# final report

Animal Health and Welfare

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**Prepared by:** **Dr Ian Carmichael**

**South Australian Research and Development Institute**

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Meat & Livestock Australia Limited
Locked Bag 991
NORTH SYDNEY NSW 2059

# Parasite Control in Southern Prime Lamb Production Systems

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Government of South Australia

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# Abstract

Awareness that internal parasites were a threat to profitability of an expanding prime lamb industry prompted establishment of a project to study their epidemiology and economic impact and improve efficiency of worm management programs. Research was conducted on fifteen properties in South Australia and Victoria.

The most important worms are *Trichostrongylus* and *Ostertagia*. Peak transmission is from May – September, but can continue through summer in coastal areas. Seasonal patterns are similar on irrigation and dryland. Problems include autumn contamination of paddocks, failure to provide clean weaning paddocks, quality decline of irrigated pasture in summer and variable efficacy of drenches.

The main losses were due to reduced growth rates. In 38% of trials, worms reduced growth by 12.2%, with daily penalties averaging 19 g/day. Estimated annual impact on the lamb industry in South Australia, Victoria and the Riverina is $65.73 million, comprised of $49.47 million (74%) direct losses and $16.26 million (26%) in control programs.

Comprehensive new knowledge is provided on prime lamb worm management in all production systems, suitable for uptake by a wide range of producers. Modest changes on properties with significant worm problems can realise huge savings for the industry.

# Executive Summary

There has been significant recent growth in production and prices in the Australian prime lamb industry, with rewards for efficient, intensified production. Genetic improvement and nutritional management programs to address important factors influencing productivity were developed early, however a recognised threat was the potential impact of internal parasites. Worm management practices based on wool sheep flocks had limited application in the emerging prime lamb production systems. A project “Parasite Control in Southern Prime Lamb Production Systems” was therefore developed to evaluate constraints placed on the industry by internal parasites and demonstrate and promote tools to underpin decisions concerning worm management.

Fifteen on-farm experimental sites were established from 2004-2007 in South Australia (12) and Victoria (3), representing all key production systems, namely dryland, flood irrigation, pivot (spray) irrigation and cropping. Ewe mortalities were investigated on a further property. One seedstock operation, 10 dryland and 5 irrigation enterprises were included. All except two were broadacre specialist prime lamb farmers. On each property the success of current worm management strategies was studied. Seasonal levels of worms on pasture and worm burdens derived from them were measured, and their influence on lamb growth rates quantified. Nutrition and worm effects were separated. Altogether 28 growth studies were conducted on 12 properties and reproductive efficiency measured in 3 ewe flocks. Fundamental epidemiological data for all production systems was developed. Other specific investigations included drench resistance tests, larval survival in dung, trace element status and outcomes of destocking. In addition, a comprehensive literature search of factors influencing parasitism in sheep in southern Australia was undertaken.

Growth rates were generally disappointing. Pasture quality, (declining energy and increasing neutral detergent fibre) in summer was often insufficient to drive reasonable lamb growth rates, despite irrigation. Only 25% of ‘worm free’ flocks grew at >250 g/day: 30% failed to exceed 150 g/day. In more productive flocks the top 20% of lambs consistently grew at >335 g/day, confirming huge scope for genetic improvement. In 38% of trials, worms reduced lamb growth by 6.4%-19.8% (average 12.2%), with daily penalties averaging 19 g/day. Penalties increased in severity with time. In a further 35% of trials an average 0.3 kg carcase weight was lost. In 27% of trials there were no adverse effects, confirming efficient worm management programs. No effects of worms on ewe reproductive efficiency were confirmed. Where growth was impaired by ≥10 g/day (average growth penalty 10.8%) the average pasture contamination and scourworm burden were 1500 larvae/kg DM and 11900 worms respectively, compared with 460 larvae/kg DM and 3850 worms where growth was impaired by <10 g/day (average growth penalty 2.5%). Given good protein nutrition, contamination below 1000 larvae/kg DM is unlikely to cause economic loss. Scourworm burdens below 5,000 generally had little economic impact, but above 10000 the penalty was determined by worm burden and species, other stresses, and quality of nutrition.

The most important worms are the scourworms, *Trichostrongylus* (Black Scourworm) and *Ostertagia* (Brown Stomachworm). In cooler, wetter areas, *T. vitrinus* is often dominant from late autumn to spring, but sometimes peaks in late spring and can persist over summer in moister areas. *Ostertagia* is present throughout the year in drier areas and increases in summer in cooler areas. *Haemonchus contortus* is widespread but only sporadically important. Peak transmission of worms is from May – September, but can extend well into summer in mild coastal areas receiving summer rains. The greatest perennial danger is from accumulation of dung during dry periods and mass

emergence of larvae following significant rainfall or irrigation. Most worm larvae perish on pasture within 6-8 weeks, even in relatively mild conditions. Survival in summer is brief, but often sufficient for worm transmission to occur. Contamination of pastures by unfinished lambs in autumn perpetuates a cycle with serious effects in ewes and lambs in winter and early spring. The autumn niche is the most important basis of seasonal transmission. Lambing and weaning paddocks with high quality pasture are imperative and should be de-stocked for 6-8 weeks before use. The safety of irrigated pastures for finishing lambs is greatly increased by de-stocking, grazing with cattle, or hay/silage production before introduction. Irrigated paddocks have similar patterns of worm infection to dryland and are not as dangerous as perceived. Drenching, alone, is insufficient for effective worm control, and must be supported by provision of good quality worm free pastures for lambing and weaning. Sucker lambs often do not require drenching, but should be tested at around 10 weeks of age. All lambs should be drenched at weaning and/or before entering specific finishing or irrigated paddocks. Growth penalties for failure can approach 60 g/day. Sustained release capsules are often only partially effective. *Ostertagia* is the main drench resistant parasite.

Scouring and deaths due to worms are uncommon. The main losses to the prime and slaughter lamb industries are from reduced growth rates, leading to failure to meet market specifications, delays in marketing and lower carcase weights. The estimated total combined annual impact of internal parasites on the prime lamb industry in South Australia, Victoria and Riverina region of New South Wales is $65.73 million, comprised of $49.47 million (74%) direct losses and $16.26 million (26%) in costs associated with routine control programs.

The research, the first of its type in Australia, has benchmarked the magnitude of a serious source of loss to prime lamb production in southern Australia and identified the main areas associated with worm control requiring attention for profitable prime lamb production. It provides a platform of unique information on worm management that is applicable to all production systems, hence is suitable for knowledge transfer at various levels to a wide audience of prime lamb producers. Project extension activities have been highly successful, with changes in farming practice already initiated on several properties, providing confidence that successful knowledge transfer to industry is achievable. An encouraging recent development is direct interest and involvement of rural resellers and producer study groups. The epidemiological base of the research, segmented into themes that each influence outcomes, is a fundamentally new approach to addressing a highly variable problem from farm to farm, with special relevance to producers in transition to a broader meat sheep production base. The information is also directly applicable to systems with current significant worm control problems, where modest change over 5 years can realise huge industry savings.

The literature database contains most relevant publications and is already available for use by researchers, veterinarians, producers and educationists. It needs to be updated and revised and limited hard copies published. The research has generated a great deal of new information on prime lamb production in southern Australia, with numerous publications forthcoming over the next few years. These will reinforce the science underpinning key messages for professional advisors and advanced producers who are constantly looking for wider options to increase profitability. A proven mechanism to promote producer uptake is a series of “Tips and Tools”. Producer testimonials could be used to promote regional workshop launches of these. A high quality publication detailing best management practice would be appropriate for advanced producers, sheep production advisors, rural resellers and libraries. The research may not be directly referable to Tasmania, hence work is needed there to define the seasonal internal parasite profile, economic implications and management solutions.

# Contents

# 1 Background

## 1.1 Purpose and Description of the Project

Prime lamb profitability is driven by increasing the kilograms of lamb produced per hectare through managing increases in stocking rate, weaning percentage and weight at sale. To successfully increase the numbers and carcase weights of lambs requires good husbandry skills to ensure :
(i) optimum growth rates of prime lamb dams to maximise conception at fixed mating times,
(ii) maintenance of dam health to provide the best opportunities for their unweaned lambs and
(iii) optimum management from weaning to marketing to enable lambs to thrive and realise their genetic potential.

From the late 1990's the southern Australian lamb industry grew substantially in production and prices, with a great increase in the number of meat sheep finished for market on irrigation systems over summer. In addition, farmer groups emerged that were dedicated to increasing sustainable stock carrying capacity, with or without irrigation. Supporting this was the evolution of programs such as PROGRAZE®, and PROGRAZE PLUS®. While factors such as genetic improvement and nutrition could be confidently addressed in these promising developments, a major potential constraint to management capability was the absence of scientific knowledge on the impact of internal parasites and their control. There was anxiety that current 'best practice,' based on wool sheep flocks, might fail outright, or become unsustainable over time, due to poor understanding of the levels of parasites developing on pastures in different production systems, and their impact on production. Indeed, there were numerous examples of failure of broad parasite control recommendations for wool sheep flocks in prime lamb production systems. Adding to this difficulty was the spectre of escalating drench resistance, the management of which demanded an understanding of the epidemiology of internal parasites on pasture.

AHW.045 was born from a recognised need to address fundamental deficiencies in scientific knowledge relating to parasitism in prime lambs, in order to provide producers with the best advice and establish benchmarks for the industry. The project was designed to evaluate the economic outcomes and sustainability of established management strategies routinely applied to reduce the impact of internal parasites in ewe and prime lamb flocks, and demonstrate and promote improved tools to underpin decisions concerning worm management. It was conducted in the "high rainfall" area (>500mm) of mainland southern Australia (South-east South Australia and South-west Victoria), where internal parasitism is recognised as an important constraint to productivity. Emphasis was initially on a representative range of finishing systems for prime lambs and on lambs marketed for slaughter directly from their dams, but attention was also given to the growing out of prime lamb dams and lambing ewes. Research was conducted in all of the key prime lamb production and finishing systems in southern Australia, namely dry land, flood irrigation, pivot (spray) irrigation and cropping. Partial-farm and whole-farm control solutions were designed and tested with producers.

A key objective of the project was to educate producers to increase their awareness of the technologies and resources available to plan, implement and evaluate worm management systems in their prime lamb enterprises and increase their confidence to proceed with limited external reference. Education was to be based on demonstrated on-farm examples. To achieve this, 15 on-farm demonstration or experimental sites were established in South-eastern Australia, representing a range of systems and management. An outbreak of parasitic disease on a stud operation was also investigated. Each producer was part of a local or regional study or marketing group, or alliance, through which the benefits of successful management solutions would be transferred to industry. To complement the on-farm research and provide a reference and research tool for advisors, veterinarians and students, it was also proposed to abstract and collate in a readily retrievable form all available data on internal parasites of sheep in South-eastern Australia of relevance to prime lamb production.

## 1.2 On Farm Research Sites

The locations of the 16 diverse on-farm research/demonstration sites (13 in South Australia, 3 in Victoria) are illustrated in Figure 1. They include 1 stud operation, 10 prime lamb production enterprises operating on dry land (natural rainfall) pastures and 5 primarily on irrigated pastures. According to ABARE definition 11 of the properties represent very large scale farms (>2000 lambs sold for slaughter), 3 are large scale farms (1000-2000 lambs) and one a medium scale enterprise (500-1000 lambs). Most, therefore, fall within the top 6% of producers that account for almost a third of broadacre slaughter lamb production in Australia, and all except two operate farms producing a variable mix of wool, sheep, lambs, beef cattle and crops. All are specialist producers, earning more than 20% of receipts from the sale of lamb, or in one case, stud animals. They are thus representative of an industry that has increased its specialisation in the production of prime lambs to grow annual production by 33% from 330kt to 439kt from 2003 to 2007 (ABARE, 2008). Individual production systems are described below (1.2.1 – 1.2.16).

### 1.2.1 J Andre, "Ceres", Millicent, South Australia

This is a large beef, wool and prime lamb enterprise. Approximately 2000 Dorset X Merino prime lambs are produced annually. Lambs born in June are drenched and weaned on to dryland pastures at 10-12 weeks of age in September, shorn in November then grown out on pivot irrigation to achieve minimum liveweights of 58 kg (carcase weights of at least 28-29 kg) over the next 3-4 months. Each pivot irrigation system consists of a rigid, elevated irrigation pipeline which rotates on a central axis and delivers water from regularly spaced nozzles. With adjustments for sporadic summer rains, the equivalent of approximately 8mm of rainfall is distributed daily on the pasture from November onwards, decreasing later in the season as the weather becomes cooler.

### 1.2.2 B Gerhardy, "Woodhaven Park", Willalooka, South Australia

The business comprises hay production on flood irrigated paddocks, plus prime lamb production on a combination of perennial dryland pastures and flood irrigated fescue. Approximately 3200 Merino ewes sourced off the property are mated to Dorset rams to produce approximately 3500 lambs annually. Irrigation is from late October through to February/March. Ewes are mated in December, and are scanned for pregnancy 40-50 days after removal of the rams. Dry ewes are mated again in March. There are thus 2 lambing periods, the major one in May-June over approximately 6 weeks and the second, smaller lamb drop late in July.

Ewes lambing in May-June receive a priming drench and Ivomec™ capsule in early May and lamb on perennial dryland pastures. Lambs are drenched at marking (age range 3-9 weeks) and again at weaning approximately 6 weeks later (age range 9-15 weeks). At weaning they are placed on the best available dryland paddocks that have been free of sheep for several weeks. They remain there until mid- to late October during which time suitable batches are removed for market as they become available. The main draw is the "Coles" market (approximately 44 kg live weight minimum). Lambs

of around 35 kg may also be sold for finishing elsewhere. The remaining lambs are drenched on to irrigated paddocks recently cut for commercial hay production and free of sheep for 3 months from August. They are rotated (according to feed availability) on these paddocks throughout summer. It is sometimes deemed necessary to drench them again during this period.
Ewes lambing in late July are also drenched and dosed with an Ivomec™ capsule. They are run on dry irrigation bays until these are closed for hay production from August to late October. Their lambs are drenched and weaned directly on to irrigated bays once the hay has been cut.

The irrigated area of the farm thus has ewes and lambs on it more or less continuously for 8-9 months from November each year. However, in addition to the annual hay production period of 12 weeks in spring, there are sufficient paddocks available to enable destocking of most paddocks at other times of the year for irregular 4-6 weeks intervals between grazing episodes.

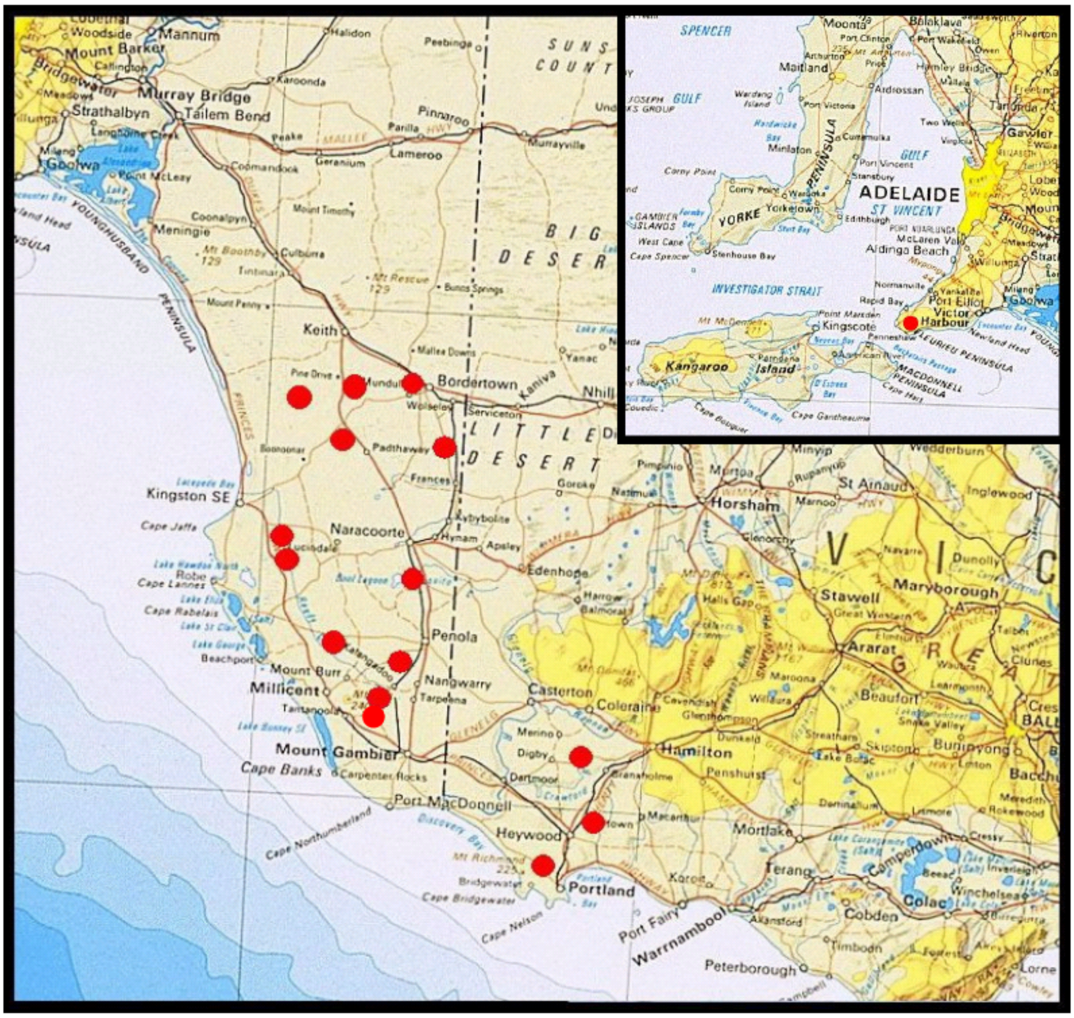



Figure 1 Location of 16 AHW.045 research sites in South Australia and Victoria, 2004 – 2008

### 1.2.3 S Graetz, “Amaroo”, Willalooka, South Australia

The business comprises lucerne seed and hay production on dryland and flood irrigated paddocks, plus prime lamb production. Approximately 440 Border Leicester X Merino ewes are mated to Dorset or White Suffolk rams to produce approximately 130% lambs. Irrigation is from November-February, occasionally to March on some hay paddocks.

Lambing starts 1 April and is finished early May. Ewes are crutched 3-4 weeks before lambing and (in 2003, 2004 and 2005) given an Ivomec® capsule. Previously, ewes received a single summer drench, now discontinued. Ewes lamb on dry land paddocks or harvested irrigation bays. Stocked at approximately 34 DSE/ha they are rotated in two mobs with lambs at foot through a series of paddocks (mainly summer-irrigated lucerne bays [dry during the period of grazing]), and graze each paddock for 7-10 days according to availability of feed. Lambs are not routinely drenched except if they are scouring or judged to be growing slowly in late winter/spring. The production objective is to market all lambs as suckers for the domestic market (live weight 44 kg plus) by the third week of October. Shortly thereafter, the lucerne bays are closed off and irrigated for commercial hay production. Financial penalties are therefore incurred for lambs not reaching market specifications by this time, because they need to be weaned, drenched and supplementary fed over summer.

### 1.2.4 W Hancock, “Fairways”, Reedy Creek, South Australia

The enterprise comprises diverse operations. There is a self-replacing Merino flock of 900 ewes for wool production. This flock also contributes replacement ewes to a crossbreeding program involving a flock of approximately 650 Dorset X Merino ewes. In addition, approximately 2500 purchased crossbreed lambs are finished for market annually.

The Merinos lamb in July and lambs are weaned in December (around 20 weeks). They are shorn in December, wether lambs are marketed at around 1 year old and cull ewes enter the crossbreeding flock. The Crossbreeds lamb in August. Lambing occurs wherever the best pasture is available, including an area of flood irrigation (fescue/ryegrass/strawberry clover) that is later used for finishing lambs over summer. Large areas of the property may be inundated in winter and early spring, leading to grazing shortages, and concentration of livestock.

Merino lambs are marked at the end of August/early September and Crossbreeds in late September. Ewes and lambs are all drenched at marking and weaning. A first summer drench is sometimes, but not always given in December or early January, and coincides with weaning. A second summer drench is given in late February/early March. Lambs for finishing on flood irrigated fescue pasture are bought in from October to December and marketed as they finish, aiming at a carcase weight of 24-25 kg. They are generally shorn around 6 weeks before marketing, to optimise skin value. Flood irrigation usually starts in October and continues throughout summer.

### 1.2.5 T Heysen, “Derrymore”, Kalangadoo, South Australia

The property of 1200 ha produces prime lambs, beef cattle and potatoes. Approximately 3400 Corriedale and first cross ewes are mated to Poll Dorset and Corriedale rams. Lambing commences early in May. Bulk faecal egg counts are done on a range of ewe flocks prior to lambing and individual flocks drenched if necessary. Lambs may be drenched at marking if required; based on faecal egg counts. Lambs are not weaned but run as suckers on dry land pastures consisting predominantly of clover and ryegrass, often concurrently with cattle at a stocking rate of around 5 DSE/ha. Lambs are routinely drenched when crutched in September. Approximately 3700 lambs with an average carcase weight of 22 kg are turned off late November to early December. A summer drench is routinely given in January to all other sheep, followed by a second summer drench if deemed necessary by faecal egg count.

### 1.2.6 K Joseph, "Churinga", Tyrendarra, Victoria

The business produces approximately 1500 prime lambs per year on dryland pastures (mainly Balansa and subterranean clovers and perennial ryegrass varieties). Border Leicester X Merino weaner ewe replacements are purchased in October/November from annual replacement ewe sales at Naracoorte, South Australia and grown out over summer. The ewes are of a recognised type (Gum Hill type Merino ewe X Johnno's Border Leicester ram) which contributes significantly to the pool of replacement ewes entering the industry in South-east Australia, particularly western Victoria. All ewes on the property are mated in February to White Suffolk or Poll Dorset rams, they lamb in June, and lambs are sent to market as suckers, directly from their mothers from late October onwards. There are no cattle and no ewe replacements bred on the property. This production system is representative of many in western Victoria.

### 1.2.7 A Lyon, "Glenisla", Reedy Creek, South Australia

The business comprises two adjacent farms ("Glenisla" and "Grahams") and a third property ("Blackmoor") nearby. Border Leicester X Merino ewes mated to Poll Dorset rams yield approximately 1600 second cross prime lambs annually. To produce first cross ewe replacements Merino ewes are mated to Border Leicester rams at the end of December; lambing starts at the end of May and continues throughout June. They are run mainly on dryland. Wether lambs plus ewes surplus to requirements are marketed as large (25 kg carcase) lambs after finishing on flood irrigation through to January.

Crossbreed ewes are joined from the beginning of March for 7 weeks to lamb from the beginning of August. Some of them are dispersed on dry irrigation bays before and during lambing. The "dry" irrigation bays and adjacent improved pastures are on flats which may be inundated or very boggy for several weeks in winter/spring. This restricts available grazing, and the numbers of sheep that can be carried overall. However, those on the system tend to concentrate on higher areas, creating patchy increases in local stocking density.

Flood irrigation on "Glenisla" generally commences in late October/early November, depending upon the season, at which time the numbers of animals joining the system from the other farms increases as more feed becomes available. Prime lambs are usually weaned at around 18 weeks of age in January and finished on irrigation through to Easter. There is therefore an irrigation period of around 6 months and occupancy of the irrigated area by sheep for most of the year. The irrigation area of 90 ha comprises 6 bays (3 of 12.8 ha and 3 of 17.5 ha), through which intensively stocked animals rotate. Between December-April individual bays are grazed for approximately 2 weeks, following which they are free of sheep for around 6 weeks. The predominant pastures are subterranean clover and ryegrass. Stocking density can be as high as 60-80 DSE/ha.

### 1.2.8 S Malcolm, "West Lakes", Portland, Victoria

The business produces approximately 4000 prime lambs per year on dryland pastures, (mainly white and strawberry clovers and perennial ryegrass). Border Leicester X Merino ewes are mated to Poll Dorset terminal sires in April to start lambing from 20 August for 6 weeks, although most lambs are dropped in the first cycle. Lambs are marketed directly from their mothers as suckers in late January at an expected liveweight of 45 kg to realise about a 20 kg carcase. There are some cattle on the property but they are not used in a coordinated grazing system designed to reduce worm infections in sheep. This production system is representative of those in the higher rainfall coastal areas of western Victoria where spring lambing occurs and lambs are marketed direct from their mothers two months later than their inland northern counterparts.

### 1.2.9 J Mossop, "Ramillies", Penola, South Australia

This dry land enterprise on approximately 1800 ha concentrates on prime lamb production and cropping. The home property of 1100 ha carries 1800 Border Leicester/Merino cross and Composite (mainly Coopworth) ewes. Ewes are joined to Dorset and Composite rams to start lambing in mid-June. Prior to lambing, ewes are either set stocked on dry land pasture or rotationally grazed through a series of "Smart Graze" paddocks every 4 – 5 days, with a 5 – 6 week turnaround before revisiting the first paddock. Lambs are weaned in mid-September (weaning percentage 145%) and set stocked on clover, rape or beans at a density of around 15 DSE/ha. They are grown out to a live weight of 48 kg or more and turned off from November onwards. The only routine drench given is at weaning to both ewes and lambs, and for the rest of the year drenches are given on an as needs basis as indicated by faecal egg count.

### 1.2.10 M Pocock, "Panlatinga", Willalooka, South Australia

"Panlatinga" covers 1100 ha, of which approximately 825 ha is allocated to sheep. This enterprise includes the production of Merino rams in a self replacing Merino flock and the production of first cross Border Leicester x Merino lambs. The Merino type is robust and large framed (Lines/Gum Hill/Bungaree type) and many ewes from this property find their way into the prime lamb industry, either to be mated to terminal sires, or (primarily) to Border Leicester rams to produce first cross breeding ewes. A base flock of 1800 Merino ewes is maintained from which rams are sourced for sale to the industry. Merino ewes are sold from this flock to first cross ewe producers. Another flock of 1000 Merino ewes contribute to the production of first cross lambs on "Panlatinga". Merino ewes culled from the larger flock on the basis of poorer wool quality and other selection criteria enter the crossbreeding flock. Lambing takes place from the beginning of August for 5 weeks. Lambs are drenched and weaned in mid-November on to 'worm free' pasture. The farmer practices "Smart Grazing" and paddocks prepared in summer and autumn are reserved specifically for ewe weaners. Merino ewe hoggets are mated at around 18 months. First cross ewes are sold at around 15 months of age in the annual November sales.

### 1.2.11 D Price, "Majardah", Glencoe, South Australia

"Majardah" comprises approximately 200 ha of dryland pasture/pasture oversown with barley, primarily used for stud ram production. Mated or artificially inseminated Poll Dorset and White Suffolk ewes lamb from mid-May to mid-August. Ewes receive a summer drench in February, a pre-lambing drench and usually one other drench as required according to faecal egg count. When a disease outbreak was investigated in July 2008, “Majardah” carried approximately 400 stud ewes, 150 hogget ewes, 600 lambs, 160 rams and 110 cattle.

### 1.2.12 B Ryan, “Tent Rock”, Delamere, South Australia

“Tent Rock” is an undulating coastal property in the highest rainfall belt in South Australia. Approximately 2000 Border Leicester X Merino ewes are mated annually to terminal sires as follows: Coopworth rams are introduced for 17 days, removed, and followed by Poll Dorset rams for a further 17 days. All lambs are dropped over a 35-day period from 1 July. Ewes are set-stocked with their lambs for 3 months until October when lambs are weaned (10-12 weeks old). Approximately 80 paddocks, each of 6 ha, provide rotational grazing for most of the year (except, as mentioned above, from lambing to weaning). Weaned lambs are drenched and go into the slow grazing rotation. They graze individual paddocks for around 5 days with a return interval of around 1 month. Weaning paddocks are generally free of sheep from the autumn break (6 months) – at worst they may have carried some sheep for 3-4 months before lambs are weaned on to them. Ewe lambs from Coopworth rams are retained as replacements in a move towards a pure-bred Coopworth flock. Lambs are marketed at around 39 kg in December, mainly to feeders in mid-north SA.

At weaning ewes are divided into 2 flocks according to condition and rotationally grazed. As feed availability declines, usually in early summer, stocking density is reduced through the sale of lambs and removal of young ewes to grazing on stubbles elsewhere in SA. An average overall stocking density of 19-20 DSE/ha reflects a high of around 35 at the end of October, declining to around 9-10 by autumn, as sheep are removed to other properties. Likewise, a paddock rotation interval of 20-30 days in spring can extend to 60-70 days in late summer. Ewes are drenched close to lambing (June), but drenching decisions at other times depend on the results of faecal egg counts. In 2004 no summer drench was given because worm egg counts were very low – by autumn they had only risen to approximately 50 epg. A herd of 180 cows is moved through 30 paddocks on a 2-day rotation.

### 1.2.13 C Smith, “Grassdale Estates”, Branxholme, Victoria

The business produces approximately 4800 second cross prime lambs per year on dryland pastures. The paddocks are generally set-stocked, but movement occurs due to seasonal feed availability. Cattle are a reasonable component of the business and sometimes graze together with sheep, but are not used strategically for control of worms in sheep. Poll Dorset rams are used as terminal sires over Merino or Corriedale ewes mated with East Friesian or Coopworth rams. The flock is self replacing. Ewes are given a drench at the time of pre-lambing crutching in mid-May. Lambs for market are dropped from the end of June over 6 weeks. At marking in early September the ewes are drenched and some “spot drenching” (approximately 10%) is done on lambs that seem to be doing poorly. Ewes and lambs are drenched when the ewes are crutched in November. A second summer drench is given to ewes in February based on the results of faecal egg counts. Lambs are marketed direct from their mothers in late December, aiming for a trade weight carcass of 18-20 kg (live weight around 37 kg).

### 1.2.14 K Staude, “Kenwyn”, Cannawigara, South Australia

The 340 ha property carries 1600 breeding ewes. Coolalee or White Dorper rams are used as terminal sires over Border Leicester X Merino ewes. There are two lambing periods, May and August. May lambs are weaned at 14 weeks in August and grown out on perennial pasture or a sown cereal/pasture crop to a 22 kg carcase (approximately 70%). The remaining 30% of lambs are finished from early November for up to 6 weeks on spray-irrigated pastures, or in a feedlot. August lambs are weaned initially on to oats/clover where they remain until stubbles are available in early January. The irrigated area may carry sheep all year.

### 1.2.15 Struan Research Centre, Naracoorte, South Australia

This is a government research and commercial operation on several interdependent properties. The main farm at Struan (1050 ha) has dryland, flood irrigated (55 ha) and pivot irrigated (95 ha) pastures. Enterprises include prime lambs, wool production, beef bulls and production of beef stores.

Approximately 5000 first cross and Merino ewes across the combined properties are joined with Dorset and Border Leicester rams to start lambing late in May. Lambs are weaned in early October and moved onto either the flood- or pivot irrigated pasture (ryegrass / fescue / white clover) in early December where they rotationally graze at a stocking rate of 20-25 lambs/ha. Lambs graze individual paddocks for around 7 days, with return intervals to paddocks of 16-20 days. Approximately 500-600 first cross ewes are retained annually as replacements and 3500 45–50 kg lambs marketed between January and March. Following sale of the last batches of lambs, the irrigated pastures are grazed only by cattle until the following season (i.e. for at least 6 months). Lambs are drenched at weaning and prior to introduction to the irrigation system, but receive no drenches whilst on the irrigated pastures.

All other sheep routinely receive a first summer drench from late November and, when deemed necessary by worm egg count, a second summer drench in February and/or a pre-lambing drench in May. Spring drenching of individual flocks is also determined on the on the basis of faecal egg counts.

### 1.2.16 D Will, “Paldaro”, Bangham, South Australia

Prime lamb production is conducted on approximately 500 ha of dryland lucerne and clover-based pastures. Approximately 2000 Border Leicester/Merino ewes are mated to White Suffolk or Poll Dorset rams. Lambing begins in mid-May. Lambs are weaned at 8 – 12 weeks of age with the aim of turning them off before grass seeds become a problem in spring, or prices are forced too low. Approximately 2400 lambs are turned off annually, usually with a dressed weight of 18 – 24 kg.

# 2 Project Objectives

## 2.1 Review all data relevant to parasitism in prime lamb production

The primary off-farm objective of AHW.045 was to collate and critically review the available published and unpublished data pertaining to the epidemiology of internal parasites of sheep in South-eastern Australia and the identified or potential effects of internal parasitism on prime lamb production. This was addressed through a comprehensive literature search, including abstracting and collation under keywords. In addition, an original raw data set of extensive, detailed, parasitological studies conducted at Kybybolite Research Station in South Australia over several years in the 1980's was to be collated and electronically recorded for statistical analysis.

Objectives 2.3.2 - 2.3.4 relate to management strategies used to control internal parasites, decision processes and tools influencing these, prediction of outcomes and measurement of levels of success.

## 2.2 Demonstrate a range of decision making tools

It was undertaken to demonstrate and promote to meat sheep producers that monitoring of levels of nematode larvae on pasture and regular flock sampling provide invaluable tools to underpin on-farm decisions. Decisions included the preparation and provision of safe pastures to stock, removal of stock from pastures before parasites reached dangerous levels, and general planning of strategic worm control in complex farming systems. Pasture larval counts and faecal egg counts were regularly done in at least one production system on every trial site.

## 2.3 Define the epidemiological basis of worm control, particularly in the newer systems

Grazing systems that intensify animal production can lead to unforseen side effects, particularly parasitism. There was virtually no information available concerning parasitism in sheep, either set stocked or rotated, on flood irrigation or any of the newer production initiatives such as pivot irrigation. Specific measurements were designed to provide fundamental epidemiological data for these systems.

## 2.4 Determine the economic impact of internal parasitism on prime lamb production and efficiency of routine management strategies

A large gap in knowledge pertinent for all livestock grazing systems in Australia is that the levels at which nematode larvae on pasture begin to assume economic importance, and the circumstances associated with the severity of their impact on productivity, have not been determined. One of the basic research protocols for AHW.045 was designed to provide substantiated quantified answers to the above deficiencies, define possible limits to parasite control in some management systems, and identify in which systems, and why, the levels of parasites, and/or their impact, were reduced.

## 2.5 Producer education

Encompassing all of the other objectives was a resolve to educate producers to increase awareness of the technologies and resources available to plan, implement and evaluate worm management systems in their prime lamb enterprises, and the confidence to proceed with limited external reference. Education was to be structured on demonstrated on-farm examples. This objective formed the cornerstone of the communications activities.

# 3 Methodology

## 3.1 General Research and Demonstration Procedures

On-farm research activities in AHW.045 from 2004-2008 can be broadly classified into 4 categories: routine farm monitoring; prime lamb productivity; ewe reproductive efficiency; and specific investigations and demonstrations.

Initially, studies were established on 12 properties to examine the effectiveness of a range of management strategies commonly employed by producers to control the impact of internal parasites on production. Examples included drenching at prescribed times of the year, *e.g.*, "summer" (strategic) drenching for overall farm control, pre-lambing (tactical) drenching of ewes to protect both them and their progeny from serious pasture contamination during the peri-parturient period, drenching of lambs at marking and again at weaning, weaning on to fodder crops or "clean" pastures, lambing on "clean pastures", mixed grazing with cattle etc. No attempt was made to influence options or combinations of options chosen by the farmer. The project evaluated the performance of the selected options using techniques designed to clearly identify production-limiting events. Parasitological impacts were assessed by measuring the levels of larval parasites that were able to survive in the environment, estimating the worm burdens derived from them and quantifying their influence on growth rates. Results from each experimental site were widely communicated and compared across systems and environments, enabling identification of practices resulting in either the greatest risks, or benefits. The frequency and intensity of measurements varied from site to site. All activities were discussed with and agreed upon with individual farmers before their implementation. For reasons of economy, and to improve comparisons, more than one production system or class of sheep was sometimes concurrently studied on the same farm.

Subsequently, activities on some properties were discontinued, primarily due to seasonal conditions, and new sites were added. Each site, however, remained representative of an important production system or producer group in the southern prime lamb industry. Some initial sites were retained for the duration of the project, either because they produced results requiring further investigation or validation, or because of their exceptional value as demonstration sites for communication of key messages to Industry. Research in the second and subsequent years either: (i) validated earlier encouraging or disappointing results, or (ii) evaluated promising untested control strategies. Again, all protocols were agreed upon with the producer before implementation. Experience from previous years provided a basis for judgement in this process, but production expectations and the specific structure of each enterprise was important in determining activities. The level of experimentation was also influenced by the risk that individual producers were prepared to accept in modifying entrenched management practices, particularly drenching.

## 3.2 Routine Farm Monitoring

This involved regular measurements of nutrition quality and quantity, faecal egg counts as an indicator of sheep worm burdens, and levels of infective worm larvae on the pastures they were grazing. All properties were subjected to monitoring to a greater or lesser degree. To produce comprehensive epidemiological data sets four properties were monitored intensively over 4 years, with emphasis on the seasonal patterns of worm larvae of pasture. Monitoring on other properties was less sustained. On some it was confined either to the period during which productivity studies were conducted (around 4 months), on others it was extended (for up to 2 years) to provide additional data to confirm trends.

### 3.2.1 Pastures

Pasture nutritive value (FEEDTEST®) and to a lesser extent Feed on Offer (kg DM/ha) were assessed on most properties during the period that sheep were under observation. As the project progressed, FEEDTEST® values assumed great importance in interpreting research findings.

### 3.2.2 Pasture larval counts

The number of nematode (worm) larvae on pasture (larvae/kg DM) was used as a key management and research tool in this project to: (i) underpin day to day decisions concerning management of pastures to reduce exposure of sheep to internal parasites (ii) provide information on the tolerance of sheep of various classes to larval challenge under different management and nutritional regimens, (iii) monitor the influence on parasite management of strategies designed to enhance production, and (iv) aid in interpretation of seasonal pasture contamination patterns. Measurements of pasture larval contamination were done at least monthly (and as frequently as weekly) on all pastures on which experimental animals were grazing.

### 3.2.3 Faecal worm egg counts

At least 15 individual faecal egg counts were regularly done on each experimental group at every site to indicate the numbers of parasites maturing in the animals and the potential for ongoing pasture contamination. Faecal egg counts were often also done on flocks not specifically involved in experiments to clarify their contribution to the overall parasitological profile on the property.

### 3.2.4 Differential larval counts

At each faecal egg count examination a composite larval culture was made from faeces of sheep that had not been suppressively treated for worms, and the worm larvae from the culture identified.

To avoid confusion the generic term *Ostertagia* for the Brown stomachworm of sheep has been retained in descriptions in this report rather than the taxonomically correct *Teladorsagia*, because producers had strong associations with the first two terms and were unaware of the latter.

## 3.3 Prime Lamb Productivity

On each property one or more studies were set up to examine the success of the producers' management strategy or series of strategies designed to control the impact of internal parasites on production in the prime lamb enterprise. Initially, these strategies were those currently applied as best practice, according to the understanding of the producer. On some farms, the strategies were modified in subsequent seasons to demonstrate and benchmark enhanced benefits. All key production systems, namely dryland, flood irrigation, pivot (spray) irrigation and cropping were included, with emphasis on the greater regional contributors to overall Industry production. In most cases lambs were weaned, either at the start of the study or shortly thereafter, however some trials involved suckling lambs that were followed through to marketing.

The general protocol underpinning all on-farm productivity studies is described in Appendix 1. Explanations of protocol design and interpretation are given below. Individual variations are described in detail in the relevant appendices to this report.

### 3.3.1 Interactions between factors affecting productivity

Apart from their key influence on production parameters in both reproducing and growing sheep, pasture quantity and quality also influence the acquisition of worm burdens by sheep and their resilience to them. Therefore, it was not appropriate to make across-farm comparisons concerning productivity. Indeed, on-farm separation of the relative contributions to productivity of nutritional status and parasite challenge would have been equally difficult. To overcome this problem a suppressive-treated group of lambs was included in every study. Slow release anthelmintic capsules (SRC) containing ivermectin or albendazole or an injectable formulation of moxidectin removed the adverse influences of incoming and developing parasite larvae and adult parasites for known periods, thereby enabling comparisons between groups of sheep grazing concurrently. Lambs were given a ‘priming drench’ to remove existing worm burdens at the time of administration of the SRC.

Evidence of comprehensive (not necessarily sustainable) parasite control for a particular flock was defined as similar growth rates for suppressive-treated and control lambs in that flock. It was intended to have at least 100 animals in each group in each study, however this proved to be impractical, and numbers were reduced.

### 3.3.2 Measurement of efficiency of the systems

Planned measures of the efficiency of individual prime lamb productions systems were either the numbers of lambs turned off meeting market specifications at a particular time, or the total weight of lambs turned off per hectare. In practice, neither of these could be reliably predicted or estimated because flocks were regularly split or combined and stocking rates altered at short notice during grow out periods due to variations in pasture between paddocks. In addition, adverse seasonal conditions prompted interventions on some properties (eg feedlotting, sale as store lambs etc) as producers adjusted to market signals. Other variations occurred where producers generously retained lambs past their planned marketing time to enable additional research data to be collected. Because of these influences it was found that the most consistent measurement of the success of the routine parasite control program on each property was the difference in daily growth rates between lambs in the suppressively treated and control groups. Lambs in productivity studies were weighed at weaning or at the first suppressive treatment and, if possible, at 4-6 weekly intervals thereafter until they left the production system or were marketed. By virtue of the mandatory treatment to slaughter withdrawal periods for the products used, there was usually a period of up to 100 days over which growth rates could be usefully compared.

### 3.3.3 Other measurements and observations

- Total worm counts: At the end of each prime lamb productivity study the gastro-intestinal tracts of up to 5 lambs from the regular management group were collected and total worm counts done to estimate numbers of worms that the lambs had acquired during their time in the system. Total worm counts were reviewed in the context of differences in growth rates between treated and control sheep, levels of larval challenge, faecal egg counts and pasture quality and quantity.
- Diarrhoea: Laboratory faecal examinations were used as an aid to differentiate transient or unusual scouring events in sheep. Because of the capacity of pasture endophytes to cause diarrhoea and adversely affect productivity, one study (at Struan Research Centre) was structured to investigate their influence.

- Cattle: On some farms and production systems cattle played a role in grazing management and their degree of influence in parasite control in the prime lamb enterprise was investigated.

## 3.4 Ewe Reproductive Efficiency

Weaning percentage (incorporating conception rate and survival of lambs following birth) provided a measure of reproductive efficiency in 3 flocks of maiden Border Leicester X Merino ewes near Portland and Tyrendarra, Victoria. In each flock two groups of ewes were randomly formed. All ewes grazed together and were subjected to identical management interventions and nutrition, except for internal parasite control. One group of ewes was suppressively treated for worms over a prolonged period, while the other group was subject to the routine worm control procedures normally applied on the property. On one property two successive replacement ewe flocks were examined for a full breeding and productive cycle (9 months); on the other, one replacement ewe flock was examined for two breeding and productive cycles (18 months).

The general protocol for these studies is described in Appendix 2 and specifics for each study detailed in the relevant property appendices.

## 3.5 Specific Investigations and Demonstrations

From 2005, additional investigations were conducted (at variable scientific robustness) to develop data on specific issues, as support for communication of key messages to Industry. It was recognised that, over and above the productivity and epidemiological information being developed, regional worm control messages required underpinning by local, practically orientated data. The main supportive investigations and demonstrations were:

- Faecal egg counts in progeny of meat sheep sires. Bordertown, South Australia, June 2005.
- Cobalt status and parasite levels in second cross weaners on flood-irrigated pastures. Reedy Creek South Australia, January - April 2006.
- Seasonal survival of larvae in desiccated faeces on pasture. Reedy Creek, South Australia, March – October 2006
- Total farm monitoring of worm control. Reedy Creek South Australia, November 2006 to present.
- Influence of endophytes in prime lambs on flood irrigated perennial ryegrass pastures. Naracoorte, South Australia, December 2006 – March 2007.
- Destocking and grazing with cattle in total farm worm control. Portland Victoria, June 2007 to present.
- Reinfection of ewes after prolonged worm suppression with capsules. Portland Victoria, October 2007 – January 2008.
- Drench resistance tests were conducted on each property if young sheep with sufficiently high faecal egg counts became available. On some properties drench resistance was identified through failure of products in trials, or through monitoring flock animals following routine treatments.

## 3.6 Statistical Evaluations

The epidemiological data represent independent variables in specific environments, hence tests for association or difference are not appropriate. Statistical analysis of lamb productivity trials was conducted using parametric ANOVA, whenever possible. For valid use of a parametric ANOVA it is necessary for 5 assumptions to be met i.e. random procedures, additivity, independence, normality and homogeneity of variance. In all trials animals were allocated randomly to groups, there was no interaction between main effects and all measurements were independent of each other. The Shapiro-Wilk normality test and Bartlett's test of equal variances were applied to the data. Where a deviation from normality or homogeneity was detected, a Kruskal-Wallis non-parametric ANOVA was used for analysis, rather than a parametric ANOVA.

## 3.7 Communications Strategy

There was a clearly defined strategy to increase awareness of the project, identify relevant additional research opportunities throughout the life of the project, and stimulate uptake of important research findings. All participants were members of local producer groups or broader marketing or production alliances. These included around 220 producers in 8 farmer groups or alliances, who produced more than 350 000 lambs annually. This provided substantial coverage of a significant geographical component of the national prime lamb industry. In addition, all sectors of the prime lamb production chain and all key production systems were represented, ensuring a wide audience for promotional and extension activities. For success of the project an understanding by producers of the objectives of the research and the relevance of findings to their particular circumstances was essential. Research activities aimed to develop easily understood, acceptable messages based on practical field experience. Experimental sites provided an example of local relevant data and individuals usually participated in the measurements and collection of samples on their properties. Progress laboratory information was sent promptly to producers and, if necessary, the implications discussed with them. Thereafter, overall results were reviewed at producer meetings in the local context, and were then compared regionally to identify risks or benefits associated with different management practices. Producers helped identify follow-up activities to clarify unanswered questions. The combination of a simple project design and definition of a series of workable management solutions was expected to facilitate awareness and adoption of key messages.

Extensive measurements were made on some properties to demonstrate the critical importance on overall production of non-parasitological factors such as pasture quality and quantity. This activity was designed to add significant value to the farmer learning experience and provide a broad variety of material to strengthen discussion at field days and other producer forums.

Field days were energetically promoted to encourage widespread participation. Professional facilitators and government officers were engaged to develop and promote technical transfer and support delivery, including field days and associated radio and press awareness. Some rural resellers and agents participated in local meetings and shared the outcomes.

Research activities in AHW.045 varied in scientific robustness, from formal, structured trials, to simple, subjective field demonstrations designed to emphasise important principles. The material arising from this effort was suitable for one or several of a range of presentation options, including publication in scientific journals, presentation at professional meetings, technical summaries, popular articles, and observations forming a platform on which to stimulate discussion with producers.

# 4 Results and Discussion

## 4.1 Scope of on-farm investigations

On-farm experiments were conducted broadly in line with the methodology described earlier (see Section 3 and Appendices 1 and 2). The results are summarised according to property in Sections 4.3 onwards. Detailed experimental procedures and tabulations are given in appendices specific for each property.

Table 1 summarises the various studies conducted from 2004-2008 on individual properties and their timeframes. In addition to routine farm monitoring for 4 months to 4 years, 28 lamb productivity trials and 3 ewe reproductive efficiency trials were conducted, plus 11 other specific investigations or demonstrations.

Table 1 Summary of on-farm research in Project AHW.045, 2004-2008

| Prime lamb producer | 2004/05 | | | 2005/2006 | | | 2006/2007 | | | 2007/2008 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | M | L | E | M | L | E | M | L | E | M | L | E |
| Andre, J. | ✓ | ✓‡ | | ✓ | | | ✓ | | | | | |
| Pocock, M. | ✓ | ✓# | | ✓ | | | | | | | | |
| Gerhardy, B | ✓ | ✓ | | ✓ | ✓ | | | | | | | |
| Graetz, S. | ✓ | ✓ | | ✓ | ✓ | | | | | | | |
| Staude, K. | ✓ | | | ✓ | ✓#$ | | ✓ | | | ✓ | | |
| Smith, C. | ✓ | ✓ | | | | | | | | | | |
| Ryan, B. | ✓ | | | ✓ | # | | ✓ | | | ✓ | | |
| Joseph, K. | ✓ | | ✓ | ✓ | | ✓ | | | | | | |
| Malcom, S. | ✓ | ✓ | | ✓ | ✓# | ✓ | ✓ | ✓ | | ✓đ | ✓ | ≠ |
| Struan Res. Centre | ✓ | ✓ | | ✓ | ✓ | | ✓ | ✓γ | | ✓ | | |
| Hancock, W. | ✓ | ✓ | | ✓ | ✓✓ | | ✓αβ | ✓ | | ✓β | ✓ | |
| Lyon, A. | ✓ | ✓ | | ✓ | ✓● | ✓✞ | ✓ | | | | | |
| Will, D. | | | | | | | ✓ | ✓ | | ✓ | ✓✓ | |
| Mossop, J. | | | | | | | | | | ✓ | ✓ | |
| Heysen, T. | | | | | | | | | | ✓ | ✓ | |
| Price, D | | | | | | | | | | ✓* | | |

M Routine farm monitoring; L Prime lamb productivity; E Ewe reproductive efficiency
‡ Comparison of systems; # Drench resistance trial; ● Lamb productivity/cobalt status
* Disease investigation; ✞ Ewe growth/trace elements; ≠ Ewe immune response
đ Destocking/cattle; $ Genetic resistance demo.; α Survival of larvae in dung
β Whole of farm monitoring; γ Endophytes in lambs

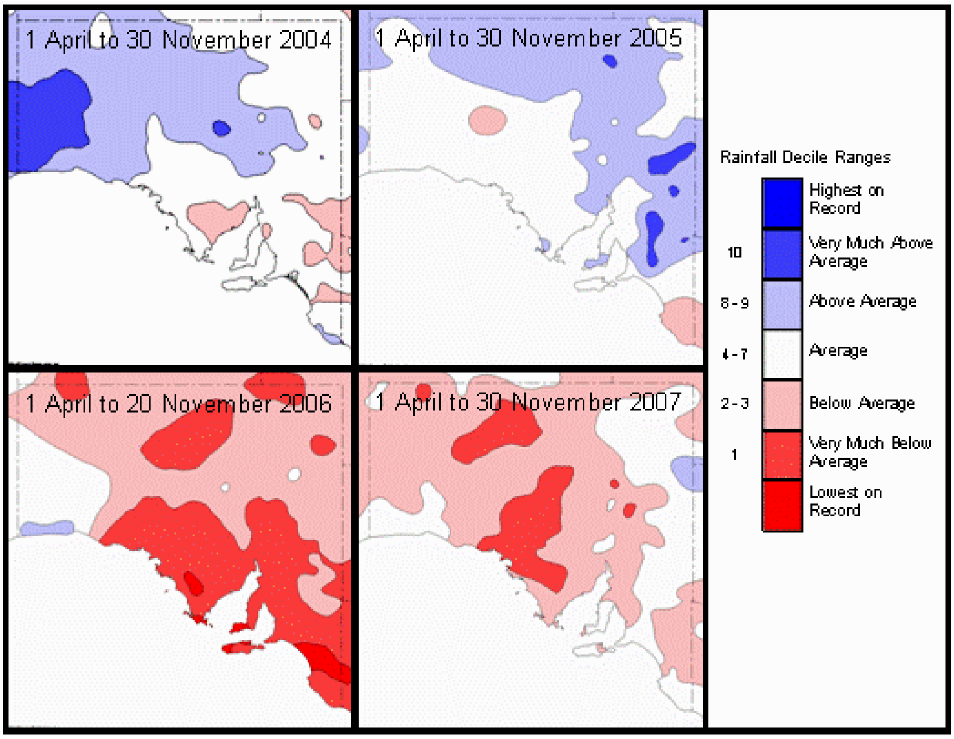
## 4.2 The influence of climatic factors

The research was conducted under the background of a series of extremely dry seasons, producing in some locations the driest period on record and in much of the remainder consistent, below average rainfall figures (Figure 2). This factor forced delays in establishing some trials, leading to adjustments to the overall timing of the project. Unfortunately, it also adversely influenced the value of research results on a few sites through two mechanisms; first, pasture shortages causing uncommonly poor lamb performance, second, significantly decreased capacity for parasite transmission compared with years of average or higher rainfall. To conserve project resources and ensure the generation of relevant research data, established studies on several sites were continued through at least 2 seasons and some planned research in important representative areas was deferred for 1-2 years, pending improved seasonal conditions. The project therefore occupied 4½ years, rather than the originally planned 3 years.

Rainfall and temperature data cited in this report were taken from the Australia Data Archive of Meteorology (Bureau of Meteorology, Commonwealth of Australia). Most records were kindly supplied by Mr Peter Clemett of the Climate Service Centre in the South Australia Office of the Bureau of Meteorology. Records from the nearest or most appropriate (according to topography) weather station were used as reference for the various properties after discussion with Bureau staff.

Figure 2 2004 –2007 wet season rainfall deciles
South Australia and South-western Victoria*

Figure 2.
2004 – 2007
wet season
rainfall deciles




*Distribution based on gridded data. Product of the National Climate Centre.
Modified from www.bom.gov.au

## 4.3 Results from individual properties

### 4.3.1 J. Andre January 2003 – February 2006 (Appendix 3)

SARDI had already completed considerable internally funded research on "Ceres" at the time the application for AHW.045 was being considered by MLA. Because of the direct relevance of some of this work to intensive prime lamb production in southern Australia, the relevant findings arising from the independent SARDI research were incorporated within AHW.045.

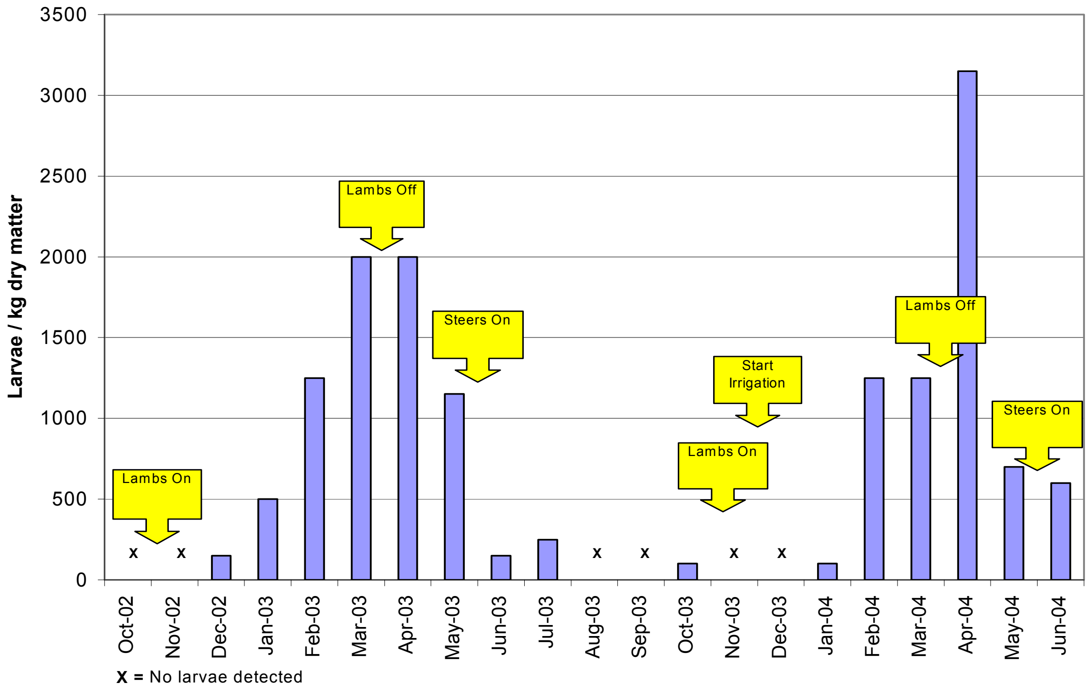
A pilot study on the property (January-October 2003) had measured the levels of larval worm contamination on pasture produced by lambs and cattle grazing concurrently on a pivot irrigation system. However, no growth data had been collected from the 2002-drop lambs. Research continued on the same pivot irrigation system in November 2003 with the introduction of a batch of 2003-drop lambs. This study was designed to follow a full production cycle, including economic outcomes, starting with the introduction of weaners, following them through to market in April 2004 and then monitoring levels of pasture infectivity in the months following their removal.

Altogether 249 weaned Poll Dorset X Merino lambs 39-47.5 kg were used in the above prime lamb production study from November 2003-January 2004. The last of the previous season's lambs had been removed nearly 8 months earlier, in April 2003, and the area prepared by grazing only with drenched cattle thereafter. The study followed the same general design as described in Appendix 1. All lambs were drenched with moxidectin (Cydectin™, Fort Dodge) according to the weight of the heaviest animals and held for one day before introduction to the irrigation system. One group of 119 lambs was dosed with an 'Ivomec™ Maximiser' bolus to provide worm control for 100 days. A second group of 130 lambs served as un-dosed controls.

They were incorporated into 2 larger flocks of approximately 500 and rotationally grazed through separate sectors of the pivot, each of which was subdivided into 6 paddocks. Individual paddocks were grazed for 3 days, giving a return interval to the original subdivision of 15 days. Cattle followed one day behind each flock and grazed concurrently with them for 2 days until the sheep moved forward at the end of their 3-day grazing period. This represented, therefore, an integrated cell grazing system. For the last 72 days of the study the pivot was divided into 6 approximately equal areas of 16 ha, each of which was set-stocked at approximately 18 DSE/ha of lambs and 32 DSE/ha of cattle. No drenches were given throughout the duration of the study. The lambs were weighed on 5 occasions from November 2003-March 2004. Pasture larval nematode counts were done monthly from November 2003-March 2004 and continued for 3 months following removal of all sheep from the pivot. Additional counts were available from the previous season (see above). Pasture quality analyses and faecal worm egg counts with larval cultures were done on 4 occasions. Four grown out lambs were slaughtered for total worm counts in April 2004.

In the 2002/2003 pilot study, pasture larval counts rose steadily over summer, to peak at around 2000 larvae/kg DM as the last lambs were marketed (Figure 3). Larval contamination declined to low levels over the next 2 months and remained so for several months, until February 2004, approximately 3 months into the 2003/2004 growth study. Levels peaked at over 3000 larvae/kg DM early in April 2004, coinciding with removal of lambs from the pasture, and then rapidly declined as in the previous season. Pasture larval counts in March-April 2003 and again in April 2004 were sufficiently high to have had an adverse effect on production had lambs remained longer on the system. A similar pattern of seasonal pasture contamination and decontamination was again observed in 2005, although larval concentrations did not reach the very high levels of the previous two years, possibly because of dry seasonal conditions. The established system is therefore sustainable, providing pastures have been "cleaned" with grazing cattle prior to introduction of lambs treated with a highly effective anthelmintic.

Figure 3 Seasonal levels of sheep worm larvae on pivot irrigation (larvae/kg DM)
J Andre, Kangaroo Inn, October 2002 – June 2004




Lambs receiving continuous suppressive worm control through sustained release Ivomec™ capsules gained 1.6 kg more than their untreated counterparts over 118 days and weights of the 2 groups became significantly different. However, untreated lambs grew overall at 191 g/day compared with 204 g/day for suppressively treated lambs, therefore additional drenching would not have been economically justified. Furthermore, at each weighing interval there were no differences between treatment groups in the numbers of animals that had reached the minimum weight target of 58 kg. This, together with the weight data, confirms that if the pasture is sufficiently "clean," internal parasites are unlikely to be an impediment to profitable prime lamb production within the parameters described above. This does not imply, however, that the lambs would have remained in good health indefinitely, or even for another few weeks. The differential growth rates between the two groups can be considered in 3 phases of approximately 50, 30 and 30 days respectively. In the first phase there was virtually no difference in growth between the groups (4 g/day), in the second this had increased only slightly (to 8 g/day), but during the final phase there was a substantial increase to 27 g/day. Over the final phase the growth of untreated lambs had slowed such that it would have taken an additional 12 days at their current growth rate to make up the deficit incurred over this interval. In real terms, however, their growth rate was declining, hence the actual delay would almost certainly have been greater than 12 days. Towards the end of the trial pasture larval levels were rising rapidly, and untreated animals were at risk of accumulating worm burdens detrimental to production.

Low levels of cattle worms on pasture were unlikely to have adversely influenced lamb growth.

The research demonstrates that preparation of a “clean pasture” on pivot systems through removal of sheep for several months over winter and spring will enable sustainable economic prime lamb production for up to 4 months over summer. Other work done by SARDI Parasitology has confirmed that an effective de-stocking period before introduction of lambs can be as short as 3-4 months. Cattle probably contribute significantly to the process, although in the current study it was not possible to confirm this benefit.

Ivermectin capsules were highly effective in controlling the acquisition of worm burdens by the lambs. *Trichostrongylus* was the dominant parasite recovered from cultures of faeces from control lambs.

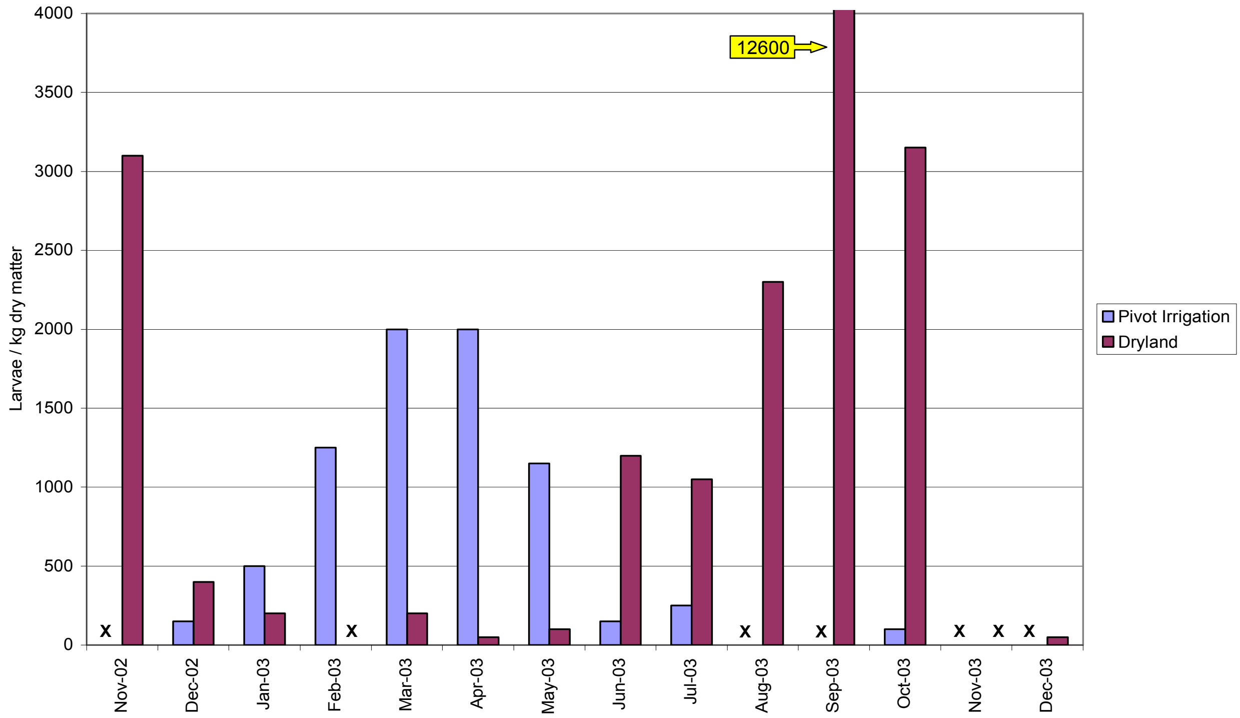
Pasture quality, at least during the last 8 weeks of grazing, was excellent (greater than 72% digestibility and 10.5 MJ energy/kg DM).

Four finished control lambs had an average of 29105 *Trichostrongylus* spp., with up to nearly 50000 in one lamb. This represents a significant worm burden. Approximately half of the burden was *T. vitrinus*, the most pathogenic species in this genus. This level of worms would be expected to adversely affect growth, and possibly also cause some scouring in the flock. Although lambs were not scouring, a significant divergence in growth rates between treated and control lambs had emerged by the end of the study, and had they remained on the pasture, even for a short period of time, economic penalties were inevitable. The absence of substantial economic penalties from worm infections is ascribed to very high quality nutrition for at least the last 56 days.

From November 2002-December 2003 levels of pasture larval contamination on 2 paddocks receiving only natural rainfall and grazed with sheep according to seasonal pasture availability were compared with those on the pivot irrigation system that was stocked with cattle throughout the year, with prime lambs added during an irrigation period from November to March (Figure 4).

The normal seasonal profile of dryland pasture contamination was dramatically modified by interactions between sheep and cattle placements and irrigation. Seasonal contamination profiles on the dryland and irrigation systems were virtually the inverse of one another. These observations provide compelling evidence that strategic placement of cattle and sheep can be employed to manipulate pasture infectivity and dramatically reduce parasite exposure of lambs being finished on irrigated pastures over summer. Adjustment of cattle placement schedules might also be made to allow a period of winter and early spring grazing by sheep, providing that pastures were cleaned by cattle before and after occupation of the site by sheep. To provide peace of mind, this process, at least in the first instance, should be supported by pasture larval measurements.

Figure 4 Levels of sheep worm larvae on pivot irrigation and dryland paddocks (larvae/kg DM)
J Andre, Kangaroo Inn, November 2002 – December 2003




X – no larvae recovered

**Key findings and recommendations**

- Replacement of sheep with cattle on a pivot irrigated pasture from late autumn to spring led to rapid decline in numbers of sheep larvae on the pasture. Effectively drenched lambs from the following season's crop were then safely finished throughout summer without further drenching. Cattle can therefore be used to "clean" pivot irrigated pastures making them safe for finishing prime lambs over summer. If the above principles are followed there is unlikely to be any economic benefits from drenching or dosing slow release anthelmintic capsules to lambs during finishing on a pivot system.
- Control lambs had acquired moderately high levels of *Trichostrongylus* when finished, but did not scour and grew overall at 191 g/day over 118 days. The absence of substantial economic penalties from worm infections is ascribed to very high quality nutrition for at least the last 56 days.
- Regardless of the efficiency of worm control over summer, retention of lambs on pivot-irrigated pastures into late autumn resulted in the accumulation of dangerous levels of pasture contamination that persisted for at least 3 months. If the market objective in systems of this type is heavy trade or export lambs, greater vigilance than usual is needed, because to achieve the additional weight, lambs will inevitably be held longer and exposed to the dangers of increasing levels of larvae on pasture. In these situations it is advisable to monitor, at minimum, faecal egg

counts and lamb growth towards the end of the grow-out period. Once it becomes necessary to drench or shift the lambs, any perceived marketing advantage is lost.

- In this study worms from cattle did not adversely affect the lambs. However, *Trichostrongylus axei,* which is potentially the greatest danger, was present only at low levels in cattle grazing with the lambs. Cattle (especially those less than 18 months of age) that share grazing with lambs, either in rotation or concurrently, should be drenched.
- Strategic placement of cattle and sheep can be employed to manipulate pasture infectivity and dramatically reduce parasite exposure of lambs being finished on irrigated pastures over summer. Adjustment of cattle placement schedules might also be made to enable a safe period of winter and early spring grazing by sheep, providing that pastures were cleaned by cattle before and after occupation of the site by sheep.

### 4.3.2 M. Pocock July 2004 – October 2005 (Appendix 4)

Research on "Panlatinga" included a growth study and associated parasitological measurements in a flock of mixed sex Merino weaners, a drench resistance trial, and pasture monitoring over 12 months.

In this area of South Australia spring 2004 was extremely poor, and conditions worsened in 2005. (Figure 2, p.25). There were no useful autumn rains and when rain did eventually come in July the weather was cold. It was one of the driest 12-month periods on record. Priority was given to valuable seedstock rather than production animals. Lambs had moderate exposure to worms early in summer, but thereafter conditions dried off very rapidly. Early in 2005 flock animals were regularly rotated through several paddocks to utilise the limited available feed. As conditions worsened in autumn and winter they were amalgamated in larger convenient groups and fed rations to keep them alive. Environmental conditions in 2005 were unsuitable for development of worms, so pasture larval contamination was low and worm infections in trial animals minimal. Routine weighing of weaners in the growth study continued for 6 months until May 2005. Nematode larval counts on pasture continued on several paddocks through which stock rotated until October, when it was discontinued because the workload did not justify the potential value of the information to the producer or the project. Useful parasitological and production data were limited. A drench resistance test in November 2004 confirmed that macrocyclic lactone and combination benzimidazole/levamisole drenches were effective.

**Key findings**

- Low levels of worm transmission occurred over summer and virtually none between February and May 2005.
- Weaners gained no weight over 6 months from November 2004 and approximately 30% are estimated to have perished due to drought.
- *Trichostrongylus rugatus* was the dominant parasite species. *Ostertagia* was usually present in low numbers. *Haemonchus contortus* persisted at low levels throughout most of the year and was transmitted over summer; peak levels occurred in July.
- Macrocyclic lactone and combination benzimidazole/levamisole drenches were effective. Residual worm burdens following drenching comprised only *Ostertagia*.

### 4.3.3 B. Gerhardy August 2004 – January 2006 (Appendix 5)

Lamb growth study August 2004 – February 2005

Two groups of 60 Merino X Dorset wether weaners (20.0 - 30.0 kg) aged 12 weeks were used in the prime lamb study. All were drenched (moxidectin) at marking in July. On 25 August 2004 one group was given an 'Ivomec Maximiser™ bolus. The other group served as an un-dosed control. All animals were given a weaning drench [Triton® Merial], weighed and placed on a relatively "clean" dryland pasture dominant in capeweed and white clover. The paddock had been periodically grazed by dry ewes until approximately 3 months earlier and had carried some ewes dosed with Ivomec™ capsules until approximately 6 weeks earlier. The lambs grazed this paddock as part of a total flock of 180 lambs until 19 October (62 days) when they were shorn and moved to a "clean" fescue/strawberry clover pasture because of deteriorating seasonal conditions. Two hundred additional drenched lambs joined the flock to optimise grazing pressure. Control lambs were drenched with moxidectin on 14 November 2004. Capsuled lambs were drenched with moxidectin and given another (adult BZ) capsule on 16 November 2004. The initial Ivomec™ capsules expired on December 3. On December 3 all lambs were transferred to a newly established fescue/strawberry clover irrigated pasture, where observations were continued through to market in February 2005. The lambs were weighed in August, October and November 2004, and February 2005.

Worm levels acquired in the interval between marking, and weaning (56 days) were higher than expected, suggesting general environmental contamination and/or failure of ivermectin capsules dosed to ewes pre-lambing. Serious capsule failure in the lambs confirmed macrocyclic lactone resistance on the property, however BZ capsules were highly effective.

Levels of worm larvae on pasture and lamb faecal egg counts rose surprisingly rapidly on presumed "clean" paddocks, suggesting the presence of existing reservoirs of larvae on the paddock. These reservoirs probably originated from faeces deposited more than 12 weeks earlier in the year by undrenched ewes and/or from ewes dosed with ineffective ivermectin capsules that had occupied the paddock up to 6 weeks earlier.

Over the first 55 days growth rates in both groups exceeded 240 g/day. Suppressively treated lambs averaged 21 g/day more than controls. Pasture on the weaning paddock was of good quality with high digestibility and energy levels. Adverse seasonal conditions dramatically affected pastures in late October/early November. Both groups lost weight over approximately 1 month, those with Ivomec™ capsules at a slower rate (20 g/day) than controls. A deleterious effect of worms on control lambs was evident in both positive and negative growth phases.

The irrigated pasture to which the lambs were transferred in December contained adequate protein, but only moderate energy and digestibility values. By February 2005, declining E coupled with increasing NDF (60% of DM) resulted in a pasture that was no longer able to support worthwhile growth rates of lambs averaging around 50 kg.

Allowing for initial differences in weight, lambs given Ivomec™ capsules gained 1.7 kg more than their untreated counterparts over the first 83 days. Average weight gains over the entire 166-day period were 141 g/day for control lambs and 157 g/day for suppressively treated lambs. Despite consistent differences between the groups, there was no cost benefit in additional drenching nor definable economic penalty at the market level for untreated animals. However, at the current growth rates it would have taken control lambs only an additional 5 days to offset the weight deficit in October, whereas by February this had extended to 20 days, representing a tangible financial penalty had the target weight been greater than 50 kg. The dominant parasites were *Trichostrongylus rugatus* and other *Trichostrongylus* species, except on the irrigated pasture over summer (December to February), when *Ostertagia* was the largest component. No *Haemonchus contortus* larvae were recovered.

Observations on mature heavily pregnant ewes and prime lamb growth study from marking - March 2005 – January 2006

In March 2005, elevated faecal egg counts with significant *Haemoncus contortus* levels in apparently healthy and robust ewes confirmed that they were contributing significantly to autumn pasture contamination that threatened the health of their lambs. Routine pre-lambing dosing with ivermectin capsules was replaced with a moxidectin drench in April and the ewes were transfered to 'clean' lambing paddocks. Over the years the farmer had experienced serious losses of lambs unless they were drenched at both marking and weaning. Two studies were conducted on lambs from the drenched ewes. The first examined the worm levels in lambs at marking to establish the necessity for a routine marking drench, and then the acquisition of worms between marking and weaning (38 days). The second study followed the same lambs from weaning on to dryland lucerne paddocks through to market 28 weeks later in January 2006. Throughout the second study the weaned lambs were rotated through 4 dryland lucerne paddocks. The lambs were weighed on 5 occasions from July 2005 (marking), until marketing in January 2006.

At marking both the lambs and their dams had mean faecal egg counts of <20 epg. Clearly, there was no need to drench either ewes or lambs. The daily rate of growth of the two groups of lambs between marking and weaning was identical (159 g/day), confirming that the levels of worms in the untreated lambs were not suppressing optimum performance. The mean faecal egg count of the control group (not drenched at marking) was 542 epg (range 100-1200 epg). No lambs were recorded as scouring and growth rates were unaffected. Nevertheless, this represents a potentially dangerous worm burden, both in terms of lamb health and pasture contamination. An important consideration is that larval worms ingested by the lambs in the previous 3 weeks would not yet be contributing to the measured worm egg count. Given that every effort had been made to minimise exposure of lambs to worms, there is ample justification for routine drenching of lambs at weaning, providing a highly effective drench is used. Lambs were infected with *Haemonchus contortus* early in life (May and June). By the time they were weaned most of the *H. contortus* burden was replaced by Scourworms. The weaning drench effectively removed the threat of *H. contortus* to the prime lamb production enterprise.

Overall growth rates from marking to marketing (195 days) were very good – 206 g/day in suppressively treated lambs vs 210 g/day in controls. Growth rates from weaning to market were 225 g/day and 229 g/day respectively. There was no deleterious effect of worms on lamb growth.

In both 2004 and 2005 it was confirmed that ivermectin capsules were failing against *Ostertagia*. The farm has a record of worm problems in young lambs, necessitating drenching at marking. For several years, pre-lambing dosing with ivermectin capsules had proven effective in solving this problem, presumably through removal for 100 days of pasture contamination with *Haemonchus, Trichostrongylus* and *Ostertagia*. The evidence confirms that this situation is not sustainable - *Ostertagia* is no longer controlled. In 2005, however, highly effective worm control was achieved by pre-lambing drenching of ewes with moxidectin, combined with their placement on very clean pastures for lambing. The strategy was probably assisted by very dry climatic conditions. It is concluded that dosing with ivermectin capsules has no further useful role on the property.

Repeated measures of worm larval contamination on paddocks grazed by lambs in both 2004 and 2005 confirmed the potential for transmission of worms late into spring, with the implication that worm control through pasture spelling (or rotation in the case of lucerne) is very important. Dryland lucerne paddocks are thus not worm-safe havens for prime lambs, indeed, their physical nature may provide greater protection for larvae from sunlight and desiccation than some other pastures. Hence, the same attention to spelling of paddocks is necessary.

Protein levels in the lucerne pastures were adequate, but energy levels and digestibility were generally lower than optimum, sometimes markedly so. Field collections with a disproportionate ratio of dry and green stem to leaf led to some misleading underestimates of the true nutritive value of lucerne for selectively grazing lambs.

**Key findings**

Worms are a threat to the enterprise, mainly through increasing the time to finish the prime lamb flock to market specifications. Periodic, immediate setbacks have been historically addressed by drenching, as required. Drenching, alone, is a vulnerable strategy and will not provide effective, sustainable worm control. Drenching must be supported through meticulous attention to the preparation of good quality worm free pastures for weaners.

Providing that autumn and winter contamination of pastures is minimised through effective worm control in ewes and the provision of clean pastures for lambing, drenching of lambs at marking is unnecessary. However, it is vital that lambs are drenched at weaning and placed on clean good quality pastures.

The 2005-2006 lamb growth study, from marking through to market, highlights a successful worm control program that provided appropriate effective drenching, provision of safe paddocks and abundant good quality nutrition. Lambs picked up only around 5000 Scourworms, which was insufficient to adversely influence their growth.

Dryland lucerne paddocks are not worm-safe havens for prime lambs. The same attention to spelling of paddocks is necessary as for the other dryland and irrigated pastures on the property.

- Ivermectin capsules are ineffective against *Ostertagia* and therefore they have no further useful role in worm control on the property. Although BZ capsules were effective in 2004, they were less than 90% effective in 2005. *Ostertagia* was again confirmed as the resistant parasite.

### 4.3.4 S. Graetz July 2004 - February 2006 (Appendix 6)

Research included intensive monitoring of seasonal pasture contamination, observations on ewes and their suckled or weaned lambs, a productivity study on weaned lambs, and total worm counts on marketed lambs.

A flock of ewes with lambs at foot approximately 11 weeks old was monitored from early July 2004 until the lambs were marketed in November. Ewes had been dosed with Ivomec capsules that expired in July. Faecal worm egg counts confirmed that the capsules were highly effective. Egg counts in ewes in September 2004 indicated that they had acquired low levels of worms during July and August following expiration of the capsules. The average faecal egg count of lambs in July was 580 epg and 64 days later in September was 417 epg. The average count in 3 commercial slaughter lambs in November was 33 epg. Mean *Nematodirus* egg counts approached 500 epg in

July. Lambs were not drenched and there were no observable ill effects of worm burdens. The decline of the lamb worm egg counts over 19 weeks suggests that high quality spring lucerne pastures encouraged strong immunity to worms.

In November 2004, the total worm counts of 3 grown out un-drenched commercial lambs were: *Ostertagia,* 1572; *Trichostrongylus,* 123; *Nematodirus* 2937. *Haemonchus contortus* was not recovered, despite its presence in composite faecal cultures earlier in the year.

Larval cultures in 2004 confirm that lambs were infected with *Haemonchus contortus* early in life (from April onwards). Cultures from ewes following expiration of capsules suggest that *Haemonchus contortus* infections do not occur or are minimal from early July to early September. *Ostertagia* was dominant in ewes and lambs in spring. *Trichostrongylus* spp. (Black Scourworm) is of minor importance. It is not clear whether this is due to use of Ivomec capsules over several seasons, or is a characteristic of this specific production system.

Lambs introduced from the cereal zone in September 2004 had a mean faecal egg count of 250 epg. They were not given a routine quarantine drench, which presents risks; first, compromised production in individuals with higher egg counts (the "tail"); second, introduction of a reservoir of additional contamination; third, introduction of strongly drench resistant worms from the cereal zone.

Early in March 2005 the worm egg count of ewes at pre-lambing dosing with Ivomec capsules was 310 epg. They were re-sampled 33, 71 and 113 days later. The capsules were effective in eliminating infections present at dosing, and preventing the establishment of new infections.

To complete a year of observations on transmission of *Haemonchus contortus*, ewes were sampled again in December 2005 and February 2006, at which times mean egg counts were 118 and 440 epg. *H. contortus* comprised 45% and 40% respectively of cultured larvae, providing evidence that ewes (which had been free of *Haemonchus* since April) had acquired burdens of *H. contortus* in spring, which they carried over summer.

In 2005 lambs acquired worms slowly in their first 12 weeks with the worm egg count only 192 epg by late July. The count stabilised at around this level, then declined markedly from October, until lambs were marketed in November. *Ostertagia* was the dominant spring Scourworm in lambs. *H. contortus* comprised 0%, 39%, 3%, 8%, 2% and 6% of larvae in cultures in June, July, early and late August, October and November 2005 respectively. Lambs, therefore, were first exposed to *Haemonchus* infection in June 2005. They had grazed with their dams (which had been given Ivomec capsules in March) from birth. Although Ivomec capsules dosed in March would have reduced pasture contamination arising from ewes, it did not eliminate exposure of lambs to contamination from faeces deposited by the ewes, probably 1-3 months earlier. The larval differentiation data suggest that transmission of *H. contortus* to lambs is limited throughout the remainder of the grow-out period from August through to November. Indeed, after the July peak there is an immediate rapid decline of *Haemonchus* in lambs to a consistent winter/spring level of 2-8% of larvae. A conclusion, supported by the 2004 data, plus total worm counts at marketing in 2004 and 2005, is that lambs may progressively rid themselves of *Haemonchus* infections over spring.

Despite repeated observations *Nematodirus* was only found once in ewes (February 2006). In contrast, most young lambs became moderately infected (mean 850 epg in July) and egg counts had declined significantly by 8 months of age. There was no evidence of ill thrift or disease associated with *Nematodirus* .

Because of adverse seasonal conditions lambs were weaned in late July 2005. A productivity study was conducted from August to October using 110 weaners from 25-30 kg. The objective was to determine the effect of a single drench on growth rates of lambs with low winter/spring worm levels in the 8 weeks preceding marketing. Half the lambs were drenched with BZ/levamisole and half were untreated. Trichostrongyle-type egg counts of treated lambs were reduced by 80% relative to controls 19 days later. Faecal cultures identified *Ostertagia* resistant to BZ/levamisole combination. *Nematodirus* eggs were reduced >90%. After 57 days, egg counts of control lambs had declined naturally (57 epg) and drenched lambs had retained their low counts (27 epg). Through spring the dominant parasite in undrenched lambs was *Ostertagia. Haemonchus* persisted only at low levels. The growth rate in drenched lambs over 57 days was 238 g/day compared with 218 g/day in controls. In this system it is regular practice to give all lambs a drench in August to 'finish them off'. For this particular example, the benefit was 1.6 kg live body weight, or slightly higher, given that the drench was only 80% effective. Although mean bodyweights of the two groups were significantly different (P = 0.004) after 57 days, undrenched lambs grew at 218 g/day, hence the real economic benefit, weighed against cost and selection for drench resistance was, at best, marginal.

Four un-drenched lambs were slaughtered in November 2005 for total worm counts. Mean worm counts were: *Ostertagia,* 1572; *Trichostrongylus,* 1613; *Nematodirus* 10150 *Haemonchus contortus* was not recovered. These findings support the 2004 data, suggesting that exposure of lambs to *Haemonchus* might occur only in the first few months of life in autumn and that worm burdens in lambs are shed under the influence of good quality spring nutrition.

To determine seasonal transmission of worms, 61 pasture samples from 28 farm visits over 20 months (July 2004-February 2006) were collected. Levels of trichostrongyle larvae were generally low in 2004, peaking at 1700 larvae/kg DM in July, and again in July 2005 (2750 larvae/kg DM on one paddock used as a lambing and holding paddock for ewes). *Nematodirus* larvae reached peak levels between October and December. No *Haemonchus* larvae were recovered from pasture.

**Key findings**

- Trichostrongyle larvae were not detected on pasture from December to April. Levels were generally low at other times except for a peak in July on lambing and ewe holding paddocks. *Nematodirus* larvae reach peak levels between October and December. No *Haemonchus* larvae were recovered from pasture.
- *Ostertagia* is dominant in ewes and lambs in spring. *Trichostrongylus* spp. (Black Scourworm) is of minor importance. Lambs develop high *Nematodirus* egg counts early in life (up to a mean 850 epg in July) without observable ill effects. Counts decline significantly without drenching by around 8 months of age. *Nematodirus* is rare in mature ewes.
- Worm egg counts in lambs peak in July and then decline naturally to low levels by October, suggesting that high quality spring lucerne pastures support strong immunity to worms. Total worm counts in commercial prime lambs in November were low in both years.
- Ewes acquire *H. contortus* in spring and carry adult worms over summer. Ivomec capsules given to ewes in March reduce pasture contamination. However, when conditions are suitable at the season break, April/May-born lambs are exposed to contamination from faeces deposited by ewes prior to dosing. *Haemonchus* levels in lambs peak in July, then decline markedly over

spring. Lambs for slaughter are removed from the transmission cycle before summer. A single summer drench of ewes should resolve this problem.

- Purchased undrenched lambs add unnecessary contamination, with the danger of introduction of strongly drench resistant worms from the cereal zone.
- A single combination (BZ/levamisole) drench given to lambs in August to 'finish them off' over the last 8 weeks preceding marketing resulted in growth rates in drenched lambs of 238 g/day compared with 218 g/day in controls. The real economic benefit was marginal, considered against cost and selection for drench resistance.
- Ivermectin capsules were highly effective in eliminating worm infections in ewes and preventing the establishment of new infections. Resistance of *Ostertagia* to combination drench (benzimidazole/levamisole) was re-confirmed on the property.

### 4.3.5 K. Staude August 2004 - December 2008 (Appendix 7)

Research conducted on "Kenwyn" from August 2004 to December 2008 included regular measurement of larval worm numbers on a spray / lateral pivot irrigation system over four years. More than 150 measurements of pasture contamination were made on 81 separate sampling occasions. The parasite status of commercial flocks on the property was also periodically monitored over 4 years to provide a picture of whole of farm worm control. In addition, in 2005 there was a drench resistance test, a lamb productivity trial, and background information was gathered from ram hoggets on genetic differences in resistance. Unfortunately, very dry conditions were experienced over some years with wet season rainfall being below average in 2004 and 2007 and the lowest on record in 2006.

<u>Drench resistance test</u>
In March 2005 seventy lambs were used in a drench resistance test to examine the efficacy of moxidectin, ivermectin at both recommended and half dose levels and levamisole/albendazole mixture. High efficacies (>95%) were demonstrated for the chemical groups and combinations tested. All larvae recovered from cultures of lambs treated with macrocyclic lactones and most from those treated with albendazole/levamisole were *Ostertagia*.

<u>Lamb growth study</u>
A lamb growth study was started on 20/7/2005 using 95 newly weaned White Dorper ¾ cross lambs weighing 16 – 21 kg. Forty-eight lambs (treatment group) were given albendazole (BZ) capsules (CapTec™ Extender™ Junior; Captech; Nupharm), and a moxidectin (Cydectin® oral drench for sheep; Fort Dodge) priming drench. The remaining 47 lambs (controls) received no treatment. Lambs grazed an oat/feed barley fodder crop that was monitored regularly for contamination with infective nematode larvae until trial completion on 21/9/2005 (63 days), at which stage grazing was declining and lambs returned to the home property for final finishing with grain and on irrigation. On 21/11/05 4 control lambs were slaughtered for total worm counts.
Worm egg counts were very low at weaning, at the end of the trial and for 3 months thereafter, confirming limited pickup from the pasture and/or solid immunity of the lambs to worms due to high quality nutrition. BZ capsules were completely ineffective and it is recommended that the use of BZ remedies except in combination should be discontinued. At trial completion *Ostertagia* accounted for 100% of larvae from faecal cultures, therefore it was dominant and BZ resistant.

Pasture contamination remained low throughout the trial and pasture was high quality (Digestibility 81% DM; Metabolisable energy 11.9 MJ/kg DM). Lambs grew at an average of greater than 270 g/day due to good nutrition and low levels of exposure to worms. The top 20% grew at >335 g/day.

Finished lambs had low total worm counts. The provision of a prepared weaning paddock meant that lambs were provided with high quality nutrition and exposed to minimal parasite challenge for at least two months after weaning and were able to achieve close to their potential growth rate over this time.

<u>Observations on commercial animals 2004-2008</u>
Over 4 years numerous observations were made on the internal parasite status of commercial flocks subject to normal farm management to give a picture of whole of farm worm control, identify possible opportunities for improvement, and assist in decision making at critical times. Overall, 49 faecal egg counts with larval identifications were done on 27 occasions. Egg counts associated with decision making at critical times often did not have a detailed history, therefore have little retrospective or predictive value. Others contributed to a data set underpinning confidence in management initiatives, or could be associated with measurements demonstrating ongoing safety of pastures, and thereby have greater long-term value.

**Key findings**

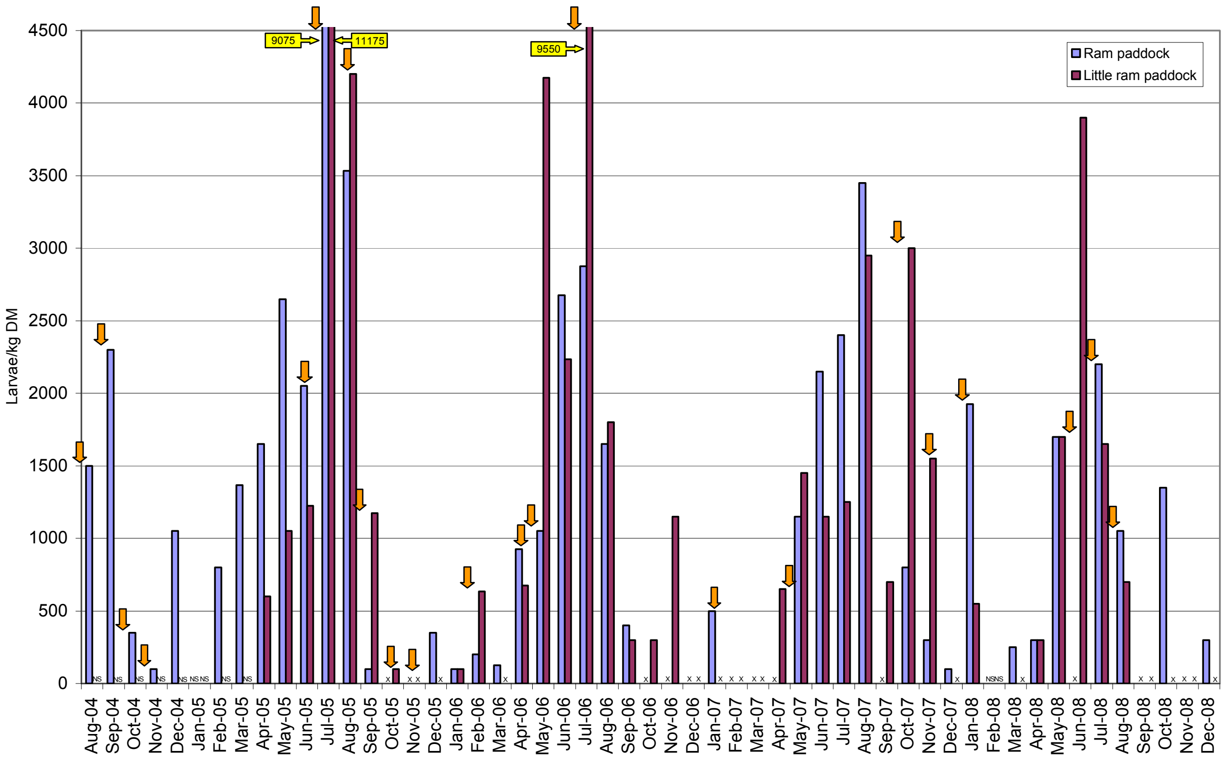
- Total worm burdens in finished lambs in 2004 were low and unlikely to have incurred an economic penalty.
- Based on faecal egg counts the level of parasitism across flocks over 4 years was moderate, probably due to relatively dry years, good feed quality, resilient animals, and good management. *Ostertagia* is the dominant scourworm throughout most of the year, with an ill-defined rise in *Trichostrongylus* (due to *T. rugatus*) in October/November.
- Higher levels of *Haemonchus contortus* were present between April and July from infections acquired in summer and autumn. Exposure to *Haemonchus* was not consistent across paddocks on the property.
- In March 2005 the faecal egg count of ram lambs was eight fold that of their female siblings subjected to identical management and grazing, highlighting the greater natural immunity of ewes compared to rams.
- In February 2006 it was demonstrated through faecal egg count examinations that persistent scouring in lambs was not due to adult or larval worms.
- Undrenched Dohne Merino ewes transferred infection from Western Australia in 2008. The importance of quarantine drenching all new arrivals and holding in yards for 24 – 48 hours post treatment must not be underestimated. Failure to do this, risks the introduction of strongly resistant strains of worms.

<u>Demonstration of differences in resistance</u>
In 2005 worm egg counts in some lines of naturally exposed young rams were examined to demonstrate individual variation and promote the principle that worm egg counts can be used to develop breeding values for this heritable trait; this was not a designed experiment in the genetics of resistance. Full Coolalee rams and Coolalee/Dorset had the highest proportional representation in the lowest 25% of counts. Differentiations between the groups were not so convincing in the lowest 50% of ranked counts. Coolalee/Dorset had the lowest proportion of rams in the top 25% of counts. Coolalee composite rams were over represented in the highest 25% of faecal egg counts. It is important to stress that these results do not demonstrate genetic differences between breed lines.

At best, they suggest that there are significant opportunities for selection for worm resistance in the currently less prominent meat sheep breeds.

<u>Seasonality of worm contamination on spray irrigated perennial ryegrass pasture</u>
Numbers of larval worms were regularly measured (more than 150 measurements on 81 sampling occasions) on a spray/lateral pivot irrigated perennial ryegrass pasture from August 2004 - December 2008. The system was grazed throughout the year and occasionally destocked for regeneration/renovation. No specific quarantine procedure was in place to reduce contamination. General parasite awareness and control elsewhere on the farm was good. Sheep were subject to the normal farm worm management program, with drenching decisions based largely on regular bulk worm egg counts.

Figure 5 Average monthly *Trichostrongylus*/*Ostertagia* levels on adjacent irrigated pastures K Staude, Cannawigara, South Australia, August 2004 – December 2008




X = No larvae detected; NS = Not sampled; Orange arrows indicate rainfall >20mm in ≤ 7 days .

Despite varying grazing pressures and management conditions, seasonal pasture contamination was similar over 4 years (Figure 5). Contamination with *Ostertagia/Trichostrongylus/Haemonchus* larvae was generally low over summer and peaked between April and August. Annual availability of *Haemonchus* is restricted to 1-2 months only, but its transmission in late summer and autumn has potential to cause problems in winter when grazing and lactation stresses emerge. Ewes carrying low numbers of *Haemonchus* through summer probably provide the nucleus for autumn transmission. Even in dry months there is a clear increase in pasture contamination in response to rainfall, but it is especially evident every year from around April to June. The pattern of contamination, therefore, is similar to that on dryland pasture. Summer irrigation is not associated with an immediate increased threat from worms because it promotes rapid development and emergence of larvae on to pasture, where they are desiccated rapidly in the prevailing hot summer conditions. Each year there were highly dangerous peaks of contamination from July - August and a period of around 4-5 months when the pasture was unsuitable for lambs or lambing ewes. The dangerous contamination arises from faeces deposited from January – March. Drenching of all animals on the system in January, or those entering it from January – March, would probably reduce the seasonal peak substantially, more so in some seasons than others. The return of a component of the prime lamb flock for finishing in October is compatible with an expected decline in contamination at that time, but awareness is needed of seasonal increases in risk (e.g., in 2007). The concept of carrying mature immune sheep on the pasture in late summer and autumn to reduce contamination is appealing, but unlikely to be effective, because even low egg counts in these sheep will lead to significant accumulation of contamination in deposited faeces over a short time.

Levels of *Nematodirus* larvae on pasture were often moderate to high, and sometimes extremely high on irrigated paddocks. On "Kenwyn", where deposition of eggs occurs throughout the year, the pattern of contamination was determined by the timing of a series of variable events (deposition of eggs in faeces, development period in the egg, dryness, inundation). In some years (eg, 2005 and 2008) contamination was strictly seasonal, in others, partially seasonal (2006) and in others completely non-seasonal (2007). *Nematodirus* is likely to cause disease only in very young lambs and therefore is not currently a serious risk to production. Even occasional use of the paddocks for lambing could alter the situation dramatically.

Overall, despite the opportunity provided by substantial seasonal contamination on the irrigated area, there were moderate levels of worm infections in most flocks, and important losses were not identified. The most reasonable explanations for this were a constant awareness of parasitism and its consequences by the owner, the provision of safe paddocks with excellent nutrition for the most vulnerable stock, generally good quality nutrition for most animal classes for much of the year, judicious drenching based on faecal egg counts and the possibility (not proven) of general resilience to parasites in the combination of breed lines on the property.

### 4.3.6 C. Smith October 2004 – January 2005 (Appendix 8)

Research included a lamb growth study with associated measurements, including faecal egg counts, larval differentiations, pasture larval counts, total worm counts on 4 finished lambs and feed quality analyses. In addition, the potential of dried cattle and sheep faeces to serve as a reservoir for pasture contamination with worms was investigated.

A flock of 350 mature ewes (Corriedale X Coopworth) with approximately 385 (110%) 10-12 week old lambs at foot (Poll Dorset sire) was used for the growth study. On 6 October 2004 two groups of 51 lambs were formed in the weight range 22.0-27.0 kg. One group was drenched with moxidectin and given a bolus (CapTec™ Extender™; Captech; Nupharm) to provide sustained release of albendazole over 90 days. The other group served as a control. The flock was set-stocked on a 40 ha paddock (16 DSE/ha) and concurrently grazed with cattle. The paddock had substantial parasite contamination. Retrospective comparisons across sites place this paddock among the more heavily contaminated late spring and summer pastures The sheep tended to concentrate in areas of good quality short pasture where larvae were more likely to survive, such as by a creek, sheltered ridges and moist drainage lines. All lambs and ewes were drenched with BZ when the ewes were crutched

in mid-November. Capsules expired on 4 January 2005 and lambs were weighed on 11 January before consignment for slaughter. Four control lambs were retained for total worm counts.
The weights of the two groups of lambs were not statistically different at the start of the study (P = 0.97), but were significantly different 97 days later (P = 0.002). Worms, therefore, had a serious negative influence on this production system with an average difference of 2.3 kg developing between groups. Slaughtered lambs had average Scourworm burdens of approximately 11 600. Substantial numbers of *T. axei* were found (up to 10 000 in one lamb). Although this is primarily a parasite of cattle it probably contributed to the overall deleterious effect of worms on the lambs. The ewes also may have been compromised by worm infections, given that the efficacy of white and clear drenches used over the preceding several months was doubtful.

Disappointing growth rates (136 g/day in worm suppressed lambs) are probably due to shortfalls in pasture quantity (600-700 kg DM/ha) and quality, affecting both them and their dams.
BZ capsules were only approximately 90% effective, providing strong evidence of BZ resistance on the property. It is unlikely that BZ drenches could be confidently used in a worm control programme. *Trichostrongylus* remains susceptible to slow release BZ capsules.

It was demonstrated that accumulations of dried cattle and sheep faeces provide a reservoir for serious pasture contamination with worms. In November, 800 g of mixed dried faeces from cattle and sheep yielded 103 nematode larvae; in December, 842 g of dried sheep faeces yielded 160 larvae. Significant rains will enable mass exodus of trapped larvae on to the pasture, where they immediately become available to grazing stock.

**Key findings**

- Internal parasites are responsible for losses of economic significance in prime lamb productivity. The sub-clinical health and productivity of lactating ewes may also be affected. In addition to losses due to worms, less than optimal growth rates of lambs may be due to insufficient good quality grazing.
- There was considerable accumulation on pastures of dried faeces, containing viable larvae of both cattle and sheep worms. Significant summer rains may rapidly lead to dangerous pasture contamination.
- Worms originating from cattle, specifically *Trichostrongylus axei*, probably contribute to reduced productivity in lambs. All cattle on the property should be drenched annually and undrenched cattle under one year should not be grazed concurrently with sheep.
- Benzimidazole drenches are regularly used and are not fully effective. Worm control on the property is most likely compromised through the use of ineffective drenches.

### 4.3.7 B. Ryan August 2004 - December 2007 (Appendix 9)

The faecal egg counts of different age classes were regularly monitored from August 2004-December 2007. There were 26 sampling points, with 68 flock collections covering 41 months. A comprehensive drenching history assisted in interpretation of findings, and supported day-to-day management decisions. Faecal cultures were done from 2004-2006. A drench resistance test was conducted in November 2005. Lamb growth trials were not done because parasite levels were consistently very low.

Faecal worm egg counts remained low throughout a period of nearly 4 years, indicating good worm control with reasonably limited anthelmintic use. Some ewes had consistently low egg counts over several months. Lambs had minimal worm egg counts compared with counterparts on other properties. Although dry seasons may have played a role, highly efficient worm control is largely ascribed to the use of regular faecal egg counts to plan seasonal management and provide confidence that the immediate health of large flocks of ewes and lambs is not threatened. Nevertheless, animals were occasionally drenched unnecessarily, especially lambs given both marking and weaning drenches.

Napthalofos (Rametin™), mixed with a virtually exhausted BZ/levamisole combination, provided highly effective treatment throughout the year. The more potent ML drenches are used sparingly and ivermectin is not used. Worm control on "Tent Rock" was more efficient than on other properties, yet there was significantly greater reliance on Rametin™ and BZ/levamisole combination than elsewhere.

An important possible 'downside' from sustained efficient worm control is that there are low levels of parasites *in refugia*, either in the animals themselves, or, for the greater part of the year, on pasture. This increases selection pressure for drench resistance.

Overall, 86% of cultured trichostrongylid larvae were *Ostertagia*. Dominance of *Ostertagia* throughout the year is unusual in South Australia. This may represent the regular epidemiological niche of *Ostertagia* on this specific property, or provide evidence of previous and current drench selection for a resistant parasite species. *Haemonchus contortus* was not recovered from cultures, and was only detected once on pasture.

*Cooperia oncophora*, which is primarily a parasite of cattle, was regularly identified in both lambs and ewes. Its presence is expected, given the practice of rotating cattle through paddocks. There are probably no deleterious effects. Small numbers of *Trichostrongylus axei*, another cattle worm, were also found. A cattle worm control program is important, to avoid pasture contamination with *T. axei* and *Ostertagia ostertagi*, both of which can have adverse effects on lambs.

A seasonal peak of larvae on pasture from August-October is associated with the presence of large numbers of young animals on the property. This is well managed by pasture spelling and rotation through paddocks, so that they are not heavily exposed. Rainfall and mild conditions can extend the worm transmission period well into summer.

There is strong resistance to benzimidazole/levamisole (BZ/L) combination drench alone. Combination of napthalofos (Rametin™) with BZ/L is highly effective (>97%). There is evidence of emerging macrocyclic lactone (ML) resistance on the property, although abamectin and moxidectin could still be expected to be highly effective.

BZ/L drenches are poorly effective against both scourworm genera. Rametin™ combined with BZ/L drenches is highly effective against *Ostertagia* and almost completely eliminates *Trichotrongylus*. Developing ML resistance is exclusively against *Ostertagia.*

**Key findings**

- A systematic worm monitoring and control system that has been established on the property for some years, rotation and spelling of paddocks, good nutrition, and the use of cattle to provide cleaner pastures, undoubtedly combine to maintain consistent low worm burdens in all classes of sheep.

- Drenches were sometimes unnecessarily given, especially to lambs at both marking and weaning.
- Sustained efficient worm control provides low levels of parasites *in refugia* in the animals or on pasture, and increases selection pressure for drench resistance.
- Peak seasonal transmission of worms is from August-October, however this can be extended well into summer in mild met years.
- There is strong resistance to BZ/L combination drenches and evidence of emerging macrocyclic lactone (ML) resistance. Napthalofos (Rametin™), mixed with BZ/L combination provided highly effective treatment.

### 4.3.8 K. Joseph December 2004 – October 2006 (Appendix 10)

Research conducted on “Churinga” from December 2004 to October 2006 included ewe reproductive efficiency trials in 2004/2005 and 2005/2006 with associated growth rate, pasture quality and parasitology evaluations, and measurements of the seasonal abundance of larvae on pasture grazed by the ewes over 2 years.

The first reproductive efficiency trial was conducted over 287 days from December 1 2004 to September 14 2005. Border Leicester x Merino maiden ewes were weighed and randomly allocated to two groups (treated and control), each of 106 animals. The treated group was given ivermectin capsules (Ivomec Maximiser™, Merial) to provide sustained worm control. Spent boluses were replaced twice at approximately 3-monthly intervals, giving around 9 months of continuous protection against worms. Controls were drenched according to the normal farm schedule. Other management was the same for both groups. The ewes were joined with White Suffolk rams in February-March and ultrasound scanned for pregnancy (identified as empty, single or multiple) on June 6. There was a serious shortfall of grazing in autumn 2005 caused by a poor spring in 2004, an absence of summer rain and delayed autumn break. Pasture quality was also poor. Barley supplement was provided from April. On 10 October 2005 ewes were examined for lactation status, with dry ewes assumed to have lost their lambs, and the percentage lamb mortality for each scanning group (as identified on June 6) was calculated. Ewes were weighed five times during the trial and feed quality monitored periodically. Pasture contamination with worms was monitored monthly, following the movements of the ewes.

Ewes acquired only low levels of worms throughout the trial period. Larval cultures showed that *Ostertagia* was dominant for much of the year (particularly over summer) and *Trichostrongylu*s dominant during winter. Ivermectin capsules had variable efficacy, ranging from 100% in January 2005, to complete failure in September 2005; 100% of surviving larvae were *Ostertagia*. Treated ewes grew at 5 g/day more than controls over 287 days, leading to a significant ($P = 0.0209$) divergence in weight between the groups of 1.4 kg, brought about by relatively low numbers of worms, evidenced by an average faecal egg count of 100-150 epg.

Pasture contamination with worms was relatively low for most of the year, except for a brief peak in June-July 2005. Low contamination was assisted by several factors, including very much below average winter rainfall, effective drenching in late January and late June, and fairly regular movement to cleaner paddocks at times which coincided with higher levels of contamination (e.g. beginning of February and July).

No conclusions should be drawn from the reproduction data due to small sample sizes and difficulty with statistical analyses, but there are some interesting general observations. Although more control than treated ewes were empty, 6% more carried twins than treated ewes, leading to an overall expected lambing percentage 5% higher for controls. From the time of scanning the overall mortality of lambs from controls was almost twice that of treated ewes.

A second ewe reproductive efficiency trial was conducted from 14 December 2005 to 28 September 2006 (264 days) using 179 Border Leicester x Merino maiden ewes. A treated group (n = 90) received ivermectin capsules (Ivomec Mazimiser™, Merial) and the remaining ewes (controls) were not treated. Spent boluses were replaced twice at approximately 3-monthly intervals, giving around 9 months of continuous protection against worms. Controls were drenched in early February 2006 with moxidectin / naphthalophos and in late June with levamisole / oxfendazole and naphthalophos according to the normal farm schedule. Other management was the same for both groups. Ewes were joined with White Suffolk and Poll Dorset rams from early February to early April and ultrasound scanned for pregnancy (identified as empty, single or multiple) on 20/5/06. From late March they received 325 g/day of an oat/lupin mix. On 28/9/06 ewes were examined for lactation status, and the percentage lamb mortality for each scanning group (as identified on 20/5/06) was calculated. Ewes were weighed 4 times during the trial and feed quality was monitored periodically. Pasture contamination with worms was monitored monthly, following ewe movements.

Levels of worms on pasture remained low throughout 2006, with a peak of only 1450 larvae per kg DM in late September. This was related to extremely dry conditions, with seasonal rainfall very much below average. No doubt, effective parasite management also contributed, ewes receiving a second summer drench in February, a pre-lambing drench in June and moving approximately every 3 months to clean pastures. Over 19 weeks from February – June 2006 control ewe faecal egg counts only rose to 175 epg. Then during 10 weeks to lamb marking the count returned to 323 epg, a moderate level for ewes in early lactation. In a similar pattern to 2004/2005, *Ostertagia* dominated control faecal cultures in summer (December), with *Trichostrongylus* increasing during autumn and winter to around 30% of larvae by early spring. As in 2004/2005, ivermectin capsules had variable efficacy against *Ostertagia*.

Pasture quality was poor through summer and autumn and ewes would have seriously deteriorated in condition in the first half of pregnancy had they not been supplemented with oats and lupins from late March. Pasture quality improved from June and was excellent towards the end of pregnancy and during lambing. Overall, treated and control ewes grew at very similar rates (75 and 73 g/day respectively) leading to an insignificant (P = 0.3556) 0.58 kg divergence between the groups over 9 months. This is not an unexpected finding, because worm levels in control ewes were low throughout the entire period.

Pregnancy rates based on scanning were 108% and 117% for control and treated ewes respectively and did not differ significantly (P = 0.0735). Treated ewes had an overall non-significant (P = 0.2113) lower lamb mortality rate than controls. Conclusions should not be drawn from these results due to the small sample sizes and power of the statistical analyses.

**Key findings**

- Pasture contamination remained low throughout both years and ewes only acquired minimal worm burdens. Low contamination was related to extremely dry conditions in both 2005 and

2006. Sound parasite management also contributed, with effective summer and pre-lambing drenches and regular moves to clean pastures.
- Efficacy of ivermectin capsules was highly variable in 2005 and 2006.
- Resistance of *Ostertagia* to ivermectin capsules.
- *Ostertagia* dominant for much of the year (particularly over summer) and *Trichostrongylus* increased during autumn and winter to around 30% of larvae by early spring.
- In both trials ewes with suppressive worm control had lower lamb mortalities than those with the normal drenching schedule, but findings are not robust due to the small sample sizes and power of the statistical analyses.
- Estimated overall loss of lambs from scanning during pregnancy to 24-48 days after lamb marking was 14% in 2005 and 18% in 2006.

### 4.3.9 S. Malcolm November 2004 – September 2008 (Appendix 11)

Extensive research was conducted on “West Lakes” over 4 years from November 2004:
- Lamb productivity (growth) trials in 2004/2005, 2005/2006, 2006/2007 and 2007/2008.
- A faecal egg count reduction test (drench resistance test) on unweaned lambs in November 2005.
- A 569-day ewe reproductive efficiency trial over 2 lambings from March 2006.
- Ewe response to worm challenge after long-term chemical worm suppression.
- Seasonal levels of pasture infectivity with larval trichostrongylids (*Ostertagia, Trichostrongylus* and *Haemonchus*) and *Nematodirus* from 2004 to 2008.
- An ongoing study from October 2007 on the impact of destocking of sheep and grazing with cattle on the rate of reduction of pasture contamination with infective sheep nematode larvae.
- Monitoring the efficacy of and necessity for routine drenching in ewe flocks at critical times.

Unfortunately, abnormally dry conditions were experienced in some years. These conditions undoubtedly reduced the potential influence of internal parasites and forced adjustments to normal management and marketing practices.

#### 4.3.9.1 Prime lamb growth studies

<u>Prime lamb growth study 2004/2005</u>
Trial 1 (10 November 2004 to 25 January 2005) included 110 unweaned second cross lambs weighing 24 – 30kg. Half of the lambs received a long acting albendazole bolus and moxidectin priming drench and the remainder were untreated. On 18 November all ewes and lambs in the flock were drenched with ivermectin as normal farm management practice. Albendazole capsules were ineffective; 100% of surviving larvae were *Ostertagia*.

Initially pasture quality was high but declined rapidly from November (crude protein 18% DM, energy 10.8 MJ/kg DM) to December (crude protein 12% DM, energy 7.7 MJ/kg DM) to be barely sufficient for maintenance. Lambs were exposed to moderate pasture contamination with a peak of 4500 *Trichostrongylus*/*Ostertagia* larvae/kg DM in December.

Average worm burdens of 4 control lambs at trial completion in February 2005 were low (*Ostertagia* 6838, *Trichostrongylus* 581, *Nematodirus* 4788). However, due to failure of albendazole capsules it was not possible to determine the impact of worms on growth rate. Both groups of lambs grew at an overall poor rate of 187 g/day. Only around 50 – 60% of lambs were turned off in early February, far below usual expectations of up to 80%.

Prime lamb growth study 2005/2006

Trial 2 (12 October 2005 to 25 January 2006) included 50 second cross lambs (18 – 22kg). Half received ivermectin capsules and moxidectin priming drench (treatment group). Control lambs received no initial treatment, however, in line with normal farm practice, both groups were drenched (abamectin) on 13 December. Ivermectin capsules were only 70% effective.
Both groups grew at 289 g/day over the first 51 days however, over the next 54 days treatment group lambs grew at 164 g/day, compared to controls at 150 g/day. A widening divergence in weight gain between the two groups suggests an increasing worm impact over the last six weeks of the trial following the summer drench. Given that ivermectin capsules were not fully effective, it is likely that the actual worm effect was considerably underestimated.

A rapid seasonal decline in pasture quality was consistent with other years. The decline occurs as lambs move from the 30 kg to 40 kg weight range, and energy (E) required for rapid growth is insufficient. Neutral detergent fibre (NDF) levels are a specific concern, because they directly influence the capacity for food intake. It is calculated for January 2006 that a 40 kg lamb could only have consumed 0.81 kg dry matter daily, providing 7.9 MJ E. Through selective foraging lambs are able to source material with higher E and protein levels and, importantly, lower NDF, than that shown in FEEDTEST® analyses.

Growth rates in control lambs in 2005/2006 were 30 g/day higher than those in 2004/2005. Over 105 days they would have gained more than 3 kg extra, illustrating the huge significance of seasonal variability on the success of the enterprise.

Three lambs that grazed for an additional 35 days after the trial was completed had high total worm counts (average *T. vitrinus* burden exceeding 19,000), but these are not indicative of worm burdens that may have influenced growth rates in the study. However, they illustrate the potential for dangerous levels of worm transmission on non-irrigated pastures over summer in this environment.

Prime lamb growth study 2006/2007

Trial 3 (29 November 2006 to 1 May 2007) included 50 unweaned second cross lambs (22 - 32 kg). Half were injected with moxidectin (treatment group) and the remainder (controls) drenched with abamectin as per normal farm practice (first summer drench). The trial was postponed for 6 weeks because lambs developed perennial ryegrass staggers and could not be handled. Production details are therefore not given here (full details in Appendix 11, Section I 3. pp. 14-20). However, pasture quality and quantity were serious modifying factors in 2006/2007 and justify more attention.

The lambs and their dams initially grazed pasture of excellent quality, but a dramatic collapse in the season led to premature weaning on to a rapidly senescing pasture for a few weeks from late December. Although they were transferred to pasture of moderate quality from mid January to mid February, voluntary intake would have been adversely affected through pasture senescence, as indicated by high levels of NDF. For the last 2 months the E levels in pasture were insufficient for even moderate growth rates and NDF very high. Selected pasture quality components are illustrated in Figures 6 and 7.

Figure 6  Digestibility [(DOMD) %DM] and energy (MJ/kg DM) levels of pasture November 2006 – May 2007S Malcolm, Portland, Victoria

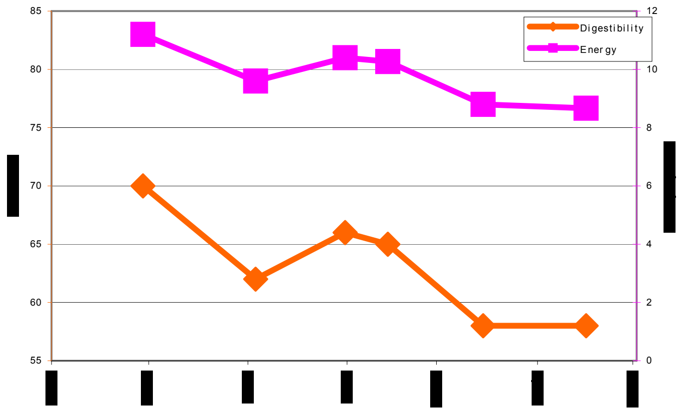
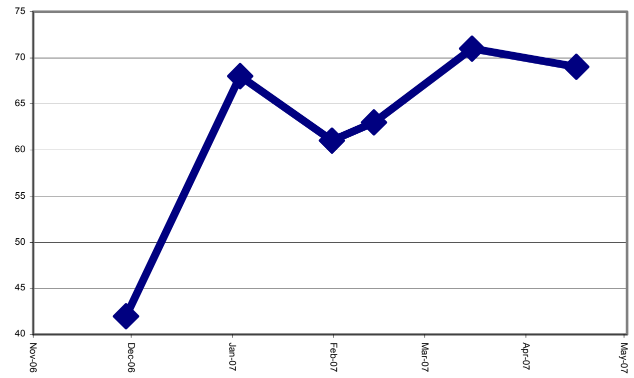



Figure 7  Neutral detergent fibre levels (%DM) in pasture November 2006 – May 2007, S Malcolm, Portland, Victoria




These figures show a dramatic decline of pasture quality, from excellent (November) to very poor (March).  In reality, rapid lignification (increase in NDF levels) in December meant that lambs were transferred from a highly nutritive pasture to one on which they could barely consume sufficient dry matter to support growth (calculated daily E available 5.8 MJ for 34 kg lambs).  The diet selected would naturally be of better quality than the average quality of that available and they would preferentially avoid older, stemmy material and seek out younger leafier forage, but the level of choice was clearly compromised.

From mid-February the quantity of food on offer (<800 kg green DM/ha) became a seriously limiting factor for production, independently of the problems associated with low E and high NDF levels. Given a digestibility of less than 65% the very best growth rate that could be expected would be around 75 g/day or around 30% of potential growth.  The actual growth rate achieved from mid-January was around 67 g/day.

Prime lamb growth study 2007/2008

The fourth lamb productivity trial (10 October 2007 to 9 January 2008) included 105 unweaned second cross lambs: 53 treatment group lambs were injected with moxidectin, whilst 52 controls received no treatment. Both groups were drenched with levamisole/fenbendazole as normal farm practice in mid November. On day 20 faecal egg counts showed moxidectin to be 100% effective. This was well within the effective period for moxidectin (up to 49 days for *Trichostrongylus* and 91 days for *Ostertagia*) and therefore not surprising. However, at trial completion after 91 days, faecal egg counts of treatment group lambs were only 55% lower than controls. *Ostertagia* comprised 70% and *Trichostrongylus* 30% of recovered larvae. It therefore appears that the period of residual efficacy of moxidectin injectable against *O. circumcincta* was reduced.

Although there was always sufficient quantity of pasture (1000 – 2000 kg green DM/ha), quality declined over the trial period from 10 October 2007 (crude protein 27 % DM, energy 10.2 MJ/kg DM) to 9 January 2008 (crude protein 15 % DM, energy 9.4 MJ/kg DM). Pasture contamination with worm larvae was initially moderate to high (4350 *Trichostrongylus*/*Ostertagia* larvae/kg) in October 2007, but generally low thereafter. At trial completion in January 2008, 4 control lambs had low total worm burdens (mean *Ostertagia* 2838, *Trichostrongylus* 625 and *Nematodirus* 3150). Both groups of lambs achieved excellent growth rates of ≥275g/day.

#### 4.3.9.2 Drench resistance testing – 2005

On "West Lakes" in 2004/2005, albendazole capsules were ineffective in preventing the establishment of *Ostertagia* in lambs. Comparison with controls showed that *Trichostrongylus* and *Haemonchus* were still probably susceptible to benzimidazoles. A drench resistance test (FECRT) was conducted in December 2005 using 84 undrenched, unweaned, second cross lambs aged approximately 12 weeks. Six drenches or combinations were tested. Efficacies were calculated relative to the average egg count of controls 11 days after treatment.

Efficacies were as follows :

| | |
|---|---|
| ivermectin (200 µg/kg) | 89% |
| ivermectin (100 µg/kg) | 77% |
| moxidectin | 99% |
| levamisole/albendazole | 97% |
| naphthalophos/fenbendazole/levamisole | 94% |
| ivermectin/albendazole/levamisole | 97% |

Resistance to ivermectin is advanced, even at full dose, and therefore its continued use in any formulation is not recommended. There is, in reality, little difference in efficacy between the other 4 products, all of which were highly effective. All larvae recovered from the faeces of treated lambs, including those given combination drenches, were *Ostertagia*, which implies that it is currently the only resistance threat to lamb production on this property.

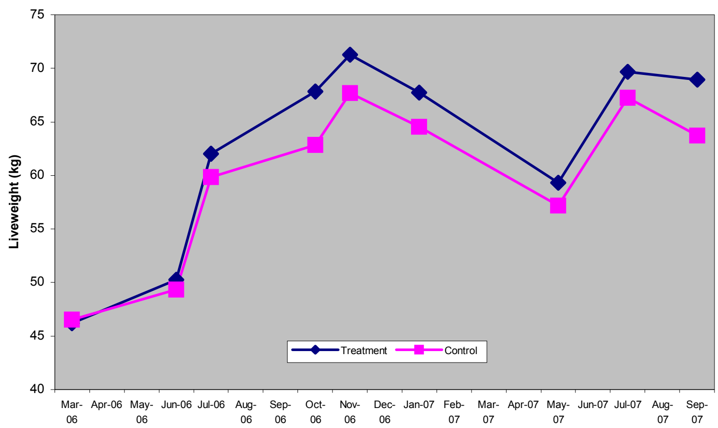
#### 4.3.9.3 Ewe reproductive efficiency

A study to examine the influence of parasitism on reproductive performance in Border Leicester X Merino maiden ewes was conducted over 568 days from 1 March 2006 to 20 September 2007, and covered two complete lambing cycles. One group of 120 ewes (treated) was given suppressive worm treatment, initially with an ivermectin bolus, followed by repeated treatments with moxidectin injection (2/6/06; 26/7/06; 11/10/06; 29/11/06; 16/1/07; 1/5/07 and 24/7/07). The remaining 132 control ewes received only worm treatments given as normal farm management practice on the property. In both years ewes were joined from mid March. The groups grazed together, except over the 2007 lambing period when they were separated to enable observations on early lamb survival.

Both groups were weighed 9 times over the course of the trial. Average group weights were significantly different (P = 0.003) within 147 days (by 26 July 2006), and remained so thereafter. By October 2006 (post first lambing), group weights had diverged by 4.99 kg. Weights then converged to May 2007 when treated ewes were 2.12 kg heavier, and diverged again to 5.25 kg in September 2007 following the second lambing (Figure 8).

Worms, therefore, had a significant effect upon ewe weight gain. The two periods of greatest weight divergence between treated and control ewes from July-October 2006 (2.81 kg) and July-September 2007 (2.82 kg) coincided with the peaks of faecal egg counts associated with greatest levels of worm challenge on pasture. This highlights the importance of worm infections in sheep in this area

Figure 8 Divergence of ewe body weights, March 2006 – September 2007
S. Malcolm, Portland, Victoria




Feed quality was generally good from May to November but poor over summer. From November 2006 nutrition was insufficient to maintain 70 kg ewes, and they lost an average of 70-80 g/day (10.5 – 11.9 kg) over the next 5 months. Feed on offer, monitored fortnightly from late January 2007 remained quite low (largely below 1000 kg green DM/ha).

The trial duration of 589 days allowed observation of full annual patterns of exposure of ewes to worms. Initially low in March 2006, contamination increased rapidly in May to peak at 5900 larvae/kg DM in June. It then remained low to moderate until October 2006, after which there was minimal contamination over summer/early autumn. Contamination rapidly peaked again in late May 2007 (4750 larvae/kg) and then declined again to moderate levels. A general pattern of summer domination of *Ostertagia* (as recovered from culture) was found. This confirmed annual findings from 2004-2007 in the lamb growth trials.

Ivermectin capsules dosed on 1/3/06 were 99% effective 75 days later. In other trials, ivermectin formulations given from October–January were only 89% (oral) and 70% (capsule) effective. This highlights the potential for seasonal worm population dynamics (*Ostertagia* vs *Trichostrongylus*) to influence drench efficacy.

In 2006 ewes were scanned for pregnancy status on 18 June, and classed as either empty or carrying single or twin lambs. As expected, no differences between treatment groups were observed because only 2 suppressive worm treatments had been given at that stage.

Pregnancy scanning was not done in 2007 due to the unavailability of qualified personnel. In late July 2007 ewe treatment groups were separated and set stocked on similar adjacent paddocks until marking in mid September. During this time lamb and ewe mortalities were recorded. At lamb marking, total lambs and ewes in each group were recorded and ewes were individually assessed for their lactation status ("wet" or "dry"). "Dry" ewes may have originally been non-pregnant, or have lost their lamb or lambs at any time thereafter. "Wet" ewes may have lost one of a pair of twins. Mortality rates of lambs and ewes and the percentage of wet and dry ewes were similar in both groups. The marking percentage in the suppressive treated ewe group was 15% higher than in the control group. Although this is an encouraging result, no conclusions can be drawn, because the experiment effectively comprises a single replicate and is not appropriate for statistical analysis. More trials with larger numbers of ewes and further replicates would be required to identify if this is a true worm effect or an aberration in this trial

No clear effect of worm infections on ewe reproductive efficiency was found. Much larger numbers of ewes would be required to demonstrate any effect with confidence. Body weights of the 2 groups had diverged considerably by 2007, but this did not bring about any measurable differences in reproduction parameters.

#### 4.3.9.4 Ewe immune response to worm challenge after long-term chemical worm suppression.

At the completion of the ewe reproductive efficiency trial, 60 of the ewes were included in a study over 10 weeks to determine whether susceptibility to worms was increased through long-term artificial suppression of worm burdens. On 30 October 2007, a week after expiry of the protection period of moxidectin injection against *Ostertagia,* the ewes were drenched with abamectin. Thirty ewes that had received sustained worm suppression over 568 days (former treatment group), and 30 drenched only in accordance with regular management practice (former control group), were identified and individual faecal egg counts done 3 times over 10 weeks.

After 4 and 6 weeks faecal egg counts of control group ewes were respectively 19% and 31% greater than those of treatment group ewes; counts in the 2 groups were similar after 10 weeks. Clearly there was no increased susceptibility of suppressive treated ewes to the establishment of worm burdens.

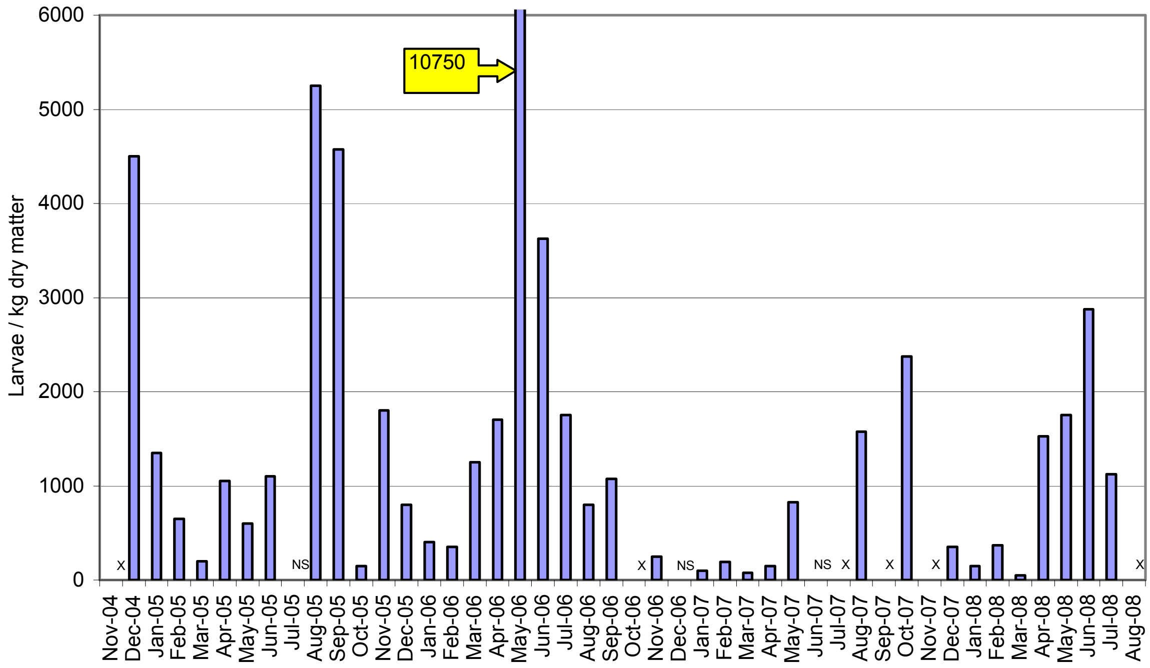
#### 4.3.9.5 Seasonal levels of pasture infectivity with larval worms from 2004 to 2008

Between November 2004-August 2008, measurements of worm larvae levels on pasture were regularly conducted on "West Lakes" and a similar neighbouring property to show the seasonality of contamination with *Trichostrongylus*/*Ostertagia* and *Nematodirus*. Each month 1-4 paddocks were sampled, initially monthly, but from June 2006 measurements were made approximately fortnightly. Altogether 159 pasture larval measurements were made, incorporating 13 paddocks collected on 75 separate farm visits. The average monthly contamination with trichostrongylid worms on Potato paddock which was intensively sampled over 4 years (Figure 9) provides useful information on the seasonality of worms in this environment, because it was predominantly grazed by sheep without cattle present. Interpretation is helped by complementary data sets from other areas on the farm also regularly grazed by sheep.

For detailed discussion and interpretation of the data the reader is referred to Appendix 11. The present section of the report summarises and interprets the key events chronologically, and outlines the value and limitations of the data and the implications for internal parasite management in prime lamb production systems in this area.

#### 4.3.9.5.1 Seasonal patterns of *Trichostrongylus* and *Ostertagia*

Figure 9 Monthly averages of pasture larval contamination on Potato paddock, Sections A-C S Malcolm, Portland, Victoria, November 2004 - August 2008




X = no larvae detected NS = not sampled

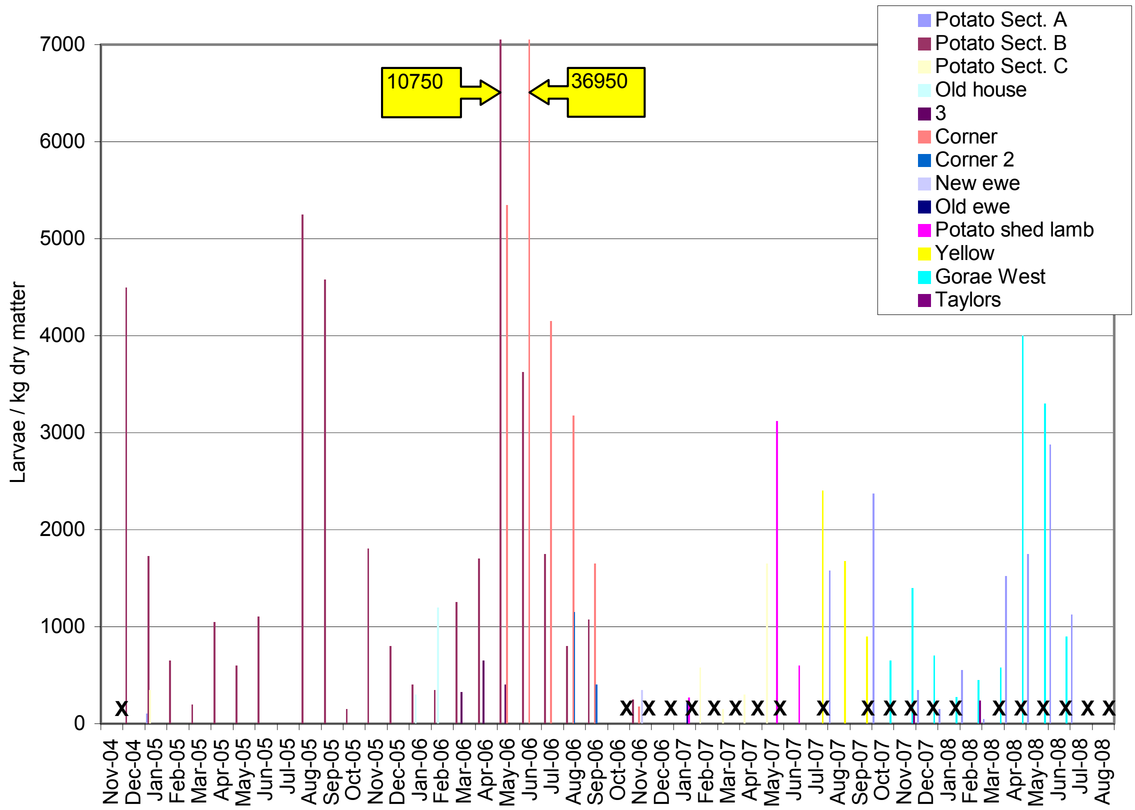
2004/2005

Measurements for the first 11 months, (November 2004 - December 2005) were confined to Potato paddock. Contamination remained elevated throughout December/January, despite mean average daily temperatures of 25°C and 27.5°C respectively. Substantial single rainfall episodes of 15 mm on 11/12/04 and 5/1/05 released larvae from dry faeces on pasture. Lambs and ewes were exposed to moderate contamination throughout, but did not develop alarming worm burdens, probably because protein intake was reasonable. Regular substantial rainfall events from February to June

2005 facilitated constant moderate contamination and reinfection over several months, leading to a dangerous peak of 7950 larvae/kg DM early in September in the middle of lambing. During September and October sheep did not constantly occupy Potato paddock B and larval numbers declined naturally. Untreated lambs in the second lamb growth study and ewes supplied substantial contamination until drenching in mid-December.

From January 2006 sampling was regularly extended to additional paddocks. Data for the average monthly pasture contamination of all individual paddocks from November 2004-August 2008 are consolidated in Figure 10.

Figure 10 Consolidated monthly averages of pasture larval contamination for individual paddocks S Malcolm, Portland, Victoria, 2008




X = no larvae detected in one or more of paddocks sampled in that month

<u>2005/2006</u>

Larvae were constantly present on Potato paddock throughout summer, at sufficient levels to produce significant worm burdens in lambs.

Following a season break over the first 3 weeks of April, contamination peaked dramatically at dangerous levels in May/June 2006 on both Potato B and Corner paddocks. Corner paddock, (almost 37000 larvae/kg), had been grazed by sheep from late April/early May before de-stocking in early June to allow feed growth as a pre-lambing paddock. After 1 week of grazing with cattle in early July, contamination had fallen to 6000 larvae/kg and by 26/7/06 to 2300 larvae/kg. This decline highlights the efficiency of cattle as a tool to clean pasture of sheep nematodes.

Spring 2006 was short and very dry forcing the weaning of lambs in late December for the first time in the history of this property. A combination of seasonal factors and reduced contamination from ewes after early October led to extremely low levels of pasture contamination which persisted for 6 months through to May 2007.

<u>2006/2007</u>

Contamination in 2007 was an outcome of conditions starting in late spring 2006. Although more rain fell in the 2006 autumn to spring "wet season" than in 2005 it was still very much below average. Moreover, falls were not usefully placed and the season was a failure. Only 56 mm rain fell over 104 days from 6/10/06 to 18/1/07 and there were no individual rainfall events over this period sufficient to enable worm larvae to escape from faeces. Except for November, late spring and summer were also very hot. The numbers of days with maximum temperatures above 25°C and 30°C respectively for December were 4:3, January 5:6 and February 5:4. Significant rain from 19-22 January 2007 freed larvae from faeces on to pasture, but in the following 2 months to 23/3/07 there was only 14 mm rainfall. In addition, extremely hot weather from 15-18 February 2007 (average maximum temperature 35°C) desiccated surviving larvae from the January emergence. In summary, a single substantial rainfall event in an otherwise very dry, hot summer contributed significantly to exhausting the reservoir of larvae. Most larvae available for the following season originated from faeces deposited after the January rains and their survival in faeces on pasture was probably compromised by conditions following the rains. Significant numbers of larvae released from faeces on to pasture in early October could not be detected by mid-November, confirming that even in relatively mild conditions (average maximum temperatures in October 16.7°C and November 18.4°C respectively, with no days >28°C) larvae are unlikely to survive for longer than 4-6 weeks.

<u>2007/2008</u>

Observations started on Taylor's paddock and Gorae West in October 2007. Taylor's paddock had been de-stocked of sheep in June 2007 and subsequently rotationally grazed by cattle; the same was done with Gorae West in February 2008 (see 4.3.9.6).

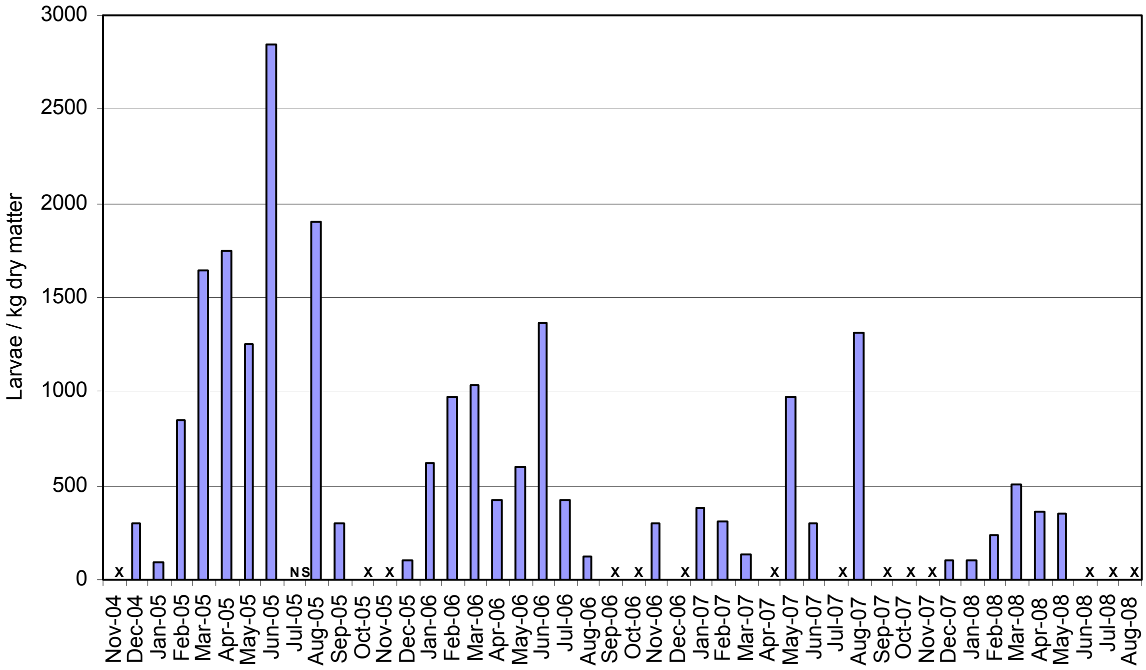
Although February 2006 was very dry (total rainfall 25 mm), 13.6 mm on 20/2/08 was sufficient to release a flush of larvae on both Potato paddock Section A and Gorae West. Apart from one sampling interval, Taylor's paddock remained free of worm larvae throughout summer.

In 2008 worm control was significantly enhanced by a sustained, unseasonal heat wave in March. Portland, a mild maritime environment, recorded 2 days >25°C, 6 days >30°C and 1 day >40°C over 3 weeks, with an average monthly maximum of 23.5°C. However, this was insufficient to eliminate residual larvae in faeces on pasture. Larvae peaked on Potato paddock Section A and Gorae West shortly after early seasonal rains (46 mm from 25-31 March). Over 6000 larvae/kg DM, were found on Gorae West, which was free of sheep for 6 weeks, highlighting the survival of sheep worms in faeces on pasture. The failure of larvae to appear on Taylor's paddock after the season break confirmed that reservoirs trapped in faeces were exhausted. No larvae could be detected on Gorae West paddock from 13 weeks after the break.

#### 4.3.9.5.2 Seasonal patterns of *Nematodirus*

Despite being often found in moderate to high numbers in young sheep and suspected of involvement in poor production, *Nematodirus* parasites (*N.spathiger, N fillicollis* and *N. abnormalis*) have not been positively incriminated in clinical or subclinical disease in sheep in southern Australia, although it is likely that they may threaten the health of recently born lambs. A large amount of both systematic and piecemeal data on seasonal availability of *Nematodirus* larvae on pasture at Portland became available in the process of measuring levels of *Trichostrongylus/Ostertagia* larvae. Average monthly levels of *Nematodirus* larvae across all paddocks are presented in Figure 11.

Figure 11 Monthly averages of *Nematodirus* contamination across paddocks S Malcolm, Portland, Victoria, 2004 - 2008




X = no larvae detected

*Nematodirus* larvae are seasonally available on pasture. Generally they are in very low numbers or absent from October to January. Annual peaks are directly related to the first significant rainfall. Overall, the highest numbers of larvae were found from February to May, depending on season, and, except for 2005 and 2007, they did not persist into spring. It appears, therefore, that eggs deposited during the winter months either do not develop or do not hatch until they have undergone a significant period of desiccation through late spring and early summer, or for even longer if the season dictates.

Data from de-stocked Gorae West paddock confirm that once *Nematodirus* eggs hatch in response to substantial rainfall, larvae persist in substantial numbers for 8 weeks and then perish in a matter of 2 weeks. The results suggest a single annual generation of *Nematodirus*, highly dependent on initial desiccation followed, probably months later, by inundation. A larval peak on pasture may be sustained over a few months due to sequential hatching of batches of eggs, but individual larvae do not survive for that long. A large proportion of prime lambs in southern Australia will not have significant exposure to *Nematodirus* because in many years they are born after the peak of larvae has passed. Late finished autumn lambs may receive considerable exposure in some years but by the time that it happens they are already immunologically competent against *Nematodirus*

#### 4.3.9.5.3 Value and limitations of the data

There are some important generalities with implications for practical worm control.

- Larval contamination is seasonal with peak numbers from April - August and a decline from January to March. Contamination from September - December is highly variable.
- There is a huge variation from year to year in seasonal availability of larvae.
- Management and weather act independently or together to modify exposure.

The data on seasonality of worm infections have superimposed management and environmental factors that influence the results, including rotation of sheep classes according to feed availability, de-stocking of pastures for variable times to enable their recovery, drenching and drench failure, seasonal weather variations, immediate weather extremes, variable pasture quality or availability, other disease processes, the presence of other livestock species, etc.

In general, summer rains greater than 15 mm are followed by a flush of larvae on to pasture, the magnitude of which is determined by the amount and persistence of rain and the numbers of trapped larvae in faeces. Steady soaking rains of at least 25-30 mm are usually needed to soften dried faeces sufficiently to enable escape of all trapped larvae. Recently deposited faeces have greater proportional yields of larvae, but significant contamination can accumulate over a few months or even weeks from large adult flocks, with a small overall egg count, particularly when there are no significant rainfall events to flush larvae out. The survival period of larvae on pasture in summer depends on the capacity of the environment to cause death by desiccation. Survival is influenced by pasture length, short dry pastures having far less potential to protect larvae than lush green ones that afford protection from direct sunlight. Immediate weather, specifically air temperature and wind, has an overriding role. Daily maximum temperatures from the high 20°C range and above, especially if accompanied by hot northerly winds, will limit the life of larvae from a few days to a week or two at most. This means that there is a large element of chance in whether or not sheep are exposed to significant worm infections in summer.

The timing of the season break is important. When it occurs before April/May the duration of the larval peak will be short, as exposed larvae rapidly perish in hot weather. However, transient peaks of larvae in either summer or autumn can provide sufficient larvae in even a few days to establish subclinical worm burdens that supply dangerous contamination in late autumn to subsequently threaten flock health after the season break.

When there is limited rainfall in the cooler autumn months the winter/spring peak will be greater because larvae have been confined within faeces and greater volumes of infected faeces accumulated on pasture over time. The survival of most larvae on pasture, even in relatively mild months of the year is little more than 8 weeks, and closer to 4-6 weeks in late spring.

#### 4.3.9.5.4 Implications for worm control programs

The general seasonal pattern observed cannot be used to blindly define a calendar of treatment options. The critical combinations of (i) magnitude of potential contamination, (ii) recent significant rainfall and (iii) weather in the 2-3 weeks following the rainfall, provide a useful basis on which to gauge risk at any time. In this environment it must be assumed that sheep can potentially be exposed to worms throughout the year. The underlying objective of a control program should be to keep the inevitable winter peak of worms within reasonable limits.

From September to May any period of persistent dry weather with no significant rainfall event >15 mm or episode of 30 mm over a few days will enable accumulation of larvae in faeces on pasture that will emerge at the next opportunity and infect sheep immediately. In summer, larvae will survive for a week or so at most, in spring and autumn survival may be for 2 months, depending on conditions. Four to six weeks after significant rain preceded by a dry spell sheep that have been infected will begin re-contaminating the environment.

Levels of larvae decline naturally in late spring every year. The practice of “summer” drenching when ewes are crutched in November is therefore justified in that it reduces accumulation of larvae that will be released as soon as there are significant summer rains. The faecal egg counts of ewes should then be monitored either as a routine in February or 6 weeks after the first substantial summer rain (if any) following the November drench. Where the bulk egg count is >100 epg drenching is justified, otherwise it should not be done. If necessary, autumn drenching should be limited to 4-6 weeks after the season break. In general, this coincides with the routine pre-lambing drench, but not always. In the case of an early break, a drench given according to the calendar 10-12 weeks later may be too late, for the reinfected ewes may already have contaminated the environment. A trigger level for drenching ewes in autumn is 200 epg. With good summer and autumn control, there is generally no requirement for drenching ewes or lambs in spring, because contamination on pasture should only be moderate and nutrition quality high. A ‘finishing drench’ for prime lambs on their mothers may sometimes be necessary at crutching in November, with a bulk faecal egg count trigger level of 250 epg. The same applies to lambs failing to make the first draft for market. If it is necessary to drench lambs on their mothers two or three times during growout, overall farm worm control is deficient.

Attention to the expected levels of larval accumulation on individual paddocks is a useful tool. Simply because a paddock has been spelled for a few months does not imply that it is free of worms. However, most paddocks will be relatively “clean” if they have been free of stock for 8 weeks following substantial rainfall.

### 4.3.9.6 The impact of cattle and de-stocking on pasture contamination with sheep nematode larvae

A study to investigate the feasibility of strategically utilising cattle to support a whole of farm sheep worm control program, and reduce dependence on failing drenches began on 30/10/07. The study relies upon measurements of pasture larval contamination to define when pastures are sufficiently free of sheep parasites to permit the return of sheep with confidence that they will not rapidly become reinfected. Once sheep return to these “worm free” refuges they will be subjected to the best possible integrated worm management to reduce the levels of chemical intervention required to maintain efficient production. In this process it is envisaged that a series of relatively worm free areas might be utilised to reduce regular worm challenge on specific target groups of stock, for example prime lambs and their dams.

Three similar paddocks within a 4 km radius are being used. Pasture contamination on all 3 paddocks has been monitored fortnightly from 30 October 2007 and continues into 2009. Potato paddock section A is subjected to normal sheep worm control practices without the intervention of cattle. Taylor's paddock (48 ha) was de-stocked of sheep in June 2007 and grazed only by cattle since then. It remained free of detectable worm larvae throughout summer 2007-2008 and continued so after the 2008 season break. Gorae West (100 ha) was de-stocked in February 2008 and grazed rotationally by cattle. Early seasonal rains released large numbers of worm larvae from faeces accumulated on the paddock, but, as reservoirs were exhausted, worm larvae could not be detected from approximately 4 months after de-stocking. In contrast, the absence of larvae on Taylor's paddock following the season break in late March, and for a further 5 months, confirms that reservoirs of sheep larvae trapped in faeces deposited on that pasture were already exhausted.

Sheep have been reintroduced to Taylor's and Gorae West paddocks in 2009 and the effects of integrated worm control practices are being monitored with a view to reducing the drenching requirement to a zero or a single treatment per annum.

Early results (2007-2008) for Taylor's, Gorae West and Potato A paddocks are given on p.52 and in Figure 10, p.51. Detailed results are in Appendix 11, Section VI, pp. 60-63.

**Key research findings and recommendations**

<u>Lamb growth studies and pasture quality</u>

- Growth rates of lambs in 2004/2005 were disappointing (187 g/day), ascribed mainly to a dramatic decline in pasture quality from December 2004. A similar seasonal decline from December 2005 was associated with a drop in lamb growth rates from around 290 g/day to 155 g/day, however overall growth was 30 g/day more than in 2004/2005. A disappointing growth rate of less than 90 g/day over 153 days in 2006/2007 was due largely to perennial ryegrass toxicity and declining pasture quality and quantity, especially from February onwards. In 2007/2008 growth rates of lambs were excellent (around 280 g/day).

<u>Drench resistance</u>

- Useful data on the impact of worms on growth rates were not collected in 2005 and 2006 because albendazole, and ivermectin capsules failed against *Ostertagia*.
- In 2007/2008 the presence of *Ostertagia* in lambs within the 91 days protection period registered for moxidectin injection (reduced protection period) confirmed resistance to macrocyclic lactones.
- It was recommended that the use of ivermectin in any formulation be discontinued
- Effective combination drenches were identified to replace ivermectin capsules for worm control in pre-lambing ewes, and for the routine drench of lambs and other stock classes when ewes are crutched in November.
- It is recommended that moxidectin and abamectin should be used only for strategic drenches in summer. This should not accelerate the development of resistance because there is a large pool of worms in summer *refugia* in this environment.

The parasites
- There is great variation in the seasonal and annual danger posed by worms. Although significant infections can be acquired in summer, peak contamination is from April to August.
- The dominant parasite is *Ostertagia circumcincta*. If conditions are suitable *Haemonchus contortus* is transmitted from late spring to the peak of summer. *Trichostrongylus* is generally more numerous on pasture from the end of October to December, but from mid-December 2005 to February 2006 conditions were suitable for transmission of significant burdens of T. *vitrinus* and *O. circumcincta* to lambs.
- Under harsh summer conditions in 2006/2007, lambs acquired very low worm burdens over 5 months.
- Trichostrongylid larvae are unlikely to survive much longer than 6-8 weeks on pasture, even in relatively mild conditions.
- *Nematodirus* larvae are seasonal on pasture and rarely present from October to January. Annual peaks are directly related to the first significant rainfall after January. There is a single annual generation, dependent on desiccation of the egg followed, usually months later, by inundation. A larval peak on pasture may be sustained over a few months due to sequential hatching of batches of eggs, but individual larvae do not survive longer than 2 months.

Ewe reproductive efficiency
- Worms had a significant effect upon ewe weight gain with average treatment and control group weights diverging by 4.99 kg pre-lambing in October 2006, before converging to a difference of 2.12 kg in May 2007. Weights then again diverged to reach a difference of 5.25 kg pre-lambing in September 2007.
- The two periods of greatest weight divergence between treated and control ewes from July-October 2006 (2.81 kg) and July-September 2007 (2.82 kg) coincided with the peaks of faecal egg counts associated with greatest levels of worm challenge on pasture.
- No effects of worms on ewe reproductive efficacy were observed although in 2007 treatment group ewes had a 15% higher marking rate than controls.
- From November 2006 nutrition was insufficient to maintain 70 kg ewes, and they lost an average of 70-80 g/day (10.5 – 11.9 kg) over the next 5 months.

Worm challenge after long term chemical worm suppression
- Prolonged anthelmintic worm suppression did not adversely affect immune response maintenance in ewes.

### 4.3.10 Struan Research Centre December 2002 – December 2008 (Appendix 12)

Research at Struan included lamb growth trials on pivot irrigation in 2002/2003, 2003/2004 and 2004/2005, on flood irrigation in 2005/2006 and 2006/2007, and intensive monitoring of pasture contamination with worms on flood irrigated pasture over 4 years. Studies in the first 2 seasons were done before the agreed collaboration of MLA and SARDI in AHW.045, but were advanced as preliminary data in the discussions leading to the design and approval of the research project. They are therefore presented here as part of the formal report of research activities of AHW.045.

Routine management practices were similar for the 3 studies on pivot irrigation, and also for both seasons where lambs were finished on flood irrigation. Lambs are drenched at weaning in early

October and again before placement on irrigated pastures, usually around early December, but receive no further drenches. In 2002, the 40 ha perennial ryegrass pasture on the pivot irrigation system was oversown with a mix including white clover and chicory, and had been free of sheep for several months. The pasture declined over the next 2 seasons and was eventually sprayed out, at which time trials on prime lambs were transferred to the flood irrigation system which comprises 55 ha of perennial ryegrass dominant pastures. Lambs rotationally graze individual bays for around 7 days at 20-25 lambs/ha, with return intervals of 16-20 days. Water is applied on an approximate 12 days rotation from November to late March. Originally, in both systems, after the last batches of lambs were sold (in May/June), cattle alone grazed the pastures until next season (i.e. for at least 6 months). More recently, cattle have been removed in late August/early September and silage is cut in mid-October. Lambs are only introduced when there are no detectable worm larvae on pasture. All lambs are eventually transferred from irrigated pasture directly to an abattoir or feedlot. There is thus a defined program to reduce exposure to worms, provide sufficient time for the majority of resistant worms on pasture to die and prevent transfer of worms from the flood irrigation system to elsewhere on the property.

All lamb growth trials on Struan were conducted according to the principles described in Appendix 1, *i.e.*, a treatment group in which worms were suppressed (or suppression was attempted) by ivermectin capsules or repeated drenching, was compared with a control group given no drenches apart from a routine treatment shortly before placement on irrigated pastures. Both groups graze together. Details differ slightly for each of the 5 trials (see Appendix 12).

### 4.3.10.1 Prime lamb growth studies

<u>Prime lamb growth study 2002/2003</u>
A trial was conducted from 5/12/02 to 9/4/03 using 240 Dorset x Merino lambs in the weight range 13.5 – 34.5 kg on pivot irrigated pasture (Bool lagoon pivot). The paddock was also occupied by a small herd of cattle. Levels of parasites on pasture were not measured.

During very hot weather early in February 2003 the lambs were observed to be distressed. Most of the flock were not grazing, numerous individuals were isolated from groups, and there was a general reluctance to walk, with many seeking the cool spray from the operating pivot. Nervous signs were not observed. No lambs died directly from this episode and the flock superficially appeared to have recovered. However, when they were weighed on 27/2/03, it was noticed that an unusual number were scouring, some severely. Dag scores were done on 10/4/03.

Overall growth rates of around 170 g/day over 125 days were disappointing. For the greater part the pasture was of excellent quality with digestibility exceeding 80% DM. Growth rates slumped dramatically by an average of 85 g/day over 6 weeks from mid-January. In early April, 75% of lambs were scouring, 24% severely. Clinical history, weather conditions, pasture composition and minimal worm burdens strongly suggest that the flock was suffering from perennial ryegrass endophyte toxicosis. The average growth rate was around 85 and 30 g/day below expectations over 2 consecutive six-week periods, representing a significant average loss approaching 5 kg per lamb. Sheep acquired extremely low levels of worms over summer. The maximum burden of *Haemonchus contortus* was only 800, and of Scourworms was 1360 worms. Worms did not have an economic influence on flock production.

Prime lamb growth study 2003/2004
A trial was conducted from 17/12/03 to 1/4/04 using 263 Poll Dorset x Merino wether lambs 27 – 38 kg about to enter the pivot irrigation system ("Bool lagoon"). The trial lambs were part of a total flock of around 500 from which non-trial lambs were periodically removed for market when finished. Because of a shortfall of grazing in January the flock was moved to another similar nearby system ("Techno" pivot).

The lambs had developed high worm egg counts in 2 months since their weaning drench, confirming the requirement for a routine drench before entering prepared irrigated pasture for finishing. Ivermectin capsules were ineffective, so a "worm free" treatment group to evaluate the impact of worms in control lambs was not established.

An unsatisfactory average growth rate, marginally over 150 g/day, was most probably due to insufficient feed of declining quality as summer progressed. Lambs developed very low worm egg counts over 106 days. The average total Scourworm (*Trichostrongylus* spp. plus *Ostertagia*) burden in controls was 3131 worms early in April 2004. Non-trial lambs grazing Bool lagoon pivot for more than 5 months averaged only 3525 Scourworms late in May 2004. This confirms the effectiveness of preparing safe paddocks on pivot irrigation for prime lamb finishing.

Prime lamb growth study 2004/2005
A trial was conducted on the pivot irrigation system from 7/12/04 to 9/3/05 using 120 weaned Poll Dorset x Merino lambs weighing between 23 – 30 kg.

Resistance of *Ostertagia* to ivermectin was identified in lambs given ivermectin capsules. Pasture quality was initially only moderate and probably declined further, resulting in an overall growth rate of around 135 g/day over 92 days, as good as could have been expected. The results provide data on the average levels of Scourworms (around 8000 worms) acquired by lambs over summer on paddocks with low contamination (300 larvae/kg DM) and the average egg count (around 80 epg) arising from these worm burdens.

Prime lamb growth study 2005/2006
A trial was conducted on flood irrigated pasture from 23/11/05 to 2/3/06 using 108 weaned Poll Dorset x Merino lambs from 24.5 – 29.5 kg.

*Trichostrongylus*/*Ostertagia* larvae were not detected in the month before placement of lambs or during the trial and only reached detectable levels after completion of the trial. Pasture quality was high before the trial, but declined markedly in November/December and continued to deteriorate over the next 2 months. In mid-December 30 kg lambs would have been able to access around 6.4 MJ of energy daily and in early February, at a weight of 36 kg, only 5.4 MJ daily. The latter is barely sufficient for maintenance. Pasture quality improved in March, too late for the lambs to benefit. Overall growth rates were poor (≤130 g/day). Treated lambs averaged 8 g/day more than controls, with a major divergence of 18 g/day in the last 6 weeks period. Lambs had not yet reached market weights by early March and at their current growth rate would have required a further 75 days to do so. Worms imposed an additional impediment of 20 days. Provision of clean pasture ensured that lambs acquired only low worm burdens (less than 2000 Scourworms), but these were sufficient to adversely influence growth on the moderate to poor nutritional regime.

Prime lamb growth study 2006/2007
A trial was conducted on flood irrigation from 6/12/06 – 12/4/07 using 80 weaned Poll Dorset x Merino lambs from 21 – 26 kg. A supplement of barley (400 g/head/day) was provided from early March when pasture growth slowed.

To investigate suspicions that previous poor growth rates were associated with subclinical perennial ryegrass toxicity (endophyte ill thrift), additional measurements and sampling of both lambs and pasture were done to determine the proportion of infected perennial ryegrass plants in the pasture, track fluctuations in alkaloid concentration in the ryegrass plants, confirm uptake by the lambs via urine analysis, and relate findings to lamb growth rates. Due to budget constraints, the testing of urine and pasture samples has not yet been done and they are stored frozen.

Ivermectin capsules were again ineffective and a treatment group was maintained through repeated injection with moxidectin. Pasture contamination was also again low, confirming success in preparing a worm free pasture through spelling, grazing with cattle and silage preparation. The disappointing overall growth rate (around 120 g/day) was unlikely to be influenced by the very low worm burdens (average of <1700 Scourworms) acquired.

The profile of pasture quality in 2006/2007 was almost identical to that in 2005/2006. In both years declining pasture quality from December to February was reflected in reduced growth rates, evidence that the perennial ryegrass pasture may not have the capacity to economically finish prime lambs to a market live weight of around 45 kg in summer. The pasture improved in quality in March and April when energy and protein levels increased and neutral detergent fibre decreased. There is suspicion, born of experience over years of lambs initially doing well, and then failing to finish, that subclinical perennial ryegrass toxicosis may also play a role, more so in some seasons than others. It is hoped that analyses of the plant and animal samples collected in 2006/2007 may contribute towards an explanation.

**Key findings**

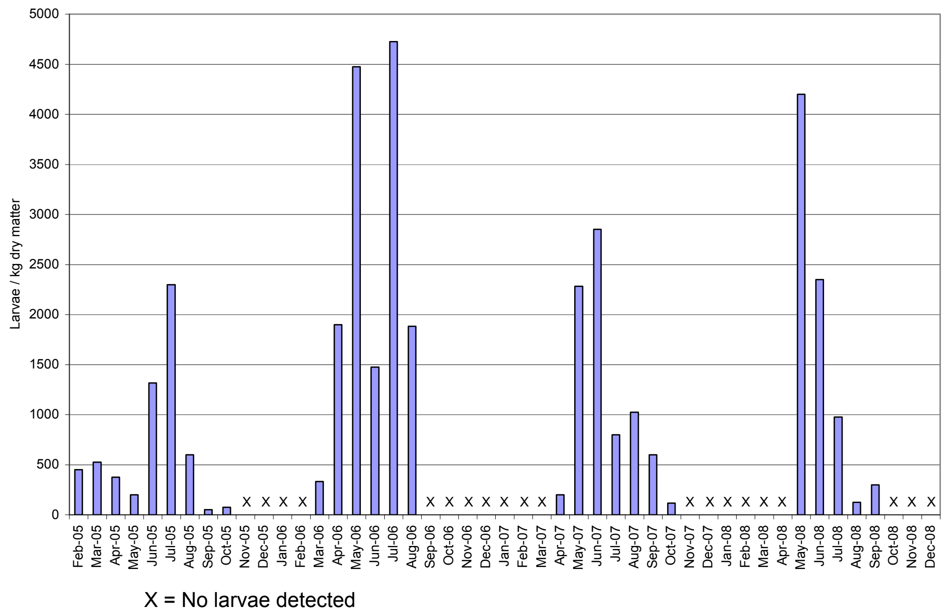
- *Ostertagia* was incriminated in consistent failure of ivermectin capsules.
- Unsatisfactory growth rates of lambs in trials over 5 years on pivot and flood irrigation were associated with a decline in quality of perennial ryegrass pasture from December to February and its inability to economically finish prime lambs to a market live weight of around 45 kg in summer. There is strong suspicion that subclinical perennial ryegrass toxicosis may also play a role, more so in some seasons than others. It is estimated that in 2003 there was a huge average loss approaching 5 kg per lamb due to ryegrass toxicosis.
- Over 5 seasons pasture contamination was low and lambs developed minimal worm burdens of little or no economic importance.

### 4.3.10.2 Regulation of seasonal contamination with worms on flood irrigated pasture

The defined management program on the flood irrigation system to prepare worm-safe pastures for finishing prime lambs is described earlier. To monitor the efficiency of the program, levels of worm contamination on the flood irrigation system were systematically measured (96 collection points over 46 months) on one 9.2 ha bay from February 2005 –December 2008. Figures 12 and 13 show average monthly pasture levels of *Trichostrongylus/Ostertagia* and *Nematodirus* larvae respectively.

There was a consistent very marked autumn/winter peak of *Trichostrongylus*/*Ostertagia* pasture contamination over years. By the time the peak occurs most lambs have already been marketed, so very few or no sheep remain on the system. Larval numbers then decline, so that when a fresh batch of lambs re-enters the system in November/December each year there are no detectable larvae on pasture, a status that generally persists for 3-4 months. During the irrigation phase in summer, third stage larvae are regularly released from faeces and rapidly perish when exposed to high temperatures and desiccation, before the next inundation in around 2 weeks time. The supply of larvae *in refugia* remains low over this period. Accumulation of larvae in faeces on pasture only proceeds once irrigation ceases, usually sometime in March. Larvae trapped in faeces are then dependent on significant rains to enable their escape and migration to pasture. The timing of the rapid increase in levels each year reflects the season break. The only danger to nearly finished lambs might arise from their retention on the system even for a week or two after the season break. The tremendous capacity of sheep with even low faecal egg counts to contaminate pasture can be seen in the fact that the contamination in 2006 originated from lambs with an average of only 12 epg, and that in 2007 from lambs with around 30 epg.

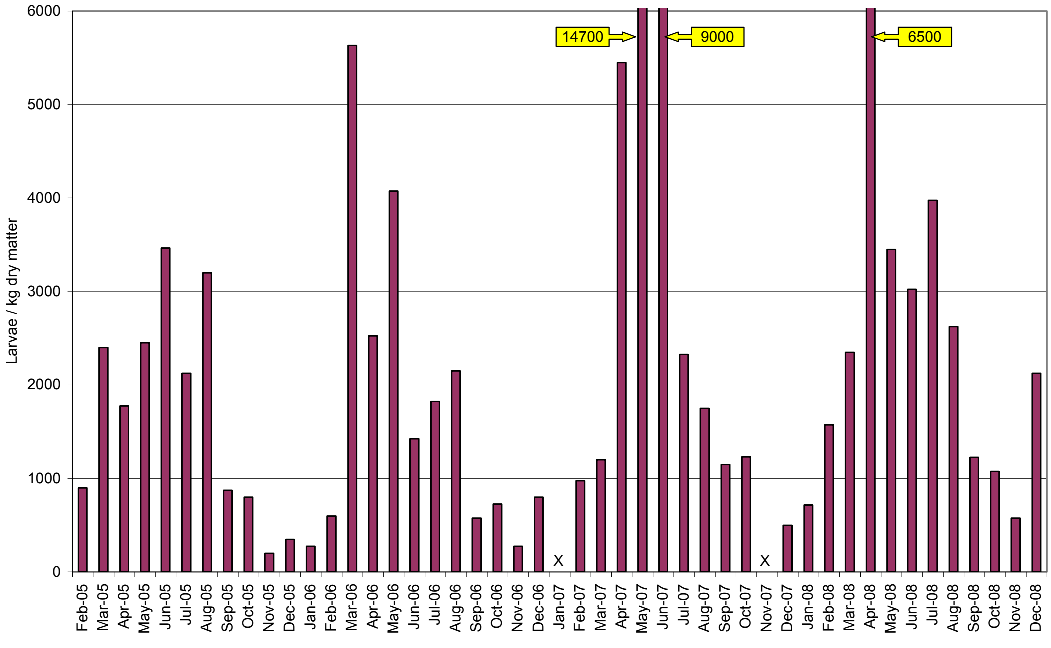
Figure 12: Average monthly *Trichostrongylus*/*Ostertagia* pasture contamination
Flood irrigation, Struan Research Centre, South Australia
February 2005 – December 2008




It is essential that 'residual' larvae do not enter the general worm population elsewhere on the farm, for most will be progeny of worms that have survived one or possibly even two drenches the previous spring, and are probably drench resistant. Lambs grown out on this system should either be moved directly to market or into a feedlot for finishing. Those retained or sold for stores should be given a quarantine drench. In addition, they should not be replaced on the flood irrigation with sheep of any class, unless they too are destined for slaughter.

*Nematodirus* larvae were found on pasture throughout the year, but with small exceptions there was a clearly defined trough from September-February and a peak from March-August. For *Nematodirus*, larvae measured at any point originate from eggs deposited in faeces at least 2-3 months earlier that have slowly developed in the egg, matured, and hatched and migrated to pasture only following inundation from either irrigation or rainfall. The peaks in March and April, therefore originate from contamination deposited by lambs in the first month or two of their occupation of the system (December/January). Successive waves of replenishment flow from sequential egg deposition in the first 3-5 months of the year, or for as long as lambs remain on the pasture. The initial rise may be initiated either by a later episode of irrigation towards the end of the season, or by significant early rains, but later emergence of larvae will be in response to rainfall. Once the lambs are removed, the reservoir of unhatched eggs naturally depletes. Concurrently, larvae already on pasture survive for little more than 2-3 months, so that there is a gradual decline in numbers on pasture as summer approaches. Sufficient residual larvae are, however, available to reinfect the next batch of weaners arriving in November/December. Young lambs would be in grave danger from very high *Nematodirus* levels from March to June of some years, so the system is highly unsuitable for lambing ewes.

Figure 13: Average monthly *Nematodirus* pasture contamination
Flood irrigated pasture, Struan Research Centre, South Australia,
February 2005 – December 2008




X = No larvae detected

**Key findings**

- Over several seasons the threat of worms to prime lamb finishing at Struan has been overcome through preparing ‘worm safe’ flood and pivot irrigated pastures by de-stocking, grazing with cattle and silage preparation. To reduce the threat from resistant worms lambs should either go directly to market or into a feedlot for finishing. Those retained on farm or sold as stores should be given a quarantine drench. In addition, they should not be replaced on the flood irrigation with sheep of any class, unless they too are destined for slaughter.

- The pastures are potentially dangerous for lambs following the season break and levels of *Nematodirus* render them unsuitable for lambing ewes from March to at least June each year.

### 4.3.11 W. Hancock August 2004 – December 2008 (Appendix 13)

Extensive research was conducted on "Fairways" from 2004-2008 and included the following:

- On–farm monitoring, August - December 2004.
- Lamb growth study: November 2004 – February 2005.
- On–farm monitoring: February – September 2005.
- Lamb growth study from marking: August 2005 – March 2006.
- Lamb growth study from weaning: October 2005 – January 2006.
- Ewe production/recovery study: September 2005 – January 2006.
- Winter/spring occupancy of flood irrigation by lambing ewes: June 2006 – December 2006.
- Lamb growth study: December 2006 – April 2007.
- Lamb growth study: September 2007 – December 2007.
- Total farm worm control: March 2006 – August 2008.
    - Seasonal persistence of worm larvae in faeces on pasture
    - Farm monitoring, selective drenching and identification of dangerous paddocks

All growth trials were done on the flood irrigation system. Key findings are summarised in Table 2, p.69, following descriptions of the trials. The seasonality of worms on the pasture was measured over 4 years to provide insight into immediate and potential risks associated with management options.

#### 4.3.11.1 Prime lamb growth studies

<u>Prime lamb growth study 2004/2005</u>

Trial 1 (17/11/04 – 1/2/05 - 76 days) used 120 weaned Poll Dorset X Merino lambs approximately 16 weeks old, weighing 32.5 – 36.5 kg. The lambs had been drenched with moxidectin on 28/10/04. One group of 60 lambs was given a bolus (CapTec™ Extender Junior ™; Captech; Nupharm) to provide sustained release of albendazole over 90 days. Irrigation commenced on 22/11/04. Sheep had regularly grazed the system throughout 2004, including a flock of clinically parasitised lambing ewes in winter and early spring. On 14/12/04 the treated group was again drenched with moxidectin to ensure that they remained worm free.

BZ capsules were reasonably effective [93%]. The majority of worms acquired by control lambs over summer were *Trichostrongylus*. Lambs given suppressive worm control gained 2.54 kg more ($P<0.001$) than controls. In the last 7 weeks the growth of controls was retarded by 31 g/day relative to treated lambs. The difference in growth would not have justified financially the routine administration of a capsule. However, at their current growth rate controls would have taken an additional 31 days to reach the weight of treated lambs, confirming an important constraint of worms on production in this system. This exaggerated response, associated with only moderate levels of worms (average 5700 Scourworms) is ascribed to declining pasture quality. By mid-December, lambs of 47 kg weight could only have consumed sufficient forage to supply 9.9 MJ energy/day, which would not drive growth above 100 g/day.

In early spring 2004, before the trial started, levels of worm larvae on pasture were dangerously high as evidenced by clinical disease and deaths of periparturient Merino ewes and their lambs. Emergency drenching at marking in August was necessary to avert escalating losses. The problem was ascribed directly to concentration of infected sheep on the system in autumn and winter. Grazing was exhausted in September and sheep were moved to allow recovery of pasture before irrigation commenced in November. Unseasonally warm weather in October undoubtedly contributed to reducing pasture contamination. Numbers of larvae on pasture declined dramatically in December, so lambs were not exposed to significant infection over the next 76 days.

<u>Prime lamb growth study 2005/2006 (1)</u>
Trial 2 (12/8/05 – 6/3/06 - 207 days) included 42 Border Leicester X Merino lambs (12 –17 kg) from marking. The intention was to compare the response to a relatively short acting drench with that from prolonged protection through to weaning. Serious ongoing parasitic disease had forced a decision to drench all ewes at marking. Historically it had been necessary to drench all lambs at marking, so that was continued as a routine procedure. Controls were drenched orally with moxidectin and treated lambs given moxidectin long acting injection based on accurate body weight. Moxidectin injection failed to protect several lambs from reinfection, probably because of their limited fat reserves. Lambs and ewes were transferred to a separate 'clean' paddock on 13/9/05 and on 20/9/05 when next yarded, the treated group were given Ivomec™ capsules to maintain constant low worm levels. They were weaned back to the irrigation bays where they joined another group of weaners (Trial 3) on 19/10/05, but were not drenched. On 6/12/05, as ivermectin capsules approached expiry, treated lambs were dosed with BZ capsules, followed by a "top-up" BZ capsule on 11/1/06 to provide for some lambs above 40 kg. Controls receiving normal farm practice were drenched on 20/9/05 and 11/1/06.

The average worm egg count of lambs at marking was only 19 epg, providing evidence that drenching was unjustified. However, they became very rapidly infected with worms in the following 6 weeks as larval challenge from contamination provided by the ewes increased substantially into September. Drenching on 20/9/04 was timely, but control lambs continued to steadily acquire worms, even though pasture contamination was below 1000 larvae/kg DM from late October. Average worm egg counts of 206, 498 and 717 epg in November, December and January respectively, prompted a further routine drench on 11/1/06. It is evident that pastures need more time to reduce to minimal levels of contamination before susceptible lambs are introduced, otherwise production losses will be an annual event that drenching will not resolve. A significant decline in pasture protein levels from December may have contributed to susceptibility to worms. The routine January drench would have been better placed after egg count monitoring in late November, to remove *Trichostrongylus* infections and give lambs the best opportunity in the face of declining pasture quality.

Positive faecal egg counts in lambs given ivermectin capsules indicate compromised efficacy (86% and 94% efficacy after 49 and 78 days respectively) and confirm emerging macrocyclic lactone resistance to *Ostertagia*. The BZ capsule dosed on 6/12/05 deteriorated in efficacy with time (91% effective after 36 days, but only 70% after 91 days), confirming BZ resistance. Both *Ostertagia* and *Trichostrongylus* are implicated, so BZ capsules are unsuitable for use on the property. As in 2004, the dominant parasite in young lambs in September was *Ostertagia*, but *Trichostrongylus* assumed increasing importance as the season progressed. Towards the end of summer *Trichostrongylus* declined and the two genera were found in equal numbers.

Suppressive treated lambs averaged 3.3 kg more weight gain than controls. Growth rates were similar for several weeks, however, between 8/11/05 and 11/1/06 they diverged considerably (throughout November the gap reached 62 g/day), leading to significant differences between weights on 11/1/06 ($P<0.02$) and 6/3/06 ($P<0.05$). Worm burdens acquired by lambs over 8 weeks from 11/1/06 did not adversely affect growth and elevated faecal egg counts over summer did not translate into escalating infectivity of the pastures. The damage had already been done. By early March control lambs at their current growth rate would have required an additional 27 days to reach the average weight of the suppressive treated group. The cost of additional drenching to bridge this gap would not have been economically justified. However, the penalty from a sub-optimal worm control program is clearly demonstrated.

In October the pasture was of reasonable quality and 28 kg lambs would have derived an estimated 7.2 MJ energy from it daily, sufficient for daily growth of greater than 150 g as observed. In December, the pasture had rapidly declined in quality, such that the lambs, now at 38 kg, would at best only have accessed 6.8 MJ energy daily, and growth rate declined accordingly. Shearing in hot, dry weather at the end of December provided an additional serious setback to growth.

Prime lamb growth study 2005/2006 (2)

Trial 3 (19/10/05 – 11/1/06 - 84 days) included 50 Poll Dorset X Merino lambs (20.6 - 27.8 kg) from weaning. All were drenched with abamectin and half were given BZ capsules. They were combined on the irrigation bays with another group of weaners (Trial 2). Observations were discontinued on 11/1/06, they were drenched with abamectin and returned to the irrigated pasture until finished for market. The average worm egg count at weaning was 175 epg, justifying a weaning drench. BZ capsules were 93% effective in controlling worm burdens.

Between October and January *Trichostrongylus* replaced *Ostertagia* as the dominant parasite. Control lambs acquired an average of 16500 adult Scourworms (*Ostertagia* plus T*richostrongylus)* over 84 days, which incurred a growth penalty of 2.1 kg from December onwards. Although the difference in weight gain was not significant, controls did not suffer the same dramatic growth decline due to worms in November as did lambs in Trial 2 that had not been drenched at weaning. There was a net difference in weight gain of 59 g/day between control groups in the 2 trials, emphasising the importance of the weaning drench in the overall lamb health program.

Prime lamb growth study 2006/2007

Trial 4 (7/12/06 – 3/4/07 - 117 days) included 80 Border Leicester X Merino weaned lambs (24 – 35 kg). All lambs were drenched with abamectin and half were given BZ capsules to suppress/prevent worm burdens. Suppressive treatment was maintained by additional oral treatments with abamectin at intervals of 48 and 42 days. The experimental group formed part of a larger flock of 300 weaners set stocked on the flood irrigation system, and all drenched with abamectin before placement. The irrigation bays had been free of sheep for 59 days from 9/10/06. BZ capsules failed, but abamectin was around 96% effective. Repeated treatment with abamectin suppressed worm egg counts of treated lambs below 70% of those of controls for most of the trial period, thereby providing a guide to the level of impact of worms. *Ostertagia* was dominant throughout the trial in control lambs and was the only parasite recovered from January-March 2007 from lambs given capsules.

The pasture was of adequate quality to enable moderate growth rates of lambs at placement; thereafter energy levels fell and could support only progressively declining growth rates over the next 3 months. Apart from December, when pasture was 66% digestible and there was sometimes more than 1500 kg DM/ha available, there was insufficient pasture to drive reasonable growth rates. Daily herbage intake by lambs would have fallen from February onwards as sward height declined to finish under 3 cm by April. Growth was therefore compromised by declines in both pasture quality (from January) and quantity (from February).

Over the last 8 weeks growth rates in controls gradually fell behind those of suppressive treated lambs with a divergence of 26 and then 30 g/day in each of the last 4-week periods, leading to a significant difference in weights of 1.22 kg (P = 0.0335) between the groups at the last weighing. The estimated worm effect is very conservative, given that faecal egg counts were only 70% reduced in treated lambs. A more realistic value would be 1.74 kg. The data confirm that even low numbers of scourworms (average around 2500 worms) can add to poor production arising from compromised nutrition quality and quantity. Growth had virtually come to a standstill by early April. Nearly 50% of lambs in both groups had not yet reached anticipated turnoff weight of 45 kg. The farmer had prepared silage earlier in the season and this was used to finish batches of lambs on an adjacent paddock. Unfinished control lambs would require longer to finish for market than suppressive treated lambs, but in the 2006/2007 season, the main penalty to production was from declining pasture quality and quantity. The pasture was remarkably lightly contaminated with worm larvae throughout the entire summer and early autumn, brought about by de-stocking for around 8 weeks before introduction of lambs, and rigorous attention to maintenance of clean pastures through introduction only of pre-drenched lambs. The success of the strategy is reflected in low worm egg counts and low total worm counts in controls at completion of the trial.

There were carry over effects from the events of December to April. At the completion of the growth trial on 3/4/07 the flock was retained on the irrigation system. Considerable numbers of lambs were not ready for sale. Saleable lambs were removed on 15/4/07 and on 17/4/07 all remaining lambs were drenched with abamectin, including an added flock of unfinished lambs from a dryland paddock. The faecal egg count of the majority of the lambs in the original flock was over 200 epg for at least 6 weeks from early March 2007. The season break was 25 mm from 27-30/4/07, followed by 101 mm evenly distributed throughout May. Worm larvae, freed from accumulated dried faeces, rapidly appeared on pasture. Persistent, cool moist conditions sustained the larval population on pasture over the following 2 months. On 16/5/07, 307 lambs remained on the system (average worm egg count 34 epg), reducing to 238 lambs on 18/5/07. The average worm egg count on 28/5/07 was 25 epg. Although worm egg counts were low towards the end of occupancy of the system, they were sufficient to provide for a peak of 10000 larvae/kg DM on 14/6/07. The last lambs were removed on 5/6/07 and replaced on 6/6/07 by Merino ewes due to start lambing in the first week of July. The ewes, therefore, entered a significantly contaminated environment in the last month of gestation and would have become immediately reinfected following placement.

<u>Prime lamb growth study 2007</u>

Trial 5 (12/9/07 – 11/12/07 - 90 days) included 56 unweaned single Border Leicester X Merino (20 – 28kg) lambs. Worm levels in 28 treated lambs were suppressed with moxidectin injection (Cydectin® LA for Sheep, Fort Dodge), at a dose rate of 1.1 - 1.5 mg/kg. Controls were untreated. Due to failure of spring rains irrigation started very early (21/9/07). Lambs were weaned 49 days after the start of the trial and continued to graze the flood irrigated paddocks.

Worm egg counts of controls at weaning had declined naturally from those of 7 weeks earlier, no doubt due to adequate good quality grazing. Thereafter substantial worm burdens were acquired from mid-October onwards. Recovery of 44% *Ostertagia* larvae from significant worm egg counts in treated lambs after 90 days provides evidence that sustained control of *Ostertagia* by moxidectin long acting injection was compromised. Macrocyclic lactone resistance has been confirmed on several occasions on the property over the previous 3 years. It is recommended that the use of ivermectin in all formulations is discontinued together with all other sustained release or long acting macrocyclic lactone formulations.

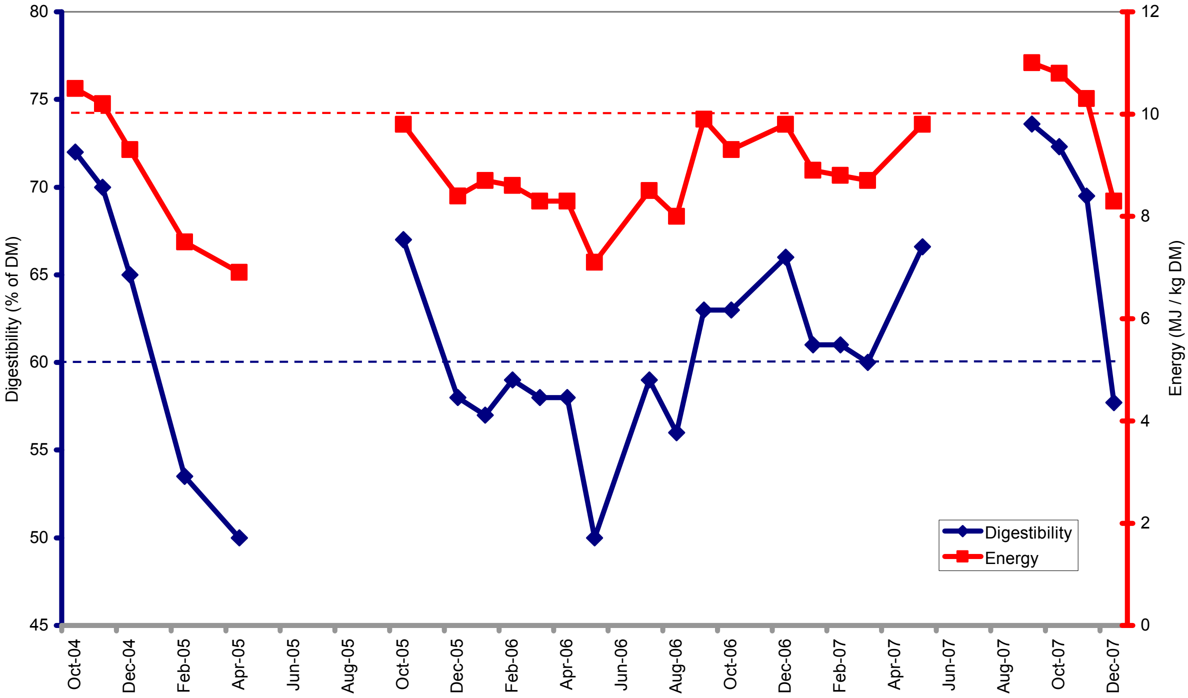
*Ostertagia* was dominant in lambs in September, but by December *Trichostrongylus* was dominant. Ewes had a low worm egg count at the start of lambing, which increased four fold early in lactation, remained elevated for a month or so and then declined naturally from 2 months post-lambing. *Ostertagia* was dominant in larval cultures in July-August but by September was replaced by *Trichostrongylus.* This confirms the seasonal emergence of *Trichostrongylus* in spring observed in lambs, although in ewes it occurred earlier.

Over 90 days lambs given a single moxidectin long acting injection gained 2.49 kg more than untreated lambs and were significantly heavier ($P<0.05$) at the last weighing. Overall growth rates for treated and control lambs were 226 and 198 g/day. A conservative estimate is that there was a worm effect sufficient to delay finishing of control lambs by a minimum of 17 days at their current rate of growth. Lambs were exposed over 3 months to a sustained average of nearly 3200 worm larvae/kg DM of pasture, at which time they would have been depending progressively less on their dams for nutrient intake. Had the pasture not been of reasonable quality and quantity at that time, the impact of parasites would probably have been much more severe. Undrenched control lambs born on the flood irrigation system approximately 5 months earlier carried an average of approximately 26000 scourworms that incurred the above growth penalty. A weaning drench would have been beneficial, for it was in the post-weaning period that the worm effect became most severe.

The sequence of events is constructed, as follows. Lambs born on contaminated pasture from early July rapidly acquired worm infections, sourced from the previous batch of lambs that had remained on the pasture until June and augmented by a steep rise in worm egg counts of their ewes from mid-July to mid-August. The nutritional regime was of sufficient quality to support a strong immune response by the lambs, an initially high egg count in early September declined significantly over the next 7 weeks, and there was only a moderate penalty in growth rates over this time. Worm challenge on the pasture then remained relatively constant for several weeks, partly due to dry weather. A large increase in worm challenge from early October (including a highly dangerous peak) followed the commencement of irrigation, sporadic significant rainfall, and the release of larvae in faecal masses deposited by the lambs and their dams. The challenge was sufficient to again put the lambs under threat, moderate to high worm burdens were acquired, and there was a significant effect on growth, increasing with time. Over time the vulnerability of lambs increased because of constant high challenge, increasing dependence upon grazing for their source of nutrition and, throughout November, declining pasture quality, including protein levels.

Figure 14 illustrates the digestibility and metabolisable energy values of the flood irrigated pastures on “Fairways” from October 2004 to December 2007. Dotted lines indicate arbitrary targets of 10 MJ/kg DM metabolisable energy and minimum 60% digestibility needed if lambs of 30 kg are to be grown out at reasonable rates. Optimal rates demand much higher values of 11 MJ/kg DM metabolisable energy or greater, and 75% digestibility.

Figure 14 Digestibility (% DOM) and metabolisable energy (MJ/kg DM) of pasture
Flood irrigation system, "Fairways", Reedy Creek, SA
October 2004 – December 2007




It is clear that for much of the summer period pasture quality is insufficient to drive good growth. The practical implications and their interaction with internal parasite infections are addressed in the relevant sections of Appendix 13. (See 2.2.5 p.5; 3.2.3, pp.9-10; 4.2.4, p.15; 7.3.5, p.29; 8.2.5, pp.34-35; and 9.2.5, p.40).

Table 2 Key findings in lamb growth studies on flood irrigated pastures
"Fairways", Kingston, SA 2004 - 2007

| 2004 | 2005 |
|---|---|
| • Excessive contamination of dry irrigation bays in autumn and early winter was critical in the development of serious worm problems in spring. Undrenched, nutritionally stressed ewes lambed on this pasture and exacerbated the situation.<br>• Following the commencement of flood irrigation in late November, larvae within deposited faeces emerged *en masse* on to pasture, where most rapidly perished due to hot dry weather. Therefore, although contamination levels were high when lambs entered the irrigation bays, they were not significantly exposed thereafter.<br>• Suppressive treated lambs gained 2.5 kg more weight than undrenched lambs over 76 days.<br>• In the last 7 weeks, growth in controls was retarded by 31 g/day relative to treated lambs. The difference did not financially justify further drenching, however, they would have required an additional 31 days to reach the weight of the treated lambs, confirming a worm problem in this system, associated with declining feed quality from mid-December.<br>• *Trichostrongylus vitrinus* was the dominant Scourworm. | • Drenching at marking was unjustified<br>• The need to drench lambs should be determined by faecal egg count in late November and, if necessary, drenching promptly done to reduce the effects of *Trichostrongylus* on production.<br>• A significant decline in pasture protein from December may have contributed to susceptibility to worms.<br>• Elevated faecal egg counts over summer did not translate into escalating infectivity of pastures<br>• Control lambs averaged 3.3 kg less weight gain than suppressive treated lambs, mainly through losses in November and December from *Trichostrongylus*. Worms acquired over 8 weeks from early January did not adversely affect growth. By early March controls would have required a minimum 27 days to reach the average weight of treated lambs. Additional drenching to bridge this gap would not have been economically justified. The marketing penalty for a marginal worm control program is clearly demonstrated.<br>• Control lambs in Trial 3 did not suffer the dramatic growth decline due to worms in November as those in Trial 2 on the same pasture that were not given a weaning drench. A net difference in weight gain of 59 g/day between the 2 groups emphasises the vital importance of a weaning drench in the overall lamb health program. |
| **2006** | **2007** |
| • De-stocking of irrigation bays for around 8 weeks before introduction of lambs and rigorous attention to maintenance of clean pastures through introduction only of pre-drenched lambs led to very light pasture contamination with worms from January to April. Lambs grazing over this period had low worm egg counts and total worm counts.<br>• Nevertheless, low worm burdens had a significant effect on overall growth rate in February and March 2007, associated with decline in the availability and quality of forage from January onwards. Low worm numbers therefore added to poor production arising from compromised nutrition.<br>• A significant '"tail" of unfinished lambs remained from April onwards, and provided a reservoir of substantial pasture contamination that emerged immediately after the season break. Ewes in late pregnancy entering the pasture in early June were heavily exposed to worms. | • Sustained control of *Ostertagia* by moxidectin long acting injection in accordance with registered claims was compromised. Significant numbers of *Ostertagia* established in lambs at least 3 weeks earlier than they should have, had the product been fully effective.<br>• Over 90 days lambs given a single moxidectin long acting injection gained 2.49 kg more than untreated lambs. The difference was sufficient to delay finishing of control lambs by a minimum of 17 days at their current growth rate.<br>• Adequate pasture of good quality was available until November but quality declined rapidly thereafter. Energy levels became limiting for finishing lambs, regardless of the availability of irrigation.<br>• Lambs born on contaminated pasture from early July rapidly acquired worm infections, mainly from others held over from the previous season. Initially, due to good nutrition there was only a moderate penalty in growth rates. Escalating worm challenge in October followed early irrigation and sporadic significant rainfall. Moderately high worm burdens were acquired, with a significant effect on growth, increasing with time. Lambs were vulnerable due to constant high challenge, increasing dependence upon grazing and, throughout November, declining pasture quality, including protein levels. |

#### 4.3.11.2 Observations on ewes July 2005 – January 2006

Merino ewes are an integral part of the prime lamb enterprise on this property as they are on many properties in southern Australia – it is clear that unless properly managed for internal parasite control they are an important source of economic risk for prime lamb enterprises.

A flock of 180 heavily pregnant 6½ years old Merino ewes was purchased, drenched with moxidectin and placed on the irrigation bays at "Fairways" on 4/6/05, 6 days after the last batch of lambs were removed. Lambing started around 18/6/05. Approximately 20 ewes died in dribs and drabs during June-July and this was initially ascribed to lambing problems, poor teeth, nutritional challenge, exposure to cold and other miscellaneous causes. On 26/7/05 the mean faecal egg count was 572 epg with 6 counts exceeding 750 epg. For management reasons (extended lambing) drenching with moxidectin was delayed until the flock was yarded for marking 17 days later on 12/8/05. By then the average egg count had risen to 890 epg with 7 counts of 900 epg or greater. Ewes were noticeably weak. Viewed against moderate levels of larvae to which they were exposed during June and July egg counts were much greater than would normally be expected. Because of a shortage of paddocks the flock was retained on the irrigation bays. They were next sampled 32 days later on 13/9/05 when the average egg count had again risen to >500 epg. Certain individuals were much more seriously affected than others. Four additional animals had died. Over this period there had been a massive increase in exposure to worms on pasture, potentially lethal to any sheep class. The ewes were again drenched with moxidectin and moved from the irrigation bays to a separate 'clean' paddock. No worm eggs were found in 10 individual faecal samples collected 7 days later.

<u>The main issues were</u>:

- The ewes were aged, heavily pregnant and some had compromised dentition.
- They were subjected to severe nutritional stress at the time of lambing and in early lactation.
- They were exposed only to moderate levels of worms arising from contamination deposited by lambs that preceded them on the pasture. From this moderate exposure they rapidly developed unusually high and sometimes fatal scour worm burdens in two separate intervals (4/6/05-12/8/05 [69 days] and 12/8/05-13/9/05 [32 days]). It is concluded that overwhelming periparturient stresses resulted in collapse of natural immunity of the ewes to worms and exacerbation of the condition.
- The ewes significantly contaminated the pasture leading to a peak of over 4000 larvae/kg DM by the time they were moved to another paddock.

On 20/9/05, 100 lactating ewes from this flock were included in a trial to observe the influence of internal parasites in the combined production/recovery phase. Half were dosed with Ivomec™ capsules to prevent/reduce the acquisition of worm burdens. The other half was not treated, apart from the moxidectin drench of all ewes 7 days earlier. Their lambs (including a cohort enrolled in a trial from marking on 12/8/05) were weaned on 19/10/05 and the ewe trial continued until 11/1/06, shortly after expiry of capsules.

Faecal egg counts in control ewes peaked at 260 epg after around 2 months and then stabilised at lower levels that did not warrant drenching in terms of flock health. However, drenching in January would have been justified on the basis of a whole-of-farm worm control strategy. A difference in body weight gain of 0.9 kg between capsuled and control ewes was statistically insignificant.

Worm contamination on pasture was relatively low (150 larvae/kg DM on 8/11/05), but infections in control ewes with a worm egg count of around only 200 epg negatively influenced (46 g/day) their recovery rate post-weaning from November to December. Weight gain ceased from December onwards as pasture quality (measured elsewhere on the property) and availability declined. Although ewes were not weighed after January, pasture analyses confirm a quality decline from summer to autumn to below maintenance. Without significant energy supplementation ewes would have continued to lose weight, and if held over and rejoined, conception rates would probably be impaired.

**Key findings** :

- Ewes with egg counts around 200 epg were penalised in growth by 46 g/day post-weaning from November to December.
- There is significant risk from parasitism through grazing pregnant ewes on the irrigation bays in winter. Although the 2005 season was harsh, conditions for worm transmission were not exceptional, yet it was necessary for salvage drenches to be given in August and September.

#### 4.3.11.3 Winter to spring occupancy of flood irrigation by lambing ewes - 2006

To optimise use of the flood irrigation system on the property it is annually grazed with introduced ewes in the "off-season" (usually from June), from just before lambing through to weaning. These ewes replace the last drafts of lambs from the previous season that have been gradually finished through autumn. In both 2004 and 2005 there were serious problems in these ewes, including significant losses from parasitism. Risks and potential shortfalls are summarised above. In 2006 a trial was established to examine more closely the outcomes of the practice. Management events in the first half of 2006 followed the established pattern. Lambs (including those from Trials 2 & 3) that had not reached market specifications over spring and summer were retained and marketed opportunistically through autumn. On 11/1/06, 340 lambs short of the heavy trade category were drenched with abamectin and retained. On 6/3/06 the flock worm egg count was a little over 100 epg. All lambs were again drenched with abamectin on 2/5/06. On 30/5/06 the worm egg count was 17 epg, confirming very little reinfection (and by implication little contamination of the pasture) in May. On 28/5/06, 301 lambs remained. The last lambs were removed on 16/6/06.

The trial used 81 out of a flock of 120 heavily pregnant, aged Merino ewes covered by Poll Dorset rams. On 23/6/06 they were randomly divided into 2 experimental groups of 40 ewes. All were drenched with abamectin, one group (treated) was given an Ivomec™ capsule, and the other group served as an 'untreated' control. The flood irrigation area was fenced into 3 equivalent areas each of 6.5 ha (divisions 1, 2 & 3). Thirty-four ewes from each group were located on divisions 2 (controls) and 3 (treated). Six ewes from each group were placed with the alternative treatment group (*ie*., 6 ewes with capsules placed on division 2 with the control group and 6 controls placed on division 3 with the capsule treated group). Division 1 was occupied by the 40 remaining flock ewes, which were dosed with BZ capsules by the farmer, but not formally included in the trial. Ewes started lambing on 2/7/06. Lambs were marked on 16/8/06 and the trial completed 54 days later on 9/10/06 (duration 108 days).

Worm egg counts rose rapidly in control ewes grazing both divisions 2 and 3 to reach potentially dangerous levels by lamb marking on 16/8/06. Control ewes were drenched with abamectin on 23/8/06. Egg counts (average 18 epg) 33 days later confirmed that the drench had been highly effective. Reasonable protection (around 90%) was provided by ivermectin capsules against worm infections in divisions 2 and 3 for the first 54 days, providing confidence that the difference between groups was indeed due to worms.

Both groups lost weight over 54 days from 23/6/06 until lamb marking, however heavy challenge with worms in July had a serious additive influence (61 g/day) on the rate of weight loss in control ewes. Controls lost around 15% of their body weight over this period; the need for salvage drenching convincingly demonstrates the serious implications of worm infections for ewes in the periparturient period. Given that ivermectin capsules were around 90% effective, the true penalty from worms was probably closer to 70 g/day. Lamb growth rates over this period were similar in both groups, but came with a significant penalty to control ewes. There was marked acceleration of growth rates (compensatory growth) in control relative to treated ewes in the 54 days following drenching.

Regular measurements were made of pasture contamination before and throughout the trial (weekly measurements were continued for 95 weeks from 7/6/06 until 14/4/08). Pasture larval contamination rose rapidly in mid-May and reached a substantial and dangerous average peak greater than 11000 larvae/kg DM on the system overall in mid-July. The logical source of larvae on the irrigation bays from May through to at least July was lambs retained on them through to mid June despite drenching with abamectin on 11/1/06 and 2/5/06. Most larvae would have originated from accumulated faeces deposited in April, with an average worm egg concentration somewhat above 100 epg. Contamination remained high, with a second serious peak in late September – early October, and did not decline to levels that were unlikely to impair production until late in November, around 6 weeks after the ewes and their lambs were removed from the paddocks.

The initial larval peak followed soaking rains of 42 mm from 1/5/06-10/5/06. The remainder of May was dry (balance of rainfall only 3.4 mm) and June was also dry. Only 5.8 mm of rain was recorded over 28 days from 2/6/06-29/6/06. During this period lambs were depositing large numbers of eggs that would lead to the serious escalation of larval numbers on pasture following significant rainfall events in early- (8-9), mid- (15-17) and late- (29-31) July. “Worm free” ewes were only introduced to the system on 23/6/06, so it is improbable that they made any serious contribution to the peak levels of larvae in July. However, they became rapidly infected (faecal egg counts >1300 epg within 8 weeks) and were undoubtedly directly responsible for the second peak of contamination in September, even though they were effectively drenched on 23/8/06, nearly a month before the peak was observed. Again, an explanation for the delay in appearance of larvae on pasture can be found in the rainfall pattern. August 2006 was yet another very dry month; only 26 mm rainfall was recorded, with the single highest fall of 3.4 mm on 3/8/06. September was also relatively dry (46.8 mm), but 94% of the rain fell in two episodes, each sufficient to enable translation of larvae from faeces to pasture (23 mm from 6-9/9/06 and 21 mm from 20-24/9/06). This emphasises the problem that even in a very dry season the distribution of available rain in relation to the timing of faecal deposition by grazing sheep can profoundly influence the level of danger that worms present to a flock. In this case, immediately after drenching, ewes were exposed to significant larval concentrations on pasture. Even though October (5.2 mm) and November (14.2 mm) were both also dry, 6 weeks were required after removal of the ewes and lambs for larval numbers on pasture to decline to unimportant levels. Hot, dry (relative humidity <12%) spells with northerly winds on 11$^{th}$-12$^{th}$ and 24$^{th}$ October and again from 18$^{th}$-20$^{th}$ and 27$^{th}$-28$^{th}$ November would no doubt have accelerated the rate of desiccation of larvae on pasture.

Bearing in mind that the sequence of events involving the ewes represents an annual management practice, there are sufficient shortfalls and risks to justify critical economical analysis of the process. Factors that need to be included, among others, are age; general health status including dentition, pregnancy levels, availability of feed (quality and quantity) in late pregnancy and early lactation; capacity to provide clean worm free pastures at parturition; impact on feed budgeting for other sheep including lambs and replacement ewes; availability and cost/trade-offs for feeding ewes once lambs weaned; numbers of lambs from ewes recycled into a second year, etc. The risk from parasitism to both the ewes and their progeny is significant and cannot be ignored. Although 2005 presented a harsh season (late break and cold weather leading to feed shortages), conditions for worm transmission were not exceptionally favourable, yet it was necessary for salvage drenches to be given in August and September. At best, this appears to be a high risk and potential low return venture.

**Key findings** :

- Lambs seriously contaminated irrigation bays in autumn despite drenching in January and May. Pasture infectivity rose rapidly from mid-May to dangerous levels by mid-July. Ewes were rapidly infected and initiated a second peak of contamination in late September.
- Control ewes lost around 15% in body weight over 54 days from late pregnancy to lamb marking and required salvage drenching, demonstrating serious implications of worm infections for ewes in the periparturient period. Lambs at foot grew at 227 – 242 g/day.
- There was marked acceleration of growth rates in control relative to treated ewes over 54-days following drenching. The compensation in growth was not related to reduced worm challenge, but may be linked to improved spring nutrition.
- Even in a very dry season the distribution of available rain in relation to the timing of faecal deposition by grazing sheep can profoundly influence the danger from worms.
- There are sufficient shortfalls and risks to justify critical economical analysis of the practice of running pregnant ewes on the irrigation bays in winter.

## 4.3.11.4 Total farm worm control

This component of the research on "Fairways" was designed to illustrate the practical environmental outcomes and benefits of structured worm control across the entire enterprise. The work involved on-farm demonstration and measurement of general issues and concepts fundamental to developing a robust overall worm control program, and was concurrent with ongoing trials and measurements on the main flood irrigation system and, in many cases, directly relevant to them.

### 4.3.11.4.1 Seasonal persistence of worm larvae in faeces on pasture

Between March and October 2006 at least 2 kg of dried faeces was collected monthly from non-inundated areas of the flood irrigation system on "Fairways" Only white, hardened and obviously aged faecal masses or pellets were gathered, with the assumption that they had been deposited at least 1, but more likely 2 months before collection. At the laboratory the faeces were moistened then soaked with water and emerging larvae recovered. Monthly estimates were made of numbers retained in aged faeces on pasture. The site had been relatively heavily contaminated with infected faeces through to January and was moderately, but consistently, contaminated from then until June. In broad terms, each monthly collection represented faeces deposited around 2 months previously.

Faeces collected in March/April (deposited in January/February), yielded approximately 1/40$^{th}$ to 1/80$^{th}$ of the larvae recovered from faeces collected in the following 2 months, despite a much greater initial concentration of worm eggs than faeces deposited later. Adjustment for the numbers of eggs deposited suggests a very rough survival index of 250-500 fold greater for larvae in faeces deposited once conditions have cooled in late summer. This emphasises the extreme importance of awareness of the dangers arising from accumulations of faeces in autumn, even those from healthy animals with low worm egg counts. This survival niche arguably forms the most important basis of seasonal transmission of worms in South–eastern Australia.

Significant rainfall events in summer and conditions immediately following the rain can have an important influence on the availability of worm larvae on pasture. Larvae trapped in faecal masses are released and create peaks of infection on pasture. Depending on immediate short term weather, released larvae may either persist for a few weeks or be rapidly desiccated.

#### 4.3.11.4.2 Farm monitoring, selective drenching and identification of dangerous paddocks

Measurements of pasture contamination and worm egg counts across a wide range of flocks were done from August 2006 to August 2008. The worm egg counts in summer 2006/2007 demonstrated that contamination varies greatly across the property and differentiated flocks requiring drenching from those that did not. On the basis of worm egg counts 10 flocks were drenched in March 2007, but it was not necessary to drench 3 flocks including nearly 1000 sheep. Worm egg counts were generally much lower at the close of 2007 than the previous year, probably due to some timely targeted drenching of heavily infected flocks in spring, and growing awareness and on-farm application of quarantine and preventive interventions to reduce transmission. Flock monitoring in February 2008 confirmed a much lower level of infection approaching autumn than in the previous year, indicating significant improvement in worm status across the enterprise. In general, over the first 5 months of 2008, sheep did not pick up large numbers of worms. After 8 months, potentially dangerous worm burdens were detected in 4 flocks and rectified, so that they could benefit from improving pasture quality and quantity from August onwards. The concept of the producer identifying the flocks believed to be more likely to have worms, based on history, age and location on the property, followed by monitoring to select specific flocks for drenching, was useful in allocating time and resources. In addition, there were significant savings in drench costs and greater peace of mind that specific production objectives were not seriously threatened by worm infections.

An important observation in summer 2006/2007 was that a single summer drench in isolation was insufficient to control worms and sheep became reinfected over 2 months on all sections of the enterprise. Re-infection was particularly severe and rapid on some paddocks at “Fairways”, which were mainly or partially irrigated, but had enough dry areas to function, in addition, as dryland reservoirs. Faecal egg counts in December 2006 confirmed that all were being heavily contaminated. The last 3 months of 2006 were exceptionally dry until 22/12/06 when there was the first significant rainfall sufficient to release massive numbers of accumulated larvae on to pasture. Lambs drenched with abamectin only the day before were therefore immediately re-exposed. On the worst paddocks an additional factor operated. Irrigation bays were not clearly structured, so that water found lower contours and rose to different levels at different times. Lambs grazed the newly emergent green pick from flooding in previous weeks and could not access some areas when flooding was in progress. They thus consistently occupied the most heavily contaminated area throughout summer, but were also exposed to contamination on dryland following rainfall events.

Based on data from earlier growth studies it was judged that worms on these paddocks may threaten the productivity of the prime lamb and wool enterprises. Therefore, in addition to the flood irrigation system, the level of worm contamination on 5 'dangerous' paddocks was monitored for 12-16 months from May 2007-August 2008. All except one paddock had at least one month where average monthly exposure to worms was greater than 4000 larvae/kg DM and two paddocks (Creek and Pincher's) were regularly contaminated at levels that it was judged would adversely affect sheep health. All paddocks were compromised to some degree with a high frequency of "moderate" exposures leading to an expected production penalty. Threats from increasing levels of *Trichostrongylus/Ostertagia* larvae on pasture on this property and others were roughly graded into 'minor', 'moderate', 'major,' 'serious' and 'highly dangerous' categories. Levels of pasture contamination for each category are given below. It is stressed that these are general, not absolute, indications of the degree of danger and can be greatly influenced by parasite population dynamics and concomitant stresses such as inclement weather, insufficient quality or quantity of feed, etc.

Threats presented by increasing levels of *Trichostrongylus/Ostertagia* larvae on pasture

| Larvae/kg DM pasture | Danger level |
|---|---|
| <1000 | Minor |
| 1000 – 4000 | Moderate |
| 4000 – 8000 | Major |
| 8000 – 12000 | Serious |
| >12000 | Highly dangerous |

Minor levels do not usually present a threat, except where pasture is short and in insufficient supply, so that there is nutritional stress and lambs consistently access most of the larvae available. This leads to gradual accumulation of worm burdens with both nutritional and worm related penalties. Moderate contamination is usually associated with a growth penalty, although in all cases it may not be of economic significance. Nutrition has a major influence on the level of the penalty. In the upper 3 danger levels (major, serious and highly dangerous), however, there are invariably economic penalties according to the level and duration of exposure. The gradation in danger of exposure across paddocks on "Fairways" is summarised in Table 3 and actual levels are illustrated in Figure 15.

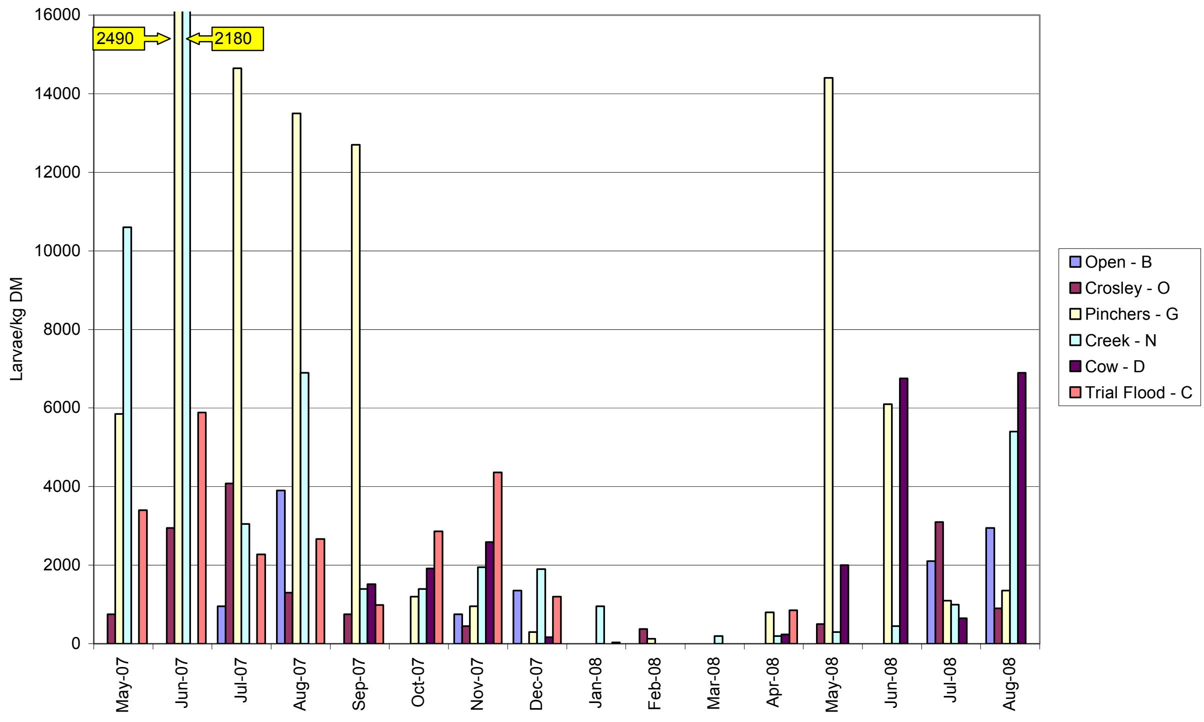
The graph highlights the magnitude of infections on Pincher's and Creek paddocks relative to the others. All paddocks are potentially dangerous from May to at least the end of July, and then most are not really safe until December. The irony is that all environments, except Open paddock, are subject to some degree of irrigation, during the greater part of which they are reasonably free of worms. The pastures become dangerously contaminated in autumn, at a time when their quality and quantity is marginal, to the detriment of sheep that will be grazing them when their quality and quantity is moving towards optimal levels. There is remarkable similarity in the broad pattern and seasonality of worm larvae between paddocks, brought about by similar management. All carry sheep for most of the year, all accumulate infection in faeces in autumn which is then freed to the pasture following significant seasonal rain, and all carry susceptible sheep at this time to continue the cycle. The impact of parasites in the critical May to July period might be significantly reduced through diversion of resources to provide supplementary feed for autumn, plus freeing up of dangerous paddocks for around 8 weeks in autumn, or their grazing only by cattle for a similar period following the break, supported by methodical testing to ensure that only clean animals are placed on those paddocks.

Table 3  Number of months that worm infections on pasture fell within specific categories
W. Hancock, Reedy Creek, SA – May 2007 – August 2008

| Paddock | Level of infection (larvae/kg DM)† | | | | | | Total months |
|---|---|---|---|---|---|---|---|
| | 0‡ (0) | <1000 (1) | 1000-4000 (2) | 4000-8000 (3) | 8000-12000 (4) | >12000 (5) | |
| Open | 10 | 2 | 4 | 0 | 0 | 0 | 16 |
| Cow | 3 | 3 | 4 | 2 | 0 | 0 | 12 |
| Crossley's | 6 | 6 | 3 | 1 | 0 | 0 | 16 |
| Trial Flood | 2 | 3 | 5 | 2 | 0 | 0 | 12 |
| Creek | 1 | 5 | 6 | 2 | 1 | 1 | 16 |
| Pincher's | 2 | 4 | 3 | 2 | 0 | 5 | 16 |

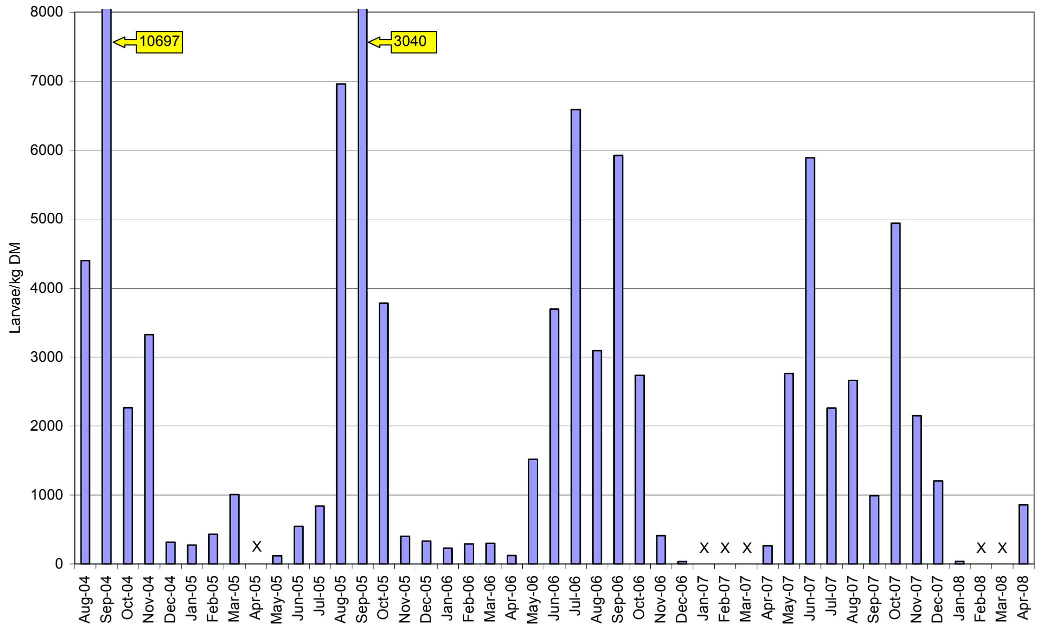
†Danger levels in parentheses (see discussion above).
‡Larvae not detected within test limits – this does not imply that the paddock was free of larvae.

Figure 15  Larval contamination over 16 months on six paddocks on "Fairways"



Pasture larval contamination was measured monthly on the flood irrigation system (C) from 12/8/04 to 1/2/05 (7 measurements), then fortnightly until 30/5/06 (36 measurements), then weekly until 14/4/08 (95 measurements), at which time the pasture was sprayed out. A comprehensive data set over nearly 4 years was collected. Consolidated monthly averages are illustrated in Figure 16.

Figure 16 Average monthly contamination with worm larvae (larvae/kg DM)
Flood irrigation system, "Fairways", Reedy Creek, South Australia
August 2004 – April 2008




The seasonality of larval contamination is remarkably consistent, with variations from year to year being largely due to timing of animal placement or removal, levels of introduced infection, significant rainfall events and other factors. The practice of lambing down aged Merino ewes on the system in July was unsuccessful, for they experienced serious parasite problems in the first couple of years and were unable to produce large numbers of healthy lambs to make full use of spring pastures. An issue was declining pasture quality from December onwards, which became inextricably linked to extended efforts to finish lambs with only moderate worm burdens in autumn, without recourse to drenching. And in every year was the inevitability that the season break ushered in renewed parasite challenge to the next batch of lambing ewes. Perhaps the most damaging influence, apart from a series of extremely poor seasons, was methodical contamination of pastures by unfinished lambs in late autumn, which perpetuated the cycle of parasitism.

Summer flood irrigation plays no major differentiating role in transmission patterns across paddocks, in that it readily frees larvae to pasture where they usually rapidly perish, whereas on dryland, worm eggs and larvae are mostly trapped in faeces in summer where they perish more slowly. Differences between the systems are only likely to emerge as exceptions to the rule, in response to unseasonal summer rains, persistent cool conditions, the introduction of heavily infected sheep to irrigation, etc. Thus, flood irrigated pastures are generally no more dangerous than dryland pastures over summer in this part of Australia. The only caveat is that worm levels can slowly build up on irrigation over summer; later in the season, as pasture quality falls, relatively small burdens can have an adverse influence on growth, additional to that associated with declining nutrition quality and/or quality.

*Haemonchus contortus* was recovered in cultures from some flocks, generally in low numbers, but comprising >30% of larvae from two crossbreed lamb flocks in February 2008. The levels of infection presented no immediate threat, but the potential for unexpected outbreaks of disease should not be overlooked. Current routine treatments directed at Scourworms are sufficient for control, provided they are based on monitoring at the end of summer, so that only flocks with elevated worm egg counts are drenched.

In summer 2006/2007 and again in 2007/2008 there was great variability between and within different areas of the enterprise in the proportions of *Ostertagia* and *Trichostrongylus* recovered from larval cultures. In general, the trend was for greater levels of *Trichostrongylus* towards the end of spring and in early summer, and *Ostertagia* later in summer. *Trichostrongylus* is especially dangerous when it dominates early in the season, i.e., from May/June onwards. Ewes had a lower proportion of *Trichostrongylus* (6%) than lambs (31%) in infections acquired over summer, suggesting that they may be better able than lambs to resist establishment of this parasite.

**Key findings**

- There is much greater survival of larvae in faeces deposited in autumn compared with faeces deposited at the height of summer. The autumn niche forms the most important basis of seasonal transmission of worms.
- Sheep were infected with worms over 2 months in summer and infection was especially severe and rapid on certain paddocks. The principle was demonstrated that the degree of contamination and proportions of parasite species varies greatly across the property.
- The concept of the producer identifying flocks believed to be more likely to have worms, based on history, age and location on the property, followed by monitoring to select those requiring drenching, was useful in allocating time and resources. There were significant savings in drench costs and peace of mind that production was not seriously threatened by worms.
- In southern Australia, the threat presented by increasing levels of worm larvae on pasture (*Trichostrongylus/Ostertagia* larvae/kg DM pasture) can be roughly graded into 5 categories : Minor <1000; Moderate 1000 – 4000; Major 4000 – 8000; Serious 8000 – 12000; Highly dangerous >12000. This grading was used to rank several paddocks on “Fairways”. Two very dangerous paddocks were identified.
- There was remarkable similarity in the broad pattern and seasonality of worm larvae on several paddocks, including the flood irrigation system, because patterns of stocking vary little between them. Summer flood irrigation plays little differentiating role in overall patterns or levels of infection, in that it readily frees larvae to pasture where they rapidly perish, whereas on dryland, they are trapped in faeces in summer and perish more slowly. Differences between systems are exceptions, arising from unseasonal weather or identifiable heavy contamination.
- Methodical contamination of pastures by unfinished lambs in late autumn perpetuates a cycle of parasitism that has serious effects on sheep of all classes in winter and early spring.

### 4.3.12 A Lyons August 2004 – August 2006 (Appendix 14)

Research on "Glenisla" included intensive monitoring of the seasonality of worm infections on flood irrigated pastures from 2004-2006, lamb productivity studies in 2004 and 2005, a growth and trace element study in ewes recovering from severe stress and a trial that examined the suspected combined influence of worm infections and cobalt deficiency on the growth of lambs.

#### 4.3.12.1 Parasite profile on flood irrigated paddocks

August – December 2004
The objective of research during this period was to profile the parasite status of a flood irrigation (perennial ryegrass dominant) system and the animals grazing on it in the "off season", that is during spring, before irrigation was applied. A flock of 760 Border Leicester X Merino ewes and their lambs was followed from lambing (August 2004) until weaning of lambs (December 2004).

Ewes lambed on paddocks (irrigation bays and adjacent dry land) waterlogged from spring rains. Initially, the available pasture on both dryland and irrigated paddocks was restricted to small areas of higher ground where samples were collected for measurement of worm contamination. Larval levels were low through to December, but no epidemiological conclusions could be made because the system had not yet been evaluated through a full season. On 17/8/04 the average faecal egg count of lambing ewes drenched with moxidectin 82 days earlier was 70 epg and it increased to 125 epg on 15/9/04 and 305 epg by 12/10/04 (138 days). This level of control over 19 weeks is encouraging, but for some time the ewes may have been contributing potentially dangerous contamination to a system about to be irrigated. *Ostertagia* was dominant in larval cultures from both lambs and ewes and comprised 94%-100% of Scourworm larvae on most occasions. Pasture quality was adequate in October, but declined in December.

At weaning (16-18 weeks of age) 4 lambs averaged a moderate Scourworm (*Trichostrongylus* plus *Ostertagia*) burden of 7340 worms, acquired mainly from 'dry' irrigation bays. Levels of pasture larvae to which they had been exposed ranged from 0 - 1500 larvae/kg dry matter. To follow contamination of pastures and transmission of parasites to weaned lambs throughout the summer irrigation period a growth study on a batch of the above lambs was commenced on 22/12/04 as they were re-introduced to the flood irrigation system.

February 2005 – September 2005
In spring and early summer 2004 monthly worm larval counts were erratic on irrigated pastures, presumably because of a combination of the influences of variable grazing times of individual bays, short periods of extremely hot dry weather, and the absence of an association between grazing patterns and the timing of irrigation cycles. In addition, only a single bay had been sampled at each visit and lambs either moved at irregular intervals through successive bays or occupied several at once.

From February 2005 three of the most consistently populated adjacent bays were measured fortnightly, and an average value used as an approximation of the overall level of contamination. Moderate larval levels on irrigated pastures that were found in early summer were not sustained, indeed, in February 2005 levels were higher on adjacent dryland than on the irrigation paddocks themselves. Contamination on irrigated bays was greatest from May-August, consistent with findings on dryland pasture over most of South-eastern Australia. An explanation is that repeated flooding over summer enables wholesale migration of larvae from dung to pasture, where they perish relatively quickly. As the weather cools and irrigation is discontinued, larvae trapped in faeces emerge from the dung in response to rainfall rather than being regularly flushed by flooding. In cooler weather they survive longer and accumulate on the pasture. Irrigation paddocks that carry sheep past late autumn have the same May - September parasite profile as dryland pastures and present the same dangers.

October 2005 - August 2006
Fortnightly measurements of worm larval concentrations on 3 irrigated paddocks through which sheep rotated had been conducted from February-September 2005 (12 visits, 36 collections – see earlier). Collections were continued on the same 3 paddocks from October 2005 - August 2006 (18 visits, 54 collections), to complete a comprehensive seasonal data set of average pasture contamination over 19 months. For comprehensive comparisons with a dry land system, measurements were continued on an adjacent paddock that had been previously sampled from August 2004-July 2005.

Interpretation of the seasonality of pasture contamination needs to be considered in the context of a flood irrigation phase of only 4-5 months (November-March), severe waterlogging for around 2 months due to seasonal rains (July-September), and effective occupation of the system by sheep for 12 months.

The extended intensive measurements through to August 2006 confirm that the seasonality of larval availability on flood irrigated pastures occupied by sheep for the greater part of the year is similar to that found on dryland pastures. Larval contamination was low from November to March. Peak levels of larvae are present from May-September, although peaks and troughs will be strongly influenced by periods of occupation of individual paddocks, the absolute levels of eggs deposited on the pasture over short periods and the timing of irrigation episodes. In this environment there appears to be no specific danger from worms associated with the practice of irrigation. Only small numbers of larvae are able to survive on pasture in summer, therefore relatively short term pasture spelling can be employed to assist in controlling parasites. Haphazard or random grazing patterns would, however, be subject to risk.

### 4.3.12.2 Prime lamb growth studies

Prime lamb growth study 2004/2005
A growth study was conducted from 22/12/04 to 8/4/05 (107 days) using 2 groups of 65 weaned second cross lambs (weight range 33.0 – 43.0 kg) grazing flood irrigated pastures. Both groups were drenched (moxidectin) at the start, and the treatment group received ivermectin capsules.

On arrival at the property on the first day it was found that the producer was under-dosing approximately 50% of weaner lambs with moxidectin, based on subjective estimation of body weight. This emphasises the importance of objective measurement of weights in determining drenching doses for livestock. In March 2005, concern by the producer that the lambs were suffering from worms (including observations of scouring) led to drenching. Retrospectively, other findings (faecal egg counts, growth rates, pasture quality and post-mortem material) confirmed that worms were not a problem at that time and it was suspected that pasture endophytes and other stresses were involved. This highlights the importance of testing lambs by faecal egg count before concluding by visual examination alone that they require drenching.

*Ostertagia* was the dominant parasite recovered from larval cultures from lambs, more markedly so (around 90%) in early autumn (March, April). There was no difference between growth rates of the groups (64 *vs*. 65 g/day), indicating no worm effect. Poor lamb growth over 107 days has serious financial implications for the enterprise. The findings are similar to those in a previous PIRD in this district in 1998 (Greenways Mineral PIRD – J Stafford, facilitator) in which feed quality and quantity were the main factors associated with lamb growth rates well below expectation, and worm problems were suspected. Even at weaning in December 2004, nutritional quality was marginal for growth. Neutral detergent fibre levels were such, that although there was plenty of feed on offer, lambs of 40 kg would only have been able to consume enough to supply 7.8 MJ of energy/day, insufficient for reasonable growth. This value declined further, so that in February lambs would have been able to consume sufficient to provide only 6.1 MJ of energy/day. This figure can be looked at from two perspectives. First, dry sheep (40 kg) maintenance requirements are 6 MJ ME/day (*Making More from Sheep. Module 11: Healthy and Contented Sheep*. Australian Wool Innovation & MLA, 2008). Second, growing lambs of only 20 kg require 6.3 MJ ME/day to grow at 100 g/day, whereas 30 kg animals require approximately 10 and 12 MJ ME/day to grow at 100 and 200 g/day respectively (NRC, 2007). The lambs were approaching 40 kg, therefore there was no capacity for worthwhile growth rates in the forage available to them from weaning.

<u>Prime lamb growth study 2005/2006</u>

A growth study was conducted from 5/10/05 to 28/3/06 (173 days) using 2 groups of 25 single, unweaned second cross lambs on flood irrigated pastures. The lambs were born on the “dry” irrigation bays and had rotated with their mothers between the bays and adjacent dryland paddocks. Suppressive worm treatment was provided in treated lambs with moxidectin injection (5/10/05), ivermectin capsules (6/12/05) and albendazole capsules (12/1/06). Control lambs were treated with ivermectin/levamisole/albendazole at weaning on 6/12/05.

Over 62 days to weaning, lambs grazing with their dams on spring pasture grew at around 300 g/day. Growth rates declined rapidly thereafter to around 108 g/day from December-January to only 48 g/day from January to early March. This was followed by a remarkable increase in weight gains (compensatory growth) over 21 days from 7/3/06. Average growth rates were 252 and 274 g/day in control and suppressive treated lambs respectively, compared with only 54 and 42 g/day in the previous 54-day interval. A second, larger cohort of slightly younger lambs in a concurrent trial on adjacent irrigation paddocks, and sharing two common weighing dates with the older lambs, expressed the same phenomenon. In 44 days following 7/3/06 they averaged 218 g/day growth compared with 64 g/day in the previous 54-day interval. A common factor or factors (excluding internal parasites, trace element or pasture deficiencies, or poor pasture quality) operated on both groups to adversely influence growth throughout January and February. It is postulated that the source of stress is endophyte activity in the perennial ryegrass pasture. High ambient temperatures and possible water deprivation may have potentiated the effects. Recovery (compensatory growth) in the first group of lambs was documented in March, and in the second group in April 2006. It seems that critical concentrations of ryegrass endophyte alkaloids neither persisted in the pasture in February nor had sustained residual effects in infected lambs. Onset of compensatory growth was not specifically associated with dramatic relief from hot weather.

Given that lambs will select a diet of better quality than the average composition of what is available, there is, nonetheless, evidence from feed quality analyses over 15 weeks from early November 2005 that the pasture provided insufficient nutrition to strongly drive commercial growth rates. No adverse effects due to worms were identified. At the end of March 2006 control lambs drenched 112 days previously had accumulated average Scourworm (*Trichostrongylus* plus *Ostertagia*) burdens of only 8650 worms that had not significantly influenced growth rates.

#### 4.3.12.3 Parasites and trace element levels in ewes on flood irrigation – October 2005-January 2006

Fifty mature lactating (5-year old) Border Leicester X Merino ewes were included in a study from 5/10/05 to 11/1/06 to examine the influence of worm infections acquired on flood-irrigated paddocks. There was concern among many producers in the area that trace element deficiencies were a major contributory factor to poor regional productivity on farms along the southern coastal belt, so samples of blood and plasma collected from 15 ewes at the start of the trial were analysed for selenium, copper, zinc and cobalt.

Ewes had been severely stressed in July-August due to feed shortages, harsh environmental conditions and lambing. They grew dramatically at over 300 g/day as conditions improved in late spring (compensatory growth), but growth ceased from December onwards as pasture senesced and energy levels declined and by January 2006 they could not maintain body weight. Based on faecal egg counts, worm burdens were minimal and would have played no part in the dramatic reduction in growth rate from early December. There was no evidence of deficiencies in levels of selenium, copper, zinc or cobalt. The ewes had been given cobalt bullets pre-lambing in July and Vitamin B12 (cobalt indicator) levels were elevated.

#### 4.3.12.4 Prime lamb growth, parasites and cobalt interaction – January – April 2006

Cobalt deficiency has been a historical problem in southern coastal areas of South Australia and is in the forefront of producers' minds when ill thrift is considered. No evidence of deficiencies in levels of selenium, copper, zinc or cobalt was found in ewes from October 2005-January 2006. A study was conducted to examine the influence of cobalt and other trace elements on growth and parasite levels of second cross lambs weaned on to flood-irrigated pastures.

Groups of 29-31 lambs born in September were drenched at weaning on 12/1/06 and assigned to one of four 4 treatment groups: Cobalt plus sustained release albendazole (BZ) capsule; Cobalt only and no BZ capsule; No cobalt plus BZ capsule; No cobalt and no BZ capsule. Cobalt was administered by means of a cobalt bullet with grinder. To determine worm uptake from January-April and the influence, if any, of cobalt status, 5 untreated control lambs and 5 from the group given only cobalt bullets were slaughtered for total worm counts on 19/4/06.

The lambs had the same growth pattern as another older cohort of lambs on similar adjacent pasture, namely depressed growth rates in January-February ascribed to ryegrass endophyte alkaloids, followed by dramatic compensatory gain in March (see 2005/2006 prime lamb growth study). No differences in overall growth were demonstrated between any of the groups (no independent effects or interactions between worm and cobalt treatments).

Lambs had adequate levels of selenium, copper and zinc at weaning in January. In view of similar findings in ewes in October 2005 the status of these 3 trace elements was not measured again. The Vitamin B12 status of lambs was marginal to adequate at weaning, however levels well above requirements were maintained for the following 93 days, even in animals receiving no cobalt supplementation. Lambs given cobalt bullets maintained Vitamin B12 levels 1½ - 2 times those of their un-dosed counterparts, but no specific benefit is ascribed to the elevated levels.

Feed quality analyses provide evidence that, as in the previous year, overall pasture quality in summer is insufficient to strongly drive commercial growth rates. From December onwards it is unlikely that lambs could access sufficient energy to grow at greater than 150 g/day, even in the absence of other problems. Average worm egg counts and total adult scourworm burdens (4740 and 5780 worms respectively) were not substantially different in untreated lambs and lambs dosed with cobalt bullets.

#### 4.3.12.5 Pasture quality, October 2004 – August 2006

FEEDTEST™ analyses of the pasture available to the lambs on irrigated paddocks were done in October and December 2004 and January, February and April 2005, followed by 11 systematic measurements from October 2005 – August 2006. Implications for each of the trials are discussed elsewhere, but because pasture quality had an overriding negative influence on efficiency of production in the system the main findings are summarised below.

Energy levels greater than 10 MJ /kgDM were only found in October 2004, November 2005 and August 2006, so it is reasonable to assume that with appropriate fertilising and minimal inundation in winter and early spring the pastures would be highly productive from late spring to early summer. Indeed, this capacity was demonstrated in both ewes and lambs from October to December 2005. Throughout most of summer however, despite irrigation, there was only sufficient energy available in pasture to support light to moderate growth in younger lambs or maintenance requirements for larger animals. For example, at weaning in 2004, 40 kg lambs would have accessed only 7.8 MJ of energy/day, insufficient for reasonable growth. By February this had declined to only 6.1 MJ of energy/day. Superimposed were other unquantified issues such as water access and subclinical effects of pasture endophytes. Energy remains consistent at 8-9 MJ /kg DM through autumn and winter. Ewes of 60 kg can probably consume around 1.5 kg DM of this pasture daily, providing sufficient energy for pregnancy, however there is insufficient to support lactation and they will drop off dramatically in condition. In wetter years nutritional shortcomings of the pasture will be exacerbated by a combination of waterlogging, leading to reduced grazing availability, plus additional stress from sustained discomfort and exposure. An extreme example of this was evident in the recovery by lactating ewes of 15.3 kg body weight over 48 days from mid-October 2005.

#### 4.3.12.6 Worm burdens in lambs on flood irrigated pasture, December 2004 – April 2006

Overall, 26 total worm counts were done on lambs of various ages grazing flood irrigated pastures at "Glenisla", at different points over summer and autumn. Average scourworm (*Trichostrongylus* plus *Ostertagia*) burdens acquired by lambs in spring and measured at weaning in 2004 were only moderate (7340 worms), but the following season levels at weaning were much higher (18260 worms). Although these burdens are unlikely to have serious implications for production in the presence of good spring nutrition, the situation would be quite different post-weaning in the presence of declining nutrition. Therefore a routine weaning drench of all lambs in early summer remains a recommendation, even though they are entering a period in which worm transmission will be minimal.

Three groups of slaughter lambs were born on the system, drenched at weaning and acquired worm burdens during finishing over 14-16 weeks in summer. All 3 groups had substantially lower worm levels than those acquired by unweaned lambs in spring. Apart from exposure to fewer larvae on pasture, an age immunity influence may also have operated. Spring worm burdens had a greater proportion of *Trichostrongylus* than summer burdens in which *Ostertagia* was always dominant. Worms in lambs at weaning, therefore, assume more potential economic importance than those acquired in the finishing process on irrigated pasture thereafter. It is also important that >99% of *Trichostrongylus* spp. were *T.vitrinus*, the most pathogenic species.

**Key findings**

- Underdosing of lambs with drench due to inaccurate estimation of body weights – importance of weighing.
- Lambs with minimal worm burdens unnecessarily drenched based on clinical signs and failure to thrive – importance of faecal egg counts in decision process.
- Rapid decline in pasture quality from December to February so that it cannot support economical growth rates of prime lambs. Additional suspected subclinical ryegrass toxicity.
- The seasonality of worms on flood irrigated pastures grazed by sheep throughout the year is similar to that on dryland pastures and they are equally dangerous from May – September.
- No evidence of deficiencies in selenium, copper, zinc or cobalt in ewes. Lambs had adequate selenium, copper and zinc at weaning. Lambs given cobalt bullets maintained Vitamin B12 levels 1½ - 2 times those of un-dosed lambs, but there was no specific benefit in growth rates or worm levels.
- Average worm burdens low to moderate. Fewer worms in lambs finished over 14-16 weeks in summer than at weaning. Spring worm burdens had a greater proportion of *Trichostrongylus* than summer burdens in which *Ostertagia* was dominant. A routine weaning drench in early summer is important.

### 4.3.13 D & P Will August 2006 - January 2008 (Appendix 15)

Research on "Paldaro" included routine property monitoring in 2006 and 2007, and 3 lamb productivity studies, one in 2006 and two in 2007: 2006 was a very poor season with Bangham area receiving the lowest growing season rainfall on record. At Frances weather station, approximately 30 km south of Bangham, there was only 280 mm of rainfall in 2006 (long term average 520 mm/annum) and growing season rainfall was only 183 mm.

A study involving 70 recently weaned Border Leicester x Merino lambs (19 – 25 kg) on dry land lucerne was started on 30 August 2006. Initially underpinned by good nutrition, lambs grew at over 275 g/day in the presence of a low to moderate worm burden averaging 6600 adult *Trichostrongylus*/*Ostertagia* scourworms. Unfortunately, due to persistent drought there was insufficient feed available to grow out the lambs, the trial was abandoned in October after 56 days and they were sold for feedlot finishing.

Growth studies with overlapping time schedules were started in two flocks of newly weaned lambs in August 2007. The first study included 112 newly weaned Poll Dorset X BL/Merino lambs (20-25 kg) from 15 August to 22 November 2007. The second included 110 first cross Border Leicester X Merino lambs (27-35 kg) from 30 August 30 to 22 November 2007. The flocks were drenched with moxidectin at weaning, half of the experimental lambs were given sustained release capsules and they rotated approximately fortnightly for 63 and 48 days respectively through primarily dry land lucerne paddocks. On 17 October they were amalgamated for the final 36 days of the study. Two cohorts of four control lambs from each study were slaughtered for total worm counts, the first at the time of amalgamation of the two flocks, the second at the end of the trial. On completion of the study the lambs were retained through to January 2008 to access the most attractive market.

In the first growth study faecal egg counts in lambs at weaning were low (54 epg), indicating a very good level of worm control over winter. Ivomec™ capsules were ineffective as a suppressive treatment, so lambs in the treated group were drenched again with Cydectin™ to control worm burdens and provide useful comparative information on growth. Over the 99-day trial period suppressive treated lambs grew at 268 g/day and controls at 265 g/day (P = 0.64). A peak of 4650 *Trichostrongylus*/*Ostertagia* larvae/kg DM pasture in late October was the only significant exposure that the lambs had to worms throughout the study. Pastures were of very high quality (digestibility and energy usually above 70% DOM and 11.5 MJ/kg DM respectively), and grazing management ensured consistent feed on offer of around 1000 kg green DM/ha or more, thereby providing sufficient quality feed to maintain excellent growth rates. Average adult scourworm (*Ostertagia* plus *Trichostrongylus*) burdens in both cohorts of slaughtered lambs were low (<3500 worms) and there was no evidence that the second cohort acquired increasing levels of worms consequent to an additional 36 days of grazing. Around 70% of *Trichostrongylus* was *T. rugatus*, a less pathogenic species than *T. vitrinus*, therefore the impact of the *Trichostrongylus* burden upon lamb productivity is likely to be reduced.

In the second growth study faecal egg counts in lambs at weaning (30/8/07) were again low (70 epg), indicating a very good level of worm control over winter. Faecal egg counts in suppressive treated lambs were more reduced (95%) by Optamax™ capsules (alternating ivermectin and albendazole delivery) than they had been by Ivomec™ capsules in the first growth study. However, it is strongly suspected that the high efficacy observed would not be maintained over successive seasons. Lambs achieved excellent growth rates, both groups exceeding 263 g/day over 84 days. There was an insignificant (P = 0.49) weight divergence of 850 g between treatment groups in favour of untreated lambs. Therefore, additional anthelmintic treatment with an Optamax™ capsule gave no improvement in lamb productivity and used routinely would only increase selection pressure for resistance. The production system was the same for the two studies, and pastures available to the second group of lambs were also of very high quality.

Average adult scourworm (*Ostertagia* plus *Trichostrongylus*) burdens in the first cohort of lambs (48 days of grazing) were very low (<1500 worms). However, compared with the first cohort in the first growth study they had a much greater proportion of immature relative to adult *Ostertagia*, which suggests that lambs in the second study were recently exposed to worms and those in the first study were not. Total worm burdens increased but did not by any means reach dangerous levels in the second cohort that grazed for an additional 36 days. However, relative to the first cohort, adult *Ostertagia* increased fourfold and immatures doubled. The average adult plus immature scourworm count of the second cohort was 12426 compared with 5088 in the first cohort and 5838 in the equivalent second cohort of earlier weaned lambs. It is clear that lambs in the second growth study were exposed to greater parasite challenge than those in the first growth study immediately before amalgamation of the two flocks. This is confirmed by fortnightly measurements of contamination on individual paddocks over the trial period. Again, *T. rugatus*, a less pathogenic species than *T. vitrinus*, was dominant in the *Trichostrongylus* mix, with an expected less severe impact upon productivity. An important observation is that in terms of total adult worms, *Trichostrongylus* was not the dominant parasite on this property, even though *T. rugatus* was dominant in faecal cultures in late spring. The implication is that female *T. rugatus* are probably more fecund than *Ostertagia*.

At the completion of the trial/s, lambs were held for sale in early January. They were weighed again presale on 7 January 2008 but had gained little. In the interim, lamb prices at the Naracoorte sales had risen from 268 to 332 cents/kg carcase weight between 4 December 2007 and 8 January 2008, increasing the estimated average return on the two groups of lambs by $15.03/head. This, along with a small wool return from shearing in December, plus better skins, would have justified the decision to hold them over for 46 days.

There was a strong seasonality of larval availability on pasture. From May until the end of August *Trichostrongylus*/*Ostertagia* larvae were only detected twice in 27 pasture samples collected on 8 property visits. Although levels increased from late August through to late October 2007 there were no clear peaks, presumably due to frequent relocation of stock and resting of paddocks. A short period of exposure of lambs to moderate numbers of larvae was usually followed by one or more intervals in which there was little or no exposure. However, it was confirmed that levels of pasture contamination can dramatically decline or increase over a short period and this could present potential dangers in late spring. Among other factors, day-to-day weather, previous grazing history of the paddock, drenching history and nutritional status of lambs will play a role in these processes. One factor that may have contributed to greater exposure of the second group is that in September and October they grazed 2 paddocks that had been contaminated by the first group; a two week recovery period, sufficient for the lucerne pasture, was probably insufficient for optimal worm control. Nevertheless, a balance involving frequent relocation of stock between paddocks and their spelling even if only for short periods, high quality nutrition, and an effective weaning drench are the keys to production success in this system and there would be no economic benefit in additional drenching. Furthermore, sustained release devices are ineffective against *Ostertagia* and their use is strongly discouraged.

Larvae were recovered only 3 times from lambs dosed with capsules. Two cultures in the first growth study yielded 100% and 97% *Ostertagia* respectively and one in the second growth study yielded 100% *Ostertagia*. This suggests that *Ostertagia* is at least the main, if not the only parasite implicated in macrocyclic lactone resistance on the property.

**Key findings**

- Resistance of *Ostertagia* to ivermectin was identified.
- Low to moderate worm burdens did not have an economic impact in the presence of high quality nutrition.
- Frequent shifts to new pastures or between those that had been spelled for around 2 weeks provided low worm contamination on pasture, with short periods of exposure.
- There would be no additional productivity benefit through further drenching.
- *Ostertagia* is dominant for much of the year, but levels of *Trichostrongylus*, mainly *T. rugatus*, increase from mid to late spring.

### 4.3.14 J Mossop July - December 2007 (Appendix 16)

Research from July to December 2007 included a lamb growth trial and fortnightly monitoring of seasonal pasture larval contamination.

From early September to December a lamb growth trial was conducted using 100 unweaned 'Composite' (mainly Coopworth) lambs in an initial weight range of 20-27 kg. Half of the lambs received an Optamax™ capsule (alternating daily low dose delivery of albendazole and ivermectin in 10-day intervals) and half received no treatment. From the lambing period, beginning in early June and during the early part of the growth trial, lambs ran with their dams through a series of cells in a prepared "Smart Graze" system on dense phalaris/clover pasture. After 13 days they were drenched and weaned onto a prepared clover paddock, where they remained until the completion of the trial, with the exception of less than two weeks when they grazed a neighbouring paddock for ease of management.

The Optamax™ capsule reduced trichostrongyle type egg counts by 71% and 84% at 40 and 89 days respectively, showing the presence of multiple drug resistance to albendazole and ivermectin. Larval cultures confirmed *Ostertagia* as the resistant genus.

The lambs grazed excellent quality pastures. From July-October dry matter digestibility always exceeded 69% and crude protein and energy levels were above 24% DM and 10.9 MJ/kg DM respectively. Throughout the trial period 'food on offer' was always greater than 1400 kg green DM/ha. Worm larvae were only detected on pasture on 4 of 11 sampling occasions. Pasture contamination "peaked" at a low level of 1650 *Trichostrongylus*/*Ostertagia* larvae/kg dry matter in early September, prior to the lambs being drenched and moved to the weaning paddock. Larvae were not detected again until late November/early December.

Both treated and control lambs grew at 272 g/day over 89 days. However, all male lambs in the trial were shorn prior to the final weighing in early December and were therefore compared separately in the analysis. Shorn treated and control lambs grew at 295 and 274 g/day respectively, leading to an insignificant (P = 0.3) divergence of 1.9 kg, whilst the non-shorn treated and control lambs grew at 259 and 270 g/day respectively, leading to an insignificant (P = 0.1) divergence of -0.95 kg. Hence there is likely to be no benefit from additional drenching. Arguably, "best practice" strategies are in place on the property for both nutrition and parasite control in the form of "smart grazing" for ewes and lambs pre-weaning, a single weaning drench, and weaning onto prepared paddocks with high quality nutrition and low worm challenge.

Four control lambs were slaughtered at the completion of the growth trial in December 2007. On average they had low to moderate adult worm burdens comprising 2400 *Ostertagia circumcincta*, 5163 *Trichostrongylus* spp. and 3513 *Nematodirus*. An excellent nutritional regimen ensured that these worm burdens had an insignificant effect on lamb growth rates.

**Key findings**

- Multiple resistance of *Ostertagia* to albendazole and ivermectin.
- Good nutrition enables lambs with low to moderate worm burdens to achieve high growth rates.
- Current farm management ('smart grazing' paddocks for lambing ewes, dedicated low-risk, nutritious weaning paddocks) ensures consistently low worm contamination on pasture, providing the capacity to grow out lambs with a single drench at weaning.
- No additional productivity benefit would be gained through further drenching.

### 4.3.15 T Heysen July 2007 – May 2008 (Appendix 17)

Research from July 2007 - May 2008 included a lamb growth study and systematic examination of seasonal pasture contamination over 10 months.

From mid August to late November 2007 a lamb growth study was conducted, starting with 117 second cross sucker lambs within a weight range of 20 – 38 kg. Suppressively treated lambs were dosed with Optamax™ capsules, delivering albendazole and ivermectin for alternating 10 day intervals, whilst the remaining half were left untreated. Lambs with their dams grazed a dryland clover and ryegrass pasture (significant capeweed), concurrently with cattle. There was adequate feed of excellent quality throughout the entire trial period. Through to late October, digestibility always exceeded 70%, metabolisable energy 10MJ/kg DM and crude protein 23% DM, while neutral detergent fibre never exceeded 36% DM. Feed quality was therefore optimal for lamb growth.

To clarify interpretation of the data two statistical analyses were done, one of animals in the original wide weight range, the other (reported here) using those in a compact (20 – 30 kg) weight range. Over the 96-day trial period treated lambs grew at 258 g/day compared to non-treated lambs at 247 g/day, producing an insignificant (P = 0.0819) weight divergence of 1.07 kg. Hence, additional drenching of sucker lambs, apart from increasing selection pressure for drench resistance, is not cost effective.

Optamax™ capsules reduced faecal worm egg counts by only 88 and 81% at 35 and 96 days respectively, showing the presence of multiple drug resistance to albendazole and ivermectin.

Levels of worm larvae on pasture were measured fortnightly from July 2007-May 2008. Pasture larval scourworm (*Trichostrongylus/Ostertagia*) contamination was greatest from when sampling began in early July 2007 through to a peak of 5500 larvae/kg DM in mid-October 2007. Contamination then remained low, providing a period of safe grazing through to May 2008. Pasture contamination levels may have been significantly reduced through concurrent grazing with cattle.

Four control lambs were slaughtered at the completion of the growth trial in November 2007. Mean adult worm counts were: *Ostertagia* 4800; *Trichostrongylus* 8175; *Nematodirus* 388. Despite the presence of these moderate worm burdens lambs still grew at excellent rates (247 g/day), most likely due to the availability of good nutrition.

<u>Key findings</u>

- Multiple drug resistance identified to albendazole and ivermectin.
- Moderate levels of pasture infectivity persisted over four months from July-October
- Lambs on adequate high quality nutrition carried moderate worm burdens (average 13000 *Trichostrongylus/Ostertagia*) without significant penalty.

### 4.3.16 D. Price July – November 2008 (Appendix 18)

An investigation was conducted on “Majardah” following the sudden death of several Poll Dorset ewes in July 2008. The deaths were ascribed to infections with *Haemonchus contortus* acquired in the previous 12 weeks, either from the paddock on which they lambed or from the one they grazed immediately prior to lambing. Confirmatory evidence was provided by extremely high worm egg counts dominated by *H. contortus* in surviving flock members, and comparable infections in ewe flocks currently occupying the original lambing and pre-lambing paddocks. Based on differentiation of larvae harvested from composite faecal cultures, *H. contortus* was dominant in most flocks across the enterprise. Mortalities ceased immediately following treatment for worms.

It is suggested that peak levels of *H. contortus* larvae on pasture occurred in autumn when conditions were warm, with sufficient moisture available for development of the parasite. Contamination of paddocks was by sheep carrying burdens of *H. contortus* over summer. An effective drench in December, which is not routine practice on the property, would probably have averted the problem.

Concentration of all pregnant ewes on a pre-lambing paddock where they were lot fed from mid-February to mid-June may have initiated transmission. Following routine drenching a month before lambing the affected flock returned to the pre-lambing paddock, providing ample opportunity for reinfection with *Haemonchus*. Ewes moved on to the lambing paddock for a maximum of 12 days. Successive flocks followed. The management practice of staged lambing of all ewes in one paddock results in the concentration, over months, of all available infection in one location. Given suitable conditions, even modest levels of worm egg deposition can rapidly translate to serious larval contamination in a small area. Although the ewes only occupied the paddock for a very short period, they may have been exposed to dangerous levels of parasites. *H. contortus* larvae were only present at low levels on pasture in July but may have been much more numerous in mid-May when the ewes were lambing.

To reduce the risk of this happening again, a structured summer drenching program is necessary. This applies also to control of Scourworms, for there were potentially dangerous levels of these on pasture from July to September. An effective drench given annually in December to all sheep on the property will adequately control *Haemonchus* in this environment. Control using long acting or sustained release drenches is unnecessary. It is recommended to conduct a drench resistance test as a basis for determining the best options for the property. Another suggestion is that separate “clean” paddocks are made available where ewes with similar lambing dates can graze from the time of their pre-lambing drench until lambing, to reduce re-infection in that critical one-month period.

## 4.4 Summary of key management, epidemiological and operational findings

In this report 118 key findings have been identified across the various properties. These include practices or conditions - specific, general, positive and negative - affecting the impact of worm infections and their outcomes. In addition, much information was gathered on available nutrition, especially its quality. Findings varied greatly, not only between properties and from season to season, but within properties, even in the same season. However, some were repetitive and common to several production systems. General findings most likely to influence prime lamb production across a range of systems, together with recommendations arising, are consolidated below in several categories, and supported where it is felt to be useful, with brief examples. Full details are in the body of the report and relevant appendices. These findings have been the cornerstone of expanding transfer of information to producers and other industry sectors from 2005-2009. Economic implications are addressed either in the reports for each property, or in Section 4.5, below.

**Cattle**

- Cattle are highly effective in "cleaning" irrigated pastures, making them safe for finishing prime lambs over summer.
- Cattle (especially those less than 18 months of age) that share grazing with lambs, either in rotation or concurrently, should be drenched, because they can be a source of infection with *Trichostrongylus axei*, which may adversely affect growth.

**Destocking**

- De-stocking of irrigation paddocks for around 8 weeks before introduction of lambs significantly reduces risks from worms.
- Paddocks can be effectively eliminated of worms ('worm free') over 4 months by destocking shortly before the season break and grazing with cattle.

**Drench resistance**

- Worm control on many properties is compromised through the use of ineffective drenches. All drenches used should be tested for efficacy. The efficacy of capsules should be checked by faecal egg counts mid-term and, if failing, their use discontinued permanently.
- Benzimidazoles or levamisole in uncombined formulations have no useful role in worm control programs. On some properties combined formulations fail, on others they are highly effective. Napthalophos given together with BZ/L combination sometimes dramatically improves efficacy.
- Ivermectin is rapidly failing as a useful drench on many properties. Once confirmed to be failing on a property its use in any formulation risks acceleration of ML resistance.
- Capsules delivering sustained release of benzimidazole and/or ivermectin are ineffective or unreliable on many properties and their ongoing value as a regular management tool is dubious.
- Abamectin and moxidectin generally remain highly effective. The protective period of moxidectin injection against *Ostertagia* is significantly reduced on some properties, confirming advanced resistance to macrocyclic lactones.

**Epidemiology**

- There is much greater survival of larvae in faeces deposited in autumn compared with faeces deposited at the height of summer. The autumn niche forms the most important basis of seasonal transmission of worms.
- Contamination of pastures by unfinished lambs in late autumn perpetuates a cycle of parasitism that has serious effects on sheep of all classes in winter and early spring.
- Peak seasonal transmission of worms is from May – September, however this can be extended well into summer in mild coastal areas receiving summer rains. Given sufficient pasture contamination in late spring, sheep can become heavily infected with worms on dryland pastures over summer.
- Summer rains >15 mm are followed by a flush of larvae on to pasture, the magnitude of the flush being determined by the amount of trapped worm larvae in faeces.
- Most worm larvae do not survive much longer than 6-8 weeks on pasture, even in relatively mild conditions. In summer larvae may perish within a few days, but this may be sufficient for significant transmission of worms to sheep.
- The degree of contamination and proportions of parasite species vary across a property.

**Ewe reproductive efficiency**

- Worms can influence pre-lambing live weights by 5 kg. No effects of worms on ewe reproductive efficacy were confirmed although it was suspected that lamb marking rates were reduced.

**Genetic and sex differences**

- Worm egg counts of ram lambs are greater than those of their female siblings subjected to identical management and grazing.
- Worm egg counts showed large variations between individuals in susceptibility to worms, confirming a useful trait for selection indices.

**Immunity**

- Prolonged anthelmintic worm suppression did not adversely affect immune response maintenance in ewes.

**Irrigation**

- Irrigated paddocks are not as dangerous to economic prime lamb production as perceived. Overall patterns and levels of worm infection on irrigated pasture and dryland in summer are similar. Irrigation enables larvae to escape to pasture where they rapidly perish, whereas on dryland, they are trapped in faeces in summer and perish more slowly.

**Lamb growth**

- Growth rates were generally disappointing. Only 25% of flocks grew at >250 g/day. All of these were on dryland. In more productive flocks the top 20% consistently grew at >335 g/day.

**Marketing**

- Heavy lambs are usually held longer and exposed to increasing levels of worms as they approach market specifications. If drenching is necessary, marketing advantage is lost.

**Levels of worm infection on pasture**

- In southern Australia, the threat presented by increasing levels of worm larvae on pasture (*Trichostrongylus/Ostertagia* larvae/kg DM pasture) can be roughly graded into 5 categories : Minor <1000; Moderate 1000 – 4000; Major 4000 – 8000; Serious 8000 – 12000; Highly dangerous >12000.

**Management practices – animal movements**

- To reduce the threat from resistant worms, lambs raised on prepared low risk paddocks should either go directly to market or into a feedlot for finishing. Those retained on farm or sold as stores should be given a quarantine drench.

**Management practices – drenching**

- Drenching, alone will not provide effective, sustainable worm control, but must be supported through meticulous attention to the preparation of good quality worm free pastures for ewes with lambs at foot, and weaners.
- Drenching according to the calendar in this part of Australia is unlikely to be highly effective in ensuring good worm control, except sometimes by chance.

- Lambs are sometimes drenched unnecessarily at both marking and weaning. The need to drench at both times reflects poor worm control earlier in the year and will not resolve production problems.
- Quarantine drenching of all new arrivals is important to reduce the risk of introduction of strongly resistant worms.
- All prime lambs should be given a highly effective drench at weaning. Growth penalties can approach 60 g/day if this is not done.
- All prime lambs should be given a highly effective drench before introduction to finishing or irrigated paddocks. Capsules regularly fail and are a poor alternative management choice.

**Management practices – pasture**

- Regardless of the efficiency of summer worm control, retention of lambs on irrigated pastures into late autumn leads to accumulation of dangerous levels of pasture contamination that can persist for 3 months.
- The threat of worms to prime lamb finishing on irrigation is greatly reduced by de-stocking for around 8 weeks. Grazing with cattle or hay/silage production before introduction also provides low risk paddocks.
- Practices associated with productive enterprises where lambs were drenched only once at weaning included ‘smart grazing’ paddocks for lambing ewes, dedicated low-risk, nutritious weaning paddocks and frequent shifts between pastures that had been spelled for around 2 weeks.

**Management practices - processes**

- Under-drenching of lambs due to inaccurate estimation of body weights was observed – importance of weighing.
- Unthrifty lambs with minimal worm burdens were unnecessarily drenched based on clinical signs – importance of faecal egg counts in decision process.
- Persistent scouring in lambs incorrectly ascribed to worm infections.

**Pasture composition**

- Dryland lucerne paddocks are not worm-safe havens for prime lambs. Lambing paddocks are the most dangerous. The same attention to spelling of paddocks is necessary as for other dryland and irrigated pastures.
- Unsatisfactory lamb growth rates were associated with a decline in quality of irrigated perennial ryegrass pasture in the hottest months of the year. This may be a broad general industry problem.
- Subclinical perennial ryegrass toxicosis causes serious losses in some seasons.

**Pasture quality**

- On many properties pasture quality, particularly energy levels in summer was insufficient to drive reasonable prime lamb growth rates, regardless of the availability of irrigation. The summer decline in digestibility and energy content of mixed grass/legume pastures and its influence on the capacity of lambs to grow is seriously underestimated, or overlooked.
- High quality spring lucerne pastures, cereal crops and other prepared forages support strong growth associated with low worm levels.
- Low scourworm burdens (<4000) can have a significant additive effect to growth rates that are declining because of poor nutrition.

- Lambs on adequate high quality nutrition will tolerate moderate scourworm burdens (15000 or greater) without significant penalty.

**The parasites**

- On some properties, mainly in the drier areas, *Ostertagia* is the dominant scourworm throughout much of the year, especially in summer. On others, particularly in cooler, wetter areas, it is displaced by *Trichostrongylus vitrinus* in late autumn and on others from mid-Spring until early summer. Transmission of *T. vitrinus* persists over summer on irrigated pastures in cooler areas and on dryland in mild southerly areas. *T rugatus* replaces *T vitrinus* as the dominant *Trichostrongylus* species in the sandy, lower rainfall mallee regions.
- *Haemonchus contortus* is widespread but only sporadically important. Ewes acquire infections in spring and carry adult worms over summer. Transmission occasionally occurs over summer, but early lambs are usually exposed following the autumn break to contamination from faeces deposited by ewes in late summer/autumn. Levels in lambs peak in July, then decline markedly. A single drench of ewes before February is sufficient for control.
- Lambs on most properties develop high *Nematodirus* egg counts early in life without measurable ill effects. Counts decline significantly by around 8 months of age. *Nematodirus* is rare in mature ewes.

**Producer attitudes and awareness**

Some general observations were made on attitudes and awareness of prime lamb producers, and problems they face, which may assist, in part, in improving future technology transfer efficiently.

- Prime lamb producers expanding from primarily wool-based operations have the greatest problem in changing practices and find themselves in transition from a maintenance-of-livestock system which functions effectively, to a production-of-livestock one, which doesn't. The first and greatest difficulty comes from failure to provide adequate high quality nutrition, or an expectation that it will be sourced from irrigation over summer. The second arises from a false expectation that a drenching program is more important or can supplant the provision of low risk pastures for lambing ewes and weaners. Nothing could be further from the truth. These are the most important fundamental production issues facing the industry, and at least half of the enterprises failed in one or both of these requirements.
- At the heart of the difficulties faced by prime lamb producers is a pool (various sources) of inadequate, contradictory or incorrect information and the absence of a practical decision support system. Farmers have good educational support in improved genetics, quality assurance, carcase characteristics and market requirements and access, but many do not have the confidence or tools to initiate change to maximise opportunities available from addressing internal parasite problems. 'Wormboss' helps in part by providing sound background information, but is largely peripheral in that it does not address prime lamb production at the practical 'paddock level'. There is a clear need for unambiguous written and electronic tools that articulate at least the minimum needs that must be satisfied for profitable prime lamb production.

## 4.5 Economic implications

### 4.5.1 The effects of worms

In broad terms, challenge of lambs by larval gastro-intestinal parasites on pasture can have 4 grades of severity of outcome, each of which may be influenced adversely by inadequate nutrition, particularly protein.

The first is where there is no immediate economic effect on growth and no likely subsequent effect consequent to accumulation of high levels of contamination on pasture over time. The second is where enough worms are able to establish and accumulate to interfere with growth rates and impose an (often unrecognised) economic penalty, usually in the form of a "tail" of unfinished lambs that need to be retained for finishing to market specifications. The third is an extension of the second, where lambs generate sufficient pasture contamination themselves to drive a decline into escalating chronic production loss with clinical disease (for example a 20% level of scouring) in some animals. This situation usually poses an additional threat to other flocks grazing the area subsequently. Drenching is usually necessary and marketing always delayed. The fourth is where infection is overwhelming and clinical disease appears rapidly. If lambs are not drenched, serious production losses, including deaths, are inevitable. Many lambs will not fully recover from this experience.

Nutrition (with influences such as season, management, pasture composition and degree of maturity etc.), plus other factors associated with immune responsiveness (eg., the level and timing of previous exposure to worms), play important roles in determining the outcomes from worm challenge. For reviews of nutritional influences see Knox et al., (2003) and Steel, (2003).

Another major determinant of the final outcome is the magnitude and duration of the challenge from worms. Because of farmer awareness of overt worm disease, we expected, and found that outbreaks of clinical disease from worms in prime lambs were uncommon. Most exposures were low or moderate over a few months, with cumulative penalties based on an often declining equilibrium between level of challenge and nutrition, no doubt tempered by development, with time, of immunity. However, short term challenge with massive numbers of worms, or consistently high exposure, both of which can easily overcome a fragile immunity in lambs, were also seen.

### 4.5.2 Assumptions, industry base statistics and sources of loss

Some assumptions and benchmarks are established to help interpret the economic implications of the findings in AHW.045. We conducted 28 lamb growth studies on 13 properties from 2004-2007 (Table 1, p.17) and are confident that they are sufficiently diverse to be representative of production systems in South-eastern mainland Australia at that time. An overriding feature of the production environment from 2004-2007 was drought, in many areas the worst on record, so this needs to be taken into account in considering industry performance. However, despite drought, many producers profitably produced commercial prime lambs whilst others failed to do so, even on irrigated pastures.

The average growth rate (270 g/day) of suppressive treated lambs in the 7 most productive flocks (upper 25% - all of which were dryland production systems) has been used as a benchmark for good productivity over this period, with a cut off growth rate of 150 g/day representing a level at which economic returns were likely to be marginal. Differences between properties and within individual properties were brought about by interactions of nutrition quality and quantity and levels of worm challenge as discussed above. Where sub-optimal production due to parasites was identified, the economic penalty could be estimated directly (*ie*, in kilograms of body weight <u>not</u> gained) or indirectly (*ie,* increased time to reach market specifications or failure to do so, resulting in progression to hogget status at the time of marketing). It is expected that the values derived from these calculations for direct losses will apply across the whole slaughter lamb industry (including prime lambs, light lamb, feeder/restocker lamb and Merino lambs sold for slaughter), whereas indirect losses would specifically penalise prime lamb profitability. Other factors affecting either profitability (such as nutritional influence on carcase dressing percentage), or with broader implications for the industry (such as meat quality in nutritionally compromised lambs [Hegarty *et al*., 2006; Martin *et al.*, 2006; Hopkins *et al.*, 2007]) were not accounted for in this exercise, although mention is made of their potential impact.

Economic impact calculations for South-eastern Australia assume that the results are broadly referable to New South Wales (Riverina), Victoria, and South Australia, which collectively account for 57% and 54 % of total national gross receipts for slaughter lamb and prime lamb respectively (data for 2007-2008 derived from ABARE, 2009). Total prime lamb production for these regions in 2007-2008 was 7.32 million and total other slaughter lamb production 4.01 million head.

It is difficult to quantify the penalty to commercial opportunity arising from delayed finishing of slaughter lambs to market specifications. It might be attempted on a farm-by farm basis using standard estimates for the cost of additional DSE loads added to normal budgeting parameters (R. Apps, Research Adoption Manager, Sheep, Livestock Production Industries, MLA, personal communication, 2009). However, the imposition comes at a time when its effect is maximised by declining feed availability, not in the spring flush or early in the irrigation season when pastures are optimal. Therefore, a standard “agistment penalty” of 80 cents/week has been used for calculations, based on normal commercial figures for lambs in which moderate growth is required (R Steen, PPS&H, Livestock Agents, Naracoorte, personal communication 2009); this is doubled in value due to the requirement to provide alternative feed to sheep displaced from pastures occupied by the retained lambs. The rate of growth measured in the last interval for each growth trial has been used in calculations to determine the additional time required to bridge the weight gap between worm affected and worm free lambs. An adjustment of 25% is made to provide for decline in growth rate as the season progresses. Where lambs are growing quickly or the gap small, the penalty is minimal, but large gaps and slow growth rates incur substantial penalties.

Prices for prime lamb and other slaughter lamb are based on average South Australian saleyard lamb prices (cents/kg carcase weight) for January-May 2009 (MLA, 2009). For calculations, the categories of heavy and trade lamb are combined to represent prime lambs (average value 427 c/kg) and those of light lamb, Merino lamb and restocker/feeder lamb combined to represent slaughter lamb (average value 379 c/kg). Whilst there are some anomalies in the latter grouping (Merino lamb values are 32 c/kg below the average and restocker/feeder lambs 47 c/kg above the average) it is the only mechanism of estimating direct loss to the non-prime lamb component, because they are not separated at point of slaughter in ABARE statistics. The final penalty values are the product of numbers of slaughtered animals across regions and average per capita losses derived from the research results. In our calculations we have conservatively provided for proportional loss in the Merino and light lamb market categories, based on prime lamb data. The true penalty is probably greater than the estimate provided.

The differential ($1.53/kg carcase weight) between the value for hogget carcases compared with prime lamb carcases is derived from the average market values at the South Australian Livestock Exchange (Dublin, SA) and Naracoorte, SA sales on 19/5/09 (Stock Journal 21/5/09). Based on a 22 kg carcase the differential is $33.65/head.

Generally, deaths of ewes or of lambs due to worms were uncommon, although on one property it was a regular event with 5-7% deaths in aged Merino ewes mated to meat breed sires. With increased demand, hence rising prices for good quality young crossbred ewes, old Merino ewes in lamb are commonly traded or retained on properties as producers seek cheaper options for immediately getting lambs on ground. A conservative estimate of 0.5% losses of ewes plus associated loss of lambs across the industry is not unreasonable. A nominal value of $35/ewe and $15 for a single lamb is assigned to this loss.

In AHW.045 no clear effect of worm infections on ewe reproductive efficiency were found in 3 trials, each including 179-252 first cross ewes (see appendices 10 and 11). In one trial over 568 days control ewes were significantly lighter than suppressive treated ewes for 14 months, including a difference of around 3 kg at mating and over 5 kg at lamb marking. There were indications of increased (5-15%) lamb mortality in control ewes, but insufficient numbers to demonstrate significant differences. Therefore impaired fertility or other theoretical measures of reduced reproductive efficiency have not been included in estimations of industry loss due to worms.

In the current studies lambs received an average of 1.7 drenches and ewes 2.5 drenches (or 0-1 drenches and one sustained release capsule, the cost of which is similar to 2.5 drenches). For ease of calculation a dose of macrocyclic lactone sufficient for 50 kg at 22 cents/dose is used as standard (S. Love, NSW DPI, personal communication, 2009) and 15 cents/head for own labour plus 20 cents/head for own labour crutching of ewes, once. Adjustments are made to calculations for ewes assuming a lambing rate of 120 per cent, and for slaughtered lambs other than prime lambs to reflect only one drench for a 25 kg animal.

Estimation of the additional impost of production lost due to ineffective drenches is problematic. For moxidectin and abamectin it is minimal, as both remain highly effective on most farms. The same applies to benzimidazole/levamisole combinations, especially with added napthalophos. Ivermectin is now failing against *Ostertagia* on most properties; nevertheless many generic products are still widely used. Slow release capsules (containing benzimidazole, levamisole or both actives) have highly variable efficacies across seasons, even on the same property. They are probably used by around 20% of prime lamb producers for worm control in ewes but are not widely administered to lambs. Efficacy rates vary from 0-100%. A best guess is that a 5% addition to the losses ascribed to retention of prime lambs for finishing to market weights and to weight gain failure in marketed lambs adequately represents this source of loss.

### 4.5.3 Impacts on production

Summarised growth rates and related data for each trial are given in Table 4. Full tabulations of the results are presented in Appendix 19. It is important to remember that the baseline is the regular farm worm management program including drenching, with its associated costs over and above the penalties estimated. Two trials are excluded from consideration/comparison of economic effects (14: completely ineffective treatment; 16: clinical ryegrass toxicosis), leaving 26 records.

Average growth rates in ‘worm free’ lambs ranged from 64 – 290 g/day. On 8 occasions (30%) growth rates in ‘worm free’ lambs failed to exceed 150 g/day, representing important nutritional constraints to prime lamb production that need to be addressed independently of worm effects. Growth rates only equalled or exceeded 225 g/day on 10 occasions (38%).

Although small property numbers limit comparison of production systems, growth rates >200 g/day were measured in 12 trials on dryland and 2 on irrigated pasture and <200 g/day in 12 trials on irrigated pasture and 1 each on dryland and dryland/irrigated pasture. There was a significant slowing in growth rates on all pastures, from around the end of November onwards, depending on season.

Table 4 Lamb growth rates (g/day) and reductions[#&] and penalties due to worms. South-east South Australian and South-west Victorian properties

| Trial Number | 26 | 17 | 18 | 20 | 27 | 28 | 10 | 4 | 9 | 15 | 3 | 1 | 14 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Days | 56 | 91 | 89 | 63 | 99 | 84 | 96 | 57 | 90 | 105 | 157 | 118 | 76 | 174 |
| "Worm Free" rate | 290 | 280 | 272 | 271 | 268 | 264 | 258 | 238 | 226 | 225 | 218 | 204 | 187 | 179 |
| "Normal Practice" rate | 276 | 275 | 272 | 282 | 265 | 275 | 247 | 219 | 198 | 218 | 222 | 191 | 187 | 181 |
| Difference(g/day) | 14 | 5 | 0 | -11 | 3 | -11 | 11 | 19 | 28 | 7 | -4 | 13 | 0 | -2 |
| Reduction(%) | 4.8 | 1.8 | 0 | N/A | 1.1 | N/A | 4.3 | 8.0 | 12.4 | 3.1 | N/A | 6.4 | 0 | N/A |
| Growth penalty (kg) | 0.75 | 0.54 | 0 | 0 | 0.63 | 0 | 1.07 | 1.59 | 1.94 | 0.82 | 0 | 1.92 | N/A | 0 |
| Final period growth rate[†] | 276 | 258 | 230 | 282 | 160 | 181 | 203 | 174 | 107 | 150 | 121 | 68 | 187 | 252 |
| Days held over[‡] | 3 | 2 | 0 | N/A | 5 | N/A | 6 | 11 | 22 | 7 | N/A | 28 | N/A | N/A |
| Scourworm burden (X 100) | 66 | 35 | 76 | 13 | 33 | 30 | 130 | 32 | 260 | N/A | 53 | 305 | N/A | 87 |
| Larval exposure (rounded X 10) | 118 | 74 | 33 | 23 | 76 | 181 | 152 | 13 | 237 | 79 | 38 | 52 | N/A | 61 |

| Trial Number | 21 | 5 | 6 | 2 | 22 | 7 | 19 | 23 | 13 | 24 | 25 | 8 | 16 | 11 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Days** | 125 | 76 | 207 | 166 | 106 | 84 | 97 | 92 | 97 | 99 | 127 | 117 | 153 | 107 |
| **"Worm Free" rate** | 176 | 172 | 162 | 157 | 156 | 147 | 136 | 136 | 132 | 130 | 122 | 112 | 88 | 64 |
| **"Normal Practice" rate** | 169 | 138 | 147 | 140 | 153 | 122 | 113 | 135 | 137 | 122 | 120 | 102 | 85 | 67 |
| **Difference (g/day)** | 7 | 34 | 15 | 17 | 3 | 25 | 23 | 1 | -5 | 8 | 2 | 10 | 3 | -3 |
| **Reduction (%)** | 4.0 | 19.8 | 9.3 | 10.8 | 1.9 | 17.0 | 16.9 | 0.7 | N/A | 6.2 | 1.6 | 8.9 | 3.4 | N/A |
| **Growth penalty (kg)** | 1.29 | 2.62 | 2.91 | 2.92 | 0.32 | 1.73 | 2.30 | 0.22 | 0 | 0.87 | 0.06 | 1.52 | N/A | 0 |
| **Final period growth rate[†]** | 183 | 81 | 109 | 136 | 122 | 42 | 113 | 94 | 230 | 63 | 93 | 13[δ] | 66 | 65 |
| **Days held over[‡]** | 8 | 40 | 33 | 27 | 3 | 51 | 26 | 3 | N/A | 17 | 1 | 116 | N/A | N/A |
| **Scourworm burden (X 100)** | 6 | 58 | 55 | 95 | 32 | 164 | 117 | 82 | 47 | 17 | 17 | 25 | N/A | 10 |
| **Larval exposure (rounded X 10)** | N/A | 104 | 566 | 26 | 15 | 66 | 299 | 15 | 37 | 0 | 4 | 13 | N/A | 31 |

[#] Light grey highlighted areas (values in red) had statistically significant weight differences at the end of the growth study.
[&] Trials 14 and 16 are excluded from calculations of economic impact - see text.
[†] Growth rate of control (normal management) lambs in the last measured interval (average 49 days) of the trial.
[‡] Adjusted value. See text for assumptions.
[δ] Growth seriously compromised due to drought, but declined dramatically due to worms in March 2007.

Control lambs subject to the normal farm worm control program grew slower than suppressive treated lambs in 10 trials (38%) leading to significant differences in final weights 57-207 days later (average difference 2.16 kg, range 1.52 - 2.92 kg). In these trials lamb growth was reduced by 6.4%-19.8% (average 12.2%) by worms, with daily penalties ranging from 10-34 g/day (average 19 g/day). Penalties due to worms increased in severity with time. For daily penalties of 10 g or more, the percentage penalty during the last weighing interval (10-107 days, average 49 days) doubled (22%) relative to that across the duration of the trial.

Control lambs in 9 trials (35%) lost production relative to suppressive treated lambs without significant differences developing in final weights (average difference 0.66 kg, range 0.06 – 1.29 kg). Nonetheless, based on a 46% dressing percentage there was an average loss across these trials of 0.3 kg/carcase at market. In 7 (27%) trials there was no difference between treatments, in other words there was an effective worm control program in place on the property.

On-farm worm infections in this study do not appear to be as consistently severe as those suggested from an abattoir survey by Besier, Ryan and Bath (2004) in Western Australia. The elevated worm egg counts reported by them may be ascribed, at least in part, to concentration of eggs in faeces due to water and feed deprivation imposed through the processes of marketing, transport and holding in lairage prior to slaughter. In AHW.045 it was found that in 14 groups of 4-5 lambs with an initial average worm egg count greater than 100 epg the count increased by an average of 196% (range 0%.- 413%) following transport and holding for slaughter for a day or longer. Average worm egg counts in flocks of lambs repeatedly measured on-farm in South Australia and Victoria only exceeded 400 epg twice in 28 growth studies over 4 years. Nevertheless, in Western Australia some very high faecal egg counts and scouring suggested that numerous abattoir consignments were heavily infected with worms. Notwithstanding that the Western Australian survey preferentially targeted scouring lines of sheep, it is illogical that a serious prime lamb producer would consign heavily worm-infected, scouring lambs to market. It is also unreasonable to conclude that Western Australian prime lamb producers are poorer managers than their eastern counterparts. A plausible explanation for the severe infections in Western Australia, rarely seen under field conditions in South-eastern Australia, might be that their sampled population included greater representation from unfinished lightweight lambs (≤16 kg carcase weight) or Merino lambs as compared to prime lambs. We have not examined the marketing environment in Western Australia at the time (2002/2003) of the survey, however in recent years, many lambs in these categories enter as culls due to ongoing reduction of overall sheep numbers, particularly Merinos, or as underweight Crossbreed lines, discarded because insufficient feed has been available to finish them to trade specifications. Farmers have had early warning in recent severe seasons that finishing of all of their available lambs to specifications was likely to be difficult. Although slaughter lamb production has increased nationally in recent years, a response to drought has been that only 64% of lambs have been sold as prime lambs, well below longer term pre-drought averages of almost 90%. For example, in 2005-2006 only 37% of lambs nationally were sold as prime lambs (Hooper, 2008). Under such circumstances many farmers would be justified in not investing in drenching, for it would bring little or no financial reward in classes of lambs destined to be significantly penalised by market prices. Producers are being constantly reminded, for very good reasons, of the need to reduce drenching, and this practical circumstance provides ample justification for compliance.

### 4.5.4 Estimation of losses

#### 4.5.4.1 Maturity of lambs through to hoggets

Only 1 out of 26 lamb growouts (3.8%) was potentially penalised by retention through to hogget class. Lambs were eventually finished at 11 months of age by feeding with silage. However, the penalty across the industry is generally more widespread in that it applies to that proportion of the flock (the third or fourth draft for market) which becomes increasingly difficult to finish with time. A realistic, conservative estimate is an across-industry penalty of 3-4%, so the above value (3.6%) is used in calculations. To the above penalty is invariably added the cost of crutching, shearing, and an additional drench. Contract shearing less value of wool is assumed to leave a residual loss of

$1.50/head;, contract crutching is valued at $0.5/head (J Cooper, Farm Manager, Struan Research Centre, personal communication, 2009) and drenching at $1.04/head (Sackett et al., 2006).

Penalty = 3.8% X $33.65 X prime lamb numbers (SA, Riverina, Victoria) = $9.36 million
Plus crutching, shearing and drenching (264,000 lambs) = $0.73 million
Total estimated loss = $10.09 million

#### 4.5.4.2 Retention of prime lambs for finishing to market weights

The average (adjusted) retention time on 38% of occasions was 5.6 weeks (Table 4, values in red).
Penalty = 38% X prime lamb numbers X $1.60 X 5.6 = $24.92 million

#### 4.5.4.3 Failure to gain weight in non-retained prime lambs

The average loss in 35% of trials was 0.66 kg liveweight equating to 0.3 kg carcase weight at 46% dressing percentage.
Penalty = 35% X prime lamb numbers X 0.3 X $4.27 = $3.28 million

#### 4.5.4.4 Growth penalties in other slaughter lambs

These are estimated for total slaughter lambs other than prime lambs using the same values as for prime lambs, except that the overall average carcase loss for 19 trials was used (because there was no separate penalty for retention on property), and the market price was adjusted for this class of lambs (see above). The average loss for 73% of trials was 1.37 kg liveweight, equating to 0.63 kg carcase weight at 46% dressing percentage.
Penalty = 73% x slaughter lamb (other than prime lamb) numbers X 0.63 x $3.79 = $6.99 million.

#### 4.5.4.5 Deaths of ewes and their lambs

Assuming only single lambs.
Penalty = 0.5% X total lamb numbers X $50 = $2.83 million

#### 4.5.4.6 Drenching and crutching costs

Conservatively estimated using own labour and generic ML drench at 22 cents/dose.
Cost $M for prime lambs = 7.321 X ([1.7 X 0.22] + [1.7 X 0.15]) = $4.60 million
Cost $M for other slaughter lambs = 4.009 X ([1.0 X 0.11] + [1.0 X 0.15]) = $1.04 million
Cost $M for ewes = 11.33 X 100/120 X ([2.5 X 0.22] + [2.5 X 0.15] + [1 X 0.20]) = $10.62 million
Total cost = $16.26 million

#### 4.5.4.7 Drench failure

Penalty = 5% of $M(23.61 + 3.56) = $1.36 million

The estimated total combined annual impact of internal parasites on the prime lamb industry in South Australia, Victoria and Riverina region of New South Wales is $65.73 million, comprised of $49.47 million (74%) direct losses and $16.26 million (26%) in costs associated with routine control programs. Given that New South Wales (Riverina), Victoria, and South Australia collectively account for 57% and 54% of total national gross receipts for slaughter lamb and prime lamb respectively (ABARE, 2009) the national loss is probably greater than the $90.6 million modelled by Sackett *et al*. (2006) using an entirely different approach to that in AHW.045. Indeed, in northern New South Wales the component of loss from mortalities of ewes (and therefore their lambs at foot) due to *Haemonchus contortus*, is likely to be higher than that from scourworms in southern and eastern Australia, inflating national projections further. Another issue is that the Sackett *et al*. (2006) figures apply to a national prime lamb population of 10.65 million, whereas the ABARE (2009) figures used in the current calculations identify 13.87 million prime lambs and 6.68 million other slaughter lambs nationally. Allowing for these baseline differences the two estimates are therefore remarkably comparable and both reflect the serious impost on the industry of internal parasite infections. AHW 045 has identified that important contributors to the loss are contamination of pastures in autumn, failure to provide sufficient high quality pasture on clean weaning paddocks in spring, decline of pasture quality, including irrigated pasture, in summer and the use of drenches with suboptimal efficacy.

## 4.6 The influence of levels of pasture contamination

Average monthly levels of worm contamination on pasture over the period of each lamb grow-out were compared with growth penalties incurred in control lambs. Despite, as expected, large variations across sites and within sites at different observation points there were also clear trends. Where growth was impaired by ≥10 g/day (11 records) the average level of pasture contamination was 1500 larvae/kg DM, compared with 460 larvae/kg DM (15 records) where growth was impaired by <10 g/day (rounded averages). For 4 records where growth was impaired ≥20 g/day the average worm contamination on pasture was 1760 larvae/kg DM. The usefulness of this information lies in a broad interpretation that (provided nutrition is adequate) sustained levels of larvae on pasture of around 1000 larvae/kg DM are unlikely to be associated with economic loss, but levels greater than 1500 larvae/kg DM may well be.

## 4.7 The relationship of total worm burdens to productivity

Rounded average adult scourworm (*Trichostrongylus*, including *T. axei*, plus *Ostertagia*) burdens in 3-4 representative control lambs were compared against growth performance of their respective control groups across 25 trials. Again, large variations are to be expected because of environmental influences, particularly nutrition, and individual host susceptibility leading to skew distribution of worm burdens, especially relevant to small samples. However, the results again provide useful general information on the impact of scourworms under field conditions. Where flock growth was impaired by ≥10 g/day (11 records) causing an average penalty in weight gain of 10.8%, the average scourworm burden was 11,900 worms, compared with 3,850 worms (14 records) where growth was impaired by <10 g/day with an average penalty in weight gain (where penalties were actually measured) of 2.5%. For 6 records where growth was impaired by ≥15 g/day worm burdens averaged 12,100 with an average 14.2% penalty in flock growth. It can be broadly inferred that scourworm burdens below 5,000 will not incur a significant economic penalty but once they exceed 10,000-15,000, the balance between worm burden, other stresses and quality of nutrition becomes critical in determining the economic outcome.

# 5 Success in Achieving Objectives

## 5.1 Review all data relevant to parasitism in prime lamb production

To the best of our knowledge all of the important research results over the last 70 years relevant to internal parasitism in sheep in southern Australia have been captured in a readily accessible database for use by researchers, veterinarians, producers and educationists. The database was sourced electronically and manually from publications in refereed Australian and international journals, books or book chapters, theses in departmental and personal libraries and university collections, conference abstracts, occasional publications and government reports. This was published in CD format by Meat and Livestock Australia Ltd in 2007 (Carmichael, IH, Barton, DP and Low, SG 2007). Overall, 940 publications and communications are cited. Most references have been abstracted or annotated. Key publications usually have detailed summaries to emphasise important issues. According to the specificity of the subject material each reference has been allocated up to several search keywords from a list of 165 options. References of particular or potential relevance to prime lamb production in southern Australia have been allocated the keyword “prime lamb relevant”, even where the report does not specifically include reference to prime lambs. There are 293 (31% of the total) references in this category. Most relate to work generated under the patronage of the wool industry, but which assume relevance in the changing dimensions and importance of the prime lamb industry. The database can also be searched according to individual author. The database is not intended to be an exhaustive chronological assemblage of references on parasitism in sheep in Australia. For the greater part it comprises references with practical application, including field epidemiology of the important worms, their influence on the host, control and impact of parasitism, economic effects and environmental, genetic and management factors influencing these. More than 300 copies have been distributed to libraries, educational institutions, research laboratories, veterinarians and rural scientists.

In addition, an extensive original raw data set of detailed, parasitological studies conducted at Kybybolite Research Station in South Australia over several years in the 1980’s has been fully electronically recorded and collated, ready for statistical analysis and publication. The work is probably the most comprehensive study of its type ever conducted in Australia and remains relevant because it will serve to standardise the baseline of economic penalties and parasitological outcomes from a variety of management interventions. Analysis has been delayed pending the availability of a suitably experienced statistician. However, funds from AHW. 045 have been budgeted for this purpose and it is expected to proceed early in 2010.

## 5.2 Demonstrate a range of decision making tools

It was undertaken to demonstrate and promote to meat sheep producers that monitoring of levels of nematode larvae on pasture and regular flock sampling provide invaluable tools to underpin on-farm decisions such as preparation and provision of safe pastures for stock, removal of stock from pastures before parasites reached dangerous levels, and planning of strategic worm control. These measurements were regularly made in at least one production system on every trial site and on some sites provided the cornerstone of expansive research activities over 3-4 years. Their use, however, was not confined to planning or the accumulation of epidemiological data, but played a major role in critical review of the outcomes of the worm control programs established (or as amended) by the producers. In many cases the measurements provided confidence that worm control was not amiss, but in others, confirmed either that the enterprise was threatened or that a perceived threat was not present. In addition, pasture larval counts provided security for producers to follow their individual worm control programs in the knowledge that serious potential problems would be detected early. Other tests such as larval differentiations from faecal cultures were used to clarify real or imagined dangers (is Barber's Pole Worm present?; what worms are resistant to drenches?) and explain differences across properties, or those associated with seasonal phenomena. In short, the measurements that were made provided a broad perspective for viewing the interface between internal parasites, the pasture, and superimposed management influences.

It was not the intention that every producer would adopt all of the tests they were made aware of, however, the more productive ones were already regularly using worm egg counts to inform decisions and the less productive ones were generally unsure of their potential application. A general impression is that initially they were regarded as a tool solely for determining the need to drench, rather than the subtle nuance of confirming when not to drench. Through constant repetition and example the benefits of measuring or estimating internal parasitism using a combination of means have been widely demonstrated. The magnitude of this effort deserves specific attention.

AHW.045 involved an extremely large suite of on-farm studies. SARDI research staff and collaborating producers often worked closely, collecting samples or handling animals. Producers were very receptive to feedback of results, because many of them had participated in their generation and had a growing understanding of their implications. Excluding extension activities and collections at Struan Research Centre, and counting parties as single visits, there were 621 separate visits to private farms, which meant that farmers were constantly reminded of the research presence and objectives. Many thousands of results were generated in the laboratory. Those of specific interest or timeliness were faxed to relevant producers as written reports with formal or informal comments, depending upon circumstances. Phone discussions often arose from these reports. They served as personal updates of progress, notification of new trends, or as warnings, and all were based upon information from the tools currently in use. Altogether 505 such reports were despatched. It is strongly believed that the above processes have widely demonstrated the tools to industry at farm level. This has continued at producer forums and seminars, where a fixed agenda item is discussion of the value and application of tools to measure levels of parasitism, and awareness of the factors that contribute to the results.

## 5.3 Define the epidemiological basis of worm control, particularly in the newer systems

At the start of AHW.045 there was virtually no information available concerning parasitism in sheep grazing flood irrigated pastures or on any of the newer production systems such as pivot irrigation. In fact, the literature review revealed that no thorough, systematic studies had been conducted on internal parasites in prime lambs in any Australian environment. A major research thrust of AHW. 045, therefore, was to address this deficiency and provide fundamental epidemiological information for a range of production systems to support realistic recommendations for worm control. The wide variety of properties included in the project reflected this requirement.

Short term measurements and observations of the interactions between environment, management and the dynamics of sheep worms are useful starting points, but cannot substitute for data accumulated over whole seasons. Data sets covering consecutive seasons, reflecting highly variable weather patterns, have even greater value. It is in this regard that the information generated in AHW.045 is unique, for it comprehensively encompasses all of the major production systems over several seasons. Epidemiological information was systematically collected under commercial operating conditions on 8 properties over periods of 20-53 months (average 36 months).

Shorter term information was collected over 4-15 months (average 9 months) on 8 properties, although the value of some of it was influenced by drought conditions.

In addition to short term observations of lambs on cereal and other finishing crops, the epidemiological basis of worm control across the entire flock has been defined on the following production bases, relevant either to the generation of sucker lambs or weaners for market: Dryland lucerne; Flood irrigation perennial rygegrass/clover; Pivot or sprinkle irrigation; Dryland perennial grasses/clover.

Summarised information can be found in Section 4.4 of this report (see p.80). Greater detail is given in the individual research summaries for each of the properties (Sections 4.3.1-4.3.16). Detailed information and extensive discussions of the implications of the research results in relationship to management and weather patterns are located in the relevant appendices, especially numbers 3, 5, 6, 7, 11, 12 and 13.

## 5.4 Determine the economic impact of internal parasitism on prime lamb production and efficiency of routine management strategies

The objective has been successfully achieved. Through a series of 28 growth production trials the economic impact of internal parasitism on prime lamb production has been determined at a micro-level (on farm). Using the assumption that the farms are representative of broad industry practices and productivity, the economic loss at a macro- level for the regional southern prime lamb industry has also been estimated. In addition, broad estimates have been made of the dangers from increasing levels of pasture contamination with worms and the relationship of total worm burdens to prime lamb growth rates.

As expected, producers were all aware of the threat from worms and each had a control program in place. Some programs were effective and sustainable and others clearly not. Broadly categorised, around 27% of trials reflected highly effective worm control programs, 35% indicated relatively minor losses that could be addressed through management adjustments and 38% showed significant losses requiring full re-evaluation of the existing worm control program. The measurements of worm egg counts, pasture larval counts, drench efficacies etc. provided the basis for interpretation of deficiencies or strengths in programs. Key findings are summarised for each growth trial in the relevant appendix and consolidated in Section 4.4 of the final report.

It is estimated that the total combined annual impact of internal parasites on the prime lamb industry in South Australia, Victoria and Riverina region of New South Wales is $65.73 million, comprised of $49.47 million (74%) direct losses and $16.26 million (26%) in costs associated with routine control programs. Extrapolation to a national level gives a greater loss than that modelled by Sackett *et al*. (2006) using an entirely different approach to that in AHW.045; however both estimates are comparable and reflect the serious impost on the industry of internal parasite infections.

## 5.5 Producer education

The extension activities of AHW.045 have been highly successful and will continue to expand and develop. They evolved from initial creation of awareness that the project was underway, with recruitment of interest (2004/2005); proceeded through steady release of emerging research findings and clarification of issues of immediate concern, towards direct engagement with producer groups to consolidate knowledge (2006/2007); and have moved to industry meetings and workshops with specific study groups, from which changes in practice will emerge (2008/2009). Continued contributions to new scientific information will appear as publications are completed.

Activities associated with project awareness and knowledge transfer to the end of May 2009, are detailed in Appendix 20. They can be broadly classified into:
Extension and advertising articles and publications (10).
Press articles (14, plus 3 radio interviews).
Field extension activities and educational forums (29).
Scientific publications and conference proceedings (8).

Development of project awareness in the farming community was started very early in the life of AHW. 045, initially utilising the expertise and networks of Elke Hocking (SA Sheep Industries Development Consultant), Heidi Schuster (PIRSA Rural Solutions, editor of SA Lamb Journal) and Dr Leo Cummins, Sheep Production Consultant, Victoria. The project was promoted through producer meetings, and articles and fliers were widely distributed in South Australia and South-western Victoria to farmers, industry affiliates and government officers. Farmer producer groups and properties on which early research efforts were concentrated were identified through extensive consultation in 2004/2005.

Once the first research results began to emerge a formal programme was established to grow awareness and transfer knowledge and confidence to industry. To secure participation of the recognised facilitation and communication strengths of Kate Dowler (SA Sheep Industries Development Consultant), formal presentation of early findings was initially linked in 2006 with the SheepPlus® program, which already had considerable local success and publicity in other areas of management and production improvement. A much wider extension network than that provided by the original producer groups was achieved from this linkage, and it remained highly relevant. Although SheepPlus® was nominally targeted at wool producers, many enterprises included both production systems, so there was considerable commonality in the key messages delivered.

Workshops were held in 4 key regions on the properties of producers participating in the research. The theme in the initial process was ”Worm Control”, within the discipline of “Developing Livestock Health and Welfare Strategies”, with sub-themes “Determining a health strategy for livestock”, ”Diagnosis and implementing a program”, and “Monitoring of the program”. The objectives of AHW.045 were presented and mechanisms of the on-farm research explained, with updates on life cycles, local epidemiology, diagnostic and monitoring tests, principles and realities of drench resistance, and system failure. Worked examples illustrating problems and solutions were derived from local and regional research results generated in AHW.045. Individual research records from the host farmer and other producers were systematically analysed and compared, to differentiate, partition and quantify constraints to production due to nutritional, parasitic and other influences. Practical demonstrations of worms, larvae and eggs and post mortem material were provided. A paddock walk examined the environment, so producers could relate to the conditions where lamb production or parasite data were actually generated and the structure and management of the flocks. The groups were able to hone skills in estimation of food on offer and subjective evaluations of pasture quality (to be confirmed later by FeedTest), examine dung contamination and consider seasonal influences current and historical, on the paddock. Importantly, they were also able to communicate independently on problem areas with the facilitators. The SARDI parasitological team were usually all present, resulting in considerable interaction and establishment of linkages with many producers. Assistance in interpreting nutritional influences was provided by Tim Prance

(Senior Consultant, Pastures and Grazing Systems). Kate Dowler facilitated meetings, ensured extensive publicity and organised follow up sessions. The first workshop/field day was run near Bordertown, SA in June 2006 and was followed by others near Portland Victoria, Kingston SA and Victor Harbor SA. There was intensive publicity of the project with widespread rural press articles (circulation >25,000) highlighting the relevance of its achievements. Comprehensive field days have become annual events at Portland and Kingston (research only finished at Kingston in August 2008 and observations are still continuing at Portland). The messages have also been formally delivered to other producer study groups at Wirrega (near Keith), Biscuit Flat (near Robe) and Walker Flat (near Bordertown). Rural resellers, pharmaceutical company representatives and government officers have attended most of the larger meetings.

In addition, livestock and veterinary staff of PIRSA have been formally updated of developments in 2005, 2007 and 2009, and other specialist interest groups (eg., Sheepvention, South East Irrigators Association and Meat Elites/Super Whites) have requested information and offered involvement and support. For example, arising from the meeting with Meat Elite in March 2007, its members directly assisted in the establishment of new research activities at “Derrymore” (Kalangadoo) and “Ramillies” (Penola). A strong presence has been maintained at relevant regional field days and events, eg., MLA Meat for Profit and Lucindale Field Days.

Now that the consolidated scientific findings from 4 years of field research are assuming a broad regional perspective, an encouraging recent development is direct interest and involvement of rural resellers (Castec Rural and Ancare) and groups dedicated to adoption and application of the latest technologies, such as the South-east Prime Livestock Achievers, with whom a specialist seminar on scientific outcomes of AHW was held in May 2009. Success with the Ancare – sponsored seminar in Naracoorte in May 2009 has prompted planning by Castec Rural of another more comprehensive forum with producer groups in September 2009. It is therefore clear that the extension of research results to industry, leading to change in practices on-farm, is gaining momentum and is likely to continue strongly over the next few years.

To date, presentation of research results to professional bodies has been restricted to the CD literature database and 7 presentations and publications for scientific meetings. The research has generated a great deal of new economic and scientific information on prime lamb production in Southern Australia and there will be numerous publications arising from this over the next couple of years.

# 6 Impact on Meat and Livestock Industry – now & in five years time

## 6.1 Current impact

An overriding feature of the research environment from 2004-2007 was drought, in many areas the worst on record, so this needs to be taken into account in considering industry performance. However, despite drought, many producers profitably produced commercial prime lambs whilst others failed to do so, even on irrigated pastures. Although the suite of growth trials was conducted on only 12 properties we believe from the broad scoping of the project and careful selection of sites that the results generated are reasonably representative of the regional prime lamb industry and that industry impact as defined is an accurate reflection of the important issues.

The average growth rate of 'worm free' lambs in the upper 25% of trials exceeded 270 g/day. All were dryland production systems. However, in 30% of trials growth rates in 'worm free' lambs failed to exceed 150 g/day and in a further 22% of trials lambs grew at less than 200 g/day, identifying important nutritional constraints to efficient prime lamb production. Growth rates only equalled or exceeded 225 g/day on 10 occasions (38%). Some worm control programs were effective and sustainable and others clearly not. Broadly categorised, around 27% of trials reflected highly effective worm control programs, 35% indicated relatively minor losses that could be addressed through management adjustments and 38% showed significant losses requiring full re-evaluation of the existing worm control program. The significant economic penalties for the latter 2 categories have been estimated at farm and industry level.

Some production results are very disappointing at an industry level. There was wide discrepancy in the success that producers had in raising prime lambs, and disturbing signs that investment in irrigation, even in the absence of marked worm effects, did not always produce anticipated returns in production. Limited data point to a significant decline in quality of irrigated perennial ryegrass pastures in summer. Although slower gains are not necessarily undesirable if they are cost effective, there may well be justification for review of the wisdom of finishing lambs past January on grass-based irrigated pastures in this area. Based on measured growth rates of over 3000 individually identified prime lambs in 28 trials under diverse environmental influences it is clear that there is huge scope for genetic improvement in growth rates in the national flock.

The research, which is the first of its type in Australia, has quantified the magnitude of a serious source of loss to prime lamb production in southern Australia and identified the main areas of farm management requiring attention for profitable prime lamb production. As such it has fulfilled an important initial objective in providing the first information of this type on which commercial production can be realistically benchmarked. In addition it has provided a comprehensive data base of literature for use by researchers, livestock advisors and veterinarians.

## 6.2 Impact in 5 years time

The research provides a platform of unique information for knowledge transfer at various levels to a wide audience of prime lamb producers. Across the various trials and by means of regular measurement of epidemiological parameters, 118 key findings affecting the impact of worm infections in prime lambs were identified. Findings varied greatly between properties, from season to season, and within properties, even in the same season. However, some were repetitive and common to several production systems. Those most likely to influence prime lamb production across a range of systems have been consolidated under 19 themes containing 46 'check points'. These have been the cornerstone of expanding transfer of information to producers and other industry sectors from 2005-2009.

The information lends itself to segmentation ranging from core management and epidemiological principles illustrated by on-farm examples, to advanced outcomes, interactions between factors, testing of hypotheses and development of options etc. A practical example, is that in May 2009, broad sections of the findings were presented to clients of Castec Rural and on the following day, in another forum, complex issues arising from interpretation of field findings were workshopped with the Prime Lamb Achievers group.

Changes in farming practice have already been initiated on several properties. Examples of this are the discontinuation of capsule use and of drenching of lambs at both marking and weaning, provision of 'guaranteed clean pasture' for lambing, introduction of a summer drench with monitoring of flocks as a decision tool, timely preparation of weaning paddocks, and seeking of professional advice to underpin management decisions. One large producer has started investigations into creating 'worm free' paddocks on 2 properties. The research does not provide specific novel technologies, but fundamental new ways of defining and addressing an existing, often variable, problem, especially pertinent to vulnerable producers shifting from wool to a broader meat sheep production base. The most efficient practices for optimum worm control and the penalties/wastage from failure to adopt these are defined. The momentum of on-farm practice change over forthcoming years can be increased, but has several hurdles to cross, not least of which is transfer of a fixation on drenching programmes, which are bound to eventually fail, to emphasis on integrated programs, which AHW.045 has clearly demonstrated, on several properties, to be effective.

The popular press is not the most useful medium for this process in that articles are usually not well read, rarely responded to by producers and are generally subject to editorial simplification or enforced brevity to the point of irrelevance. In addition, although drench resistance is not trivial, it receives hugely disproportionate emphasis compared with other more important and easily addressed issues (nutrition and paddock cleanliness) facing the industry. The titles of many of the press articles promoting AHW. 045 bear testimony to this assertion. Arguably, the best method to increase uptake is the proven medium of "Tips and Tools" which are professionally produced, well respected and informative. A substantial publication including greater experimental and financial discussion may be appropriate for more advanced producers, private and government advisors and rural resellers. In addition, information will also now be forthcoming in professional journals.

A rough estimate is that around 38% of systems have significant worm control problems. Identification, broadly, of the enterprises that fall into this category, and concentration of knowledge transfer efforts on this area, would seem to be a reasonable place to start. If 40% of this group could be convinced within 5 years that change is useful, even if it only involves a move to the second cadre where losses are minor, the effective annual saving (including reduction of 0.5 drenches for lambs annually) for the Riverina, South Australia and Victoria would be $16.64 million. It is not unrealistic to expect that with the information available this can be aspired to. Advancement at a similar rate of the second cadre to the first, where they only have fixed costs of drenching and crutching to consider, is equally achievable and would conservatively provide another $2.65 million in savings. These figures do not include consideration of reduction in the cost of worm control in ewes, which undoubtedly would go hand in hand with advances in lamb worm control.

# 7 Conclusions and Recommendations

Much of the research was conducted in years of drought, in many areas the worst on record. This needs to be taken into account in considering overall industry performance. It is reasonable to assume, however, that drought had little or no impact on either the epidemiology of worms or growth of lambs on irrigated pasture, but negatively influenced lamb growth, worm numbers and probably also the balance of worm species on dryland systems. For this reason the long term impact of worms on the industry may be underestimated. Nevertheless, the scale of the loss and epidemiological principles are based on realistic measurement s and observations over 4 years on many diverse sites. Although the suite of growth trials was conducted on only 12 properties, we believe from the broad scoping of the project and careful selection of sites that the results generated are reasonably representative of the regional prime lamb industry and that industry impact as defined is an accurate reflection of the important issues. Several items of 'unfinished business' and issues arising from the research remain to be addressed to round off the project.

## 7.1 Determination of the epidemiology and impact on production of internal parasites in prime lambs in Tasmania

Overall issues facing the industry in Tasmania are similar to those on mainland South-eastern Australia in that there is a trend for increased output of prime lambs from irrigated pastures in response to high lamb prices, plus efforts to find alternative options for use of irrigation infrastructure due to loss of poppy contracts. However, although there is compelling anecdotal evidence that *Trichostrongylus vitrinus* is a dominant and serious parasite, there is no published epidemiological information for Tasmania on which to base worm control programs for any sheep enterprise. The situation there may be sufficiently different, such that broad recommendations from the current program are inapplicable. Research should be continued in Tasmania to determine the seasonal transmission pattern, industry impact and optimum strategies for management of *T.vitrinus* under irrigation systems, and in the districts where it is problematic without irrigation. There is considerable government and private support in Tasmania for this activity and it formed one of the recommendations of mid-term review of AHW.045 by Dr D Sackett. SARDI Parasitology will submit a proposal to MLA for conduct of this research in collaboration with DPIWE and industry consultants.

## 7.2 "Tips and Tools" and regional workshops

A proven mechanism to promote producer uptake is a series of "Tips and Tools" addressing the important facets of worm management in prime lamb flocks, and including the range of production systems. These MLA publications are professionally produced, well respected, easy to understand and informative. They can be used to create wide producer awareness of achievable production objectives. It is believed that producer testimonials could be used to promote regional whole-day dedicated thematic workshop launches of "Tips and Tools". The term 'dedicated' is important, for uptake of many of the ideas requires certain changes in embedded thought processes, which cannot be achieved with other distractions.

## 7.3 Update and publication of the literature database in hard and electronic copies

The compact disc containing the literature database published by MLA includes 904 references and is current to June 2007. The compact disc could benefit from an update of references and review of its 'user friendliness'. Amendment of the CD would not be an expensive exercise. It was originally distributed with little fanfare and seems to have missed the attention of many who would find it a useful reference, hence a re-launch of a new amended publication would be timely.

An updated hardcopy of the literature data base using a Word document of the original Endnote file as described in one of the publications relating to this project (Carmichael *et al*., 2006) can be relatively easily produced. Several scientists including Drs B Besier and S Williams (and D Sackett in his review of AHW. 045) have agreed that this would be a useful document that could be widely used and portable.

## 7.4 Producer guide

A substantial, high quality Producer Guide, including experimental and financial discussion or case histories would be timely and appropriate for advanced producers, private and government advisors, rural resellers and libraries.

## 7.5 Analysis of perennial ryegrass pasture samples

Lamb growth on irrigated perennial ryegrass pastures on several research sites was disappointing. Although the quality of the pastures was clearly a factor, it was strongly suspected that the problems were associated with varying expressions of subclinical perennial ryegrass toxicity (endophyte ill thrift). In the 2006/2007 prime lamb growth study at Struan Research Centre, samples of urine, ryegrass tillers and plants were collected for measurements of alkaloid concentrations. The aim was to determine the proportion of infected perennial ryegrass plants in the pasture, track fluctuations in alkaloid concentration in the ryegrass plants, confirm uptake by the lambs via urine analysis, and relate findings to lamb growth rates. Due to budget constraints, the additional testing on urine and pasture samples has not yet been done and they remain frozen until funds become available. A proposal will be prepared for MLA funding consideration.

## 7.6 Incorporation of references and a section on prime lambs written for "Wormboss"

Although the target audience of the reference database is primarily scientists and academics as well as those involved in extension of sheep health and production it could be made available electronically on the web, possibly as a link to "Wormboss" to ensure that as many people as possible have access to it. In addition, the basics of the producer guide could be distilled for a specific section on prime lambs in "Wormboss", filling a significant deficiency in that area.

## 7.7 Statistical analysis of background data from Kybybolite Research Station

An extensive original raw data set of detailed, parasitological studies conducted at Kybbolite Research Station in South Australia over several years in the 1980's has been fully electronically recorded and collated as part of activities in AHW.045, ready for statistical analysis and publication. The work is probably the most comprehensive study of its type ever conducted in Australia and remains relevant because it will serve to standardise the baseline of economic penalties and parasitological outcomes from a variety of management interventions. It could never be repeated because the end point of one field experimental group was death of lambs due to parasitic disease. Analysis has been delayed pending the availability of a suitably experienced statistician. However, the last of the funds from AHW.045 have been budgeted for this purpose and analysis is expected to proceed early in 2010. Once this is done the results will be prepared as an addendum to AHW.045 and published.

## 7.8 Publication of results

Once the final report has been approved a series of scientific publications will be prepared as a priority of the SARDI Parasitology Group.

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# 9 Appendices

There are 20 appendices, covering several hundred pages. Nearly all of them are independent, indexed, research reference documents in their own right, that have been prepared for discussion with individual producers and groups. Their inclusion in this document would make it physically unwieldy and extremely difficult to transfer electronically. Appendices are therefore listed below and assembled in a folder to accompany the final report (AHW.045 Parasite Control in Southern Prime Lamb Production Systems – Part 2 of Final Report – Appendices 1-20).

| | |
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| **Appendix 1** | Protocol for conduct of prime lamb grow out studies (2 pp.) |
| **Appendix 2** | Protocol for conduct of maiden replacement ewe studies (2 pp.) |
| **Appendix 3** | J Andre “Ceres”, Kangaroo Inn, SA (10 pp., 6 Tables, 2 Fig.) |
| **Appendix 4** | M Pocock “Panlatinga”, Willalooka, SA (8 pp., 5 Tables) |
| **Appendix 5** | B Gerhardy “Woodhaven Park”, Willalooka, SA (17 pp., 12 Tables) |
| **Appendix 6** | S Graetz “Amaroo”, Willalooka, SA (14 pp., 11 Tables) |
| **Appendix 7** | K Staude “Kenwyn”, Cannawigara, SA (23 pp., 20 Tables, 3 Fig.) |
| **Appendix 8** | C Smith “Grasslands Estate”, Branxholme, Vic. (7 pp., 6 Tables) |
| **Appendix 9** | B Ryan “Tent Rock”, Delamere, SA (16 pp., 11 Tables) |
| **Appendix 10** | K Joseph “Churinga”, Tyrendarra, Vic. (15 pp., 15 Tables, 1 Fig.) |
| **Appendix 11** | S Malcolm “West Lakes”, Portland, Vic. (64 pp., Sect. I-VII, 31 Tables, 12 Fig.) |
| **Appendix 12** | Struan Research Centre, Naracoorte, SA (30 pp., 22 Tables, 3 Fig.) |
| **Appendix 13** | W Hancock “Fairways”, Reedy Creek, SA (71 pp., 51 Tables, 12 Fig.) |
| **Appendix 14** | A Lyon “Glenisla”, Reedy Creek”, SA (37 pp., 20 Tables) |
| **Appendix 15** | D & P Will “Paldaro”, Bangham, SA (15 pp., 10 Tables, 1 Fig) |
| **Appendix 16** | J Mossop, “Ramillies”, Penola, SA (7 pp., 7 Tables) |
| **Appendix 17** | T Heysen, “Derrymore”, Kalangadoo, SA (7 pp., 6 Tables) |
| **Appendix 18** | D Price, “Majardah”, Glencoe, SA (5 pp., 3 Tables) |
| **Appendix 19** | Tabulations of lamb growth rates in 28 trials (4 pp., 4 Tables) |
| **Appendix 20** | Project Awareness and Knowledge Transfer Activities (6 pp., 4 Tables) |