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A quantitative analysis of attitudes and behaviours concerning sustainable parasite control practices from Scottish sheep farmers

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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.

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 et al., 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 et al., 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, 2016) 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 & 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.

Material and methods

Model framework

Attitudinal questionnaire items were initially devised based on a range of different source material. Questions came from a combination of common themes highlighted from farmer focus group meetings (unpublished data), 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 such as the Health belief model (HBM) which has been used to explain and predict preventive health behaviours (Rosenstock et al., 1988). Such items derived from this model include 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 combination of these risk items is referred to as 'risk perception' and was incorporated into the general attitudes section of the questionnaire. Figure 1 illustrates the model framework used in this paper to examine the influence of general roundworm control and AR attitudes and farming demographic influences on the overall uptake of SCOPS and known AR selective practices.

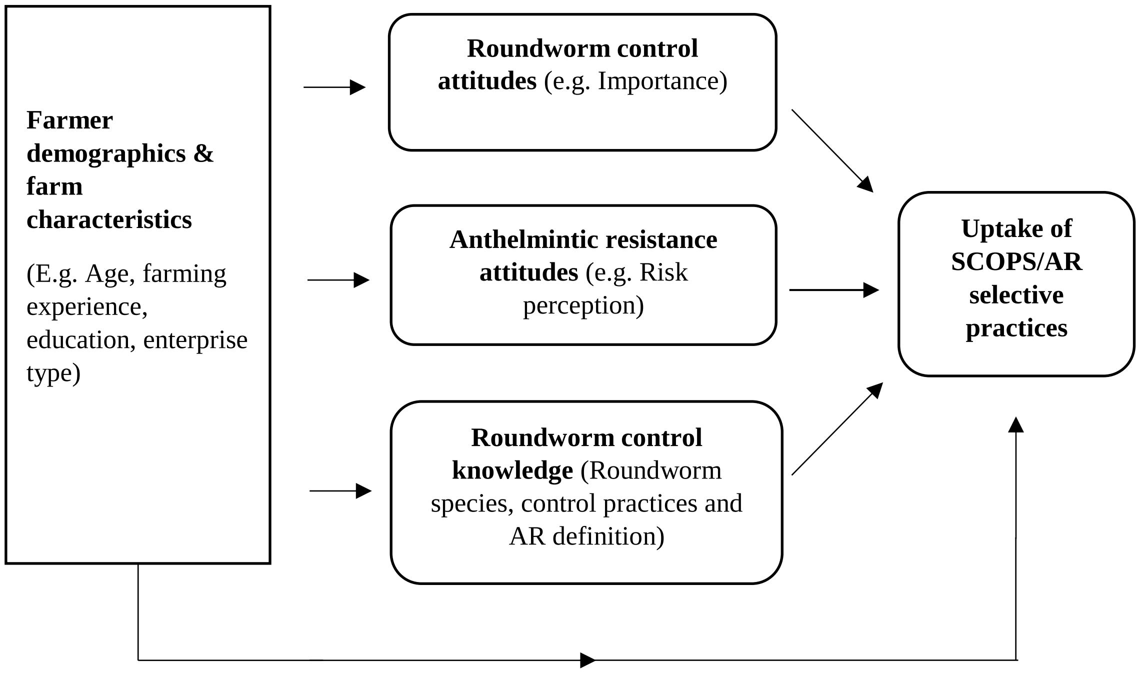


Fig.1. Theoretical framework for general uptake of SCOPS recommended and AR selective roundworm control practices

Quantitative attitudinal survey design

The survey design was informed from the model framework (Figure 1) and built around four main components which were arranged in the following order; 1) farmer demographics and enterprise characteristics, 2) general roundworm control/AR attitude statements, 3) open-ended roundworm control knowledge questions and 4) 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 (e.g. enterprise type, flock size, land topography, farming priorities). 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, Attitudes to veterinary service 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 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 were measured on a 5-point-Likert scale: Strongly Disagree (1), Disagree (2), Unsure (3), Agree (4) and Strongly Agree (5). Sections 1 and 4 were recorded by interviewers based on a pre-determined coding frame.

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 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. The sampling frame was further stratified regionally by animal health divisional office (AHDO) in order to ensure a proportional population sample from each region. 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)

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

Opt-out letters were sent out to farmers two weeks prior to the implementation of the survey. The letters 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.

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.) and responses were documented by the interviewer and compiled on a Microsoft Excel spreadsheet. All interviews were conducted under internal quality assurance procedures using computer assisted telephone interviewing systems. 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.

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). The data was then assessed for normality using the Kolmogorov-Smirnov statistical test. All variables included in the analysis were recorded as per the original coding frame detailed in Table 2, 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 continuous 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 or 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.

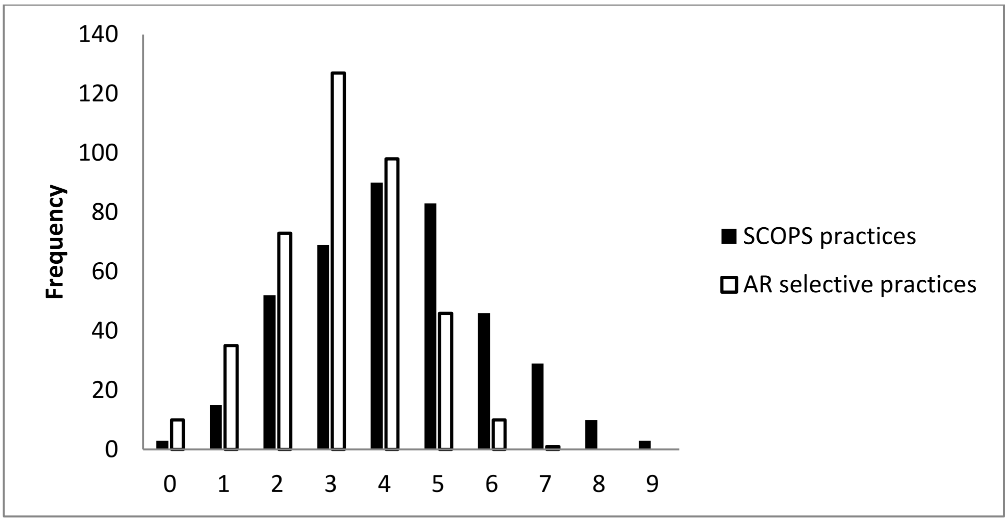
The endogenous i.e. dependent variables ('SCOPS practice uptake' & 'AR selective practice uptake') were formulated into ordinal scores by summating the total number of practices that were identified as either 'best practice' or selective for AR development based on the SCOPS manual (Abbot et al., 2012). The designation of AR selective practices was based on the selection of behaviours which were converse to best practice approaches, also which were 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 1 presents the descriptive statistics of the practices used to formulate both outcome variables (i.e. SCOPS and AR selective practices) and figure 2 presents the frequency distributions of the outcome variables.

Table 1.

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*)	90	23	Ewes (> average*)	172	43
	Lambs (< average†)	66	17	Lambs (> average†)	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? ‡	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
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	-	-	-

*Ewe treatment average (2) † lamb treatment average (2) ‡ results exclude closed flock farms (*n* = 77)



Fig, 2 - Total number of SCOPS (filled bars) and AR selective (open bars) practices employed by respondents (*n* = 400)

Statistical analysis

<u>Factor analysis</u>

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.

<u>Structural equation modelling</u>

In order to examine the inter-relationships between the observed and unobserved (latent) variables in the proposed theoretical model (as represented in Figure 1), the analysis was performed using the multivariate analysis technique known as Structural Equation Modelling (SEM). This technique comprises of 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 explanatory 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).

Results

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 2

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?	0.764	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	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	Categorical
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	Ordinal
Worm control knowledge	Knowledge score	NA	0 = none correct; 1 = one correct; 2 = two correct; 3	Ordinal

			= three correct	
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
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
SCOPS practice uptake	Number of SCOPS practices implemented	NA	0 = none; 1 = one; 2 = two;, 3 = three; 4 = four; 5 =	Ordinal

			five; 6 = six; 7 = seven; 8 = eight; 9 = nine; 10 = ten	
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

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 2. The exploratory factor analysis established acceptable factor loadings i.e. > 0.70 for all multiple-indicator latent variables (Presented in Appendix A). Additionally, the Cronbach alpha reliability analysis shown in Table 2, demonstrated suitable measures (α = >0.60) between all sets of indicators with the exception of 'AR risk'.

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 3 and 4. An illustrated version of the direct influences on SCOPS practice uptake model is presented in Figure 3; 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’ (β = 0.55) followed by ‘Enterprise type’ (β = 0.30), ‘AR risk’ (β = 0.21) and ‘Vet service pro’ (β = 0.20). The greatest indirect positive influence on SCOPS uptake was ‘Worm control knowledge’ (β = 0.34) mediated by ‘AR confirmation’ (β = 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’ (β = 0.43) and a moderate effect on ‘Occurrence of worm problems’ (β = 0.20). In addition to ‘Education’ with a positive effect on ‘AR risk’ (β = 0.31) and ‘Worm control importance’ with a positive influence on ‘Vet service pro’ (β = 0.36). Factors which demonstrated a negative influence on SCOPS uptake through mediating factors included ‘Experience’ on ‘AR risk’ (β = -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 ‘Typography’ (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).

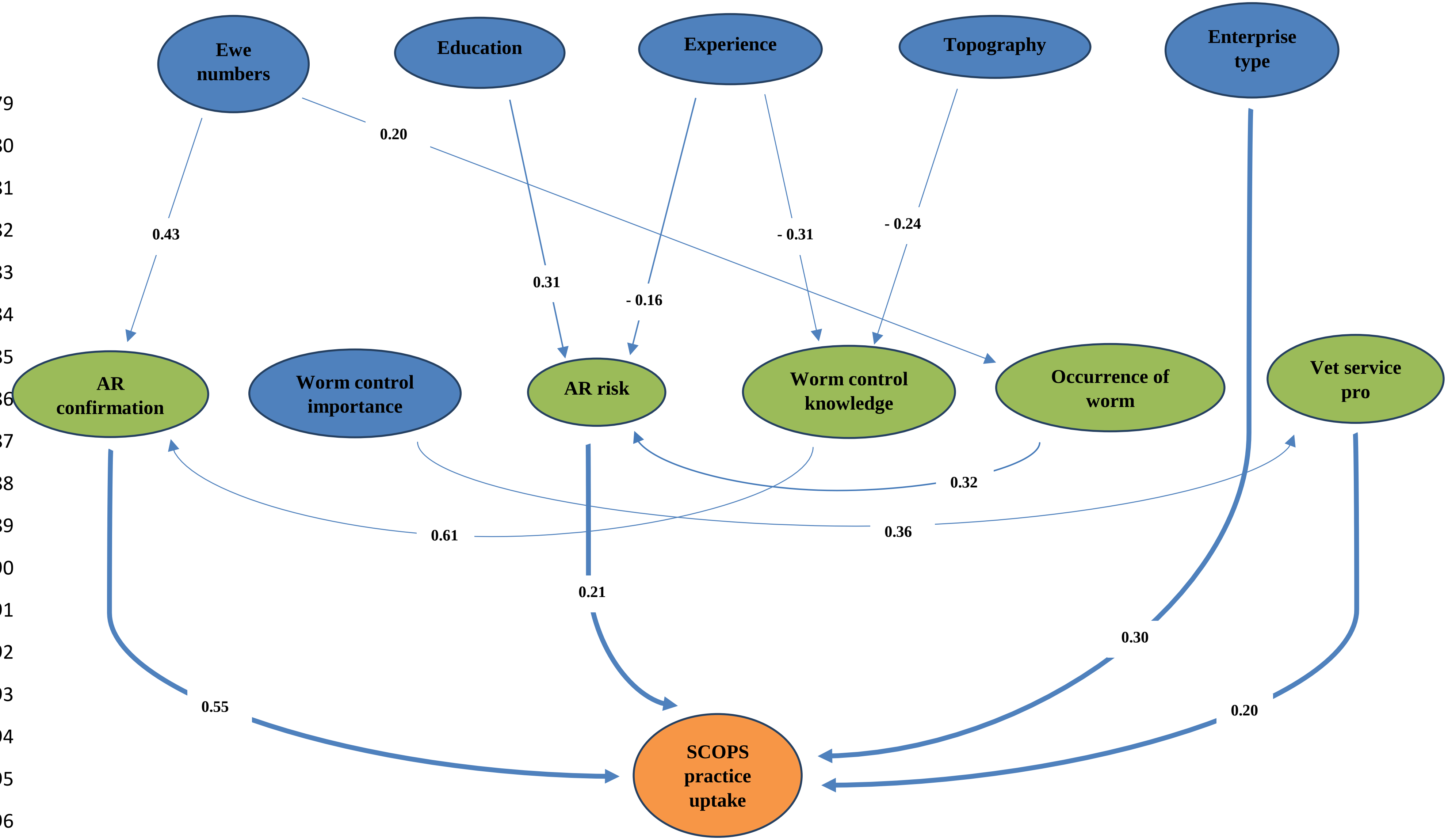


Fig.3. SCOPS uptake structural model (standardised solution). Bold arrows represent the direct influences of latent variables on the behavioural latent ‘SCOPS practice uptake‘, with non- bold arrows representing the direct effect influences on other latent variables. The corresponding numbers are the 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 3.

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

	Total (direct and indirect) effects on effector 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 4.

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

	Total (direct and indirect) effects on effector variables						
Determinants	'AR selective practice uptake'	'AR Confirmation'	'Worm control Importance'	'AR risk'	'Worm control knowledge'	'Occurrence of worm problems'	'Vet servic e 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	-

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, 2016). 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, 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 knowledge. An agricultural college education was shown to positively influence AR risk perception whereas experience was shown to negatively influence numerous factors including 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). This concept of self-identity in relation to the importance of farmers own abilities to identify problems poses a likely barrier towards more experienced farmers seeking external guidance regarding roundworm control (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.

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.

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Conflict of interest

None

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