous parasite challenge to develop, which can also be diminished if animals are safeguarded from infection such as if moved to a worm-free environment or receiving a long acting treatment (Abbott et al., 2004). Although the adaptive immune response can be very effective against the establishment of L_3, it does not provide absolute protection from GIN infection. For instance, where the intake of L_3 from contaminated pasture, also referred to as the infective mass, is sufficiently high to overcome the adaptive immune response (Smith, 2014), or in the case of concurrent infection (Lello, 2012). Nevertheless, the implications of immunity for adult worms has been associated with a reduction in worm length and fecundity (Stear et al., 1997), which has also been correlated with a reduction in faecal egg output (Stear and Bishop, 1999) and egg viability (Jorgenson et al,1998).

In regard to the physiological influences on susceptibility/resistance to GIN infection, circumstances which can impact substantially on animals' immunological capabilities to combat GIN infection include the peri-parturient relaxation in immunity (PPRI). This phenomenon occurs pre/post pregnancy when nutrients namely proteins are diverted from maintenance of immunity to lamb development and lactation. This demonstrates the importance of protein intake for sustaining immune function, which when used in supplementary feeding is able to minimize the effects of PPRI (Donaldson et al., 1998). Additional nutritional requirements for the maintenance of effective immune function include the balance of minerals such as copper and cobalt (Shalaby, 2013).

The variation in immune responses has also be attributed to a genetic component influencing immune competence to GIN infection. For example, certain sheep breeds have been shown to have significant differences in fecal egg output for example include the Red Maasai breed in comparison with the Romney marsh breed (Bain et al., 1993). In a UK context, this has been shown when comparing Scottish Blackface nematode resistance with Finn Dorset and Hampshire sheep breeds (Abbott et al., 1985).

1.5.2 Persistence

Arguably, one of the strongest survival traits of most GIN species is their ability to persist for extended periods within the environment as well as within the host. However, the pre-infective larval stage (L_1-L_2) can also be when the developing parasite is most susceptible, due to environmental factors (O'Connor et al., 2006).

Each of the Trichostrongylus species have distinct seasonalities suited to development under different climatic conditions. For instance, the *Teladorsagia circumcincta* and Trichostronglyus species are more adapted to develop at lower temperatures than species such as *Haemonchus contortus*. Hence, the aforementioned species are more predominant in cooler, temperate climates such as in the Northern areas of Europe, Asia, America as well as New Zealand. The peak development periods are observed in the summer and autumn months in line with warmer, wetter conditions, that enhances activity and consequently reduces longevity. As conditions become cooler, larval activity and metabolism reduces allowing them to prolong their survival. Following the onset of less favourable winter conditions, ensheathed L_3 are also able to overwinter on pasture due to their resistant cuticle layer. The ability to overwinter and persist for long periods is a particular feature of the nematode species *Nematodirus battus*, which requires a period of cool conditions followed by a period of warmer temperature in order to hatch typically in the springtime. This mass hatching of *N. battus* poses a significant risk for susceptible first season lambs, which if unmanaged can often result in severe clinical disease and death in many cases.

Within the host, L_3 are also able to prolong survival by delaying their development to L_4, therefore becoming dormant (hypobiotic) until triggered by cues such as hormonal or immune changes, which coincide with improved external conditions. Within the tropic and subtropical areas, species such as *Haemonchus contortus* are the major contributors to parasite disease, due to their adaption to warmer climates. Increasingly more occurrences of *H. contortus* are reported within the UK (van Dijk et al., 2008).

The survival mechanisms enacted by the parasite species mentioned ensure that sufficient populations' sizes of both free-living and parasitic stages are present throughout the year, in order to maintain regeneration in the face of ever-changing climatic and management conditions.

1.5.3 Spread

Nematodes are understood to have two fundamental mechanisms for increasing their transmission potential, either by producing large numbers of short-lived offspring or producing a low number of long-lived offspring (Rea and Irwin, 1994). From this theory, it has been proposed that transmission potential may be a product of both offspring production and larval survivability, which may be associated with parasite virulence (Medica and Sukhdeo, 2001). As previously discussed larval survivability is an important feature of GIN species, and as such is likely to increase the likelihood of transmission between hosts. The fecundity i.e. the ability to reproduce is also thought to play an important role in the dispersal and transmission process (Rea and Irwin, 1994). The variability in fecundity between GIN species is extensive with studies indicating egg production per worm for *T.circumcincta* at between 0-350 per day (Stear et al., 1999) compared with *H. contortus* where an average adult female was shown to produce 4,700 eggs per day (Coyne and Smith, 1992). This disparity in fecundity has been linked to a variety of factors including the extent of larval survival, parasite burden, in addition to level of virulence

A common measure for transmission potential of infectious agents is the basic reproduction number (R_0), which is used to estimate the number of secondary cases resulting from an infectious individual, with $R_0>1$ signifying the ability of a parasite to maintain itself in the host population. This concept has also been adapted to estimate the dynamics of free living and parasitic stages of macro-parasites (Roberts and Heesterbeek, 1995). Evaluations of R_0 have also been investigated in relation to different countries conditions including New Zealand, Australia and the UK. Figures for the UK and New Zealand suggest R_0 values for *T. circumcincta* in naïve lambs to be as high as 16, which emphasizes the importance of this species to young lambs in temperate climates (Kao et al., 2000).

In regard to host related factors which are important for transmission potential, these include aspects such as larval ingestion rate and host density, which are largely influenced by host grazing behaviour and flock management. Research into the sheep grazing behaviours indicates a dynamic selective grazing process in relation to nutrition and parasitism. Attraction of sheep towards nitrogen rich swards has been observed, in addition to swards containing calcium oxide and crude fibre content (Hunter, 1962). However, particular aversion towards contaminated areas were observed regardless of nutritional content or host immune and parasitized statuses (Hutchings et al., 1999). Although in certain reproductive circumstances such as with ewes bearing twins lambs, the added risks of parasitism from grazing nutrients rich contaminated areas were necessary for lamb development (Smith et al., 2006). This may also influence grazing behaviours of sheep in extensive grazing systems where selective grazing is also observed due to the general nutrient-deficient herbage, which is significantly improved through faecal contamination (Edwards and Hollis, 1982). This work suggests an inevitable trade-off between nutritional benefits and potential parasitism in foraging decisions (Hutchings et al., 2000).

The grazing behaviours are also likely to be influenced by host/stocking density due to flock management, with more intensive systems resulting in greater grazing competition, lower nutrient intake, and closer proximity of animals to infectious pastures and ultimately greater severity of disease (Thamsborg et al., 1998). The spread of parasites is also likely to occur due to the movement of animals for breeding purposes or for those sold as store stock for fattening in productive grazing areas. This movement could introduce non-endemic species or genotypes into the resident parasite population that may possess advantageous mechanisms for development or survival in the new system.

1.6 EFFECTS OF GASTROINTESTINAL NEMATODES ON SHEEP HEALTH AND PRODUCTION

The impacts associated with GIN infection can have varying pathophysiological effects on animals depending on the parasite species involved and the immune competency of the host. The effects on animal morbidity can range from generally chronic subclinical disease to severe clinical illness, as well as animal mortality where severe parasitism exists. The impacts of GIN affect both young lambs as well as older adult stock with significant implications on the health, welfare and production of grazing animals.

1.6.1 Pathogenesis

GIN genera such as *Teladorsagia*, *Trichostrongylus* and *Nematodirus* species can be characterized as causing clinical signs relating to gastroenteritis. The main features of clinical disease include appetite suppression, impaired GIT function and altered metabolism of proteins, energy or minerals leading ultimately to reduce body condition (Fox, 1997). The other distinctive clinical indicator of GIN infection is anaemia as a result of *Haemonchus* infection, which causes signs such as pale mucous membrane and oedema of the submandibular tissues known commonly as bottle-jaw.

Abomasal parasites including *T. circumcinta* firstly infect the gastric glands within the mucosal membrane of the abomasum. As the parasite undergoes development, it releases excretory products acting upon the hydrochloric acid producing parietal cells leading to local cell damage as well as triggering inflammation of the mucosal surface (Simpson, 2000). The damaged cells are then replaced with undifferentiated, non-acid producing cells causing a rise in pH levels in the abomasum. Alterations in the abomasal environment and impairment lead to loss of serum plasma proteins and adverse effects on the nutrition of the host. These processes manifest in the host with clinical signs including reduced appetite, diarrhoea, dehydration and weight loss.

In the case of *Haemonchus* infections, the main pathological effects are attributed to blood loss, due to the haematophagic activity of the parasite. The high biotic potential of the parasite can result in substantial burdens on the host, with an average infection estimated to remove around 400mls of blood per day (Sutherland and Scott, 2009). The loss of blood and proteins during the haemonchosis infection consequently leads to characteristic clinical signs associated with anaemia, which can result in death in severe cases if left untreated.

1.7 ECONOMIC IMPORTANCE AND CHALLENGES ASSOCIATED WITH GASTROINTESTINAL NEMATODES IN SMALL RUMINANTS

Gastrointestinal nematodes have been credited as one of the greatest economic concerns for the global sheep and cattle industries (Perry et al, 2002; Nieuwhof and Bishop, 2005). Of the world's largest sheep producing countries including Australia, New Zealand and the UK, production losses attributed to GIN are estimated to cost in excess of $222 million (Mcleod, 1995), $275 million (Brunsdon, 1988) and £84 million (Nieuwhof and Bishop, 2005), respectively.

The costs incurred from GIN disease and control are manifold and extend to cover many different types of resources including production outputs such as live-weight gain, reproduction rate, mortality rates, as well as inputs such as feed, labour and veterinary/treatment costs. Despite the identification of the relevant parameters involved in GIN disease control, in practice the challenging nature of helminth epidemiology and the influence of variable host and climatic conditions complicate the reliability of production estimates (Tisdell et al., 1999). Additionally, the correlation between diagnostic tests and disease burden and production impacts, adds further uncertainty for determining the economics of GIN control (Charlier et al., 2014).

Nevertheless, different approaches to assess the economic impacts of GIN disease and its control have been undertaken. For example, the functional relationship between anthelmintic control strategies and the profitability of outputs has been explored. Experimental studies in Australia, investigated the economic benefits between two anthelmintic treatment regimens for ewes and lambs. This demonstrated an increased profitability from using a strategic prophylactic treatment strategy in comparison to a 'traditional' preventive treatment scheme based on responses from surveyed farmers (Anderson et al., 1976; Morris et al., 1977). The increased monetary value from ewe production was attributed to an increase in wool quantity and quality per head, and to a lesser extent from improvements to weight gain (Morris et al., 1977). From the lamb production perspective this was attributed to the reduction in mortality rates between the 'strategic' and 'traditional' treatment schemes (Anderson et al., 1976).

Such studies potentially help to identify the optimal treatment strategies to satisfy the requirements of the farming system. However due to the wide variability of farming environments and production systems, it is unfeasible for extension efforts to optimize economic strategies for all individual circumstances, therefore more generalized estimates are permitted based on average conditions. Where necessary further structuring can be applied to implement more specific advice in connection with the aims and objectives of the individual producer (Tisdell et al., 1999). This may include trying to establish the relationship between expenditure on disease control and the cost of the disease itself which is an important consideration for optimizing economic efficiency (McInerney et al., 1992).

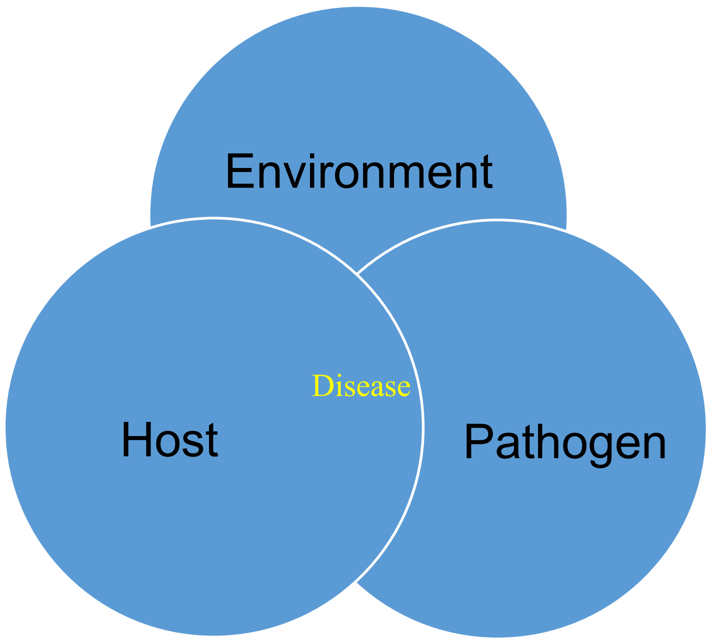


Figure 2 - Basic disease model representation (Adapted from Francl, 2001)

1.8 GASTROINSTINAL NEMATODE CONTROL STRATEGIES

The development of effective control strategies relies on a sound understanding of the epidemiology of the pathogen. Knowledge of the life cycle and the factors influencing its progression is fundamental to targeting strategies corresponding with each stage of parasite development. Essentially the disease model as illustrated in Figure 2, represents the overarching mediators of disease development. Each of these components is required for disease to occur, and therefore if one of these is affected then the likelihood of disease is reduced. The following control strategies will discuss means of targeting the parasite both within the environment during the free-living parasite stage as well as within the host parasitic stages.

1.8.1 Non-chemical control strategies

1.8.1.1 Grazing management

1.8.1.2 Mixed/alternate grazing

This approach can either utilize host specificity or host susceptibility depending on which species of animals are available. The former relies on either concurrent or alternation of grazing with different host species such as a combination of small ruminants with cattle or horses, with each species possessing distinct parasite specificities (illustrated in Figure 3). This enables each host species to reduce the density of infective larvae for the other host species. The same principle applies with grazing animals of the same species; however, in this case animals with greater resistance (acquired immunity) to infection i.e. dry, adult stock would be used to reduce the density of infective larvae for more susceptible stock such as first season lambs (illustrated in Figure 4).

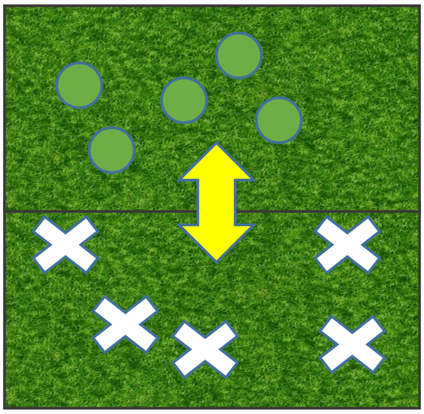


Figure 3 - Representation of rotational grazing system between animal species with distinct host specificities (Adapted from Buckingham et al., 2013).

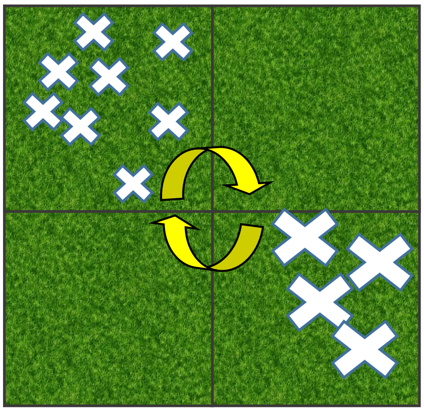


Figure 4 - Representation of rotational grazing system between more parasite-resistant stock (X) grazing ahead of more parasite-susceptible stock (x).

There are however, considerations that need to be made when employing such methods including the timing intervals between alternation of grazing species and the possibility of cross-infection between alternate host species. The timing between alternations of host species is important for ensuring that the period of peak larval availability coincides with the less susceptible host. This is however variable to parasite seasonality's and climatic conditions. Furthermore, there are reports of cross infection of certain parasite species between alternate hosts, primarily from cattle parasites (e.g. *Ostertagia ostertag*i) to sheep or vice versa (e.g. *Haemonchus contortus*) (Barger, 1999).

1.8.1.3 Rotational grazing

This method of grazing management involves an intensive subdivision of pasture, which allows a short period of concentrated grazing and contamination followed by a much longer resting period to allow pasture regrowth and reduced infectivity of pasture due to larval die off from the previous grazing period (illustrated in Figure 5). Establishing the optimal length of time between grazing and resting is challenging particularly in cooler, temperate climates where infective larvae may persist in the environment anywhere from 3 to 9 months. This practice has been more successful when conducted in warmer, tropical conditions where larval development and survival periods are much shorter (3 to 7 weeks) and therefore allows easier estimations for optimising rotation periods (Barger et al., 1994).

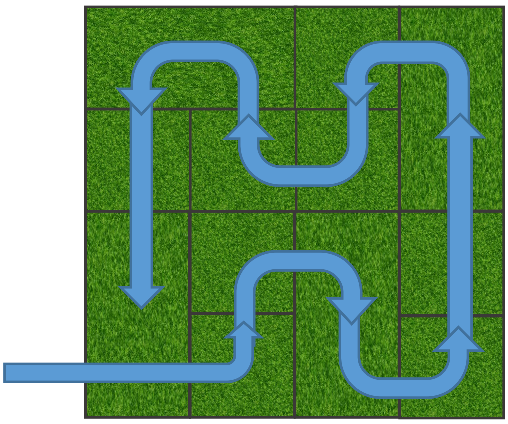


Figure 5 - Illustration of a rotational grazing paddock system with blue line indicating animal movements (Adapted from Buckingham et al., 2013).

1.8.1.4 Biological controls

The discovery of microorganisms, principally the nematophagous fungi, *Duddingtonia flagrans* that are able to feed on the free-living nematode stage, offers a promising prospect for a biological control alternative. The capabilities of this organism include the survival of passage through the GIT of livestock species such as sheep (Fontenot et al., 2003), cattle (Dias et al., 2007) and horses (de Andrade et al., 2016), as well as an ability to grow within fresh faeces in both temperate (Larsen et al., 1995) and tropical climates (Chandrawathani et al., 2004). Different formulations of *D. flagrans* products have been developed including feed blocks (Chandrawathani et al., 2004; Waller, 2006b) and a controlled release device (Waller et al., 2001). The limitation of using nematophagous fungi is the longevity of control achieved from the available formulations, with overall 3-week persistence from using a controlled release device. Additionally control is limited to the proximity of fresh faeces and as such has demonstrated little effect on nematodes present in the soil layers (Faedo et al., 2002) where substantial numbers of nematodes have been found (Callinan and Westcott, 1986). The potential of this method for reducing parasite survival and therefore providing an additional means of controlling nematodes is an important candidate for a commercial non-chemical alternative.

1.8.2 Chemical control options

Anthelmintics are chemical compounds that are licensed for the control of a wide spectrum of establishing and existing helminth parasites within a host. Since the 1960's the introduction of broad-spectrum anthelmintics has revolutionized the way in which GIN are managed, and accordingly has enhanced the global scale of grazing livestock production. The benefits that such treatments have afforded to producers include high efficacies, a broad spectrum of activity, good safety margins and ease of use, which all contributed to the successes of both farming and pharmaceutical industries and an infallible impression for the future of parasite control (Waller, 2006a).

1.8.2.1 Broad and narrow spectrum anthelmintics

Currently there are five distinct classes of broad-spectrum anthelmintics licensed for sheep within the UK. The compounds differ in their chemical structure and modes of action as detailed in Table 1. Furthermore, the spectrum of parasite activity and efficacy of control against each genus/species can differ between anthelmintic classes. For specific nematode control, various narrow spectrum anthelmintics are available which offer more targeted control of certain parasite species e.g. closantel effective against *H. contortus* and *Fasciola hepatica* (liver fluke) or triclabendiazole for the control of liver fluke. It is also important to note that anthelmintics may only have a label claim against certain stages of a parasites life cycle, which is relevant to immature liver fluke and hypobiotic stages of certain nematode parasites such as *T. circumcincta* and *H. contortus*.

1.8.2.2 Anthelmintic formulations

There is a range of different delivery systems available for anthelmintic treatments designed principally at either improving drug persistence or for their ease of use e.g. oral drench, injectable, paste, in-feed, pour-on and controlled release devices (i.e. boluses). Only certain anthelmintic class products are available in each formulation, such as with injectable treatments limited to the 3-ML and 2-LV groups and pour-on treatments only available as a 3-ML treatment. Although all the mentioned formulations have been developed for use in both sheep and cattle and are sold internationally, within the UK however, treatments for sheep are limited to the oral and injectable forms, whereas all formulations are available for use in cattle.

1.8.2.3 Long-acting (persistent) anthelmintics

The persistent characteristics of an anthelmintic drug are determined by its pharmacokinetic properties i.e. the effect of the body on the drug. These properties influence a number of important factors including the absorption, distribution, metabolism and excretion of a drug, which influences both its efficacy persistence and withdrawal time (Vercruysse and Claerebout, 2017). The majority of anthelmintics have a relatively short duration of activity post treatment ranging between 24 and 36 hours. The only anthelmintics licensed in the UK with persistent activity are products containing moxidectin. The length of persistence also varies depending on the parasite species present, the dose rate and route of administration, for example oral moxidectin has persistent effects in preventing re-infection by *T. circumcinta* and *H. contortus* for 5 weeks, whereas moxidectin injection can maintain the same activity for at least 97 and 111 days respectively (NOAH Compendium, 2017).

Table 1 – Details of current broad-spectrum anthelmintics including mode of action, active ingredient and parasite acivity (adapted from Abbott et al, 2012).

Anthelmintic class	Chemical name	Initial release year	Product colour	Mode of action	Active ingredient(s)	Parasite activity		
						GIN*	Cestode	Lungworm
Class 1	Benzimidazoles (1-BZ)	1960	White	Inhibits tubulin activity in intestinal cells of nematodes or tegumental cells of cestodes	Albendazole	+	+	+
					Fenbendazole	+	+	+
					Mebendazole	+	+	+
					Oxfendazole	+	+	+
Class 2	Levamisole (2-LV)	1968	Yellow	Nicotinic antagonist acting on the nerve ganglion of the parasite, causing paralysis	Levamisole	+		+
					Morantel-citrate	+		+
Class 3	Macro-cyclic Lactones (3-ML)	1981	Clear	Act on glutimate-chloride ion channels, blocking interneuronal stimulation leading to paralysis	Doramectin	+		+
					Avermectin	+		+
					Ivermectin	+		+
					Moxidectin	+		+
Class 4	Amino-acetonitrile derivatives (4-AD)	2010	Orange	Acts on nicotinic acetylcholine receptor causing paralysis	Monepantel	+		
Class 5	Spiroindoles (5-SI)	2012	Purple	A nicotinic cholinergic antagonist, which blocks neuromuscular transmission and induces flaccid paralysis	Derquantel & Abamectin	+		+

*GIN, gastro-intestinal nematode

1.8.3 Anthelmintic treatment strategies

With the introduction of highly effective chemicals to treat clinical disease, over time a number of chemical control strategies have been developed in conjunction with grazing management with the aim to either suppress or evade nematode infection. The ability to implement each of these strategies is dependent on a number of factors influencing the parasite epidemiology such as climate and farming system as well as the requirements of the farmer. Examples of such treatment programmes and the rationale behind their use will be discussed further in this section.

1.8.3.1 Set drench programmes

This approach was developed with the introduction of anthelmintic treatments and involves the administration of a blanket treatment to a group at regular intervals. These intervals generally coincide with the pre-patent period of the intended parasite, which during the summer may vary between 2-3 weeks. The application of treatments at these intervals suppresses the ability of larvae to develop into the adult egg producing stage and therefore prevents further contamination on pasture. Studies have shown the potential benefits of such an approach for suppressing development of future generations of parasites, which reduces the threat of serious helminthiasis. However, it has been proposed that the short duration of protection will not prevent exposure of animals to pasture infestation in the interim between treatments, which will consequently result in no immunity built up (Brunsdon, 1980). The use of long-acting anthelmintic treatments, which is an alternative suppressive control method, has been shown to reduce pasture contamination and increase daily weight gains in treated lambs (Balmer et al., 2015). However, both of these approaches invariably increase exposure of a large proportion of the parasite population to anthelmintic which is recognized as a major influence on the development of anthelmintic resistance (AR (Van Wyk, 2001; Sargison et al., 2012). Additionally, the use of frequent or persistent treatment regimens has also been demonstrated to impair immune responses to nematode infection compared to untreated animals (Downey et al., 1993).

*1.8.3.2 '*Dose and move'

Dose and move is perhaps one of the most effective and widely implemented nematode control practices utilized by livestock producers to maximize live weight gain; this preventive strategy involves putting anthelmintic treated animals directly onto a parasite 'clean' grazing such as an aftermath or pastures used by less susceptible stock e.g. dry, adult ewes. The low risk grazing enables animals to optimize their productivity for a prolonged period by substantially reducing the rate of re-infection compared with higher risk pastures (Waller, 2006b). This allows animals to go untreated for considerably longer when compared to a move without treatment, which is considered a less efficient control method (Boa et al., 2001). The main concern for this approach however is the greater risk for AR selection as a result of a low 'refugia' parasite population, which is a concept that is further discussed in section 1.11.4.

1.8.3.3 Strategic

The aim of a strategic treatment method is to prevent an accumulation of parasite larvae contaminating pasture by removing the parasite burden before it can produce sufficient quantities of eggs (Barger, 1999). The approach is reliant on the understanding of patterns associated with seasonality and intensity of contamination relating to various GIN species, which is influenced by climatic and flock management conditions (Sutherland and Scott, 2009). These treatment decisions may also consider different degrees of parasite susceptibility depending on the characteristics of the flock. For instance, different age groups i.e. between adult ewes and naïve lambs, will necessitate treatments at different times of the years. For adult stock this would be most notable for lambing ewes as a result of PPRI. In temperate climates where conditions are more likely to be unfavourable for larval overwintering, the lambing period will contribute largely to the contamination of pastures. Treatments coinciding with PPRI will consequently help to reduce the extent of pasture contamination, which will benefit young lambs grazing later in the season. This knock-on effect is imperative for reducing the peak larval challenge especially for first-season lambs throughout the grazing season, as illustrated in Figure 6.

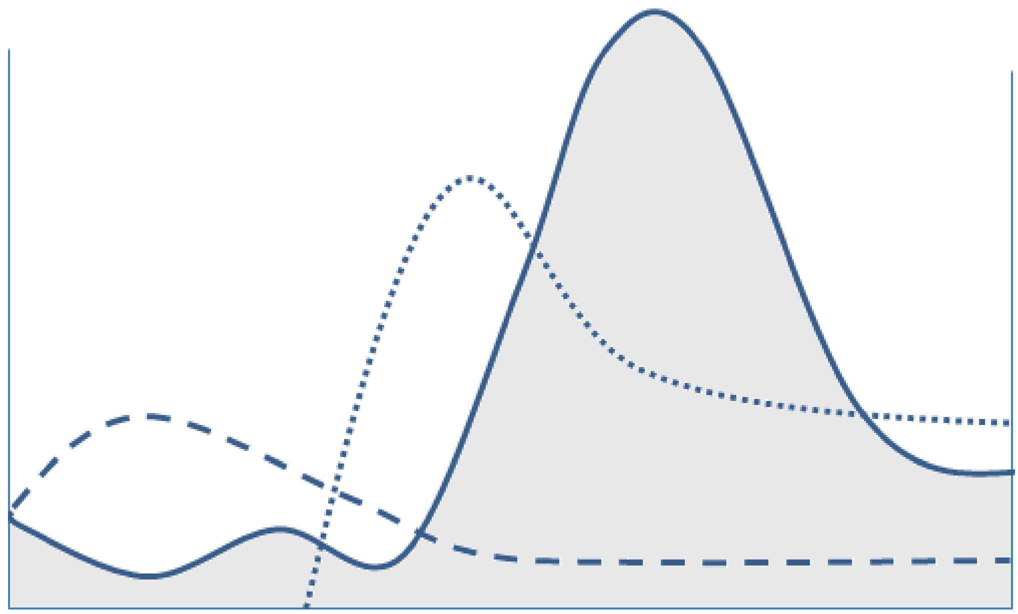


Figure 6 - The impact of the PPRI on faecal egg output and pasture contamination (Adapted from (Sargison, 2009).

For lambs, strategic treatments may be given at weaning time when temperatures are more conducive to larval development on pasture. Subsequent lamb treatments may be given during the peak grazing season depending on the availability of safe grazing and through monitoring of faecal egg counts and clinical disease.

In climates where extreme conditions prompt high larval mortality on pasture, treatments may be given early in such circumstances which enable extended periods of low contamination and subsequent low re-infection rates (Barger, 1999). Furthermore in conditions where *H.contortus* or *T.colubriformis* predominate, treatments may be timed together with the acquisition of immunity. This strategy enables already residing parasites to be expelled, whilst reducing establishment of new infection through an acquired immunity. This strategy may be most applicable to the treatment of ewes in the late stages of lactation as this typically indicates the reoccurrence of immunity (Barger, 1999).

1.9 FACTORS AFFECTING ANTHELMINTIC EFFICACY

A number of different issues may be linked to a reduction or complete failure of an anthelmintic treatment to resolve both sub-clinical and clinical disease. The factors associated with the variability of anthelmintic efficacy are further discussed in relation to the identification of disease, the product used, treatment administration as well the characteristics of the host and parasitic activity.

1.9.1 Aetiological identification

Before an appropriate course of action can be taken to treat an animal for GIN, it is important to establish the correct causative agent connected with the observed clinical signs. As signs of PGE can be connected to a range of health issues, it may be difficult to ascertain the cause through physical assessment alone. For that reason, further information may be required to differentiate the probable cause including a history of previous anthelmintic treatments and grazing management or the use of a diagnostic test such as a faecal egg count (Sargison, 2009).

1.9.2 Anthelmintic product

As of the time of writing there are 64 anthelmintic products commercially available for sheep (Sustainable Control of Parasites in Sheep, 2016), consisting of a range of both broad and narrow spectrum treatments providing activity against a variety parasite species. With this in mind, it is important to match the product with the target parasite that it is licensed to control. Failure to do so may result in unsuccessful control and further production losses.

Additionally, the formulation of an anthelmintic will have an influence on its pharmacokinetics properties and as a result will affect a number of characteristics including the duration, meat withdrawal period and level of treatment efficacy. This has been demonstrated in comparative studies investigating differences in treatment efficacy between injection and oral formulations of moxidectin in sheep (Gopal et al., 2001) as well as in cattle, with the addition of a pour-on formulation comparator (Leathwick and Miller, 2013).

Differences in the quality of anthelmintic products has also been observed in the case of generic products. Van Wyk et al (1997) demonstrated a substandard treatment efficacy of three commercially rafoxanide products available in South Africa, against known susceptible and partially resistant strains of *H. contortus*. The results showed treatment efficacies as low as 66% in the susceptible isolate and 28% in the partially resistant isolate. It is proposed that the issues related to generic products are likely to be attributed to the traceability of different batches of the active ingredients as well as the inadequacies of testing between batches of product.

Once an anthelmintic product is purchased it is also important to ensure that appropriate storage conditions are employed i.e. is away from direct sunlight at between 4-25°C (Sustainable Control of Parasites in Sheep, 2016), as well as adhering to the use-by date. By following these directions this helps to safeguard the integrity of the product, which will aid to conserve the efficacy of treatments.

1.9.3 Dose determination and administration

In order for animals to receive the correct dose of anthelmintic as per the manufacturer's instruction three main criteria must be met. Firstly, an accurate measure of the animals' weight is required for an accurate determination of treatment dose. A study by Besier and Hopkins (1988) was conducted to establish the accuracy of sheep farmers' weight estimations for heaviest ewes and lambs in a group of 10-20 animals. The overall results demonstrated a low accuracy of weight estimation with only 27% of all farmers questioned, correctly estimating within 20% of the actual weight. Eighty-six per cent of all responses were below the correct weight, which demonstrates a tendency of most farmers to underestimate animal weights. Furthermore, the study also indicated that miscalculation of drug volume was also a cause of inaccurate dose determination. The potential consequences of under-dosing not only can result in a suboptimal reduction in parasite burden, but can additionally select for AR, which is discussed further in section 1.11.2.

Another potential cause for inaccurate dosing of animals is the equipment used to administer treatment. Drenching guns used to administer and regulate the volume of each treatment dose may change inadvertently through usage which consequently can result in inaccurate treatment dosages being given. The final step, the dosing technique itself, can have a major effect on how the drug is distributed and metabolized. For oral formulations, the treatment should be delivered over the tongue into the oesophagus where it then enters the rumen to be metabolized. The rumen acts as a drug reservoir by slowing the passage of unabsorbed drug through the GIT, and as a result sustains plasma drug concentrations (Vercruysse and Claerebout, 2017). If, however the treatment is administered into the buccal cavity, the treatment may by-pass the rumen and go directly into the abomasum, which can shorten the duration of absorption and increase its excretion, which ultimately may reduce treatment efficacy (Vercruysse and Claerebout, 2017).

1.9.4 Animal physiology

The physiological characteristics of the host can have substantial effects on the way in which anthelmintic treatments are metabolized, absorbed and transported to the desired sites of parasitism, which subsequently effects the potential efficacy of treatments (Prichard, 1985). Such factors influencing the host-drug interaction may be inherent within the host such as breed or species differences. Other factors may be related to the physical condition of the host which may depend on aspects such as the nutritional or disease state.

In regards to species differences, when comparing sheep and cattle pharmacologic responses to albendazole (ABZ) administration, the biological half-life of the active metabolite was significantly higher in sheep compared with cattle, consistent with a lower plasma concentration of ABZ in sheep compared with cattle (Delatour et al., 1990). However, when comparing the kinetics of oxfendazole treatment between goats and sheep, the converse responses were found with sheep demonstrating a higher systemic availability of metabolite compared with goats together with a slower rate of elimination, suggesting a greater rate of metabolism in goats than in sheep (Hennessy et al., 1993).

The age and sex characteristics are also known to influence the pharmacokinetics of anthelmintic treatment. In young lambs a prolonged elimination time is observed as a result of an immaturity of metabolizing enzymes and excretion mechanisms. For this reason, young lambs are considered to be much greater risk of drug toxicity than older animals. Between ewes and rams, a longer elimination time was found in ewes compared with rams when administered with an ABZ treatment. Furthermore, plasma concentrations were higher in ewes than in rams. The pharmacological differences are considered to be influenced by a number of physiological factors such as sex hormones, body mass, plasma volume and plasma protein content (Krizova-Forstova et al., 2011).

The nutritional status of the host plays a significant role in the uptake of enterically administered anthelmintic treatments. Studies comparing the pharmacokinetics of benzimadazole administration between different grades of satiation demonstrated that animals which were fed half equivalent of others had a significantly increase in anthelmintic efficacy (Ali and Hennessy, 1995). Additionally, animals starved for 24 hours prior to treatment obtained the same bioequivalence of anthelmintic compound as fed animals administered a 50% higher dose. This difference in treatment efficacy is attributed to a reduction in gut flow rate in fasted animals, allowing a greater level of metabolism and absorption (Lifschitz et al., 1997).

The pathological state of the host has been shown to influence the activity of anthelmintic treatments. This occurrence is true of various infectious and non-infectious diseases affecting the function of the liver and gastro-intestinal tract. Examples where helminth disease is known to influence anthelmintic efficacy may include *Fasciola hepatica* (Liver fluke) infection where impairment of drug-metabolizing enzymes reduces the bio-transformation and subsequent drug bioavailability (Krizova-Forstova et al., 2011). In addition, infection with abomasal parasites such as *T. circumcincta* and *T. colubriformis* can impact the pH levels within the abomasum. The rise in pH caused by the disease pathogenesis is thought to reduce the solubilisation of the anthelmintic, thereby reducing the drug absorption potential (Prichard, 1980; Marriner et al., 1985). Furthermore, parasitized animals demonstrate a lower moxidectin drug deposition as well as increased drug clearance compared to parasite naïve lambs. It is proposed that parasitism may influence the fat composition of animals important for moxidectin binding and deposition (Lespine et al., 2004).

The ability for a sufficient anthelmintic dose to reach the target parasite is not only important for effective nematode control but also regarding the development of AR. This is due to the understanding that the presentation of a non-lethal dose may allow partially resistant parasites to survive treatment and continue development within the host (Prichard, 1985).

1.10 ANTHELMINTIC RESISTANCE

As described in previous sections, there has been a progression of modern major sheep producing countries towards more commercial, intensive based systems, tailored primarily towards lamb meat production. As such, the epidemiology of parasitic disease under these conditions has altered with heightened parasite-host interactions, to the detriment of the more susceptible host species. In the advent of anthelmintic treatments, attempts of sheep producers to eliminate the threat of parasitic infection was countered by the emergence of AR, discovered only three years after the release of the first broad-spectrum anthelmintics (Kaplan, 2004).

Anthelmintic resistance can be defined as ‘a heritable reduction in the sensitivity of a parasite population to the action of a drug’ (Conder and Campbell, 1995). As this statement asserts, the development of AR is a genetic phenomenon passed down through future generations, which jeopardizes the efficacy of chemotherapeutic control strategies. The evolutionary abilities of nematodes have seen nematode species diverge, colonize and co-evolve with their various hosts across the globe for millennia (Stear et al., 2011). This high evolutionary potential has been proposed to be determined by three main selective forces influencing the rate of evolution including the generation interval, effective population size and the intensity of selection (Nicholas, 1987). As most GIN species have short generational intervals coupled with a large population size, the selection pressure applied by highly efficacious chemical treatments has had the potential to substantially increase the rate of evolution towards an AR dominant parasite population.

1.10.1 Prevalence

The earliest reports of AR in sheep originated from countries within the southern hemisphere including Australia, New Zealand, South Africa and South America, where conditions are recognized as more favourable to parasite development and successively AR development (Waller, 1987). This may be attributed to climatic conditions which either permit longer grazing seasons, which in turn may result in a greater frequency of anthelmintic treatment given (Consultation, 2006). Or alternatively more arid conditions which can impact heavily on the maintenance of a susceptible refugia population (Shalaby, 2013).

It is now evident that the development of AR is a global phenomenon with studies identifying AR to single and multiple anthelmintic drug classes as detailed in Tables 2 and 3. As most initial reports of AR were targeted from farms either experiencing severe drug inefficacy or farms considered to be at high risk based on certain parasite management practices used (discussed further in section 1.11); Such reports may only represent the ‘tip of the iceberg’ and therefore efforts to conduct more representative prevalence studies using larger-randomly selected samples have been used.

Details of AR reports and prevalence studies within the UK (presented in Table 2) demonstrate widespread resistance, primarily within the 1-BZ anthelmintic class, but increasingly within the alternative classes. 1-BZ resistance was first reported in Britain in 1982 (Britt, 1982) and since then the occurrence of AR to multiple anthelmintic drug classes have been reported in various regions of the UK including Scotland (Bartley et al., 2004; Sargison et al., 2007), England (Taylor et al., 2009) and Wales (Thomas, 2015). Elsewhere in the world, severe or complete inefficacy have also been reported (details in Table 3) primarily within the humid tropic/subtropics regions including Malaysia (Chandrawathani et al., 2004), Paraguay (Maciel et al., 1996) and South Africa (Van Wyk, 1990). Similar observations have also reported in the UK (Sargison et al., 2005; Blake and Coles, 2007). In such cases the loss of production from either insufficient flock weight gains or mortality considerably impacts the economic viability of the operation, resulting in some producers withdrawing from sheep farming (Waller, 2004).

Table 2 - Previous AR surveys conducted in UK sheep flocks (Adapted from Jackson and Coop, 2000)

Region	Type of study	No. of farms tested	AR detected	Percentage positive (%)	Dominant species	Reference
Scotland	S	90	1-BZ	64	Teladorsagia	(Bartley et al., 2003)
Scotland	S	37	1-BZ	24	Teladorsagia	(Mitchell et al., 1991)
SE/C Scotland	S	38	3-ML	66-92	Teladorsagia	(Bartley et al., 2006)
N. Ireland	S	27 7 35	1-BZ 2-LV 3-ML*	81 14 57	Trichostrongylus	(McMahon et al., 2013a)
Wales	S	122	1-BZ 2-LV 1-BZ & 2-LV	46 5 31	Teladorsagia	(Mitchell et al., 2010)
SE England	S	52	1-BZ	14	Haemonchus	(Cawthorne and Cheong, 1984)
SW England	R	84	1-BZ 2-LV	44 1	Teladorsagia	(Hong et al., 1996)
NE England	R	54	1-BZ	15	Teladorsagia	

R= Randomised, S= Selective. * An aggregation of tests against Avermectin and Moxidectin.

Table 3 – Reported cases of anthelmintic resistance in small ruminants worldwide, selected references.

Country	BZ	LV	ML	AD	SI	Reference	Country	BZ	LV	ML	AD	SI	Reference
Algeria	+	-	+	-	-	(Bentounsi et al., 2007)	Morocco	+	-	-			(Berrag et al., 2009)
Argentina	+	+	+	-	-	(Eddi et al., 1996)	Netherlands	+	+	+	+	-	(Borgsteede et al., 2007; Van den Brom et al., 2015).
Australia	+	+	+	+	+	(Jambre, 1993; Overend et al., 1994; Sales and Love, 2016).	New Zealand	+	+	+	+	-	(Sutherland et al., 2008; Scott et al., 2013)
Belgium	+	-	-	-	-	(Vercruysse et al., 1989)	Pakistan	+	+	-	-	-	(Muhammad et al., 2015)
Brazil	+	+	+	-	-	(Echevarria et al., 1996)	Paraguay	+	+	+	-	-	(Maciel et al., 1996)
Cameroon	+	-	-			(Ndamukong and Sewell, 1992)	Philippines	+	-	-			Ancheta (Ancheta et al., 2004)
Colombia	+	+	+	-	-	(Garcia et al., 2016)	Slovakia	+	-	+	-	-	Dolinská (Dolinska et al., 2014)
Costa Rica	+	-	+	-	-	(Maroto et al., 2011)	South Africa	+	+	+	-	-	(Van Wyk et al., 1999)

Table 3 – Reported cases of anthelmintic resistance in small ruminants worldwide, selected references.

Country	BZ	LV	ML	AD	SI	Reference	Country	BZ	LV	ML	AD	SI	Reference
Denmark	+	+	+	-	-	(Maingi et al., 1996)	Spain	+	+	+	-	-	(Martinez-Valladares et al., 2013)
Ethiopia	+	+	+			(Sissay et al., 2006)	Sweden	+	-	-	-	-	(Hoglund et al., 2009)
France	+	+	-	-	-	(Chartier et al., 1998)	Switzerland	+	-	+	-	-	(Artho et al., 2007)
Germany	+	+	+	-	-	(Voigt et al., 2012)	Sri Lanka	+	-	-	-	-	(Van Aken et al., 1989)
Greece	+	+	+	-	-	(Geurden et al., 2014)	Tanzania	+	-	-	-	-	(Maingi et al., 1996)
India	+	+	-	-	-	(Easwaran et al., 2009)	Thailand	+	-	-	-	-	(Kohapakdee et al., 1995)
Italy	-	+	+	-	-	(Traversa et al., 2007)	Turkey	-	+	+	-	-	(Kose et al., 2007)
Kenya	+	+	+	-	-	(Waruiru et al., 1997)	Uruguay	+	+	+	-	-	(Nari et al., 1996)
Malaysia	+	+	+	-	-	(Chandrawathani et al., 1999)	USA	+	+	+	-	-	(Howell et al., 2008)
Martinique	+	-	-			(Gruner et al., 1986)	Zambia	+	-	+	-	-	(Gabriel et al., 2001)
Mexico	+	-	-			(Torres-Acosta et al., 2003)	Zimbabwe	+	+	-	-	-	(Mukaratirwa et al., 1997)

1.10.2 Detection

Various diagnostic methods have been developed for detecting both the presence of parasitic infection as well as to establish the resistance status of species present within an individual or group. These techniques include both in-vitro and in-vivo methods. The faecal egg count (FEC) test is the most common method used for assessing faecal egg count output as an indicator of GIN burden. The FEC test also forms the basis of in-vivo assessments of anthelmintic efficacy either by use of a faecal egg count reduction test (FECRT) or a post-treatment test.

1.10.2.1 Faecal egg count reduction test

The FECRT is the current gold standard method for determining the resistance status of a parasite population on a property (Sutherland and Scott, 2009). The method assesses the percentage reduction in the faecal egg counts of treated animals compared with an untreated control group. Resistance may be suspected where the percentage reduction is less than 95%. The FECRT procedure involves randomly assigning animals to groups of at least 10, with each group designated for each anthelmintic treatment tested, in addition to an untreated control group. Pre-treatment faecal samples are collected and tested for each group. The treatment groups are then treated according to bodyweight and re-sampled 7-14 days' post-treatment depending on the treatment class used. The pre/post-treatment FEC's are then compared against the control group pre/post treatment FEC's, which provides the user with a quantifiable estimation of treatment efficacy.

1.10.2.2 Post-treatment test

In comparison to the FECRT, the post-treatment test involves the collection and assessment of only samples after treatment is administered. The test is therefore less comprehensive than the FECRT as it does not enable a comparable reference to determine the extent of treatment efficacy. The test result therefore provides evidence of whether the treatment was 100% effective but cannot deduce whether the cause of treatment inefficacy is caused by resistance or from inappropriate treatment technique (Sargison, 2009).

1.11 RISK FACTORS FOR ANTHELMINTIC RESISTANCE DEVELOPMENT

The presence of drug-resistant nematodes within a population is expected to occur on all farms. This is true of all anthelmintic classes, albeit the relative size of these resistant populations is likely to vary considerably, with extremely low proportions likely to occur in the initial periods of drug usage. The subsequent rate at which AR can be selected however is subject to several factors relating to drug selection, drug administration and animal management practices which all influence the epidemiology of resistant parasites.

1.11.1 Treatment frequency/persistence

It is generally accepted that exposure of nematodes to anthelmintic treatment is associated with an increased selective pressure for resistance development. This is due to an increased reproductive advantage of resistant parasites surviving treatment. Without reproductive competition from susceptible worms, the resistant parasites are able to predominate egg production and subsequent pasture contamination. It can therefore be assumed that the extent of treatment exposure increases the extent of resistance development. For this reason, the main feature affecting AR selection in regard to treatment exposure is the interval between drug administrations. If the interval is greater than the pre-patent period (PPP; approx. 2-3 weeks), this enables the development of ingested susceptible parasites, which can lessen the reproductive advantage of existing resistant parasites. Conversely if the treatment interval is less than the PPP then the potential reinfection and development of susceptible parasites is not possible.

The contention as to whether a greater treatment frequency or treatment persistence is more selective for drug resistance is not definitive. It can be argued that a single administration of a long-acting product may be less selective for AR in circumstances of sustained parasite infection. However, the period whereby persistence declines, also known as the tail of activity, may also allow greater selection of resistance traits, whilst continuing to remove susceptible worms. In contrast the use of more frequent effective treatments may improve the removal of resistant worms, thereby reducing their reproductive impact.

1.11.2 Under-dosing

As touched upon in the previous section, the dose level of drug administered is likely to influence the extent of parasite control and the selection for AR. By administering a sub-therapeutic dose of wormer, the presence of worms with either dominant or recessive resistant traits are more likely to survive treatment. Whereas if a full therapeutic dose of treatment is administered this reduces the likelihood of recessive resistant worms surviving treatment and therefore reduces the risk of AR selection.

A number of reasons may be attributed to under-dosing animals, including a misjudgement of bodyweight for determining the correct dose and miscalculation of the correct dose volume. Other technical issues may include the use of uncalibrated drenching equipment or faulty weighing scales.

1.11.3 Exclusive use of anthelmintics

By using one class of anthelmintic exclusively this is likely to increase the rate of AR development to that one class. By alternating anthelmintic classes either annually or within season, this is proposed to reduce the rate of AR development to one class in isolation, thereby improving the longevity of all the available classes.

1.11.4 Size of susceptible 'refugia' population

The term refugia refers to a subset of the parasite population that is not exposed to an anthelmintic, such as parasite larvae on pasture as well as within untreated animals. This unselected population must also conserve the genes for susceptibility to anthelmintics being used at the time of treatment for the target host. The abundance of refugia therefore may vary depending on a number of management factors. For example, if pasture is contaminated with high levels of 1-BZ resistant species and low levels of resistance towards other treatment classes, then the pasture would be considered to have high refugia for all treatment classes except when using 1-BZ treatments. The environment also plays a role in the preservation of refugia, particularly in arid and tropical climates where rapid development and mortality rates result in extreme contrasts in refugia numbers. These conditions were particularly utilized in countries such as Western Australia where peak summer temperatures result in high larval mortality on pasture.

As the proportion of refugia decreases such as on clean/safe pastures grazed by alternate hosts or parasite resistant hosts, the greater the potential for AR to predominate. One of the most effective roundworm control methods recommended for farmers is the practice known as 'dose and move'. This control method involves the movement of treated animals onto low contaminated grazing in order to benefits from extensive periods of low reinfection. Early studies conducted by Michel (1969) and (Thomas and Boag, 1973) demonstrated the effectiveness of this method at removing an important source of contamination for clean pastures, in addition to escaping exposure to peak larval availability on the previous grazing pasture. This practice has also been established to select highly for AR as only parasites surviving treatment are moved onto low refugia grazing, resulting in a heightened reproductive advantage for drug-resistant species (Van Wyk, 2001). The maintenance of a refugia population can therefore be said to provide a dilution effect for the contamination of resistant parasite eggs on pasture. The relative impacts of each of the previously mentioned risk factors have therefore proposed to be regulated by the relative size of the refugia population, as illustrated in Figure 7.

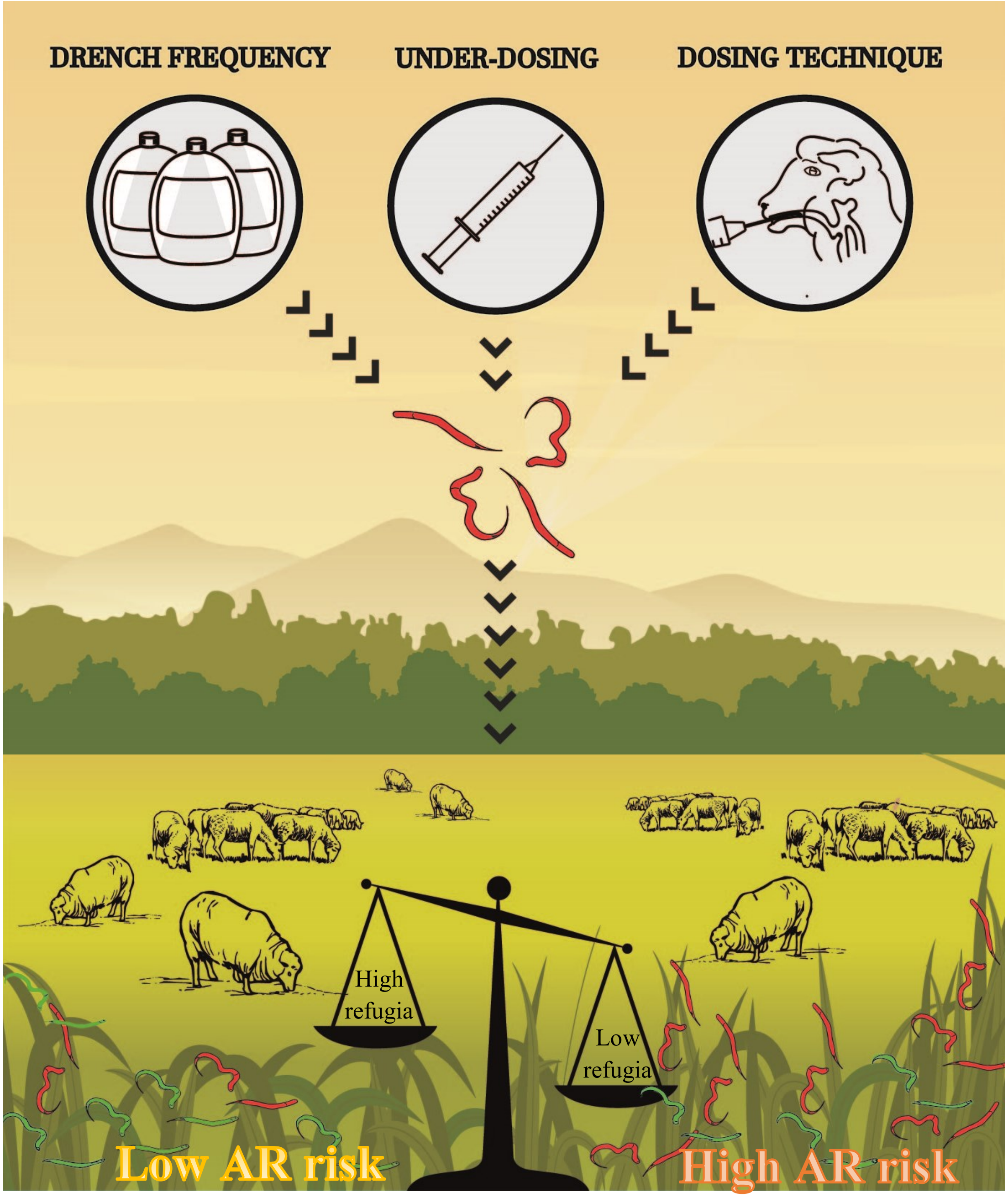


Figure 7 – Illustration of AR selective practices and dominant 'refugia' factor (Red larvae = resistant, green larvae = susceptible (refugia).

1.12 ROUNDWORM CONTROL RECOMMENDATIONS – PAST AND PRESENT

As the necessity for controlling roundworms has grown with the increased intensification of sheep farming, as to have our understandings of parasitic disease and its means of management. Over time, many developments within the agriculture, veterinary sciences and pharmaceutical industries have altered the advice and treatments offered to farmers and animal health advisors. The following section describes the developments relating to parasite control recommendations since the introduction of anthelmintics, based on the available literature.

1.12.1 Past advice (1955-2000)

From this period of the mid-20th century, the first wave of anthelmintic treatments became available to producers, which heralded the 'chemotherapeutic era' for parasitic control reflected in the publications directed to both stockman and veterinarians (Waller, 2006a). Prior to the discovery of novel anthelmintic compounds, the precursor drugs included preparations such as 'Cunic' solution containing a mixture of Copper Sulphate, Nicotine sulphate and Water, recommended for administration every 3-4 weeks during the spring and summer months (Siegmund, 1979). Phenothiazine, the first broad-spectrum anthelmintic was recommended to vets (Siegmund, 1967) and producers (Ensminger, 1978) to administer as a phenothiazine-salt mixture at a continuous low-dose, in order to maintain a good level of control throughout the season. Later editions of the MVM have also noted the benefits of continuous low-level administration methods for reducing pasture contamination, but also note the potential drawbacks which include erratic drug consumption, tissue residues as well as encouragement of drug resistance (Merck, 1986). Another notable feature of advice from these resources was to move treated animals onto safe pastures (i.e. dose and move). This recommendation also extended within the scientific literature, promoted as a means of ensuring optimal production for lambs by providing a worm-free grazing environment (Southcott, 1971), or alternatively as a way of reducing anthelmintic usage in order to reduce reliance on wormers as well as resistance selection (Morley and Donald, 1980). Later publications have since acknowledged the practice as applying high selective pressure for resistance development (Michel, 1985; Barger, 1999).

Recommendations for treatment timings have also evolved over time as a result of improvements to the identification of infection patterns throughout the grazing season. This is evident when comparing examples of text such as between the 3rd and 6th editions of the Merck Veterinary Manual. The former suggesting the application of chemotherapeutic methods continually for parasite control as well as for situations of heavy infection (Merk, 1967). Whereas the latter introduces the use of more strategic treatments designed to prevent the build of contamination and losses associated with infection, in addition to encouraging the development of host immunity/resistance to infection (Merck, 1986). Special considerations suggested for timing sheep treatments include treating a month before and after parturition, coinciding with the PPRI period as well as a 'flushing' treatment given prior to breeding. A treatment at weaning is also recommended (Morley and Donald, 1980), with all treatments followed by a move to safe pastures.

As anthelmintics continued to develop with the introduction of the next drug successor Thiabendazole, large-scale field studies using this product were also being conducted in Australia. The administration of treatments at varying intervals demonstrated distinct differences in productivity achieved, predominantly for those animals receiving suppressive monthly treatments as shown in Figure 8. Further advancements of new anthelmintic compounds notably Levamisole and Ivermectin, assured the industry of novel broad-spectrum products with high levels of efficacy and safety. Indeed, the confidence of distributors for Nilverm® (Levamisole) was demonstrated when proposing the use of a half-dose to control against *Haemonchus contortus* (Waller, 2006a).

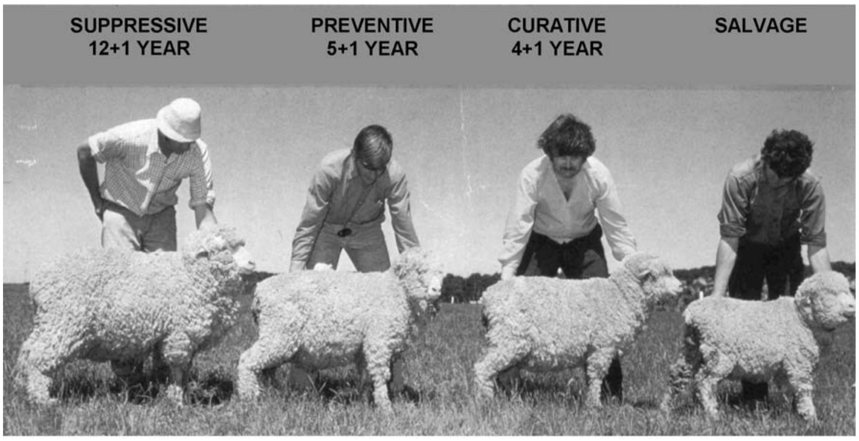


Figure 8 - Visual demonstration of the use of Thiabendazole at different frequencies (Image taken from Waller, 2006a reproduced with kind permission from Elsevier Limited).

While the halcyon days of suppressive dosing strategies enabled producers to achieve immediate high production responses and confidence to manage parasitic disease, the discovery of drug resistance transformed the long-term prospects on anthelmintic control, which created the inevitable dilemma between animal productivity and anthelmintic sustainability.

1.13 CURRENT PARASITE CONTROL RECOMMENDATIONS

In the wake of growing concerns within the sheep farming industry over increasing AR reports, a number of extension programmes were devised in some of the major sheep producing countries including the UK (SCOPS) and Australia (WormBoss). The following section outlines the development and nature of these current recommendations in comparison with historic advice.

1.13.1 SCOPS

The Sustainable Control of Parasites in Sheep (SCOPS) initiative was set up in 2003. The remit was to promote practical guidance for producers and animal health advisors (Abbott et al., 2004). The central aims are to raise the awareness of AR in the sheep industry and to advise on current parasite control strategies incorporating principles and methods for reducing selection pressures for AR, whilst maintaining acceptable or enhanced productivity. Currently these recommendations are summarized into eight guidelines (Figure 9) each of which outline a variety of measures to preserve the effectiveness of current and future anthelmintics. The guidelines are each described as follows:

1.13.1.1 Guideline 1 – Work out a control strategy with your veterinarian or advisor

This recommendation is for producers to consult with their animal health advisor in order to devise a parasite control strategy to complement the specific farm conditions and management systems on each farm. By tailoring a strategy in line with the farmer's aims and objectives this helps to ensure that the plan is structured in a practical, cost-effective and sustainable manner. In addition, periodic evaluation of the strategy would be taken with an advisor to ensure the aforementioned criteria are met using treatment records as well as frequent analysis of faecal samples to determine the health/AR status of the flock.

SCOPS Guidelines
1. Work out a control strategy with your veterinarian or advisor 2. Use effective quarantine strategies to prevent the importation of resistant worms in introduced sheep and goats 3. Test for anthelmintic resistance on your farm 4. Administer anthelmintics effectively 5. Use anthelmintics only when necessary 6. Select the appropriate anthelmintic for the task 7. Adopt strategies to preserve susceptible worms on the farm 8. Reduce dependence on anthelmintics

Figure 9 – SCOPS guidelines: A technical manual for veterinary surgeons and advisors (adapted from Abbott et al., 2004.

1.13.1.2 Guideline 2 – Implementing an effective quarantine strategy

The aim of a parasite quarantine strategy is to minimize the likelihood of introducing any roundworm species potentially harbouring resistance alleles not present on the farm. By preventing or minimizing the risk of introducing new resistant strains onto the farm this will avoid or considerably delay the development of new resistance introduced into the resident flock. The guideline recommends that all incoming animals (newly purchased or returning) are treated sequentially with a full dose of two different wormer classes, from one of the new compounds (i.e. 4-AD and 5-SI) and a moxidectin product. The rationale behind this is that the moxidectin treatment will remove any 1-BZ and/or 2-LV resistant parasites, whilst the new compounds would remove any parasites resistant to the moxidectin treatment. The next step of the protocol requires that animals are withheld from pasture from between 24-48 hours after treatment. This time period allows the treatments to eliminate all adult larvae present as well as for the animal to void any worm eggs produced prior to treatment. The final step is that the quarantined animals are turned-out onto contaminated grazing (high in refugia) which would dilute any resistant progeny produced if any worms survived treatment.

1.13.1.3 Guideline 3 – Testing for anthelmintic resistance

Establishing the resistance status for all anthelmintic classes used on the farm is recommended in order to inform future treatment strategies. This is because diagnostics tests can provide information of which species may be resistant to each anthelmintic class used which can be used to plan future treatment at that time of year. Furthermore, by detecting resistance early this allows mitigation measures to be implemented to prolong the effectiveness of future treatments.

1.13.1.4 Guideline 4 – Administering anthelmintic effectively

This guideline relates to a number of issues which may lead to a sub-optimal dose being administered to an individual or group. This includes ensuring that treatment doses are determined either by individual animal weights or using the weight of the heaviest individual in a group. Also checking that drenching guns are regularly calibrated, helps to ensure the correct doses are administered. And finally, the correct oral drench technique should involve delivery of the dose into the oesophagus and not the buccal cavity. Similarly, anthelmintic injections should be administered via the recommended site (i.e. subcutaneous or intramuscular) as detailed by the manufacturer.

1.13.1.5 Guideline 5 – Using anthelmintic only when necessary

The current recommendations advise a judicious use of treatments based on known risks periods such as for pregnant ewes around parturition, as well for lambs at weaning time. For the remaining periods it is advised that monitoring of FEC and visual assessment of clinical disease be used to inform decisions on whether to treat animals. In contrast to historic advice it is not recommended to treat ewes in good condition before mating, as it is assumed that mature, healthy ewes should be resistant to infection and by applying a treatment may unnecessarily select for resistance due to relative low levels of infective larvae on pasture.

1.13.1.6 Guideline 6 – Selecting the appropriate anthelmintic

This advice is intended to make users consider what types of treatment are most appropriate for targeting nematode species that are currently prevalent on pasture. For example the use of a narrow spectrum anthelmintic (e.g. benzimidazoles for *N. battus* control) avoids the off-target exposure of other nematode species that may be unnecessarily exposed or resistant to this compound. It is therefore advised that combination fluke and roundworm treatments be used only when necessary and that rotation of anthelmintics be used to target certain nematode species throughout the year. Furthermore, the decision to use persistent anthelmintic treatments should be considered only when animals are continuously exposed to infection i.e. on grazing highly contaminated pastures.

1.13.1.7 Guideline 7 - Preserving a susceptible 'refugia' population

To minimize the impact associated with post-treatment grazing management strategies such as 'dose and move', a number of alternatives have been devised to enable farmers to utilize clean grazing without selecting heavily for AR, based on the principle of refugia.

1.13.1.8 Part-flock treatment and targeted selective treatment (TST)

Both approaches involve the selection of certain animals for treatment, thereby leaving a proportion of animals untreated to allow the transfer of unexposed 'refugia' parasites to clean grazing. The first approach aims to allow a specified proportion of animals to be left untreated (approx. 10% of a group) which may vary depending on the efficacy of treatment used i.e. the less efficacious the treatment, the greater the number of untreated animals required. The second approach relies more on a selection criteria to inform which animals to treat or leave untreated, this may involve assessing indicators either of GIN disease based on clinical signs or FEC, or production measures such as body weight/growth rates.

1.13.1.9 Dose, delay and move

A variation of the 'dose and move' practice, the addition of a 'delay' component requires that once treated, animals are moved back onto contaminated grazing in order to become 'mildly' re-infected before a move to clean grazing. This enables the transfer of 'refugia' parasites once ingested larvae have developed, to reduce the reproductive advantage of resistant parasites when moved onto clean grazing.

1.13.1.10 Guideline 8 - Reducing dependence on anthelmintics

The final guideline aims to promote non-chemical alternative strategies to incorporate into farmers' roundworm control strategies. As previously described in section 1.8.1, these approaches may include the use of grazing management strategies (i.e. mixed/rotational grazing) or methods to reduce the susceptibility of the flock to roundworm infection (host resistance) or clinical disease (host resilience) by employing genetic selection or by introducing bioactive forages to grazing pastures.

1.13.2 WORMBOSS

The initial impetus for changing the approaches towards worm control occurred through early surveys which identified a growing prevalence of drug resistance to the broad spectrum anthelmintics. The frequent use of broad spectrum treatments to primarily control the haemophagic species *Haemonchus contortus,* lead to a simultaneous increase in resistance development in *Trichostrongylus* and *Ostertagia* species. To combat the issue, the 'WormKill' programme was established in the most affected region of New South Wales in 1984. The aim was to instigate a control strategy to reduce the frequency of treatments with broad spectrum anthelmintics by advising the use of closantel as a targeted treatment for controlling *H. contortus*. The recommendations also included strategic treatment timings to minimize pasture contamination before conditions were favourable for parasite development, as well as practical advice for effective dosing and grazing management for young stock (Waller et al., 1995). These simple and prescriptive recommendations were readily adopted in the area and encouraged the development of worm control programmes in other regions of Australia (Woodgate and Love, 2012). Interviews with farmers on factors influencing adoption of recommendations identified that, hopes for a more efficient and less costly worm control, with less labour is required (Dash et al., 1985). This has been proposed to be a key reason behind the high level of endorsement for the WormKill programme due to the savings in cost of treatments and labour, and not necessarily for reducing the selection for resistance (Anderson et al., 1985).

Other worm control programmes such as 'CRACK' in Western Australia followed a similar rationale to the WormKill message, such as dosing to the weight of the heaviest animal and the use of strategic summer drenches in order to reduce the need for winter treatments (Suter et al., 2005). These worm control practices were also widely adopted, although the extension of practices including targeting treatments based on faecal egg counts and drench efficacy testing were much less endorsed by surveyed producers (Woodgate and Love, 2012). As the occurrence of drug resistance to closantel and the macrocylic lactone group increased in the 1990's, so did the complexity of advice with more emphasis on integrated management systems incorporating grazing management and preserving refugia. Since 2005, 'WormBoss' has become the national repository for information and recommendations regarding sheep worm control in Australia. The effective use of the internet platform for extension has given WormBoss a high level of awareness amongst farmers; however, establishing the transition from awareness to adoption is uncertain (Woodgate and Love, 2012).

1.13.3 Sustainable parasite control practice uptake

Various questionnaire surveys have been undertaken and published on the parasite management practices of sheep farmers from around the world, as well as within the UK (Coles, 1997; Bartley et al., 2004; Suter et al., 2005; Fraser et al., 2006; Hughes et al., 2007; Lawrence et al., 2007; Sargison et al., 2007; Morgan et al., 2012; McMahon et al., 2013b). In Scotland, surveys have been conducted to establish farmers' roundworm control practices, both at a regional level in the south-east (Sargison and Scott, 2003) and at a wider national level (Bartley, 2008).

Such studies have highlighted the variable adoption of sustainable roundworm control practices (as detailed in Table 4). Examples of this include the high proportion of surveyed farmers using visual weight assessments for determining anthelmintic treatment doses (Sargison and Scott, 2003; McMahon et al., 2013b) as well as the lack of farmers' employing parasite diagnostic testing for identifying AR (Sargison and Scott, 2003) or for monitoring parasite burdens (Vande Velde et al., 2015). These studies emphasize the need to improve promotion and perception of these practices if sustainable parasite control is to be generally accepted.

Table 4 – Percentage uptake of recommended worm control practices from UK sheep farmer surveys

Recommendation	Percentage uptake (%)	Year conducted	References
Quarantine drench	17	N/A	(Coles, 1997)
	64 64	2005 2007	(Morgan and Coles, 2010)
	86	N/A	(Morgan et al., 2012)
	85 88	2005 2007	McMahon et al, 2013
Withhold from pasture after treatment	70 72	2005 2011	McMahon et al, 2013
Drench rotation annually	32 17	2000 2004	Bartley, 2008
	22 22	2005 2007	(Morgan and Coles, 2010)
	48	N/A	(Coles, 1997)
Tested for AR	7	N/A	(Coles, 1997)
	19	N/A	(Morgan et al., 2012)
	32	N/A	(Fraser et al., 2006)
Dose & move (no)	54 61	2000 2004	(Bartley, 2008)
	43	2005	(McMahon et al., 2013b)
Rotational grazing	39 20	2005 2011	(McMahon et al., 2013b)
	39	N/A	(Coles, 1997)
Co-grazing	32 43	2005 2011	(McMahon et al., 2013b)
Dose determination by weight	35 60	2005 2011	(McMahon et al., 2013b)
	43	2002	(Sargison and Scott, 2003)
	49 44	2000 2004	(Bartley, 2008)
Selective treatments	4 9	2005 2011	(McMahon et al., 2013b)

1.14 AGRICULTURAL EXTENSION

For governments, the growth and development of the agricultural sector is important for economic growth, hence the requirement to create and maintain an infrastructure to support farmers is essential. Included within this infrastructure are research and extension services, aimed at providing farmers with continuously updated information comprised of production recommendations as well as new agricultural technologies to help improve their farming systems. The transference of such information from within the scientific community to their intended stakeholders is inherently an integral part of the research process. This fundamental dynamic between research and its application and impacts on the farming community is an important return on research investment. Although one of the main issues that is recognized is the difficulty of determining the impact of extension efforts on the adoption of technologies and practices (Benor and Harrison, 1977). This among other matters has resulted in a loss of funding from governments for agricultural extension services, which has placed major restraints on resources to the detriment of effective extension of research innovations (Benor and Harrison, 1977; Vanclay and Lawrence, 1994). The pressures on extension services lead to a period of change with the induction of a new extension paradigm based on updated models (modern extension) from the original classical models (i.e. traditional). The remainder of this section will discuss further the principles differences concerning both extension approaches.

1.14.1 Traditional extension

Traditional extension refers to a system based on social-psychological models such as the diffusion of innovation (Rogers, 2010). Also referred to as the top-down process or linear model, whereby innovations (i.e. technologies, practices, ideas) developed by researchers are then disseminated by extension agencies to the benefit of farmers. Although I go on to discuss the details of the diffusion of innovation model in section 1.15.7, the basic process involves firstly a progression from awareness of an innovation to understanding, then an evaluation, trial and ultimately adoption (Rogers, 2010). By basing innovations on technical scientific knowledge this has enabled the prediction and formulation of definitive interventions and technologies which can be applied with conclusive outcomes (Röling, 1996). This acquisition of evidence-based knowledge helps to reduce uncertainty towards such practices and therefore engenders confidence that adoption of such innovations will benefit the user (Rogers, 2010). The adoption of such innovations may also have wider societal benefits such as preventing the spread of highly infectious diseases or from practices of significant environmental importance, which may otherwise be unrecognized or overlooked by individuals.

The traditional model has however received criticism, with recognition of multiple faults. It has been acknowledged by researchers that the traditional extension system is driven by the rationality of researchers from scientific and socio-economic traditions, which do not often take into account the requirements and desires of the farmers or their farming conditions (Benor and Harrison, 1977; Vanclay and Lawrence, 1994). Furthermore, the traditional model has also been proposed to be grounded on the promotion of primarily commercial (economic) innovations, which assume that innovations apply equally to all farmers and are inarguably beneficial to all farmers.

The model also seeks to praise those who are early adopters of such innovations and discredit those who reject the innovation based on their own rationales and consequently are characterized as ‘laggards’ (Vanclay and Lawrence, 1994).

In practice, additional issues have also been acknowledged; Benor (1977) identifies nine general problems based on a traditional extension method known as the ‘training and visit system’ which could be summarized into three main categories including: organizational structure, training and operations. The organizational structure refers to the activities of task allocation, coordination and supervision. Benor, explains that generally the field-level extension workers are unspecialized and overextended, with field workers often having to perform a range of both extension duties as well as other tasks (e.g. distributing agricultural inputs, completing reports, recording statistics). Furthermore, extension goals set out by extension workers are often too broad and unrealistic to achieve. Secondly, the coverage of extension is limited by the resources available, as such the majority of farmers may not be able to be visited, resulting in a prioritization of larger farms (Benor, 1977). Thirdly inadequate supervision methods are suspected, whereby the emphasis of supervision is to ensure the efficiency of extension efforts e.g. the number of visits or demonstrations given, rather than aiming to achieve goals set out by the extension worker and their clients.

The training aspect regarding extension problems has also been scrutinized with a belief that there is a lack of continual extension development involved past the point of initial training. Additionally, the training that is taught is believed to be mostly theoretical and classroom-orientated, as well as covering a wide variety of agricultural extension topics and practices. The outcome of which results in extension workers with a broad ranging but uncomprehensive knowledge/skill set, which is unable to be updated with the latest research findings. The final problem facing the traditional system of extension linked with the previously highlighted issues is the operations, with particular reference to the use of demonstrations. Usually devised and conducted by the extension workers and not the farmer, this approach even when demonstrating promising improvements lacks the involvement of the farmer and as such often results in variable adoption.

1.14.2 Modern extension paradigm

In contrast to the traditional approach, the modern extension methods also referred for instance as 'bottom-up' or 'farmer first' approaches (Chambers and Thrupp, 1994), look to allow the farmers themselves to set the agenda for future extension programmes and enables farmers to identify priorities and potential barriers through group discussion. It is believed that by shifting the orientation of discussion towards farmers, this will eliminate any previous discrepancies in opinions towards the importance and practicality of recommendations. The important addition is that a group facilitator is involved in order to inform and manipulate the learning process so as to subtly divert the attention towards socially desirable views (Vanclay and Lawrence, 1994).

1.14.3 A middle ground

As proposed by Benor's 'training and visit system' (1977), there are opportunities to incorporate both systems together by enabling a knowledge exchange feedback between researchers, extension agencies and farmers. The system involves the up-to-date training of extension workers and frequent visitation of workers with farmers to exchange information as well as feedback. Practical demonstrations can also be implemented to trial new innovations on the farmer's own fields which can improve engagement and persuasion of farmers to the potential benefits of adoption. Furthermore, the feedback process relays issues that are faced by farmers on a regular basis, which also provides a driving force for informing future research. Therefore the potential consequence of not having a feedback process could result in more farmers not utilizing the agricultural advances available to them (Benor and Harrison, 1977).

The development of cooperative projects between farmers and universities has also been undertaken in past studies. In an example described by Francis (1990), arable farmers in Iowa proposed ideas for experiments and provided the required inputs. The researchers then conduct the trials, collected the necessary data and help the farmers when needed. The subsequent results are then discussed within the groups meetings, in order to be used by producers in the following season.

1.14.4 Communication channels

A number of alternative tools for agricultural extension are also used to disseminate information for wider audiences, in addition to the direct communication routes. The main purposes of mass media is to reinforce the messages of researchers and extension agencies by increasing the publicity and impact of advice in combination with other extension methods.

1.14.4.1 Traditional methods

Direct personal interaction between advisors and farmers has also remained an integral means of informing and engaging individuals, as previously described. Such approaches can include farmer talks, agricultural events, demonstrations etc. (as presented in Figure 10) which can be used to communicate information in different ways to suit the target audiences. It is also important to consider the influence of 'word of mouth' between individuals within a farmer's social network be it through immediate interaction or through the use of a virtual network i.e. social media.

Traditional media platforms i.e. paper publications, have been the mainstay for commercial information dissemination, which is just as true today in regard to agricultural publications. Indeed, it has been noted that some 90% of farmers still rely on farming media for their information needs (Stocks, 2011). This is despite the dramatic fall in total readerships in recent years, but this appears to be less apparent with respect to agricultural publications such as the Farmer Weekly, with an average net circulation of 56,752 per issue, in 2014 (ABC, 2015). Examples of articles from Farmers Weekly concerning roundworm control and anthelmintic resistance are presented in Figures 11 and 12. It is however predicted that the paper publication medium will decline with the advent of new interactive media formats (Stocks, 2011).

1.14.4.2 Agricultural organisations

Many farmers receive their information through the various farming organisations set up to support the agricultural industry. Within Scotland, examples of organisations can include those representing the whole agricultural industry such as the National Farmers Union Scotland (NFUS) or specific farming sectors such as the National Sheep Association Scotland (NSA) and Scottish Beef Association (SBA). Such organisations provide their members with various benefits including access to both written and online publications including technical information aimed to inform farmers of ways to improve their animal health and performance. Events are also be held by such organisations which showcase the latest information, technologies and innovations available.

Figure 10 – Traditional communication method examples taken from Moredun archives and Anonymous, 2010).

Roundworm control advice headlines

Routine worming of in-lamb ewes 'unnecessary and time wasting'

5/2/2008 Farmer weekly – J. Hunt

Vaccine is a major boost for control of roundworm

10/12/2009. Farmers weekly - S. Trickett

Target worming plan to fit farm worm status

19/4/2013. Farmers weekly – O. Cooper

* Selective pre-lambing worming will not lead to lambs being more at risk and will reduce the risk of anthelmintic resistance
MATT COLSTON

Parasite risk to grazing lambs should be assessed

5/3/2010. Farmer weekly - S. Trickett

Focus on maternal lines for worm resistance gains

20/11/2009. Farmers weekly - J. Long

* Find out your resistance status – if you don't know where you are, you blame problems on everything else
Matthew Blyth

19/4/2013. Farmers weekly - O. Cooper

Producers urged to use targeted worm control to build resistance

10/6/2011. Farmers weekly - A. Balsom & G. Mackenzie

Figure 11 – Farmers weekly headlines and excerpts regarding roundworm control

Figure 12 – Farmers weekly headlines and excerpts regarding AR

1.14.4.3 Digital media

The advancement of new digital technologies has enabled the development of a range of electronic media formats for disseminating information including: websites, online publications, mobile applications, videos, and social media platforms (as presented in Figure 13). The multitude of benefits provided by electronic media when compared to paper publications include: its ease of accessibility, unrestricted space to deliver information, the ability to search for specific information and the prospect of accessing free information (Stocks, 2011). A recent study of UK farmers use of decision making tools (DMT) demonstrated that of the 49% of farmers using DMT's, the formats found to be most useful including computer software and applications, most favoured by 22% and 10% of participants respectively (Rose et al., 2016). Other studies also show that within agricultural industries in New Zealand, agribusiness and research communities tended to use social media most compared with farmers, albeit formats such as Facebook were used daily by 20% and at least once a week by 40% of farmers, in addition to other modes such as LinkedIn and mobile apps (Casey et al., 2016).

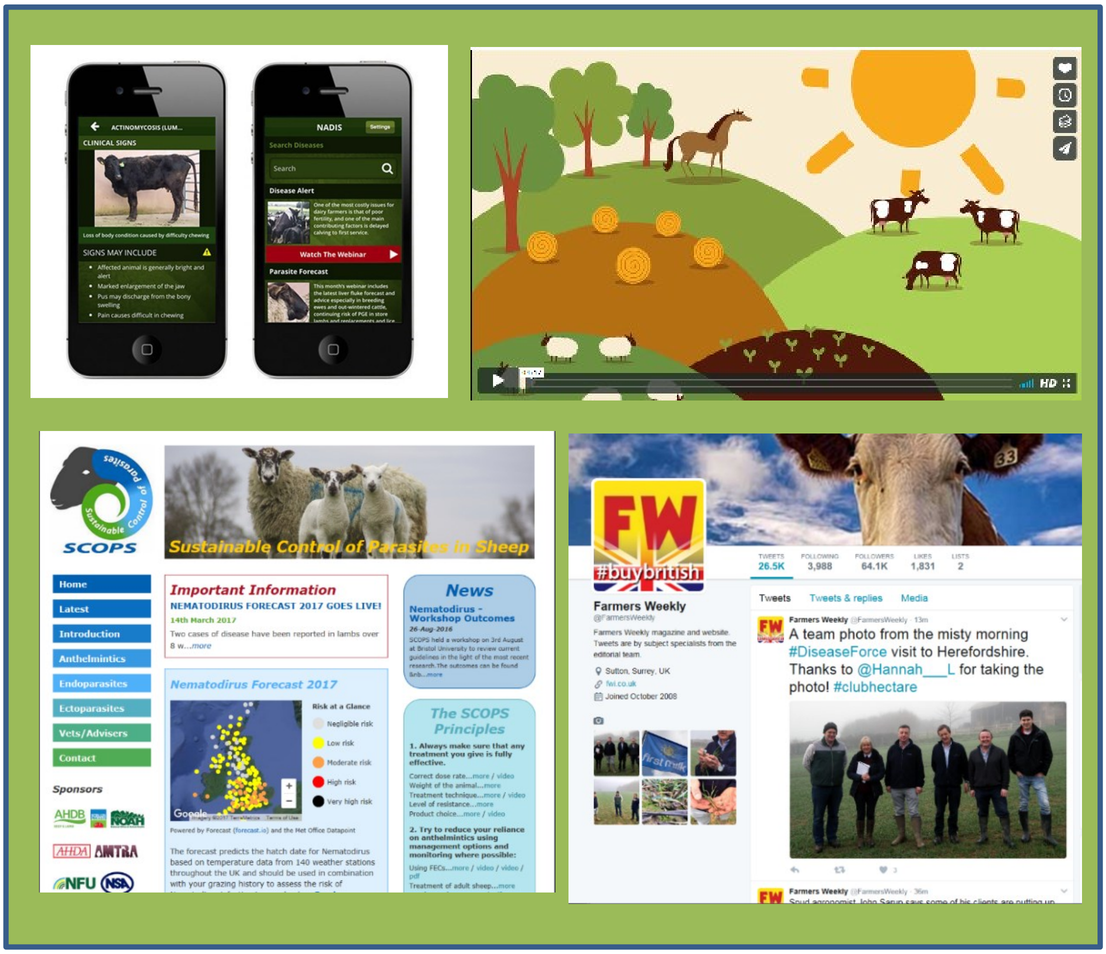


Figure 13 - Digital media communication method examples taken from Moredun Research Institute, 2016; Farmers Weekly, 2017; NADIS, 2017; SCOPS, 2017.

1.15 BACKGROUND OF SOCIO-PSYCHOLOGICAL CONCEPTS

The social sciences may be considered an all-encompassing term for a range of disciplines investigating the institutions and functioning's of human society, and the relationships which exist between individuals within our societies. As such there are many related branches within social science spectrum that study the different aspects of human society which include for example: political science, human geography, sociology, economics, anthropology, psychology etc. For the purposes of this thesis the following sections will focus principally on examples of concepts within the fields of Psychology and Sociology i.e. the study of human behavior and mental processes in connection with social group interaction and situation-specific behaviors.

1.15.1 Apperception

Johann Friedrich Herbert was the founder of the discipline concerning education (Pedagogy) and the first to attribute the importance of psychology to the role of teaching. The concept of apperception posits how the mind is able to assimilate and organize new thoughts and ideas with our existing beliefs. Herbert believed that ideas are formed from a combination of experiences and sensations which dynamically interact within our conscious and unconscious mind. He proposed that ideas, similar to magnetic forces, are able to attract and repel each other, as represented in Figure 14. Ideas which complement our existing thoughts are said to cross the boundary into our conscious mind and aggregate within a restricted complex known as the 'apperception mass'. Conversely, ideas which differ or contradict our existing thoughts are said to cause resistance which pushes such ideas out of consciousness and into our unconscious mind (Herbart, 1896).

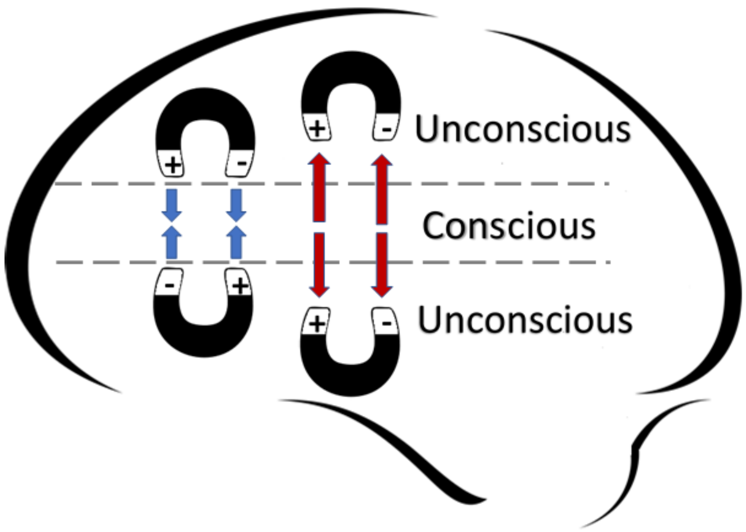


Figure 14 - Illustrative representation of the dynamic 'apperception' process (adapted from Collin, 2012).

1.15.2 Behaviourism

In comparison to the more philosophic theories such as proposed by apperception, the behaviourist approach marked the development of theories supported by empirical data from observations of measurable human and animal behaviours. This approach is therefore detached from the inquiry of innate features of the human psyche (i.e. cognition, emotions) but rather highlights the role of external environmental factors influencing learning behaviours (Collin, 2012).

1.15.2.1 Connectionism

Experimental studies by notable behaviourist psychologists including Edward Thorndike (1898), John Watson (1920) and Ivan Pavlov (1897-1902) demonstrated that neural connections can be made between a specific stimuli (S) and a response (R). Thorndike's law of effect theory (1898) states that the outcome of an action determines the strength of the S-R connection. In other words, actions which have strong desirable outcomes are more likely to be remembered and subsequently repeated.

1.15.3 Radical behaviourism

Experiments pioneered by Frank Skinner investigated the consequence of actions on learned behaviours ('Operant conditioning'), as opposed to the introduction of artificial stimulus as used by behaviourists such as Ivan Pavlov ('Classical conditioning'). Skinner's experiments on rats tested the conditioning effects of using both positive and negative reinforcements. The findings concluded that behaviour was shaped more efficiently from a programme of positive reinforcement than from using negative reinforcement. Indeed, the latter may prove to be counter-productive to learning with subjects continuing to seek positive affirmation toward a desired behaviour, resulting in attempts to evade negative responses (Collin, 2012).

1.15.4 Cognitive Psychology

While the first half of the 20th century focused on behaviourist and psychoanalytical approaches, subsequent research considered the mental or 'cognitive' processes including aspects such as memory, perception, problem solving and decision making (Collin, 2012).

1.15.4.1 Cognitive development

The work of Jerome Bruner (1960) built upon previous cognitive models from Piaget (1952) and Vygotsky (1978) which acknowledged the requirement for 'active' experience and social/cultural interaction when attributing meaning to information learnt in childhood. In view of these insights, Bruner added that the acquisition of knowledge should be seen as a process rather than an end result. This process involving the active reasoning of information through encouragement and guidance rather than through the passive absorbing of information (Collin, 2012).

Other concepts thought to affect learning include theories such as cognitive consistency related to attitudes, beliefs and behaviours. Leon Festinger's cognitive dissonance theory (Festinger, 1962) proposed that when strong beliefs are challenged by conflicting evidence, we enter a state of disorder (dissonance). Our natural instinct is to restore order (consonance) by carrying out any of the following rationalisations: 1) make the evidence consistent with the past belief 2) change our attitudes to suite the new belief system 3) acquire new information to support/disprove the old belief or 4) reduce the importance of the belief (Festinger, 1964).

1.15.5 Social Psychology

From the 1930's the field of social psychology emerged to explore the interactions of individuals within a group as well as between groups or institutions within a greater society. With this a new set of topics were introduced to psychology such as group dynamics, conformity, obedience and social change etc. (Collin, 2012). This section will focus on the concepts of conformism and social constructivism. Additional examples of theories relating to social change will also be discussed in section 1.15.7.

1.15.5.1 Conformism

Conformity can be described as the urge to follow the beliefs or behaviours of others in order to 'fit in' with a group. Deutsch and Gerrard (1955) identified two types of conformity behaviours consisting of normative and informational. Normative conformity relates to the tendency to conform to group/societal pressures to avoid rejection from a group by publicly favouring the majority, even if it defies personal beliefs (Deutsch and Gerard, 1955). A prominent example of this behaviour was highlighted in Asch's line study (1951) where a vision test involved the simple matching of lines by their lengths. All but one of the participants were involved in the experiment and gave prearranged incorrect answers. The findings demonstrated that around 75% of participants conformed at least once with the remaining 25% demonstrating no conformity to group pressure.

The informational conformation behaviour can be described as a situation where there is a genuine acceptance of the group's belief as a result of a lack of knowledge or certainty. The individual therefore looks to the group for guidance and goes through the process of internalization by firstly accepting the groups view and then adopting the view as their own. This behaviour was observed by Sheriff (1935) in his auto-kinetic effect experiment. The experiment involved the use of a visual illusion (a spot of light 'appearing' to move on a dark wall), the participant's task involved estimating the distance of the lights movement. The ambiguity of the experiment resulted in uncertainty among participants. After the task, participants were gathered into groups of three, with two sharing similar interpretations on the outcome and one with a differing view. By manipulating the group compositions in this way, Sheriff observed that the individual with the differing view would conform to the majority, due to the sense of uncertainty.

1.15.5.2 Social Constructivism

This social theory is a combination of the ideas of socialization and interaction, where knowledge is proposed to be constructed through interaction with others. It is thought that our urge to share our thoughts and experiences triggers the transmission of knowledge and keeps us within the circle of conversion. As these conversations progress, attitudes become organized and values become established into a unifying force or 'collective consciousness' a term introduced by Émile Durkheim (1892).

1.15.6 Models of individual behaviour and behavioural change

The aim of this section is to describe examples of the most prominent and prevalently used models designed to predict human social behaviours. This will involve outlining the key concepts which form the framework of these models as well as reviewing how these models have been applied to determine their influence on farmers' agricultural behviours.

1.15.6.1 Theory of planned behaviour and theory of reasoned action

The theory of planned behaviour (TPB) is one of the most cited and widely applied theories for predicting human behaviour. The TPB theory (Fishbein, 1975; Ajzen, 1991) incorporates both sociological and cognitive principles which are developed into a framework of behaviour-specific factors (presented in Figure 15). The TPB model consists of three main predictive factors which are believed to have a direct influence on behavioural intention as a cognitive precursor of behaviour. Ajzen (1991) proposes that behavioural intention captures the willingness or motivation that influences the enactment of certain behaviours. It can therefore be deduced that a combination of strong positive correlations between the three predictive factors results in strong behavioural intentions and subsequently an increased likelihood of conducting the behaviour of interest.

The first of the belief predictors is ‘Attitude’ which assesses the individual’s positive and negative beliefs regarding the outcome of the specific behaviour. The second predictor is ‘Subjective Norms’ which refers to the wider social environment and the perceived expectation of significant others towards adopting behaviours. The third predictor ‘perceived behavioural control’ (PBC) reflects the individual’s perceived ability to perform the specific behaviour based on factors believed to facilitate or hinder its use i.e. cost, labour, time, facilities etc. PBC was added as an extension to the original theory of reasoned action (TRA) model as it was envisaged that both motivation (intention) and ability (PBC) interact in their effects on behavioural achievement (Ajzen, 1991).

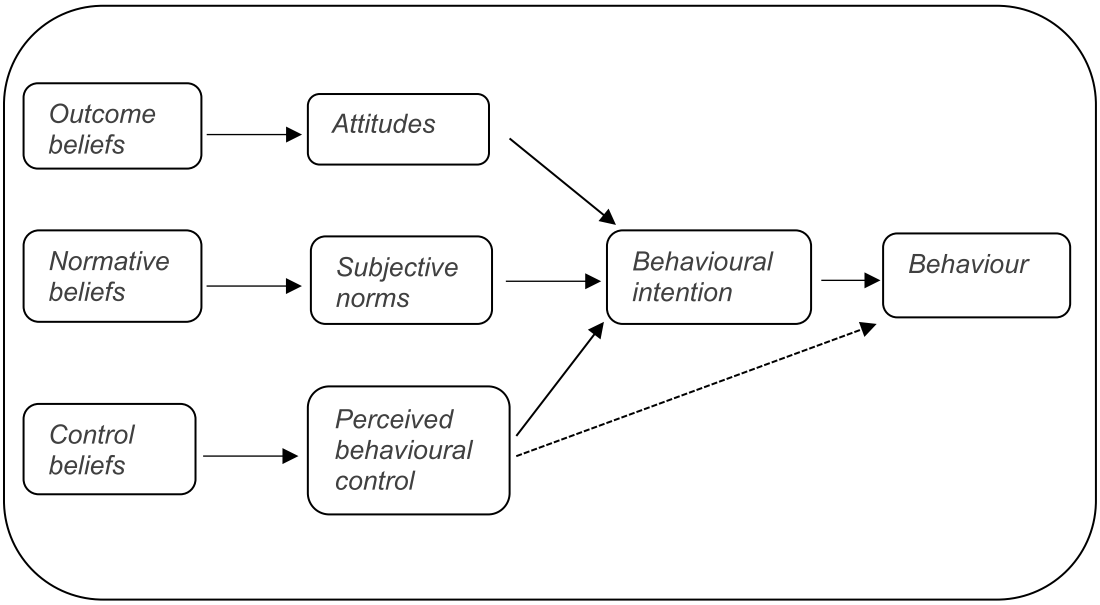


Figure 15 - Theory of planned behaviour model (taken from Armitage and Conner, 2000)

TPB has been used to predict a wide variety of agricultural behaviours including farmers’ uptake of conservation behaviours (Lynne et al., 1995; Beedell and Rehman, 2000; Wauters et al., 2010), organic farming practices (Hattam, 2006; Lapple and Kelley, 2013), animal welfare (Kauppinen et al., 2010; de Lauwere et al., 2012) and disease control measures (Gunn et al., 2008; Ellis-Iversen et al., 2010; Garforth et al., 2013; Toma et al., 2013; Alarcon et al., 2014; Toma et al., 2015; Vande Velde et al., 2015). Where statistical analytical techniques have been applied to farmers' questionnaire responses, a range of studies have demonstrated the significant influence of TPB factors, including attitudes on behaviours (Willock et al., 1999; Toma et al., 2013) and behavioural intentions (Adrian et al., 2005; Vande Velde et al., 2015), social norms on behaviour intentions (Vande Velde et al., 2015) and PBC on behavioural intentions (Adrian et al., 2005; Vande Velde et al., 2015).

Extensive reviews conducted by Armitage and Conner (2001) and Taylor (2007) on the TPB collated evidence suggested that between 20 and 30% of the variance of behaviours can be predicted by TPB, and a greater proportion by means of behavioural intention. The social norm factor was claimed to be a weak predictor of intention; however this was attributed to a combination of poor measurement and a need to expand the current concept (Armitage and Connor, 2001). In terms of the conclusions which should be drawn from the use of TPB, Hardeman et al (2002) noted that TPB should identify which particular influences on behaviour could be targeted for future change, rather than for planning and designing the types of interventions to use which demonstrated weak effects on behaviour change.

1.15.6.2 Health belief model

Developed by investigators within the public health services between the 1950's and 60's, the Health belief model (HBM) was created out of necessity due to a reorientation of research focus towards prevention, and not the treatment of disease (Rosenstock, 1974). The HBM model as opposed to the TPB was developed specifically to help predict and explain the adoption of preventive health behaviours. This HBM model (Rosenstock et al., 1988), presented in Figure 16, shares some comparable factors to the TPB with predictors including ‘perceived benefits/barriers‘ (i.e. outcome beliefs), as well as self-efficacy i.e. perceived confidence in abilities to perform behaviours (i.e. Perceived behavioural control). Of distinction, the HBM model include factors such as the outcome mediator ‘cues to action’ as well as the antecedent factors ‘perceived susceptibility’, ‘perceived severity’ and ‘modifying factors’. The former of these factors proposes that a prompt or trigger, which may be internal (e.g. pain) or external (e.g. media) is necessary to spark engagement in a health behaviour. The second set of factors relate to the perceived level of risk, which comprises of susceptibility i.e. likelihood of an event occurring, as well as severity i.e. the impact of the event occurring. The ‘modifying factors’ was included to incorporate various alternative individual characteristics believed to indirectly influence behaviour, these include demographics, psychosocial and structural variables. Demographics include aspects such as age, gender, education etc. Socio-psychological variables include features such as personality, peer/group pressure, social class etc. and structural variables relate to an individual’s knowledge and experience of the health condition of interest.

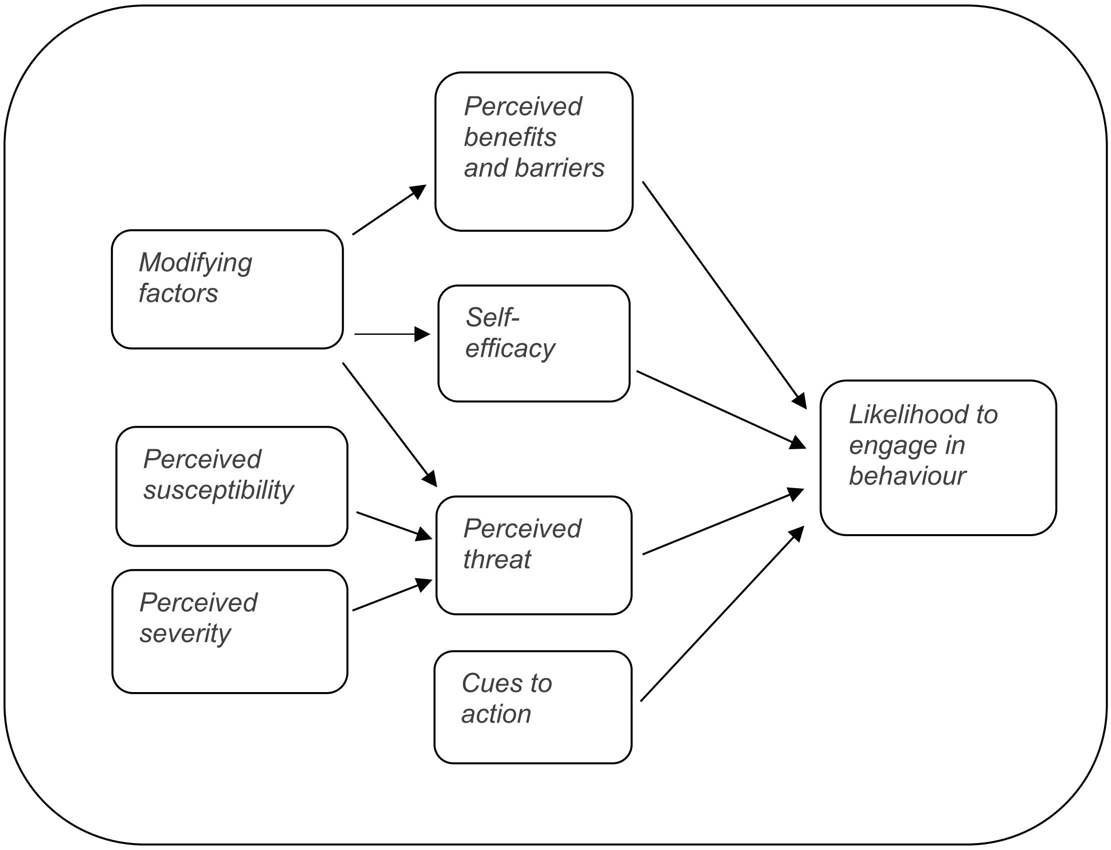


Figure 16 - The Health Belief Model (Taken from Rosenstock et al., 1988)

The principles proposed by the HBM model have been frequently used to various degrees in studies relating to farmers influences on animal health including aspects such as disease reporting behaviour (Palmer, 2009; Bronner et al., 2014), animal disease management (Valeeva et al., 2011; Garforth et al., 2013; Alarcon et al., 2014) as well as particular livestock disease control measures (Delgado et al., 2012; Toma et al., 2013; Vande Velde et al., 2015). Further uses have also included the application of the HBM to veterinarians' views toward topics such as herd health management (Derks et al., 2013) and issues with biosecurity (Shortall et al., 2016).

1.15.7 Theories for general behavioural change

1.15.7.1 Field theory

Kurt Lewin's social transformation theory (1951) believed the interaction between people, their environment 'field' and situational forces were key to understanding the system, and through making changes to the system, this reveals important information regarding its qualities and values (Collin, 2012). Lewin's model describes three pivotal stages required for individual or organizational transformation, which include: unfreezing, a change process and then refreezing.

1.15.7.2 Unfreezing

Considered the most complex and challenging stage of the process, unfreezing refers to the dismantling of old beliefs and practices in order to introduce a new belief system. This stage is understood to require careful training and preparation with the aim of minimising the natural inclination to resist change, especially where mind-sets and routines are well established. This preparation may involve creating a stimulating vision for the change, and communicating it effectively by adding a sense of necessity or urgency for change. The implementation of stage should allow the people involved to actively question and argue the changes proposed to which support must be provided to resolve any issues or insecurities to ease the psychological transition (Collin, 2012).

1.15.7.3 Change process

Establishing the new belief system/mind-set requires personal acceptance of the change, which can only be supported rather than imposed. If an individual's old beliefs are proven wrong or ineffective, the next step naturally is to replace the old beliefs with new beliefs to eliminate the state of cognitive dissonance. This can be achieved by a combination of means including providing information to support the new belief system and convincing role models within the group which can alleviate the fear and uncertainty created from the transition between mind-sets (Collin, 2012).

1.15.7.4 Refreezing

After the change has been implemented, the practices or behaviours must become part of the group's routine/culture, in order to maintain long-term engagement. This can be supported by establishing and nurturing positive feelings towards the change. The test of the refreezing stage is whether the evaluation of the change is ultimately positive or negative, which will either reinforce the new change or result in a modification of the new system or relapse toward the old system (Collin, 2012).

1.15.7.5 Diffusion of innovation

The diffusion of innovation (DOI) theory seeks to explain the process in which a new innovation or technology is adopted and spread within society. Everett Rogers (2003) developed the theory from extensive reviewing of studies across various research traditions comprising of anthropology, education, sociology, geography, public health, communication and marketing, among others (Rogers, 2003). The most influential of these studies came from the subfield of rural sociology connected with the adoption of new technologies in agriculture. Ryan and Gross's (1943) study of the diffusion of hybrid corn seeds among Iowa farmers exemplified the DOI concept which Rogers summarizes into four main components: innovation, communication channels, time and social system.

1.15.7.6 Innovation

Rogers (2003) describes an innovation as an idea, practice or object which is perceived as new to an individual. He proposes that five characteristics of how an innovation is perceived can influence its rate of adoption, these include 1) relative advantage 2) compatibility 3) complexity 4) trialability and 5) observability.

1.15.7.7 Communication channels

The ways in which messages are communicated between individuals impacts the likelihood of adoption. The use of mass media channels for example is proposed to be an effective method of transferring the knowledge of innovations to a wide audience, however direct contact between individuals is more effective at changing attitudes towards an innovation, which will have a greater influence on the decision to either adopt or reject the innovation. Rogers also proposes that the communication dynamics between individuals can be affected by their degree of compatibility or heterophily. Individuals who are incompatible (heterophilous) are said to have contrasting personal characteristics such as beliefs, education, social status etc. Whereas compatible (homophilous) individuals are those who share similar attributes, under which conditions will lead to more effective communication (Rogers, 2010).

1.15.7.8 Time

The rate of the diffusion process is inherently influenced by the length of time between its extension and subsequently adoption by individuals and then groups, which is referred to by Rogers as the innovation-diffusion process. More specifically the process examines the progression from first knowledge of an innovation to then making the decision whether to adopt or reject, after which implementing the innovation and evaluating the outcomes and ultimately confirmation of the innovation. Time is also said to affect the degree of innovativeness of the new knowledge or technology, which tries to characterize the type of individuals in their efforts to adopt innovations. These characterizations include the following 1) innovators, 2) early adopters, 3) early majority 4) late majority and 5) laggards. The rate of adoption is proposed to be determined by the relative progression of adoption between the previously characterized members of a social system (Rogers, 2010).

1.15.7.9 Social system

The social and communicative structure of a social system is considered integral to providing stability and regularity for informing individual behaviour within a system. The robustness of a social system is determined largely by the 'social norms' and how well established these behaviour patterns are between members of a social system. Rogers posits that there are distinct actors within the social system that have different powers of influence, 'opinion leadership' relates to degree to which an individual is able to informally influence others attitudes or behaviours with relative frequency. A 'chain agent' is an individual whose agenda is directed towards influencing the innovation-decision. An 'aide' is a support worker whose aim is to intensively contact clients to influence their innovation-decision processes (Rogers, 2010).

1.16 RESEARCH PROBLEM

The widespread threat of anthelmintic resistance poses a significant risk to the agricultural industry concerning the effectiveness and sustainability of modern roundworm control approaches, which inevitably impact the viability of productive sheep farming. The current general low uptake and engagement of 'best practice' approaches from livestock farmers will only sustain the spread and development of AR until anthelmintics become virtually ineffective.

1.17 PROJECT AIMS & OBJECTIVES

The changing nature of agricultural extension methods and of roundworm control recommendations requires that a holistic approach is taken to understand the influences of stakeholder's engagement and adoption of 'best practice' approaches to parasite management.

To tackle these issues, the main aims of the project are as follows:

- Identify socio-psychological factors influencing farmers' decision-making regarding roundworm control strategies and uptake of 'best practice' recommendations.
- Identify farmers' preferred methods of accessing disease control information
- Inform future formatting and promotion of best practice recommendations

Based on the project aims presented, the main objectives of the project are as detailed below. The ordering of the objectives also corresponds with the thesis chapter structure:

- **Chapter 2-** Analyse and evaluate historical questionnaire data concerning UK farmers' parasite management practices and anthelmintic usage to inform the development of sheep farmer focus groups.
- **Chapter 3** – Explore sheep farmers' and veterinarians' views and attitudes towards 'best practice' recommendations and identify keys areas concerning sheep farmers' from a cross section of the industry.
- **Chapter 4 -** Assess Scottish sheep farmers' current attitudes and behaviours regarding parasite control and SCOPS recommendations.
- **Chapter 5** –Investigate the influence of socio-psychological factors on the overall adoption of SCOPS practices and AR selective practices.
- **Chapter 6** – Determine the influence of behaviour specific socio-psychological factors on the adoption of individual roundworm control practices.
- **Chapter 7** – General discussion and recommendations

CHAPTER 2: A QUANTITATIVE AND QUALITATIVE ANALYSIS OF UPTAKE OF SUSTAINABLE PARASITE CONTROL PRACTICES BY UK SHEEP FARMERS

2.1 INTRODUCTION

The aims of this chapter were to first retrospectively explore historical questionnaire datasets originally conducted by Dr. D.J Bartley, to examine roundworm control implementation between two sets of Moredun Foundation survey respondents in Scotland (2000) and across Great Britain (2010). The surveys were designed to identify farmers' roundworm control practices including anthelmintic usage and to then examine the relationship between roundworm control practices and the presence/absence of resistance to multiple anthelmintic classes. By retrospectively examining the general uptake of best practice advice this can help to evaluate Moredun Foundation members' endorsement of sustainable parasite control approaches.

The second aim of this study was to use statistical analysis techniques (chi square and logistic regression analysis) which had yet to be applied to these questionnaire datasets. This allowed the opportunity to investigate the association between farming characteristics and information sourcing on roundworm control implementation. Additionally to compare these association over time and between different regions of Great Britain.

From the descriptive analysis, we identified that some roundworm practices strongly associated with AR development such as high drench frequency, dose and move practice and set drench treatments regimens had reduced between surveys populations.

Farm characteristics and information sourcing were found to be significantly associated with specific worm control practices. Therefore, requirements to tailor advice to suit the broad range of farming systems are integral to optimising uptake throughout the industry.

2.2 MATERIALS AND METHODS

2.2.1 Historical questionnaire design and implementation

The postal questionnaires were devised and conducted by Dr David J Bartley in the years 2000 and 2010 (Bartley, 2008). The questionnaires consisted of 29 and 33 multiple choice questions relating to individuals farm demographics, information sourcing, roundworm control practices and anthelmintic usage. The primary aim of the questionnaires was to provide supplementary information which could be linked to the prevalence of anthelmintic resistant nematode species in British sheep flocks.

The surveys were non-randomly distributed by post to all sheep farming members of the Moredun Foundation in Scotland (2000) and Great Britain (2010). Freepost envelopes were included within both surveys conducted, in order to optimise response rates. Reminder letter were not used during the survey implementation. In 2000, one-thousand Scottish members were mailed with details of the survey and invited to take part. A total of 97 completed surveys were returned resulting in a 9% response rate. In the 2010 survey, 2088 Moredun Foundation members in Great Britain were invited to participate by post, of which 280 completed surveys were returned resulting in a 13% response rate.

2.2.2 Data formatting and manipulation

The original data was formatted with each row as per respondent and each column representing the questions and their possible answer options. The multiple choice responses were converted into a binomial format (Yes/No) and open ended values e.g. number of ewes & lambs were entered as received.

In order to investigate regional differences in worm control practices within the 2010 survey, English and Welsh respondents were combined and separated from Scottish respondents.

All question responses were evaluated for suitability in subsequent statistical analyses. Inclusion of data involved checking for any missing data or inputting errors, as well as examining frequencies of each response category and collapsing those categories with few responses. Continuous variables were also assessed for evidence of a linear relationship with the outcome using generalise additive model (GAM) plots (R). Any continuous variable that did not have a linear relationship with the outcome was categorised for further analysis. Categories were derived by examining the structure of the data, ensuring that the same categories could be used for all 3 surveys and ensuring the categories were biologically meaningful. It was also considered whether respondents could select more than one response category for that question or whether only one response was selected. For example, considering which quarantine treatment was given, farmers could select multiple anthelmintic classes. Therefore each anthelmintic class was assigned as a separate binary response for that question. In contrast, when considering how farmers determine the dose of anthelmintic, single responses were given (one of: estimated weights, average weights, heaviest and individual weights). In this case, the response variable was 'how do you determine the dose' and this response was categorical.

2.2.3 Selection of variables for analysis

Behavioural questions relating to best practice advice in reference to SCOPS guidelines were selected for analysis. Only questions used in both 2000 and 2010 surveys were included. A list of the dependent variables used in the analysis is presented in Table 5. Independent variables considered *a priori* to be influential on the dependant variables were selected for analysis i.e. farming demographics and information sourcing (presented in Table 6).

Table 5 - List of dependent variables and categories used in logistic regression analysis

Associated SCOP guideline	Dependent variables	Categories
Implementing an effective quarantine strategy	Drench incoming animals?	Yes/No
	Quarantine treat 1-BZ	Yes/No
	Quarantine treat 2-LV	Yes/No
	Quarantine treat 3-ML	Yes/No
Test for anthelmintic resistance on your farm	Confirmed anthelmintic resistance	Yes/No
Administering anthelmintics effectively	Determine wormer dose	Estimated weights
		An average weight
		Heaviest weight of individual in the group

Table 5 - List of dependent variables and categories used in logistic regression analysis

Associated SCOP guideline	Dependent variables	Categories
		Individual weights of animals
	Withholding feed before anthelmintic treatment?	Yes/No
Use anthelmintic only when necessary	Give ewe/lamb treatments based on a set drench programme	Yes/No
	Give ewe/lamb treatments based on signs of disease	Yes/No
	Give ewe/lamb treatments at housing time	Yes/No
	Give ewe/lamb treatments at docking or hoof trimming	Yes/No
	Give ewe/lamb treatments at weaning time	Yes/No
	Give ewe/lamb treatments at turn-out	Yes/No
	Give ewe treatments pre-tupping	Yes/No
	Give ewe treatment pre or post lambing	Yes/No
	Number of ewe treatments/year	<2/>2
	Number of lamb treatments/year	<3/>3
Select the appropriate anthelmintic	Administer oral drench?	Yes/No
	Administer injectable treatments?	Yes/No
Adopt strategies to preserve susceptible worm on farm	Do you move animals to clean grazing after treatment?	Yes/No
Reduce dependence on anthelmintics	Use of rotation grazing between livestock?	Yes/No
	Use of co-grazing of livestock	Yes/No

Table 6 – Breakdown of Independent variables and their categories used for logistic regression analysis

Independent variables	Category numbers	Categories
Number of lambs	1	0-200
	2	200-600
	3	600-24,000
Number of ewes	1	0-150
	2	150-400
	3	>400
Farm size (acres)	1	0-250
	2	250-900
	3	>900
Highest ranked worm control information source	1	Veterinarian
	2	Other
Predominant farm type	1	Hill/upland
	2	Lowland

2.2.4 Statistical analysis

2.2.4.1 Univariate analysis for binary outcomes

The purpose of this analytical method is to measure the relationship between a dependent variable (i.e. an outcome) and an independent variable. The outputs generated from the analysis give a probability value (P Value) and an odds ratio (OR). The OR represents the relative odds that an outcome will occur given the exposure to a variable of interest compared with the odds of an outcome occurring in the absence of the variable of interest. For example, if the OR between variables is greater than 1, then the occurrence of the exposure is associated with higher odds of the outcome occurring (Szumilas, 2010). Whereas if the OR is less than 1, then the occurrence of the exposure is associated with lower odds of the outcome occurring. The OR are considered significant if the output P value is less than 0.05 or if the 95% confidence interval (CI) does not overlap with the null value i.e. OR = 1 (exposure does not affect odds of the outcome occurring). This was carried out using chi-squared analysis (Minitab) or binary logistic regression (R studio).

2.2.4.2 Multivariable analysis for binary outcomes

The second method is used to describe the relationship between two or more independent variables and a response variable. All the outputs from the univariate analysis with P values that were less than 0.25 were aggregated with their corresponding response variable to derive a final model equation. Stepwise elimination was then used to condense the number of independent variables, so that only significant variables (<0.05) were present if they fit the final model. This was carried out using multivariable logistic regression (R studio). Variables were screened for multi-collinearity by chi-squared analysis for categorical variables and Pearson's rank correlation for continuous variables (Minitab). If significance was detected then only one of the correlated variables was included in the multivariable model.

2.2.4.3 Categorical outcomes

Response variables that were categorical i.e. where responses are limited to a particular group or category were assessed for association between independent variables. Anthelmintic dose determination was the only categorical practice used in this analysis. Cross tabulation and chi-squared analysis was carried out using Minitab.

2.3 RESULTS

2.3.1 Respondent demographics

2.3.1.1 Questionnaire, 2000 (Scotland)

The total number of completed questionnaire responses was 97.

Figure 17 - Geographical distribution of Scottish respondents in 2000 (BatchGeo)

Table 7 - Descriptive statistics of independent variables for Scottish respondents in 2000 (n =97)

Variable	Min	Max	Median	Interquartile range (Q3 – Q1)	Missing values
Total area of pasture (acres)	12	6,178	320	680 (750-70)	1
Number of ewes	11	2,500	300	599 (685-11)	2
Number of lambs	16	24,000	400	840 (960-16)	5
Farm type	**Upland**		**Lowland**		
	74 (*n*)	77%	19 (*n*)	20%	4
No.1 information source	**Vets**		**Other**		
	53 (*n*)	55%	44 (*n*)	45%	0

2.3.1.2 Questionnaire, 2010 (Scottish respondents)

The total number of completed surveys from Scottish respondents in 2010 was 104.

Figure 18 - Geographical distribution of Scottish respondents in 2010 (BatchGeo)

Table 8 - Descriptive statistics of independent variables for Scottish respondents in 2010 (n =104)

Variable	Min	Max	Median	Interquartile range (Q3 - Q1)	Missing values
Total area of pasture (acres)	5.5	18,000	410	1067 (1200-133)	5
Number of ewes	10	3,000	430	600 (740-140)	1
Number of lambs	0	3,600	500	941 (1143-202)	4
Farm type	**Upland**		**Lowland**		
	74 (n)	76%	22 (n)	22%	8
No.1 information source	**Vets**		**Other**		
	56 (n)	54%	48 (n)	46%	0

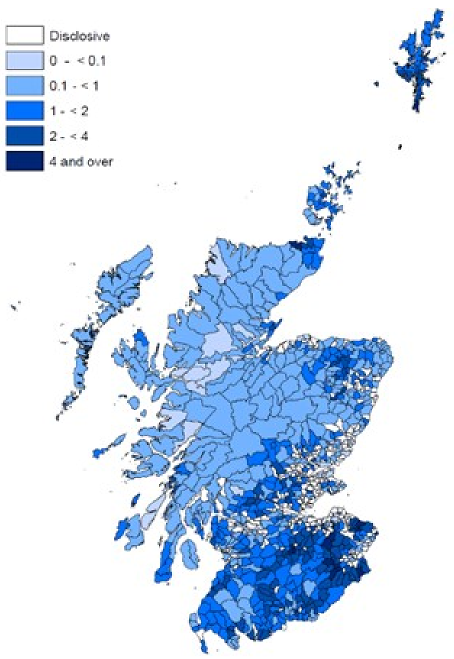
2.3.1.3 Questionnaire, 2010 (English and Welsh respondents)

The total number of respondents from English and Welsh respondents was 176.

Figure 19 - Geographical distribution of English and Welsh respondents in 2010 (BatchGeo)

Table 9 - Descriptive statistics of independent variables for English and Welsh respondents in 2010 (n =104)

Variable	Min	Max	Median	Interquartile range (Q3 – Q1)	Missing values
Total area of pasture (acres)	3	19,560	150	287 (339-52)	7
Number of ewes	10	13,521	260	537 (600-63)	3
Number of lambs	0	16,700	400	800 (900-100)	16
	Upland		**Lowland**		
Farm type	51 (n)	29%	101	57%	24
	Vets		**Other**		
No.1 information source	63 (n)	36%	113	64%	0



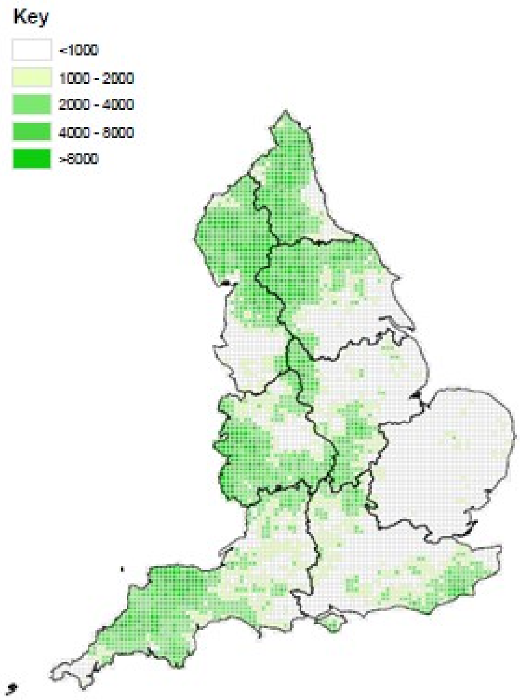


Figure 20 – (left) Density map for number of sheep per hectare in agricultural parish (Scottish Government, 2015). Figure 21 – (right) Density map for the number of sheep by 5 km² grid squares in England (DEFRA, 2015).

It can be seen from Figures 17 and 18, that respondents from Scotland were clustered mostly in the southern and eastern regions of the country and then spread fairly sporadically in other regions. In Figure 19, English respondents were mostly located in the south west, south east and northern regions. Whilst in Wales the majority of respondents were either from the southern or central areas. The overall distribution of survey respondents shows a good similarity to that of the sheep density maps (Figure 20 and 21).

The farming structure is highly varied among respondents both within and between survey groups, as denoted by the high interquartile ranges (detailed in Tables 7-9). The results of the GAM plots demonstrated a limited relationship between dependent variables and continuous independent variables, which was likely due to a strong positive skew towards smaller farms/flock sizes. This is due to a select few respondents who either have particularly large farms or have multiple premises which have been accounted for. In order to allow consistency within the analysis the continuous variables were categorised into ‘small, medium and large’ farm sizes to ensure comparable numbers between all demographic groups (detailed breakdown shown in Table 6). The number of non-responses with regards to farm acreage and flock size was greatest among English and Welsh respondents overall (n=26), followed by Scottish respondent in 2010 (n=10) and respondents in 2000 (n= 8)

When comparing between survey demographics it is possible to observe similarities and differences in farm structure based on the parameters shown. For instance in Scotland there are comparable similarities in overall farm size, flock size and farm type between surveyed respondents. However in 2010 notable differences can be observed between regions, with relatively smaller farm and flock sizes in English and Welsh farms when compared with Scottish respondents. Additionally, farm topography was predominantly lowland in England and Wales compared to mostly upland in Scottish farms. The number of non-responses with regard to topography was highest for English and Welsh respondents across all survey groups with 24 (14%) participants not responding to this question.

To validate the comparisons between survey groups based on the farming demographics, Pairwise Mann Whitney tests (Minitab) were used to compare the medians of continuous variables between survey groups (Scotland 2000 vs. 2010 and 2010 Scotland vs. England/Wales) as well as chi-squared test used to compare categorical variables (i.e. farm type).

Information sourcing in regards to worm control advice was almost identical between Scottish respondents with most farmers indicating their veterinarian as their primary source of information. In contrast, the majority of farmers in England and Wales sought their information from ‘other’ sources.

2.3.2 Descriptive statistics

The breakdown of results is detailed in Table 10, regarding roundworm control practices employed by survey respondents and is further described in relation to the SCOPS guidelines.

2.3.2.1 Quarantine practice

The use of anthelmintic treatments for treating incoming animals was implemented by the majority (>70%) of respondents across both surveys. Not treating incoming stock for parasites was practised by almost a tenth of respondents (8%) in 2000, compared to almost a quarter of respondents (23%) in 2010 (Scotland) with England and Welsh respondents in between these Figures (16%).

The use of a single active treatment was most common in the 2000 survey (57%) with the Benzimidazole group most widely used by respondents (29%) followed by macrocyclic lactones (25%) and levamisole used least (3%). In comparison, in 2010, the use of Benzimidazole products in isolation differed considerably, with an overall increase in the use of the remaining anthelmintic groups. The use of multiple treatments classes was employed most by respondents from England/Wales in 2010 (36%), followed by 2010 Scotland (23%) and 2000 (15%).

2.3.2.2 Testing for resistance

The confirmation of anthelmintic resistance by respondents to the three main classes increased between time points from 2000 to 2010. The most comparable difference was between Scottish respondents in 2000 and 2010 with an increase (9%) in the frequency of confirmed benzimidazole resistance. Respondents in England and Wales had the overall highest levels of confirmed benzimidazole resistance (19%) which was considerably higher in comparison to respondents surveyed in Scotland (11%). Known resistance to the levamisole and macrocyclic lactone groups was marginally higher between time points with little regional differences in 2010.

Table 10 – Roundworm control practice employment statistics for 2000 (Scotland) and 2010 (Great Britain) surveys.

Roundworm control practices		**Scotland (2000)**		**Scotland (2010)**		**England/Wales**	
		n	**%**	**n**	**%**	**n**	**%**
Do you drench animals brought onto the farm?	No	8	8	24	23	28	16
(multiple choice question)	Benzimidazole (1-BZ) only	28	29	8	8	16	9
	Levamisole (2-LV) only	3	3	6	6	8	5
	Macrocyclic Lactone (3-ML) only	24	25	34	33	39	22
	Multiple classes (>1)	14	15	24	23	63	36
	Non responses	20	19	8	8	22	13
	Total	97	100	104	100	176	100
Do you have any confirmed resistance?	No	95	98	88	85	131	74
	Benzimidazole (1-BZ) only	2	2	11	11	34	19
	Levamisole (2-LV) only	0	0	3	3	3	2
	Macrocyclic Lactone (3-ML) only	0	0	2	2	0	0
	Multiple classes	0	0	0	0	6	3
	No response	0	0	0	0	2	1
	Total	97	100	104	100	176	100
How do you determine how much drench to use?	Estimated weight only	31	32	42	40	65	37
	Average weight only	15	15	7	7	13	7
	Heaviest weight only	46	47	48	46	87	49
	Individual weight only	1	1	2	2	4	2
	Combination	4	4	5	5	7	4
	Total	97	100	104	100	176	100

Table 10 – Roundworm control practice employment statistics for 2000 (Scotland) and 2010 (Great Britain) surveys.

Roundworm control practices		**Scotland (2000)**		**Scotland (2010)**		**England/Wales**	
		n	**%**	**n**	**n**	**%**	**n**
How do you determine how much drench to use?	Estimated weight only	31	32	42	40	65	37
	Average weight only	15	15	7	7	13	7
	Heaviest weight only	46	47	48	46	87	49
	Individual weight only	1	1	2	2	4	2
	Combination	4	4	5	5	7	4
	Total	97	100	104	100	176	100
Do you withhold food before drenching?	No	77	79	78	75	142	81
	Yes	20	21	25	24	34	19
	No response	0	0	1	1	0	0
	Total	97	100	104	100	176	100
How do you treat your ewes?	Set drench programme	50	52	35	34	34	19
(Multiple choice question)	Sign of disease	15	16	17	16	29	16
	Housing	20	21	10	10	30	17
	Docking/hoof trimming	10	10	6	6	8	5
	Weaning	9	9	9	9	16	9
	Turn-out	17	18	15	14	39	22
	Pre-tupping	67	70	58	56	78	44
	Pre/post lambing	67	70	70	67	97	55

Table 10 – Roundworm control practice employment statistics for 2000 (Scotland) and 2010 (Great Britain) surveys.

Roundworm control practices		**Scotland (2000)**		**Scotland (2010)**		**England/Wales**	
		n	**%**	**n**	**n**	**%**	**n**
How do you treat your lambs?	Set drench programme	56	58	42	40	71	40
(Multiple choice question)	Sign of disease	46	48	48	46	99	56
	Housing	5	5	2	2	11	6
	Docking/hoof trimming	12	13	10	10	5	3
	Weaning	43	45	49	47	85	48
	Turn-out	5	5	3	3	6	3
How often do you drench your ewes?	None	11	11	0	0	6	3
	Once	10	10	30	29	67	38
	Twice	36	37	39	38	67	38
	Three times	23	24	20	19	18	10
	Four times	9	9	8	8	9	5
	Five times	4	4	0	0	1	1
	More than five times	4	4	3	3	1	1
	Non response	0	0	4	0	7	4
	Total	97	100	104	100	176	100
Do you co-graze, rotationally graze or graze separately?	Co-graze	48	50	42	40	43	24
(multiple choice question)	Rotational graze	20	21	35	34	49	28
	Graze separately	39	40	12	12	14	8

Table 10 – Roundworm control practice employment statistics for 2000 (Scotland) and 2010 (Great Britain) surveys.

Roundworm control practices		**Scotland (2000)**		**Scotland (2010)**		**England/Wales**	
		n	**%**	**n**	**%**	**n**	**%**
How often do you drench your lambs?	None	17	18	7	7	3	2
	Once	6	6	18	17	16	9
	Twice	27	28	31	30	30	17
	Three times	16	16	23	22	45	26
	Four times	19	20	19	18	42	24
	Five times	5	5	3	3	16	9
	More than five times	7	7	3	3	10	6
	No response	0	0	0	0	14	8
	Total	97	100	104	100	176	100
What form of anthelmintic do you use to treat your sheep?	Oral drench only	64	66	58	56	125	71
	Injectable only	1	1	3	3	2	1
	Both	29	30	42	40	46	26
	None	3	3	1	1	3	2
	Total	97	100	104	100	176	100
Do you move your animals to clean pasture after treatment?	No	52	53	69	66	107	61
	Yes	43	44	35	34	69	39
	Both	2	2	0	0	0	0
	Total	97	100	104	100	176	100

2.3.2.3 Administering anthelmintics effectively

In order to establish the effectiveness of anthelmintic treatment administration, farmers were asked how they determined their treatment doses. Almost half of respondents from the 2000 survey used either the recommended heaviest (47%) or individual weights (1%) of animals to determine treatment dose. The other half of respondents predominantly used an estimated weight (35%) or used an average weight for the treatment group (19%). Between the 2000 and 2010 Scottish respondents there was a notable increase (5%) in the proportion of farmers using estimated weights and an equivalent decrease in those using average weights (8%).

The advice to withhold feed before treatment was adopted by between 19-24% of respondents across all survey groups, with no discernible difference in the uptake of this practice between years or between regions within the 2010 survey.

2.3.2.4 Treating animals only when necessary

2.3.2.5 Treatment timings

In general the most common regimen for the treatment of ewes was based on either a set drenching programme or treatments before mating time or around lambing. The treatment of lambs in most cases is practised based on either a set drenching programme, signs of clinical disease or at weaning time.

When comparing differences in treatment practice between Scottish respondents in 2000 and 2010, the most apparent change is the decline in the use of a set drench programme to treat ewes and lambs (18% reduction). Additionally the use of treatments at pre-mating and housing time for ewes was reduced between survey groups (14% and 11% reduction).

When examining regional differences between respondents in 2010, almost a fifth of farmers in England and Wales (19%) were using a set drench programme to decide ewe treatment timings, which is 15% less than stated by Scottish respondents (34%). However there was no regional difference between the proportions of farmers using a set drench programme to treat lambs (40%). The use of lamb treatments based on signs of disease was 10% greater from English and Welsh respondents (56%) compared with those in Scotland (46%). The use of ewe treatments at pre-mating and lambing times were 12% less in English and Welsh farmers (44% and 55%) compared with Scottish farmers (56% and 67%).

2.3.2.6 Treatment frequency

The average number of ewe and lambs treatments in 2000 was 2.6 and 3.1 respectively, which is slightly higher in comparison to the 2010 Scottish mean ewe and lamb treatment frequency of 2.2 and 2.6 respectively. When comparing regional differences in 2010, English and Welsh respondents gave on average a lower number of ewe treatments (1.8) but a higher number of lamb treatments respectively (3.2). The percentage of respondents administering above average number of treatments (i.e. 3) was 18% higher from farmers surveyed in England and Wales compared with Scottish respondents. The total number of non-responses to ewe and lamb treatment frequency was highest among English and Welsh respondents (n=21), followed by Scottish respondents in 2001 (n=8) and Scottish respondents in 2010 (n=4).

2.3.2.7 Selecting the appropriate anthelmintic

The use of oral formulations of anthelmintics was consistent between all survey groups (96-97%); however the use of injectable treatments was 12% higher from Scottish respondents in 2010 than in 2000. Within the 2010 survey, 16% fewer English and Welsh respondents used injectable anthelmintic treatments when compared with Scottish respondents (43%).

2.3.2.8 Preserving susceptible worms

The proportion of farmers implementing the practice of moving treated animals to clean/safe grazing ('dose and move') reduced 10% between 2000 and 2010 from Scottish respondents. When comparing regional differences in 2010, respondents in England and Wales had a 5% higher proportion of farmers using this practice in comparison to Scottish farmers.

2.3.2.9 Alternative worm control strategies

Grazing management strategies as indicated by Scottish respondents were proportionally higher for those co-grazing livestock than rotational grazing. Although in 2010, 13% more Scottish respondents were using rotational grazing with a 10% decrease in those co-grazing livestock. Within the 2010 survey, 16% fewer respondents in England and Wales used co-grazing (24%) than in Scotland (40%) and also 6% fewer respondents used rotational grazing in England and Wales (28%) than in Scotland (28%).

2.3.3 Statistical analysis

2.3.3.1 Quarantine practice

In the analysis of respondents surveyed in 2000, farmers that ranked their veterinarians as their primary source of roundworm control information were significantly more likely to use benzimidazole to treat incoming animals (Table 11; OR 2.58, 95% CI 1.11-6.02) than those farmers that ranked another source as their number one source of information.

In the English and Welsh 2010 survey (Table 14), farm size was significantly associated with giving quarantine treatments with larger farm sizes (>900 acres) more likely to administer a quarantine anthelmintic treatment to incoming animals (OR 5.11, 95% CI 1.48-17.65). There was also a significant association between farm size (acres) and the use of levamisole with larger farms (>900 acres) less likely than small farms (<250 acres) to use this class of anthelmintic (OR 0.14, 95% CI 0.02-1.14). English and Welsh respondents with moderate numbers of breeding ewes (150-400) were also significantly more likely than smaller sized flocks (0-150) to use a levamisole product for quarantine treatments (OR 2.82, 95% CI 1.28-6.22).

2.3.3.2 Administering anthelmintics effectively

In 2000 there was evidence of an association between the method of dose determination and number of lambs (P=0.004), as farms with >600 lambs were more likely to dose according to the heaviest animal and farms with <200 lambs more likely to take an average weight (Table 16). Farms with between 200-600 lambs were more likely to estimate the weight of the lambs for dosing.

A similar trend was observed in 2010 English and Welsh respondents (Table 17 & 18) with number of ewes and lambs associated with method of determining dose (P=0.0001 and P=0.007). Here though, farms with fewer sheep (<150 ewes and <200 lambs) were more likely to estimate the weights.

In the 2010 Scottish respondents, the number 1 source of information was associated with determining dosing practice (P=0.006), with those using vets more to dose according to the heaviest animals and less likely to take the average weight than those who seek advice elsewhere (Table 19).

2.3.3.3 Treating only when necessary

Flock size (based on either ewe or lamb numbers) was found to be significantly associated with certain treatment strategies. Farms with larger numbers of ewes (>400) were significantly less likely to treat ewes at turn-out than smaller flocks (<200) in 2000 (Table 11; OR 0.16, 95% CI 0.03-0.82). Furthermore, farms with large numbers of lambs (>600) were significantly less likely than smaller lamb flocks (<200) to treat based on clinical signs of disease (Table 11; OR 0.14, 95% 0.03-0.72) in 2000, as well as by Scottish respondents in 2010 (Table 13; OR 0.18, 95% CI 0.06-0.53). Additionally in the multivariable analysis (Table 12), farmers in 2000 who treat their ewes at weaning time were significantly less likely to have larger flocks (OR 0.11, 95% CI 0.02-0.70) and rank their veterinarians as their primary information source regarding roundworm control (OR 0.06, 95% CI 0.01-0.55).

Farm acreage was significantly associated with similar treatment practices as identified by flock size with large farms (>900 acres) less likely to treat based on clinical signs of disease (Table 11; OR 0.32, 95% CI 0.11-0.95) and at turn-out (Table 13; OR 0.1, 95% CI 0.01-0.81) in 2010. Furthermore, large farms in England and Wales (>900 acres) were more likely than smaller farms (<250 acres) to use a set drenching programme (Table 14; OR 2.56, 95% CI 0.75-8.79).

The topography of farmland was also associated with specific treatment strategies, with upland more likely to treat animals based on a routine set drench programme in both Scottish (Table 13; OR 4.27, 95% CI 1.44-12.66) and English and Welsh (Table 14; OR 2.35, 95% CI 1.02-5.42) groups in 2010. In the 2000 multivariable analysis, treating based on a predetermined programme was also more likely on upland farms (Table 12; OR 2.83, 95% CI 1.13-7.10) as well as with worm control information primarily sourced from their veterinarians (OR 7.66, 95% CI 2.15-27.26). In England and Wales (2010), upland farms were more likely to administer more than the average 2 ewe treatments per year compared with lowland farms (Table 14; OR 3.03, 95% CI 1.26-7.24).

Information sourcing either with a veterinarian or an 'other' source was significantly associated with varying treatment strategies between 2000 and 2010. Farmers who sourced their roundworm control information from their veterinarians were significantly more likely in 2000 to treat ewes at docking/hoof trimming (Table 11; OR 8.59, 95% CI 1.04-70.77), in 2010 (Scotland) treat at turn-out (Table 13; OR 4.09, 95% CI 1.08-15.49) and at pre-post lambing, in England and Wales (Table 14; OR 2.35, 95% CI 1.02-5.42). In the multivariable analysis, farmers in 2000 that primarily sourced information from their veterinarians were more likely to treat ewes based on a set drenching programme (Table 12; OR 7.66, 95% CI 2.15-27.26). In 2000 and 2010 farmers who ranked vets as their primary information source were less likely to treat ewes at weaning (Table 12; OR 0.06, 95% CI 0.06-0.01-0.55), while in 2010 (England and Wales) farmers were more likely to treat lambs at weaning (Table 15; OR 2.37, 95% CI 1.15-4.89).

2.3.3.4 Selecting the appropriate anthelmintic

In the 2010 survey, English and Welsh respondents using an injectable formulation of anthelmintic were significantly associated with farm type, with upland farmers more likely to carry use an injectable anthelmintic compared with lowland farms (Table 14; OR 2.67, 95% CI 1.28- 5.57).

2.3.3.5 Preserving susceptible worms

In the 2000 survey the practice of moving treated animals onto clean/safe grazing was significantly associated with farm size with larger sized farms (>900 acres) more likely to carry out this practice (Table 11; OR 3.83, 95% CI 1.11-13.25).

2.3.3.6 Grazing management strategies

From the Scottish farmers surveyed in 2000, there was a significant association between co-grazing of livestock species and flock size as well as farm size, with larger premises (>900 acres) more likely to co-graze livestock (Table 11; OR 6.86, 95% CI 2.08-22.57) as well as larger flocks (>400 ewes; OR 9.2, 95% CI 3.03-27.98). English and Welsh farmers in 2010 that are predominantly upland were also more likely to co-graze livestock (Table 14; OR 2.52, CI 1.17-5.42).

Table 11 - Univariable analysis outputs from Scotland survey (2000) determining the association between farming characteristics and information sourcing on roundworm control practices.

Factor	Dependent variable	Independent variable	Independent categories	Dependent response: No	Dependent response: Yes	Dependent response: Total	Dependent response: NA	Odds ratios	CI (95%)	P - value
Effective quarantine practice	Quarantine treat incoming stock with 1-BZ	Vets ranked #1 information source regarding roundworm control	Vet	25	29	97	0	2.58	1.11-6.02	0.025
			Other sources	30	13					
Treat only when necessary	Treating ewes at docking/hoof trimming	Vets ranked #1 information source regarding roundworm control	Vet	44	10	97	0	8.59	1.04-70.77	0.012
			Other sources	42	1					
	Treat ewes at sign of disease	Annual number of lambs	0-200	21	10	93	4	1		0.023
			200-600	23	3			0.3	0.07-1.28	
			>600	33	2			0.14	0.03-0.72	
		Vets ranked #1 information source regarding roundworm control	Vet	49	5	97	0	0.24	0.07-0.81	0.015
			Other sources	32	11					
	Treat ewes at turn-out	Annual number of ewes	0-150	24	10	95	2	1		0.043
			150-400	21	5			0.63	0.18-2.19	
			>400	33	2			0.16	0.03-0.82	
	Treat lambs at sign of disease	Farm size (acres)	0-250	17	30	96	1	1		0.021
			250-900	19	10			0.31	0.12-0.82	
			> 900	13	7			0.32	0.11-0.95	

Table 11 - Univariable analysis outputs from Scotland survey (2000) determining the association between farming characteristics and information sourcing on roundworm control practices.

Factor	Dependent variable	Independent variable	Independent categories	Dependent response				Odds ratios	CI (95%)	P - value
				No	Yes	Total	NA			
Preserving susceptible worms	Moving treated animals to clean grazing	Farm size (acres)	0-250	23	23	95	2	1		0.019
			250-900	12	17			0.68	0.26-1.73	
			> 900	16	4			3.83	1.11-13.25	
Adopting alternative worm control strategies	Co-grazing livestock species	Annual number of ewes	0-150	23	11	95	2	1		<0.001
			150-400	16	10			1.44	0.49-4.25	
			>400	7	28			9.2	3.03-27.98	
		Annual number of lambs	0-200	21	10	92	5	1		0.003
			200-600	14	12			2	0.67-5.99	
			>600	10	25			5.83	2.0-17.03	
		Farm size (acres)	0-250	32	15	96	1	1		<0.001
			250-900	11	18			3.74	1.41-9.95	
			> 900	5	15			6.86	2.08-22.57	

Table 12 – Multivariate analysis outputs from Scotland survey (2000) determining the association between farming characteristics and information sourcing on roundworm control practices.

Factor	Dependent variable	Independent variable	Independent categories	Dependent responses				Odds Ratios	CI (95%)	P - value
				No	Yes	Total	NA			
Treating only when necessary	Treat ewes based on set drench programme	Vets ranked #1 information source regarding roundworm control	Vet	22	32	97	0	7.66	2.15-27.26	<0.001
			Other sources	24	19					
		Predominant farm type (Upland)	Upland	30	45	94	3	2.83	1.13-7.1	0.023
			Lowland	15	4					
	Treat ewes weaning	Annual number of lambs	0-200	24	7	92	5	1		0.011
			200-600	25	1			0.07	0.01-0.75	
			>600	33	2			0.11	0.02-0.7	
		Vets ranked #1 information source regarding roundworm control	Vet	45	9	97	0	0.06	0.01-0.55	0.002
			Other sources	42	1					

Table 13 – Univariable outputs from 2010 survey (Scottish respondents) determining the association between farming characteristics and information sourcing on roundworm control practices.

Factor	Dependent variable	Independent variable	Independent categories	Dependent response				Odds Ratios	CI (95%)	P - value
				No	Yes	Total	NA			
Treating only when necessary	Treating lambs based on a set drench programme	Annual number of lambs	0-200	18	6	99	5	1		0.013
			200-600	23	9			1.17	0.35-3.91	
			>600	19	24			3.79	1.26-11.41	
		Predominant farm type (Upland)	Upland	39	35	96	8	3.05	1.02-9.14	0.035
			Lowland	17	5					
	Treat lambs at sign of disease	Annual number of ewes	0-150	10	19	103	1	1		0.001
			150-400	8	14			0.92	0.29-2.93	
			>400	37	15			0.21	0.08-0.56	
		Annual number of lambs	0-200	7	17	99	5	1		0.004
			200-600	15	17			0.47	0.15-1.43	
			>600	30	13			0.18	0.06-0.53	
		Farm size (acres)	0-250	15	20	99	5	1		0.033
			250-900	18	15			0.63	0.24-1.63	
			> 900	23	8			0.26	0.09-0.74	
	Treat ewes based on a set drench programme	Farm size (acres)	0-250	28	7	99	5	1		0.025
			250-900	22	11			2	0.67-6.01	
			> 900	15	16			4.27	1.44-12.66	

Table 13 – Univariable outputs from 2010 survey (Scottish respondents) determining the association between farming characteristics and information sourcing on roundworm control practices.

Factor	Dependent variable	Independent variable	Independent categories	Dependent response				Odds Ratios	CI (95%)	P - value
				No	Yes	Total	NA			
Treating only when necessary	Treat ewes based on signs of disease	Annual number of ewes	0-150	19	10	103	1	1		<0.001
			150-400	17	5			0.56	0.16-1.96	
			>400	50	2			0.08	0.02-0.38	
		Annual number of lambs	0-200	16	8	99	5	1		0.007
			200-600	26	6			0.46	0.14-1.58	
			>600	41	2			0.1	0.02-0.51	
		Farm size (acres)	0-250	24	11	99	5	1		0.011
			250-900	30	3			0.22	0.05-0.87	
			> 900	29	2			0.15	0.03-0.75	
	Treat ewes at turn-out	Farm size (acres)	0-250	26	9	99	5	1		0.017
			250-900	30	3			0.29	0.07-1.18	
			> 900	30	1			0.1	0.01-0.81	
		Vets ranked #1 information source regarding worm control	Vet	44	12	99	5	4.09	1.08-15.49	0.023
			Other sources	45	3					

Table 14 – Univariable outputs from 2010 survey (English and Welsh respondents) determining the association between farming characteristics and information sourcing on roundworm control practices.

Factor	**Dependent variable**	**Independent variable**	**Independent categories**	**Dependent variable**				**Odds Ratios**	**CI (95%)**	**P - value**
				No	**Yes**	**Total**	**NA**			
Effective quarantine practice	Treat incoming animals	Farm size (acres)	0-250	92	18	169	7	1		0.033
			250-900	40	7			0.89	0.35-2.31	
			> 900	6	6			5.11	1.48-17.65	
	Quarantine treat incoming stock with 2-LV	Annual number of ewes	0-150	47	20	173	3	1		0.029
			150-400	20	24			2.82	1.28-6.22	
			>400	40	22			1.29	0.62-2.7	
		Farm size (acres)	0-250	67	43	169	7	1		0.039
			250-900	26	21			1.26	0.63-2.51	
			> 900	11	1			0.14	0.02-1.14	
Treating only when necessary	Treat lambs at weaning	Annual number of ewes	0-150	42	25	173	3	1		0.042
			150-400	18	26			2.43	1.11-5.29	
			>400	28	34			2.04	1.01-4.12	
	Treat ewes based on a set drench programme	Farm size (acres)	0-250	86	24	169	7	1		0.02
			250-900	43	4			0.33	0.11-1.02	
			> 900	7	5			2.56	0.75-8.79	
		Predominant farm type (Upland)	Upland	37	14	152	24	2.35	1.02-5.42	0.046
			Lowland	87	14					

Table 14 – Univariable outputs from 2010 survey (English and Welsh respondents) determining the association between farming characteristics and information sourcing on roundworm control practices.

Factor	Dependent variable	Independent variable	Independent categories	Dependent variable				Odds Ratios	CI (95%)	P - value
				No	Yes	Total	NA			
Treating only when necessary	Treat ewes pre-post lambing	Vets ranked #1 information source regarding roundworm control	Vet	20	43	176	0	2.35	1.23-4.48	0.008
			Other sources	59	54					
	Above average (>2) annual number of ewe treatments	Predominant farm type (Upland)	Upland	32	14	152	24	3.03	1.26-7.24	0.013
			Lowland	83	12					
Selecting appropriate treatment	Use injectable form of anthelmintic	Predominant farm type (Upland)	Upland	30	21	152	24	2.67	1.28-5.57	0.009
			Lowland	80	21					
Adopting alternative worm control strategies	Grazing livestock separately	Farm size (acres)	0-250	106	4	169	7	1		0.031
			250-900	40	7			4.64	1.29-16.7	
			> 900	10	2			5.3	0.86-32.61	
	Co-grazing livestock species	Predominant farm type (Upland)	Upland	33	18	152	24	2.52	1.17-5.42	0.019
			Lowland	83	18					

Table 15 - Multivariable outputs from 2010 survey (English and Welsh respondents) determining the association between farming characteristics and information sourcing on roundworm control practices.

Factor	Dependent variable	Independent variable	Independent categories	Dependent responses				Odds Ratios	CI (95%)	P - value
				No	Yes	Total	NA			
Treating only when necessary	Treat lambs at weaning	Vets ranked #1 information source regarding roundworm control	Vet	28	35	176	0	2.37	1.15-4.89	0.002
			Other sources	63	50					
		Predominant farm type (Upland)	Upland	16	35	152	24	3.56	1.71-7.4	<0.001
			Lowland	61	40					

Table 16 - Chi square output between dose determination method and annual number of lambs (2000-Scotland)

How anthelmintic dose determined	*Observed and expected counts*	*Annual number of lambs*			
		<200	*200-600*	*>600*	*Total*
Estimated	*Observed*	*11*	*13*	*7*	*31*
	Expected	*9.99*	*8.96*	*12.06*	
Average	*Observed*	*10*	*1*	*7*	*18*
	Expected	*5.80*	*5.20*	*7.0*	
Heaviest	*Observed*	*8*	*12*	*21*	*41*
	Expected	*13.21*	*11.84*	*15.94*	
Total	*-*	*29*	*26*	*35*	*90*

Pearson Chi-Square = 14.143, DF = 4, P-Value = 0.007
Likelihood Ratio Chi-Square = 15.652, DF = 4,
P-Value = 0.004

Table 17 – Chi square output between dose determination method and annual number of ewes (2010- England and Wales)

How anthelmintic dose determined	*Observed and expected counts*	*Annual number of ewes*			
		<150	*150-400*	*<150*	*150-400*
Estimated	*Observed*	*25*	*9*	*13*	*47*
	Expected	*16.90*	*12.29*	*17.82*	
Average	*Observed*	*6*	*0*	*7*	*13*
	Expected	*4.67*	*3.40*	*4.93*	
Heaviest	*Observed*	*24*	*31*	*38*	*93*
	Expected	*33.43*	*24.31*	*35.25*	
Total	*-*	*55*	*40*	*58*	*153*

Pearson Chi-Square = 15.429, DF = 4, P-Value = 0.004
Likelihood Ratio Chi-Square = 18.556, DF = 4,
P-Value = 0.001

Table 18 - Chi square output between dose determination method and annual number of lambs (2010- England and Wales)

How anthelmintic dose determined	Observed and expected counts	Annual number of lambs			
		<200	200-600	<200	200-600
Estimated	Observed Expected	24 17.31	8 10.07	13 17.62	45
Average	Observed Expected	6 5.00	0 2.91	7 5.09	13
Heaviest	Observed Expected	25 32.69	24 19.02	36 33.29	85
Total	-	55	32	56	143

Pearson Chi-Square = 11.385, DF = 4, P-Value = 0.023
Likelihood Ratio Chi-Square = 14.135, DF = 4,
P-Value = 0.007

Table 19 Chi square output between dose determination method and highest ranked information source (2010- Scotland)

How anthelmintic dose determined	**Observed and expected counts**	**#1 ranked information source**		
		Vets	**Other**	**Total**
Estimated	Observed Expected	25 23.02	18 19.98	43
Average	Observed Expected	0 4.82	9 4.18	9
Heaviest	Observed Expected	28 25.16	19 21.84	47
Total	-	53	46	99

Pearson Chi-Square = 11.425, DF = 2, P-Value =0.003
Likelihood Ratio Chi-Square = 14.860 DF = 2,
P-Value = 0.001

2.3.3.7 Comparing roundworm practices between 2000 and 2010

When comparing responses between Scottish respondents to 2000 and 2010 surveys (Table 20), there was a significant shift towards farmers not giving a quarantine treatment to incoming animals (P=0.013). Farmers who did treat incoming animals were less likely to give a 1-BZ treatment in 2010 (P=0.000) and more likely to be using 3-ML treatments. In 2010 Scottish farmers were more likely to have confirmed resistance (P=0.028), and more specifically likely to have 1-BZ resistance (P=0.028). Farmers in 2010 were less likely to determine dose by using an average weight than in 2000 (P=0.024) and also less likely to treat ewes with a set drench programme or at housing and pre-tupping (P=0.009, P=0.030 and P=0.042). Furthermore, lambs treatments were less likely to be given based on a pre-determined set drenching programme (P=0.012).

Table 20 - Binary logistic regression outputs comparing significant differences in Scottish roundworm control practices (2000 and 2010), P<0.05

Dependent variable	Predictor variable	Dependent responses			Odds ratio	CI (95%)	P-value
		No	Yes	Total			
No quarantine drench for incoming animals	2000	89	8	97	1	1.56-9.33	0.002
	2010	80	24	104	3.81		
Quarantine drench 1-BZ	2000	55	42	97	1	0.12-0.48	0.000
	2010	88	16	104	0.24		
Quarantine drench 3-ML	2000	61	36	97	1	1.07-3.32	0.029
	2010	50	54	104	1.88		
Confirmed anthelmintic resistance	2000	94	3	97	1	1.91-38.24	0.005
	2010	88	16	104	8.55		
Confirmed 1-BZ resistance	2000	94	3	97	1	1.20-25.77	0.028
	2010	93	11	104	5.56		
Determining dose by an average weight	2000	78	13	97	1	0.15-0.87	0.024
	2010	96	8	104	0.36		
Treat ewes based on a set drench programme	2000	46	51	97	1	0.26-0.83	0.009
	2010	69	35	104	0.47		
Treat ewes at housing	2000	76	21	97	1	0.18-0.92	0.030
	2010	94	10	104	0.40		
Treat ewes at pre-tupping	2000	29	68	97	1	0.30-0.98	0.042
	2010	46	58	104	0.55		
Treat lambs based on a set drench programme	2000	40	57	97	1	0.28-0.85	0.012
	2010	62	42	104	0.48		

2.4 DISCUSSION

Since the first survey was conducted, the SCOPS guidelines were introduced (2003), two new anthelmintic groups were developed (4-AD - Monepantel and 5-SI - Derquantel) and multiple-resistant parasite species were identified (Sargison et al., 2007). All of these events may have had an impact on the awareness and subsequent uptake of the recommendations by sheep farmers and veterinary health advisors.

The implementation of an effective biosecurity strategy is an important aspect of disease prevention for a range of infectious diseases including parasitic disease. The general pattern of quarantine treatment selection between surveys would suggest that there is a significant shift toward the use of 3-ML treatments. This may be a result of a greater awareness within the farming community of the potential risks of introducing 1-BZ resistant species, when using 1-BZ treatments in isolation. Additionally, certain 3-ML treatments can provide extensive control for a broad range of both internal and external parasites which is likely to be more cost effective and convenient for farmers when introducing new stock. The advice that was given around 2010 (SCOPS 3rd edition) was to administer sequential treatments containing of 2-LV and 3-ML. The uptake of multiple active treatments appears to have increased between time points, which is an essential step for ensuring multi-drug resistant species do not spread to new animal populations. However the proportion of farmers not administering an anthelmintic treatment to incoming stock appears to differ considerably between surveyed respondents, although this is most likely to reflect the independence of the two survey populations.

The factors associated with the selection of different quarantine treatments include veterinary advice in 2000 relating to the use of 1-BZ treatments and farm/flock size in 2010 relating to the use of 2-LV. It could be argued whether veterinary advice was the likely cause for the use of quarantine 1-BZ treatment in 2000, or whether it may have been the common practice among farmers in the preceding years to the introduction of SCOPS. The association between the use of 2-LV and medium sized farms/flocks in England and Wales could be due to a greater awareness of the risks of introducing 1-BZ resistance on these farms.

Establishing the resistance status on farms before clinical indication is vital in order to mitigate further development against the current active(s) used, as well as to potentially instil improvements to the current control strategy. The significant difference in levels of confirmed 1-BZ resistance could be an indicator of improved awareness of drug resistance and its associated impact on treatment efficacy. Although further insight would be required as to how AR was confirmed, if through anecdotal evidence or by empirical methods such as a faecal egg count reduction test (FECRT). Interestingly, more farmers in 2000 believed their drench efficacy had reduced than those with confirmed resistance, and conversely in 2010 more farmers had confirmed resistance than those who perceived a reduction in treatment efficacy. This might suggest that respondents in 2000 may require a greater incentive to test for resistance than awareness alone. Also those respondents in 2010 may be benefiting from the availability of more classes of anthelmintic, in which case would likely reduce the likelihood of identifying an issue with their treatment efficacy. The highest level of confirmed resistance was found by English and Welsh respondents with over a fifth identifying 1-BZ resistance. Based on the parameters evaluated in this study, possible reasons for this may include the above average number of lambs treatments administered in addition to a considerable proportion of farmers practising 'dose and move' in England and Wales. Both of these factors are thought to be important contributors to the development of AR (Falzon et al., 2014). It has also been suggested that prevalence of AR might be lower in northern regions of the UK, possibly due to contrasting management systems and climatic conditions, with southern regions running more intensive flocks on lowland terrain compared to more extensively run flocks on upland or hill in northern regions (Jackson and Coop, 2000). This is likely to influence the scale of parasite exposure and development which in turn is expected to vary the need for chemical intervention.

The findings for dose determination show that a large proportion of farmers in Scotland are estimating weights of animals when dosing. This proportion of farmers estimating animal weights is also comparable in other surveys such as McMahon et al (2013) conducted in Northern Ireland. The significant association between estimating weights for determining treatment and veterinary information sourcing gives reason to believe that there could be difficulty for veterinary advisors to enforce this advice. The weighing of animals although adding an element of cost and labour is arguably one of the most straightforward measures to rationalise to farmers in terms of benefits made from optimising treatment administration. The alternative however is likely to lead to a proportion of animals receiving a sub-optimal dose, which in turn is likely to advance the positive selection of homozygous and some heterozygous resistant parasites (Jackson and Coop, 2000). The findings however demonstrate that just over half of respondents are following the best practice advice to either dose by the heaviest or individual weights of animals. Additionally in Scotland between surveyed groups, respondents were significantly less likely to use an average flock weight to determine their treatment dose, which may demonstrate a disparity between respondent's treatment regimens.

The most frequent timings for the treatment of ewes and lambs is as would be expected, with ewes treated with the aim of improving breeding condition before mating or to counteract the effects of the peri-parturient relaxation in immunity (PPRI) around lambing time. Lambs are treated most frequently when clinical signs associated with parasitic gastroenteritis are identified as well as at weaning time when lambs are at risk of parasite exposure from the elevated faecal egg output from pregnant ewes. The difficulty when advising farmers regarding anthelmintic treatment timings is that the internal and external factors influencing risk of infection need to be assessed on an individual flock basis (Sargison, 2009). For instance, animals' body condition and nutritional status should be considered when deciding whether to administer a pre-tupping treatment, as adult ewes in good condition will benefit little from a treatment and may also unnecessarily select for anthelmintic resistance (Sargison, 2009). The treatment of lambs based on clinical signs may select less strongly for AR by targeting periods of peak larval availability, however this may also incur significant impacts on production (Barger, 1999).

The use of a set drench programme provides farmers with a straightforward, prescriptive regimen for the control of parasites to fit in amongst many other farm management commitments. The timings of these treatments will depend on the characteristics of the farming system, for example hill farmers were more likely to set drench their flocks, possibly due to labour demands required to gather and treat an extensively run flock (Morgan-Davies et al., 2006). The issue with this approach to treating animals is that the epidemiology of parasites are not generally considered, which results in the application of untargeted and potentially unnecessary suppressive treatments (Barger, 1999), the consequence of which, as formerly mentioned, can be favourable for AR development. In 2010, respondents were significantly less likely to use a set drenching programme for treating ewes and lambs for roundworms, as well as for treating ewes at housing and pre-mating, which is likely to encourage a more targeted approach to parasite treatments. To add to this point, the average number of treatments given to ewes and lambs between surveyed groups could suggest that farmers are becoming more selective with their treatment frequency, with a higher proportion of farmers giving a single ewe and lamb treatment between surveys. In England and Wales there was the greatest disparity between the average number of ewe and lamb treatments between demographic groups, with lambs on average receiving almost one and a half times (1.4) more treatments than ewes. This may be a result of there being over twice as many respondents using a set drenching programme to decide lambs treatments compared with ewes. This regional variation has also been observed by Morgan et al (2012) with respondents from various regions of England administering on average more lamb treatments than respondents in Scotland and Wales.

The administration methods of anthelmintics did not differ significantly between surveys in 2000 and 2010, however the proportion of respondents using both oral and injectable treatment formulations did differ considerably between surveys. This difference in the use of injectable wormers may in part be due to pharmacological benefits associated with persistent activity longer when compared to the oral drench equivalent (Alvinerie et al., 1998). These products in addition to conferring roundworm control also have activity against *Psoroptes ovis* (sheep scab) which is practically favourable to farmers when compared with conventional dipping methods (Parker et al., 1999). It would be useful to know the purpose or timings for the administration of injectable wormers, in order to assess the appropriateness of their usage. For example, the use of persistent injectable treatments (containing Moxidectin) for in-lamb ewes can be used to counteract the effects of PPRI, which can significantly control worm burdens in immune-compromised ewes. This is an important preventative measure for reducing the infection pressure for grazing lambs later in the season, especially if the availability of safe grazing pasture for lambs is limited (Sargison et al., 2012). However, this practice could also be highly selective for surviving drug-resistant worms depending on the size of the refugia population on grazing (Sargison et al., 2002). Therefore, to safeguard the efficacy of this group of anthelmintics, the positive and negative impacts of using these products should be considered whenever they are used.

The preservation of a susceptible 'refugia' population is one of most fundamental factors for controlling the rate of anthelmintic resistance development (Van Wyk, 2001). The practice of 'dose and move' whereby treated stock potentially harbouring resistant nematode species are moved onto low contaminated pasture, has proved highly effective at controlling nematodes. However, they prevent the maintenance of a drug susceptible 'refugia' population, which confers a high reproductive advantage to drug resistant species (Van Wyk, 2001). Between surveyed respondents in 2000 and 2010, there appears to be a reduction in the use of this practice, which is likely to have the greatest impact on slowing down resistance development in the livestock industry. Among the repeat respondents it would be useful to determine the motives for this reduction, whether there is an increasing awareness or consideration for sustainability over productivity or if grazing availability is the dominant factor. There does not appear to be a notable regional difference between the use of this practice between respondents in 2010, which may possibly reflect the wide acceptance of the practice in the farming community as an effective means of suppressing parasite numbers.

The final concepts to consider are the alternative control strategies, such as grazing management to reduce dependence on chemical control methods. Such strategies for reducing the risk of high worm burdens on pasture include the use of rotational and co-grazing management. Rotational (or alternate grazing) relies on an interchange between host species with different parasite specificities, consequently each grazing host will populate pasture with parasite species that will either not infect the alternate host or cause little pathogenic effect (Waller, 2006b). This practice has shown promising results in both tropical and temperate climates and appears to be utilised more by Scottish respondents in 2010. The approach of grazing mixed livestock species (co-grazing) together works on the same principle as alternate grazing as either species are able to reduce a proportion of the nematode larvae on herbage causing a dilution effect, however is unlikely to generate potentially 'safe' grazing (Sargison, 2009). The main constraint on the adoption of grazing strategies is the availability of adequately rested pasture (McMahon et al, 2013), which is in turn influenced by individual farm characteristics. Upland farms were more likely to be using a co-grazing system in England and Wales and larger flock and pasture sizes were also more likely to use this system based on Scottish response in 2000. The ability of farmers to adopt alternative parasite control strategies is an integral step towards reducing the dependence on one such method in isolation. This holistic approach to parasite management is therefore an important target for developing long term effective control strategies (Waller, 2006b).

It is important to acknowledge that there were significant limitations in the study design as will be discussed. This study was designed primarily to determine the parasite management practices of Moredun foundation members, in addition to examining the relationship between parasite management practices and the presence/absence of resistance to multiple anthelmintic classes (data not shown). Therefore, the design of the questionnaires was not intended, or suitable for comparative analysis between the two surveyed populations, as reflected by the small number of repeat respondents. The analysis presented in this chapter therefore gives an indication of the general uptake of roundworm control practices by Moredun Foundation members in Scotland and throughout Great Britain in 2000 and 2010.

The second limitation of the study was that statistical power calculations were not conducted prior to the analysis. It could therefore not be determined whether the sample sizes of both surveys were sufficient to confidently detect an anticipated effect or to correctly accept the possibility of alternative explanations. This presents an issue regarding the internal validity and therefore limits the extent to which robust inferences can be made from the findings.

The use of a non-random sampling method for this study could have also introduced the potential for selection bias due to the inclusion of only Moredun Foundation members. This can present issues concerning the external validity of the findings i.e. the ability to generalise the results to the wider sheep farming population. It could be hypothesised that Moredun Foundation members are likely to be more informed about the SCOPS recommendations compared to non-members, due to the fact that membership includes regular mailings relating to animal health However it could be argued that factors other than an awareness of the SCOPS recommendations may be influential for adoption.

Overall, the drop-out rate across all surveys i.e. the number of respondents not completing all survey questions, was minimal with the exception of a small number of farm characteristic questions including farm topography, farm acreage, animal numbers and treatment frequency. The first of these question had the highest overall non-response total in the survey, which was greatest from English and Welsh respondents. This may be due to English and Welsh respondents having a mixture of farm topographies when compared with Scottish participants, which are likely to be predominantly upland and hill farm types.

To increase the generalisability of results to the wider sheep farming community a randomised sampling method would have been used to select participants, together with a sample size adequate enough to achieve a statistical power of at least 80% as generally recommended. This would improve both the internal and external validity of survey findings. Additionally, in order to investigate trends in practice adoption by respondents over time, a longitudinal study of repeat respondents would have been necessary to permit the assessment of changing practices.

2.5 CONCLUSIONS

Differences between surveyed populations' roundworm control practices were observed between time points, although these differences could not be attributed to changes in behaviour over time as this was not the original intention for the survey design. However bearing this is mind, roundworm practices that are strongly associated with AR development such as high drench frequency, dose and move practice and set drench treatments regimens were reduced between surveys. Additionally, more confirmation of AR is observed which is important for raising awareness of the issue and for encouraging early detection before treatments eventually become ineffective. It is also evident that a considerable proportion of farmers are not employing best practice advice, including inappropriate dose determination and lack of quarantine treatments, which are factors likely to select and spread AR.

Farm characteristics and information sourcing were found to be significantly associated with specific worm control practices. Therefore requirements to tailor advice to suit the broad range of farming systems are integral to optimising uptake throughout the industry. Furthermore the high regard for veterinarians in advising farmer's roundworm control highlights an important channel for promoting best practice advice.

The almost exclusive use of oral anthelmintics among respondents reflects the importance of chemical control approaches to the sheep farming industry, and reinforces the requirements for their responsible usage, if sustainability in sheep farming is to be achieved.

CHAPTER 3: A FOCUS GROUP APPROACH TO EXPLORE SHEEP FARMERS' ATTITUDES TO ROUNDWORM CONTROL AND 'BEST PRACTICE' RECOMMENDATIONS

3.1 INTRODUCTION

The attitudes of livestock producers towards new agricultural innovations is an area that has been widely investigated concerning many various novel concepts and technologies. However, with regard to veterinary disease control, farmers' attitudes toward intestinal parasites and anthelmintic resistance management had yet to be explored in depth. The aim of this study was therefore to design and conduct focus group meetings with participants from a cross section of the sheep farming industry in order to explore attitudes towards the various aspects of roundworm control practice as well as the proposed industry recommendations i.e. SCOPS. The discussion topics were designed to identify key areas of interest and concern with regard to parasite control using a scenario based approach. The SCOPS guidelines were also introduced with the purpose of discussing potential motivators and barriers towards adoption of the recommended practices. The findings were intended to aid development of an attitudinal questionnaire that was used to canvass opinions representative of the nationwide level.

From the analysis, four overarching themes were identified as affecting sheep producers' attitudes to roundworm control and best practice advice. These themes comprised of a lack of perceived need to change, the complexity of advice, the ease of implementation of recommended practices and the effectiveness of extension approaches. Additionally, the most important and implementable guidelines identified by sheep farmers were 'Working out a roundworm control strategy with an advisor' and 'administering anthelmintics effectively'. These findings were compared against responses from veterinarians from a sheep veterinary society workshop conducted prior to the focus group meetings. Similarities were exhibited between farmers and veterinarians' rankings with also, 'testing for AR', 'preserving susceptible parasites' and 'reducing dependence on anthelmintics' receiving the lowest rankings for importance and implementability. Some disparity was also observed regarding perceived barriers towards adoption of SCOPS guidelines. Veterinarians predominantly designated 'no perceived need' and 'perceived complexity' as inhibiting general uptake of recommended practices, whereas farmers also acknowledged resource requirements and conflicting advice as barriers to adoption of particular guidelines.

3.2 MATERIALS AND METHODS

3.2.1 Focus group development

3.2.1.1 Identifying central topics for discussion

The starting point for developing the focus group format was to decide on a common theme relating to parasite control to which all participants could relate and express an opinion. As a result it was decided that the discussions revolve around common anthelmintic treatment scenarios based around the sheep farming calendar. From this we could identify the worm control practices implemented by participants and subsequently discuss the motives influencing their behaviours. This foundation resulted in the treatment scenarios as outlined in Figure 22. From the framework sets of questions were devised to underpin which factors are influencing parasite control practices

Figure 22 - Anthelmintic treatment scenarios considered for discussion.

3.2.1.2 Decision tree analysis

In order to identify all possible decision processes behind each of the treatment scenarios, a decision tree analysis was undertaken. This method is principally used in the development of risk assessments as well as for evaluating economic decision outcomes. For this purpose, decision trees (Figures 23-28) were used to highlight important decision processes within the context of 'good' (i.e. non-AR selective) and 'bad' (i.e. AR selective) roundworm control practices as outlined by the SCOPS recommendations. From the decision trees, an extensive list of questions was identified and developed into discussion points for each of the scenarios.

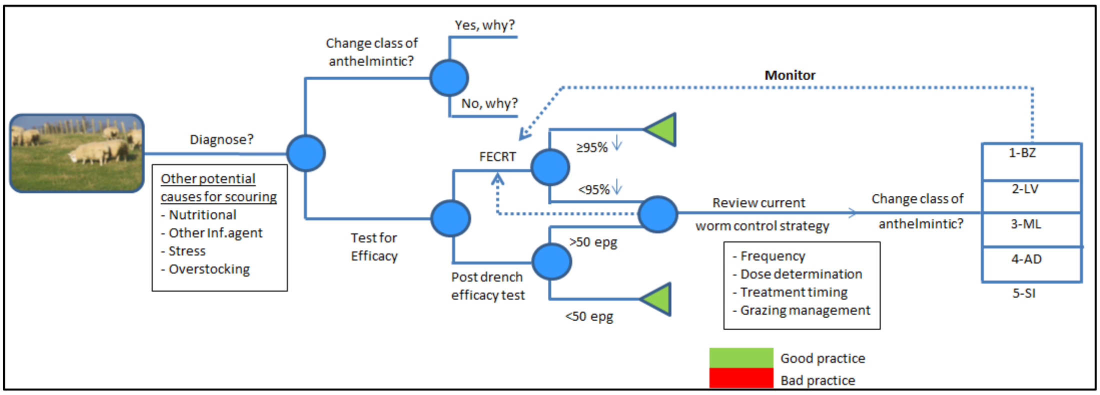
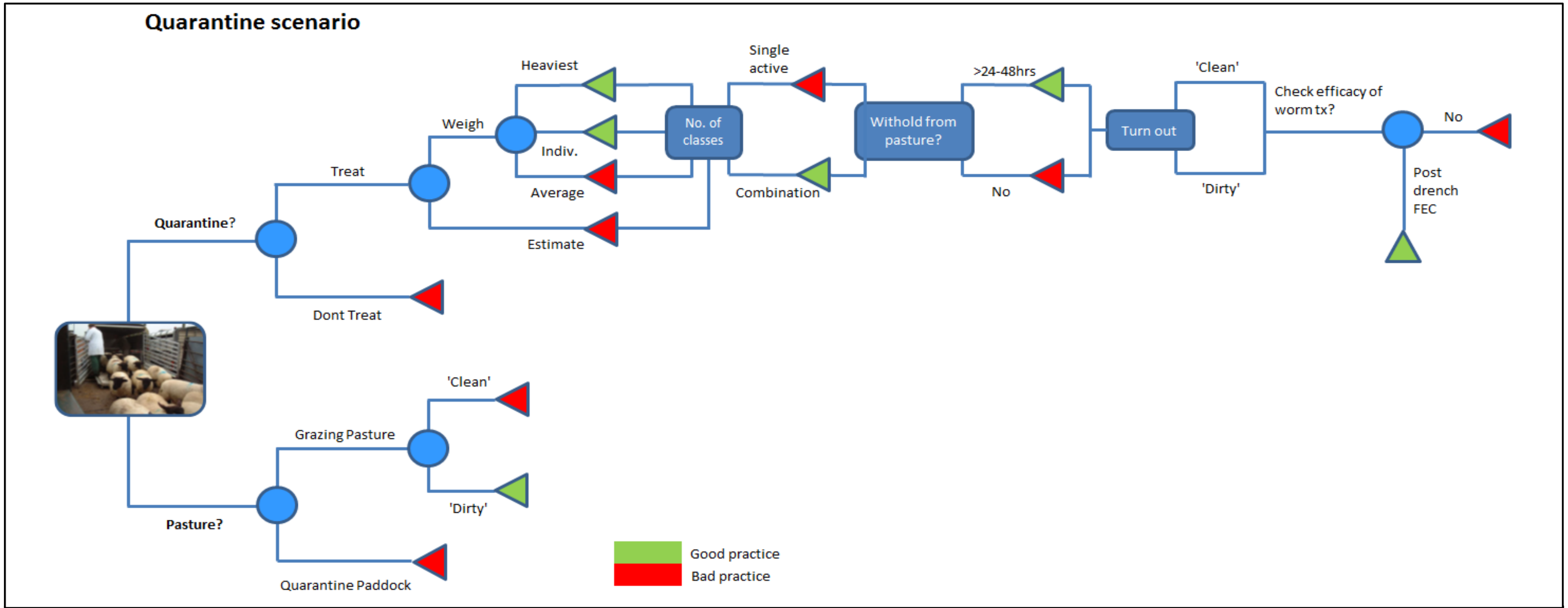


Figure 23 - Decision tree analysis diagram based on a post treatment scouring lambs scenario.



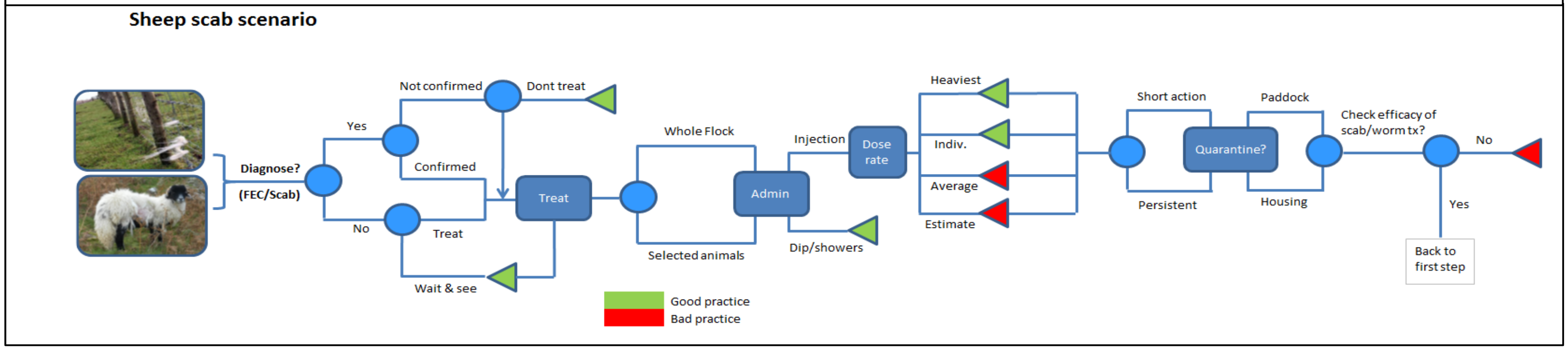


Figure 24 - Decision tree analysis based on a quarantine scenario (top). Figure 25 – Decision tree analysis based on suspected sheep scab scenario (bottom).

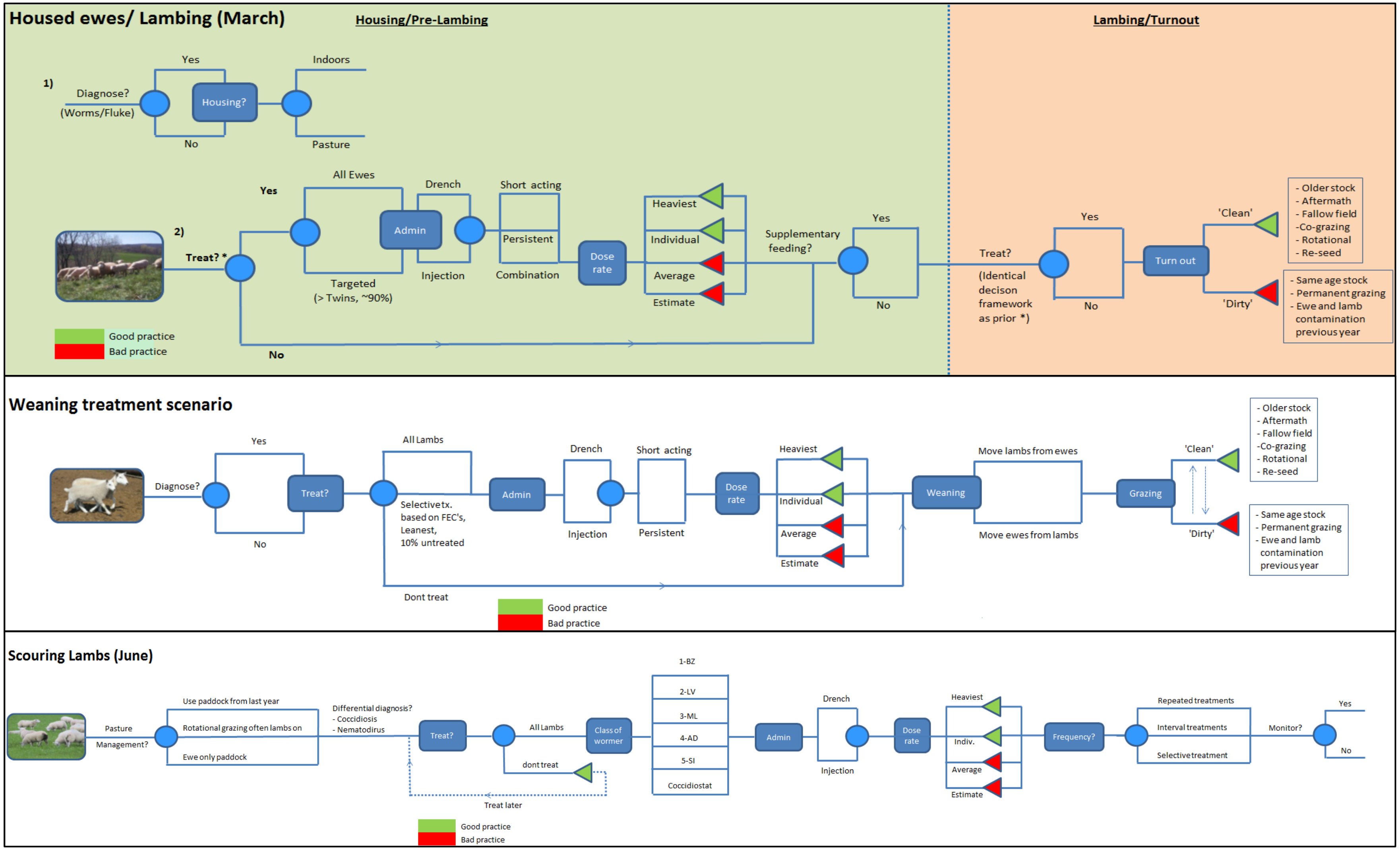


Figure 26 – Treatment decision tree based on a housing/lambing scenario (top). Figure 27 – Treatment decision tree based on a weaning lamb scenario (middle). Figure 28 – Treatment decision tree based on a scouring lamb scenario (bottom).

3.2.2 Sustainable parasite control discussion

In addition to the treatment scenarios it was also imperative that a focused discussion on the SCOPS guidelines was incorporated into the meetings discussion. The main aim of the section was to determine the perceived motivators and barriers to adoption of practices included within each guideline, as well as to evaluate their importance and implementability to sheep farmers. To make sure that all participants were aware of the SCOPS guidelines, a brief overview of the recommendations was given as well as condensed written handouts prior to the discussion. Participants were asked to rank their top 5 most important and most implementable guidelines. Participants were then asked to nominate up to three barriers to adoption for each of the SCOPS guidelines out of a possible eight barriers (i.e. lack of time, lack of labour, lack of facilities, expense, impact on production, conflicting advice, too complex and no perceived need).

3.2.2.1 Focus group format

It is important to consider which methods of generating discussion were likely to be most appropriate for collecting useful data. In this particular instance the elicitation of all participants' roundworm control practices may not have been achievable if not for the use of an audience response system (ARS). Therefore it was decided that ARS would be a valuable tool for developing an interactive format from which to engage and stimulate discussion. The use of ARS has been used extensively for educational research purposes as well as in focus group settings (Sparks, 2011) and have reported improvements in students' performance and engagement (Draper and Brown, 2004;

Preszler et al., 2007). It is thought that this engagement may be due to a number of features which ARS provides, such as anonymity of responses and instantaneous feedback from other participants. Ultimately this allows all views to be recognized and as a result may help to make participants feel more actively involved in the discussion process (Kay and LeSage, 2009) especially in cases where out-spoken characters may dominate the discussion (Sparks, 2011). Furthermore, the use of ARS allows the collection of quantitative data which can be analysed after each meeting as well as compare findings between different focus group meetings.

Other data collection materials were also employed e.g. flip charts with stickers, to suit the different components of the focus group meetings (presented in Figure 30), as well as to allow periods without using the clickers in order to combat the effects of multi-item fatigue (Rathod and LaBruna, 2005). The other formats used and their corresponding sections within the meeting are outlined in Figure 30.

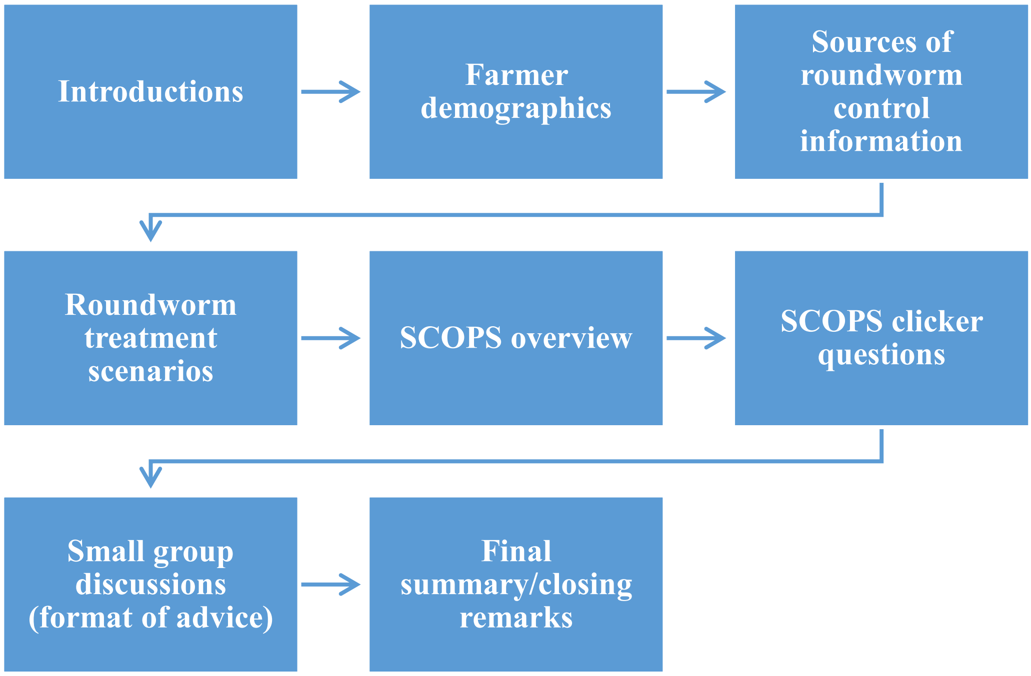


Figure 29 – Preliminary focus group outline

3.2.2.2 Optimizing the focus group format

Time management is an essential aspect to consider when planning the format of focus group meetings. The amount of time that participants will be able to commit to the meeting as well as maintain engagement is likely to vary depending on individual circumstances, but in general around a 2 hour limit is advised to be suitable (Krueger, 1998). Therefore the preliminary outline (shown in Figure 29) had to be evaluated to ensure that enough time could be allocated to each component without compromising the overall aims. This required that parts of the discussion be either removed, reduced and priorities made to ensure that sufficient time is given to each section.

A number of changes were made to the preliminary format. When assessing the treatment scenarios, although each of these addresses a unique situation where anthelmintic treatments may be considered, an overlap in terms of decision making processes was recognized. For example there are many commonalities between biosecurity procedures for purchased animals and for returning sheep even if the emphasis is geared towards suspected sheep scab infection. Therefore only scenarios demonstrating independence were included in the final version (i.e. Quarantine treatments for purchased stock and suspected anthelmintic resistance scenario). Additional MCQ's were added to cover common decisions regarding treatments such as how anthelmintics selected and purchased as well as post-treatment grazing management. Furthermore aspects of the small group discussion section were incorporated into the proceeding SCOPS ARS discussion in order to simplify the format and due to time limitations.

3.2.2.3 Final focus group format

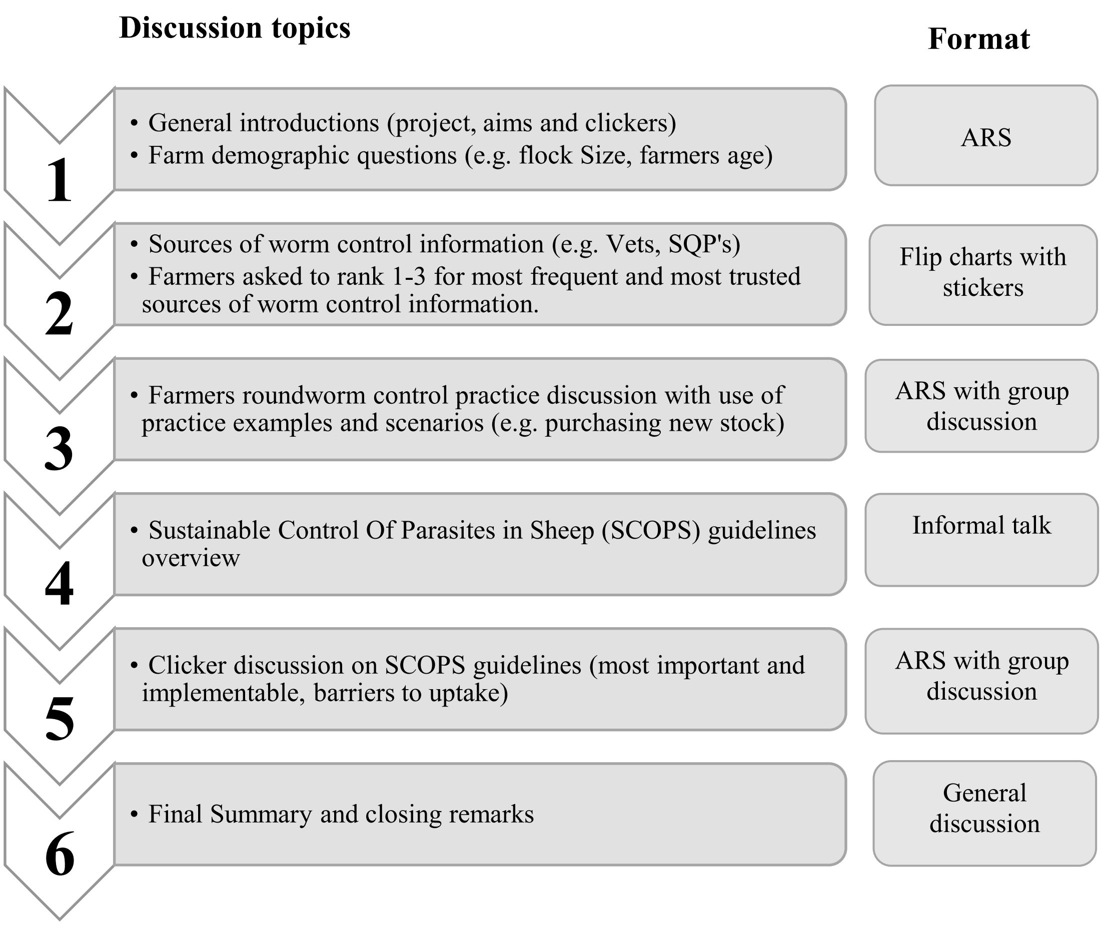


Figure 30 – Final outline of focus group format with discussion topics (left) and recording materials for each discussion component (right).

3.2.3 Rationale for meeting components

3.2.3.1 Section 1 – Introduction

The purpose is to introduce the participants to the moderators involved as well as to the overall project and the format of the focus group discussion as presented in Figure 30. The use of simple demographic questions not only gives us and the group background information about the attendees but also allows time to familiarize participants with the electronic clickers before starting the first section of questions.

3.2.3.2 Section 2 – Sources of roundworm control information

This section required that participants consider which sources of information are most trusted and most frequent. Two sets of coloured stickers numbered 1-3 were allocated to each participant and asked to rank their top three most trusted and frequent sources of information from various options (Veterinarians, suitably qualified person, internet, university, other farmers etc.) and stick their responses onto their chosen options on a flip chart. As well as providing useful information it also provided an alternative task for participants to undertake.

3.2.3.3 Section 3 – Farmers roundworm control practice examples and scenarios

The use of scenario based questions allows participants time to familiarize themselves with the topic of roundworm control and gives each individual a chance to recollect on personal experiences as well as listen to the opinions of other participants. By giving context to the questions this helps individuals relate to their own experiences and therefore enables a greater insight into the decision-making processes.

3.2.3.4 Section 4 – SCOPS guideline overview

By giving an overview of the SCOPS guidelines as an introduction to the main discussion, this helps ensure that all participants are aware of the recommendations and therefore any opinions that are given are based on the same level of information.

3.2.3.5 Section 5 – SCOPS discussion

The main topics of discussion based on the information given previously, was which of the eight guidelines are perceived as most important and most implementable. Subsequently each of the guidelines were reviewed individually to identify key barriers to adoption of each practice. For the main discussion, the ARS format allowed each individual to give their anonymous responses without influence from others. Once the results were generated and visually presented to the group, the key findings facilitated further discussion.

3.2.3.6 Section 6 – Final summary

To conclude each meeting the moderators would allow individuals to reflect and summarize their thoughts on the meetings discussion and on the information given to them.

3.2.3.7 Future steps

The next step would be to disseminate the findings from the focus group meetings to stakeholders, to provide the feedback from participants to those concerned, as well as allow the opportunity to receive comments from the wider farming community about any assumptions made from the discussions.

3.2.4 Focus group implementation preparation

Advisor groups associated with the Moredun Research Institute (MRI) from different geographic regions of Scotland were contacted in December 2013. Advisors were approached and asked to help arrange the farmer meetings in their area to discuss the topic of roundworm control and uptake of sustainable worm control practices. The general selection criteria for attendees was to include between 10-15 sheep producers, preferably from a range of backgrounds and farming systems (Details of criterion featured below in Figure 31) in order to achieve a cohort to represent a cross section of the sheep farming industry. The proposed period for conducting the focus groups was January/February 2014, which was chosen due to the relative quietness of this time of year for farmers in order to maximize attendance. Four of the regional advisors were able to arrange meetings at this time of year in their respective areas which included the following: Midlothian, Angus, Fife and Morayshire (map in Figure 32). The venues for conducting the meetings were also arranged by the regional advisors. The backgrounds of the four regional advisors included two full-time farmers, a veterinarian and a suitably qualified person (SQP). An SQP refers to an individual who are entitled to prescribe and/or supply certain veterinary medicines under the Veterinary Medicines Regulations (AMTRA, 2017). The focus groups meetings ran in consecutive evenings from January 20th to 23rd 2014.

Figure 31 - Moredun regional advisor request letter to organise focus group meetings and participant selection criteria.

Dear _____,

We are interested in setting up a focus group in your area that is looking at the drivers and barriers to the uptake of recommendations on sustainable worm control. The project is part of a Scottish Government funded PhD and is looking to use the focus groups as a sounding board for identification of areas of interest in order to allow us to better target a questionnaire next year.

We would like to identify 15-20 sheep producers (although they don't need to be sheep only enterprises) from a cross section of the industry that would be willing to discuss the topic of worm control. It would be nice to get as wide a cohort of participants as possible in respect to enterprise type, commercial v pedigree, geographic and topological location, age/experience etc but realise that this may be extremely difficult to achieve. We realise that you are in a position to best identify those individuals. They do not need to necessarily be Moredun Foundation members, and ideally would include both members and non-members.

We would hope to run the meetings over the winter period (November to January), they shouldn't take longer than approximately 2 hours and we thought that if they were held at around lunch time (us supplying lunch) this may encourage participation. If you have any ideas of suitable venues or times for this type of event we would be grateful for any suggestions.

Please contact us if you have any question on the request.

Figure 32 – Map of focus group meeting locations (created using BatchGeo©)

Group A = Moredun Penicuik (Moredun)
Group B = Kirriemuir
Group C = Cupar
Group D = Grantown-on-Spey

3.2.5 Implementation and data collection

The meetings were conducted by three moderators including myself, Dr Dave Bartley and Dr Emily Hotchkiss. At the time of the study the researchers' occupations and backgrounds were related to applied veterinary parasitology and veterinary epidemiology. Guidance regarding the focus group development and implementation were acquired from the literature as well as from Dr Catherine Milne, a socio-economic researcher and knowledge exchange designer from Scotland's Rural College (SRUC). Ethics approval for the focus group meetings was granted through by the Moredun's internal ethics committee prior to conducting the studies.

Both qualitative and quantitative data were recorded at each of the focus group meetings. Audio recordings were taken using an electronic Dictaphone recording device from which audio files were uploaded and later manually transcribed by the author into individual word documents for analysis. Ethical approval for the meetings was given by the Local Ethics Review Committee. Informed consent was obtained via a process that began on invitation to the meeting and at the start of each of the focus group meetings, where the purpose of the study and how the data received would be used was explained. Participants were informed that the meetings would be audio recorded and that any information taken from the recordings would be anonymised so that no individual could be identified and no attempt was made to follow the same individual's responses over the course of the transcripts. Participants were able to drop out at any time. Quantitative data was obtained through primarily the use of ARS in addition to using flip charts. The ARS software collates the responses for each session and compiles the results into a report which displays both numeric and graphical representations of the recorded data.

The flip charts were used to allow participants to assign individual rankings (1-3) using numbered stickers of their most trusted and preferred sources of roundworm control information which included the following examples: Vets and animal health advisors, agricultural merchants & SQP's, pharmaceutical reps, other farmers, farming press, the internet, research organisations (e.g. MRI, SRUC) and others.

3.2.6 Thematic analysis

The first step of the analysis involved the development of the provisional coding frame. The coding frame aims to categorise the extensive qualitative data into a set of broad themes which can then be further subcategorised into more specific themes or topics.

Initially the development of the coding frame involved using the focus group format/topic guide (presented in Figure 30) to inform the categorising and arrangement of the coding frame i.e. based on the scenarios and question guide. The use of this 'a priori' framework was later adapted to include the use of 'in vivo' codes which were derived from the data itself. This semi-structured approach allows for better flexibility within the coding frame design to suit the exploratory nature of qualitative data analysis. The use of more discursive coding themes as compared between example 1 and 2, helps to change the emphasis of the themes from a descriptive format (Figure 33) to a more conversational, expansive style (Figure 34).

Sourcing wormer

- All wormer sourced from Animal health outlets
- Farmers may ask for vet to provide pre-purchase advice for which wormer to buy, and to purchase Zolvix/Startect.
- AHO were the only source of wormer in group...based on price of product.
  - May ask for advice depending on company/SQP
  - SQP's known to be trained in providing advice
    - Based on sourcing of information Vets and SQP's have a similar number of votes for frequency, however with higher ranking for vets.
    - Vets greater ranked for trusted source compared with SQP's.

Figure 33 – An excerpt of the provisional coding frame.

Sourcing wormer

- Wormer price vs. service
    - Vets can't compete with animal health outlets on price.
        - Possibly reflects the importance of worm control advice to farmers
        - Is quality advice worth paying for?

Figure 34 – An excerpt of the revised coding frame

3.2.7 Framework analysis

In order to compare patterns of themes and codes between each of the focus group meetings, a framework analysis approach was used as detailed by Barbour (2008). This method involves generating a grid of themes identified and their codes, which are cross tabulated against the number of focus group meetings. When a certain code was referred to in the discussion a score is added which can then be used to compare with the other meetings findings. This method is useful for assessing similarities and differences particularly when there are hypothesised differences between group compositions as is assumed based on regional variation and farming systems. Frameworks were created within each of the broad themes i.e. for each of the SCOPS guidelines, and the results are presented in Appendix 1.

3.2.8 Sheep Veterinary Society meeting

In 2014, a combined roundworm and fluke workshop was held in conjunction with the Sheep Veterinary Society annual meeting. The workshop was primarily designed to teach practising veterinarians applicable control strategies using case-study examples. The event also allowed the opportunity to request participants to complete a survey in relation to the SCOPS guidelines, detailing which of the eight guidelines they would rank from most important/implementable (1) to least important/implementable (8). The intention was to compare the findings with sheep farmer's responses as conducted during the focus group meetings with the aid of the ARS devices.

3.3 RESULTS

3.3.1 Participant characteristics

A total of 56 individuals participated in the four focus groups conducted. The ARS response rates for the demographic questions (detailed in Table 21) varied between 70-100% for Groups A, B and C and between 44-88% for Group D, respectively. Overall based on the participant responses, ages varied between all categories, with the majority of participants aged between 36 and 65 years old (35/49; 75%). Groups A and C had the greatest number of participants below this age bracket, comprising of 35% (5/14) and 21% (4/19) for both groups respectively.

In regards to farm characteristics, the majority of participants' farms overall were categorized as upland farms (25/46; 54%) with the exception of Group C with mostly lowland farms (12/18; 66%). The majority of participants' farm sizes was over 500 acres (33/50; 66%) followed by between 250-500 acres (10/50; 20%). In terms of enterprise types, the majority of participants were a mix of livestock and arable farmers (30/49; 61%) followed equally by sheep only and mixed livestock farmers (10/49; 20%). The number of breeding ewes stated by participants varied between all categories, although the majority varied between 151-1499 (42/48; 87%). Most participants' enterprises overall were categorized as commercial (30/50; 60%) followed by both commercial and pedigree (16/50; 32%) and then pedigree only (4/50; 8%).

Table 21 – Participants ARS responses regarding demographic and farm characteristics (n=56)

Demographics	Categories	Focus group meetings				
		Group A	Group B	Group C	Group D	Total
Age	18 – 25	0	0	2	0	2
	26 – 35	5	1	2	0	8
	36 – 45	2	6	2	0	10
	46 – 55	1	2	7	3	13
	56 – 65	2	3	4	5	14
	66 +	1	0	1	0	2
	No response	3	2	1	1	7
Topography	Hill	3	1	0	1	5
	Upland	6	7	6	6	25
	Lowland	1	2	12	1	16
	No response	4	4	1	1	10
Livestock type	Sheep only	3	3	4	0	10
	Mixed livestock	6	2	1	1	10
	Livestock & arable	3	8	13	6	30
	No response	2	2	1	2	7
Enterprise type	Commercial	7	6	14	3	30
	Pedigree	1	0	1	2	4
	Both	4	7	2	3	16
	No response	2	1	2	1	6
Farm size in acres	0 – 50	1	1	0	0	2
	51 – 150	0	0	0	0	0
	151- 250	0	0	4	1	5
	251 – 500	2	2	4	2	10
	500 +	9	10	9	5	33
	No response	2	1	2	1	6
Number of breeding ewes	Under 50	1	1	0	0	2
	50 – 150	0	0	1	0	1
	151 – 399	1	4	10	1	16
	400 – 800	2	5	6	2	15
	800 – 1499	6	2	2	1	11
	1500 +	2	1	0	0	3
	No response	2	1	0	5	8

3.3.2 Participants' information sources

As presented in Figure 35, it is apparent that veterinarians were regarded by the majority of participants as their most preferred information source based on both trust of advice and frequency of use. The second most frequently ranked information source overall was research organisations, receiving most votes as a trusted resource. For frequency of use, agricultural merchants received the second greatest number of votes followed closely by research organisations and the farming press. Pharmaceutical representatives, other farmers and Internet received collectively a similar number of votes with 'other' alternative information sources receiving the least number of votes overall.

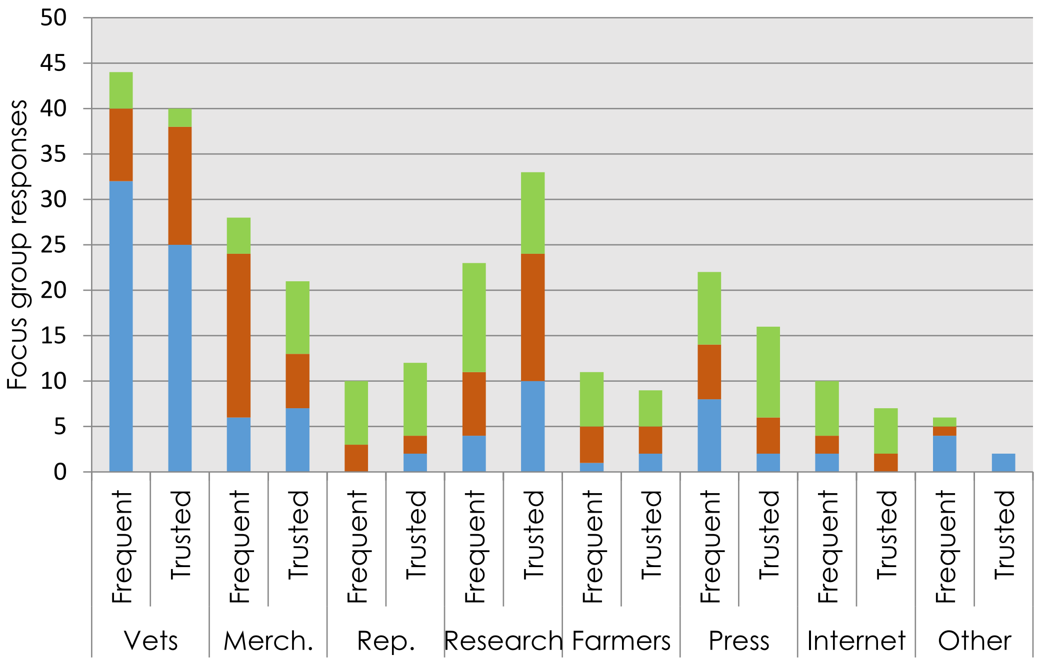


Figure 35 – Farmer's rankings for most frequent and trusted disease information sources.

Figure legend - Merch. = Agricultural merchant, **Rep.** = Pharmaceutical representative, **Research** = Research organizations. Blue= #1 rank, Red= #2 rank and Green= #3 rank.

3.3.3 Audience response systems results

In regards to the importance and implementability rankings for the SCOPS guidelines (Figures 36 & 37), almost all (26/32) of the focus group and SVS participants responses varied across all ranking levels. Between both groups, the greatest variation in rankings were reported within the focus group responses. This is most apparent between rankings for guidelines 1 and 7 concerning implementability and guidelines 1 and 8 concerning importance. Outliers were also observed at both ends of the ranking scale with reference to guidelines 3 and 5 for importance. The least variability from the focus group rankings were demonstrated within guidelines 6 for implementability and between 3 and 5 concerning importance. The farmers' rankings for guideline importance and implementability is fairly comparable in terms of the mean and median statistics which indicates that guidelines 1, 2 and 4 received the highest ranks overall for importance and implementability.

For the SVS responses, a similar level of agreement was observed across the majority of guidelines with moderately less variation observed regarding the implementability rankings. Albeit outliers were also observed with reference to guidelines 2, 4 and 8. Similar to the focus group rankings, guidelines 2 and 4 were perceived overall to be most implementable and guidelines 1 and 4 were regarded as most important by SVS participants. With regards to perceived barriers to uptake of SCOPS guidelines (Table 22 & 23), overall there are almost as many aspects which are in agreement as there are in disagreement. Across all the guidelines, above average numbers of responses from SVS participants expressed the belief that complexity and a lack of need were the main issues affecting farmers adoption of SCOPS guidelines. Although this is reflected by a notable proportion of farmers responses concerning complexity for six of the eight guidelines (1, 3, 5, 6, 7 and 8), this is however largely dissimilar in regard to the barrier expressing a lack of perceived need to adopt which was only comparable for two of the guidelines (3 and 7). It can be seen however that there is also some agreement between focus group and SVS participants' perceived barriers concerning practical issues (i.e. lack of certain resources) affecting uptake of guidelines 1 to 4. Additionally the barriers perceived to affect adoption of guidelines 5 to 8 are both largely concerned with cognitive factors affecting the internalisation of advice, such as if the advice is perceived to be too complex, contradictory or detrimental to production.

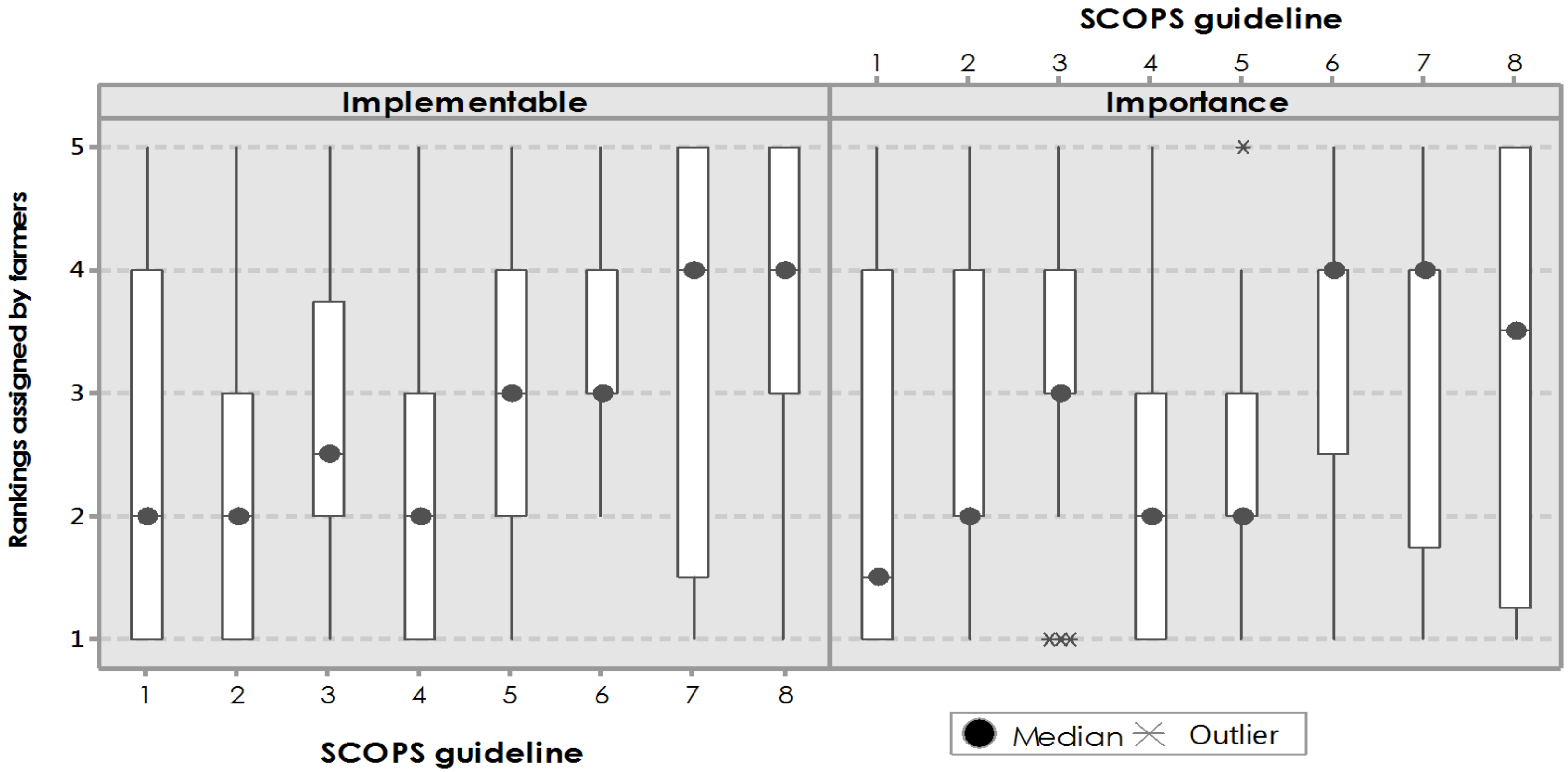


Figure 36 - Focus group participants rankings for SCOPS guidelines concerning importance and implementability (1= highest ranking, 5= lowest ranking).

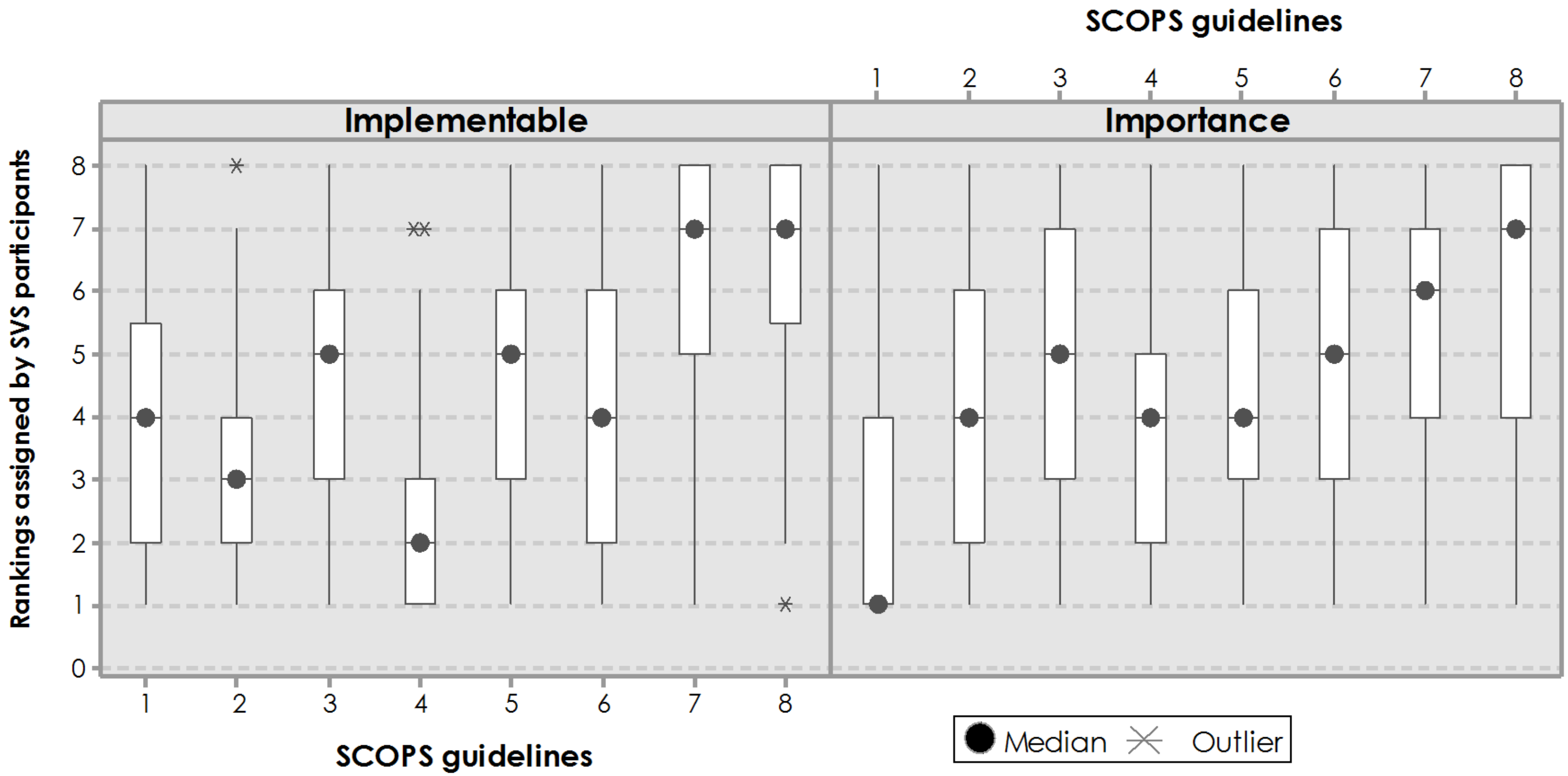


Figure 37 - Sheep veterinary society rankings for SCOPS guidelines concerning importance and implementability (1=highest ranking, 8= lowest ranking)

Table 22 - Sheep farmers' responses concerning perceived barriers to uptake of SCOPS guidelines. Each participant allocated a maximum of three unweighted votes for barriers to each of the SCOPS guidelines. Red highlights indicate above average number of responses per guideline category.

Barriers	SCOP 1	SCOP 2	SCOP 3	SCOP 4	SCOP 5	SCOP 6	SCOP 7	SCOP 8	Total
Lack of time	19	16	24	24	11	9	17	10	130
Lack of labour	16	12	12	22	7	8	8	5	90
Lack of facilities	7	37	11	25	6	3	10	14	113
Expense	15	3	14	1	4	21	2	9	69
Impact on production	10	10	4	5	14	13	16	23	95
Conflicting advice	23	3	11	7	14	30	17	17	122
Too complex	23	8	16	2	10	14	23	21	117
No percieved need	14	9	20	7	7	12	14	10	93
total	127	98	112	93	73	110	107	109	829

Table 23 - Sheep veterinary society responses concerning perceived barriers to uptake of SCOPS guidelines. Each participant allocated three unweighted votes for barriers to each of the SCOPS guidelines. Red highlights indicate above average number of responses per guideline category.

Barriers	SCOP 1	SCOP 2	SCOP 3	SCOP 4	SCOP 5	SCOP 6	SCOP 7	SCOP 8	Total
Lack of time	18	20	27	26	4	4	4	6	109
Lack of labour	3	9	19	25	3	1	0	2	62
Lack of facilities	0	34	4	13	3	1	6	5	66
Expense	33	18	38	1	2	8	0	9	109
Impact on production	4	2	3	3	24	3	12	25	76
Conflicting advice	21	5	7	7	24	27	17	14	122
Too complex	30	28	20	28	45	53	67	41	312
No perceived need	51	44	37	23	30	23	37	35	280
total	160	160	155	126	135	120	143	137	1136

3.3.4 Discussion results

3.3.4.1 Quarantine strategy

3.3.4.2 Livestock purchasing information

From the individual accounts of what information is important, it appears that a number of factors are considered when buying in animals, which can differ depending on whether rams (tups) or ewes were purchased. The physical assessment of animal condition is likely to feature first and foremost when initially deciding to purchase animals as indicated by the high rankings from participants. In regards to specific treatment information sought as well as the routine treatments given, a number of participants stated making sure that the animals treatment status harmonises with their current health system.

> *'Well if you're buying females, you may want to check if they're on a Hep P system, if you are already in the Hep P system it makes it a lot easier'*
>
> *'If it's females then they are going to get heptavac or ovivac from ten months until they've had a jab' (Group A)*
>
> *'Yes I would do something similar' (Group B)*

One of the main concerns raised was the reliability or trust in the information provided by the seller.

> *'To a certain extent, you're relying on somebody telling you the truth, when you don't know them. You're going to treat them anyway when you get home' (Group C)*

This point was also highlighted when participants were prompted about whether the participants would pay a premium for animals that had undergone appropriate quarantine procedures.

'I think maybe I'm too cynical but I don't know if I would really believe the signing off…'

'No.'

'…If somebody's trying to sell you something they can tell you what you want to hear.' (Group D).

Albeit the lack of trust from some participants regarding such claims from vendors, other mentions were also made in relation to purchasing from farms with disease-free accreditation.

'…there is something to be said for buying from accredited stock and from a secure place that you know you've purchased from in the past, and there is a bit of a relationship with them and if things can be isolated. Having done it in cattle, I don't have sheep but I was to go into sheep I would probably have the same mind-set in sheep because of what I've done with the cattle.' (Group D)

In regards to specific biosecurity threats posed to farmers the most commonly recognised risk was associated with sheep scab (*Psoroptes ovis*), which was referred to by participants in most meetings. Indeed, any comments made from participants in relation to roundworm treatment history suggest that it may not feature as important as other possible disease risks.

'…To add to that worming history not so much. (Group A)

'And maybe it doesn't apply to worming very much, but anything that came on my place that had been in the market I would want to isolate anyway, full stop.' (Group D)

3.3.4.3 Isolating animals

When discussing the recommendation to isolate incoming animals from pasture for between 24-48 hours after treatment, the practical implications of this were objected to by some individuals from multiple groups. These comments predominantly cover issues relating to resource requirements to feed animals off pasture. This issue is further highlighted by the general ARS responses (Table 24) from participants with particular concern regarding a lack of time and lack of facilities:

> *'...In our case that would apply to lambs that had been brought in... Now those lambs have gone through the market, have been on the road and if we kept them in for another day or two days they would be left dead...'*
>
> *'But you're still talking about feeding them and watering them' (Moderator)*
>
> *'But if you've got lambs coming in off the hill, what are they going to eat?'*
>
> *'But then if that's not possible' (Moderator)*
>
> *'I understand the theory behind it I just feel that, that bit is completely absurd' (Group B)*
>
> *'Again I didn't answer it but the only thing it would be that you ended up by not being able to put something where there was sufficient grass or whatever, either the ones you were keeping at home or the ones you introduced' (Group D)*

Table 24 - ARS responses concerning factors influencing dose determination method from focus group participants

Motivators	Heaviest (n)	Individual (n)	Average (n)	Estimate (n)	Total
Time	1	0	0	1	2
Labour	1	0	0	1	2
Past experience	9	1	4	7	21
Access to facilities	3	1	0	2	6
Recommendation	14	1	1	0	16
Other	0	0	0	0	0
Total	28	3	5	11	47

Additional examples of time constraints were made in relation to an urgency to introduce a ram or bull for mating.

> *If you had to buy in a bull for example out of necessity when you're actually putting the bulls with the cows you might have just have to buy the bull and put him straight in...'*
>
> *'And is this a similar situation with rams?' (Moderator)*
>
> *'Similarly, if you're buying in feeding lambs you don't want to stand up not getting feed...'*
>
> *'But would you still treat them?' (Moderator)*
>
> *'I would treat them and then go in the pen' (Group C)*

3.3.4.4 Testing for anthelmintic resistance

3.3.4.5 Proactive versus Reactive

The discussion regarding the use of AR testing suggest that many farmers do not perceive the need to test for resistance in their flocks. From the discussion, a couple of points were raised, firstly the thought of using an AR test to confirm a problem when it occurs, and consequently a lack of perceived need in the absence of a crisis/problem. The counter argument that was posed by individuals was if you are unaware of a problem, then you are unable to respond to the problem.

> *'Unless you have a crisis, there might not be a perceived need. Working out a strategy maybe, you need to know if it's working or not, if you're changing your wormers...not knowing, you can't do anything more to stop it if you're doing all that's necessary.*
>
> *I guess the point as well without doing it; do you know that they are working? (Moderator)*
>
> *If you're in a routine though or a system and your sheep are healthy then you're going to continue doing that and think that there is no need to test because what I'm doing looks pretty good anyway.' (Group C)*

The second point that directly follows on from one participant was whether there may be a sense of reluctance to discover that a problem exists and therefore an avoidance of confirmation may be taken.

> *'Nobody wants to test if you see something's not working'*
>
> *'If you run into problem you might test' (Group C)*

3.3.4.6 Lack of time/labour

One of the issues concerning implementation that received the greatest overall ARS response (Table 22) from all meetings was the perceived lack of time component. This may be in part due to the perception of such measures being onerous to conduct, from the time taken to sample animals to receiving the results:

> *'And does the fact that a week may be the turnaround time put you off from doing it more regularly? (Moderator)*
>
> *'I don't know, I suppose at the end of the day it's perceived as a bit of a hassle, is the long and short of it.'*
>
> *'And the cost in the sense of the labour if you have 500 lambs stuck in a pen you get the samples you can't put them away back out in the field you have to get on. You have them dosed in 2 hours and back in the field and if it doesn't work, maybe we have a problem here, back in change the wormer and do it again. That's probably what most people do, by the time you get the results you could have 2 or 3 dead if it wasn't doing the job, its speed you're moving onto the next lot...'*
>
> *'So getting the mindset of test before you dose then you would know what you need to dose for. And I guess you would test afterwards to make sure what you used has worked. That's a lot of collecting!' (Group C)*

Such remarks suggest that the overall practicality of sampling is perceived to be unfeasible from a number of participants. This was also evident from one of the organisers of the meeting who shared one experience from a farmer he had spoken to regarding the practicality of testing a hill sheep flock.

> *'I spoke to a hill farmer tonight about coming...and he says it's hard for him to test for anthelmintic resistance because he only handles his sheep four times a year so to go and check them first, put them back on the hill, get a result back then go and do a faecal egg count reduction test says it is physically not practical to do it.' (Group A)*

3.3.4.7 Complexity

The perceived complexity of testing for AR was indicated from the ARS responses (Table 22) which demonstrated high rankings from most of the meetings. The apparent complexity was stated by one participant after the moderator explained the requirement for testing to be conducted for the anthelmintics used at different time of the year to correlate with the parasite species present.

> *'…So it maybe that you have resistance to your white drenches mid-season, which is potentially when brown scour worm is, but then again it works against Nematodirus and it works against the black scour worm at the end of the season. Which is the thing about understanding is it working at that time of year and are you getting best production out of those animals on the back of that, because that again is where there may be some complexity to it.' (Moderator)*
>
> *'But's that's pretty complex because you'll end up having god knows how many trials.' (Group C)*

3.3.4.8 Somebody else's problem

One of the messages that also came from this discussion was the view that there are other farmers that should be testing their flocks for AR; that is there are farmers that require more observation than others:

> *'Well am I the only who's thought the resistance thing has to my knowledge never been a huge issue for me, so I haven't gone out there and get a test. But is that message getting sent out to everybody who should be testing for resistance or am I the only one who doesn't think that? Has everybody been testing for resistance here?'*
>
> *'I would agree with you'*
>
> *'I don't think that message comes out, apart from if there was a problem you hear about people testing' (Group C)*

3.3.4.9 Administer anthelmintics effectively

3.3.4.10 Dosing by weight, a bad guide?

The advice to determine anthelmintic dose by weight was received by participants with mixed views, particularly in circumstances where ill thrifty animals are believed to require treatment which poses a dilemma to some farmers whose intuition would be to administer a greater dose than required for their weight.

> *'Weight can be a bad guide as to wormer because if ewes are in bad condition and they're light, they're the ones that need the biggest dose, so it's not necessarily the right way to assess…it's a guide' (Group C)*
>
> *So what I'm wandering sometimes in the case of a particular runt amongst the lot maybe it wants the same dose as the rest? (Group D)*

Conversely it was also recognised that such circumstances where a greater treatment dose is administered than is required may have a detrimental effect on the animal.

> *'It's quite dangerous that question as well, because it depends how potent the drug is, because if you overdose you could have problem' (Group D)*

From the ARS responses (Table 25) it was shown that the majority of participants from Group A used a single dose rate based on the weight of the heaviest animal (92%), which was much greater when compared to the other meetings responses, varying between 46 and 50%, respectively. It was indicated that this approach is an easier and more efficient procedure than using an electronic drafting system (EDS) to determine individual dose rates.

> *'Does anyone have any experience with these technological drafting systems? Would that help or just carry on anyway?' (Moderator)*

'Still do it that way (by heaviest weight) ...because by the time you reset your dosing gun for every different animal...you can't be that far out'

'Not unless there was an exceptionally big one in a lot you will give it extra...common sense!' (Group A)

Table 25 – ARS percentage responses regarding which method is used for dose determination by focus group participants.

Treatment methods	Group 1 (%)	Group 2 (%)	Group 3 (%)	Group 4 (%)
Estimated weight	0	38	28	17
Average weight	8	8	22	0
Heaviest weight	92	46	50	50
Individual weight	0	8	0	33

The discussion around use of EDS was brought up by a couple of experienced users from Group B's meeting. The procedure for using such technologies involved grouping animals into weight bands and then deciding whether to treat if they perceived a need. The following dialogue between participants demonstrates the circumstances that influence how decisions are made as well indicating the level of knowledge from some participants within the Group B.

'I got a weigh system where you see the individual weight immediately and if you have your gun held right you can dose them to their weight. Also I help a commercial farms trial a new drug ... They picked the biggest lamb which was 20kg heavier than the

lightest lamb, and they dosed all the lambs the same and I thought well that bloody drug does not work and that just seems completely foolish and we said to the head vet what to weigh each one? No that's just the protocol, and that seems absolutely crazy.'

'Possibly if you're dosing for 500 it's not'

'But surely the good ones do not need it?'

'These people will recommend not dosing 10%, and that 10% will not be the good ones.' (Group B)

The general consensus among participants of the importance of applying a sufficient dose was recognised and strongly viewed as a basic requirement when treating animals. Yet despite this strong belief from some participants a considerable proportion (between 17 and 38%) indicated using an estimation of animal weights when determining a treatment dose.

'For what the stuff's costing you, it's important that it's done correctly'

You're wasting your money! You start getting filthy pastures, you start getting filthy stock…' (Group D)

'A job worth doing is a job worth doing properly. At the end of the day it's your pockets that's being squeezed if you don't do it right' (Group C)

'If you're going to dose your gun you're going to do it to the best of your ability....I don't see the point of it' (Group A)

3.3.4.11 Using past experience

From the ARS responses (Table 26) the main influence of participants' dose determining practices was based on previous experience which was responded to by the majority of those using either an estimated or an average weight for determining treatment dose. Previous experience was also indicated as the second most frequent influence on the use of the heaviest weight followed by recommendation. From Group C's meeting discussion one participant both indicated the ease of using an estimation as well as the potential hazards.

> *'So past experience could include: well I found weighing the heaviest animal has been quite easy and effective or actually estimating them I found to be just as effective I suppose' (Moderator)*
>
> *'If you've never weighed sheep you've got a fair idea what weight they are from experience'*
>
> *'Have you ever weighed and find that you're out?' (Moderator)*
>
> *'We often found a fat lamb and turns out to be a bit lighter than you thought it would be' (Group C)*

Table 26 – ARS responses concerning factors influencing dose determination method from focus group participants

Treatment methods	Heaviest (n)	Individual (n)	Average (n)	Estimate (n)	Total
Time	1	0	0	1	2
Labour	1	0	0	1	2
Past experience	9	1	4	7	21
Access to facilities	3	1	0	2	6
Recommendation	14	1	1	0	16
Other	0	0	0	0	0
Total	28	3	5	11	47

From the ARS responses, the main perceived barriers to using the SCOPS recommended protocols for determining dosing and calibrating equipment comprised the following lack of resources including time, labour and facilities.

3.3.4.12 Use anthelmintics only when necessary

The discussion regarding how to assess the need to treat animals (e.g. using decision making tools) and when to treat animals were dichotomized into two broader categories based on whether an objective or subjective assessment method was discussed. Additionally participant's responses regarding their choice of treatment strategy are presented in Table 27.

Table 27 - ARS percentage responses concerning which treatment methods employed by focus group participants

Treatment methods	**Group 1 (%)**	**Group 2 (%)**	**Group 3 (%)**	**Group 4 (%)**
Set drench programme	23	8	19	21
Sign of disease	15	8	22	23
Targeted treatments	8	33	16	8
Strategically	46	33	29	27
Following advice	8	17	14	21
Other	0	0	0	0

3.3.4.13 Using objective assessment methods

3.3.4.14 Pros (targeted advice)

Participants from multiple meetings acknowledged the benefits of FEC as a useful decision making tool when accompanied by veterinarian advice. This service was said to provide farmers with tailored information to help assess whether a treatment may be required as well as which treatment should be used.

> *'Well the fact that they didn't have stomach worms in them according to his results on the faecal egg count, we just went straight down with a Tribex which is far cheaper than using Combinex or something like that, it's seems to act like it did the job' (Group D)*
>
> *'…The lambs might get 2 doses before they're away but I take an egg count, goes through the vet. Then the vet tells me should we do them? Shouldn't we do them? What you should be doing them with' (Group B)*

3.3.4.15 Cons (uncertainty/complexity)

In contrast to the preceding observations, one participant expressed that the use of FEC testing had the prospect of adding complexity to the decision-making process.

> *'I think you need to be involved in taking samples and testing, which would add to the complexity of making a decision. And if you're not into taking samples and checking it you could see it as a waste of time' (Group C)*

In addition to this point, participants from multiple meetings also felt that using FEC may only give a snapshot of the parasite burden and therefore cannot be used to predict when disease is likely to occur.

'…can't see how it can tell you if you've got the disease or if you do not have worms and you get the test to say ok you've no worms. But what's to say that you're not going to have worms 2-3 days later? …'

'If you used your wormer when you do not have anything, I wouldn't be killing anything, it would pass through...'

'I worm them before they need it'' (Group B)

'You're saying use anthelmintics only when necessary? … You would have to test every month to know what's going on' (Group A)

There is also some reservation from some participants in the cases where low FEC results are received and consequently no course of action is recommended. This may reflect some unease or distrust from some participants who may have developed a routine for treating at certain times of year, and by not treating animals they may feel that they are not actively managing potential problems.

'I used to (treat pre-tupping) but this year tested the ewes and the vet recommended doing nothing there wasn't enough to worm. I was looking for fluke and haven't found it yet. I'm not sure if I did right or wrong, I should have dosed them with something' (Group B)

Additional uncertainty was expressed by one other participant regarding the potential for unrepresentativeness when sampling.

'I think there's always the question of numbers; despite the recommended number of samples per head it's still in the back of your head if that's a representative sample, giving yourself the peace of mind that you've done them all' (Group C)

3.3.4.16 Practicalities/Limitations of FEC testing

Overall the timeliness of receiving results was perceived to be suitable with three out of four participants who had spoken having received their results within a day of submission, and one participant stating a turnaround of a week. Indeed, the only meeting where the responses towards using FEC were perceived as potentially inefficient for purpose was from participants at the Group C meeting. The following comment from one participant may well reflect the particular circumstances in how this group operate, which mostly comprised mixed livestock and arable farmers (68%) with sheep forming a less predominant role on the business.

> *'…Lack of labour and lack of time are most important, particularly in this room because we are mixed farms. The sheep or cattle are just part of what's going on and if the weather's right we would dose these cattle today….It's not like we've got 2 or 3 days to think about it, that's the issue, people are just fitting things in when they can… and it's just too late if the result comes back and they're full of worms but I've got a fortnight's combining to do and there's a disaster, damn it I should have wormed those when we had the chance. That's how these decisions get made' (Group C)*

The views from this group also demonstrated the potential benefits for using a FEC monitoring approach, but also reiterate the requirement for a more efficient system.

> *'Well it comes back to how much money as an industry we waste on products. We're dosing at the wrong time or they don't need dosed...Probably a fortune. But the sampling needs to be made more slightly easier'*
>
> *'We do dose them to improve productivity; if you could make that more efficient that would be (good)… it would cost us maybe less'. (Group C)*

To add to this these points, one participant also expressed the need for farmers themselves to change their mind-set to make full use of this approach as part of their management routines.

> *'Maybe if it was simplified a bit of the process then people would be more aware that you could do it in a practical way then it might be…' (Moderator)*
>
> *'If you got into a habit of somehow doing it in the field beforehand and you weren't getting any high counts at all then you wouldn't need to do it.'*
>
> *'Yes exactly' (Moderator)*
>
> *'So getting the mind-set of testing before you dose then you would know what you need to dose for. And I guess you would test afterwards to make sure what you used has worked. That's a lot of collecting!' (Group C)*

3.3.4.17 Following advice

3.3.4.18 Vets

Veterinarians were generally credited with providing a good quality of service for farmers in terms of their expertise, up-to-date knowledge and specific advice such as for organic farmers. Vets were also recognised for providing an outside perspective on farm management.

> *'… A lot of farmers maybe didn't have the time to sit round a table and discuss what they were doing in the farm, they didn't see a perceived need to do it. But actually when they sat down with their vets and went through things, there were things that were wrong that could be corrected. From the vets point of view that was good so they got more in depth information on the farms than they ever had in the past. I like to think the farm I'm on was always quite proactive, trying to keep on top of things and analyse things and what have you, but a lot of the people weren't. I take what [participant] says that you don't need to do anything if it's right,*

but sometimes it maybe isn't right but you don't realise it's not right'

'An hour to 2 hours to go through what you've done in the past year and go through all the vets bills and see the amount of antibiotics you've used or vaccines and stuff and just review/justify why you've used them, why you have that expense' (Group D)

'Because we are using organic management then we're looking for fairly specific advice and that's why we go to the vet...and they're very up to speed on that side of what you can and can't do.' (Group B)

One of the matters that was raised however was that certain vets are not actively encouraging farmers to review their flock health plans, but instead are there to resolve immediate problems.

'…The rep comes on your farm and talks about the product, the vet comes on your farm and does your caesarean and other things, and unless you ask him to speak about it, he does not speak about strategies.'

'I think also the vet practices are missing a trick on this one this because everybody around the table here will have an actual health plan of some description, whether it's done by the vet's or SQP's. But I certainly find that in our own situation that the vets basically started of a health plan 4 or 5 years ago and they got a bit complacent on it.' (Group C)

3.3.4.19 Suitably qualified persons (SQPS's)

Discussion regarding the use of SQP's produced varied responses, in two of the group meetings it was suggested that the level of interaction and advice given can vary depending on the company used and who it is they are dealing with. The role of SQP's is regarded by most participants as primarily a supplier/salesman. Some participants did indicate that the information provided by SQP's was beneficial, however others were also sceptical about the motives behind the advice given.

> *'Depends what company you get.... I think it is a good thing when a rep comes round and gives you what information you need.' (Group A)*
>
> *'I think it depends on the animal health outlet there some of them where you never get to speak to the same person twice and generally close your ears. There's one person I deal with and he's pretty switched on...' (Group B)*
>
> *'So it's trust in him being...' (Moderator)*
>
> *'Aye, he's got a lot experience and he's also dealing with different farms in different areas, fluke being one thing, even the central belt across the west, so he's pretty switched on as most vets. So far his advice proved pretty sound.'*
>
> *'Farmers are their own worst enemy as well because if you have a rep coming round preaching you to do this and that, well sometimes they'll listen to their rep before they'll listen to their own vet. If the reps a good salesman telling you it'll do this and do that and say that your neighbour down the road he's doing this as well so you think oh he's got an advantage over me. They will fall into a trap and do it, and that's a danger sometimes.' (Group D)*

3.3.4.20 NADIS

Views towards the use of disease forecasting systems such as NADIS tended to be mixed. The individuals that regularly received the NADIS reports either via email or through their veterinarians' monthly newsletters, expressed positive opinions. However, participants that were less familiar were mostly skeptical of the applicability of the advice to their individual farm systems.

> *'S: Who's responsible for disseminating NADIS reports? Because they're brilliant. If everyone could get their hands on them, I get them by email; if they were on circulation for everyone it would be fantastic' (Group A)*

'The vet puts it out in the newsletter monthly, which is good.' (Group B)

'I suppose there are various forecasts for assessing the risk depending on the weather and waiting for when to treat, but how do you interpret that for your own situation, would make it more difficult to come to an appropriate decision, without testing them' (Group C)

'... You tend up here when you're working at 1000 feet and above and you're working with a different set of temperatures, weathers from the rest of the country, so you kind of make a decision.' (Group D)

3.3.4.21 Conflicting advice

One of the most prominent issues raised by participants from all the meetings relating to general roundworm control advice is conflicting advice between advisors including veterinarians, and the lack of clear, definitive advice.

'Think maybe we all know of most of it but don't feel like we understand it because understanding it is the key thing with so much conflicting advice with cannot do this cannot do that...if you do this you have to do that...it's all quite confusing.' (Group A)

'Yeah, quite often you have conflicting advice and in a way, there's no definitive advice, you talk about us going to our vets and sorting out a programme with our vets, but again one vet will be different from the other' (Group C).

'Conflicting advice from you lads will tell us something, you'll read in the press something, and then the vets will tell you something else' (Group B)

The issue of conflicting advice is also evident between different disease control strategies such as between roundworm control and Johne's disease in regards to appropriate grazing management.

'For certain diseases we're getting advised nowadays not to graze your cattle and sheep together and not to graze them sequentially' (Group D).

3.3.4.22 Using subjective assessments

Several common factors were considered by participants when deciding when to treat animals, when not relying on advice or diagnostic information. The main common factors which were discussed throughout the meetings are illustrated in Figure 38, and all considered to be largely influenced by previous experience.

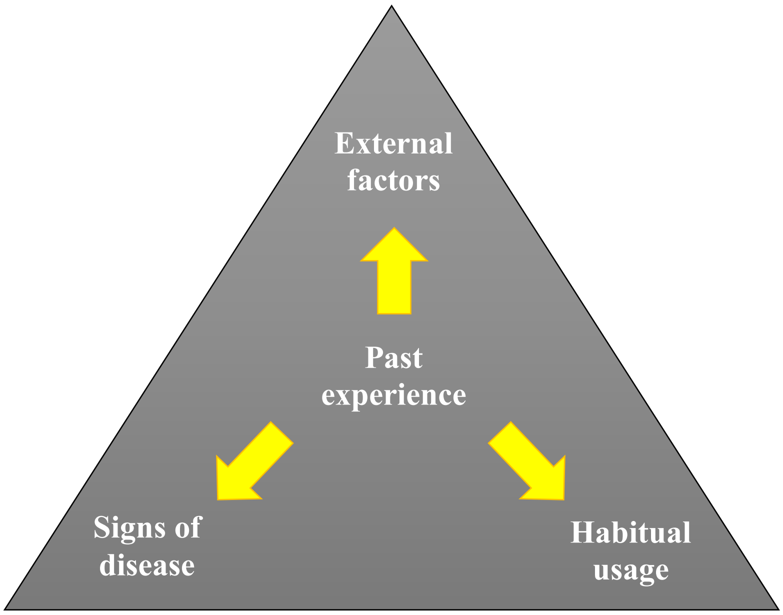


Figure 38 – Illustrative representation of subjective influences for deciding treatment regimens

3.3.4.23 External factors

This feature relates to factors which are not directly influenced by the management system, such as the weather and mineral content of the pastures. The use of strategic treatments based on both the time of year and weather is most often mentioned in relation to the threat of *Nematodirus* infection in spring lambs. Other instances where the weather may influence is if the season is particularly wet and mild and therefore ideal conditions for roundworm development.

‘Well the wet weather probably doing more harm, I might test again and find it and just give them a dose anyway, just to keep them going on’ (Group A)

‘My young lambs if I think they need dosing in May, I'll dose them in May or if I think they need dosing in the first week of June, I will leave them till then. Because you’re not going to tell me you’re going to get the same weather year on year’ (Group B)

‘The sheep or cattle are just part of what's going on and if the weather's right we would dose these cattle today’ (Group C)

3.3.4.24 Signs of disease

One of the most common impetuses for deciding when to treat was based on visual assessment of clinical signs of gastroenteritis or if animals were not considered to be performing sufficiently. Such skills (referred to as stockmanship skills) were highly regarded by participants ad formed an essential indication for deciding when to treat.

‘You know that you are observing the beasts, so as soon as you see little touch of scitter in one or two of them, then you should do the whole lot’ (Group C)

‘In general terms that wee bit of stockmanship comes into this... a lot of folk are in too much of a damn hurry nowadays to look at their stock...it’s like you’re told to feed this much per ewe. Surely if you’re amongst sheep all your life you just know if they need more...’

‘… just slow down a bit and look at your sheep and think about what you’re doing rather than bam, bam, bam.’ (Group A)

‘I think its common sense again, you’re checking your animals, five days’ time, ten days’ time you don't know what they'll be like this time. You've got to pick up on signals like that, we only drug when we see the need with dosing lambs in the summer time’

‘Aye, at the end of the day you're looking for performance out your stock, if they’re not performing you’re wasting your time.’ (Group D)

Other suggestions for possible causes of problems associated with roundworm infection were the ingestion of fresh grass by lambs, as well as the possibility of mineral deficiency which were proposed to affect animals' immune responses.

> *'… In the spring we dosed all the lambs for Nematodirus and two days later they were dirtier than before. So I panicked a little bit but then took some dung samples to the vet to make sure the wormer (was working) but it was just the fact that the grass had started growing and they all just took too much spring grass' (Group A)*
>
> *'What about fresh grass?'*
>
> *'But mineral deficiency hasn't got anything to do with worms?'*
>
> *'Could affect immunity; make them more susceptible to worms.' (Group B)*
>
> *'Mineral's play a huge part in thriving sheep' (Group C)*
>
> *'… people have gone away from using copper, and the copper reduces what is excreted onto the pastures, and it reducing the fluke I believe in the animal, and also the immune system of the sheep, if it's low in copper, giving copper will be able to fight.' (Group C)*

3.3.4.25 Habitual usage

This feature refers to the routine use of treatments either based on a set drenching programme or at certain times of year e.g. pre-tupping. The opinions of using a set drenching programme were both positive and negative depending on the circumstances. The thought of treating animals without clinical signs was surprising to some participants.

> *'I'm really surprised by the amount of people doing set drench programmes. That's just the recipe that has caused all the problems'*
>
> *'Not if you're doing it right' (Group A)*

'Well why would you do it on a loop basis, like if they are doing OK and there's no sign of scitter then why do it again? I don't see the point.

'Depends how good your management is…' (Group D)

There were mentions of instances where a set drench programme may be warranted.

'A sheep worst enemy is its neighbour, so the more intensively stocked you are the bigger worm burdens you're going to build up over time. So to knock that thing on the head is a regular dosing programme and variation of treatments when you can.' (Group D)

'Depends on the time of year and past experience, but yours is based on what's happened in the past. But then we have a set programme until we wean them and then and assume that they can cope with worms for a couple of days until we discover they're there' (Group A)

The administration of anthelmintic treatments to ewes before mating was perceived by the majority of respondents as a good management practice for improving the condition of ewes going into winter. This belief was also held by those despite whether the ewes were thought to be healthy or 'resistant' to roundworms, as they were perceived to be potentially prone to concurrent infections or immune pressure.

'… Ewes are basically immune, but they still using up their metabolism to counteract challenge if you like. Now if you give them a dose, we do twice a year at post-lambing and pre-tupping. As you say it gives them a boost.'

'No I rarely do that I would have said, we used Combinex in the past but this particular year we did a FEC in the ewes pre-tupping and it comes back that their no worms in your ewes so we went straight for 5% Tribex (Triclabendazole) just for fluke' (Group D)

3.3.4.26 Selecting the appropriate anthelmintic

When selecting anthelmintics, participants expressed a number of different influences affecting both their choice of anthelmintics as well as their chosen source for purchasing anthelmintics. In regards to product selection, participants ARS responses demonstrated overall that the main purchasing motivators included expense, withdrawal period, recommendation and most notably effectiveness as detailed in Table 28.

Table 28 – ARS percentage responses concerning factors motivating purchase of anthelmintics

Purchase motivator	Group 1 (%)	Group 2 (%)	Group 3 (%)	Group 4 (%)
Historical usage	0	8	6	6
Ease of use	4	0	12	5
Expense	15	13	8	10
Availability	7	0	0	0
Effectiveness	41	32	26	35
Withdrawal	10	13	29	15
Recommendation	22	34	18	27
Other	0	0	0	0

3.3.4.27 Sourcing anthelmintics (Price versus Service)

The majority of participants stated that vet prices for anthelmintics cannot compete with the animal health outlets. Consequently, this results in some participants bypassing their vets in favour of the low-cost suppliers.

'You wondered why they didn't go for the vet, but our vets say that they supply wormer just as a service because they said they can't compete on the price' (Group A)

'I think I would follow a vet's advice over a merchant's advice well for the qualifications for a start, but I think if they were to come away with a reasonable price we would give them a bit extra but not the money they're looking for just now'

'... You tend to bypass him for advice and go to the man who's doing you the better deal, whether his advice is better or worse nobody knows. I think the vet would be used far more if they could improve on price' (Group D)

Or alternatively seeking advice from their veterinarian first before purchasing from the animal health supplier.

'Sometimes take vets advice before (going to an animal health supplier)' (Group A)

3.3.4.28 Combination treatments

The use of combination treatments to control concurrent infection against roundworms and fluke were perceived to have a number of benefits as well as some drawbacks from participants. Firstly, if the treatment is deemed necessary, the cost-effectiveness of using a combination is likely to be more economical than purchasing separate treatments.

'You wouldn't beat it to have 5 litres of one kind and you need another five litres of something else. You need a lot of money sitting especially if you got a big flock of sheep.' (Group C)

However, this perceived necessity was questioned in relation to the added expense of using a combination treatment.

'It's a lot a more expensive if you don't actually need the combination'

> *'If there's a perceived need then expense shouldn't matter like, because it's the performance in the stock you're looking at and that far outweighs any expense if that treatment is required' (Group D)*

One participant also voiced concern for unnecessarily selecting for anthelmintic resistance by applying untargeted treatments.

> *'You have to be careful of combination drugs as well because the two drugs might not be the best for the two things you're trying to treat' (Group D)*

One instance where combinations were perceived to be particularly necessary was around pre-tupping time. However even despite acknowledging that mature ewes are more likely to be immune to roundworm infection at this time, it is still regarded as necessary due to the perceived risk of concurrent fluke and roundworm infection.

> *'A typical mature ewe should be resistant to roundworms, but if she's got a high pressure in the pasture plus she's being hit by fluke then your immune systems going to be suppressed so she's not going to cope with both of them. So it makes sense to treat both I would say. (Group D)*

The practical argument for using combination treatments was also raised because of the constraints of the farming system and resource availability.

> *'Yes we have to, well they're so far from home. We do everything in one run otherwise you'd be there for days.'*
>
> *'The use of combinations because it's easy and it cuts down on labour and time, that's why I use it because nobody's keen on working with sheep except me so I get grudging help, so the faster they can go through the better. The combination does the job for us, which will be the wrong answer but it's the truth'* (Group D)

3.3.4.29 Long-acting treatments

The use for persistent treatments was perceived to have multiple benefits for parasite control. For instance, in controlling both endoparasites and ectoparasites, namely sheep scab was frequently stated as an important quarantine treatment for returning and new stock. Other situations where a persistent treatment was considered useful was for ewes at lambing time to coincide with the peri-parturient relaxation in immunity (PPRI). For lambs, the use of a persistent treatment was stated as having dual benefits, firstly as a means of reducing anthelmintic usage and secondly by reducing disease burden on lamb growth.

> *'I tend to use them for lambs, save you having to dose them again.' (Group D)*
>
> *'I used Cydectin drench on ewes at lambing, and using it for lambs in the middle of the season just to try to give them breathing space...' (Group B)*

The use of long-acting products was also recognized for its potential issues relating to meat withdrawal, as well as concerning resistance development and weakening parasite immunity in ewes.

> *'What worries me is the common use of long acting wormers could be the biggest disaster...I think'*
>
> *'Aye because I think it's important because there's an issue of ewe's resistance and partial immunity to worm burden. And I think these (long-acting) products are a big thing destroying that...' (Group A)*

3.3.4.30 Preserve a susceptible worm population

A number of different issues were raised in relation to the practice known commonly as ‘dose and move’ whereby treated animals are moved onto ‘clean’ low contaminated grazing. The issues relating to best practice were directed at both the concept of ‘refugia’ as well as the practicality of either altering the dose and move practice or avoiding its use.

From the ARS responses (Table 22) the highest ranked barriers towards adoption of this guideline were complexity, conflicting advice and lack of time and labour. In regards to the refugia concept, the majority of the meetings participants were not aware of this concept and therefore an explanation of this was required. One participant queried about the dynamics of resistant and susceptible roundworms and the gains from not employing the dose and move practice. The participant then went on to simplify the terminology used by the moderator by referring to susceptible and resistant worms as ‘good’ and ‘bad’ worms. This helped to convey how not moving treated animals onto clean grazing helps to dilute resistance and reduces to the likelihood of reproducing resistant dominant parasites.

> *‘If you've only got resistant worms then they will only produce resistant worms, but If you've got susceptible one's then you have a chance of diluting the resistance’ (Moderator)*
>
> *‘So a goody and a baddy produces a not so baddy’ (Group C)*

The general recommendation prior to SCOPS promoted the use of the dose and move practice, as an effective means of minimizing parasite numbers on clean pasture.

> *‘You’re less likely to be transferring the burden onto where they are going’ (Group C)*

However, the current SCOPS advice discourages farmers from using the dose and move practice and therefore the issue concerning conflicting advice was expressed in all of the meetings.

> *'When I was fresh out of college it was use one wormer at one time and another form the next time and that went on, and you dosed onto clean pasture and now apparently that's… and I'm not that old... now that's the completely wrong thing to do' (Group A)*

An additional barrier to implementing alternatives to the dose and move best practice advice is the practicality.

> *'I think most people would like to dose and leave them on their old grazing for 24 hours before they move them, but it's not always terribly practical. Because if you gather the sheep and move them a long distance you're not going to put them back to move them again in a couple of days. So I think where its practical people do it, but I would say it's not always…' (Group B)*

> *'If you going to move them, then you've got a hold of them so that's the time to dose them' (Group C)*

3.3.4.31 Reduce dependence on anthelmintics

3.3.4.32 Impact on production

From the ARS responses (Table 22) the highest ranking barrier to this guideline was the potential for an impact on production if anthelmintic usage was reduced. This concern was also expressed by one participant which also supports one of the previous comments which reflect the conflict between reducing anthelmintic usage and the intent on improving animal productivity.

> *'It's fear that if you stop using anthelmintics you will lose production' (Group D)*

3.3.4.33 Availability of clean grazing

The lack of available clean grazing was also raised for using a graze and move system which was utilised by an organic producer at the Group B meeting

> *'…We keep out young clean grass for lambs and we don't worm them, we don't have a problem because they are on grass that hasn't had stock on it before, so the lambs get the first pick of the grass'*
>
> *'You were going on about the graze and move system, well that's super if you've got a few hundred or thousands of acres of ground and you can keep the field clear of sheep for a year with cattle but that can't be done nowadays' (Group B)*

3.3.4.34 Rotational/co-grazing

There was recognition from participants of the benefits of using alternate grazing between cattle and sheep for reducing high risk grazing between hosts. The organic producer utilizes this grazing management approach when the availability of clean grazing is limited.

> *'And that's only early in the season as we don't have enough grass to do that all the time, so their mixed grazing later on' (Group B)*

3.3.4.35 Selective breeding

The discussion on selective breeding varied between groups depending on the level of involvement by participants. Participants in Group C indicated not being involved in these types of breeding programmes and suggested that this approach is more suited to pedigree farm enterprises.

'I think in general you will find that in the pedigree world rather than in the commercial world, that's mainly at the table tonight. Because in Scotland there is only 2 who take up QMS subsidy for the vet counts and that was a pedigree.' (Group C)

Whereas participants from the Group B were more engaged on this topic, with two participants discussing their use of electronic drafting systems and faecal egg count monitoring to inform their breeding programme.

'I think the biggest thing we've seen, is the ewes that we have out of rams that are by very low egg count rams, their daughters are doing a very good job. They are punching over their weight as ewes.'

'They are having an easier go than some of the other ewes, and they seem to do a better job. In general, we've probably been following that for 5 to 6 years, and in general I'd say we're worming probably less than we were, I don't think our management of the worms have improved at all in that time, but I think we are worming less.' (Group B)

From the Group D meeting, there was recognition of the breeding programmes targeting parasite resistance that is being carried out in Australia and New Zealand.

'Going on from what __ said about heavier stocking sheep in the lower down fields, that's what more or less drove the kiwi's to breeding worm resistant sheep because the ground was so filthy using drugs until there's resistance. And over the years the lambs are less and less well until they found some of the genes that helped the situation they were going nowhere fast.' (Group D)

3.3.4.36 Bioactive forages

The opinions expressed by some participants reflected both the possible benefits and limitations that using bioactive forages can have on production. Although notable effects were indicated by participants from multiple meetings, these suggest different impacts. One participant stated a marked improvement from using red clover silage whilst another participant suggested trade-offs between lower animal productivity and greater parasite resilience by using chicory. The reliability and affordability of using such forage crops was also questioned.

> *'Yeah red clover silage has made the biggest difference' (Group B)*
>
> *'Well if you use chicory that was supposedly reduces it but the amount of production you can get off an acre of chicory is half what you could do on grass...chicory is far too expensive to grow and not reliable enough...what they did at __ (farm) they said it didn't actually reduce the worm egg count, they had more resilience to the worms...' (Group A)*

3.3.4.37 General attitudes to SCOPS recommended guidelines and practices

3.3.4.38 Why should I change?

Participants' perceived need to change their roundworm control strategy was a notion questioned numerously by participants from each of the meetings discussions. The prevailing opinion amongst these participants was that they are not aware of having problems associated with their roundworm control strategy and therefore did not perceive a need to change. A number of these responses were then followed by the view that others who are perhaps in a worse situation, should be the ones changing their practices.

> *'You're asking what stops guideline to work out a control strategy, but if your existing strategy is working effectively in your own particular circumstance. My response to that would probably fall different to some of rest of you; I would not see a perceived need'. (Group D)*

'I think it should be targeted at people that don't come to these things...that's the problem. People that are not coming in are not getting the advice' (Group A)

Another argument raised by participants particularly at the Group D meeting was what level of gains could be made from investing time and resources into improving their roundworm control strategies. The following discussion was prompted from the ARS responses to perceived barriers to the guideline of working out a control strategy with a veterinarian (results presented in Table 22).

'And no perceived need will include things like, well I think there will only be a slight improvement from what I'm doing now, so is it worth doing? That's my interpretation of it'

'I think if you can see the pound signs at the end of the day, you will do something about it'

'You will try something'

'It depends on where you're at, because where you say £5 better off if you got a three quarter decent system already you're not going to get the £5, but was I thinking when you said the vet group (of farmers), I was trying to think of the people a vet might send. Now the vet might be sending to you people he thought needed to do something about their worm control. In which case their going to get their £10 a time improvement' (Group D)

The importance of sheep to the farm enterprise was also a factor that was considered to influence the hierarchy of decisions made, as referred to previously in the case of the predominantly mixed livestock and arable farmers that attended the Group C meeting. This point was also raised by a participant from Group B in regards to why farmers were not optimising their control strategies.

'I think you've got mostly sheep farmers around here and I think a lot of sheep are bred on farms that are not sheep farms, sheep are just the third or fourth enterprise on the farm so it's not very

important or high up' (?)

In conjunction with these points, one perspective that was expressed by a participant was whether roundworm control is an issue requiring a high level attention or consideration in light of other pressing concerns. This outlook raises a number of concerns for farmers in general terms including those regarding farm inspections, farming profitability and reducing government subsidy. This also suggests that farmers are inundated with such recommendations to implement and therefore proposes that simplified, practical messages are required.

> *'Aye it depends...we are all going to lose single farm payments between 10 and 30 per cent depending on how pessimistic everybody is...is a worm control strategy really going to put money in the bank and pay for my lifestyle? And if worms come down on the low list of priority for profitability and then it's not going to make any attempts. At the moment my farm profitability is not getting terribly affected by my worming strategy... and I don't want to care anymore so I'm going to move onto something else...keep it as simple as physically possible easy to administer...and Christ you'll not be sleeping tonight if you're trying to implement...we are farmers we've got farm inspections... your head explodes and you've got to say that's worms and forget about it'*
>
> *You're quite right but there are people around the country which do have real problems with it....'*
>
> *That's fair enough...and in my personal situation it's not something that I worry about' (Group A)*

Very few participants stated that AR was a particular issue for them. One participant who did, was much more wary of practices such as the use of set drenching programmes, dose and move practices and the use of long-acting wormers. Another participant's comment may help to explain the possible reason for participants not openly discussing problems with AR.

> *'There always will be taboos in this industry. Things you don't want to speak about, you speak about it one to one to your vet' (Group D)*

Albeit comments were also expressed regarding participants concerns over AR and the impacts it may cause to the sheep farming industry.

> *'As a sheep farmer, it's actually quite worrying to read the press with a lot of the sheep becoming resistant to the doses, because without them the modern way of farming you would never survive it without wormers' (Group B)*

3.3.4.39 Complexity

One of the main overarching barriers as mentioned frequently throughout the discussion is the overall perceived complexity of the recommendations.

> *'Think maybe we all know of most of it...but don't feel like we understand it...because understanding it is the key thing…'*

Interestingly an impression was made by participants from multiple meetings about the perceived complexity of parasite control based on discussions particularly in regard to the commentaries made between moderators.

> *'to me just sitting here it's very complex the whole worm thing, actually to be quite honest you're giving me the impression that you're finding it quite complex as well, if you know what I mean?' (Group C)*
>
> *'You can only learn by asking or experience, but then if the experts can't tell you...what chance have we got?' (Group A)*

3.3.4.40 Implementability

It was apparent from the discussions that not all of the recommended practices would be feasible to implement on the participant's farms. The differences between participant's enterprises particularly between focus groups as well as within groups, demonstrates the diversity of farming systems and characteristics. This was therefore believed by some participants that such diversity creates a challenge for endorsing a universal set of guidelines.

> *'The thing is its easy if you see it black or white but everybody's farms are different and it's not a one model fits all...you have to adapt to everybody's situation' (Group A)*

3.3.4.41 Problems with SCOPS extension

A number of general issues were raised regarding the content of the recommendations. The participants from the Group C meeting were concerned about the lack of a prescriptive advice regarding when to treat and which treatments should be given.

> *If you compare the livestock side of things with the arable side the livestock advice is a bit wishy washy, on the arable side there are people that will come out in the start of the season and they will give a definitive programme of fungicides for a crop. We don't ever get a perceived best practice of individual wormers laid out by the likes of yourselves…'*
> *(Group C)*

Additionally, there was also concern of changes to recommended practices over time particularly in regards to the practice of dose and move. This is likely to be attributing to the general perception of conflicting advice among participants.

> *'The thing that I think...there are no concrete answers...with advice from years ago all opposite not...you wouldn't nowhere to go...you and vet man are arguing between the two of you...it's quite confusing...'*
>
> *'With so much conflicting advice with cannot do this cannot do that...if you do this you have to do that...it's all quite confusing'*
>
> *'I wouldn't say I don't trust but we read all the publications...and five years' time we did it all wrong and there's a new set of rules...we actually trying to make money out of sheep!' (Group A)*

3.3.4.42 How long till the next product?

When discussing the most recent anthelmintic additions i.e. Zolvix and Startect, the point was raised about the development of new anthelmintic products. One participant commented as to whether farmers need to be concerned about AR development when new products are thought to be readily developed.

> *'And also it wasn't that long ago that we had three things .... So better me thinks well they'll keep coming up with new products so is there any point giving a hell of a hassle if they come up with another product anyway...' (Group A)*

3.4 DISCUSSION

The issues relating to parasite control management are wide ranging, taking into account many of the different features of farm management from biosecurity to animal husbandry, grazing management and risk assessment.

One of the main barriers to adopting AR mitigating practices was the prospective perception of a lack of need of other farmers to improve on their current control strategies. Indeed the risk attributed to roundworm control did not appear to pose a particular threat to participants' farming systems, and consequently neither was AR perceived to be a personal issue amongst most participants. In fact participants expressed much greater suspicion of other farmers' AR status than their own. Which was also reflected by the overall low rankings for the importance of AR testing. This issue of legitimation has also been suggested by others (Vanclay and Lawrence, 1994; Garforth et al., 2004), whereby farmers do not feel that the advice is relevant to them. Other studies by Toma et al (2013) have also demonstrated the link between farmers' perceived importance and usefulness of measures on farmers' adoption behaviours. It was apparent that the main stimulus for participants to test treatment efficacy came from a subjective assessment of whether a treatment is shown to improve animal condition. Although testing in this manner is important for confirming whether AR is the primary cause for treatment failure, it is counterintuitive to implementing mitigation strategies. Nevertheless obtaining evidence of declining efficacy is likely to increase farmers' perceived risk towards AR, which in turn has been suggested to strengthen knowledge acquisition through trusted sources (Sligo and Massey, 2007). Based on Rasmussen's (2011) proposed reactive to proactive continuum, this type of response could be categorized as 'reactive-responsive' whereby the identification of an existing problem is followed up by the development of a practical action plan. This type of response may have been facilitated due to the range of anthelmintics available, as well as the anticipation of new anthelmintic products being developed. This approach differs from a more 'reactive-defensive' response which exhibits a resistance to change which was also demonstrated by respondents. The desired outcome would be towards an 'anticipatory-reactive' response which tries to anticipate the future and develop a pre-emptive strategy to combat future challenges.

Other factors that were considered to contribute to the perceived lack of need to improve their current strategy were the uncertain gains from implementing sustainable practices. The discussion from this point perhaps reflect some farmers' economic orientations in terms of how benefits are assessed, and the perceived returns that could be afforded by making such improvements to parasite management. Although recent developments in our understandings of farmers' decision making have also highlighted the influences of various non-economic factors, it is still nevertheless important to acknowledge the influence of financial motivations as a key incentive towards agricultural adoption (Vanclay, 1992). Interestingly the perceived expense of implementing recommended practice does not appear to be a major barrier overall, although concerns of possible returns from time and labour investment was expressed. Regarding biosecurity the perceived risk attributed to AR was not considered to be a significant threat in comparison to other disease risks such as sheep scab, which was frequently stated as a concern amongst participants. It may therefore be important to promote the dual benefits from an overall parasite control standpoint, in order to avoid under-representing the importance of introducing AR onto farms. What was also evident is that there is a common lack of trust in vendors' claims when purchasing livestock as well as the previously mentioned opinion that AR is more of an issue for other farmers. This belief could therefore be utilised in order to influence farmers to implement stricter biosecurity measures to prevent introducing AR from other farms.

The practicalities of implementing best practice advice were also acknowledged in reference to several practices. These perceived constraints related to both a lack of access to facilities and the availability of human resources (i.e. time and labour). Regarding the former, such practices which were inhibited by a lack of facilities included the quarantining of animals and the weighing of animals to determine anthelmintic treatment dose. One of the main concerns from participants regarding quarantine procedures was the requirement to keep animals off pasture. This was considered unfeasible in some circumstances where the availability of feed resources would not be able to sustain animals off pasture and therefore was believed to have implications on animal health. This may therefore require that alternative methods be developed to ensure animal health and welfare is not compromised.

For determining treatment dose it was apparent that dosing by the weight of the heaviest animal was perceived to be an efficient and accurate system for ensuring animals receive a full treatment dose. However the influence of past experience on estimating and using average weights may reflect how some farmers have developed a routine which is perceived to work appropriately, but is potentially resulting in sub-optimal dosing. In terms of extension efforts, animal health advisors and prescribers should discuss with their clients about how they determine their doses and advise on the effectiveness of their treatment approaches. As mentioned in the discussion, if farmers are made aware of the potential consequences of insufficient dosing in terms of potential production losses, then such farmers may be more inclined to invest time and money into improving their current drenching practices.

The constraints of human resources were also discussed by participants in regards to the application of several parasite control practices including quarantining, the use of parasite diagnostics, drenching animals effectively and preserving a refugia population. For each of these practices the relative resource requirements vary depending on particular farm circumstances. For instance the urgency to introduce livestock particularly regarding tups or bulls was one scenario where time constraints were perceived to be an issue for quarantining. For the use of parasite diagnostics, the efficacy of the FEC process was perceived to be time consuming. It did not appear that the time taken to receive results from the veterinarian was the issue, but rather the planning involved in collecting samples regularly and fitting it in amidst other farm responsibilities. The solution as suggested by participants may be for farmers to develop a proactive mind-set both for testing the need to treat, as well as for testing the efficacy of their treatments. If animal health advisors were to encourage either monthly or bimonthly FEC's for their clients and provide practical guidance on treatment requirements as valued by participants, this would justify the labour and time provisions required to gathering and test animals. Also in situations where it is perceived unfeasible to test samples based on an extensive sheep management system it would be beneficial to formulate a protocol to suit the particular circumstances of the farm. Regarding the time constraints for weighing animals for determining treatment dose it is clear from participants' comments that the time and expense of treatment is squandered if the task is not being implemented effectively. Lastly the practicality of moving animals back onto their old grazing after treatment was perceived by some participants to be unfeasible to their circumstances. In such situations it could be advised that some animals are left untreated in order for those animals to contribute to the unselected ‘refugia’ parasite population.

In general the difficulty with combating such practical issues is that farmers only have a finite availability of resources, which demands that farmers be pragmatic when allocating their time, labour and finances. This may be particularly pertinent to sheep farming where concerns regarding depleting labour and government subsidy are an increasing issue (Morgan-Davies et al., 2006). From the meetings discussion it could be inferred that opportunity cost is one economic concept which may influence participants’ decision making processes. This concept considers the prospective sacrifices involved in making decisions, for example an investment in one opportunity involves the inherent sacrifice of any alternative investment (Rushton, 2009). Therefore if farmers consider their investment in time and labour better suited to other tasks (especially where sheep are not a priority) then the rationale for the alternative venture is likely to be more favourable. Other examples where non-adoption resulted from farmers’ perceived impracticality of recommendations include Bennet and Cooke’s (2005) study concerning adoption of bovine TB biosecurity measures. Even where farms were affected by the disease and granted financial aid, the impractical and time consuming nature of the proposed measures caused reluctance to adopt amongst participants.

Aside from the practicalities of implementing best practice advice, one of the common criticisms expressed by participants was the perceived complexity of advice given. This issue was apparent from both the ARS responses concerning adoption of most

SCOPS guidelines, but also most pertinently from the discussion of practices which required a greater depth of knowledge of parasite epidemiology, such as when to treat animals for parasites and the concept of preserving parasites in refugia. This innate complexity regarding parasite control could be anticipated due to the myriad of internal and external factors affecting its control, made only more challenging by the emergence of AR. As indicated by participants the diversity of farming systems makes the applicability of advice more challenging. The opinions towards monitoring FEC's were varied, with more participants overall indicating that FEC are a useful tool for deciding whether to treat animals. However some concerns were raised about adding complexity to the decision making process, as well as uncertainty regarding its reliability. It might also be that such innovations may conflict with farmers sense of identify based on his/her current skills and beliefs. For instance when informing parasite control approaches a strong sense of belief towards the importance of good stockmanship skills may conflict with the ideals of using precautionary diagnostic testing methods. This may also be linked to the perception of a 'good farmer' as someone who keeps a watchful eye over their animals and as a result is less likely to encounter problems concerned with endemic disease risks (Heffernan et al., 2008). From these deductions it could be reasoned that there is a requirement for a trusted and adaptable support system to inform farmers of the most appropriate actions to ensure that targeted, effective parasite control measures are implemented. Additionally the design of such systems may need to consider ways to take into account the current parasite management styles to ensure that recommendations are able to complement rather than challenge farmers' current skills and beliefs, which has also been acknowledged by Thompson (2008) regarding Australian parasite management extension schemes.

Regarding the parasitological concept of refugia, the awareness amongst participants from all groups was negligible. Although it was indicated that many participants were aware of the practice of 'dose and move' which provided a useful working example of the concept. In essence the refugia concept covers the principles of population genetics, in this instance regarding the distribution and frequency of drug-resistant and susceptible alleles within a parasite population. The likelihood to which a lay farmer would be familiar or engaged with such concepts and terminology used, prompts the consideration to simplify the concept. As stated by Vanclay (1992) the greater the complexity of an innovation, the more difficult it is to understand, and consequently it is perceived to require greater managerial skills. The example of the participant that changed the scientific terminology into expressions that he was more accustomed, demonstrates the kind of translational approaches which are required to help clarify the issue concerning the dose and move practice.

In conjunction with the complexities of advice, additional criticisms were made concerning conflicting advice, both in regards to differing advice between advisors as well as changing advice over time. In regards to changing advice, the shift from advisors encouraging farmers to employ the practice of dose and move, to actively advising against it represents the most apparent occurrence of this matter. The added dispute regarding this advice is the conflicts of interest for farmers between using a well-established method of achieving effective roundworm control and reducing treatment administrations, versus a less suppressive approach which reduces the risk for AR selection and establishment. This potential trade-off between AR management and roundworm control effectiveness, demonstrates both positive and negative attributes (Besier, 2012). If these attributes conflict with farmers' current knowledge, skills or beliefs, then the practice may be less likely to be adopted (Eckert and Bell, 2005). By the same reasoning it could be expected that veterinarians' extension behaviours are likely to be influenced by such factors, and as a result may differ between individuals based on their training backgrounds as well as their personal views and interests towards the topic. Comparable factors have also been suggested as potential influences of veterinarians proactive flock health planning behaviour (Bellet et al., 2015) through the COM-B framework, which considers: capability, opportunity and motivation to influence behaviour (Michie et al., 2011).

In general participants' views towards veterinary services regarding roundworm control were positive. The most affirmative responses to the benefits of involving their veterinarians came from participants at the Group B meeting. In comparison the comments which featured the most cynicism towards veterinary input came from the Group C meeting. This may be largely due to how groups were selected, with participants in Group B selected by their vet which could explain why participants from the Group B indicated a better level of engagement from their vet when compared with the other groups. When considering possible explanations for disconnect between some vets and their clients on the topic of roundworm control, one of the common themes raised by participants was the price of anthelmintics versus degree of service. The decision regarding which purchasing channels to use for anthelmintics was frequently stated to be influenced by price, and for that reason many participants are swayed towards animal health outlets based on their affordability. It was also suggested that vets need to be more competitive on price and more proactive about selling such products to clients. The requirement therefore to improve engagement and proactivity among vets to promote their services to clients is therefore an important step to improving farmers roundworm control strategy in conjunction with their overall flock health plans.

The use of a focus group methodology enables the exchange of experiences and ideas between groups of individuals, in order to identify and resolve key issues which would otherwise be difficult to elicit. By conducting multiple meetings in different areas we are able to compare and contrast the findings between farmer groups. The differences between group characteristics and group dynamics are noteworthy and had considerable effects on the outcomes of the meetings. For instance the greatest depth of discussion was generated from Group D which comprised of the fewest number of participants of all the meetings as well as the lowest proportion of sheep orientated farmers. The Group C meeting in contrast had the greatest number of participants which most likely affected the level of interaction which could be made between individuals and also may have made individuals more conscious of speaking in the larger group setting. The participants in Group B in particular were recognized as having the greatest level of awareness and involvement in best practice parasite control approaches compared with the other group meetings. This was most likely due to the selection of participants by the regional advisor, a vet who was also a prominent advocate of sustainable parasite control practice. Although all the focus group recruiters were given the same participant selection (as detailed in Figure 30). It is however possible that some recruiters may have also selected participants based on other criteria such as whether the recruiter felt that some of their advisory network would benefit more from the discussions, who may otherwise might not be too familiar or interested in regard to the topic of parasite control. Other such influences on participant selection could include whether participants were identified as more outspoken and therefore would more likely contribute to discussion than others. Such participant selection approaches may introduce potential biases to discussions which may be evident for example from the participants of Group B who were considerably more knowledgeable than other groups on the topic of roundworm control. However, as the aim of the focus group discussions were to canvas a wide range of opinions from a cross section of the sheep farming industry, I am confident this was achieved overall with regard to the data gathered from all focus groups respectively. An additional limitation of the study was the level of experience of the moderators concerning the moderating qualitative focus group meetings. It is acknowledged that references to observations by moderators between meetings were used as a means of stimulating further discussion. Although this method was an effective way of enabling participants to consider opinions outside the immediate confines of the group, it can however have an effect on the subsequent beliefs of a group by presenting a view which may be perceived as a social norm by participants. This approach was generally used however as an adjunct to discussion such as after an ARS poll result was presented to a group. It is also important to note that when presenting the principles of the SCOPS recommended practices to the groups prior to the main discussion, it is possible that suggestive thoughts could be exhibited based on the moderators own beliefs as well as based on the ability to translate often complex principles to a predominantly lay audience. Naturally the consequence of the knowledge transfer process could convey certain subjective beliefs such as complexity of advice from the moderator to an audience, however for the purposes of the study this step was essential for the subsequent main discussion. A possible way to combat this would be through further moderator training as well as focus group piloting to identify potentially suggestive sections of discussion.

The use of the ARS format for the meetings was a useful tool for initiating discussion, by allowing all individuals to participate and comment on responses uninfluenced by the group, which may otherwise be swayed using a non-anonymous polling method. The potential pitfalls of using the ARS is if used excessively, which can disrupt the flow of conversation due to the alternation between polling and discussion. The other benefits of the ARS method were the collection of quantitative data, which enables the comparison with the accounts from the qualitative data. The inherent challenge therefore is to keep all participants engaged and active in using the ARS to elicit all responses within the group.

The use of farmer participatory approaches such as the use of focus groups is becoming the new standard within the field of modern agricultural extension. If the main focus of extension efforts are to improve engagement with farmers then all of the interested parties i.e. vets, SQP's and pharmacists, need to be more proactive in discussing roundworm control with their clients and providing advice where appropriate. As proposed by Garforth (2004) the art of knowledge transfer should go beyond solely providing the 'hard facts' and empirical reasoning for adopting an innovation, which will more likely appeal to researchers and animal health consultants, but less to the intended target audience. It is therefore suggested that the influence of subjective perceptions, such as whether the innovation will be cost or labour-saving, as explored in the present study may appeal more to farmers' beliefs and values. The findings from the ARS responses also demonstrated distinct similarities and differences between farmers and advisors barrier perceptions. If advisors are unaware of some of the main issues affecting farmers' adoption of best practice approaches, this is likely to limit the capabilities of advisors to support farmer's requirements.

Finally as suggested by Andrews (2009) there also needs to be a better relationship between prescribers and recognition of one another's strengths and weaknesses. For instance where an SQP or pharmacist may be better placed to give general advice and is less able to provide tailored advice to the requirements of the specific farm, then a referral should be made to contact their veterinarian or an alternative advisory source. Unfortunately due to time constraints we were unable to incorporate discussion topics such as what participants believed were the most important factors influencing their current roundworm control strategy and what might influence their future roundworm control strategy. Such discussions may prove both valuable between advisors and their clients when devising roundworm control strategies, as well as for informing future qualitative research.

Table 29 - Barriers to adoption of sustainable parasite control practices based on presented findings and previously cited factors.

How the findings support current knowledge of barriers to adoption of sustainable parasite control approaches	
Barriers to adoption	**References**
Complexity of roundworm control topic and principles underlying recommended roundworm management practices.	(Van Wyk et al, 2006; Kahn and Woodgate, 2012; Woodgate and Love, 2012; Morgan, 2013)
Changing/conflicting roundworm control advice	(Woodgate and Love, 2012)
Practicality issues i.e. time and labour requirements.	(Woodgate and Love, 2012; Morgan, 2013)
Uncertainty towards adopting new parasite management roundworm approaches	(Thompson, 2008)
The influence of farmers self-identity against adopting new parasite management approaches	(Thompson, 2008)
What this study adds to our current understanding	
The lack of urgency to change due to perceived imminent arrival of new anthelmintic products.	
The belief that other farmers pose a greater risk for AR development than themselves.	
The perceived lack of importance/impact of roundworm control in comparison to other farming issues.	
A requisite for veterinarians to be more competitive and proactive in promoting their services concerning roundworm control.	

3.5 CONCLUSIONS

From the qualitative research conducted we have identified several overarching themes and specific barriers impacting on sheep producers' attitudes to roundworm control and best practice advice (outlined in Table 29). It is apparent that more is required to convince farmers to take steps towards adapting their current roundworm control strategies to combat AR development. Emphasising and incentivising farmers to test their treatment efficacies may prove to be the type of 'cues to action' required to change farmers' AR risk perceptions and spark motivation towards more sustainable parasite control approaches. It was clear that the vast majority of participants rely on anthelmintics in order to improve animal production and therefore the prospect of AR creates a dilemma for modern sheep production.

In terms of the future extension efforts, the findings indicate a need for better clarity of messages in order to improve the translation of scientific information into knowledge which is applicable and rational to farmers' requirements. Furthermore the findings also highlight the need to improve proactivity among animal health advisors and prescribers to instigate knowledge exchange with their clients with regard to roundworm control improvements. Additional extension strategies may also benefit from alternative knowledge exchange formats which could enable the tailoring of information to suit the diverse range of farming systems.

CHAPTER 4: SCOTTISH SHEEP FARMERS' ROUNDWORM MANAGEMENT PRACTICES AND FACTORS ASSOCIATED WITH FARMERS' ROUNDWORM CONTROL ATTITUDES

4.1 INTRODUCTION

The aims of this chapter are firstly to determine the most recent adoption rates of 'best practice' roundworm control practices, as well as the most preferred formats for knowledge transfer among Scottish sheep farmers. The second aim is to demonstrate the range of attitudes and levels of agreement towards general roundworm control views and 'best practice' approaches. Univariate analysis is also applied to determine associations between demographic factors (e.g. education) and farm characteristics (e.g. enterprise type) at an individual attitudinal item level. The intention of this work is to establish where agreements and conflicts in farmers' attitudes arise, and to identify where predisposing factors may influence attitudes towards roundworm control and best practice.

The results presented demonstrate a varied adoption of best practice approaches to sustainable parasite control by Scottish sheep farmers. Practices shown to have the highest general levels of adoption included the use of quarantine procedures, low treatment frequencies and the use of alternative grazing management approaches i.e. rotational and co-grazing strategies. Such approaches will help to prevent the introduction of AR and selection pressures for AR development and manage pasture infectivity in order to mitigate the occurrence of clinical disease as well as reduce dependence on anthelmintics. The results also highlight areas requiring more attention such as promoting the rotation of anthelmintics throughout the season, the use of selective breeding and particularly the use of diagnostic testing for roundworm control and AR detection.

Significant associations between farmer demographics, farm characteristics and individual roundworm control attitudes are demonstrated. The requirement to tailor information to suit the range of management styles and to the address the associated AR risk perceptions is one such areas that will aid in promoting responsible anthelmintic usage across the whole sheep farming industry.

4.2 MATERIALS AND METHODS

A telephone questionnaire was devised based on a range of different source material. Attitudinal questionnaire items came from a combination of common themes highlighted from farmer focus group meetings (chapter 3), as well as the research groups own parasite management experience and comparable questionnaire literature related to disease management (Bartley et al., 2003; Palmer, 2009; Toma et al., 2013; Alarcon et al., 2014; Vande Velde et al., 2015). The emphasis for developing questions was to consider areas of greatest importance to sheep farmers regarding parasite control, such as treatment timings, benefits of anthelmintic treatments, dosing practice etc. The result of this was a comprehensive list of items which were categorised into components based on the SCOPS guidelines. Questions that were not specific to SCOPS practices were grouped under 'general attitudes' to roundworm control and anthelmintic resistance. Additional items were derived from behavioural models including the Theory of planned behaviour (TPB) and Health Belief Model (HBM) which have been used to explain and predict preventive health behaviours (Ajzen et al, 1991; Rosenstock et al., 1988). Such items derived from this model include perceived level of risk, which comprises susceptibility i.e. likelihood of an event occurring, as well as severity i.e. the impact of the event occurring. The combination of these risk items is referred to as 'risk perception' and was incorporated into the general attitudes section of the questionnaire.

4.2.1 Questionnaire design

The survey was designed by the author together with Dr. D.J Bartley, Dr. E.J Hotchkiss and Professor N.D Sargison. The questionnaire design was built around five main components; 1) farmer demographics and enterprise characteristics, 2) general roundworm control/AR attitude statements, 3) open-ended roundworm control knowledge questions, 4) attitudinal statements relating to SCOPS recommended practices and 5) parasite control behaviours. The first section included ten closed-ended questions relating to demographical information (age, education and years earning a living as a farmer), as well as details of the farming system (enterprise type, flock size, land topography, farming priorities). The term 'topography' is to represent types of farming systems based on the physical landscape i.e. aspects such as altitude and slope of the farm, as based on the three-tier stratification system (lowland, upland and hill). The second section included 20 broader questions relating to attitudes towards general parasite control that were not specific toward a particular control measure (e.g. the perceived importance of roundworms and risk perception of AR). The third section included three open-ended questions which were used to gauge the level of the respondent's knowledge and understanding on the topic of roundworm control and AR. The fourth section focused on 71 attitudinal statements which were framed around the eight SCOPS guidelines (Abbott et al., 2012). This fourth section formed the largest component of the questionnaire, including around 60% of all questionnaire items. The final section included 19 closed-ended questions of which 15 were directed to parasite control measures implemented on farm. Four additional questions which included directly relating to the behaviours of interest as well as preferred formats of knowledge transfer. All attitudinal items included in section 2 and 4 were measured on a 5-point-Likert scale: Strongly Disagree (1), Disagree (2), Unsure (3), Agree (4) and Strongly Agree (5). Sections 1 and 5 were recorded by interviewers based on a pre-determined coding frame. Full details of questionnaire items referred to in this section are included in Appendix 3.

4.2.2 Survey Implementation

Farmer contact details were obtained from the Scottish Government (Rural and Environment Science and Analytical Services Division; RESAS) by the use of a stratified simple random sampling method applied to the agricultural census data. The contact details were obtained subject to a confidentiality/data protection agreement between Moredun and RESAS. The selection criteria used to target farms of interest included, premises with flocks with more than 50 breeding ewes and other sheep (1-year-old and over) for breeding, and at least 25 ewes used for breeding in the previous season. This was to avoid sampling from particular smallholdings where the motives for rearing livestock are not financially driven. A total of 7,821 holdings were identified within Scotland which fitted the selection criteria, which was stratified regionally by animal health divisional office (AHDO) in order to ensure a proportional population sample from each region. The sampling frame was then calculated by RESAS from the original target population by assuming a likely positive response rate of 30%, and aiming to achieve an overall failure rate of 0.001. The resulting sampling frame included 1,930 holdings.

Based on a target of 400 completed surveys from across six geographic regions of Scotland, the number required per region was weighted based on the overall number of holdings within the region. The 400 target was established based on a calculated sample size using the number of Scottish sheep holdings (approx. 14,900; National statistics) with an error rate of 5% and confidence level of 95% (Israel, 1992). The following equation was used to calculate the sample size for the questionnaire where n is the sample size, N is the population size, and e is the level of precision (Yamane, 1967).

$$n = \frac{N}{1 + N(e)^2}$$

This equation approximates the sample size required at the 95% level of confidence, allowing for a finite population correction, while assuming a 'worst-case scenario' for the prevalence. In the calculation, the prevalence is assumed to take a value of 0.5, giving maximum variability

In line with confidentiality/data protection agreement with RESAS, opt-out letters were required to be sent to farmers with a designated waiting period of two weeks for any responses to be returned. The letters (included in Appendix 2) outlined the aim of the study, the estimated interview duration, the voluntary nature of the survey and gave assurance that any publication of results would ensure anonymity. If the recipient did not reply to the opt-out letter within the specified time it was considered that they had implicitly agreed to participate in the telephone interview. Subsequently, RESAS released the telephone details via an encryption protected disc containing the relevant contact details of farmers i.e. names and postal addresses.

A pilot study with six farmers was conducted before undertaking the main survey. This informed the modification of questionnaire items ensuring no ambiguity of questions by respondents and suitability of items for the telephone survey format. Additionally, lengths of interviews were monitored to ensure that interview times were not excessive, in order to achieve appropriate timeliness.

The survey interviews were conducted by a telecommunications company (Feedback Market Research Ltd.) under a confidentiality/data protection agreement agreed before the relevant contact details (names and telephone numbers) were released via an encrypted copy. These details excluded individuals who had previously opted out of the survey. Additionally, duplicate names as well as names addressed to companies were excluded from the final contact list All responses were documented by interviewers and compiled on a Microsoft Excel spreadsheet. All interviews were conducted under internal quality assurance procedures using computer-assisted telephone interviewing (CATI) systems. These procedures include back-checking 10% of all interviewer work, with data entry checked by no less than a 20% double entry policy. All CATI projects are monitored real-time to allow immediate identification of problems and all errors are returned to interviewers for recall and correction.

Farmers were assured that all information provided would remain completely anonymous in any subsequent reports or publications and that they and their enterprises would not be individually identifiable. Any farmers wishing to opt out after the data was collected were able to do so. After the research was completed Feedback Market Research agreed to destroy all data received.

4.2.3 Data formatting

The raw data were firstly coded into a database using Statistical Package for the Social Sciences (SPSS, IBM SPSS Statistics version 22.0). Demographic variables were selected for analysis based on a sufficient frequency of responses within each response category to ensure a suitable proportion (<20%) of the expected values should be less than 5 (Yates et al., 1999). Additionally any variable categories which contained too few responses or were not deemed necessary to the analysis were collapsed. Accordingly the dependent 'attitudinal' variables were also transformed from their originally recorded 5-point Likert scale (1= strongly disagree, 2= disagree, 3= unsure, 4= agree, 5= strongly agree) into a 3 point scale (1= disagree, 2= unsure, 3= agree).

The details of transformations were made to the following variables: 'knowledge', 'education' and 'region'. Roundworm knowledge questions were originally composed of three open-ended questions, which were coded into dichotomous variables (i.e. correct or incorrect) based on the authors' judgement, and a score was devised based on the total number of correct responses to the three questions. No additional weighting procedures were used to devise the score hence all accepted responses to all questions shared equal weighting. Categories other than 'agricultural college' within 'Education' were considered to have little influence on agricultural practice and were therefore combined. Within the variable 'region' responses from the North East/West and Island regions were grouped into 'North' and those in the South West and East were grouped into 'South'. The central region responses were excluded due to the issue of incorporating into either regional group.

4.2.4 Statistical analysis

Univariate analysis methods was used to assess associations between farm characteristics, farmer demographics and individual attitudinal statements. Independent variables were taken from section 1, with the attitudinal responses to roundworm control and best practice recommendations as the dependent variables from questionnaire sections 2-4. Chi square analysis was used as a first step analysis approach to identify significant associations ($p=<0.05$) among all attitudinal statements. The second step of the univariate analysis involved the use of multinomial logistic regression which was used to evaluate the odds ratios (OR) between response categories. For all attitudinal dependent variables, the multinomial outcomes were based on the condensed 3-point Likert scale (agree, unsure and disagree) as described previously in section 4.2.3. Demographic variables which were significantly associated ($P=\geq0.05$) with multiple attitudinal items were reported in the results.

4.3 RESULTS

4.3.1.1 Sample population

The target of 400 completed interviews was achieved with the following numbers of interviews conducted from each region: 65 in the South East, 76 in the South West 74 in Central region, 92 in the North West, 46 in the North East, and 47 in the Islands.

In terms of respondents' demographic information, the majority of farmers surveyed were aged 51-65 (n=176), followed by 36-50 (n=110), over 65 years (n=101) and 18-35 (n=13). The number of years earning a living as a farmer was most frequently between 31-40 years (n=112) with the lowest frequency at 10 years or less (n=31). The majority of respondents had some degree of further education either at university (n=145), agricultural college (n=59) or other type of college (n=20) and the remainder with no further education (n=176).

In regards to farm characteristics, the majority of respondents' farms were designated as hill farms (n =153) followed by upland farms (n =151) and then lowland situated (n=96). The types of farm enterprises were mostly mixed livestock (n= 227) with 25% of farms with sheep only (n=98) and the remaining farms with a combination of livestock and arable (n=75). Forty-four percent of respondents stated sheep as being their farming priority on their farms (n=174), with other livestock prioritised by 22% (n=89), and arable by less than 1% (n=3). Thirty-three percent of respondents attributed equal importance to their various farm enterprises (n =134). The majority of farms had less than 500 breeding ewes (75%, n=299), with a mean number of ewes at 394 (s.d. = 446.2, range = 31-2450). Seventy-three percent of respondents were commercial sheep producers (n =293), with 3% of farmers producing pedigree only (n=14) and 23% running both commercial and pedigree enterprises (n=93). Most farms were breeder only enterprises (n=183), followed by finisher only (n=132) with the remainder producing both breeder and finisher animals (n=85). Eighty-one percent of farms introduced new sheep into the main flock (n =323) and 4% of respondents were organic accredited (n=16).

4.3.1.2 Sources of roundworm control advice/planning

Respondents largely stated that they themselves were the primary planners of their roundworm control strategy (88%; 352/400), followed by animal health advisors (8%; 31/400) and farm staff/managers (4%; 17/400). The most influential source of roundworm control information (presented in Figure 39) as stated by farmers was their animal health advisor i.e. veterinarian, scientists etc. (68%; 272/400), followed by animal health supplier (18%; 72/400), other farmers (7%; 31/400) and other sources (3%; 11/400). As for respondents' most preferred method of accessing information (presented in Figure 40), the most frequently chosen methods contributing to 85% of total responses were direct communication (n=174) and receiving paper articles (n=164) . Online formats including articles/publications (n=50) and videos/webinars (n=5) contributed to 14% (55/400) of the overall preferred information method responses.

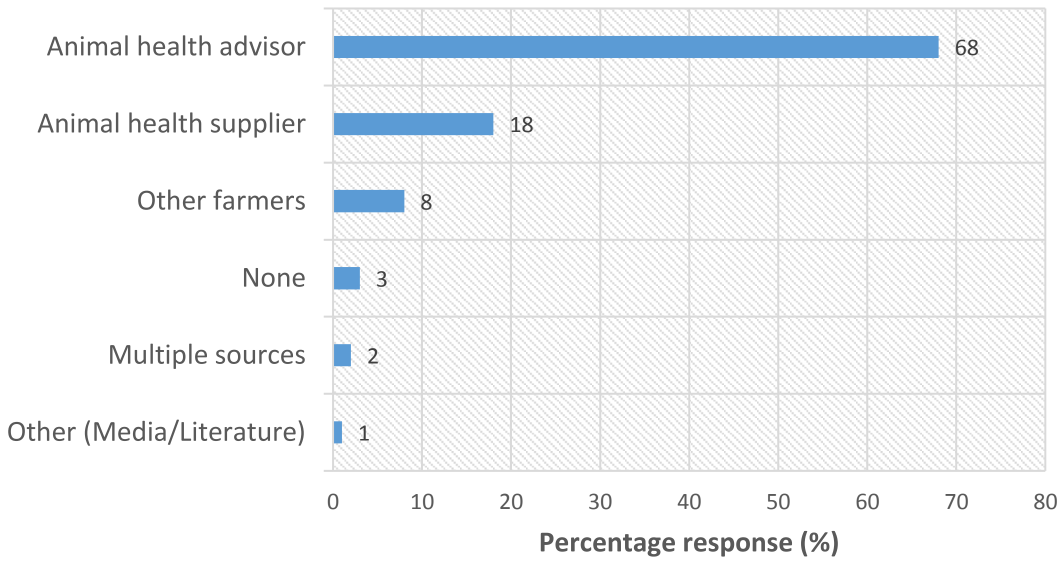


Figure 39 – Respondents most influential source of roundworm control responses.

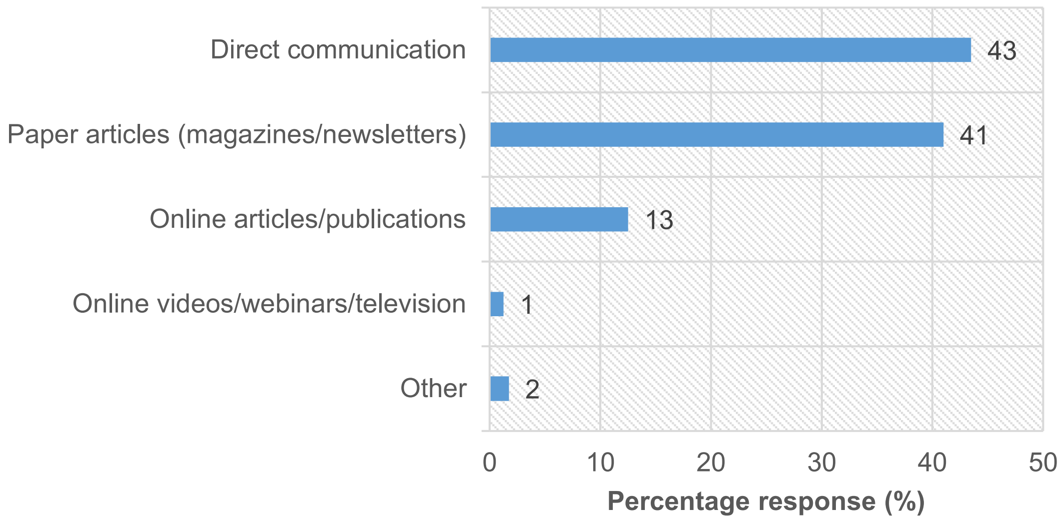


Figure 40 – Respondents most preferred method of accessing disease control information.

4.3.1.3 Roundworm control practices

The following results are arranged as per the current SCOPS guidelines (Abbott et al, 2012) which is used as a framework to distinguish different aspects of ‘best’ practice’ roundworm control.

4.3.1.4 Quarantine strategy

Of the 323 respondents who introduce new sheep onto their farms, 90% treated animals on arrival with an anthelmintic, of which 72% withheld treated animals from pasture. In contrast, the same proportion of respondents that occasionally treated incoming animals were shown overall not to withhold animals after treatment. The majority of farmers that isolated treated animals did so for at least 24 hours as recommended (Table 30).

Table 30 - Quarantine strategy (frequency and proportional percentages): Introducing new animals, drenching incoming animals and isolating treated animals. Green shading indicates recommended practices and red indicates non-recommended practice.

<table>
<tr><th colspan="3">Do you introduce new sheep onto the farm?</th><th colspan="3">Do you drench incoming animals</th><th colspan="3">Do you withhold incoming sheep from pasture?</th><th colspan="3">How long?</th></tr>
<tr><th>Response</th><th>n</th><th>%</th><th>Response</th><th>n</th><th>%</th><th>Response</th><th>n</th><th>%</th><th>Response</th><th>n</th><th>%</th></tr>
<tr><td>No</td><td>77</td><td>19</td><td>NA</td><td>-</td><td>-</td><td>NA</td><td>-</td><td>-</td><td>NA</td><td>-</td><td>-</td></tr>
<tr><td rowspan="5">Yes</td><td rowspan="5">323</td><td rowspan="5">81</td><td>No</td><td>20</td><td>6</td><td>NA</td><td>-</td><td>-</td><td>NA</td><td>-</td><td>-</td></tr>
<tr><td rowspan="4">Occasionally</td><td rowspan="4">12</td><td rowspan="4">4</td><td>No</td><td>9</td><td>75</td><td>NA</td><td>-</td><td>-</td></tr>
<tr><td rowspan="3">Yes</td><td rowspan="3">3</td><td rowspan="3">25</td><td><24 hours</td><td>1</td><td>33</td></tr>
<tr><td>24-48 hours</td><td>2</td><td>67</td></tr>
<tr><td>Longer</td><td>0</td><td>0</td></tr>
<tr><td></td><td></td><td></td><td rowspan="2">Yes</td><td rowspan="2">291</td><td rowspan="2">90</td><td>No</td><td>82</td><td>28</td><td>NA</td><td>-</td><td>-</td></tr>
<tr><td></td><td></td><td></td><td rowspan="3">Yes</td><td rowspan="3">209</td><td rowspan="3">72</td><td><24 hours</td><td>48</td><td>23</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td>24-48 hours</td><td>63</td><td>30</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td>Longer</td><td>98</td><td>47</td></tr>
</table>

4.3.1.5 Testing for anthelmintic resistance

The results from Table 31 indicate that 11% of respondents suspect they have drug resistance on their farms, with benzimidazole resistance shown to be the greatest concern by 70% of those that suspect resistance. This is also reflected by the number of respondents that tested for 1-BZ resistance when compared with levamisole and macrocyclic lactones. Of those who had tested for 1-BZ resistance, 42% had confirmed resistance compared to those respondents who tested for 2-LV and 3-ML resistance with 8, 9% confirming resistance respectively.

Table 31 - Frequency of respondents that either suspect or have tested and confirmed drug resistance

Do you suspect you have resistance on your farm?	**n**	**%**
Yes, 1-Benzimidazole	31	7
Yes, 2-Levamisole	3	1
Yes, 3-Macrocyclic Lactone	4	1
Unsure	8	2
No	337	84
Don’t know	20	5
Have you ever tested for drug resistance?	**n**	**%**
Yes, Benzimidazole	38	9
Yes, Levamisole	11	2
Yes, Macrocyclic Lactone	12	2
No	349	87
Do you have confirmed drug resistance?	**n**	**%**
Yes, Benzimidazole	16	4
Yes, Levamisole	1	0.25
Yes, Macrocyclic Lactone	1	0.25
No	384	96

4.3.1.6 Treating only when necessary

The frequency of treatments shown in Figure 41 is generally comparable between ewes and lambs, with the exception of a greater frequency of single ewe treatments compared to lambs, and a greater frequency of five or more treatments administered to lambs in comparison to ewes. The majority of respondents surveyed (66%) do not monitor faecal egg counts, with 22% using FEC's infrequently and 12% using more frequently. The mean number of treatments given by respondents in the previous year to ewes was 2.4 and 2.7 in lambs respectively, with a median of 2 for ewes and lambs. The range of treatment frequencies varied between 0-12 in ewes and 0-17 in lambs.

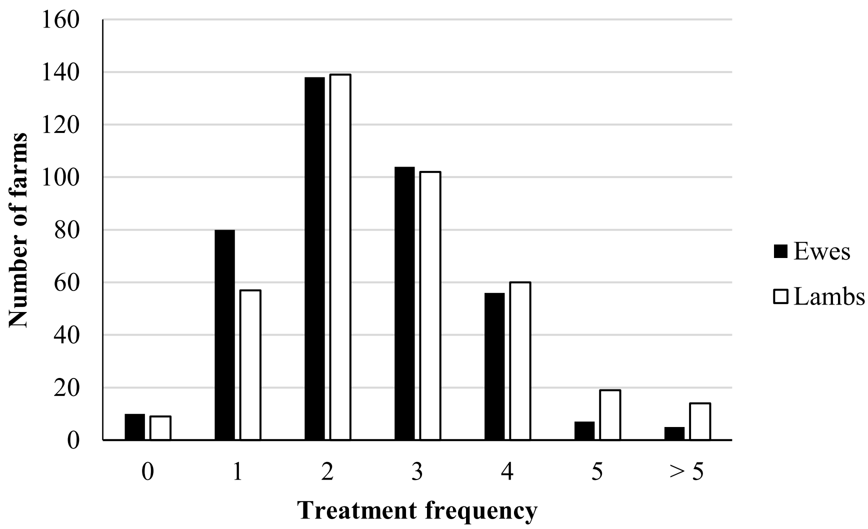


Figure 41 - Number of anthelmintic treatments administered to ewes and lambs in the previous 12 months

Selecting the appropriate treatment

Almost half of respondents (49%) exclusively used a single class of anthelmintic to treat animals within the previous 12 months. The most predominantly used class used exclusively was the 1-BZ group (32.5%) followed by the 3-ML group (12%) and 2-LV (3%), with the most recently introduced groups of anthelmintics (i.e. 4-AD and 5-SI) used by less than 1.5% of respondents. The most common combination of anthelmintics used is the 1-BZ and 3-ML groups. Only 7% of respondents rotated between 3 or more groups of anthelmintics during the year. Almost half of respondents used combination fluke and roundworm treatments and a third of respondents using long-acting treatments. Of those who stated using a combination or long-acting treatment, 22% and 33% either were uncertain of the product name or gave the name of a product which does not claim to be effective as a combination or persistently active treatment (All details of treatment selection included in Table 32).

Table 32 - Respondent's anthelmintic treatment selection within the last 12 months

Anthelmintic treatment selection		**n**	**%**
Single active used exclusively			
	1-Benzimidazole (1-BZ)	130	32.5
	2-Levamisole (2-LV)	11	3
	3-Macrocyclic Lactone (3-ML)	47	12
	4-Amino-acetonitrile derivative (AD)	2	0.5
	5-Spiroindoles (SI)	5	1
	Total	195	49
Two actives used			
	1-BZ + 2-LV	21	5
	1-BZ + 3-ML	111	28
	2-LV + 3-ML	8	2
	(Groups 1-3) + 4-AD	6	1.5
	(Groups 1-3) + 5-SI	5	1
	Total	151	37.5
Three or more actives used		28	7
No anthelmintics used		2	0.5
Unsure		24	6
	Total	**400**	**100**
Alternative anthelmintic treatments			
	Combination fluke and roundworm treatments	197	49
	Long-acting (persistent) treatments	131	33
	Total	328	82

4.3.1.7 Preserving a susceptible worm population

The dynamic between the frequency of parasites that are resistant to anthelmintic treatment and those which are susceptible to anthelmintic treatments (i.e. a *refugia* population) has been acknowledged as arguably the most important positive selection pressure for the progression of drug resistance within a parasite population. The practice known commonly as 'dose and move' whereby treated animals are moved onto grazing perceived to have a low risk of parasite contamination (i.e. 'clean grazing') encapsulates this principle of refugia. The results indicate that around 40% of respondents do not practice 'dose and move' with 28% using it occasionally and 32% always using this approach whenever possible.

4.3.1.8 Reducing dependence on anthelmintics

The use of alternative roundworm control strategies is encouraged to provide farmers with various non-chemotherapeutic options for reducing the risk of high pasture infectivity, in order to avoid over-reliance on anthelmintic treatments. Such strategies include the use of selective sheep breeding programmes to develop resistance to parasite infection, as well as strategic grazing management by either alternating grazing or co-grazing between sheep and other non-susceptible livestock species that do not share parasite specificity (e.g. cattle, horses). The majority of mixed livestock farmer respondents co-graze their animals (43%; 134/309) with 27% (84/309) alternating grazing between livestock species, leaving 29% of mixed livestock respondents grazing their animal species separately. Of the respondents surveyed 12% (49/400), employed the use of selective breeding for controlling roundworms.

4.3.1.9 Logistic regression analysis

4.3.1.10 Topography

As detailed in Table 33, upland farmers in general were significantly less likely than hill farmers to disagree than agree that wormer resistance is a threat to their farm business (OR 0.42, 95% CI 0.25-0.69). In terms of anthelmintic products, upland farmers were more likely to disagree than agree that combination treatments give peace of mind regarding parasite control compared with hill farmers (OR 2.13, 95% CI 1.09-4.18). The perception of leaving animals untreated as counterproductive was overall agreed by 65% of respondents, however upland farmers in comparison to hill farmers were more likely to express uncertainty with this statement (OR=2.89, 95% CI 1.40-5.97). With regards to alternative roundworm control strategies such as grazing management, upland farmers were less likely than hill farmers to disagree than agree that that they could improve their grazing management (OR 0.32, 95% CI 0.17-0.57), in addition to lowland farmers (OR 0.47, 95% CI 0.25-0.88). Also upland farmers were less likely to disagree than agree in comparison with hill sheep farmers that selective breeding was worthwhile in the long-term (OR=0.45, 95% CI 0.22-0.91), which was also reflected by lowland farmers (OR 0.18, 95% CI 0.06-0.57).

Table 33 - Univariable logistic regression analysis outputs from 2015 attitudinal survey; determining the association between farm topography and roundworm control attitudes (reference categories= Agree responses and Hill farms).

		Independent variable (Topography)									
Dependent variable	**Category**	**Lowland (n=96)**			**Upland (n= 153)**			**Hill (ref; n= 151)**			**P-value**
		n	**OR**	**CI (95%)**	***n***	**OR**	**CI (95%)**	***n***	**OR**	**CI (95%)**	
Wormer resistance is a problem in my region' (Q13)	**Agree (ref)**	27			45			39			0.007
	Unsure	35	1.58	0.79-3.13	54	1.46	0.79-2.69	32			
	Disagree	34	0.61	3.2-1.15	54	0.58	0.33-1.01	80			
Wormer resistance is a threat to my farming business' (Q14)	**Agree (ref)**	38			72			50			0.004
	Unsure	20	1.31	0.62-2.78	32	1.11	0.57-2.16	20			
	Disagree	38	0.61	0.34-1.09	49	0.42	0.25-0.69	81			
Advertising campaigns influence my choice of wormers (Q62)	**Agree (ref)**	25			18			33			0.000
	Unsure	23	2.02	0.88-4.65	31	3.78	1.63-8.79	15			
	Disagree	48	6.15	0.33-1.14	104	1.85	9.80-3.49	103			
Leaving a number of animals untreated for roundworms is counterproductive (Q74)	**Agree (ref)**	69			91			102			0.008
	Unsure	7	0.86	3.2-2.30	31	2.89	1.40-5.97	12			
	Disagree	20	0.79	0.42-1.49	31	0.93	0.53-1.63	37			

Table 33 - Univariable logistic regression analysis outputs from 2015 attitudinal survey; determining the association between farm topography and roundworm control attitudes (reference categories= Agree responses and Hill farms).

		Independent variable (Topography)									
Dependent variable	**Category**	**Lowland (n=96)**			**Upland (n= 153)**			**Hill (ref; n= 151)**			**P-value**
		n	**OR**	**CI (95%)**	***n***	**OR**	**CI (95%)**	***n***	**OR**	**CI (95%)**	
Combination fluke and worm treatments give me peace of mind regarding parasite control (Q59)	**Agree (ref)**	69			89			105			0.044
	Unsure	20	1.01	0.53-1.92	35	1.37	0.78-2.41	30			
	Disagree	7	0.66	0.26-1.70	29	2.13	1.09-4.18	16			
I am confident I could improve my grazing management (Q68)	**Agree (ref)**	68			112			86			0.002
	Unsure	10	0.74	0.32-1.72	21	0.74	0.32-1.72	17			
	Disagree	18	0.47	0.25-0.88	20	0.32	0.17-0.57	48			
Selective breeding programmes are worthwhile in the long-term (Q79)	**Agree (ref)**	65			102			80			0.006
	Unsure	27	0.73	0.41-1.31	36	0.62	0.37-1.06	45			
	Disagree	4	0.18	0.06-0.57	15	0.45	0.22-0.91	26			

4.3.1.11 Region

As detailed in Table 34, specific regional differences in AR risk perceptions were identified, with respondents from the north regions of Scotland three times more likely to disagree that AR is a problem in their region (OR 3.74, 95% CI 2.13-6.55) or a threat to their farming business (OR 3.00, 95% CI 1.79-5.02) compared to respondents from southern regions of Scotland. With concern to restricting anthelmintics to veterinary prescription, respondents from central were less likely (OR 0.55, 95% CI 0.30-1.02) as well as from northern regions (OR 0.37, 95% CI 0.22-0.61) to disagree than agree that this would promote responsible usage, when compared with southern sheep farmers.

In terms of respondents' perceived abilities to detect problems associated with AR, farmers in the central regions of Scotland were more to disagree than agree that they were confident to detect problems, than respondents from the southern regions (OR 4.10, 95% CI 1.18-14.2). Additionally, in terms of respondents' confidence to improve their grazing management, farmers in the north were significantly more likely to disagree with this statement than respondents in the south (OR 2.78, 95% CI 1.53-2.05). The opinion that the use of combination treatments gives peace of mind regarding parasite control was significantly more likely to have expressed disagreement by respondents in the northern regions compared with farmers from the southern regions of Scotland (OR 0.29, 95% CI 0.14-0.60).

Table 34 - Univariable logistic regression analysis outputs from 2015 attitudinal survey; determining the association between farm geographic region and roundworm control attitudes (reference categories= Agree responses and farm in the south).

		independent variable (Region)									
Dependent variable	**Category**	**North (n=185)**			**Central (n=74)**			**South (ref; n =141)**			**P-value**
		n	**OR**	**CI (95%)**	***n***	**OR**	**CI (95%)**	***n***	**OR**	**CI (95%)**	
Wormer resistance is a problem in my region (Q13)	**Agree (ref)**	39			22			50			0.000
	Unsure	38	0.90	0.50-1.62	29	1.22	0.62-2.39	54			
	Disagree	108	3.74	2.13-6.55	23	1.41	0.68-2.91	37			
Wormer resistance is a threat to my farming business (Q14)	**Agree (ref)**	58			37			65			0.000
	Unsure	25	0.73	0.39-1.36	9	0.41	0.18-0.95	38			
	Disagree	102	3.00	1.79-5.02	28	1.29	0.68-2.43	38			
Keeping wormers restricted to veterinary prescription promotes responsible usage (Q27)	**Agree (ref)**	98			36			50			0.001
	Unsure	36	0.87	0.46-1.65	10	0.66	0.27-1.57	21			
	Disagree	51	0.37	0.22-0.61	28	0.55	0.30-1.02	70			
I am confident in my abilities to detect problems associated with wormer failure (Q42)	**Agree (ref)**	130			57			117			0.017
	Unsure	42	1.89	1.05-3.40	9	0.92	0.39-2.15	20			
	Disagree	13	2.92	0.92-9.22	8	4.10	1.18-14.2	4			

Table 34 - Univariable logistic regression analysis outputs from 2015 attitudinal survey; determining the association between farm geographic region and roundworm control attitudes (reference categories= Agree responses and farms in the south).

		Independent variable (Region)									
Dependent variable	**Category**	**North (n=185)**			**Central (n=74)**			**South (ref; n =141)**			**P-value**
		n	**OR**	**CI (95%)**	***n***	**OR**	**CI (95%)**	***n***	**OR**	**CI (95%)**	
Combination fluke and worm treatments give me peace of mind regarding parasite control (Q59)	**Agree (ref)**	137			46			80			0.004
	Unsure	35	0.58	0.33-1.00	15	0.74	0.36-1.50	35			
	Disagree	13	0.29	0.14-0.60	13	0.87	0.40-1.85	26			
I am confident I could improve my grazing management (Q68)	**Agree (ref)**	111			52			103			0.008
	Unsure	20	0.92	0.47-1.82	8	0.92	0.47-1.82	20			
	Disagree	54	2.78	1.53-2.05	14	1.54	0.71-3.34	18			

4.3.1.12 Education

As detailed in Table 35, Those respondents with no further education were significantly more likely to disagree than agree that AR is a problem in their region (OR 2.87, 95% CI 1.65-5.01) or a threat to their farm business (OR 2.83, 95% CI 1.71-4.70) compared with the respondents who attended an agricultural college. Furthermore respondents' with no further education were more likely to disagree than agree that they could improve their grazing management compared with those who attended an agricultural college (OR 4.25, 95% CI 1.96-9.22), in addition to respondents with a non-agricultural education (OR 4.49, 95% CI 2.26-8.89). Respondents that attended a non- agricultural college were less likely to disagree than agree that restricting anthelmintics to veterinary prescription would promote responsible usage compared with respondents that attended an agricultural college (OR 0.49, 95% CI 0.26-0.90). Respondents that attended a non-agricultural college were either more likely to indicate disagreement or uncertainty with the statement concerning confidence in their abilities to detect problems associated with AR, compared with the respondents that attended an agricultural college (OR 5.98, 95% CI 1.96-18.2). Additionally non-agriculturally educated respondents were more likely to disagree than agree with treating ewes at mating time (OR 2.10, 95% CI 1.00-4.40), compared with agricultural college educated respondents. Also respondents without further education were less likely to disagree with treating ewes at mating time than those who attended an agricultural college (OR 0.27, 95% CI 0.11-0.68).

The statement regarding the influence of advertising campaigns on wormer choice was significantly more likely to be disagreed by non-agricultural college educated respondents than those who did attend an agricultural college (OR 3.2, 95% CI 1.32-7.74). This increased likelihood of disagreement is also true for statements regarding the simplicity of using treatment as opposed to implementing grazing management (OR 2.34, 95% CI 1.22-4.46), the counter-productiveness of leaving untreated animals (OR 2.00, 95% CI 1.11-3.96) as well as implementing a targeted treatment regimen based on live-weight gains (OR 3.42, 95% CI 1.75-6.66).

Table 35 - Univariable logistic regression analysis outputs from 2015 attitudinal survey; determining the association between respondents' level of education and roundworm control attitudes (reference categories= Agree responses and Agricultural College education).

		Independent variable (Further education)									**P-value**
Dependent variable	**Category**	**Yes, other (n=81)**			**None (n=176)**			**Agric. College (ref; n = 143)**			
		n=	**OR**	**CI (95%)**	**n=**	**OR**	**CI (95%)**	**n=**	**OR**	**CI (95%)**	
Wormer resistance is a problem in my region (Q13)	**Agree (ref)**	24			38			49			0.000
	Unsure	28	1.12	0.57-2.19	42	1.06	0.59-1.91	51			
	Disagree	29	1.37	0.69-2.71	96	2.87	1.65-5.01	43			
Wormer resistance is a threat to my farming business (Q14)	**Agree (ref)**	56			33			71			0.001
	Unsure	26	1.09	0.58-2.06	16	1.14	0.55-2.39	30			
	Disagree	94	2.83	1.71-4.70	32	1.63	0.88-3.04	42			
Keeping wormers restricted to veterinary prescription promotes responsible usage (Q27)	**Agree (ref)**	92			41			51			0.034
	Unsure	27	0.57	0.30-1.09	14	0.67	0.31-1.44	26			
	Disagree	57	0.47	0.29-0.78	26	0.49	0.26-0.90	66			
I am confident in my abilities to detect problems associated with wormer failure (Q42)	**Agree (ref)**	114			43			117			0.000
	Unsure	23	0.89	0.46-1.68	27	3.49	1.79-6.82	21			
	Disagree	9	1.46	0.47-4.48	11	5.98	1.96-18.2	5			

Table 35 - Univariable logistic regression analysis outputs from 2015 attitudinal survey; determining the association between respondents' level of education and roundworm control attitudes (reference categories= Agree responses and Agricultural College education).

Dependent variable	Category	Independent variable (Further education)									P-value
		Yes, other (n=81)			None (n=176)			Agric. College (ref; n = 143)			
		n=	OR	CI (95%)	n=	OR	CI (95%)	n=	OR	CI (95%)	
Treating ewes around mating time improves their condition (Q57)	**Agree (ref)**	143			48			101			0.000
	Unsure	26	0.76	0.41-1.40	15	1.31	0.63-2.73	24			
	Disagree	7	0.27	0.11-0.68	18	2.10	1.00-4.40	18			
The use of long acting wormers around lambing is beneficial for productivity (Q60)	**Agree (ref)**	143			55			109			0.009
	Unsure	31	1.02	0.56-1.86	21	1.80	0.92-0.35	23			
	Disagree	2	0.13	0.03-0.63	5	0.90	0.29-2.77	11			
Advertising campaigns influence my choice of wormers' (Q62)	**Agree (ref)**	39			7			30			0.009
	Unsure	34	1.00	0.50-2.02	9	1.48	0.48-4.54	26			
	Disagree	103	0.91	0.52-1.58	65	3.2	1.32-7.74	87			
Leaving a number of animals untreated for roundworms is counterproductive (Q74)	**Agree (ref)**	129			39			94			0.004
	Unsure	17	0.68	0.33-1.40	15	2.00	0.92-4.38	18			
	Disagree	30	0.70	0.40-1.24	27	2.0	1.11-3.96	31			

Table 35 - Univariable logistic regression analysis outputs from 2015 attitudinal survey; determining the association between respondents' level of education and roundworm control attitudes (reference categories= Agree responses and Agricultural College education).

		Independent variable (Further education)									
Dependent variable	**Category**	**Yes, other (n=81)**			**None (n=176)**			**Agric. College (ref; n = 143)**			**P-value**
		n=	**OR**	**CI (95%)**	**n=**	**OR**	**CI (95%)**	**n=**	**OR**	**CI (95%)**	
Targeting wormer treatments based on live weight gains would be achievable on my farm (Q73)	**Agree (ref)**	93			19			65			0.001
	Unsure	35	0.68	0.38-1.19	20	1.90	0.89-4.17	36			
	Disagree	48	0.79	0.47-1.34	42	3.42	1.75-6.66	42			
I am confident I could improve my grazing management' (Q68)	**Agree (ref)**	105			50			111			0.000
	Unsure	20	1.05	0.53-2.07	8	0.88	0.36-2.15	20			
	Disagree	51	4.49	2.26-8.89	23	4.25	1.96-9.22	12			
It is simpler to use a wormer than implement a grazing management strategy' (Q70)	**Agree (ref)**	91			41			86			0.013
	Unsure	47	1.43	0.83-2.46	11	0.74	0.34-1.62	31			
	Disagree	38	1.38	0.77-2.46	29	2.34	1.22-4.46	26			

4.3.1.13 Roundworm control knowledge

As detailed in Table 36, Those respondents who gave no correct responses were less likely to disagree than agree that it is simpler to use a wormer than implement a grazing management strategy, compared with those who gave two or more correct responses (OR 0.06, 95% CI 0.08-0.48). Additionally respondents who gave no correct responses were more likely to disagree that they could improve their grazing management strategy than those who gave two are more correct responses (OR 3.27, 95% CI 1.50-7.10). Whether selective breeding programmes are worthwhile in the long-term was more likely to be disagreed by respondents that gave no correct response compared with those who gave two or more correct responses (OR 2.62, 95% CI 0.92-7.45).

Table 36 - Univariable logistic regression analysis outputs from 2015 attitudinal survey; determining the association between respondents roundworm control knowledge and roundworm control attitudes (reference categories= Agree responses and >1 correct roundworm knowledge score).

		Independent variable (Knowledge score)									
Dependent variable	**Category**	**None correct (n=40)**			**1 correct (n=143)**			**>1 correct (ref; n=217)**			**P-value**
		n=	**OR**	**CI (95%)**	**n=**	**OR**	**CI (95%)**	**n=**	**OR**	**CI (95%)**	
I am confident I could improve my grazing management (Q68)	**Agree (ref)**	21			88			157			0.008
	Unsure	5	1.33	0.46-3.83	15	0.95	0.48-1.88	28			
	Disagree	14	3.27	1.50-7.10	40	2.23	1.30-3.80	32			
It is simpler to use a wormer than implement a grazing management strategy (Q70)	**Agree (ref)**	24			91			103			0.000
	Unsure	15	1.37	0.65-2.84	27	0.65	0.37-1.12	47			
	Disagree	1	0.06	0.08-0.48	25	0.42	0.24-0.72	67			
Selective breeding programmes are worthwhile in the long-term (Q79)	**Agree (ref)**	21			79			147			0.038
	Unsure	13	1.68	0.78-3.59	41	1.41	0.86-2.30	54			
	Disagree	6	2.62	0.92-7.45	23	2.67	1.33-5.35	16			

4.3.1.14 Enterprise type

As detailed in Table 37, Breeder farmers were more likely to disagree that wormer resistance is a problem in their region compared with both feeder/finisher farmers (OR 2.92, 95% CI 1.62-5.23). Breeder farmers also were less likely to disagree than agree that keeping wormers restricted to veterinary prescription promotes responsible usage (OR 0.58, 95% CI 0.34-0.98) whereas finisher farmers were less likely to express uncertainty than agreement to this statement compared with both feeder/finisher farms (OR 0.36, 95% CI 0.15-0.86). Breeder farmers were less likely to disagree than agree that combination fluke and worm treatments give peace of mind regarding parasite control' (OR 0.29, 95% CI 0.12-0.71), also regarding whether it would be achievable to employ targeted wormer treatments based on live weight gains, compared with both feeder/finisher farmers (OR 0.49, 95% CI 0.25-0.95). Breeder farmers were more likely to disagree than agree that they could improve their grazing management compared with both feeder/finisher farmers (OR 2.93, 95% CI 1.65-5.18). Breeder farmers were less likely to disagree than agree as to whether it is simpler to give a wormer than implement a grazing management strategy compared with both breeder/finisher farmers (OR 0.54, 95% CI 0.29-0.98). Finisher farmers were more likely to express uncertainty regarding whether selective breeding programmes are worthwhile in the long-term compared with both breeder/finisher farmers (OR 2.32, 95% CI 1.29-4.16).

Table 37 - Univariable logistic regression analysis outputs from 2015 attitudinal survey; determining the association between respondents farm nterprise type (Feeder, breeder or both) and roundworm control attitudes (reference categories= agree responses and enterprise type (Breeder/finisher/both).

		Independent variable (Enterprise type)									
Dependent variable	**Category**	**Finisher (n=81)**			**Breeder (n=123)**			**Both (ref; n=176)**			**P-value**
		n=	**OR**	**CI (95%)**	**n=**	**OR**	**CI (95%)**	**n=**	**OR**	**CI (95%)**	
Wormer resistance is a problem in my region (Q13)	**Agree (ref)**	23			24			57			0.000
	Unsure	30	1.28	0.66-2.46	24	0.96	0.50-1.92	58			
	Disagree	28	1.13	0.58-2.19	75	2.92	1.62-5.23	61			
Keeping wormers restricted to veterinary prescription promotes responsible usage (Q27)	**Agree (ref)**	41			66			70			0.047
	Unsure	8	0.36	0.15-0.86	19	0.54	0.28-1.04	37			
	Disagree	32	0.79	0.44-1.39	38	0.58	0.34-0.98	69			
Treating ewes around mating time improves their condition (Q57)	**Agree (ref)**	95			64			120			0.041
	Unsure	22	0.92	0.50-1.70	11	0.68	0.32-1.46	30			
	Disagree	6	0.29	0.15-0.73	6	0.43	0.16-1.10	26			
Combination fluke and worm treatments give me peace of mind regarding parasite control (Q59)	**Agree (ref)**	92			48			114			0.016
	Unsure	24	0.90	0.49-1.63	23	1.65	0.88-3.10	33			
	Disagree	7	0.29	0.12-0.71	10	0.81	0.37-1.81	29			

Table 37 - Univariable logistic regression analysis outputs from 2015 attitudinal survey; determining the association between respondents farm enterprise type (Feeder, breeder or both) and roundworm control attitudes (reference categories= agree responses and enterprise type (Breeder/finisher/both).

		Independent variable (Enterprise type)									
Dependent variable	**Category**	**Finisher (n=81)**			**Breeder (n=123)**			**Both (ref; n=176)**			**P-value**
		n=	**OR**	**CI (95%)**	**n=**	**OR**	**CI (95%)**	**n=**	**OR**	**CI (95%)**	
Targeting wormer treatments based on live weight gains would be achievable on my farm (Q73)	**Agree (ref)**	50			46			74			0.009
	Unsure	21	0.66	0.35-1.23	18	0.61	0.32-1.18	47			
	Disagree	52	1.39	0.83-2.35	17	0.49	0.25-0.95	55			
I am confident I could improve my grazing management (Q68)	**Agree (ref)**	70			54			127			0.004
	Unsure	11	0.86	0.40-1.88	10	1.02	0.45-2.29	23			
	Disagree	42	2.93	1.65-5.18	17	1.53	0.77-3.06	26			
It is simpler to use a wormer than implement a grazing management strategy (Q70)	**Agree (ref)**	70			42			94			0.017
	Unsure	32	1.43	0.79-0.25	25	1.86	0.98-3.54	30			
	Disagree	21	0.54	0.29-0.98	14	0.60	3.01-1.20	52			
Selective breeding programmes are worthwhile in the long-term (Q79)	**Agree (ref)**	71			41			119			0.025
	Unsure	32	1.34	0.77-2.32	32	2.32	1.29-4.16	40			
	Disagree	20	1.97	0.96-4.01	8	1.36	0.54-3.40	17			

4.3.1.15 Livestock species

As detailed in Table 38, attitudes regarding the treatment of ewes around mating time was more likely to be disagreed by livestock and arable farmers (OR 2.80, 95% CI 1.08-7.25) when compared with sheep only farmers. Mixed livestock farmers were more likely to state uncertainty regarding this statement (OR 2.25, 95% CI 1.04-4.85) compared with sheep only farmers. Livestock and arable farmers were more likely to disagree than sheep only farmers that using long-acting wormers around lambing is beneficial for productivity (OR 10.76, 95% CI 1.28-89.9). Mixed livestock farmers were less likely to disagree than agree that selective breeding is worthwhile in the long-term, in comparison with sheep only farmers (OR 0.42, 95% CI 0.21-0.85) Livestock and arable farmers were also were less likely to disagree than agree that selective breeding is worthwhile in the long-term, in comparison with sheep only farmers (OR 0.20, 95% CI 0.06-0.63).

Table 38 - Univariable logistic regression analysis outputs from 2015 attitudinal survey; determining the association between farm livestock type and roundworm control attitudes (reference categories= agree responses and farm livestock type).

		Independent variable (Livestock type)									
Dependent variable	**Category**	**Livestock and arable (n=75)**			**Mixed livestock (n=227)**			**Sheep only (ref; n=98)**			**P-value**
		n=	**OR**	**CI (95%)**	**n=**	**OR**	**CI (95%)**	**n=**	**OR**	**CI (95%)**	
Treating ewes around mating time improves their condition (Q57)	**Agree (ref)**	47			164			81			0.033
	Unsure	15	2.87	1.16-7.07	41	2.25	1.04-4.85	9			
	Disagree	13	2.80	1.08-7.25	22	1.35	0.57-3.18	8			
The use of long acting wormers around lambing is beneficial for productivity (Q60)	**Agree (ref)**	54			170			83			0.050
	Unsure	14	1.53	0.68-3.47	47	1.63	0.85-3.14	14			
	Disagree	7	10.7	1.28-89.9	10	4.88	0.61-38.7	1			
Selective breeding programmes are worthwhile in the long-term (Q79)	**Agree (ref)**	54			141			52			0.023
	Unsure	17	0.60	0.29-1.24	64	0.87	0.50-1.51	27			
	Disagree	4	0.20	0.06-0.63	22	0.42	0.21-0.85	19			

4.4 DISCUSSION

The reporting of parasite management practices is an important means of assessing the general trends in farmers' behaviours at a regional and national level. By identifying which practices are being widely implemented against those that are having a low uptake we can start to evaluate the possible reasoning behind certain trends and focus attention on those areas which require it. The practices which had the highest overall levels of uptake included quarantining practices for incoming animals, frequency of ewe and lamb treatments and grazing management. The proportion of respondents routinely administering anthelmintic treatments to incoming sheep (90%) is comparable with a number of surveys conducted within the UK and Ireland, with adoption varying from 66% to 94%, with an average uptake of 85% between studies (Bartley et al., 2003; Sargison and Scott, 2003; Morgan et al., 2012; McMahon et al., 2013b; Moore et al., 2016) . The separation of introduced animals from the main flock was also comparable with studies by McMahon (2012) and Moore (2016), demonstrating a range of adoption between 70% and 80%, respectively. The length of quarantining treated animals was overall sufficiently implemented in line with the best practice recommendations (i.e. between 24-48 hours) to ensure a low risk of introducing eggs from potentially drug-resistant parasites. However almost a quarter (23%) of respondents withholding treated animals were applying this measure for less than 24 hours, which is more likely to result in a limited exposure of any existing parasites to treatment. This therefore may increase the risk of introducing resistance into the main flock, as well as potentially missing clinical signs associated with other infectious diseases.

The frequency of treatments given to a flock is an important aspect to consider as it determines the exposure level of the parasitic population to anthelmintic, which in turn will increase the scale for resistance selection (Barton, 1983). Interestingly there was little difference in the mean frequency of treatments and no difference in the median frequency of treatments administered between ewes and lambs. The only observable differences were between single treatments and treatments greater than five as would be expected. This result would suggest an adequate level of usage perhaps when compared with other UK wide surveys e.g. (Coles, 1997; Morgan et al., 2012). However the high range of ewe and lamb treatment frequencies is a cause for concern on some farms, as well as the frequency of farms treating ewes several times per season. Under appropriate nutritional and environmental conditions, adult ewes should be able to maintain a high level of acquired immunity when exposed to regular nematode challenge (Brunsdon, 1971), with a notable exception at lambing time when immunity in lactating ewes is compromised due to the effects of the peri-parturient relaxation in immunity (PPRI; Shubber, 1981). It is therefore important for farmers to evaluate the necessity for anthelmintic treatment beyond this period, using methods such as faecal egg counting, in order to assess the level of parasite burden and faecal egg output. Where nutritional resources are limited, the trade-offs also need to be considered between the maintenance of production and the sustaining of an acquired immunity (Greer, 2008).

The PPRI period of susceptibility to parasite infection is likely to contribute significantly to pasture contamination and for lamb infection in the forthcoming grazing season (Sargison, 2009).The opinion that using long-acting anthelmintic products during the lambing period is beneficial for productivity was positively expressed by the majority of respondents irrespective of their farming background. The results also suggest that in comparison with livestock and arable farmers, sheep only farmers are more likely to agree with this statement. This may reflect the impact that PPRI may have particularly on sheep-only farms, and to the significant reduction in pasture contamination that can be achieved by maintaining therapeutic control during this risk period. However depending on the previous management of the lambing paddocks, the potential for AR selection can be high where there is likely to be low numbers of parasites present in 'refugia' (Sargison et al., 2012). Balances can be achieved in order to reduce AR selection of using long-acting treatments, such as turning out treated ewes onto pastures previously grazed in the autumn or winter, or by not treating well-conditioned, single-bearing ewes, which will generally have lower FEC's compared with multiple bearing ewes (Morris et al., 1998).

Of concern is the number of respondents that were unable to correctly name the long-acting or combination product used. This may suggest a requirement for both better clarity from manufacturers and suppliers in terms of advertising the anthelmintic properties on products, as well as for farmers to be more mindful of which products are persistent and against which parasite species.

The use of alternative roundworm control strategies is encouraged to provide farmers with various non-chemotherapeutic options for reducing the risk of high pasture infectivity, in order to avoid over-reliance on anthelmintic treatments. Such strategies include strategic grazing management by either alternating grazing or co-grazing between sheep and other non-susceptible livestock species (e.g. cattle, horses) that do not share parasite specificity (Waller, 2006b). For the majority of mixed livestock respondents either alternating grazing between species or co-grazing species together was employed. As this question was designed to determine what grazing management strategies respondents were employing and not their motives behind this decision, it would be unfeasible to connect these decisions largely to roundworm control. Indeed a number of factors may influence farmers' grazing management strategies such as the intention to optimise pasture growth by alternating grazing, or practical issues such as a limited availability of grazing. As most of the respondents farms were situated on upland or hill farms, this may limit options in terms of implementation of grazing management strategies. In connection with this, physical characteristics were also shown to be associated with respondents' views on their confidence to improve grazing management. Respondents in the northern regions and those on hill farms were more likely to disagree that they could improve their grazing management, which is likely to reflect the difficulties of managing a hill flock on terrains typically associated with rough, extensive grazing areas. The benefits of using co-grazing strategies has been shown to positively influence lamb growth rates (Marley et al., 2006; Fraser et al., 2013). Additionally, alternative grazing was shown to reduce lamb faecal egg output particularly when sequentially grazed from cattle to sheep (Marley, 2006). However the use of such strategies should be considered as an alternative rather than an adjunct to anthelmintic treatment, as this will likely be positive for AR development (Waller, 2006b).

Other strategies for utilizing 'safe' grazing such as the practice of dose and move was used to varying extents by the majority of respondents (60%). Similar observations to this practice have been documented in Northern Ireland (McMahon et al., 2013b). Overall the majority of respondents expressed an agreement with the statement concerning the simplicity of using anthelmintics in contrast to implementing a grazing management strategy. This demonstrates a need to simplify the way in which grazing management is promoted in order to improve it acceptance as a form of disease prevention, in favour of a curative approach which would be expected to result in clinical disease and production losses (Barger, 1999). The results from the regression analysis suggest that education and parasite control knowledge are both associated with differing attitudes towards this statement. This might be expected as those who are more knowledgeable are more likely to be engaged on this topic, and as a result may view such management approaches more favourably than others.

Practices which were shown to have the lowest general uptake by respondents included the use of parasite diagnostic testing, rotation of anthelmintic classes, selective breeding for resistance and planning of a roundworm control strategy with a veterinarian.

The low use of parasite diagnostic testing to determine treatment efficacy may be in large part due to the relatively small proportion of respondents that suspect they have resistance on their farms. In comparison to the literature, this finding is similar to some reports (Bartley et al., 2003; Morgan et al., 2012) and contrasts with others (Sargison and Scott, 2003; Lawrence et al., 2007; Moore et al., 2016). However this may also be indicative of the relative size and regional variability of the study populations surveyed. The motives behind farmers' not testing for AR could well be multifactorial and different in each individual. For example it may be due to a perceived impracticality of sampling animals due to their farming system, or a reluctance to confirm a problem which may require the recipient to change their management approach. Alternatively, there may also be a dissonance between how farmers and researchers view or interpret AR. For instance where researchers view AR as a progressive reduction in treatment efficacy over time, farmers may perceive resistance as more of an absolute occurrence between treatments working effectively to then showing no visible signs of efficacy.

The issue may also be linked to AR risk perception as demonstrated by the significant differences between respondents based on characteristics such as region, educational background, and enterprise type and farm topography. Furthermore, region and education demonstrated significant associations between respondents confidence in their abilities to detect problems associated with wormer failure. The identification of associations between these factors will help to distinguish the types of farming systems which are more likely to have different AR risk perceptions than others. The results suggest that hill farmers and those respondents from the northern regions of Scotland are in general more likely to have a low AR risk perception, which may reflect differences in farming mentalities due to different management approaches. Typically more extensive farming is associated with hill farms and the northern regions compared with more intensive sheep farming associated with lowlands and southern regions of Scotland. The association between education, risk perception and self-efficacy may be related to exposure to new information and level of farm experience. Respondents that did not pursue further education may have less awareness about AR compared with respondents that have acquired further education. However those respondents without further education may have more confidence in detecting problems associated with wormer failure due to gaining more farm experience than those who attended a non-agricultural college.

Additionally, there was a low uptake of recommendations relating to anthelmintic selection such as the rotation of anthelmintic classes throughout the season. The recommendation by SCOPS is to use the most appropriate anthelmintic for the particular treatment circumstance, in order to most effectively target the specific parasites present, so as to avoid unnecessary exposure of parasite species that are in low abundance. In accordance with this, farmers are advised to change or alternate the anthelmintics used during the year taking into account the parasites population present within the animal and on pasture in regards to the development of AR. The high proportion of respondents using a single active compound exclusively in their roundworm control programmes is concerning, in particular considering a third of respondents are using the 1-BZ group, which is likely to have a high existing prevalence of resistance. The second most frequently used product used exclusively is the 3-ML group of anthelmintics, which has also been suggested to increase in the future likely due to its high spectrum of endoparasite activity, also products containing Moxidectin have the added benefits of persistent drug release as well as high efficacy activity against the ectoparasite, *Psorptes ovis* (Parker et al., 1999).

The low usage of the 2-LV, 4-AD and 5-SI groups of anthelmintics is also consistent with other UK surveys (Morgan, 2012) and therefore offers many farms a contingency for cases where multiple resistances to 1-BZ and 3-ML is present. It is however recommended that these products be utilized more in order to preserve the efficacy of the remaining anthelmintic groups. The possible reasons for this low use of 2-LV is likely to be due to the narrower safety margins which will require farmers to use more accurate dose determination in order to prevent signs of chemical toxicity (Vercruysse, 2014). As for the 4^{th} and 5^{th} groups of anthelmintics this is most likely attributable to the restriction of these new products to veterinary prescription only (POM-V). Interestingly opinions were divided regarding whether restricting anthelmintics to POM-V promotes responsible usage. Furthermore with only a tenth of respondents using their veterinarians for planning their roundworm control, this presents a paradox with veterinarians as highly influential resources of parasite control information. This lack of collaboration between farmers and veterinarians has been suggested by stakeholders in regards to general flock health planning (Kaler and Green, 2013), biosecurity disease planning (Heffernan et al., 2008), as well as in regards to parasite control planning (Morgan et al., 2012). Animal health suppliers were the second most frequently stated influential source of roundworm control information. Considering this distribution channel has been reported to supply over 85% of anthelmintic medicines (Scott, 2010), it is vitally important that prescribers are actively involved in providing advice to their customers at the point of purchase. This is especially pertinent due to the high proportion of respondents stating a preference for direct communication. The relatively low proportion of respondents stating a preference for electronic formats for accessing information may reflect the skewed age distribution of respondents, as a number of studies have indicated a preference for electronic formats by younger farmers (Abbott, 1989; Riesenberg and Gor, 1989). This would suggest that a range of information formats are warranted with prospects of electronic formats becoming increasingly important in the future.

The use of selective breeding for establishing parasite resistance in sheep can also be used as a long-term solution for improving the ability of a flock to combat roundworm infection, by selecting animals demonstrating a disposition for resisting parasitic infection or clinical disease. From the evaluation of attitudes expressed as to whether selective breeding is worthwhile in the long-term, it appears that overall most demographic groups shown are in favour of selective breeding, although a considerable proportion of respondents indicated uncertainty regarding this particular statement. This may come from scepticism regarding breeding programmes by some farmers, due to a lack of trust regarding the long-term benefits of employing such schemes, as well as the prospect of a reduction in valued production traits, in favour of an improved immune response to a particular disease which may also inadvertently increase susceptibility to other disease agents (Stear et al., 2001). The benefits of selective breeding would also not likely be afforded to lambs before they reach 4-5 months of age, therefore this type of approach is more intended for those systems breeding their own ewe replacements (Abbott et al., 2004). Interestingly hill farmers were more likely to disagree with the long term benefits of selective breeding programmes. This view may be counterintuitive in some respects as traditionally many hill flocks are involved in the breeding and trade of hill breed ewes to upland or lowland farms (Rodriguez et al., 2009). However as the hill farmers' responses indicated an overall low risk perception towards AR, this may help to explain why such innovations may be viewed as less beneficial to their circumstances; particularly in light of uncertainties regarding the overall sustainability of hill sheep farming (Thompson, 2009).

Surveys are inherently prone to limitations due to various factors including its design and administration that can ultimately affect response rates and validity. From this survey, several strengths and limitations have been identified which concern aspects such as response bias, survey fatigue and misclassification bias. Response bias can occur both via the selection of people who participated in the survey as well as whether respondents completed all survey questions. The use of an opt-out participant selection resulted in a relatively low dropout rate (<30%) prior to conducting the survey. Although this enabled a larger selection of potential participants, it also increases the risk of non-responses when administering the survey i.e. farmers not consenting to be interviewed at the point of telephone contact by researchers. The effect of non-response bias can skew findings towards more engaged participants, with those who declined to take part or were unavailable to be contact being excluded, which can affect the representativeness of opinions expressed. Unfortunately, the numbers of respondents who declined to participate in the survey when telephoned were not recorded as a matter of policy by the company administering the questionnaire, although efforts were made by interviewers to contact every contact available until the target numbers for each region was achieved. In terms of completion rates for surveys the use of the telephone format (versus postal) for conducting the surveys as well as the use of trained interviewers ensured optimal participant engagement to help ensure that all questions were completed. It is however possible that the large volume of questions asked in section four of the survey could have led to survey fatigue whereby too many questions can reduce the accuracy of responses given.

The last limitation to address is the potential for misinterpretation of questions between the survey designers and the interviewees. One particular example of note within this survey could include the possibility of different interpretations of farm type in relation to topography i.e. 'lowland, upland and hill' farms. The use of these categories could be open to interpretation based on different characteristics of a farming system, e.g. breeds of sheep, geographic location, farmland altitude, slope etc. this could lead to a misclassification bias based on individual perceptions. The term topography was intended to represent the different types of farming systems based on the physical landscape of the farm i.e. aspects such as altitude and slope. The choice to use the categories was based on the 3-tier stratification system, which is how the farming industry tends to refer to the different farming systems. Ideally, more questions would have been asked to improve the categorization of respondents' including the farm characteristic examples mentioned previously.

4.5 CONCLUSIONS

The results presented demonstrate varied adoption of best practice approaches to sustainable parasite control by Scottish sheep farmers. The practices that were shown to have the highest general levels of adoption included the use of quarantine practices, which are likely to be widely accepted due to parallels with other infectious disease control strategies. Additionally reducing treatment frequency is a recommendation which is likely to be logical and has clear economic benefits to farmers in terms of reduced labour and treatment costs. The ethos of reducing chemical usage in agriculture is also well publicized and has implications for other livestock disease agents, most prominently with the advent of antimicrobial resistance (O'Neill, 2015). The high use of alternative grazing management approaches by respondents allows farmers to manage parasite risk in order to mitigate the occurrence of clinical disease as well as reduce dependence on anthelmintics.

The results also highlight areas requiring more attention such as promoting the rotation of anthelmintics throughout the season, the use of selective breeding and particularly the use of diagnostic testing for roundworm control and AR detection. With such a low proportion of respondents suspecting resistance on their farms, it may be most appropriate to consider all the possible reasons which may inhibit farmers from testing their treatment efficacies, with the intention of changing the general mind-set towards a more proactive stance on assessing treatment efficacy. As by establishing the extent of resistance development this will ultimately demonstrate to farmers the impact AR has on the efficacy of treatments given, which may encourage farmers to test periodically in order track the progression of AR and find solutions to mitigate its development.

The identification of significant associations between farming demographics and roundworm control attitudes at the univariable level helps to establish potential factors which may influence the general uptake of sustainable roundworm control approaches. The requirement to tailor information to suit the range of management styles and to the address the associated AR risk perceptions as observed, is one such areas which will aid in promoting responsible anthelmintic usage across the whole sheep farming industry.

CHAPTER 5: A QUANTITATIVE ANALYSIS OF ATTITUDES AND BEHAVIOURS CONCERNING SUSTAINABLE PARASITE CONTROL PRACTICES FROM SCOTTISH SHEEP FARMERS

Corin Jack [a,*], Emily Hotchkiss [a], Neil D. Sargison [b], Luiza Toma [c], Catherine Milne [c], David. J. Bartley [a]

[a] Disease control, Moredun Research Institute, Pentlands Science Park, Bush Loan, Penicuik, EH26 0PZ, UK.

[b] Royal (Dick) School of Veterinary Studies, University of Edinburgh, Easter Bush Campus, Midlothian, EH25 9RG, UK

[c] Scotland's Rural College (SRUC), Peter Wilson Building, Kings Buildings, West Mains Road, Edinburgh EH9 3JG, UK

*Corresponding author. Tel.: +44 0131 4455111; fax: +44 0131 4455222

E-mail address: corin.jack@moredun.ac.uk

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5.1 AIMS OF CHAPTER

To use the quantitative multivariate analysis technique known as Structural Equation Modelling, to test the relationships between socio-psychological factors and the overall adoption level of sustainable roundworm control practices. The results of the analysis will determine the effect of observable and unobserved (latent) factors on the adoption of SCOPS practices. This will help to identify factors with greater and lesser influence on farmers roundworm control behaviours, which may be of use to target future extension efforts.

5.2 ABSTRACT

Nematode control in sheep, by strategic use of anthelmintics, is threatened by the emergence of roundworms populations that are resistant to one or more of the currently available drugs. In response to growing concerns of Anthelmintic Resistance (AR) development in UK sheep flocks, the Sustainable Control of Parasites in Sheep (SCOPS) initiative was set up in 2003 in order to promote practical guidelines for producers and advisors. To facilitate the uptake of ‘best practice’ approaches to nematode management, a comprehensive understanding of the various factors influencing sheep farmers’ adoption of the SCOPS principles is required.

A telephone survey of 400 Scottish sheep farmers was conducted to elicit attitudes regarding roundworm control, AR and ‘best practice’ recommendations. A

quantitative statistical analysis approach using Structural Equation Modelling was chosen to test the relationships between both observed and latent variables relating to general roundworm control beliefs. A model framework was developed to test the influence of socio-psychological factors on the uptake of sustainable (SCOPS) and known unsustainable (AR selective) roundworm control practices. The analysis identified eleven factors with significant influences on the adoption of SCOPS recommended practices and AR selective practices. Two models established a good fit with the observed data with each model explaining 54% and 47% of the variance in SCOPS and AR selective behaviours, respectively. The key influences toward the adoption of best practice parasite management, as well as demonstrating negative influences on employing AR selective practices were farmer's base line understanding about roundworm control and confirmation about lack of anthelmintic efficacy in a flock. The findings suggest that improving farmers' acceptance and uptake of diagnostic testing and improving underlying knowledge and awareness about nematode control may influence adoption of best practice behaviour.

5.3 INTRODUCTION

The sustainable control of gastro-intestinal nematode parasites remains one of the main perennial endemic disease pressures that livestock farmers face globally (Jackson and Coop, 2000; Nieuwhof and Bishop, 2005). Gastro-intestinal nematodes impact on the health, welfare and production efficiency of livestock (Coop and Kyriazakis, 2001). For over 50 years parasite control strategies have heavily relied on suppressing nematode populations with frequent use of highly efficacious, broad spectrum anthelmintics (Bartley, 2008). The effectiveness of these treatments is threatened by the emergence of nematode populations that are resistant to one or more of the anthelmintic drugs available. In the UK alone, studies have reported resistance to all three of the commercially available broad-spectrum anthelmintic drug classes i.e. benzimadazoles (1-BZ), levamisole (2-LV) and macrocyclic lactones (3-ML). Widespread 1-BZ resistance has been reported throughout the UK (Cawthorne and Whitehead, 1983; Sutherland et al., 1988; Grimshaw et al., 1994; Bartley et al., 2003; Mitchell et al., 2010; Thomas, 2015), with a much lower number of 2-LV resistance reports observed (Hong et al., 1994; Coles and Simkins, 1996; Mitchell et al., 2010) and increasing reports of 3-ML resistance associated with multiple drug resistance to two or more anthelmintic drug classes (Bartley et al., 2004; Sargison et al., 2005; Sargison et al., 2007; Thomas, 2015). It is therefore increasingly apparent that taking steps toward maintaining sustainable productivity in the growing face of anthelmintic resistance (AR) is required by farmers.

In response to growing concerns of AR development in the UK sheep industry, the Sustainable Control of Parasites in Sheep (SCOPS) initiative was set up in 2003. SCOPS is an industry led group that represents the interests of the UK sheep industry with a remit to develop and promote practical recommendations for producers and advisors regarding 'best practice' approaches to parasite control (Abbott et al., 2012). Currently these recommendations are summarised into eight guidelines each of which outline a variety of measures to preserve the effectiveness of current and future anthelmintics. These eight guidelines broadly cover the following aspects of best practice roundworm control including: 1) Working out a control strategy with a veterinary advisor 2) implementing an effective quarantine strategy 3) testing for anthelmintic resistance, 4) administering anthelmintics effectively 5) using anthelmintics only when necessary 6) selecting the appropriate anthelmintics 7) preserving a susceptible worm population and 8) introducing alternative, non-chemotherapeutic roundworm control strategies (Abbott et al., 2012). There are numerous channels for the dissemination of the SCOPS recommendations such as through animal health advisors (e.g. veterinarians, suitably qualified persons and researchers), online/printed publications as well as face-to-face promotion at agricultural events. In other sheep producing countries such as Australia, the current equivalent repository for information and recommended practices regarding roundworm control *WormBoss* (Anonymous, 2016b) has achieved a high level of awareness amongst farmers. This is in part due to the effective use of the internet platform including the use of an electronic support system. However steps to measure and enhance the transition from awareness to adoption are an uncertainty recognised by both extension schemes (Woodgate and Love, 2012; Anonymous., 2013).

Various questionnaire surveys have been undertaken and published on the parasite management practices of sheep farmers from around the world, as well as within the UK (Coles, 1997; Bartley et al., 2004; Suter et al., 2005; Hughes et al., 2007; Lawrence et al., 2007; Sargison et al., 2007; Morgan et al., 2012; McMahon et al., 2013). Such studies have highlighted the variable adoption of sustainable roundworm control practices, and emphasised the need to improve promotion and perception of these practices if sustainable parasite control is to be generally accepted. In recent years the rapidly growing application of socio-psychological research methods in behavioural science has highlighted their influence on animal health decision making. These studies have investigated behaviours relating to a wide range of disease management practices related to many livestock species as described by Wauters and Rojo-Gimeno (2014). However, a limited amount of work has investigated how socio-psychological factors may influence farmer's parasite control behaviours e.g. Relf et al., 2012; Vande Velde et al., 2015. Moreover few studies have employed the use of quantitative modelling techniques to assess the extent at which such factors influence farmers' parasite control behaviours. The measure of human behaviour in these studies has either been indicated via behavioural intentions (e.g. Toma et al., 2015; Vande Velde et al., 2015) or by respondents' self-reported behaviours (Toma et al., 2013). The use of behavioural intention i.e. a readiness to perform a given behaviour has been proposed to be a direct proxy for actual behaviour based on the widely applied theory of planned behaviour model (Ajzen, 1991). Self-reported behaviour on the other hand requires respondents to personally state their actions regarding a specific circumstance. More recent applications of decision-making models have moved from primarily economic driven factors to also incorporate non-economic influences such as farm characteristics, farmer demographics and psychological factors. This helps to represent the range of both financial and non-financial factors involved and their potential influences in the decision making process (Edwards-Jones, 2006).

This study aims to use a quantitative statistical modelling approach to investigate the influence of socio-psychological factors on the overall adoption of SCOPS practices and practices recognised to be selective for the development of AR (designated AR selective practices hereafter). By employing such methods this will help to evaluate potential mitigation strategies to assist the adoption of best practice parasite management approaches.

5.4 MATERIALS AND METHODS

5.4.1 Model framework

From the attitudinal questionnaire detailed in Chapter 4, a model framework (illustrated in Figure 42) was developed and used to examine the influence of general roundworm control and AR attitudes (from section 2), roundworm control knowledge (section 3) and farming demographic influences (section 1) on the overall uptake of SCOPS and known AR selective practices. Quantitative statistical modelling analysis (Structural Equation Modelling) were used to test the model framework as detailed in section 1.36.3.2.

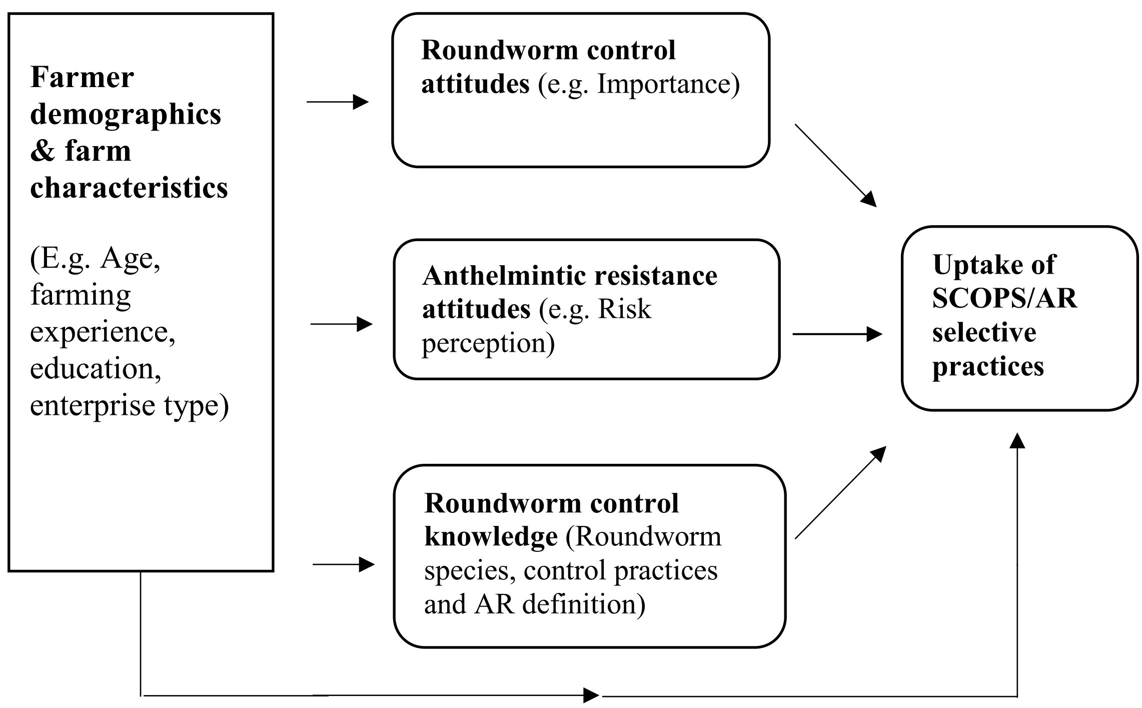

Figure 42 - Theoretical framework for general uptake of SCOPS recommended and AR selective roundworm

5.4.2 Data formatting/transformation

The raw data was firstly coded into a database using Statistical Package for the Social Sciences (SPSS, IBM SPSS Statistics version 22.0). All variables included in the analysis were recorded as per the original coding frame detailed in Table 40, with the exception of 'Education', 'Ewe numbers' and 'Roundworm control knowledge'. Categories other than 'agricultural college' within 'Education' were considered to have little influence on agricultural practice and were therefore combined. The variable 'Ewe numbers' was categorised based on an evaluation of the data structure. The three open-ended knowledge question responses were individually assessed and classified into a dichotomous variable (i.e. correct or incorrect) based on the authors' judgement. Two of the three questions required the respondent to list specific examples of parasite species and roundworm control practices. The third question required a description of their understanding of the term wormer resistance, a correct response required a description of the basic principle i.e. a reduction in the effectiveness of a drug treatment or an inherent ability of parasites to survive drug treatment. A score was devised based on the number of correct responses to the three questions.

The endogenous variables i.e. a multi-item equivalent of a dependent variable ('SCOPS practice uptake' & 'AR selective practice uptake') were formulated into ordinal scores by summating the total number of practices that were identified as either 'best practice' or selective for AR development based on the SCOPS manual (Abbot et al., 2012). The designation of AR selective practices was based on the selection of behaviours which were converse to best practice approaches and which were also impartial towards particular farming systems. The total number of practices identified as best practice was ten, and the total number of AR selective practices identified was seven. Table 39 presents the descriptive statistics of the practices used to formulate both dependent variables (i.e. SCOPS and AR selective practices) and Figure 43 presents the frequency distributions of the dependent variables.

Table 39 - Respondents roundworm control behaviours associated with 'SCOPS uptake' and 'AR selective' formulated scores (n = 400).

Roundworm control practices	**SCOPS recommended**			**AR selective**		
	Levels	***n*** **=**	**%**	**Levels**	***n*** **=**	**%**
In the last 12 months how often have you sought advice specifically regarding roundworm control?	At least once	255	64	-	-	-
In the last 12 months how many times have you treated your ewes and lambs for roundworms?	Ewes (< average [a])	90	23	Ewes (> average [a])	172	43
	Lambs (< average [b])	66	17	Lambs (> average [b])	195	49
Do you monitor worm egg counts?	Yes	136	34	No	264	66
Do you drench incoming sheep brought onto the farm? ‡	Yes	303	94	No	20	6
Do you withhold sheep from pasture? [c]	Yes	221	68	No	102	32
Have you ever tested for drug resistance?	Yes	51	13	No	349	87
Do you move your animals immediately to clean pasture after treatment?	No	158	40	Yes	244	61

Table 39 - Respondents roundworm control behaviours associated with 'SCOPS uptake' and 'AR selective' formulated scores (n = 400).

Roundworm control practices	**SCOPS recommended**			**AR selective**		
	Levels	***n*** **=**	**%**	**Levels**	***n*** **=**	**%**

Do you use selective breeding for roundworm control in your flock?	Yes	49	12	-	-	-
Do you graze sheep and cattle together, graze separately or rotate grazing between the two?	Yes – Rotational	84	21	-	-	-
	Yes – Co-graze	134	36	-	-	-

[a] Ewe treatment average (2) [b] lamb treatment average (2) [c] results exclude closed flock farms (n = 77)

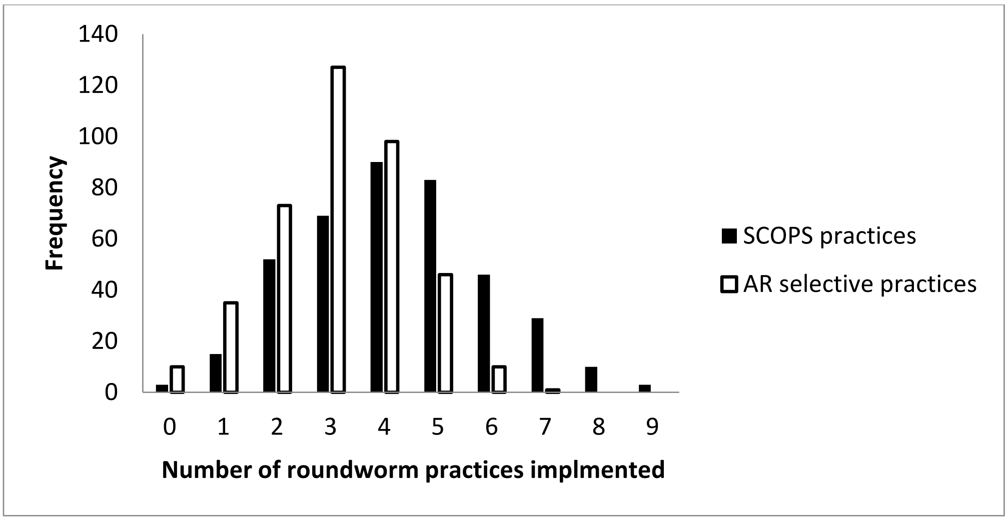

Figure 43 - Total number of SCOPS (filled bars) and AR selective (open bars) practices employed by respondents (n = 400).

5.4.3 Statistical analysis

5.4.3.1 Factor analysis

Initial exploratory factor analysis was performed on ordinal (Likert Scale) items related to the general uptake of SCOPS and AR selective practices, in order to identify and evaluate inter-relationships between variables. Based on their covariation, the total number of observed variables was condensed into a smaller set of unobserved (latent) factors. In the development of the proposed models, items within section 2, i.e. general attitudes to roundworm control section were assessed. The procedures for the assessment of factor loadings (correlation coefficients) and reliability analysis (Cronbach alpha) were conducted as described by Hair et al. (2006). Accordingly, based on the study sample size (n = 400), in order to achieve statistical significance for each value with a statistical power of 80 per cent, a minimum threshold of ±0.30 factor loading was used. Factor loadings below ±0.30, or loadings that demonstrated significant loadings across more than one factor i.e. cross loading, were not included within the resultant factor. The internal reliability measure (Cronbach alpha) was set at an approximate minimum threshold of 0.60 with a value >0.70 indicating a good reliability measure. Factors which demonstrated acceptable factor loadings and Cronbach alpha measures were retained for further analysis. The method of extraction applied was Principal Component Analysis. An orthogonal factor rotation method 'Varimax' was used to interpret the extracted factors.

5.4.3.2 Structural Equation Modelling

In order to examine the inter-relationships between the observed and unobserved (latent) variables in the proposed theoretical model (as represented in Figure 42), the analysis was performed using the multivariate analysis technique known as Structural Equation Modelling (SEM). This technique comprises two parts, the first is the measurement model which represents the relationships between the specified indicators and their latent constructs. The second part is the structural model which then examines the relationships between the model constructs. The relationship between variables as measured by the regression coefficient represents the change in the dependent variable for one unit change in the independent variable**.** The regression coefficients are standardised (β values) in order to allow direct comparisons of the relative effects of each variable on the dependent variable. The individual effects are estimated independent of the effects of the other variables to allow assessment of individual relationships within the model (i.e. ceteris paribus). All factors were included in both models with the exception of 'Vet service pros' and 'Vet service cons' which were selected for 'SCOPS practice uptake' and 'AR selective practice uptake' respectively The statistical package Lisrel 8.80 (Jöreskog and Sörbom, 2007) was chosen for the purposes of the SEM analysis. Due to the non-normality of the Independent variable data, a Diagonally Weighted Least Squares (DWLS) method was used to estimate the model parameters. The resulting model output was evaluated for goodness of fit by using the following model fit indices as detailed by Hair et al. (2006); Root Mean Square Error of Approximation (RMSEA), Standardised Root Mean Residual (SRMR), Comparative Fit Index (CFI), Incremental Fit Index (IFI), Goodness of fit (GFI), Adjusted Goodness of Fit Index (AGFI) and Normed Fit Index (NFI).

5.5 RESULTS

5.5.1 Participant descriptive statistics

The total number of opt-out letters received from the original 1,930 farmers contacted was 427 (22%), leaving 1,503 farmers eligible to be contacted. The target of 400 completed interviews was achieved with the following numbers of interviews resulting from each region: 65 in the South East, 76 in the South West 74 in Central region, 92 in the North West, 46 in the North East, and 47 in the Islands.

In terms of respondents demographic responses, the majority of farmers (69%) in the survey sample were aged in the 51-65 or >65 year brackets with only 3% of the respondents representing the youngest age bracket (18-35). The number of years earning a living as a farmer was normally distributed with less of a skew towards more experienced farmers. The level of education showed that most respondents (55%) had had some degree of further education, with approximately 35% studying at an agricultural college.

In regards to the farming enterprises, almost two thirds of respondents' farms were situated on either upland or hill grazing land, with over half of the sample population comprising of mixed livestock farmers and a quarter sheep-only farmers. The proportional flock sizes as indicated by numbers of breeding ewes are more orientated towards small to medium sized flocks (i.e. <500 ewes), with a quarter of farms with larger flocks (>500 ewes).

Table 40 - Description of latent constructs with corresponding indicators and Cronbach alpha reliability measures (α)

Latent variable	Statement	α	Value and labels	Variable type
Experience	What is your age? How many years have you been earning a living as a farmer?	0.764	1 = 18-35; 2 = 36-50; 3 = 51-65; 4 = over 65 1 = 10 years or less; 2 = 11-20; 3 = 21-30; 4 = 31-40; 5 = 41-50; 6 = over 51	Ordinal Ordinal
Education	Did you attend a place of further education?	NA	0 = no or yes, education other than agriculture college 1 = yes, Agricultural college	Binary
Ewe numbers	Number of breeding ewes?	NA	1 = 0-100; 2 = 101-200; 3 = 201-500; 4 = 501-1000; 5 = 1001 or more	Ordinal
Enterprise type	Is your farm: sheep only, mixed livestock or livestock and arable?	NA	0 = sheep only; 1 = mixed livestock; 2 = livestock and arable	Categorical
Topography	Is your farm designated as lowland, upland or hill?	NA	0 = lowland; 1 = upland; 2 = hill	Categorical
Worm control knowledge	Knowledge score	NA	0 = none correct; 1 = one correct; 2 = two correct; 3 = three correct	Ordinal
Occurrence of worm problems	How would you classify the occurrence of roundworm problems in your flock?	NA	0 = low; 1 = moderate; 2 = high	Ordinal
AR confirmation	Do you have confirmed drug resistance?	NA	1= no 2= yes	Binary

Table 40 - Description of latent constructs with corresponding indicators and Cronbach alpha reliability measures (α)

Latent variable	Statement	α	Value and labels	Variable type
Worm control importance	**1. -** Roundworm control is important on my farm	0.877	5-point Likert scale [a]	Ordinal
	2. - My roundworm control strategy improves the productiveness of my animals		5-point Likert scale [a]	Ordinal
	3. - Roundworm control is important for the profitability of my farm		5-point Likert scale [a]	Ordinal
	4. - Roundworm control is important for the health & welfare of my animals		5-point Likert scale [a]	Ordinal
AR risk	**1.** - Wormer resistance is a problem in my region	0.593	5-point Likert scale [a]	Ordinal
	2. - Wormer resistance is a threat to my farming business		5-point Likert scale [a]	Ordinal
Vet service pros	**1. -** Working with my vet could improve my roundworm control strategy	0.877	5-point Likert scale [a]	Ordinal
	2. - Working out a roundworm control strategy with my vet is cost effective		5-point Likert scale [a]	Ordinal
	3. - Working out a roundworm control strategy with my vet ensures I get reliable advice		5-point Likert scale [a]	Ordinal
Vet service cons	**1. -** Roundworm control advice provided by vets is too complex	0.81	5-point Likert scale [a]	Ordinal
	2. - Roundworm control advice provided by vets is difficult to implement		5-point Likert scale [a]	Ordinal

Table 40 - Description of latent constructs with corresponding indicators and Cronbach alpha reliability measures (α)

Latent variable	Statement	α	Value and labels	Variable type
SCOPS practice uptake	Number of SCOPS practices implemented	NA	0 = none; 1 = one; 2 = two;, 3 = three; 4 = four; 5 = five; 6 = six; 7 = seven; 8 = eight; 9 = nine; 10 = ten	Ordinal
AR selective practice uptake	Number of AR selective practice implemented	NA	0 = none; 1 = one; 2 = two;, 3 = three; 4 = four; 5 = five; 6 = six; 7 = seven;	Ordinal

[a] 5-point Likert scale: 1 = Strongly disagree; 2 = Disagree; 3 = Unsure; 4 = Agree; 5 = Strongly agree

5.5.2 Results of factor analysis

Both of the models proposed consist of seven single-indicator latent variables and four multiple-indicator latent variables as detailed in Table 40. The exploratory factor analysis established acceptable factor loadings i.e. > 0.70 for all multiple-indicator latent variables (presented in Table 41). Additionally, the Cronbach alpha reliability analysis shown in Table 40, demonstrated suitable measures (α = >0.60) between all sets of indicators with the exception of 'AR risk'.

Table 41 - Factor loadings between multiple indicator (latent) variable items (SCOPS model).

Item	Factor loadings
What is your age?	.926
How many years have you been earning a living as a farmer?	.926
Roundworm control is important on my farm	.829
My roundworm control strategy improves the productiveness of my animals	.887
Roundworm control is important for the profitability of my farm	.877
Roundworm control is important for the health & welfare of my animals	.843
Wormer resistance is a problem in my region	.844
Wormer resistance is a threat to my farming business	.844
Working with my vet could improve my roundworm control strategy	.885
Working out a worm control strategy with my vet is cost effective	.913
Working out a worm control strategy with my vet ensures I get reliable advice	.889
Roundworm control advice provided by vets is too complex	.915
Roundworm control advice provided by vets is difficult to implement	.915

5.5.3 Results of structural equation models

Both models reflected a goodness of fit with the observed data as indicated by the following model fit indices as according to Hair et al (2006). Significance was established for all relationships at a 0.05 level, with significant standardised coefficients (total effects) of both models detailed in Tables 42 and 43. An illustrated version of the direct influences on SCOPS practice uptake model is presented in Figure 44; however, this was not feasible in the 'AR selective practice' model due to the large number of estimates identified. The SCOPS model fit values were below the maximum threshold of 0.10 for RMSEA at 0.025, and at the 0.08 threshold for SRMR (0.08), for the subsequent fit indices values above 0.90 give an indication of acceptable fit; CFI (0.99), IFI (0.99), GFI (0.98), AGFI (0.97) and NFI (0.96). The SCOPS model explained 54% of the variance in the adoption score of sustainable parasite control practices. The factors which had the greatest direct positive effects on SCOPS uptake were 'AR confirmation' ($\beta = 0.55$) followed by 'Enterprise type' ($\beta = 0.30$), 'AR risk' ($\beta = 0.21$) and 'Vet service pro' ($\beta = 0.20$). The greatest indirect positive influence on SCOPS uptake was 'Worm control knowledge' ($\beta = 0.34$) mediated by 'AR confirmation' ($\beta = 0.61$). Exogenous factors which were shown to have a positive influence on mediating factors included 'Ewe numbers' with a strong effect on 'AR confirmation' ($\beta = 0.43$) and a moderate effect on 'Occurrence of worm problems' ($\beta = 0.20$). In addition to 'Education' with a positive effect on 'AR risk' ($\beta = 0.31$) and 'Worm control importance' with a positive influence on 'Vet service pro' ($\beta = 0.36$). Factors which demonstrated a negative influence on SCOPS uptake through mediating factors included 'Experience' on 'AR risk' ($\beta = -0.16$) and 'Worm control knowledge' (β = -0.31) as well as ‘Topography’ with moderate influences on ‘Worm control knowledge’ (β = -0.24).

The AR selective practice model fit indices were as follows; RMSEA (0.050), SRMR (0.083), CFI (0.93), IFI (0.94), GFI (0.97), AGFI (0.96) and NFI (0.90). The AR model explained 47% of the variance in the adoption of recognised AR selective roundworm control practices. Factors shown to have the greatest positive influence on the use of AR selective practices included ‘Vet service con’ with a direct effect on the behavioural outcome (β = 0.14), in addition to ‘Experience’ (β = 0.12) and ‘Topography’ (β = 0.08) which both had indirect influences on AR selective practices. The greatest direct negative influence on AR selective practices was associated with ‘AR confirmation’ (β = -0.67). Indirect negative influences on AR selective practices included ‘Worm control knowledge’ (β = -0.34), ‘Ewe numbers’ (β = -0.16), ‘AR risk’ (β = -0.15), ‘Education’ (β = -0.11), ‘Enterprise type’ (β = -0.06) and ‘Worm control importance’ (β= -0.03).

The factor ‘AR confirmation’ was shown to be directly influenced positively by ‘Worm control knowledge’ (β = 0.51), ‘Ewe numbers’ (β = 0.33) and ‘AR risk’ (β = 0.22), Indirect mediated influences included ‘Education’ (β = 0.16), ‘Enterprise type’ (β = 0.09) and ‘Worm control importance’ (β = 0.04). ‘AR confirmation’ was most negatively influenced by ‘Experience’ (β=-0.18) and ‘Topography’ (β = -0.13). The factor ‘AR risk’ attitudes were shown to be most positively influenced directly by ‘Occurrence of worm problems’ (β = 0.34), ‘Education’ (β = 0.26) and negative influenced by ‘Experience’ (β = -0.20) and ‘Topography’ (β = -0.15). The factor ‘Worm control knowledge’ was influenced directly by five factors including most prominently 'Experience', (β = -0.27) followed by 'Education' (β = 0.21), 'Topography' (β = -0.18), 'Enterprise type' (β = 0.17) and 'Ewe numbers' (β = 0.13). The factor 'Occurrence of worm problems' was influenced positively by 'Ewe numbers' (β = 0.24).

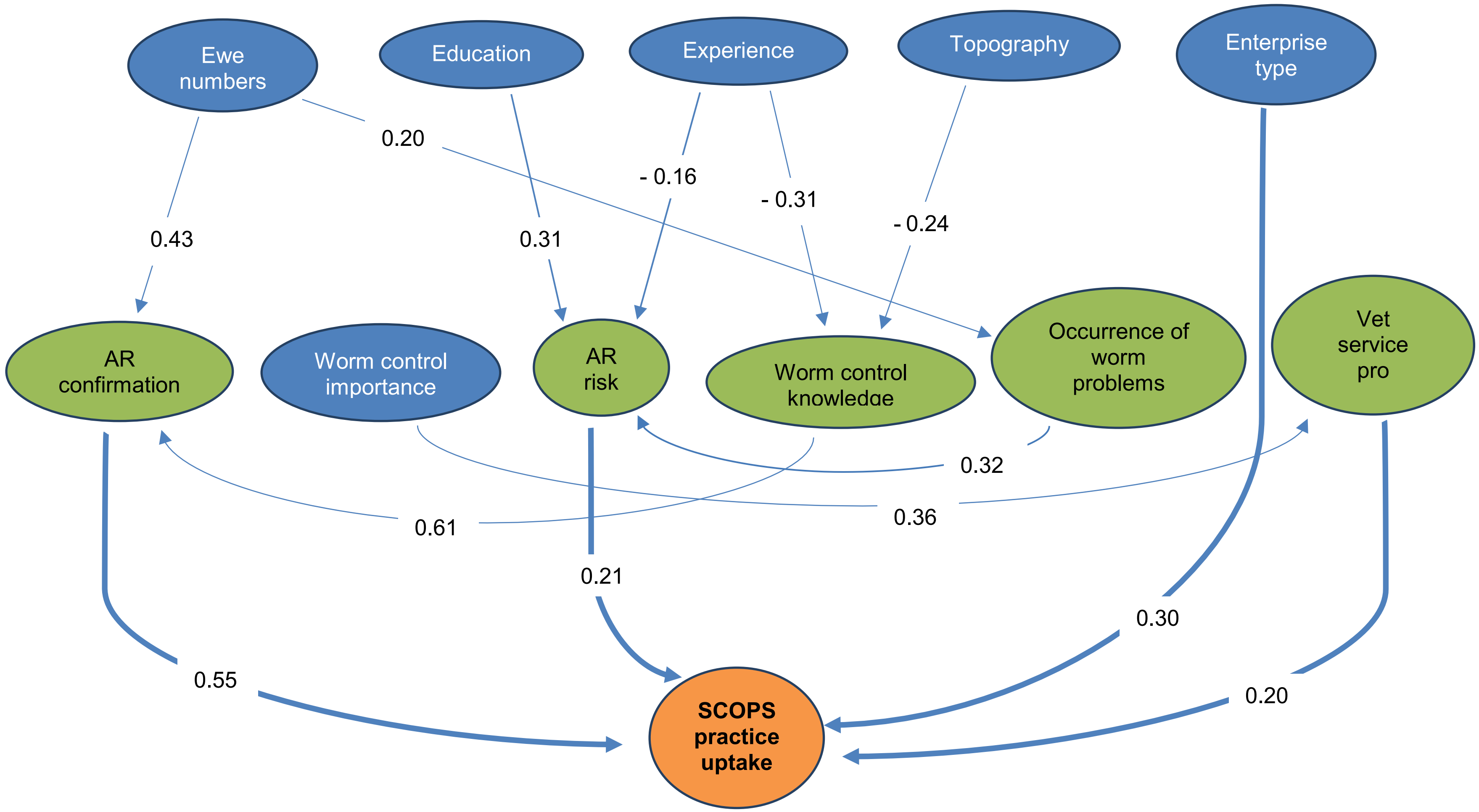

Figure 44 - SCOPS uptake structural model (standardised solution). Bold arrows represent the direct influences of latent variables on the behavioural latent 'SCOPS practice uptake', with non- bold arrows representing the direct effect influences on other latent variables. The corresponding numbers are the standardised coefficients of the variables in the structural model. Blue variables denote variables that are exogenous i.e. independent from other variables in the model, with green variables taking either exogenous or endogenous roles i.e. influenced by other variables. The orange variable represents the endogenous behavioural latent variable.

Table 42 - Standardised total effects on SCOPS model latent variables (Standard error values)

	Total (direct and indirect) effects on independent variables						
Determinants	'SCOPS practice uptake'	'AR Confirmation'	'Worm control Importance'	'AR risk'	'Worm control knowledge'	'Occurrence of worm problems'	'Vet service pro'
'Ewe numbers'	0.25 (0.04)	0.43 (0.08)	-	0.06 (0.03)	-	0.20 (0.03)	-
'Education'	0.06 (0.03)	-	-	0.31 (0.14)	-	-	-
'Experience'	-0.14 (0.05)	-0.19 (0.06)	-	-0.16 (0.11)	-0.31 (0.05)	-	-
'Topography'	-0.08 (0.03)	-0.14 (0.05)	-	-	-0.24 (0.05)	-	-
'Enterprise type'	0.30 (0.12)	-	-	-	-	-	-
'AR Confirmation'	0.55 (0.09)	NA	-	-	-	-	-
'Worm control Importance'	0.07 (0.03)	-	NA	-	-	-	0.36 (0.06)
'AR risk'	0.21 (0.06)	-	-	NA	-	-	-
'Worm control knowledge'	0.34 (0.11)	0.61 (0.14)	-	-	NA	-	-
'Occurrence of worm problems'	0.07 (0.05)	-	-	0.32 (0.18)	-	NA	-
'Vet service pro'	0.20 (0.07)	-	-	-	-	-	NA
R-square	0.54	0.56	-	0.27	0.16	0.04	0.13

Table 43 - Standardised total effects on AR model latent variables (Standard error values)

Determinants	Total (direct and indirect) effects on independent variables						
	'AR selective practice uptake'	'AR Confirmation'	'Worm control Importance'	'AR risk'	'Worm control knowledge'	'Occurrence of worm problems'	'Vet service con'
'Ewe numbers'	-0.16 (0.05)	0.33 (0.07)	-	0.08 (0.02)	0.13 (0.03)	0.24 (0.04)	-
'Education'	-0.11 (0.04)	0.16 (0.05)	-	0.26 (0.07)	0.21 (0.06)	-	-
'Experience'	0.12 (0.04)	-0.18 (0.05)	-	-0.20 (0.05)	-0.27 (0.04)	-	-
'Topography'	0.08 (0.04)	-0.13 (0.04)	-	-0.15 (0.05)	-0.18 (0.09)	-	-
'Enterprise type'	-0.06 (0.06)	0.09 (0.07)	-	-	0.17 (0.04)	-	-
'AR Confirmation'	-0.67 (0.10)	NA	-	-	-	-	-
'Worm control Importance'	-0.03 (0.02)	0.04 (0.02)	NA	0.18 (0.05)	-	-	--
'AR risk'	-0.15 (0.08)	0.22 (0.09)	-	NA	-	-	-
'Worm control knowledge'	-0.34 (0.13)	0.51 (0.13)	-	-	NA	-	-
'Occurrence of worm problems'	0.18 (0.15)	0.08 (0.05)	-	0.34 (0.10)	-	NA	-
'Vet service cons'	0.14 (0.07)		-	-	-	-	NA
R-square	0.47	0.44	-	0.28	0.19	0.06	-

5.6 DISCUSSION

The results demonstrate that of the nine significant factors positively influencing the uptake of SCOPS recommended practices, the confirmation of AR on a particular holding is shown to have the greatest influence towards the uptake of sustainable parasite control practices. This would suggest that such an event is likely to have the greatest impact on farmer's decision making, which may demonstrate a decisive mechanism for prompting farmers directly affected by AR to assess their treatment efficacies. Farmers may be motivated to modify their parasite control strategies based on the knowledge of which nematode species are resistant to a particular class of anthelmintic, which will help to ensure the preserved effectiveness of the other remaining anthelmintics. The challenge therefore is to encourage farmers to test their treatment efficacies in the absence of indication or a critical event, which has also been acknowledged as a barrier for dairy farmers to reassess their routines regarding mastitis control (Dillon, 2015).

The level of farmer's roundworm control knowledge is likely to reflect their awareness and understanding of the topic, which is fundamental to the decision making process. The impact of knowledge on SCOPS uptake emphasises the importance of informing farmers about areas such as roundworm identification, non-chemical control measures and AR as a vital target for influencing farmer's roundworm practices. Furthermore, knowledge was also identified as a strong determinant for establishing AR status which as previously stated may further influence the adoption of SCOPS practices. The negative effect of knowledge on AR practice uptake also demonstrates the influence of SCOPS awareness towards the adoption of sustainable roundworm practices. In another study using SEM, Toma et al (2015) also identified disease control knowledge to directly and indirectly influence farmer's behavioural intentions. The use of farmers' workshops has been one such strategy employed to engage farmers through providing information as well as setting up subsidised faecal egg count monitoring programmes with local veterinary practices during the peak grazing season (Anonymous, 2016a). The dual benefits of this type of approach may come from ways of improving motivation as well as providing an added financial incentive. Steers and Porter (1975) suggested motivation may be a result of firstly stimulating an initial interest on a topic (i.e. energising), directing participants to learn and master the topic (director) and then reinforcing the knowledge and skills acquired (i.e. maintenance). The maintenance of engagement has also been stated as an important aim to achieving behavioural change in the medium to long-term future (Rushmer et al., 2014). The use of economic incentives such as cost-sharing as described in this instance may spur participation from those farmers with a pre-existing interest on the subject, however for those without interest this may have little or no long term effect on the adoption of such sustainable agricultural practices (Rodriguez et al., 2009). The method used to formulate the knowledge score meant that the level of detail in participant's responses was not factored into the analyses. This will therefore have a limiting effect on the depth of understanding attributed to participant responses. Further work may benefit from assessing the influence of superficial vs. in-depth parasite knowledge on the effectiveness of implementing behaviours.

With regards to attitudinal factors, farmers' AR risk perception presented a moderate influence on the uptake of SCOPS practices and a comparable negative influence on AR selective practices. This may suggest that Scottish farmer's perceptions of AR risk in terms of susceptibility and impact may not be as influential as other factors, possibly due to the progressive 'invisible' nature of AR development in comparison with other disease threats (Woodgate and Love, 2012). In fact, the proportion of respondents' disagreeing that AR is a problem in their region or that AR is a threat to their farming business was 42% and 42% respectively. Positive attitudes towards veterinarians' roundworm control services was also shown to influence the uptake of SCOPS practices as would be anticipated due to their prominent role in educating and encouraging sustainable farming practices. The importance of veterinarians as an influential source of roundworm control information was stated by 65% of respondents, and is also widely acknowledged in the literature (Brennan and Christley, 2013; Alarcon et al., 2014). These findings, in support of others e.g. Kaler and Green (2013) reinforce the need to improve interactions between sheep farmers and veterinarians to encourage more farmers to introduce improvements to their current roundworm control strategies, as part of their overall flock health plans.

Farming characteristic factors such as ewe numbers and enterprise type were also shown to positively influence SCOPS uptake. The effect of flock size may vary the relative importance and impacts attributed to roundworm control. For instance, larger flocks would typically be more associated with greater stocking densities resulting in a higher parasite infection pressure, due to increased pasture contamination. Hence there is a greater requirement for such farms to employ various measures in order to mitigate production losses, as well as address mounting concerns over reliance on chemical control methods. Willock et al., (1999) also found farm size to be a significant influence to farmer's decision making. Enterprise type was shown to have a considerable direct influence on the uptake of SCOPS practices, which would suggest that farms with a greater diversity of farm enterprises are more likely to adopt ‘best practice’ advise. This would support the findings of other studies where more farm enterprises was shown to influence the adoption of best management practices in cattle production (Kim et al., 2005). The topography of respondent’s farms was also shown to have a relatively small direct influence on adoption of SCOPS behaviours with upland/hill farms less likely to employ such practices. This might be due to the contrasting management systems between lowland and hill farms with greater labour requirements to gather and manage an extensively run flock (Morgan-Davies et al., 2006).

Factors that were shown to have a low direct effect on SCOPS uptake included: the occurrence of roundworm control problems, education, topography and perceived roundworm control importance. These factors however demonstrated a greater direct effect through mediating factors such as ‘AR risk’, ‘AR confirmation’, ‘vet services pro’ and ‘worm control knowledge’. An agricultural college education was shown to positively influence ‘AR risk’ perception whereas experience was shown to negatively influence numerous factors including worm control knowledge, AR risk and establishing AR status. The negative influence of other internal factors such as experience suggest that more experienced farmers are less likely to employ sustainable parasite control measures, perhaps due to a greater reliance on their own sense of judgement (Garforth et al., 2013; Kaler and Green, 2013). The concept of self-identity could be relevant, as this relates to an individual’s perception of his/her self within the context of others, which could include reflecting on aspects such as personal attributes, goals, social standing etc. In the context of these findings, farmers’ level of experience could influence their self-identities in regards to their perceived level of knowledge and skills and hence their capability. Therefore the negative influence of experience on best practice uptake, may suggest that older farmers self-identities may affect their openness to external guidance compared with younger farmers, which poses an important barrier to implementing new roundworm control practices (Thompson, 2008). This is particularly relevant considering the high proportion of surveyed respondents aged above 51 years of age in contrast with the younger age brackets, which are comparable with most recent agricultural census reports (National Statistics, 2015).

The identification of factors with the greatest influences on best practice uptake can be used to direct future extension programmes towards areas where greatest impact may be expected to occur, such as developing communication strategies highlighting the benefits of diagnostic testing. The utilisation of local veterinary services as a highly trusted resource is likely to appeal most to farmers as this will also facilitate the tailoring of advice to suit the management strategies in their particular enterprises. The main difficulty of this however is the availability of sheep specialist veterinarians with the interest and expertise required to engage farmers on a wider level (Kaler and Green, 2013). Another approach could be to further support the training of animal health advisors as well as those teaching at agricultural colleges, which as demonstrated could help to encourage the next generation of young farmers to adopt best practice parasite management approaches. Finally, lessons could also be taken from other disciplines associated with influencing farmer perceptions and behaviours such as in the agricultural business and marketing sectors. By developing a suite of strategies to address farmers' perceptions and awareness of best practice advice, this will more likely have a greater general impact than using one such approach in isolation.

5.7 CONCLUSIONS

The use of Structural Equation Modelling has identified a number of significant factors influencing farmer's parasite control behaviours. Both internal and external factors are shown to influence the adoption of SCOPS and AR selective practices including most prominently parasite control knowledge and the identification of AR. Such factors will inform and prompt farmers to think more proactively regarding their roundworm control strategies in order to preserve the effectiveness of remaining anthelmintic treatments. The influence of external factors such as flock size, enterprise type and topography highlight the possible benefits of tailoring future recommendations to suit the range of farming systems present in the sheep farming industry and the challenges associated within these settings.

5.8 ACKNOWLEDGMENTS

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5.9 CONFLICT OF INTEREST

None

CHAPTER 6: DETERMINING THE INFLUENCE OF SOCIO-PSYCHOLOGICAL FACTORS ON THE ADOPTION OF INDIVIDUAL 'BEST PRACTICE' PARASITE CONTROL BEHAVIOURS FROM SCOTTISH SHEEP FARMERS

6.1 INTRODUCTION

The following chapter is used to assess the influence of behaviour-specific factors on the adoption of individual parasite control behaviours. Using the SEM analysis method, three models were developed to determine the effect of both 'general' attitudinal factors e.g. AR risk perception, (as used in Chapter 5) as well as behaviour-specific factors on individual roundworm control behaviours including quarantining for parasites, AR testing and faecal egg count testing.

The proposed models established a good fit with the observed data and explained 61%, 54% and 27% of the variance in the adoption of AR testing, FEC monitoring, and quarantine behaviours. Factors that were shown to have the greatest relative effects on individual parasite control practices included; the perceived expectation of others (i.e. Social norm) for implementing a quarantine strategy, farmers suspicions to the presence of AR on the holding for instigating AR testing and the confirmation of AR for adopting FEC monitoring.

Determining the influences of behaviour-specific factors on farmers' decision-making processes will help to identify and address positive and negative attributes concerning implementation of AR mitigating practices, as well as aid in the development of more precise targets for future intervention strategies.

6.2 MATERIALS AND METHODS

6.2.1 Data formatting/transformation

All assessments for data normality were carried out as previously detailed in chapter 4, section 1.36.2. Similarly all variables in the analysis within this chapter were recorded as per the original coding frame as detailed in Tables 45-47, with the exception of 'Education', and 'Roundworm control knowledge' as previously detailed in chapter 4, section 1.36.2.

The endogenous i.e. multi-item equivalent of a dependent variable, from the quarantine model ('Quarantine behaviours') was formulated into an ordinal measure by attributing a score to each of the following quarantine related behaviours: 'Do you drench incoming animals brought onto the farm' and 'Do you withhold incoming animals from pasture'. This was required due to the nature of the attitudinal questions which were directed at the overall quarantine strategy rather than individual aspects. The final sample total used to assess the quarantine model was 323, which included only respondents which introduce new sheep onto their farms i.e. open flocks. The endogenous variables within the other models (i.e. 'AR test' and 'FEC test') remained as dichotomous variables.

6.2.2 Statistical analysis

Factor analysis and Structural Equation Modelling procedures were conducted in line with previous model analyses as detailed in Chapter 4; section 1.36.3. All variables used within the proposed models were initially chosen based on their empirical relevance. As a preliminary step before SEM analysis, bivariate Spearman correlation was used to assess correlation between observed variables and the associated dependent variables. Outcome (categorical) variables were selected based on their relevance to the individual practice attitudes. Exploratory factor analysis was also used for ordinal Likert Scale items (from sections 2 and 4) related to each of the individual practices explored. Based on the inter-variability between variables, those which demonstrated significant factor loading across multiple factors were excluded from further analysis. Full details of the latent factors and their corresponding indicators are presented in Tables 45-47.

6.3 RESULTS

6.3.1 Descriptive results of model indicators

From the results presented in Table 44, question items which demonstrated the highest levels of agreement overall (Median = 4) included those regarding: positive veterinary service attitudes (Q32, 33), quarantine AR risk (Q40, 41), social norms (Q92, 93, 94, 95, 97, 98), AR testing cues to action (Q50, 51) and positive FEC attitudes (Q59, 60). Conversely, question items which demonstrated the higher levels of disagreement overall (Median = 1) included items concerning quarantine resource requirements i.e. time and facilities (Q45, 46). In regards to items receiving an overall moderate level of disagreement these included items such as: complexity of quarantine advice (Q47) and negative FEC sampling attitudes (Q62, 63). Attitudinal items which indicated uncertainty (Median =3) among respondents included: conflicting quarantine advice (Q48) and AR risk questions (Q23, 24).

In terms of variability of attitudinal items, an equivalent proportion of items demonstrated a relative low level of variability (n= 10; IQR= 1) as well as moderate variability (n=10; IQR=2). The only item which demonstrated a greater variability was regarding respondents concerns of introducing wormer resistance onto their farm (Q41; IQR=3).

With regards to the non-attitudinal questionnaire items, of the roundworm control behaviours included, responses indicate that quarantine behaviours were the most readily employed (Median = 2). Whereas, in regard to respondents' parasite diagnostic testing behaviour this indicated a minimal level of adoption, especially concerning testing for resistance (Median = 0, IQR = 0). In conjunction, respondents' responses concerning suspecting AR on their farms was comparably low (Median = 0, IQR = 0). The classification of roundworm problems from respondents would indicate an overall perceived low level of concern towards roundworm control problems (Median = 1). The median for respondents' knowledge scores was 1 (Q29: A, B, C).

Table 44 - Descriptive statistics (Median and interquartile range) of observed variables included in 'quarantine strategy', 'testing for AR' and 'FEC testing' models.

Indicator directory	Q	Indicators	Median	IQR
Section 1 (demographics and farm characteristics)	1	What is your age	3	1
	2	Did you attend a place of further education?	0	1
	3	How many years have you been earning a living as a farmer	4	2
	10	Is your farm designated as lowland, upland or hill?	2	1
Section 2 (general roundworm control/AR attitude items)	103	How would you classify the occurrence of roundworm problems in your flock?	1	0
	32	Working out a roundworm control strategy with my vet is cost effective	4	2
	33	Working out a roundworm control strategy with my vet ensures I get reliable advice	4	1
Section 3 (open-ended knowledge items)	29	Knowledge score	1	1
Section 4 (Quarantine items)	45	I don't have time to quarantine incoming animals on my farm	1	1
	46	I don't have the facilities to separate incoming stock from the main flock	1	1
	47	I find the quarantine advice for roundworm control is too complicated	2	2
	48	Advice is conflicted regarding best quarantine practice	3	1
	92	They would expect me to have a quarantine strategy against roundworms	4	2
	93	Their opinion of my quarantine strategy is important to me	4	2
	40	Returning or new sheep pose a risk of introducing wormer resistance onto my farm	4	1
	41	I am worried about bringing wormer resistance onto my farm	4	3

Table 44 - Descriptive statistics (Median and interquartile range) of observed variables included in 'quarantine strategy', 'testing for AR' and 'FEC testing' models.

Indicator directory	Q	Indicators	Median	IQR
Section 4 (AR testing items)	50	Unless I saw an impact on productivity, I would not feel the need to test for wormer resistance	4	2
	51	Unless I saw scouring or ill thrift, I would not feel the need to test for wormer resistance	4	2
	94	They would advise me to test my flock for wormer resistance	4	2
	95	They would expect that I should know the wormer resistance status of my flock	4	1
	23	Wormer resistance is a problem in my region	3	2
	24	Wormer resistance is a threat to my farming business	3	2
	109	Do you suspect you have any resistance on your farm?	0	0
Section 4 (FEC monitoring items)	59	Monitoring worm egg counts can improve animal productivity	4	1
	60	Monitoring worm egg counts can optimise treatment timings	4	1
	62	Collecting samples for worm egg counts is too time consuming	2	2
	63	It isn't practical to collect faecal samples from my flock for worm egg counts	2	2
	97	Their opinion of my treatment strategy is important to me	4	1
	98	Their opinion of my treatment frequency is important to me	4	1
Section 5 (Roundworm control practice items)	106/107	Number of quarantine practices implemented	2	1
	110	Have you ever tested for drug resistance?	0	0
	105	Do you monitor worm egg counts?	0	1

6.3.2 Results of factor analysis

The multiple-indicators latent variables presented within all three models established acceptable factor loadings with their underlying constructs (i.e. >0.70), as well as suitable measures of collinearity as indicated by Cronbach alpha analysis (α= >0.60), with the exception of 'AR risk' (α=0.593) within the AR test model. Factor loading and Cronbach alpha values are detailed individually for each model in Tables 45, 46 and 47.

6.3.2.1 Quarantine model

Overall seven factors were included in the Quarantine model based on their significant effect on the outcome behaviour. Five multiple-indicator latent variables were formulated from 10 indicators as detailed in Table 45. The multiple-indicator latent variables consisted of the following factors: 'Vet service pros', 'AR risk', 'Quarantine resources',' Quarantine advice' and 'Social Norms'. The two single-indicator latent variables included 'Topography' and the dependent variable 'Quarantine behaviours'. The total number of observations in this sample is 323, which excluded respondents which do not introduce new sheep onto their farms i.e. closed flocks.

Table 45 - Description of Quarantine model latent constructs with corresponding indicators and Cronbach alpha reliability measures (α)

Latent variable	Indicator and statement	α	Factor loading	Value & labels	Variable type
'Topography'	Is your farm designated as lowland, upland or hill?	NA	NA	0 = lowland; 1 = upland; 3 = hill	Ordinal
'Vet service pros'	**1. -** Working with my vet ensures I get reliable advice	0.82	.921	5-point Likert scale [a]	Ordinal
	2. - Working out a roundworm control strategy with my vet is cost effective			5-point Likert scale [a]	Ordinal
'Quarantine resources'	**1.** - I don't have time to quarantine incoming animals on my farm	0.82	.923	5-point Likert scale [a]	Ordinal
	2. - I don't have the facilities to separate incoming stock from the main flock			5-point Likert scale [a]	Ordinal
'Quarantine advice'	**1.** - I find the quarantine advice for roundworm control is too complicated	0.76	.897	5-point Likert scale [a]	Ordinal
	2. - Advice is conflicted regarding best quarantine practice			5-point Likert scale [a]	Ordinal
'Social norms'	**1.** - They would expect me to have a quarantine strategy against roundworms	0.76	.899	5-point Likert scale [a]	Ordinal
	2. - Their opinion of my quarantine strategy is important to me			5-point Likert scale [a]	Ordinal

Table 45 - Description of Quarantine model latent constructs with corresponding indicators and Cronbach alpha reliability measures (α)

Latent variable	Indicator and statement	α	Factor loading	Value & labels	Variable type
'Quarantine risk'	**1.** - Returning or new sheep pose a risk of introducing wormer resistance onto my farm	0.61	.850	5-point Likert scale [a]	Ordinal
	2. - I am worried about bringing wormer resistance onto my farm			5-point Likert scale [a]	Ordinal
'Quarantine behaviours'	Number of quarantine practices implemented	NA	NA	0 = none; 1 = one; 2 = two	Ordinal

[A] 5-POINT LIKERT SCALE: 1 = STRONGLY DISAGREE; 2 = DISAGREE; 3 = UNSURE; 4 = AGREE; 5 = STRONGLY AGREE

6.3.2.2 AR testing model

Overall 11 factors were included in the AR testing model based on their significant effect on the outcome behaviour. Five multiple-indicator latent variables were formulated from 10 indicators shown in Table 46. The multiple-indicator latent variables consisted of the following factors: ‘Experience’, ’Vet service pros’, ‘AR risk’, ‘Cues to action’ and ‘Social norms’. The six single-indicator latent variables included ‘Topography’, ‘Education’, ‘Occurrence of worm problems’, ‘Worm control knowledge’, ‘Suspect AR’ and the dependent variable ‘AR test’. The total number of observations included in this sample 400.

Table 46 - Description of AR testing model latent constructs with corresponding indicators and Cronbach alpha reliability measures (α)

Latent variable	Indicator and statement	α	Factor loading	Value & labels	Variable type
'Experience'	What is your age	0.764	.926	1 = 18-35; 2 = 36-50; 3 = 51-65; 4 = over 65	Categorical
	How many years have you been earning a living as a farmer			1 = 10 years or less; 2 = 11-20; 3 = 21-30; 4 = 31- 40; 5 = 41-50; 6 = over 51	Categorical
'Education'	Did you attend a place of further education?	NA	NA	0 = no/other colleges1 = Agricultural college	Binary
'Topography'	Is your farm designated as lowland, upland or hill?	NA	NA	0 = lowland; 1 = upland; 3 = hill	Ordinal
'Worm control knowledge'	Knowledge score	NA	NA	0 = none correct; 1 = one correct; 2 = two correct; 3 = three correct	Ordinal
'Occurrence of worm problems'	How would you classify the occurrence of roundworm problems in your flock?	NA	NA	0 = low; 1 = moderate; 2 = high	Ordinal
'Vet service pros'	**1. -** Working with my vet could improve my roundworm control strategy	0.87	.921	5-point Likert scale [a]	Ordinal
	2. - Working out a roundworm control strategy with my vet is cost effective			5-point Likert scale [a]	Ordinal

Table 46 - Description of AR testing model latent constructs with corresponding indicators and Cronbach alpha reliability measures (α)

Latent variable	Indicator and statement	α	Factor loading	Value & labels	Variable type
'Cues to action'	**1. -** Unless I saw an impact on productivity, I would not feel the need to test for wormer resistance	0.845	.931	5-point Likert scale [a]	Ordinal
	2. - Unless I saw scouring or ill thrift, I would not feel the need to test for wormer resistance			5-point Likert scale [a]	Ordinal
'Social norms'	**1. -** They would advise me to test my flock for wormer resistance	0.639	.857	5-point Likert scale [a]	Ordinal
	2. - They would expect that I should know the wormer resistance status of my flock			5-point Likert scale [a]	Ordinal
'AR risk'	**1.** - Wormer resistance is a problem in my region	0.593	.844	5-point Likert scale [a]	Ordinal
	2. - Wormer resistance is a threat to my farming business				
'Suspect AR'	Do you suspect you have any resistance on your farm?	NA	NA	0 = No; 1 = Yes	Binary
'AR test'	Have you ever tested for drug resistance?	NA	NA	0 = No; 1 = Yes	Binary

6.3.2.3 FEC testing model

Overall 11 factors were included in the FEC testing model based on their significant effect on the outcome behaviour. Six multiple-indicator latent variables were formulated from 12 indicators shown in Table 47. The multiple-indicator latent variables consisted of the following factors: ‘Experience’, ‘FEC pros’, ‘FEC cons’, ‘AR risk’, ‘Social norms’ and ‘Vet service pros. The four single-indicator latent variables included ‘Topography’, ‘Occurrence of worm problems’, ‘Worm control knowledge’, and the dependent variable ‘FEC test’. The total number of observations included in this sample 400.

Table 47 - Description of FEC testing model latent constructs with corresponding indicators and Cronbach alpha reliability measures (α)

Latent variable	Indicator and statement	α	Factor loading	Value & labels	Variable type
'Experience'	What is your age	0.764	.926	1 = 18-35; 2 = 36-50; 3 = 51-65; 4 = over 65	Categorical
	How many years have you been earning a living as a farmer			1 = 10 years or less; 2 = 11-20; 3 = 21-30; 4 = 31- 40; 5 = 41-50; 6 = over 51	Categorical
'Education'	Did you attend a place of further education?	NA	NA	0 = no/other colleges 1 = Agricultural college	Binary
'Topography'	Is your farm designated as lowland, upland or hill?	NA	NA	0 = lowland; 1 = upland; 3 = hill	Ordinal
'Worm control knowledge'	Knowledge score	NA	NA	0 = none correct; 1 = one correct; 2 = two correct; 3 = three correct	Ordinal
'Occurrence of worm problems'	How would you classify the occurrence of roundworm problems in your flock?	NA	NA	0 = low; 1 = moderate; 2 = high	Ordinal
'Vet service pros'	**1. -** Working with my vet could improve my roundworm control strategy	0.87	.921	5-point Likert scale [a]	Ordinal
	1. - Working with my vet ensures I get reliable advice			5-point Likert scale [a]	Ordinal

Table 47 - Description of FEC testing model latent constructs with corresponding indicators and Cronbach alpha reliability measures (α)

Latent variable	Indicator and statement	α	Factor loading	Value & labels	Variable type
'FEC pros'	**1.** - Monitoring worm egg counts can improve animal productivity	0.841	.929	5-point Likert scale [a]	Ordinal
	2. - Monitoring worm egg counts can optimise treatment timings			5-point Likert scale [a]	Ordinal
'FEC cons'	**1. -** Collecting samples for worm egg counts is too time consuming	0.795	.911	5-point Likert scale [a]	Ordinal
	2. - It isn't practical to collect faecal samples from my flock for worm egg counts			5-point Likert scale [a]	Ordinal
'Social norms'	**1. -** Their opinion of my treatment strategy is important to me	0.830	.925	5-point Likert scale [a]	Ordinal
	2. - Their opinion of my treatment frequency is important to me			5-point Likert scale [a]	Ordinal
'AR test'	Have you ever tested for drug resistance?	NA	NA	0 = No; 1 = Yes	Binary
'FEC test'	Do you monitor worm egg counts?	NA	NA	0 = No; 1 = Yes	Binary

[A] 5-POINT LIKERT SCALE: 1 = STRONGLY DISAGREE; 2 = DISAGREE; 3 = UNSURE; 4 = AGREE; 5 = STRONGLY AGREE

6.3.3 Results of Structural equation models

All three models reflected a goodness of fit with the observed data as indicated by the following model fit indices as according to Hair et al (2004). The model fit values as shown in Table 48, were below the maximum threshold of 0.10 for RMSEA, and at the 0.08 threshold for SRMR. For the subsequent fit indices (i.e. CFI, IFI, GFI, AGFI and NFI) values above 0.90 give an indication of acceptable fit, all of which were established above the required threshold. Significance was established for all relationships at a 0.05 level, with significant standardised coefficients (total effects) of each model detailed in Tables 49, 50 and 51. Illustrated versions of the structural models are presented in Figures 45, 46 and 47.

The quarantine model explained 25% of the variance in the outcome quarantine behaviours. The AR test model explained 61% of the variance in the outcome behaviour 'AR test'. The FEC test model explained 54% of the variance in the outcome behaviour 'FEC test'.

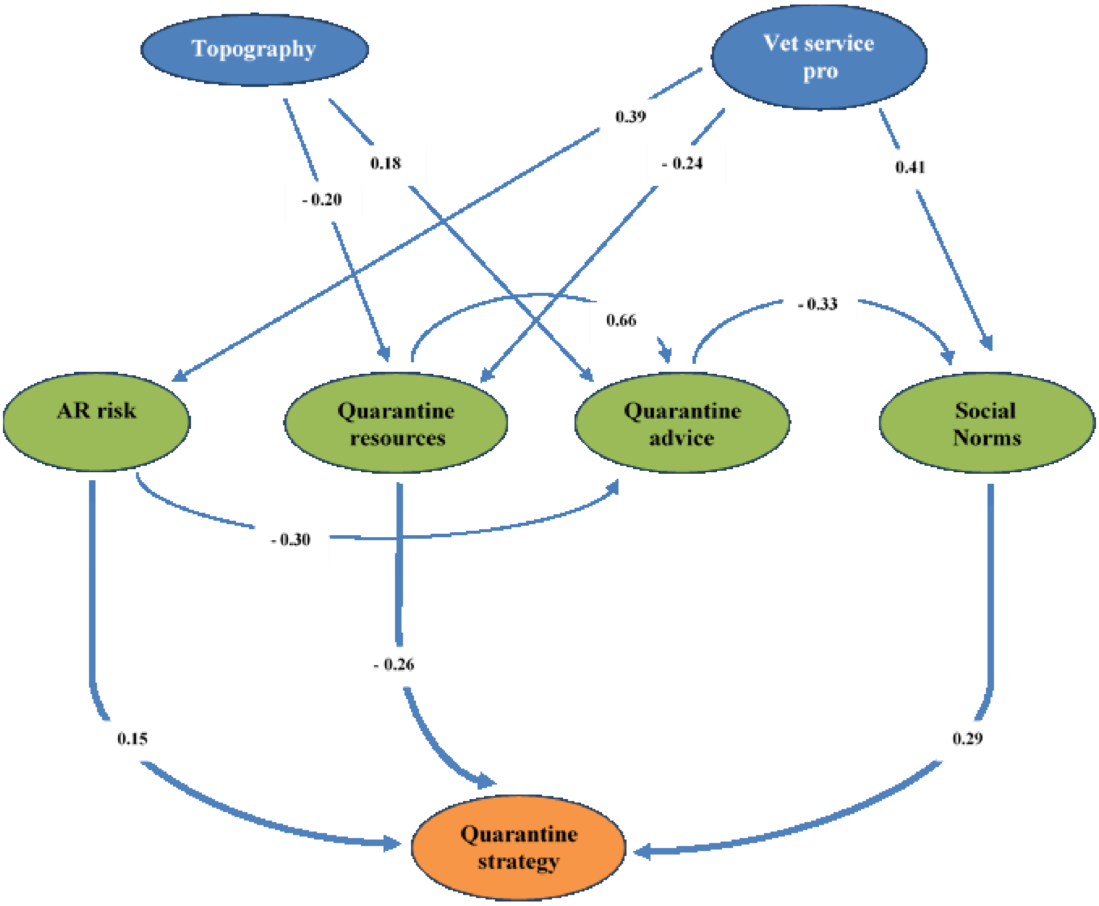

Figure 45 – Quarantine strategy uptake structural model (standardised solution). Bold arrows represent the total (direct/indirect) influences of latent variables on the behavioural latent 'AR test', with non- bold arrows representing the total effect influences on other latent variables. The corresponding numbers are the standardised coefficients of the variables in the structural model. Blue variables denote variables that are exogenous i.e. independent from other variables in the model, with green variables taking either exogenous or endogenous roles i.e. influenced by other variables. The orange variable represents the endogenous behavioural latent variable.

Table 48 – Model fit indices measures for Quarantine, AR test and FEC test models

SEM model	Goodness-of- fit indices						
	RMSEA	**SRMR**	**CFI**	**IFI**	**GFI**	**AGFI**	**NFI**
Quarantine	0.027	0.045	0.99	0.99	0.99	0.99	0.98
AR test	0.0063	0.057	1.00	1.00	0.98	0.98	0.96
FEC test	0.031	0.065	0.99	0.99	0.98	0.97	0.96

Table 49 - Standardised total effects on Quarantine model latent variables (Standard error values).

	Total (direct and indirect) effects on independent variables				
Determinants	**'Quarantine strategy'**	**'AR risk'**	**'Quarantine resources'**	**'Quarantine advice'**	**'Social Norms'**
'Topography'	-0.05 (1.97)	-	-0.20 (-3.07)	0.05 (1.10)	-0.02 (-1.01)
'Vet service pro'	0.26 (5.46)	0.39 (5.81)	-0.24 (-3.58)	-0.28 (5.7)	0.50 (7.45)
'AR risk'	0.17 (2.48)	NA	-	-0.30 (-5.67)	0.1 (3.11)
'Quarantine resources'	-0.10 (2.87)	-	NA	0.66 (12.42)	-0.22 (-4.13)
'Quarantine advice'	-0.29 (3.81)	-	-	NA	-0.33 (-4.39)
'Social Norms'	0.29 (3.81)	-	-	-	NA
R-square	0.25	0.15	0.10	0.55	0.35

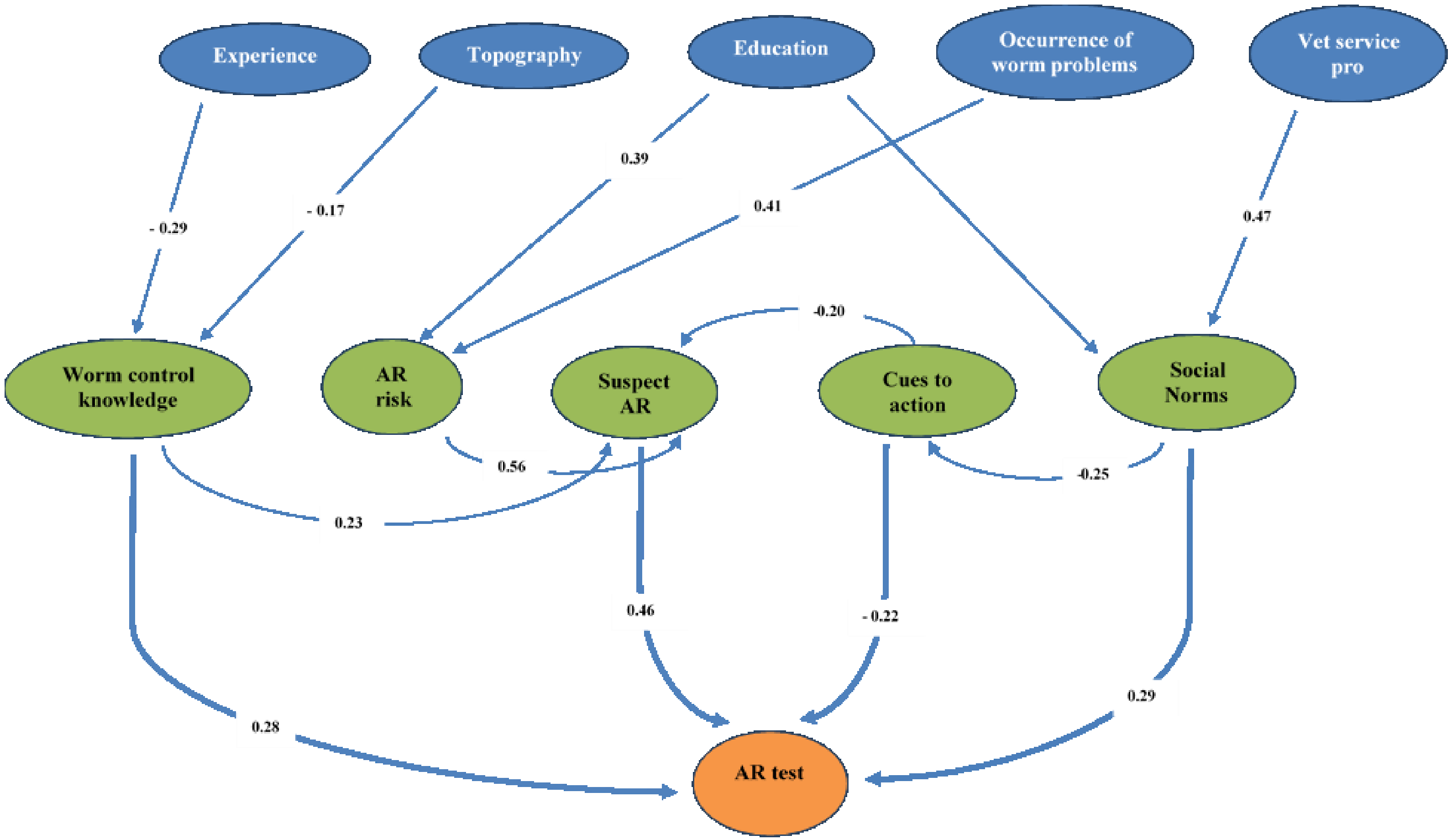

Figure 46 - AR testing uptake structural model (standardised solution). Bold arrows represent the total (direct/indirect) influences of latent variables on the behavioural latent 'AR test', with non- bold arrows representing the total effect influences on other latent variables. The corresponding numbers are the standardised coefficients of the variables in the structural model. Blue variables denote variables that are exogenous i.e. independent from other variables in the model, with green variables taking either exogenous or endogenous roles i.e. influenced by other variables. The orange variable represents the endogenous behavioural latent variable.

Table 50 - Standardised total effects on AR test model latent variables (Standard error values).

	Total (direct and indirect) effects on independent variables					
Determinants	**'AR test**	**'Worm control knowledge'**	**'AR risk'**	**'Cues to action'**	**'Social Norms'**	**'Suspect AR'**
'Experience'	-0.11 (-2.92)	-0.29 (-5.77)	-	-	-	-0.07 (-2.31)
'Topography'	-0.07 (-2.25)	-0.17 (-2.58)	-	-	-	-0.04 (-1.98)
'Education'	0.21 (4.28)	-	0.39 (4.77)	-0.08 (-2.56)	0.31 (3.92)	0.23 (5.00)
'Vet service pro'	0.17 (3.71)	-	-	-0.12 (-3.40)	0.47 (7.12)	0.02 (1.69)
'Occurrence of worm problems'	0.11 (2.62)	-	0.41 (4.61)	-	-	0.23 (3.05)
'Worm control knowledge'	0.39 (3.74)	NA	-	-	-	0.23 (2.62)
'AR risk'	0.26 (3.59)	-	NA	-	-	0.56 (5.92)
'Cues to action'	-0.31 (-3.96)	-	-	NA	-	-0.20 (-2.19)
'Social Norms'	0.37 (4.09)	-	-	-0.25 (-3.64)	NA	0.05 (1.70)
'Suspect AR'	0.46 (4.62)	-	-	-	-	NA
R-square	0.61	0.12	0.34	0.06	0.31	0.43

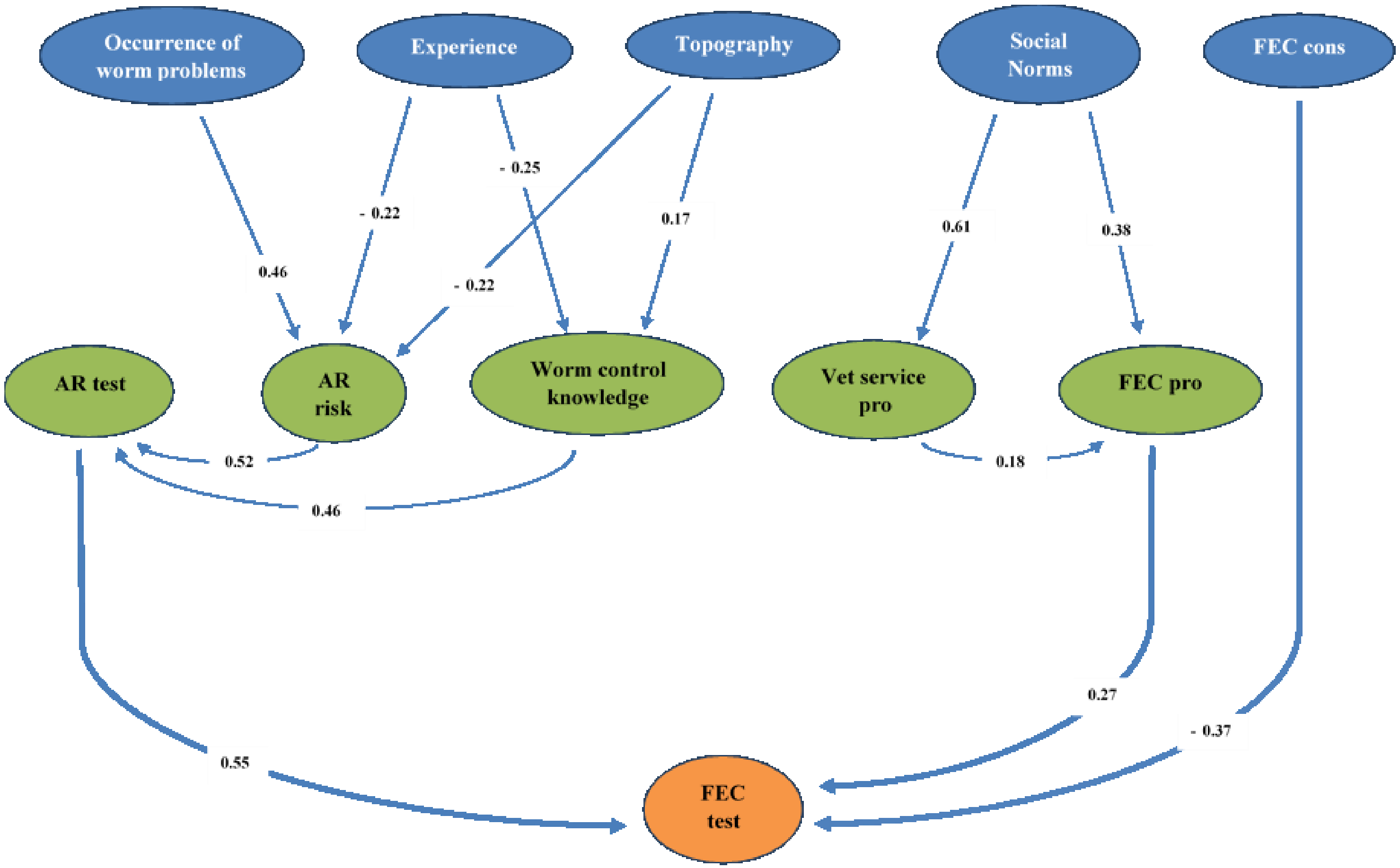

Figure 47 - FEC testing uptake structural model (standardised solution). Bold arrows represent the total (direct/indirect) influences of latent variables on the behavioural latent 'AR test', with non- bold arrows representing the total effect influences on other latent variables. The corresponding numbers are the standardised coefficients of the variables in the structural model. Blue variables denote variables that are exogenous i.e. independent from other variables in the model, with green variables taking either exogenous or endogenous roles i.e. influenced by other variables. The orange variable represents the endogenous behavioural latent variable.

Table 51 - Standardised total effects on FEC model latent variables (Standard error values).

	Total (direct and indirect) effects on independent variables					
Determinants	**'FEC test'**	**'Worm control knowledge'**	**'AR risk'**	**'Vet service pro'**	**'FEC pro'**	**'AR confirmation'**
'Experience'	-0.13 (-4.07)	-0.25 (-4.45)	-0.22 (-2.72)	-	-	-0.23 (-4.25)
'Topography'	-0.11 (-3.49)	-0.17 (-2.87)	-0.22 (-2.69)	-	-	-0.19 (-3.52)
'FEC con'	-0.37 (-5.91)	-	-	-	-	-
'Social Norms'	0.13 (3.02)	-	-	0.61 (4.28)	0.49 (4.99)	-
'Occurrence of worm problems'	0.13 (2.90)	-	0.46 (3.57)	-	-	0.24 (3.15)
'Worm control knowledge'	0.25 (4.76)	NA	-	-	-	0.46 (4.79)
'AR risk'	0.29 (4.98)	-	NA	-	-	0.52 (6.82)
'Vet service pro'	0.05 (2.25)	-	-	NA	0.18 (2.33)	-
'FEC pro'	0.27 (4.01)	-	-	-	NA	-
'AR confirmation'	0.55 (5.48)	-	-	-	-	NA
R-square	0.54	0.09	0.32	0.37	0.26	0.53

6.4 DISCUSSION

The SCOPS guidelines were designed to cover the wide range of aspects influencing AR development and offer practical solutions to enable farmers' to manage parasites effectively without inadvertently advancing AR development. The presented results aim to contribute to the limited evidence base for improving our understanding of livestock producers' parasite control decision making influences. The models included in this chapter cover a few of the important practices which are known to reduce the spread of AR as well as help to identify the extent of AR development and animal parasite burdens.

6.4.1 Quarantine model

Of the six significant factors shown to have direct influences on the adoption of quarantine related behaviours, 'Quarantine resources' and 'Quarantine advice' were both shown to have negative influences on the outcome behaviours. Between these two factors, negative attitudes regarding quarantine resources demonstrated the greatest direct influence on the quarantine behaviours assessed, explaining -33% of the variance. The perceived practical requirements concerning farm biosecurity measures have also been shown to have a strong influence on farmers' willingness to control disease (Toma et al., 2015). Resource requirements e.g. cost and time were also perceived to be a major constraint on farmers' biosecurity implementation by auxiliary industry representatives (Anonymous, 2003). In regards to quarantine advice, this study also recognised the perceived complexity of biosecurity measures associated with large variation between farms characteristics and farming systems (Anonymous, 2003). Therefore a single guideline approach to biosecurity is likely to be inadequate to suit the wide range of farming conditions and production systems found within the

UK. In conjunction with this, characteristics such as farm topography demonstrated a small but significant, positive influence on the uptake of the assessed quarantine behaviours, explaining 5% of the variance. The greatest influence of topography was towards quarantine resource attitudes, which suggests that farms located on higher topographies are less associated with negative attitudes towards quarantine resource requirements. This finding may also correlate with findings from (Anonymous, 2003) who found that the majority of surveyed upland farmers stated that both a 28 day quarantine and screening on entry were relatively easy to implement when compared with lowland farmers that mostly attributed a moderate difficulty towards implementation.

The positive influence of veterinary service attitudes supports the widely held views of veterinarians as a highly trusted resource for farmers. However this may be largely conflicting with many veterinarians own views of their knowledge or general interest to advise on biosecurity matters (Anonymous, 2003). This may reflect some reticence amongst veterinarians regarding their own abilities to adapt to their shifting role towards providers of flock/herd health advice (Ruston et al., 2016), and being viewed as a primary source for biosecurity information (Gunn et al., 2008). A positive attitude to veterinary services was also shown to have a strong influence on the perceived expectation of significant others (i.e. social norms) towards implementing biosecurity practices (explaining 50% variance). Social norm perceptions also demonstrated a prominent direct influence on respondents quarantine behaviours, explaining 29% of the variance in quarantine behaviours. Heffernan et al (2008) found that the perceptions of ‘good farmers’ as those who can manage endemic disease threats may reflect a cultural impact of collective beliefs as an important motivation for implementing farm biosecurity measures. The difficulty however is to attribute a comparable risk towards AR in comparison with other notable ovine biosecurity threats such as sheep scab, Maedi Visna or Chlamydia abortus etc. The results do however suggest that respondents quarantine risk perception towards AR does have a significant, direct influence on quarantine behaviours (explaining 17% of the variance in behaviour), which is in part also significantly influenced by positive views to veterinary services (explaining 39% of the variance).

6.4.2 Testing for AR

Of the 10 significant factors demonstrating a direct influence on AR testing behaviour, three were shown to have a negative influence including: 'Experience', 'Topography', and 'Cues to action'. Increasing levels of experience and topography both demonstrated a negative effect on 'worm control knowledge' explaining 29% and 17% of the variance, and to a lesser degree on 'suspect AR' explaining 7% and 4% of the variance. The direct negative influence of both factors on 'AR test' explained 11% and 7% of the outcome behaviour. The demographic characteristic of age has also been acknowledged as a social influence on the adoption behaviours of other agricultural innovations such as artificial insemination (Howley et al., 2012) and animal health and welfare technologies (Toma et al., 2014) with younger farmers more associated with adopting new technologies and practices in comparison with older farmers. This occurrence has been associated with younger farmers who are thought of as more likely to better educated and therefore be more aware and adaptable to new approaches in modern agriculture (Council, 2002; Howley et al., 2012). The positive influence of an agricultural college education ('Education'; explaining 21% of the variance in behaviour) has also been associated as an important characteristic of more progressive farmers (Van den Ban, 1957). The aversion of older farmers to adopting such innovations may give an indication of scepticism or caution towards implementing unfamiliar methodologies. Innovations like those recommended by SCOPS could also conflict with the self-identity of many farmers' who hold a more productivist i.e. production driven mind-set, in contrast with more contemporary post-productivist ideals orientated towards environmental issues and sustainability (Burton and Wilson, 2006). Additionally the perceived value of experience by farmers is likely to also shape farmers' self-identities, which would support the view of more experienced sheep farmers as the 'experts' of their farming system, and therefore are less likely to rely on external guidance (Kaler and Green, 2013).

The factor 'Cues to action' in this instance reflects the impetus for testing AR based on clinical signs of wormer failure. This factor is shown to have the greatest negative impacts on both 'Suspect AR' as well as directly on the behavioural outcome ('AR test'), explaining 20% and 31% of the factor variances. This demonstrates that basing AR testing decisions on visual indicators is negatively impacting on farmers' AR suspicions, which in turn has a detrimental effect on farmers testing behaviour. This progression cycle highlights the need to encourage farmers' to test for AR in the absence of clinical signs. However the lack of visual 'cues to action' associated with preclinical AR development has been recognised as a major issue for farmers concerning its detection (Woodgate and Love, 2012). Possible routes for altering these perceptions shown in this model may include raising social norm expectations, perhaps through agricultural media, or alternatively through enhanced interactions with veterinary services as well as through education, which explains 25%, 12% and 8% of the factor variances.

The greatest positive determinant of AR testing behaviour was 'Suspect AR' explaining 46% of the variance in respondents testing behaviour. By improving our understanding of what influences farmers AR suspicions this is likely to play an important role for improving the uptake of AR testing behaviours by farmers. The result of which if AR is confirmed could provide significant impetus to adopt subsequent SCOPS parasite control practices as previously reported (Jack et al., 2017). The observed relationships between 'AR risk', 'Worm control knowledge', 'Cues to action' and 'Education' (explaining 56%, 39%, -20% and 23% of the factor variance) highlight some key areas for consideration when planning future knowledge exchange programmes. Respondents AR risk perceptions in particular show considerable indirect influences as previously mentioned, as well as direct influences on AR testing behaviour (explaining 26% of the variance). The significant influences shown towards AR risk (i.e. 'Education' and 'Occurrence of worm problems') could be comparable with findings from Garforth et al (2013), suggesting that both an awareness and previous experience of a disease agent are integral to forming an opinion of disease risk, which is a strong influencer of subsequent behaviour. Interestingly worm control knowledge was not significantly associated with AR risk, however was influential on 'suspect AR' as well as directly on the outcome testing behaviour, explaining 23% and 39% of the factor variance.

6.4.3 FEC model

In line with the previous SEM models, the factors 'Experience' and 'Topography' demonstrated a negative influence on the outcome behaviour, in addition to 'FEC cons', explaining 13%, 11% and 37% of the variance in behaviour. The latter of these factors represents the perceived practicality issues relating to the faecal sampling process required for FEC testing. The importance of time and efficiency to farmers adoption behaviours is well established in the literature (Kahn and Woodgate, 2012; Woodgate and Love, 2012; Garforth et al., 2013) and presents a major constraint especially on the adoption of measures requiring routine operation such as for monitoring FEC. The sampling procedure can vary widely depending on the farming system and characteristics of the farm. For example to obtain samples that are representative of a flock or group ideally requires that a randomised proportional number of samples are taken. Therefore larger flocks may require a greater number of samples to be taken. It is also suggested that the group be loosely gathered into a corner for a short period of time and samples then taken. This approach may also prove difficult on more extensive farms with large acreages as well as on farms with limited labour availability. The large effect that this factor has on FEC testing behaviour suggests that either advice needs to be adapted to address the range of circumstances which may discourage farmers adopting this method routinely. Or alternatively, where the efficiency of sampling may not be improved, the justification of time and resources needs to be met with clear benefits such as those represented by 'FEC pro' which explained 27% of the variance in behaviour. Although it appears that the perceived practical drawbacks of conducting FEC may offset the perceived benefits in terms of improving treatment timings and animal productivity. An alternative approach as demonstrated by the model would be to further engage with veterinarians on the benefits of using FEC for their clients, as indicated by the influence of 'vet service pro' explaining 18% of the variance on positive attitudes to FEC monitoring. Furthermore the influence of social norms towards positive attitudes to FEC monitoring is shown to be a significant influence, as well as directly on behaviour, explaining 49% and 13%

of the factor variances. The influence of social norms has also been recognised as a strong determining factor towards to use of parasite diagnostics by cattle farmers' (Vande Velde et al., 2015).

The greatest positive influencing factor towards the adoption of FEC monitoring behaviour is the confirmation of AR ('AR confirmation') which explains 55% of the variance in behaviour. The importance of detecting resistance therefore is not only to inform farmers on the efficacy of anthelmintic treatments but also to heighten awareness of the problem and find potential means of mitigating further development. Respondents AR risk perception demonstrate a strong influence on the 'AR confirmation' as well as directly on FEC monitoring behaviour, explaining 52% and 29% of the factor variances. This result is contrary to findings from cattle producers which demonstrated a non-significant influence of risk perceptions towards farmers' diagnostic behavioural intentions (Vande Velde et al., 2015). This would suggest that sheep producer's AR risk perception is greater when compared with cattle producers, where the problems associated with AR are less reported.

6.5 CONCLUSIONS

The wide range of socio-psychological factors presented reflect the complex nature of behavioural change and the requirement for further work to be conducted to better understand farmers' parasite control decision making processes. The SCOPS recommendations cover many facets of parasite disease control management of which three areas were of focus in this chapter. Such practices will aid in preventing the introduction and spread of resistance between farms as well as facilitate the use of decision making tools to inform effective parasite management. Providing evidence of the significant influences concerning such practices will help to address key concerns amongst Scottish sheep farmers regarding SCOPS recommendations as well as highlight the most effective methods for targeting future knowledge exchange.

CHAPTER 7: GENERAL DISCUSSION

The requirement to re-evaluate plans and objectives is the basis for progression and evolution of innovations. This process of reviewing existing ideas, identifying their strengths and weaknesses and proposing mitigations to alleviate or remove potential weaknesses, is essential for enhancing our ideas (Reis, 2017). Without this critical component, such ideas are less likely to appeal to their target audiences and ultimately become ineffective at achieving their intended goals (Baumgartner, 2017). It could be argued that the absence of such critical evaluations of the SCOPS recommendations has limited the changes and developments seen to its extension approach since its introduction. The impact of this and more specific factors identified throughout this project will be discussed in conjunction with proposals for potential solutions. A list of proposals to improve future targeting of SCOPS guidelines are outlined in Table 52.

The studies presented in this thesis were intended to firstly establish the current state of Scottish sheep farmers roundworm control programmes and secondly, to determine which factors are likely to influence farmers towards the adoption of sustainable parasite control practices. Regarding the first of these aims, the varied adoption of best practice recommendations between surveyed populations makes it challenging to attribute the effectiveness of SCOPS to improvements in employment of certain practices, which has been acknowledged by Benor (1984) as a significant limitation concerning extension efforts. However, the notable reduction in treatment frequency and dose and move approaches employed over time may signify a conscious effort among some farmers towards reducing the selective pressures for AR development. These encouraging signs for change help to distinguish which practices are demonstrating the most influence on farmers' roundworm control strategies, which should continue to be monitored ideally using such survey approaches or potentially through a veterinary database related to client's flock health plans. The difficulty however in reaching farmers who are not actively engaged with the latest disease control recommendations, will always be the test of any innovation. As Roger's (1983) diffusion of innovation model suggests, if an innovation is evidently able to improve the efficiency or effectiveness of a system then it will likely spread to most clusters of farmers eventually, given a suitable infrastructure is available to support its dissemination and implementation.

The infrastructure for supporting extension efforts is another key consideration which has been highlighted. Veterinarians were frequently identified as the most important information resource among farmers, both from the focus groups and questionnaire studies. Veterinarians also viewed their role in developing roundworm control strategies as important for tackling the issue of AR, as indicated from the SVS meeting. However, some farmers have expressed a lack of proactivity or competitiveness among veterinarians towards advising on roundworm control or product promotion, which leads many farmers to bypass their vets in favour of economical alternatives. Many veterinarians stated that expense and lack of need as primary barriers towards farmers seeking their services regarding roundworm control. The apparent disconnect between farmers and vets on this topic may warrant further studies with vets to determine their levels of engagement regarding roundworm control planning. Furthermore, allowing vets to discuss their opinions concerning the most appropriate approaches to roundworm control, may help to identify where conflicting guidance may arise. Similar assessments may also be necessary for agricultural merchants who were identified overall as the second most frequent source for information among farmers. The importance of both resources demonstrates an important target for improving knowledge exchange through mutual collaboration. As Jansen et al (2012) proposes, the more people within a farmer's social network who apply pressure to change, the harder it may be for farmers to oppose; it is important that a concerted effort from these various sources is established, together with the promotion of consistent messages.

Although direct communication as previously stated appears by most farmers to be the most favoured approach to receiving information, the use of alternative information formats should also be enhanced to increase accessibility to independent advice. Since the advent of the digital era, changes in the means by which information is assimilated supports the need for various platforms for acquiring information, including the use of videos, animations, infographics, electronic-learning tools and decision support systems. The use of such visual educational tools is likely to help users to contextualise information within their own settings, with less requirement to understand technical concepts and vernacular. The development of a decision support system in particular, would enable tailoring of information to suit the diversity of farming structures and conditions. This would have several benefits on the ability to guide farmers to employ practices based on 'best practice' approaches. For instance, such a system could inform farmers on which treatments to use based on times of year, as well as keep a record of treatment usage. Risk assessments could also be generated based on on-farm information such as animal movements, FEC data, paddock size etc. to inform risk mapping to help farmers identify which pastures are at highest risk of contamination or to inform a decision support system to help make general farm recommendations. Furthermore, this could be integrated with other aspects of farm management, such as animal movements and pasture measurements to optimise grazing potential. The lack of necessity for farmers to meet directly with an advisor also has its own benefits such as reducing consultation fees and the convenience of access, however this may lead to further detachment of sheep farmers from seeking advice from animal health advisors. This has been acknowledged as a problem which could be detrimental to sheep farmers seeking new guidance (Garforth et al, 2013; Kaler and Green; 2013).

Whichever formats are used to promote guidance, the important consideration for future delivery of recommendations is that the advice is fundamentally transparent, which insists that complexity and ambiguity be minimized. The closer that the recommendations come to meeting these criteria, the easier it will be for stakeholders to understand the purpose and reasoning behind the recommended procedures, resulting in less confusion and less confliction between individual's perceptions. Furthermore, it may also be important to consider whether the guidance is likely to be compatible with most farmers' farm conditions, production systems, skill-sets and beliefs, which has also been recognised as notable barriers to adoption of parasite control recommendations (Thompson, 2008). In relation to individuals' beliefs, the psychological concept cognitive dissonance (Festinger, 1957) may apply within this context, whereby if an innovation is thought to be complex, ineffective or impractical, it is difficult to rationalize and therefore cannot be accepted in view of the existing beliefs. Therefore unless the new rationale can be justified, the only alternative is to demote or disregard the belief, in light of other potentially more complementary ideas which can be internalized more readily. This therefore supports the necessity to collaborate with farmers to determine where such conflicts in individual's beliefs and perceptions arise.

The physical capacities of farming system characteristics e.g. farm topography and enterprise type, demonstrated significant influence of adoption behaviours in the statistical model analysis. The association between topography and roundworm control knowledge suggests that hill farmers may be less aware of best practice approaches than lowland farmers. Whether this is due to cultural or social differences between these farming groups, is an interesting theme for discussion. What can be said however is that respondents from both hill farms and from northern regions of Scotland were significantly more likely than other groups to believe that anthelmintic resistance isn't a problem in their region or a threat to their farming businesses. This highlights a significant concern and challenge for rural societies who rely substantially on sheep farming for their incomes. The negative effect of experience level on adoption of best practice approaches, also represents a demographic majority with long-standing traditions in sheep farming, which may require greater persuasion to change farmers well-established disease control practices.

One of the main motivating factors towards to adoption of best practice approaches was the identification of resistance on a property. The statistical model analysis identified a number of factors which demonstrated significant influence on respondents' testing behaviours, including (reactive) cues to action, AR risk perception, and roundworm control knowledge, which all influenced the most prominently influencing factor 'AR suspicion'. In other words, this suggests that the most important triggers for raising farmers suspicion to test for resistance requires changing mind-sets towards proactively testing without indication of AR, raising farmers AR risk perceptions and awareness of roundworm control practices. The significant influence of factors such as education, positive attitudes to veterinary services and social norms indicates that the influence of others is likely to be the most crucial driving force for farmers to test for AR. From the focus group discussions, it may also be important to note how farmers were more critical of others need to test than themselves, which could reflect in psychology an optimistic bias, where we tend to believe that our own risks are less than the risk of peers (Weinstein and Lyon, 1999). The reality is however that all farms will likely have varying levels of resistance to anthelmintic treatments. What may be required is to try to reduce the stigma associated with AR by emphasizing both the commonness of the problem while positively reinforcing how you can act now, which may support those farmers who feel reluctance to find resistance on their farms. It is also important to highlight the dangers associated with AR development, particularly in terms of potential production losses. Studies investigating the behavioural economic impact between profit gains and losses, demonstrated that loss aversion was twice as impactful on behaviour as profit acquisition (Kahneman and Tversky, 1984). These points may demonstrate that finding a balance between evoking urgency and threat towards resistance, whilst reassuring farmers that they can do something about it, may stimulate the type of response favourable to assist voluntary behavioural change which is preferable to enforcing compulsory measures.

Based on the proposed framework for behavioural change by Michie et al (2011), the three central behaviour influencing themes comprise of capability, opportunity and motivation. Capability refers to both a physical and psychological capacity to engage in the behaviour concerned. The opportunity component of the behavioural model is the social context, this refers to the idea that people have different opportunities based on their social networks and the physical environment in which they live. The last element, motivation, concerns the decision processes which are categorized as either reflective i.e. based on rational evaluations or plans, or autonomic i.e. involving emotional and impulsive responses connected with associative learning processes.

When evaluating how these factors associate with the project findings, it is probable that all of these factors may influence each guideline or practice. However each of these factors will have a greater affect than others concerning each of the guidelines. I believe the most prominent barriers overall are psychological capabilities and motivation. The ability for farmers to process and rationalize complex multifactorial processes concerning nematode control are important aspects to address, particularly in relation concepts such as preserving refugia. The focus group discussions repeatedly highlighted this issue, and therefore supports the requirement to simplify and contextualize the concept in relation to the various circumstances representing UK sheep farming. The added issue of conflicting arguments concerning the legitimacy of employing the 'dose and move' practice has undoubtedly left many farmers in confusion or skepticism. It is therefore necessary to establish a firm, assured position within the industry regarding how to promote future treatment procedures, in order to resolve uncertainty and skepticism among farmers that may be concerned for the possibility of animal production losses.

Another limiting factor regarding the motivation to adopt a number of recommended practices is the lack of clear associative rewards from improved visual indicators, which could be disadvantageous for stimulating positive associative learning responses. Also where a perceived lack of need to implement guidelines has been highlighted, such as regarding improvements to worm control strategies, testing for resistance, preserving refugia and non-chemical worm control approaches. Such internal motivational challenges are suggested to be the most difficult to influence as they relate to many factors such as age, generation, lifestyle, education and character. In such instances external motivation may be better suited to influencing behaviour, particularly in the case of disease control programmes (Jansen et al, 2012).

From each of the behavioural factors previously discussed, various intervention and policy approaches have been proposed to address behavioural change. The R.E.S.E.T model describes five main instruments required to change behaviour which include: Regulation, Education, Social, Economic and Tools (Jansen et al, 2012). Regulation involves enforcing laws and restrictions to make people behave a certain way, this can either work through coercion by adding a cost or punishment to unfavourable behaviour or applying rules to reduce the opportunities to engage in targeted behaviours (Michie et al, 2011). The use of Regulation however can have repercussions for individuals whose infrastructure cannot support the requirements. This is particularly important to consider where a lack of physical opportunity is an issue, such as where isolated farmers may not be able to directly interact with an advisor, or where the expense of seeking veterinary services is prohibitive, such as indicated by farmers in the focus groups in relation to purchasing drug treatments. Therefore, if regulation were enforced such as anthelmintic purchasing restrictions subject to veterinary prescription, such as in countries in Scandinavia and the Netherlands, this would likely be met with strong resistance from many farmers who are either geographically disadvantaged to reach their vet or unable to afford direct veterinary services.

Education is the most commonly used and arguably overemphasized intervention tools used for influencing behaviour change (Jansen et al, 2012), although the effect of education and knowledge has been shown in this study to influence farmer's adoption behaviours. The important consideration is that education should be offered especially in the early stages of professional development i.e. to agricultural students, vet students and training SQP's. This is likely to have the greatest influence on shaping future attitudes and behaviour, as has been indicated from both focus group discussions and model analysis. It is also important to note that farmers as well as advisors may have different learning styles and preferences, which necessitates various approaches to education and knowledge exchange.

The use of different communication strategies have demonstrated effectiveness at different levels of motivation. Jansen et al (2010) used two distinct communication approaches for targeting mastitis control recommendations. The use of both a comprehensive information tool approach ('Central route') based on extensive recommendations supported by scientific reasoning, and a single-practice driven campaign ('Peripheral route') with limited evidence-base were investigated. The findings suggest that each method appealed differently to farmers depending of their level of engagement and motivation. This would advocate the employment of different communication strategies to suit the characteristics of the proposed recommendations. For example where practices are more likely to align with farmer's beliefs and rationales requiring the least persuasion, such as concerning under-dosing practice or the benefits of resistance testing, this is likely to suit the single-practice driven campaign approach. Whereas practices requiring greater explanation and reasoning such as preserving refugia or selective breeding, would better suit the use of more comprehensive informational tools. By using different approaches it is also proposed that can improve the appeal depending on whether users are seeking either a less ambitious, step-by-step approach or those individuals pursuing a more thorough, long-term plan.

Social interaction and social bonding is an important aspect of human nature, as outlined in section 1.15.5. It could therefore be reasoned that the innate need to feel included and compliant with the collective 'norm' as postulated by the social conformism theory, is one if not the most powerful intervention strategies available. The use of important social figures such as highly respected contemporaries, or expert advisors is also able to influence peoples existing beliefs or behaviours, in order to emulate their valued frames of reference. The influence of social norms was evident from the project findings, with reference to the model analysis of individual best practice behaviours (chapter 6), which has also been demonstrated in relation to adoption of parasite diagnostics by cattle producers (Velde et al, 2015). The use of 'model behaviour' examples could be used to engage at different levels, from a large mass media or large agricultural event platforms, to smaller more intimate group discussions. The flock health club initiative (Anonymous, 2016a) is one such example which has shown positive indications at a community level. The use of vet facilitated group discussions, where the costs are shared among participants, has shown to improve relationships between sheep vets and their clients, and may help to address concerns over veterinary expenses as previously mentioned. The use of such advisor-mediated discussion forums may also help farmers and vets to discuss disease control matters including roundworm control, which can be used to help reach a consensus through social constructivism (i.e. the establishment of beliefs and values based on shared knowledge and experiences). Although it is important to note that such approaches may not appeal to all farmers (Jansen et al, 2012).

The use of external motivational interventions such as economic incentives or disincentives can be used to great effect. In the dairy industry, the use of economic incentives has been used in Australia to promote farmers to reduce their bulk milk somatic cell count (BMSCC) by paying a premium below a certain threshold. More commonly a peak BMSCC threshold is also used and a penalty issued by milk processors when the threshold is exceeded (Jansen et al., 2012). The same type of approaches could be adapted to the use of drug treatments including anthelmintics and antibiotics. Alternatively, reducing the cost of disease control services could be favourable to behavioural change. In relation to roundworm control this could include reducing the cost of FEC tests or enabling grants toward electronic drafting systems for large enterprises. However it must also be recognized that such incentives may only encourage farmers with a pre-existing interest or motivation to use such services. As expressed in the focus groups, participants would pay for AR testing if they felt it was necessary. Therefore the use of such economic incentives should not form of the basis for any intervention strategy.

The last of the R.E.S.E.T intervention strategies to consider is ‘Tools’, which relates to the allocation of provisions or procedures in order to improve enablement for individuals to employ the desired behaviour. Such tools may include the introduction of a decision support software as previously discussed, which could help direct farmers to make appropriate, tailorable decisions regarding their roundworm control strategy.

Other approaches could include the use of persuasive methods such as providing free faecal sampling kits when purchasing anthelmintics, as an encouragement to test after treatment. The use of such incentives has been used to considerable effect by pharmaceutical companies such as with the inclusion of a free drenching gun with purchases of anthelmintic. By relating this to AR testing, this may help to prompt a dialogue between prescribers and clients as well as spark an association to consider testing treatment efficacy when purchasing products.

With regard to further sociological research regarding roundworm control strategies, it may be of interest to conduct observational field trial studies based on Lewin's field test approach (1951). This could involve recruiting participants ideally where their current roundworm control strategy are in contrast to best practice. By providing the appropriate guidance, facilities and services required to enact the desired behaviours, ultimately the aim would be to gauge where the new approaches conflict with current beliefs or routines and see how and if participants are able to adjust to the new system. By discussing the views and experiences with participants at regular intervals this would help to evaluate where problems arise and where positive effects are recognized. Such studies may also enable the development of cost-benefit analysis studies to determine a baseline for establishment costs and identify where expenses could be saved to add further incentive to adoption.

Other considerations which may be beneficial toward rationalizing future extension efforts, could include determining which guidelines or practices are most critical in terms of selecting for AR. Could there be a threshold level of practices which could significantly reduce the risk for AR development? Can we prioritize certain practices over others? Or is it necessary to implement all guidelines? Evaluating these questions may help to direct research or consider how future recommendations are delivered, for example by condensing or omitting less essential guidelines. One of the benefits of the current SCOPS recommendations is the divisibility of the guidelines, which allows for partial adoption which is proposed to improve the likelihood of adoption when compared to recommendations requiring full compliance (Vanclay and Lawrence, 1994).

7.1 FINAL THOUGHTS

The problematic nature of promoting innovations which are fundamentally non-commercially driven, is an inherent handicap concerning extension of sustainable roundworm control practices. This issue has also been implicit with non-adoption of other agricultural innovations such as environmental measures (Vanclay and Lawrence, 1994). Nevertheless the importance of AR to the long-term viability of commercial sheep farming necessitates that changes are made to address the key concerns and issues from farmers, who ultimately should be the main beneficiaries of such recommendations. As previously discussed such changes to the format and content of the current SCOPS recommendations need to appeal to the wider farming community. Future recommendations should demonstrate transparent benefits and practical applications in order to sustain long-term positive behavioural change. The importance of veterinarians as a highly-trusted information resource validates the need to improve engagement of veterinarians concerning sustainable parasite control approaches to facilitate collaboration with farmers. The need for interaction between farmers and their advisors is key to resolving the issues raised to enable the necessary explanation, justification and execution of recommended practices to suit farmer's needs and farming conditions. Finally, by involving primary stakeholders in the recommendation development process as proposed by modern extension approaches, this is likely to engender a collaborative and concerted effort which is critical to development within the agricultural industry as expressed by one such farmer:

> *'What I would like to say is congratulations to yourselves for opening us to information for us individual farmers around the table. Because in the past like around here farmers get a lot of criticism for this wormer resistance and stuff like that. And for you lads to get us around the table shows us a little respect towards us and our opinions, but it also shows us a little respect towards you lads for the work you are trying to do, so cheer up... Keep going on for what you're doing, but involve the farmers at every juncture if you can'.*

Table 52 - Proposed barriers and targets in relation to the SCOPS guidelines

SCOPS Guidelines	Overarching barriers	Possible targets for future SCOPS extension
Work out a control strategy with your veterinarian or advisor	• Lack of perceived need to change • Complexity of recommendations • Conflicting roundworm control advice • Lack of proactivity/engagement among veterinary advisors	• Reforms to recommendations (benefits, complexity, flexibility) • Improve awareness, engagement and motivation of all stakeholders (veterinarians, SQP's, agricultural merchants etc.) through e.g. early career education, CPD. • Elevate risk perceptions towards AR whilst offering assurances to farmers.
Use effective quarantine strategies to prevent the importation of resistant worms in introduced sheep and goats	• Resource requirements (time/labour/facilities) • Extensive quarantine procedures	• Market risks for introduction of AR with incoming stock • Simplify the number of quarantine processes, help to make process more efficient.
Test for Anthelmintic Resistance (AR) on your farm	• Lack of perceived risk • Reluctance to discover problem/crisis • Stigma associated with AR	• Elevate risk perceptions towards AR whilst offering assurances to farmers to reduce stigma towards AR and promote proactivity to test. • Persuasive methods for promoting testing such as financial incentives, distribution of testing kits with anthelmintic purchases.
Administer anthelmintics effectively	• Resource requirements (time/labour/facilities) • Lack of perceived need to change	• Campaigns against improper dosing practices • Propose government incentives/grants for affordable weighing facilities

Table 52 - Proposed barriers and targets in relation to the SCOPS guidelines

SCOPS Guidelines	Overarching barriers	Possible targets for future SCOPS extension
Use anthelmintics only when necessary	• Efficiency of FEC process • Practicality of sampling • Trust in testing procedure	• Promoting a proactive mind-set to test may help towards the issue of time and efficiency. • Promote cost/benefits from monitoring FEC • Using instructional training formats to teach procedures
Select the appropriate anthelmintic for the task	• Perceived necessity to use combination and long-acting treatments • Affordability of agricultural merchants vs. veterinarians	• Promote the lack of necessity to use combinations/long-acting anthelmintics unless needed. • Encourage vets to be more proactive in terms of recommending anthelmintics to farmers as part of flock health planning.
Adopt strategies to preserve susceptible worms on the farm	• Complexity of concept and practice • Conflicting advice • Perceived need	• Utilise different knowledge transfer formats to improve education of refugia concept. • Campaign to increase risk perception regarding dose and move practice among farmers and vets.
Reduce dependence on anthelmintics	• Impact on production • Complexity • Lack of perceived need • Conflicting advice	• Focus attention on most likely achievable non-anthelmintic control methods (i.e. grazing management, bioactive forages) • Promote more specialist roundworm control methods (selective breeding, targeted selective treatment) to those with the inclination and resources to do so.

APPENDIX 1: FRAMEWORK ANALYSIS OF FOCUS GROUP DATA IN RELATION TO THE SCOPS GUIDELINES

SCOPS Guideline 1- Working out a control strategy				
Discussion themes	**Focus group meetings**			
Why Change?	**Group 1**	**Group 2**	**Group 3**	**Group 4**
AR not an issue	✓		✓	
Current strategy working	✓	✓	✓	✓
New anthelmintics	✓			
Profitability of worm control	✓			
Importance of sheep to enterprise		✓	✓	
Risk/gains from changes to worm control				✓
Sustainable worm control extension	**Group 1**	**Group 2**	**Group 3**	**Group 4**
No prescriptive advice			✓	
No definitive advice	✓		✓	✓
Conflicting advice between advisors	✓	✓	✓	✓
Complexity	**Group 1**	**Group 2**	**Group 3**	**Group 4**
Understanding of principles	✓	✓	✓	✓
Too many components		✓		
Implementing advice	**Group 1**	**Group 2**	**Group 3**	**Group 4**
Guidelines not applicable to all farms	✓			✓
Has to suit workload of the farm			✓	✓

Implementing advice	Group 1	Group 2	Group 3	Group 4
Requires tailoring to specific farm				✓
SCOPS Guideline 2 - Implementing a quarantine strategy				
Discussion themes	**Focus group meetings**			
Treat and quarantine	**Group 1**	**Group 2**	**Group 3**	**Group 4**
Prevent disease introduction (notably scab)	✓	✓	✓	
Routine treatments – maintain system	✓	✓		
Accreditation requires it		✓		✓
No quarantine	**Group 1**	**Group 2**	**Group 3**	**Group 4**
Keeping animals of pasture		✓	✓	
Urgency to introduce tup/bull				✓
Less important to quarantine sheep				✓
Reliable purchasing information				✓
No action	**Group 1**	**Group 2**	**Group 3**	**Group 4**
Reliable purchasing information				✓
SCOPS Guideline 3 - Testing for resistance				
Complexity	**Group 1**	**Group 2**	**Group 3**	**Group 4**
Testing each drug against each species			✓	
Awareness	**Group 1**	**Group 2**	**Group 3**	**Group 4**
Sampling protocol	✓		✓	
Knowledge of the test				✓

Avoiding confirmation	**Group 1**	**Group 2**	**Group 3**	**Group 4**
'Don't want to find out what you're doing isn't working'			✓	
No perceived need	**Group 1**	**Group 2**	**Group 3**	**Group 4**
Unless you have a crisis you may not perceive a need'	✓		✓	
Knowledge transfer	**Group 1**	**Group 2**	**Group 3**	**Group 4**
'Think the message isn't get out to those who should be testing'			✓	
Testing for AR	**Group 1**	**Group 2**	**Group 3**	**Group 4**
'If you don't know you have it, you can't do anything to stop it'	✓		✓	
SCOPS Guideline 4 - Administering effectively				
Discussion themes	**Focus group meetings**			
Dosing rates	**Group 1**	**Group 2**	**Group 3**	**Group 4**
'Weight can be a bad guide'		✓	✓	✓
Dosing guns	**Group 1**	**Group 2**	**Group 3**	**Group 4**
Concerns about free dosing guns	✓		✓	
Difficult to maintain				✓
SCOPS Guideline 5 - Administer only when necessary				
Trust in test	**Group 1**	**Group 2**	**Group 3**	**Group 4**
Concern of representativeness of sampling			✓	
Useful tool for decision-making		✓		✓

Concern of leaving animals untreated		✓		✓
Test gives a snap-shot of burdens	✓	✓		
Practicality of test	**Group 1**	**Group 2**	**Group 3**	**Group 4**
Efficiency of the procedure (sample, send, response)			✓	
Good response time	✓	✓		✓
Treating animals is easier than getting a FEC			✓	
SCOPS Guideline 6 - Selecting the appropriate anthelmintic				
Discussion themes	**Focus group meetings**			
Combination treatments	**Group 1**	**Group 2**	**Group 3**	**Group 4**
Expense of using 2 products rather than 1		✓	✓	
Cuts down on labour/time				✓
Persistent treatments	**Group 1**	**Group 2**	**Group 3**	**Group 4**
Used for scab	✓	✓	✓	
Used for lambs		✓	✓	✓
Used for ewes at lambing		✓		✓
SCOPS Guideline 7 - Preserving susceptible worms				
Knowledge exchange	**Group 1**	**Group 2**	**Group 3**	**Group 4**
Conflicting advice – Dose and move practice	✓	✓	✓	✓
Awareness and complexity	**Group 1**	**Group 2**	**Group 3**	**Group 4**
Refugia concept		✓	✓	✓

Practicality	**Group 1**	**Group 2**	**Group 3**	**Group 4**
Moving treated animals onto old grazing		✓	✓	✓
SCOPS Guideline 8 - Reducing dependence on anthelmintics				
Discussion themes	**Focus group meetings**			
Impact on production	**Group 1**	**Group 2**	**Group 3**	**Group 4**
Productivity of using bio-active forages	✓			
Fear of losing productivity without using wormers				✓
Availability of clean grazing	✓	✓		✓
Selective breeding	**Group 1**	**Group 2**	**Group 3**	**Group 4**
Positive views towards selective breeding for developing resistance in animals		✓		✓
Grazing management	**Group 1**	**Group 2**	**Group 3**	**Group 4**
Using mixed stock grazing management	✓	✓		
Rotational grazing		✓		
General worm control attitudes –Framework analysis				
Deciding when to treat	**Group 1**	**Group 2**	**Group 3**	**Group 4**
Stockmanship skills	✓	✓	✓	✓
If you have a hold of them, then you dose them			✓	
Pre-tupping treatment (Performance boost)		✓	✓	✓
Biggest causes of wormer resistance	**Group 1**	**Group 2**	**Group 3**	**Group 4**
Bad worming technique	✓			

Discussion themes	**Focus group meetings**			
Biggest causes of wormer resistance	**Group 1**	**Group 2**	**Group 3**	**Group 4**
Under-dosing	✓			✓
High stocking density/low grazing availability	✓	✓		
AR inherited from past generation	✓	✓		
Purchasing anthelmintics	**Group 1**	**Group 2**	**Group 3**	**Group 4**
Vets need to be more competitive on price	✓		✓	✓
Internet used				✓
Favoured Information formats	**Group 1**	**Group 2**	**Group 3**	**Group 4**
Paper format	✓			✓
Email	✓			
NADIS format	✓	✓		
Social media				
Online				✓
Knowledge exchange	**Group 1**	**Group 2**	**Group 3**	**Group 4**
Monitor farms/farm meetings		✓	✓	✓
How to get message out to those who don't attend?	✓	✓	✓	
Farms with a low priority for sheep		✓	✓	

APPENDIX 2: ATTITUDINAL/BEHAVIOURAL SURVEY OPT-OUT LETTER

Moredun Research Institute
Pentlands Science Park
Bush Loan
Penicuik, near Edinburgh
EH26 0PZ
Scotland, UK
Tel: +44 (0)131 445 5111
Fax: +44 (0)131 445 6111
Corin.Jack@moredun.ac.uk
Dave.Bartley@moredun.ac.uk
Emily.Hotchkiss@moredun.ac.uk
www.moredun.ac.uk

11th November 2014

Dear «Exc_Name»

Roundworm control survey 2014

At Moredun Research Institute (MRI) we are dedicated to improving the help and advice available to you, in a way that best suits your needs. In order to help achieve this we are conducting a survey of Scottish sheep farmer's attitudes and behaviours towards roundworm control and 'best practice' advice. This survey has the support of the Scottish Government and aims to ask your opinions on the benefits and limitations of using best practice advice for reducing the development and impact of wormer resistance in sheep flocks. The information you provide will help to inform future recommendations to improve the way you can tackle the risk of wormer resistance.

Moredun wish to canvass the thoughts and feelings in the farming community and this is an opportunity for your opinions to be registered. We are asking for you to join in a voluntary telephone questionnaire, which should take around 20 minutes. We understand that your time is precious, however your input is vital to us. Most questions ask only if you agree or disagree with the statement made. All information will be anonymised in any subsequent reports or publications and that you and your farm will never be individually identifiable. This letter is being sent in Scotland using an address list maintained by the Scottish Government.

If you do not wish to participate please return the form below, in the reply paid envelope provided, within one week and give your County Parish Holding number (CPH number) so that you are excluded.

Thank you for your consideration concerning this work. If you are interested in this subject or have any queries regarding the survey please contact one of us using the details above.

Yours sincerely,

Corin Jack

I do not wish to participate:

Name: ....

CPH number _ _/_ _ _/_ _ _ _

APPENDIX 3: ATTITUDINAL/BEHAVIOURAL QUESTIONNAIRE SCRIPT

Farmer roundworm control survey
Interviewer script

Hello, may I please speak to ________

My name is _______ and I am calling on behalf of the Moredun Research Institute. Thank you for agreeing to answer questions to get your thoughts on roundworm control. The questions should take about 20 minutes to answer and all the information you provide will be kept confidential. There are no right or wrong answers and you can feel free to decline any of the questions.

Are you free to answer the questions now?

✓ Yes? Follow onto section 1
✗ No? Try to arrange another time/date Date: _______ Time: _______

I would like to begin by getting some details about yourself and your farm:

Q1	**What is your age?**	18-35 ☐ 36-50 ☐ 51-65 ☐ Over 65 ☐
Q2	**Did you attend a place of further education?**	No ☐ Yes; Agricultural college ☐ Yes; University ☐ Yes; other please state............................
Q3	**How many years have you been earning a living as a farmer?**	10 years or less ☐ 11-20 ☐ 21-30 ☐ 31- 40 ☐ 41-50 ☐ 50+ ☐
Q4	**Is your flock a commercial, pedigree or a mixture of both?**	Commercial ☐ Pedigree ☐ Both ☐
Q5	**Is your sheep enterprise organic accredited?**	Yes ☐ No ☐
Q6	**Do you introduce new sheep onto the farm?** **Yes, Ewe lambs, gimmers, adults ewes or rams/tups?**	No ☐ yes ☐ Ewe lambs ☐ Gimmers ☐ Adults ewes ☐ Rams/tups ☐
Q7	**Is your farm: sheep only? Mixed stock? Or arable?**	Sheep only ☐ Mixed stock ☐

		Livestock and arable ☐
Q8	**Out of those, which is the priority on your farm?**	Sheep ☐ Other livestock ☐ Arable ☐ Equal Importance ☐
Q9	**Is your sheep enterprise a breeder or finisher enterprise or a mixture of both?**	Breeder ☐ Finisher ☐ Both ☐
Q10	**Is your farm designated as lowland, upland or hill?**	Lowland ☐ Upland ☐ Hill ☐
Q11	**Who primarily plans your roundworm control?**	Myself ☐ Farm staff/manager ☐ Animal health advisor (Vet, SQP etc.) ☐ Other? Please specify.........................

Thank you, I am now going to ask you a series of questions about roundworm control and wormer resistance to which I need the response strongly agree (SA), agree (A), are unsure (U), disagree (D) or strongly disagree (SD).

Is that OK? ✓ Yes - Follow onto next section
× No - Repeat (using the first statement as an example)

	SA	A	U	D	SD
12) Roundworm control is important on my farm	○	○	○	○	○
13) My roundworm control strategy improves the productiveness of my animals	○	○	○	○	○
14) Roundworm control is important for the profitability of my farm	○	○	○	○	○
15) Roundworm control is important for the health & welfare of my animals	○	○	○	○	○
16) I am doing all I can to control roundworms in my flock	○	○	○	○	○
17) My current worm control strategy is working	○	○	○	○	○
18) I am confident in my ability to detect problems associated with roundworms	○	○	○	○	○
19) I make time to implement practices that could improve my roundworm management	○	○	○	○	○
20) It is important to keep up to date on how best to control roundworms	○	○	○	○	○
21) In comparison to other diseases the control of roundworms ranks highly in my flock	○	○	○	○	○
22) The introduction of new wormers will be crucial for future roundworm control	○	○	○	○	○
23) Farmers rely too heavily on wormers	○	○	○	○	○
24) Wormer resistance is a problem in my region	○	○	○	○	○
25) Wormer resistance is a threat to my farming business	○	○	○	○	○
26) Monitoring for wormer resistance is important to the sheep	○	○	○	○	○

	farming industry as a whole					
27)	**I could live with wormer resistance on my farm**	○	○	○	○	○
28)	**The development of wormer resistance on my farm is out of my control**	○	○	○	○	○

I would now like to ask you a few open ended questions before we move onto the main section

Q 29 (A) Could you give me any examples of types of roundworms you may know of?

Unsure ☐

Q29 (B) What do you understand by the term wormer resistance?

Unsure ☐

Q29 (C) Besides using wormer treatments, do you know anything else you can do to help control worms on your farm?

Unsure ☐

Thank you for that. We now come to the main section, we would like to know what you think about the use of recommended roundworm control practices, starting with working out a roundworm control strategy. Again this just needs the response strongly agree (SA), agree (A), are unsure (U), disagree (D) or strongly disagree (SD).

	SA	A	U	D	SD
30) I have a good working relationship with my vet	O	O	O	O	O
31) Working with my vet could improve my roundworm control strategy	O	O	O	O	O
32) Working out a roundworm control strategy with my vet is cost effective	O	O	O	O	O
33) Working out a roundworm control strategy with my vet ensures I get reliable advice	O	O	O	O	O
34) Roundworm control advice provided by vets is too complex	O	O	O	O	O
35) Roundworm control advice provided by vets is difficult to implement	O	O	O	O	O
36) My vet is keen to discuss roundworm control	O	O	O	O	O
37) I can find time to discuss roundworm control with my vet	O	O	O	O	O
38) Different advisors provide conflicting roundworm control advice	O	O	O	O	O
39) Keeping wormers restricted to veterinary prescription promotes responsible usage	O	O	O	O	O

Now some statements on treating incoming sheep

	SA	A	U	D	SD
40) Returning or new sheep pose a risk of introducing wormer resistance onto my farm	O	O	O	O	O
41) I am worried about bringing wormer resistance onto my farm	O	O	O	O	O
42) Worming incoming sheep is important for the long-term health of my flock	O	O	O	O	O
43) Implementing a good quarantine strategy for roundworms is achievable on my farm	O	O	O	O	O
44) Treating incoming sheep with wormers is cost effective	O	O	O	O	O
45) I don't have time to quarantine incoming animals on my farm	O	O	O	O	O
46) I don't have the facilities to separate incoming animals from the main flock	O	O	O	O	O
47) I find the quarantine advice for roundworm control is too complicated	O	O	O	O	O
48) Advice is conflicted regarding best quarantine practice	O	O	O	O	O

The next statements will cover testing for wormer resistance

	SA	A	U	D	SD
49) Testing wormer effectiveness is important to inform future treatments	O	O	O	O	O

50) Unless I saw an impact on productivity, I would not feel the need to test for wormer resistance	○	○	○	○	○
51) Unless I saw scouring or ill thrift, I would not feel the need to test for wormer resistance	○	○	○	○	○
52) Good wormer efficacy has a positive impact on production in my animals	○	○	○	○	○
53) Detecting wormer resistance early is important	○	○	○	○	○
54) I am confident in my ability to detect problems associated with wormer failure	○	○	○	○	○
55) Testing for wormer resistance is expensive	○	○	○	○	○

The next set of statements will focus on monitoring worm egg counts

	SA	A	U	D	SD
56) Worm egg count monitoring is useful for determining the need to treat	○	○	○	○	○
57) Deciding when to treat animals for roundworms is difficult	○	○	○	○	○
58) Reducing wormer usage would have a negative impact on productivity	○	○	○	○	○
59) Monitoring worm egg counts can improve animal productivity	○	○	○	○	○
60) Monitoring worm egg counts can optimise treatment timings	○	○	○	○	○
61) Monitoring worm egg counts is achievable in my farming system	○	○	○	○	○
62) Collecting samples for worm egg counts is too time consuming	○	○	○	○	○
63) It isn't practical to collect faecal samples from my flock for worm egg counts	○	○	○	○	○
64) Using regular worm egg counts to decide when to treat is cost-effective	○	○	○	○	○
65) Reporting of worm egg count results is too slow to be useful on my farm	○	○	○	○	○

The next set of statements will be on the selection of different types of wormers

	SA	A	U	D	SD
66) Combination worm and fluke treatments should only be used under advice from vet or advisor	○	○	○	○	○
67) Long acting wormers are better at controlling roundworms than short acting wormers	○	○	○	○	○
68) The use of long acting wormers around lambing is beneficial for productivity	○	○	○	○	○
69) Treating ewes for roundworms around mating time improves their condition	○	○	○	○	○
70) Combination fluke and worm treatments are cost-effective when compared with separate treatments	○	○	○	○	○
71) Combination fluke and worm treatments give me peace of mind regarding parasite control	○	○	○	○	○
72) The use of long-acting wormers gives me more time to do other	○	○	○	○	○

things					
73) It is difficult to know which wormers are appropriate at different times of year	○	○	○	○	○
74) Advertising campaigns influence my choice of wormer	○	○	○	○	○

The next few statements will focus on grazing management following wormer treatment

	SA	A	U	D	SD
75) Moving treated animals to clean grazing will reduce the number of treatments required later in the same season	○	○	○	○	○
76) Moving treated animals to clean grazing improves animal productivity in the same season	○	○	○	○	○
77) I understand why we are advised to move treated animals back onto their old grazing after treatment	○	○	○	○	○

The last statements in this section will ask about alternative approaches to roundworm control

	SA	A	U	D	SD
78) Wormers should be integrated with other roundworm control approaches	○	○	○	○	○
79) Optimising grazing management is important for roundworm control	○	○	○	○	○
80) I am confident I could improve my grazing management	○	○	○	○	○
81) Grazing management to control roundworms is too complex to implement	○	○	○	○	○
82) It is simpler to use a wormer than to implement a grazing management strategy	○	○	○	○	○
83) Well-nourished sheep do not suffer from roundworms					
84) I think it's possible to 'live with worms' and have productive animals	○	○	○	○	○
85) Targeting wormer treatments based on live weight gains would be achievable on my farm	○	○	○	○	○
86) Leaving a number of animals untreated for roundworms is counterproductive	○	○	○	○	○
87) Electronic drafting systems are too expensive	○	○	○	○	○
88) Electronic drafting systems are too difficult to use	○	○	○	○	○
89) Selective breeding programmes can reduce the need for wormer treatments	○	○	○	○	○
90) Selective breeding programmes are too complex to implement	○	○	○	○	○
91) Selective breeding programmes are worthwhile in the long-term	○	○	○	○	○

Thank you for that. Now regarding roundworm control who do you feel influences you most? For example other farmers, your vet, your animal health supplier (insert one response…………………………………………………..)

With that choice in mind please answer the following statements with strongly agree (SA), agree (A), disagree (D) strongly disagree (SD) or unsure (U).

	SA	A	U	D	SD
92) They would expect me to have a quarantine strategy against roundworms	○	○	○	○	○
93) Their opinion of my quarantine strategy is important to me	○	○	○	○	○
94) They would advise me to test my flock for wormer resistance	○	○	○	○	○
95) They would expect that I should know the wormer resistance status of my flock	○	○	○	○	○
96) They would want me to monitor worm egg counts before treating animals	○	○	○	○	○
97) Their opinion of my treatment strategy is important to me	○	○	○	○	○
98) Their opinion of my choice of wormers is important to me	○	○	○	○	○
99) They would advise me not to move treated animals directly onto clean grazing	○	○	○	○	○
100) Their opinion of my treatment frequency is important to me	○	○	○	○	○
101) They would advise me to adopt alternative roundworm control strategies	○	○	○	○	○

Finally, it would be helpful to know what your roundworm control practices are in the following questions:

Q102	**In the last 12 months how often have you sought advice specifically regarding roundworm control?**	Never ☐ Once a year ☐ Twice a year ☐ More often ☐ Other ☐
Q103	**How would you classify the occurrence of roundworm problems in your flock? Low, Moderate or High?**	Low ☐ Moderate ☐ High ☐
Q104	**In the last 12 months how many times have you treated your ewes and lambs for roundworms?**	Ewes _____ Lambs ______
Q105	**Do you monitor worm egg counts?**	No ☐ Once or twice ☐ More frequently ☐
Q106	**Do you drench incoming sheep brought onto the farm?**	No ☐ Yes ☐ Occasionally ☐
Q107	**Do you withhold incoming sheep from pasture?** **Yes, If so how long?**	No ☐ Yes ☐ Less than 24 hours ☐ 24 to 48 hours ☐ longer☐
Q108	**What class or classes of wormer did you use in the last 12 months?**	Unsure ☐ None ☐ Class 1 (White) ☐ Class 2 (Yellow) ☐

		Class 3 (Clear) ☐ Class 4 (Orange) ☐ Class 5 (Purple) ☐
Q109	**Do you suspect you have any resistance on your farm?**	No ☐ Yes: Class 1 ☐ Class 2 ☐ Class 3 ☐
Q110	**Have you ever tested for drug resistance?**	No ☐ Yes: Class 1 ☐ Class 2 ☐ Class 3 ☐
Q111	**Do you have confirmed drug resistance?**	No ☐ Yes: Class 1 ☐ Class 2 ☐ Class 3 ☐
Q112	**Do you use long-acting wormers?** **If yes, what do you use and when?**	Unsure ☐ No ☐ Yes ☐ ___________________ Lambing time ☐ Weaning ☐ Mating ☐ Housing ☐
Q113	**Do you use combination fluke and worm treatments?** **If yes, what do you use and when?**	Unsure ☐ No ☐ Yes ☐ ___________________ Lambing time ☐ Weaning ☐ Mating ☐ Housing ☐
Q114	**Do you move your lambs to new pasture after weaning?** **Yes, is it clean grazing, dirty grazing or unsure?**	No ☐ Yes☐ Clean grazing? ☐ Or dirty grazing? ☐ Unsure ☐
Q115	**Do you graze sheep and cattle together, graze separately or rotate grazing between the two?**	Sheep grazed separately ☐ Rotationally graze ☐ Co-graze ☐
Q116	**Do you move your animals immediately to clean pasture after treatment?**	No ☐ Occasionally ☐ Always ☐
Q117	**Do you use selective breeding for roundworm control in your flock?**	No ☐ Yes☐
Q118	**If you use EID (Electronic identification) do you use this to monitor productivity?**	No ☐ Yes ☐
Q119	**Do you treat whole groups of animals or individuals within the group?**	Whole group ☐ Select individuals ☐
Q120	**What would be your preferred method of accessing information regarding roundworms?**	Direct communication (In person, telephone) ☐ Paper articles (Magazines, newsletters, leaflets) ☐ Online articles/publications ☐ Online video clips/Podcasts/webinars/television ☐ Social media ☐ Other? ....
Q121	**What difficulties have you encountered getting information of diseases and their control?**	No problems ☐ Lack of effective communication ☐ Too much information ☐ Lack of information ☐ Lack of time (high workload) ☐ Lack of knowledge ☐

		Too few sources of information ☐ Poor communication formats ☐ Other?........................

That is the last question of the survey. Would you like to be informed of any future results from the survey?

Yes ☐ Do you have an email address? ________________________________.

No ☐

Thank you very much. We greatly appreciate your time today.

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