The Parasitology Action Plan for Wales
2011

An action plan for the Welsh sheep and beef industry
Foreword by HCC Chairman – Mr Dai Davies

One of the biggest challenges facing sheep and beef farmers not only in Wales and the UK but across the globe is parasitic infections.

Changing trends in parasitic disease, possibly driven by climate change, mean that farmers must remain alert to the economic effects that this could cause to their individual businesses as well as the industry as a whole.

This important topic deserves our detailed attention, which is why I’m pleased to introduce this new Parasitology Action Plan for Wales.

The long-term vision that drives this strategy is to maintain sustainable sheep and beef industries in Wales which have so far successfully avoided the devastating economic and welfare consequences that the diseases bring.

A tremendous amount of work had gone into the preparation of this strategy, and I must pay credit to those responsible. The report has been produced by Hybu Cig Cymru – Meat Promotion Wales on behalf of the Parasitology Steering Group for Wales. The report was compiled by ADAS through funding provided by the Rural Development Plan for Wales.

This is a valuable reference work which I would recommend to all those with an interest in sheep and beef farming in Wales.
Parasitology Action Plan for Wales 2011

Executive Summary

Parasitic gastroenteritis continues to cause worldwide production losses in sheep and cattle. Parasite control has been, and is currently seen as a greater issue to the sheep industry than the beef industry in the UK in terms of both cost and control.

Routine monthly dosing with anthelmintics through the grazing season has been common practice for many years on most sheep farms, largely due to low cost and availability of anthelmintics. Modern (Sustainable Control of Parasites in Sheep, SCOPS) strategies also need to consider anthelmintic resistance and thus can appear to contradict techniques that were considered best practice 30 years ago. Farmers are finding it difficult to adapt and move away from dosing regimes that were successful in the past.

While there are numerous anthelmintics available on the market, confusion arises on which of the anthelmintic classes they belong to. There are currently four anthelmintic groups; benzimidazole (BZ), levamisole (LM), macrocyclic lactone (ML) and the recently released amino acetonitrile derivative (AD). Excessive or inappropriate use of this small range of active ingredients has lead to the development of parasite resistance. Resistance to one brand-named product within a chemical group results in resistance to all products within that group. Once resistance is present it is permanent and triple resistance (resistance to all three of the main groups of anthelmintic) has made sheep farming unsustainable on a number of farms in the UK and worldwide. The recently released fourth group of anthelmintic may temporarily aide such sheep farms. To avoid high levels of resistance developing quickly with new products (and to avoid further development with the older products) farmers need to ensure they are delivering accurate and appropriate doses only when needed and to follow all SCOPS principles.

There has been very little change in the total amount of anthelmintics sold in Wales in the last five years. There has been a general trend of increasing use of ML drenches and in particular ML injections. There has been an increased use of products for dual use, e.g. combined treatments for scab and worms or fluke and worms.

In recent years there have been increasing concerns regarding parasitic infection and resistance. Parasitic gastroenteritis continues to be the main problem, however, there is growing concerns with the increase in liver fluke and flukicide resistance in recent years. The incidence of haemonchosis has generally increased in England and Wales over recent years and could become an increasing problem. Incidents of blowfly strike appear to have an extended season and nematodirus is becoming a problem at unusual times of the year.
1. **Background**

The main focus of the Action Plan is parasitic gastroenteritis (PGE) as it continues to cause worldwide production losses in sheep and cattle and the level of resistance is increasing. The Action Plan will consider new research on parasite control and other parasites’ of concern. Previously undertaken work will also be documented.

*Teladorsagia* and *Trichostrongylus spp* are the most common causes of PGE in Wales. Routine monthly dosing with anthelmintics through the grazing season has been common practice for many years on most sheep farms, largely due to low cost and availability of anthelmintics. Modern (like those championed by the Sustainable Control of Parasites in Sheep (SCOPS) members) strategies contradict techniques that were considered best practice 30 years ago and many farmers are finding it difficult to adapt and move away from the simple, routine dosing regimes that were successful in the past.

While there are numerous anthelmintics available on the market, widespread confusion continues to exist regarding which of the anthelmintic classes they belong to. There are currently four anthelmintic groups; benzimidazole (BZ), levamisole (LM), macrocyclic lactone (ML) and the recently released amino acetonitrile derivative (AD). Both Moxidectin and Ivermectin are macrocyclic lactones (ML).

2. **Anthelmintic resistance**

Resistance is the heritable ability of a parasite to tolerate a normally effective dose of an anthelmintic. The parasite is considered resistant if it survives exposure to the standard recommended dose of the anthelmintic and the ability to survive is passed on to its offspring (Abbott et al, 2009).

2.1 **Anthelmintic resistance in sheep**

Anthelmintic resistance continues to be an increasing problem worldwide, even in areas that have not farmed sheep for many years. One example of recent research on the subject shows that the presence of anthelmintic resistance can reduce liveweight by 2.8kg, cause significant increase in breech-soiling and a significant reduction in body condition score (Sutherland et al, 2010). Sutherland et al (2010) calculated that the presence of anthelmintic resistance resulted in a 14% reduction in carcase value of Romney cross lambs in New Zealand.

Anthelmintic resistance can be measured in a number of ways including field tests such as a simple drench test, Faecal Egg Count Reduction Test (FECRT) and laboratory assays such as the Larval Development Test (LDT) and Egg Hatch Assay. A fully effective anthelmintic is expected to reduce the FEC to zero after administration. If the reduction is 95% or less, resistance has been detected (Abbott et al, 2009). Kaplan (2004) quoted that the time from initial signs of reduced efficacy to full resistance appears to be less than 10 years for all three major drug classes.

There is increasing evidence of parasite resistance to anthelmintics in the UK and in Wales (Table 1). The Wales Worm Watch (2006) study detected anthelmintic resistance on 82% of the 122 farms tested; 46% to BZ, 5% to LM and 31% to BZ and LM. It is likely that farmers who were concerned or even suspected anthelmintic...
resistance participated more readily in the Worm Watch study along with farmers who were interested in the topic.

VLA reports show an increasing number of confirmed cases of BZ resistance and variable responses to LM and ML (VLA 2010). Abbott et al (2009) suggested that the prevalence of anthelmintic resistance among hill farms in the UK may be lower than lowland farms.

A survey of 200 Welsh beef and sheep farmers was conducted by ADAS on behalf of HCC during the summer of 2010. The survey found that only 13% of farmers who completed the questionnaire knew they had anthelmintic resistance in their flock, with the majority of these (11.5%) having BZ resistance. Many did not know if they had resistance on their farm or not. Only 29% had carried out faecal egg counts (FEC) and therefore the remaining 71% may not know if they have a resistance problem as they had not tested for it.

During 2010, 30 past and previous Red Meat Development Programme Demonstration Farms were also surveyed by ADAS; all had carried out FEC and consequently a larger percentage had a known resistance problem. 37% had resistance on their farm, of these 20% had only BZ resistance, 7% LM resistance and 10% had BZ and LM resistance. None of the Demonstration Farms had a known ML resistance.

Table 1 summarises the research carried out between 1982 and 2009 on anthelmintic resistance. These results indicate that BZ and LM anthelmintics can no longer be classed as broad-spectrum. There is also increasing evidence of anthelmintic resistance to MLs. The Wales Worm Watch study found that ML resistance was not yet a problem on the 14 farms tested. Nine farms achieved 100% reduction post drenching and the remaining five achieved greater than 95% reduction.

Table 1 Anthelmintic resistance

<table>
<thead>
<tr>
<th>Country</th>
<th>Group</th>
<th>Percentage resistant</th>
<th>Year of study</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>UK</td>
<td>Benzimidazole</td>
<td>100</td>
<td>2008/9</td>
<td>SCOPS</td>
</tr>
<tr>
<td>UK</td>
<td>Levamisole</td>
<td>47</td>
<td>2008/9</td>
<td>SCOPS</td>
</tr>
<tr>
<td>UK</td>
<td>Benzimidazole</td>
<td>60</td>
<td>2006/7</td>
<td>Moredun (2007)</td>
</tr>
<tr>
<td>UK</td>
<td>Macrocyclic lactones</td>
<td>30</td>
<td>2006/7</td>
<td>Moredun (2007)</td>
</tr>
<tr>
<td>Wales</td>
<td>Benzimidazole</td>
<td>80</td>
<td>2005</td>
<td>Wales Worm Watch (2006)</td>
</tr>
</tbody>
</table>
Bartley et al (2006) investigated thirty-eight sheep flocks, predominantly from south/central Scotland for the presence of Ivermectin resistant nematodes. Efficacies of less than 95%, 14-17 days post-treatment, were identified in 6 of 17 naturally grazing flocks. Efficacies on these Ivermectin-resistant farms ranged from 66 to 92%. The larvae detected in post-treatment coprocultures from resistant flocks were from the genera *Teladorsagia* and *Trichostrongylus*.

Moxidectin has shown to be effective in removing Ivermectin resistant *T. circumcinta* (Wilson & Sargison, 2007). Sargison et al (2005) attempted to control BZ, LM and Ivermectin resistant *T. circumcinta* using Moxidectin. They found that it failed to suppress the establishment of significant numbers of infective helminth larvae on the pastures. It was effective in removing adult female burdens of Ivermectin-resistant *T. circumcinta*, but the effect of the drug did not persist against the resistant helminth population.

Mottier and Prichard (2008) suggested that ML use may predispose parasitic nematodes to BZ resistance. This has major implications for parasite control programmes dependent on ML/BZ rotations. Hughes et al (2007) found from research on New Zealand farms that the presence of resistance to BZ or LM were associated with a higher apparent prevalence of ML resistance.

BZ resistance is acknowledged as being most widespread, followed by LM, with least evidence of resistance to MLs. However there is increasing evidence of triple resistance on a number of UK farms (Sargison, 2001; Cheng et al, 2003; Yue et al, 2003; Bartley et al, 2004). The first case of flock closure in the UK due to multiple-anthelmintic resistant nematodes occurred in Scotland in 2005 (Sargison et al 2005). Blake & Coles (2007) more recently explained how a farmer with triple resistance managed to maintain the production of lambs to slaughter for a few years by lowering stocking density, early lambing, creep feeding and treating with Moxidectin. However, this only provided a short term solution and after three years the only solution was to cull the flock.

According to a survey carried out by the Moredun Institute, triple resistance could be present in nearly one in three flocks. Tests on samples from 16 flocks in 2004 revealed triple resistance in 5 of them (Moredun, 2005).

Novartis Animal Health has developed an alternative anthelmintic (monepantel) which offers hope to many sheep farmers with triple resistance. This fourth group (AD) of anthelmintics is effective against all nematodes, including resistant ones. This needs to be used wisely to avoid development of resistance and to prolong the life of drenches in the other three groups.

### 2.2 Anthelmintic resistance in cattle

In a study on the North Island of New Zealand Ivermectin resistance was found to be present on 92% of beef farms (Waghrorn et al 2006). The first case of ML resistance in nematodes (*Cooperia* species) of cattle in the northern hemisphere was on a farm in Somerset in 1998 (Stafford & Coles 1999). Coles et al (2001) found a further product failure in Gloucestershire, and Oprin (2010) reported another failure in cattle in Leicestershire. Van Zeveren et al (2007) highlighted Ivermectin resistance in *Ostertagia ostertagi* in cattle and resistance is now considered to be widespread in northern mainland Europe (Sargison et al, 2009).
Stafford et al (2010) found a reduced or complete lack of efficacy of ML pour-on (doramectin, eprinomectin, Ivermectin and Moxidectin) on the majority of cattle farms they investigated (24 farms so far) in the south west of England. They found reduced or lack of efficacy in Cooperia species, Ostertagia ostertagi, Nematodirus helvetianus and Dictyocaulus viviparous.

Barton et al (2006) later conducted a survey to establish the perceived problems and strategies used by beef producers to control parasites in south-west England with some concerning results. Of the farms that dosed once a year 42% adopt a dose and move strategy and 5% deliberately overdosed. Barton et al (2006) also found that many cattle farmers were treating for fluke even though they did not think that they had a problem with the parasite. From the survey of 72 farmers, one farmer considered Ivermectin was not working. As there has been no recent survey for the presence of anthelmintic resistant nematodes in cattle, resistance is only likely to be noticed in cases of overt failure, therefore the extent of resistance could be far more widespread than both published information and the survey suggest (Barton et al, 2006).

### 2.3 Reasons for/causes of anthelmintic resistance

While there are numerous anthelmintics available on the market, until recently there have only been three anthelmintic groups; BZ, LM and ML. Repeated doses of a small range of chemicals and the development of parasite resistance to one brand-named product within a family results in resistance to all products within that family except Ivermectin and Moxidectin. Moxidectin can still be effective when resistance to Ivermectin is present. The recently released fourth group, monepantel, has widened the range available and there are a further two new anthelmintics (with a different mode of action) being considered for development.

Sargison et al (2007) suggested that under-dosing may have selected for benzimidazole and imidazothiazole resistance in sheep flocks in south-east Scotland. They also highlighted problems associated with the diagnosis of anthelmintic resistance, in particular the confounding effects of the onset of host immunity to nematode parasites, the possible influence of the age of the adult nematode population, and the insensitivity of the undifferentiated faecal egg count reduction test in situations where resistance is emerging.

Fraser et al (2006) found that the husbandry practices on the farms reporting anthelmintic failures suggested that relatively high treatment frequencies of ewes and lambs, combined with treatment followed by a move to ‘clean’ pasture, were common features on those farms.

Rendell et al (2006) identified explanatory factors associated with the presence of ML (Ivermectin) resistance on farms including the use of long-acting anthelmintic formulations in ewes pre-lambing, sources of refugia of unselected parasites on the farm, breed of sheep and their requirements for anthelmintic treatments, and the import of resistant parasites with purchased stock.

To avoid high levels of resistance developing quickly with new products and to avoid further development with the older products farmers need to ensure they are delivering accurate and appropriate doses, turning animals back to dirty pasture (not clean pasture) and creating a source of refugia.
We must also take into account environmental considerations. Since the development of parasite resistance to BZ and LM there has been an increase in use of avermectins. Avermectin use has increased since they are endectocides and effective against sheep scab. Residues of avermectins have potentially detrimental effects on invertebrate life and are more persistent in the environment than the other chemicals.

3. Barriers to effective parasite control

Despite best efforts by veterinarians, industry practitioners and organisations, farmers are still finding it difficult to adapt and move away from techniques that were successful in the past. Routine monthly dosing with anthelmintics through the grazing season has been common practice for many years on most farms, largely due to low cost and availability of anthelmintics (drenches, pour-ons and injectables). This is a habit that has been ingrained into farm management practices for years and modern (SCOPS) strategies contradict techniques that were considered best practice 30 years ago. The nature of family farms in large areas of Wales also makes it difficult to introduce new ideas due to the influence and/or management of the farm often by older farmers. Other barriers include:

- Effective marketing by the pharmaceutical industry
- Time constraints – the drench all approach is often perceived easier, quicker and cheaper than alternatives e.g. FEC then drench if needed.
- FEC is perceived to be too technical and time consuming by farmers
- There is a lack of data on performance e.g. growth rates and cost/benefits of alternatives to routine anthelmintic treatment

Considerable progress has been achieved in recent years to demonstrate the benefits of the new approaches and in persuading farmers to reduce the number of times they pick up their drenching gun.

4. Other parasites of concern

There has been a steady increase in diagnosis of acute and chronic liver fluke in Great Britain since 2006, with a significant increase in 2009. It is thought that this is due to warm, wet summers and mild autumn weather favouring the lifecycle of the parasite and its intermediate snail host. There are increasing reports of flukicide resistance, especially to triclabendazole, the drug of choice for acute fluke (Moredun, 2009). The cost of this resistance in terms of sheep mortality and lost production on one Scottish sheep farm was calculated as £8.32 per ewe (Sargison, 2011). Moredun has reported cases of flukicide resistance in South West Wales.

Fasciolosis is also a major cause of production loss in cattle, with reduced live weight gains, metabolic disease, reduced milk yield, and liver condemnation. An estimate of the financial loss in Swiss dairy cattle was put at €299 per infected animal (Schweitzer, 2005). There has been a significant increase in fasciolosis in cattle recorded by the VLA’s diagnostic figures since 2007. Nearly 35,000 cattle livers were condemned in Welsh abattoirs because of liver fluke in 2010 due to liver fluke damage (VLA, 2010c). Condemnation levels were over 20% for Wales, higher than those reported in England. Data gathered by the University of Liverpool Department of Parasitology for dairy farms, by means of bulk tank milk ELISA tests – the results showed that 84% of dairy farms in Wales are infected with liver fluke (Mc.Cann, 2010).

The incidence of haemonchosis has generally increased in England and Wales over recent years. *Haemonchus contortus* survives warmer temperatures than
Teladorsagia and Trichostrongylus and due to milder conditions is rapidly becoming a greater problem.

**Nematodirus** is becoming a problem at unusual times of the year. Taylor (2010) suggests that recent evidence for N. battus shows that larval hatching is occurring at times other than the traditional late spring hatch seen in areas such as Northern England and Scotland. Synchronised mass hatching usually occurs when temperatures greater than 10°C follow a period of frost. However disease is now reported at other times of the year, including the autumn, and in parts of the south of England particularly, where early lambing is practised, in late winter/early spring (January-March).

Changes in treatment practices are causing concerns for certain parasites. The reduction in vaccine use has caused an increase in the incidence of lungworm in recent years. The withdrawal of synthetic pyrethroids, concerns over implications to human health for organophosphorus products and environmental regulations has resulted in a marked decline in plunge dipping. It is thought that there has been an increase in the number of sheep with lice due to many farmers using injectables to control sheep scab (which are ineffective against lice), as opposed to plunge dipping.

**Ticks** are also becoming an increasing problem. The VLA has investigated a case of suspected organophosphate (diazinon) resistance in a population of ticks in North Wales. Contract dipping in diazinon has failed to significantly control ticks on at least three contiguous grazings for three years (VLA, 2007).

Incidents of blowfly strike appear to have an extended season (March-December) (SCOPS). The relatively mild winters (up to 2009/10) allowed for more blowfly larvae to survive the winter and emerge early. VLA (2007) suggest that with changing weather patterns flock owners should expect earlier strikes and administer timely prophylactic treatment starting in early April in some areas.

In the cattle herd, psoroptic mange is of growing concern. It is an increasing production and welfare problem in Welsh beef and dairy herds. 22 infected herds have been identified to date (21 in Wales) since 2007. There is evidence that the use of macrocyclic lactones (the only licensed products) do not effectively control the condition and there is no licensed treatment for lactating dairy cattle.

The VLA recognises *Parafilaria bovicola* (nematode) and Besnoitiosis (protozoa) as risks of emerging diseases.

5. **Recent technology transfer initiatives and schemes**

5.1 **Sustainable Control of Parasites in Sheep (SCOPS)**

SCOPS is well known to scientific and technical practitioners in the agricultural community. Unfortunately it is less well known to the general farming industry and the survey carried out by ADAS at the Royal Welsh Show in 2010 showed that only 17% of the 200 farmers interviewed had heard of SCOPS. Despite this, a large number of
farmers understood the principles of SCOPS and were weighing animals, calibrating and maintaining equipment etc.

The SCOPS group was established to develop strategies for internal parasite control in sheep in the face of the emergence of anthelmintic resistance and to oversee the delivery of recommendations to the industry. To ensure that all professionals giving advice to farmers provide the same clear concise messages, a manual and several other helpful documents have been produced by the SCOPS group.

SCOPS summary recommendations:
1. Work out a control strategy with a vet or advisor
2. Use effective quarantine strategies to prevent the importation of resistant worms
3. Test for resistance
4. Administer anthelmintics effectively
5. Use anthelmintics only when necessary
6. Select the most appropriate anthelmintic
7. Adopt strategies to preserve susceptible worms
8. Reduce dependence on anthelmintics

The SCOPS recommendations were embraced by the members of the Parasitology Steering Group that was formed in 2005 and the Steering Group have focussed on a coordinated approach to communicating these messages in Wales.

5.2 Other literature and campaigns
A considerable amount of information on parasite control is widely available to Welsh farmers including HCC fact sheets and booklets, some of these have been written by the Parasitology Steering Group members. Since 2006 there have been numerous articles in Gwlad and other farming press to raise awareness of parasite resistance, SCOPS guidelines and the activities carried out on Demonstration Farms. Across Wales there have been various farmer meetings and open days on parasite control and anthelmintic resistance delivered by a range of organisations (e.g. Farming Connect, ADAS, IBERs, Innovis, VLA, veterinary practitioners, pharmaceutical companies and other commercial companies) with the aim of reinforcing the SCOPS messages and guidelines.

The Moredun Research Institute provide a considerable number of updates and meetings such as the ‘Target Worm Control’ meetings in Autumn 2010 aimed at encouraging farmers to save time and money, reinforcing the messages and guidelines of SCOPS.

Organic Centre Wales (OCW) and other certificating bodies (e.g. The Soil Association) have produced numerous booklets, factsheets and case studies recommending best practice for parasite control and these messages have also been reiterated at many meetings. Effective parasite control with limited use of anthelmintics is equally important to organic farmers.

Pharmaceutical companies have also generated various leaflets and factsheets on the correct management of parasites using anthelmintics. This information needs to be reinforced with adequate advice from the sales representatives.
5.3 Demonstration Farms

The majority of the HCC Farming Connect demonstration farms have received a faecal egg counting kit (FECPAK). Training on how to use the kit was also provided to the discussion groups and they too have been invited to use the FECPAK on the demonstration farms. Even on demonstration farms where uptake of new technologies is common, regular faecal egg counting and adopting new parasitology strategies is slow. Very few of the demonstration farmers carry out faecal egg count reduction tests, withhold food before drenching, leave some animals untreated or look at NADIS disease forecasts.

5.4 Wales Worm Watch

The Wales Worm Watch monitor farm project enabled the 150 participating farmers to adapt their drenching programme to their own individual needs and gave them a clearer picture on resistance at different times of year. The autumn appeared to be a particularly problematic time.

Management factors were later investigated for the monitor farms and a number of observations were made:

- There was evidence to suggest that worming ewes at housing, turnout or in early spring would reduce lamb FEC in spring
- 3 of the 4 flocks with FEC >500epg in the spring lambed late (not finishing until mid May) with all of the early lambing flocks having FEC <500epg
- All farms with initial FEC >500epg away wintered ewe lambs which returned in early spring. Of the flocks with <500epg only 6 of the 14 away wintered, and of those, 2 flocks did not return them in early spring.
- All 4 of the farms with high early spring FECs had a subsequent increase in FEC in the autumn
- 6 farms showing an increase of worm burden in the spring were sheep only and prone to summer drought
- All farms that showed an increased FEC in summer were lowland farms and weaned early increasing susceptibility to worms.
- 4 farms remained similar in autumn to summer and they all practiced mixed grazing with cattle and sheep and used cattle to provide safer grazing.

Identifying the implications of management factors on FEC in sheep found five key points:

- Lamb FECs in isolation are not enough and in spring ewe FECs should be taken and ewes treated accordingly to minimise the post parturition spring rise in egg output and subsequent pasture contamination
- Early lambing indoors will minimise the effects of post parturition rise in worm egg output
- Provision of clean grazing through reseeds, aftermaths or integration with cattle systems can reduce worm burdens
- Culling of persistently dirty ewes may help reduce pasture burdens
- Early weaning flocks need to minimise lamb stress at weaning and monitor FEC after weaning.

5.5 PARASOL - Novel solutions for the sustainable control of nematodes in ruminants

PARASOL was a 3-year European Framework 6 funded project involving 10 countries and 17 partners which was completed in 2009. PARASOL (PARAsite
SOLutions) tested the practical application of various new approaches to worm control across Europe by developing strategies for Targeted Selective Treatment (TST) for the control of nematodes in ruminants.

One of the main objectives of the project was to identify when to administer anthelmintics by use of Targeted Selective Treatments (TST), where only animals showing clinical symptoms or reduced productivity are given drugs, or identifying the most appropriate time to treat entire groups of animals, Targeted Treatment (TT).

5.5.1 Evaluation of regular faecal egg counting practices on farms; its effect on anthelmintic use and animal performance

Through the project, Innovis provided a FECPAK and training for 10 farms dispersed across the UK. Each farm also received 1 day of consultancy on parasite control and physical and financial data were collected.

Main findings:
- Farmers did alter the timings of treatments in response to FEC results
- Farmers did use FEC to decide which groups of animals needed to be wormed
- Farmers used other factors as well as FEC to decide when a group of animals needed to be wormed and sometimes the decision had to fit in with management
- The average annual reduction in number of treatments per farm was 3,825 (Range from 481 to 10,810). This equates to a 35% reduction in dosing across all farms
- 63% of the farmers used FEC to check the efficacy of treatment
- The average annual savings over 8 farms was £663.86 (£0.58 per ewe) representing a 37% reduction in cost
- Two farms demonstrated an increase in lamb performance which the farmers believed was a consequence of changing anthelmintic group after discovering resistance
- Seven of the ten farms completed a faecal egg count reduction test and found resistance to at least 1 anthelmintic group
- In addition, 25% of farmers found a benefit of testing cattle with less anthelmintic treatments given to young cattle

On one farm there was an increase in growth rate in the latter years of the project which resulted in lambs sold 17 days earlier, with significant savings if a delay in sale date coincides with a price drop. There are a number of factors that could contribute to improved performance but this proved that a change to the worming strategy had not had a detrimental effect.

Innovis also carried out a survey of their existing FECPAK customers. The survey was completed by 49 of their existing clients:
- 74% of respondents had decreased the number of treatments to lambs (between 20% and 75% decrease) by using FEC
- 67% had changed the timing of treatments to lambs
- 41% of FECPAK users had changed their worming policy for adult ewes at mating and at lambing
- 91% claimed to have a better understanding of the parasite situation on their farms
• 79% of clients said that using regular faecal egg counting had been of financial benefit to their business

PARASOL results obtained right across this project demonstrated that targeted treatment (TT) and targeted selective treatment (TST) approaches are effective, practicable and reduce selection for anthelmintic resistance. These approaches are also economically competitive.

Targeted treatments (TT) are given to the entire flock/herd according to diagnostic information. Targeted selective treatments (TST) are those where individuals within the group are treated on the basis of need. Treatment indicators for small ruminants include weight gain, milk production, anaemia (FAMACHA), diarrhoea scoring, faecal egg counts and for cattle, ostertagia milk ELISA at housing, serum pepsinogen testing at housing, mid season FEC and weight gain.

5.6 Scoping study to identify the occurrence of internal parasites in sheep meat in Wales

Parasitic infestation of sheep meat and offal is a major problem for abattoirs leading to carcase and offal condemnations. The extent of the problem was poorly understood until this study was conducted by ADAS for HCC in 2006. Data was collected from weekly submissions over the year for the four main sheep abattoirs in Wales. This showed that:

- 7% of lambs killed (232,415 lambs) showed cases of *Cysticercus tenuicollis* (thin-necked bladderworm) resulting in a significant number of hearts being unsuitable for human consumption
- 3.6% of lambs had *Fasciola hepatica* (liver fluke) ie.120,442 lambs
- 1.8% of lambs had *Dictyocaulus filarial* (lungworm), ie 61,161 lambs
- 0.6% of lambs had *Cysticercus ovis* (sheep bladder worm), ie 19,461 lambs
- 0.08% of lambs had *Echinococcus granulosus* (hydatid cysts), ie 2,534 lambs

Other key findings:
- Consistent numbers of *C. tenuicollis* were recorded at all abattoirs throughout the year
- Liver fluke also followed a similar pattern in all abattoirs with a rise in the autumn, peaking at 10% in some abattoirs in April and a sharp reduction in late May/early June
- Hydatidosis was a rare occurrence in most abattoirs
- At one abattoir lungworm infections appeared to be increasing with time and numbers in 2006, and were higher than those recorded in a similar time in 2005 with up to 5% infected
- At one abattoir a marked increase in *C. ovis* occurred in January reaching detection levels of 4%
- One abattoir recorded hydatidosis most weeks, peaking in April when 167 lambs were detected in a single week. Other abattoirs recorded far fewer cases with none recorded at one abattoir, one case at another abattoir and 74 recorded in only 9 weeks at the other abattoir compared to the 2534 cases in total from all abattoirs.

The results of this study showed a significant level of parasitic infection in lambs presented to abattoirs in Wales. It also showed variation between abattoirs in the levels of infection seen. Whilst abattoirs do have a proportion of their lambs from
local sources, a number of lambs are transported long distances from both within and outside of Wales.

5.7 Merial MOO test

Merial Animal Health provided a subsidised MOO testing scheme which tested 464 bulk milk samples in 2009. The tests measured the levels of antibodies in the milk that were specific to gut worms. Elevated levels of antibodies show that the cows are exposed to a high gut worm challenge from the pasture. Results showed that 93% of herds were exposed to a high gut worm challenge at grazing. Only 5% of the tests showed a medium level of challenge, while just 2% were at a low level. Zero grazing farms also got positive results due to grazing young stock and/or dry cows.

5.8 Hydatid campaign

Because of the risk to human health from hydatid disease, a campaign was launched in Wales in 2008 to encourage farmers to regularly worm farm dogs as part of the ten year awareness campaign. The Welsh Assembly Government funded a major campaign providing free and supervised worming of all farm dogs every 3 months in a hotspot area, with the assumption that farmers were worming their dogs every 3 months and these would now be wormed every 6 weeks. To remove adult tapeworms, dogs need to be wormed every 6 weeks using a wormer containing praziquantel.

Results from the first quarter of the first year showed that the disease is still present in the targeted area with dogs on one in five farms testing positive. Testing in subsequent quarters indicated that maintaining a regular treatment programme for dogs is highly effective, with the number of positive farms dropping to less than one in twenty five.

The Welsh Assembly Government is also looking at the incidence of hydatid disease in cattle at abattoirs.

5.9 The influence of ectoparasites on Welsh sheep farms

Surveys were carried out during the winter of 2006/7 by HCC to establish the prevalence of, and treatments for, ectoparasites on sheep farms in Wales. The survey found the prevalence of blowfly strike to be 57.5%, lice 15%, sheep scab 11.6% and ticks 11.1%. These results are considerably lower than found in previous studies and in the 2010 survey carried out by ADAS.

The ADAS survey (2010) showed that sheep scab was a problem for at least 39% of the 200 farmers interviewed and lice for 42% of the farmers interviewed. Of the 30 past and present HCC demonstration farms interviewed 44% said sheep scab is a problem, 44% said lice is a problem, 25% ticks and blowfly for 97% of farms. Fraser et al (2006) found 36% of farmers in south west England had problems with sheep scab.

Other key findings from the HCC survey in 2006/07 were:

- 74% of producers and 85% of vets thought that compulsory dipping should return
- 37% of respondents do not have a written health plan
- Some products were used incorrectly for treating ectoparasites
6. The way forward – potential approaches to parasite control

6.1 Parasite monitoring – worm egg counts

FEC is the most widely available and used method to assess parasite burden. Other methods include Blood Sample Antibody measurement (BAS), Pastoral Larval Counts (PLC) and Faecal Larval Cultures (FLC). The laboratory time and technical proficiency required makes the three latter methods too expensive for the majority of commercial farmers to use.

There are a number of FEC kits (FECPAK) on farms in Wales. The results of the 2010 ADAS survey showed that these are not always used to their full potential, with many not used after the initial few years.

Many farmers are not confident in carrying out their own FEC and prefer to use their vet, VLA or commercial laboratories. VLA surveillance reports have shown a 28% increase in worm egg counts since 2005 (338 to 471) with a peak of 497 worm egg counts in 2008 in England and Wales. This represents a very low percentage of sheep farms. The perception is that farmers only use these services when their drench appears to have failed and other farmers may use it to check that their on-farm FECs are accurate. While many farmers use their vet or professional laboratories, the on-farm FEC approach does reduce the turnaround time for results and reduces the need to gather the sheep into the yards for a second time.

It is important that FEC are carried out as an indicator of worm burden to ensure treatment is only being given at times of infection. FEC continues to offer the simplest means of monitoring worm egg counts and there are many new opportunities encouraging farmers to carry out FEC with some vets and SQPs now offering a service of free FEC on a specific day.

6.2 National Animal Diseases Information Service (NADIS) disease forecasts

The NADIS data can highlight potential livestock disease and parasite threats before they peak, providing a valuable early warning for the month ahead. However, the survey carried out on the 30 demonstration farms in 2010 showed very few (39%) look at NADIS disease forecasts. Many only use the information if it has been published in the press. Many farmers go on previous years experience rather than considering seasonal weather information. NADIS forecasts are reported in the press and presentations are available on the website for vets to use.

6.3 Refugia

Creating a reservoir of unselected worms by leaving a proportion of lambs in a flock untreated with anthelmintic is advised (Waghorn et al 2010, Waghorn et al 2008, Hughes et al, 2007). This allows the next generation of worms to come from nematodes that have not been exposed to anthelmintics. Waghorn et al (2008) highlighted the difficulty in managing both worm control and resistance. Their results showed that creating a reservoir of unselected parasites slows the development of anthelmintic resistance and emphasises the risk of treating all animals prior to a shift on to low-contamination pasture. However, this results in higher levels of pasture contamination from untreated animals. The main aim is to reduce resistance and it is
hoped that by retaining a population of drench-susceptible worms that can cross with resistant ones it may be possible to dilute resistance.

Older ewes develop immunity to internal parasites and are less vulnerable. Both cattle and sheep generally develop full immunity to worms by 18 to 20 months of age. It is often mentioned that continual exposure to worms is important for the development of good immunity (Wormwise).

Leathwick et al (2008) tested the hypothesis that when untreated adult ewes are rotationally grazed on pastures after lambs receiving routine anthelmintic treatments, the ewes can function as a source of unselected parasites in refugia. This should slow the development of anthelmintic resistance, and suppress the build-up of parasites. Leathwick et al (2008) concluded that untreated adult ewes were a source of unselected genotypes, capable of slowing the development of anthelmintic resistance in most, but not all, parasite species. Further, the potential of adult ewes to remove from pasture more parasite larvae than they contribute through faecal contamination indicates a potentially useful role in suppressing parasite populations, particularly when worm control in lambs is less effective as a result of anthelmintic resistance.

Waghorn et al (2010) supports the conclusion that older animals are more refractory to the establishment of ingested parasite larvae, and that this reduces the dilution of resistant worms surviving an anthelmintic treatment. Therefore treating mature sheep with an anthelmintic should be considered a higher-risk practice for selecting anthelmintic-resistant parasites, than treating lambs.

The demonstration farm surveys in 2010 showed that many farmers now rarely treat ewes with anthelmintics and 29% leave some lambs untreated. 75% of demonstration farmers turn treated animals back to dirty pasture. This shows a number of farmers are changing their practice to increase refugia.

### 6.4 Health plans

Health plans identify and reduce the risks of introducing disease and offer a preventative programme for existing conditions. Health plans should be continuously changing depending on the risks identified.

Health plans including integrated parasite management plans have been promoted extensively in Wales over the past 5 years and are available to Welsh farmers through Farming Connect. This service has been provided to farmers through their local Farming Connect approved vet due to the variation in geography, topography and management systems between farms.

It is important that farmers adopt the SCOPS principles into their health plans:
- FEC before worming
- Change worming group
- Quarantine drench all purchased animals with monepantel and Moxidectin and yard for 24-48 hrs before turning out to pasture that has carried sheep this season, and isolate from the resident flock for at least 3 weeks.

The survey carried out by ADAS during summer 2010 found that 81% of farmers interviewed include changing worming group in their flock health plan, 46% quarantine purchased animals and 11% undertake Faecal Egg Counts.
6.5 Genetic resistance

Some sheep are more resistant to parasite infection than others and selection of sheep with enhanced resistance to gastrointestinal parasites is now possible through FEC. Greeff & Karlsson (2006) stated that research has shown that breeding for worm resistance is a highly feasible option and that genetic gains of more than 2% per year can be achieved without loss of production. Replicated field trials in which resistant animals were managed separately from unselected control sheep showed that there was a 10-fold difference in worm egg count between resistant and control ewes. Resistant ewes were 18% heavier than the controls at the time of peak worm-challenge in a mediterranean environment. At weaning, there was a five-fold difference in worm egg count between resistant and control lambs, which resulted in an improvement of weaning weight of up to 22%.

Results from research undertaken at Aberystwyth University indicated that selection for parasite resistance needs to focus on the production of more resistant breeding females which are the source of parasite infection for their growing lambs (Nakielny, 2004).

The reduction in faecal egg output which is seen in resistant animals may also bring significant benefits in reducing pasture contamination so that non-selected contemporaries will be exposed to lower levels of larval infection.

Selecting animals with resistance to parasites should reduce the need for anthelmintics. To achieve significant genetic improvements in flocks by ewe selection, the sires used to breed ewe replacements must also be selected for resistance to worms (Abbott et al, 2009).

Evidence from selection in Romney sheep in New Zealand indicates that substantial and useful improvements can be made over a 10 year period, with selected flocks requiring substantially fewer anthelmintic treatments. Selection for low FEC does not appear to lead to significant correlated responses in resilience to parasites (as opposed to resistance) (Abbott et al, 2009). Resistance to parasites is the ability of sheep to limit the establishment rate, growth, fecundity and survival of worm parasites. Resilience is the ability of sheep to continue to grow, maintain condition, lactate and reproduce despite being parasitized.

Signet’s Sheepbreeder service introduced estimated breeding values for FEC in 2000. Uptake of this has been very slow in Wales despite HCC funding to support this. The parasitology survey carried out in summer 2010 showed that 2% of farmers had bought rams on FEC EBV, 2% had looked at it and a further 29% would consider it in the future when more animals with FEC EBVs are available.

Some farmers say that the influence of terminal sires on their lambs ability to withstand internal parasite challenge was minimal because it takes at least 3 months for either resilience or resistance to develop in lambs. On the other hand the opportunity to enhance resistance to parasites through the maternal breeds offers a massive opportunity to developing replacements with resistance and resilience. The importance is in producing ewes with lower FECs to reduce contamination of pasture for lambs. Uptake of FEC EBVs amongst maternal breeds in Wales has been largely un-adopted to date.
6.6 Introduction of new stock

Quarantine treatment of all sheep entering the farm is recommended (Abbott et al., 2009, Rendell et al., 2006) and quarantine treatment messages have been promoted widely in recent years. The likelihood of introducing parasites with new stock is high, unless adequate quarantine procedures are put in place. These sheep should not be allowed on pasture for 24 to 48 hrs after worming. Until the introduction of the new (AD) wormer the advice was to give sequential doses of a LM and a ML. However with the development of triple resistance on some farms and in particular Ivermectin resistance, new advice is to treat with monepantel and Moxidectin. Sager et al (2010) investigated monepantel as a quarantine treatment and found a rapid decrease in FEC compared to other anthelmintics used in sheep.

Faeces passed by the new sheep in the 24 to 48hrs post quarantine treatment should not be applied to pastures that will subsequently be grazed by sheep or goats. It should be disposed of by incineration or by application to ground that is not grazed (Abbott et al., 2009).

Something many farmers often do not consider is the purchase or rental of contaminated pasture, which can also result in the spread of infection. It is thought that the only way to remove resistant parasites from pasture is a grazing free period for at least two years. The advised approach is to adopt a safe or low risk grazing system where lambs are grazed on pasture with minimum levels of infection e.g. aftermaths or reseeds.

6.7 Grazing management

Careful grazing management (e.g. rotation of adult sheep or cattle grazing fields after the lambs), has been shown to reduce the build up of infective larvae on the pasture. Most parasitic worm species are host specific and grazing cattle and sheep in alternate years will help reduce worm challenge. Rotational grazing does carry the risk of Nematodirus infection since Nematodirus spp. can survive on pasture for considerable periods (> 3yrs) and can cross between cattle and sheep.

Research has shown benefits of sequential grazing by cattle and sheep, with superior live-weight gains being recorded for lambs grazing swards previously grazed by cattle, without compromising cattle performance (Fraser et al., 2002). Cattle grazing pastures before sheep reduces levels of parasite infection in sheep (Reinecke, 1994).

Mixed grazing (grazing cattle and sheep in the same field) will also reduce parasite burdens as the stocking rate of each species will be reduced and cattle will consume and destroy a proportion of the sheep worms on the pasture. Some studies (e.g. Barger 1999) have shown mixed grazing to be ineffective for controlling helminth parasites in sheep. However, in an experiment which compared mixed and sequential grazing systems, both were found to improve lamb live-weight gain over sheep only systems and sequential grazing with cattle before sheep was found to reduce internal parasites in lambs compared to mixed grazing and sheep only grazing systems (Marley et al., 2003).

Some open sward pasture species provide a less suitable environment for larval survival than those with a dense thatch. Most larvae are found in the first 2 cm of pasture from the ground or in the first 1 cm of soil. When animals graze pasture with longer grass they are likely to be taking in fewer worm larvae than when they graze pasture with shorter cover. Intensive grazing exposes animals to a higher level of
larval intake than animals lightly grazing the same pasture. Amounts and patterns of
dung deposition and therefore numbers and distribution of parasites on pasture will
vary with type of grazing management (Wormwise). The external morphology of
grasses influences migration of the larvae for example larvae are more successful at
climbing tall fescue than smooth brome. A film of moisture is advantageous to
migration and upward migration is favoured by higher relative humidity.

6.8 Alternative forages

Alternative forages include crops other than grass, for example red and white clover,
chicory, birdsfoot trefoil, sainfoin that have been shown to reduce the
negative effects of parasitism in sheep. Many plants contain compounds that can
affect the development of parasitic worms e.g. condensed tannins. Tannins exert
their activity in the gut when they are released into the gut contents from the plant
during digestion. At this point they can reduce the development of parasite worms in
the gut. Furthermore, these compounds may also maintain their activity in faeces in
the field and reduce egg/larval viability in the faeces.

Considerable research has been carried out recently to investigate the effects of
these alternative forages and their effect on worm control. Athanasiadou et al (2007)
found the faecal egg counts of lambs from undrenched ewes grazing on chicory were
significantly lower than those of lambs from undrenched ewes grazing on grass. They
also found that lambs grazing chicory had higher live-weight gain compared to those
grazing on grass. Athanasiadou et al (2007) concluded that although chicory grazing
did not affect ewe nematode egg excretion, it resulted in lower egg counts in lambs
and improved their live-weight gain to the same level as those lambs on drenched
ewes.

Research at IBERS has shown that chicory, birdsfoot trefoil and white clover can
reduce internal parasite burdens in grazing lambs (Marley et al., 2003; Marley et al.,
2005). The research also investigated the effects of dietary forage on worm hatching
and development. Findings revealed that alternative forages reduced the number of
worms which developed, survived and migrated when compared to ryegrass
pastures (HCC, 2010).

Marley et al (2006a) investigated the effects of legume forages on gastrointestinal
development, migration and survival. They compared white clover, lucerne, red
clover and perennial ryegrasses. There were fewer larvae on legumes compared with
ryegrass on samples from forage above 50 mm but there was no forage effect on
larvae below this height. They also found that red clover affects the development of
H. contortus and all legumes affected larval migration above 50mm compared with
ryegrass but survival of larvae was similar on all forages.

Marley et al (2006b) results indicate that the number of infective stage larvae on
birdsfoot trefoil and chicory pasture was reduced by the effect of their sward structure
on the development/survival/migration of ovine parasitic nematodes. When forages
were compared on a dry matter basis, by day 16 there were 31% and 19% fewer
larvae on birdsfoot trefoil and chicory than on ryegrass, respectively. In the second
experiment results showed there was a minimum of 58% and 63% fewer infective
stage parasitic larvae on birdsfoot trefoil and chicory respectively, compared with
ryegrass on day 14 and 35 when forages were compared on forage dry matter, plot
area sampled and leaf area.
Chicory is the most promising bioactive forage and can be incorporated into normal grass leys or sown in conjunction with clover and/or grasses. Drought resistance is also an important property of chicory, which contributes to nutritional requirements in the latter part of the season. Importantly this also coincides with the time we normally see the highest pasture larval challenges to lambs (Taylor, 2010).

Lange et al (2006) evaluated the effect of the condensed tannin containing forage, *Lespedeza cuneata* (*sericea lespedeza*, SL) fed as hay, on *Haemonchus contortus* infection in sheep. SL hay feeding reduced worm numbers, with more of an effect on reducing naturally infected worm burdens (67.2%) than on establishment of incoming larvae (26.1%). SL fed as hay may be more useful to remove existing worms than establishing worms. The decrease in FEC would have the benefit of reduced pasture contamination. Other studies also found that feeding SL hay to sheep and goats reduced the gastrointestinal FEC and worm numbers in the abomasum and small intestines. Terrill et al (2007) found that pelleting SL hay enhanced its efficacy against parasitic nematodes and may facilitate the broader use of this forage in small ruminant gastrointestinal nematode control programmes.

Max et al (2007) investigated the effect of tanniniferous browse meal on FEC and intestinal worms in sheep and goats infested experimentally with gastrointestinal nematodes. The observed anthelmintic activity of acacia leaf meal supplement was less than expected, although they still concluded that such reductions can have practical epidemiological implications in reducing pasture larval contamination. Cenci et al (2007) found that condensed tannin from *Acacia negra* had an antiparasitic effect.

Minho et al (2008) investigated the anthelmintic effect of condensed tannin extracts from *Acacia molissima* on lambs naturally infected with *Haemonchus contortus* and *Trichostrongylus colubriformis*. They found that drenching with condensed tannin extracts was associated with a reduction in FEC and worm burden in the abomasum, but not in the small intestine.

Alternative approaches to nutritional means of worm control should be explored further and could begin by considering worm control approaches in the third world, where anthelmintic products are difficult to purchase. In Thailand the tops of pineapple leaves are used in an attempt to control internal parasites. These approaches appear to be working and it may be that control methods used elsewhere in the world could be adapted for use in the UK (IAEA Technical Co-operation Project 2005).

### 6.9 Nutritional factors

If an animal is undernourished it is more susceptible to parasitism, and manipulation of nutrition can increase host resistance and/or resilience. Protein nutrition is important during infection and leguminous crops are particularly good sources of protein. Increased supplies of crude protein in particular improve the resistance of sheep to disease and parasitism.

Research at SAC has shown that twin rearing ewes excrete more nematode eggs than their single-rearing counterparts. Increasing protein supply to twin rearing ewes increases milk production and reduces nematode egg excretion within a matter of days (Houdijk, 2005).
Cells involved in the immune system are particularly sensitive to trace element deficiencies and there is evidence that they play a role in determining the outcome of parasite infection. Molybdenum diets fed within the optimal range of 4 to 8 mg/sheep/day were given to 8-month old Merino lambs with *Trichostrongylus colubritiformis*. They were found to cause a 90% reduction in FEC and total worm count 6 weeks after challenge, compared to lambs fed less than the optimum range (McClure et al. 1999). Many farmers realise that minerals may be of general assistance in optimizing production but there appears to be unnecessary use of trace elements and minerals without analysis to determine status before treatment.

None of the points made in section 6 are sufficiently effective without anthelmintic support but they should help to reduce the development of anthelmintic resistance and reduce environmental and health implications. Other options that may be available in the future are covered in section 7.

7. **Future options**

7.1 **Combinations of anthelmintics**

Combinations of anthelmintics (BZ+LM, BZ+LM+ML) are not available in the UK despite being marketed in several other countries. Combinations of anthelmintics should be used when anthelmintics are still fully effective and when resistance alleles are at very low frequencies (Abbott et al., 2009).

Tyrrell et al (2010) concluded that there is a potential advantage of combining a pulse of short-acting drug into a long-acting anthelmintic capsule to provide better parasite control than that achieved from the existing controlled release device treatment (simulated by periodic dosing) when Ivermectin resistant worms were present. In their study faecal worm egg counts of sheep treated with Ivermectin and LM declined (99.9% reduction) after administration of oral LM and were suppressed until day 98. There was a significant difference in worm counts at slaughter between the groups.

Combinations of anthelmintics could cause further confusion and hinder the understanding of effective use of anthelmintics.

7.2 **Replacing the anthelmintic-resistant population with a susceptible population**

Moussavou-Boussougou et al (2007) suggest that since anthelmintic treatments are of limited effectiveness, one solution could be to replace the anthelmintic-resistant population by a susceptible population in order to re-establish the possibility of drug-based anthelmintic control. They investigated this in 4 paddocks and concluded that nematode replacement is feasible in temperate areas, using semi-intensive stock management, even when the initial levels of BZ resistance are very high.

7.3 **Alternatives to anthelmintics**

Multiple drug resistance and issues of residues in the food chain make alternatives to anthelmintics a priority. Rowe et al (2009) suggest silencing (inactivating) genes regulating nematode development.

Other options include:
7.3.1 Copper oxide wire particles

Burke & Miller (2006) stated that copper oxide wire particles (COWP; 2 g) have proven effective in decreasing gastro-intestinal nematode infection in lambs. However, the risk of copper toxicity has limited the usefulness of this approach. Recently, smaller doses (0.5 and 1 g) have proven effective in gastrointestinal nematode control, reducing the risk of toxicity. Burke & Miller (2006) concluded that multiple doses of COWP were as effective as LM for control of *H. contortus* without risk of copper toxicity. Further research by Burke et al (2010) found that feeding copper oxide wire particles led to a reduction in FEC but lambs from COWP treated dams were occasionally lighter. Jackson and Miller (2006) showed concern that the risk of copper toxicity may limit its potential use in some breeds of sheep.

7.3.2 Homeopathy

Homeopathy may have a supportive role in aiding recovery of damaged tissue, and Arsenium and Pulsatilla have been identified as being particularly suitable for this purpose.

7.3.3 Genetic markers

Selecting sheep genetically resistant/resilient to parasitic nematodes using genetic markers is considered far less tedious and less costly than FEC. The issue with genetic markers is that they are considered breed specific. Glasgow University Veterinary School have identified a genetic marker for increased resistance to *T. circumcincta* in Scottish Blackface sheep. This is currently being validated on commercial farms.

Burke & Miller (2008) evaluated the FAMACHA system (FAMACHA provides an assessment to be carried out before the treatment for Haemonchus using anaemia and the colour of the lower eyelid as a morbidity marker). They concluded that the FAMACHA system can be used to identify superior sires for parasite resilience/resistance, thus increasing flock resilience, and perhaps resistance.

In the future, arguably the most exciting area is that of immunomanipulation, where current advances in genomics and proteomics offer scope for the development of vaccines and genetic or bio-markers associated with infection or effective immunity (Jackson et al, 2009).

7.3.4 Vaccination

Vaccination can be used to stimulate or boost the host’s natural or acquired immunity. A commercially viable vaccine has been developed against the lungworm *Dictyocaulus viviparous* in calves (Bain, 1999) but despite considerable research there are, as yet, no commercially available vaccines for the control of sheep nematodes (Smith, 1999). Vaccine development is a complex process requiring the identification of protective antigens, the production of the recombinant protein and the development of vaccination protocols for the effective delivery of antigen and the number and frequency of vaccinations required.

Considerable work is being undertaken to develop a vaccine against Haemonchus. The vaccine has been trialled on Merinos in Australia, where vaccinated animals showed a lower rate of infection, with fewer worm eggs than non-vaccinated sheep.
Trials at the Moredun Research institute in Edinburgh have shown that it is possible to successfully immunise sheep against Haemonchus. An 80 to 90 per cent success rate is being achieved after vaccination.

The Moredun Research Institute has recently received the largest grant ever to be awarded by the EU in the field of animal health. Over 9 million Euros (£7.5 million) has been secured by a Moredun led “Paravac” consortium to develop vaccines for roundworm, tapeworm and fluke.

Parasitologists from the Institute of Biological, Environmental and Rural Sciences (IBERS) at Aberystwyth University together with Queen’s University, Belfast’s School of Biological Sciences are working with partners at Aligarh Muslim University and Tamil Nadu Veterinary and Animal Science University in India on a new vaccine to control liver fluke disease.

7.3.5 Biological control – nematophagus fungi

One of the potential new tools for integrated control strategies is biological control by means of the nematode-destroying microfungus *Duddingtonia flagrans* (Larsen, 2006). This fungus forms sticky traps that catch developing larval stages of parasitic nematodes in the faecal environment. When resting spores (chlamydospores) of this fungus are fed daily to grazing animals for a period of time, the pasture infectivity and thus the worm burden of grazing animals are reduced, especially in young lambs. Epe et al (2008) found that *Duddingtonia flagrans* reduced FEC in goats but did not reduce FEC in sheep or pasture larval counts. Earlier studies (e.g. Mendoza de Gives et al., 1998) showed that an oral dose of *Duddingtonia flagrans* significantly reduced the number of infective parasitic larvae in the faeces of sheep after treatment.

Kelly et al (2009) investigated 10 Irish farm pastures and concluded that permanent sheep pasture is a good source of nematophagous fungi and hence may harbour potential biological control agents. *Monacrosporium cionopaga, Duddingtonia flagrans, D. coniospora* and *Hirsutella rhoissilensis* were detected in fresh faecal samples indicating they may have survived the gastrointestinal tract and therefore could be a viable option as a biological control agent.

Silva et al (2009) concluded that treatment of sheep with pellets containing the nematophagous fungi *D. flagrans* and *M. thaumasium* may be used as an alternative for the control of sheep gastrointestinal nematodes.

There appears to be contradicting results for the effectiveness of nematophagus fungi controlling nematodes.

7.3.6 Bioactive plants with anthelmintic properties

Bioactive plants with anthelmintic properties represent an alternative solution to chemical treatments. The anthelmintic effect of several Mexican tannin-rich plants has been screened in vitro. The in vivo anthelmintic effect of one tannin rich legume, *Lysiloma latisiliquum* (Tzalam) on nematode larval establishment was confirmed (Martínez-Ortíz-de-Montellano et al, 2010). They observed no differences in worm burdens, worms of the treatment group were smaller and, according to their size, contained fewer eggs in utero than worms from the control group. Only minor differences in mucosal inflammatory cells were observed between groups, indicating
that the indirect effect was not evident. Thus, a short-term consumption of *L. latisiliquum* can modulate directly the biology of adult *H. contortus* affecting the worm size and female fecundity while the worm burdens were not affected. Infected animals ate more *L. latisiliquum* fodder than non-infected animals.

Many alternatives to anthelmintics have been investigated across the world. Organic farmers in Denmark use wormwood (*Artemisia absinthium*), mugwort (*A. vulgaris*), chicory (*Cichorium intybus*) and common tansy (*Tanacetum vulgare*) as a feed for the purpose of deworming in cattle (Waller et al. 2001). They also grazed animals on plants with reputed anthelmintic properties, with 26% of farms surveyed using herbs in the leys; including caraway (56%), parsley (20%), chicory (10%), chervil and dill (14%).

In India, Tariq et al (2008) evaluated the anthelmintic efficacy of crude aqueous extracts and crude ethanolic extracts of entire *Achillea millifolium* against the gastrointestinal nematodes of sheep. They found that the aqueous extracts exhibited greater anthelmintic activity under both in vitro and in vivo conditions, and could be due to the presence of water-soluble active principles in *A. millifolium*. It is concluded that the entire plant of *A. millifolium* possesses significant anthelmintic activity and could be a potential alternative for treating cases of helminth infections in ruminants. Tariq et al (2009) also suggest that *A. absinthium* extracts are a promising alternative to the commercially available anthelmintics for the treatment of gastrointestinal nematodes of sheep. Kamaraj et al (2010) found that utilization of *M. azedarach* extracts is useful in the control of *H. contortus* in India.

In Ethiopia Tadesse et al (2009) concluded that *Plectranthus punctatus* and *Maesa lanceolata* contain possible anthelmintic compounds and further evaluation of different extracts and fractions of these plants should be carried out. In the USA Squires et al (2010) investigated the use of orange oil as an alternative to anthelmintics. Results showed that a single dose of the product caused high faecal egg count reduction (97.4%) compared to control sheep. Egg counts were significantly reduced by day 2.

Nery et al (2010) investigated the effect of *Anacardium humile* on gastrointestinal worms of sheep and phytochemical analysis demonstrated the presence of tannins, flavonoids, and alkaloids in the leaves.

Keiser et al (2008) found that artemether (a derivative of artemisinin) showed interesting fasciocidal properties in sheep, but embryotoxicity was of concern. Further studies are warranted to assess the potential of additional artemisinin derivatives and other peroxidic compounds for the treatment of *Fasciola spp.* infections in different ruminants. Following up on promising results obtained with artemether in *Fasciola hepatica* infected sheep, Keiser et al (2010) investigated the efficacy of artesunate in sheep with a natural *F. hepatica* infection. They concluded that artemether caused 93.2% and 87.1% reduction in FEC and worm burden, respectively but further investigation is needed on toxicity studies as half the sheep died in this study.

Costa et al (2008) suggest that extracts of *Azadirachta indica* may be useful in the control of gastrointestinal nematodes of small ruminants in Brazil. Ademola et al (2007) suggests that *Nauclea latifolia* extract in Nigeria could find an application in the control of helminth in livestock, by the ethno veterinary medicine approach.

Lopez et al (2006) results showed that *Bacillus thuringiensis* activity was similar to anthelmintic treatment and it could be used as an alternative biological method. The
Biocide activity of *Bacillus thuringiensis* IB-16 strain was evaluated against the blood-feeding nematode *Haemonchus contortus* in vitro and in vivo assays.

A number of different products are under consideration in many countries but some of these plants are having worrying effects on the overall health of the animal. It is also difficult to grow many of these plants in the UK.

*Artemisia absinthium* (Wormwood), *Tanacetum vulgare* (Tansy), *Allium sativum* (Garlic), *Thymus vulgaris* (Thyme), *Salvia officinalis* (Sage), and *Cassia angustifolia* (Senna) can all be grown in the UK and have been shown to have anthelmintic activity in their ethanol extracts. Extracts from thyme and sage were shown to have strong anthelmintic activity, while extracts of tansy and wormwood had weak activity (Scott-Baird 2007). In contrast Athanasiadou et al (2000) and Urban et al (2008) found that wormwood had strong anthelmintic activity. Scott-Baird (2007) highlighted difficulties in interpreting results caused by the use of different extraction solvents which may extract different active substances causing variation in results. Scott-Baird (2007) identified variation in the consistency of a composite herbal product.

Lack of consistency can arise as a result of variability in composition of the product formulated by the supplier, but also from variability in the composition of the plants themselves. Differing levels of active substances can occur in herbs as a result of differing sources, drying, processing and storage, which can all alter their constituents (Niezen et al. 2002). There are often natural, genetically determined variations which exist between different populations of some plant species, where in different cultivars the active substance may be absent. Active ingredients may only occur or be most concentrated in one part of the plant, or may develop only at a certain stage of growth.

Scott-Baird (2007) investigated the use of feed supplementation of algal biomass for sheep which might contribute to a strategy of nematode control. There was a significant effect of algal biomass supplementation on red blood cells, haemoglobin and haematocrit, the effect occurred in both the ewes and the lambs and in more than one week. Algal biomass may also be of value against other parasites such as lungworm, or bacteria and viral infections. This could increase its value.

There is potential for natural plant products to partially replace conventional anthelmintics. There are many issues that need to be dealt with such as consistency, palatability and ability to grow the plants under UK conditions (Scott-Baird, 2007).
### Table 2 Plants containing anthelmintic properties

<table>
<thead>
<tr>
<th>Plant name</th>
<th>Nematode species</th>
<th>Anthelmintic Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Achillea millifolium</em></td>
<td><em>Haemonchus contortus</em></td>
<td>94% worm mortality</td>
</tr>
<tr>
<td>(Yarrow)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Allium sativum</em></td>
<td><em>Haemonchus contortus</em></td>
<td>100% worm mortality</td>
</tr>
<tr>
<td>(Garlic)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Artemether</td>
<td>Liver fluke</td>
<td>93% FEC reduction, 87% reduction in worm burden</td>
</tr>
<tr>
<td><em>Artemisia absinthium</em></td>
<td><em>Haemonchus contortus</em></td>
<td>90% FEC reduction</td>
</tr>
<tr>
<td>(Wormwood)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Azadirachta indica</em></td>
<td><em>Haemonchus contortus</em></td>
<td>inhibiting egg hatching by 99.8% and larval development by 87%</td>
</tr>
<tr>
<td>(Neem)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Maesa lanceolata</em></td>
<td><em>Haemonchus contortus</em></td>
<td>50% inhibition</td>
</tr>
<tr>
<td>(False assegai)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Melia azedarach</em></td>
<td><em>Haemonchus contortus</em></td>
<td>&gt;99.4% of the egg hatching and 100% of larval development</td>
</tr>
<tr>
<td>(Chinaberry)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Orange oil</td>
<td><em>Haemonchus contortus</em></td>
<td>97% FEC reduction</td>
</tr>
</tbody>
</table>

### 7.3.7 Other approaches

Reduction in appetite is a feature of infections with *Teladorsagia* (brown stomach worm). Reduction of appetite and consequent change in live-weight gain occurs early in the infection process before egg counts have risen to appreciable levels. These changes in live-weight can be used as markers for targeted selective treatment using automatic shedders with EID (Moredun, 2007).

Diatomaceous earth is a naturally occurring mined and milled rock of totally plant origin. An ADAS study on the effect of feeding CeltiX™ DM daily to lactating ewes and young cattle at first turnout for an 8 week period, found that worm burdens were reduced and maintained at low levels throughout the trial, in a similar pattern to the drench effect.

Other alternatives have been advertised such as radionics and Verm-X. Verm-X is a 100% herbal formulation designed to specifically repel internal parasites for numerous species ([www.verm-x.com](http://www.verm-x.com)).

These can form part of the control strategy but are unlikely to be successful in dealing with high infections of roundworms.

### 7.4 Primitive breeds

Primitive breeds often have greater resistance to gastrointestinal parasites. The preliminary results of Golding & Small (2009) suggest that primitive Shetland and Manx Loaghtan sheep may have greater resistance to gastrointestinal parasites.

Scott-Baird (2007) quoted that breeds with high levels of resistance are often found in regions where the level of larval exposure can be high and suggests that the trait has evolved as a survival advantage through natural selection, but these animals tend to be smaller and slower to mature compared to commercial breeds.
8. **Strategy for Parasite Control in Wales**

**Development of a Coordinated Action Plan**

The emergence and changing trends in parasitic disease give some forewarning of the potential problems that climate change might have on animal health and welfare. This is likely to create a number of challenges in particular the economic effect on the livestock industry.

It is inevitable that some of the approaches currently under investigation will fail to become widely applied for a variety of reasons that are not solely financial. These include issues concerned with practicability, applicability, appropriateness, availability, deliverability and above all, the failure to provide a consistent, reliable effect when used under commercial farming conditions. Farmers need quick and easy solutions and need to adopt different practices more readily.

Since some farmers are reluctant to embrace alternative approaches, urgent action continues to be required in order to prevent the further development of parasite resistance in Wales and indeed throughout the UK. This should avoid the devastating consequences which have been reported on the few farms that have resistance to the three initial anthelmintic groups. Given the perceived barriers to change which remain evident throughout the industry, a new approach is needed. This new approach will need to effect a change in “culture” and mindset.

The overarching and long-term vision which drives this strategy is that of a sustainable sheep industry in Wales which has successfully avoided the devastating economic and welfare consequences of parasite resistance to anthelmintics. There are three key strategic outcomes which will each be required in order to fulfil this vision:

- A reduction in the use of anthelmintic chemicals in Wales and delivery of mechanisms to prolong the lifespan of current anthelmintics (by strategic, accurate dosing)

- The development of practical and cost-effective alternatives to anthelmintics for the control of parasites

- Make the concept of parasite management more accessible and understandable to Welsh farmers.

A number of potential areas for future action have been identified. The actions have not been prioritised and will be actioned depending on the resources and funding available.

These are articulated in the table below. This list is not exhaustive and should be used to form the basis of future work undertaken by the Parasitology Steering Group.
### 8.1 Recommendations for future work and improvements

<table>
<thead>
<tr>
<th>Objective</th>
<th>Action</th>
<th>Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Further training of agricultural suppliers selling animal health</td>
<td>Arrange training days for SQP outlets</td>
<td>Increase awareness and understanding of the implications of anthelmintic resistance. Consistent information given to farmers</td>
</tr>
<tr>
<td>products (wormers, pour-ons and injectables)</td>
<td>A member of the Parasitology Steering Group to continue to attend AHWS Steering Group meetings and share information</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Improve communication between HCC Parasitology Steering Group and AHWS Steering Group</td>
<td></td>
</tr>
<tr>
<td>2. To continue to improve the communication between the Parasitology</td>
<td>A member of the Parasitology Steering Group to continue to attend SCOPS meetings and share information</td>
<td></td>
</tr>
<tr>
<td>Steering Group and Animal Health and Welfare Strategy Steering Group</td>
<td>Improve communication between the Parasitology Steering Group and SCOPS</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. To continue the communication between the Parasitology Steering Group</td>
<td>Develop individual parasite control plans for a large number of commercial sheep farms and monitoring of implementation and progress and promote resulting production data and cost/benefits of implementing new strategies</td>
<td></td>
</tr>
<tr>
<td>and SCOPS</td>
<td>Increase awareness and reduce the development of anthelmintic resistance</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. To raise awareness of new strategies e.g. FEC and reduce dependencies</td>
<td>Knowledge transfer activity of the benefits of quarantine and to use words such as disease control and disease prevention rather than quarantine</td>
<td></td>
</tr>
<tr>
<td>on anthelmintics</td>
<td>Increase farmers’ awareness and understanding of the benefits of quarantine treatments</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Objective</td>
<td>Action</td>
<td>Outcome</td>
</tr>
<tr>
<td>--------------------------------------------------------------------------</td>
<td>----------------------------------------------------------------------</td>
<td>---------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>6. To increase farmers’ awareness and understanding of carcase condemnations</td>
<td>Abattoirs to provide greater detail of the condemnations using common names and include leaflets/fact sheets detailing the economic loss incurred with the information they send to farmers. This could include more effective use of EID in slaughter lambs regarding tracing</td>
<td>Increase farmers’ awareness and understanding of the implications and how to reduce incidence of condemnations.</td>
</tr>
<tr>
<td>7. Make an integrated parasite control plan essential in farm assurance schemes, using best practice methods</td>
<td>Identify best practice methods for veterinary/livestock advisor to include in Health Plan</td>
<td>Increase awareness of latest technologies and effective practices</td>
</tr>
<tr>
<td>8. To review condemnations at abattoirs, specifically for cattle and sheep from Wales</td>
<td>Identify best way to obtain Welsh information preferably traced back to Holding of birth and premises reared and finished</td>
<td>Update understanding and extent of the problem</td>
</tr>
<tr>
<td>9. To investigate the level of anthelmintic resistance in the Welsh cattle herd</td>
<td>A similar project to ‘Worm Watch’ for the cattle industry in Wales</td>
<td>Increase awareness and current understanding of resistance problems in the Welsh cattle herd</td>
</tr>
<tr>
<td>10. Increase awareness of parasitic gastroenteritis and correct use of anthelmintics in cattle</td>
<td>Knowledge transfer to cattle farmers regarding parasitic gastroenteritis and correct use of anthelmintics</td>
<td>Increase awareness of parasitic gastroenteritis and correct use of anthelmintics</td>
</tr>
<tr>
<td>11. To investigate Nematodirus resistance to Benzimidazole</td>
<td>Monitor Nematodirus resistance to Benzimidazole</td>
<td>Increase awareness and current understanding of resistance problems</td>
</tr>
<tr>
<td>12. To aid strategic parasite treatments</td>
<td>Development of regional parasitic disease forecasts within Wales</td>
<td>Prevent unnecessary use of anthelmintics and flukicides</td>
</tr>
<tr>
<td>13. To control sheep scab</td>
<td>Work with Welsh Assembly Government and Trading Standards to increase awareness. Start to target high risk areas and follow into other areas</td>
<td>Increase awareness and reduce incidence of sheep scab</td>
</tr>
<tr>
<td>Objective</td>
<td>Action</td>
<td>Outcome</td>
</tr>
<tr>
<td>--------------------------------------------------------------------------</td>
<td>-------------------------------------------------------------------------------------------------------------------</td>
<td>-----------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>14. To substantiate effectiveness of various worming programmes, or trace element/nutritional supplements</td>
<td>Scientific studies to monitor lamb growth rates on various treatments</td>
<td>Identification of effective strategies</td>
</tr>
<tr>
<td>15. To identify effectiveness of new approaches</td>
<td>Scientific studies on alternative approaches that are marketed but not scientifically proven</td>
<td>Identification of effective approaches</td>
</tr>
<tr>
<td>16. To develop vaccines for worm control</td>
<td>Identify potential for vaccines in control strategies</td>
<td>An alternative strategy</td>
</tr>
<tr>
<td>17. To investigate species of parasites involved in resistance and standardisation of FECRT</td>
<td>Identify specific parasite resistance in FECRT</td>
<td>Ability to target worm species with appropriate anthelmintic</td>
</tr>
<tr>
<td>18. To investigate flukicide resistance</td>
<td>Further development of tests to detect flukicide resistance</td>
<td>Increase awareness and current understanding of flukicide resistance problem</td>
</tr>
<tr>
<td>19. To identify an alternative treatment for fluke control</td>
<td>Investigate an alternative (non chemical) method of fluke control</td>
<td>To aid sustainable control of fasciolosis on farms in Wales</td>
</tr>
<tr>
<td>20. To develop vaccines for fluke control</td>
<td>Aid development of fluke vaccines</td>
<td>Sustainably control fasciolosis</td>
</tr>
<tr>
<td>21. To investigate the level of liver fluke infection in the Welsh cattle herd</td>
<td>Development and validation of better tests to detect fluke infection and a prevalence study for liver fluke infection on beef production units and suckler farms</td>
<td>Increase awareness and understanding of fluke infection to aid effective control and improve production on cattle farms infected with fasciolosis</td>
</tr>
<tr>
<td>22. To control psoroptic mange in cattle</td>
<td>To evaluate effective treatment options. To investigate new treatments that could be used in dairy herds with no milk withdrawal. To investigate diagnostic methods to detect infected animals with minimal clinical signs.</td>
<td>Identify effective treatment and control strategies</td>
</tr>
<tr>
<td>Objective</td>
<td>Action</td>
<td>Outcome</td>
</tr>
<tr>
<td>--------------------------------------------------------------------------</td>
<td>-----------------------------------------------------------------------------------------------------------------</td>
<td>-----------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>23. Ensure all agricultural colleges/universities are giving clear, consistent and precise information on anthelmintic resistance and best practice guidelines to avoid further development of resistance</td>
<td>Training and provision of consistent information for colleges and universities to pass on to students. Promote uptake of FEC EBVs and investigate barriers to uptake.</td>
<td>Consistent messages are given and a clear understanding is developed.</td>
</tr>
<tr>
<td>24. To provide an update on worm resistance in Wales</td>
<td>A follow on from ‘Worm Watch’ to investigate how much resistance has increased and how farmer attitudes have changed. The main focus should concentrate on ML resistance.</td>
<td>Increase awareness and current understanding of resistance problem</td>
</tr>
<tr>
<td>25. To increase uptake of FEC in Wales</td>
<td>Improved service for faecal egg counting e.g. subsidised postal service/van collecting samples at central points and faster reporting</td>
<td>More efficient use of anthelmintics</td>
</tr>
<tr>
<td>26. To improve accuracy and consistency of worm egg counts</td>
<td>Training of providers of worm egg counts.</td>
<td>Accurate readings that farmers trust</td>
</tr>
<tr>
<td>27. Investigate the abattoir condemnation figures for organic lamb and beef in comparison to conventionally produced stock</td>
<td>Discuss most effective way of collecting data with abattoirs to include full tracings from holding of birth to abattoir</td>
<td>Understanding the impact of organic husbandry on abattoir condemnations</td>
</tr>
<tr>
<td>28. To evaluate the effect of grazing strategies and forage crops in control of parasites</td>
<td>Scientific studies to evaluate the effect of various grazing strategies and forage crops, in particular</td>
<td>Develop a better understanding of the mechanisms of action</td>
</tr>
<tr>
<td>29. To evaluate the use of fungal spores in feed to destroy worm eggs and larvae</td>
<td>Scientific studies on the use of fungal spores in feed to destroy worm eggs and larvae</td>
<td>Develop a better understanding of the mechanisms of action</td>
</tr>
<tr>
<td>30. To develop a better test for diagnosis of parasitic gastroenteritis</td>
<td>Look at alternatives to worm egg counts</td>
<td>Aid strategic treatment, avoid unnecessary anthelmintic treatments and aid production</td>
</tr>
</tbody>
</table>
9. References


Blake, N. & Coles, G., (2007) Flock cull due to anthelmintic resistant nematodes. Veterinary Record 161, 36


HCC (2010) Are you winning the war on worms?


Moredun, (2005) Avermectin resistance trial has surprising results. More from Moredun Issue 22a, 4


PARASOL (Parasite Solutions). EU project [www.parasol-project.org](http://www.parasol-project.org)


Sargison, N.D., Scott, P.R., (2011) Diagnosis and Economic Consequences of Triclabendazole Resistance in Fasciola hepatica in a Sheep Flock in South East Scotland. Veterinary Record, February 12th, 2011,

Sargison, N.D., Jackson, F., Bartley, D.J. & Moir, A.C.P. (2005) Failure of Moxidectin to control benzimidazole, levamisole and ivermectin resistant Teladorsagia circumcincta in a sheep flock. Veterinary Record 156, 105-109


Squires, J.M., Foster, J.G., Lindsay, D.S., Caudell, D.L. & Zajac, A.M. (2010) Efficacy of an orange oil emulsion as an anthelmintic against Haemonchus contortus in gerbils (Meriones unguiculatus) and in sheep. Veterinary Parasitology, Article in Press


Werm-X www.verm-x.com


VLA (2010a) Small Ruminant Disease Surveillance Annual report (February 2010) Vol 13 No.4

VLA (2010b) Surveillance Cattle Diseases Quarterly Report: FIRST QUARTER Date: Jan – March 2010

VLA (2010c) Monthly surveillance report May


Wormwise. A Handbook of Sustainable Worm Management for Livestock Farmers. www.wormwise.co.nz

Yue, C., Coles, G.C. & Blake, N. (2003) Multiresistant nematodes on a Devon farm Veterinary Record 153, 604