CONCEPT TO IMPACT

The story of the SHEEP CRC 2001–2019

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Australian Government
Department of Industry, Innovation and Science
Business Cooperative Research Centres Program

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IMPACT

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EDITORS: Michael Thomson & James Rowe

GRAPHIC DESIGN: Rhonda Brooks

PRODUCTION: Janelle Holzberger & Polly Ward

CONTRIBUTING AUTHORS: James Rowe, Michael Thomson, Brian Clancy, Ian Johnsson, Ken Geenty, Deborah Maxwell, Neal Fogarty, Julius van der Werf, Lu Hogan, David Tester, Trevor Mahar, Henry Wang, Graham Gardner, Forbes Brien, Lewis Kahn, David Pethick, Peter Sommerville, Amanda Doughty, Gordon Refshauge, David Hopkins, Chris Shands, Kevin Atkins, Brown Besier, and Daniel Brown.

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For the
Australian Sheep Industry

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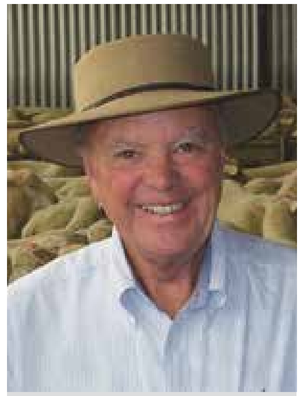
FOREWORD



John Keniry

I am very pleased to have been invited to contribute the Foreword to a book that records the outcomes of the three Cooperative Research Centres (CRCs) that have focussed on improving the Australian sheep industry over the past two decades. My comments come from the perspective of one who throughout those two decades has been a sheep producer, an active participant in the CRC program, and a research administrator. Looking back, it has been a very exciting two decades of innovation and change for the Australian sheep industry, and this book will prove to be a seminal record of significant and lasting progress for the industry.

The story that the book records begins in the 1990s with two unrelated decisions by the Australian Government.

The first was the decision to establish the CRC Program. This program provided seven-year funding for research activities that were focussed on delivering commercial outcomes for Australian industries. Recipients of CRC funding were required to match or better the funding sought from the Australian Government, which ensured a clear industry perspective for research outcomes. The seven-year funding commitment encouraged focus on big opportunities which required significant advances in science, and the opportunity for teams of scientists to make a long-term commitment to those areas of need identified by industry. As would be expected for a country that 'rode on the sheep's back', one of the first CRCs to be established was the CRC for Premium Quality Wool in 1993.

The second unrelated decision of the Australian Government was its decision to discontinue the Reserve Price Scheme for wool, a scheme which saw the wool industry borrow funds from the government to underwrite wool prices well above market value, and for the industry to accumulate a huge debt, and a stockpile of wool approximating two years' production. As wool prices tumbled, an unsuccessful bid to renew funding for a 'Wool CRC' was made, the proponents being advised, somewhat to their surprise, that the CRC program might be more receptive to a proposal that focussed on sheep, rather than just wool.

And so there emerged in 2000 a successful bid to establish the CRC for the Australian Sheep Industry. This CRC had wide-ranging research programs that covered many aspects of sheep production and management. Perhaps its greatest achievement was to promote the concept that sheep could be managed individually, rather than in mobs. Based on individual electronic identification using ear tags, this innovation drove many advances in sheep handling equipment, in classing prior to shearing, and in many other areas of sheep management.

Encouraged by the enthusiastic adoption of new technology by progressive sheep producers, a second successful CRC bid was made in 2007, under the title 'CRC for Sheep Industry Innovation'. This CRC represented a very clear statement from industry research organisations, and indeed industry peak bodies, that the focus was on the sheep, not just on the wool or the meat. The CRC established programs that focussed on genetics, meat quality, wool comfort, production management and extension.

A major innovation was the establishment of the Information Nucleus Flock (INF) which became the envy of the animal genetics world. The INF integrated the emerging science of genomics into conventional breeding and offered great potential to incorporate so-called 'hard-to-measure' traits into breeding programs and to increase the rate of genetic gain. The sheep industry was on a roll, with growing international demand for quality lamb and mutton offering valuable production options for sheep producers.

Upon conclusion of the CRC for Sheep Industry Innovation, a successful bid was made for an extension of CRC funding until 2019. By this time, innovation was taken for granted and the body was known throughout the industry as the Sheep CRC. Research and commercialisation continued on genomics, meat quality and individual management, with renewed emphasis on sheep wellbeing and the application of big data to forecasting and management systems.

As a close observer, indeed a participant for part of the 20-year journey, it has been an exciting ride. This book chronicles the transformation of the sheep industry on its journey through developments in electronics, biotechnology and data management, as well as recognising the efforts of those who played a major part in effecting the transformation.

As in any innovation space, there have been those who have not seen the potential benefits, or for their own reasons have preferred and argued for the status quo. This has applied in particular to the move away from mob-based management and the use of genomic information to supplement conventional methods of sheep selection in breeding programs. But it is difficult to resist the introduction of new technology and, as the author Stewart Brand said: "Once a new technology rolls over you, if you're not part of the steamroller, you're part of the road".

And finally, I want to pay a tribute to the Commonwealth CRC Program and to all the staff of the CRCs that have made this progress possible. The CRC funding, in long-term tranches, has allowed ambitious research directions to be set, and delivered, with stable multidisciplinary teams of eminent scientists and senior management personnel, led by James Rowe who has been tireless in driving the work and the vision for the duration of the program. I doubt that the outcomes could have been achieved by a succession of short-term, competitive grants that are becoming increasingly common in the research funding environment. As you read this book, you will develop a feel for the dedicated people within the three CRCs and from supporting organisations who have made the progress possible.

DR JOHN KENIRY AM

Chair of Sheep CRC Board (2007–2014)

CONCEPT

The gross value of the Australian sheep industry for 2019 was more than $8.6 billion. In real terms this represents an increase of almost 50% compared to when the Sheep CRC started in 2001, despite the national flock decreasing in size by more than 40% over this period. On a 'per sheep' basis the real gross value of production had increased 2.6-fold.

While many factors contributed to this economic boom for the Australian sheep industry, it is safe to say that it hasn't happened by chance. Transformational industry change like this requires vision, clear objectives, a well thought out strategy and adaptable tactics to deliver real impact.

From the beginning it was evident that if the Sheep CRC was to play a leading role in the transformation of the Australian sheep industry, it would need to develop a clear and simple concept that would guide every step that was to follow.

The central theme of the Concept Paper, drafted during the planning phase for the first term of the Sheep CRC in 1999–2000, was as follows:

> **'Understanding consumer preferences and delivering the technological advances needed to enable producers and industry to profit from delivering wool and meat products that consistently surpassed these specifications.'**

This 'concept' was then echoed in the CRC's first Strategic Plan, published in 2003, which defined the CRC's mission as ensuring that the Australian sheep industry had the technology and know-how to deliver, in a profitable and sustainable manner, products highly desired by domestic and export customers.

The Chairman of the first CRC Board, The Rt. Hon. Ian Sinclair AC, cemented the importance of this 'concept' in the strategic framework used to guide investment decisions in an integrated research program covering genetics, parasitology and nutrition, as well as meat and wool science, with a view to delivering technical advances for commercial implementation. He also emphasised that for the 'concept' to deliver real and lasting impact, the Strategic Plan must have education and training as integral components, in order to ensure that the sheep supply chain had the appropriate skills and know-how to use new technologies effectively.

What follows is the story of the circumstances which led to the creation of the Sheep CRC and how, by building on this simple yet powerful 'concept', the CRC has acted with determination to help change industry for the better.

Concept to Impact is the story of the Sheep CRC.

1 LIFE BEFORE THE SHEEP CRC

Today's sheep industry is dramatically different from that of the 1980s when lamb was fetching only $15 and the wool industry was riding high supported by the Reserve Price Scheme.

The 1980s were terrible times for Australia's lamb industry. Saleyard prices were so low they covered only 50% of a lamb producer's costs (see Figure 1.1). Nothing was going right for the lamb producer despite an annual, but highly seasonal, turnoff of 15–17 million lambs. Exports accounted for only 15% of production.

And the product itself had marketing and consumer problems. It was seasonal, which in itself created volatile prices. But more importantly lamb was regarded as 'too fatty' and the cuts were small. Most lamb was sold as chops and legs, and supermarkets specialised in packaged sides.

Specialist lamb producers were angry, and solving the problems was not going to be easy without sufficient funding. The then 20 cents per head slaughter levy was raising a meagre $3.2 million — not much for covering industry regulation, marketing and research.

Matters came to a head in 1983, perhaps lamb's low point. This was the year that for the first time producers, researchers, processors and the Australian Meat and Livestock Corporation (AMLC) met for a national conference at Orange NSW. They declared enough was enough and began to plot lamb's revival. Those who attended the conference agree now that the Orange meeting and the following reforms, initiatives and events helped build today's vibrant lamb industry.

But the picture was very different for wool producers. The 1980s saw the wool price indicator soaring to 1000c/kg and the reserve price increase from 640c/kg to 870c/kg (see Figure 1.1). The attractive guaranteed price for wool ensured that wool production continued to grow and that prime lamb production remained a minor enterprise run alongside Merinos for wool, expanding grain and beef enterprises.

The good run for wool producers ended sharply with suspension of the reserve price in February 1991. This development had a profound effect on the sheep industry dynamics. In the 10 years following the collapse, the national flock plummeted from a peak of 174 million head in 1990 to less than 100 million. Some producers liquidated their flocks and opted for cropping. Others lifted their beef numbers while others saw opportunities in the prime lamb sector. The specialist wool producers who continued, changed their flock structure by selling wethers and building up ewe numbers.

In the lead up to the formation of the Sheep CRC, the wool and lamb industries were on very different trajectories, and their industry politics was to shape what followed in the new century.

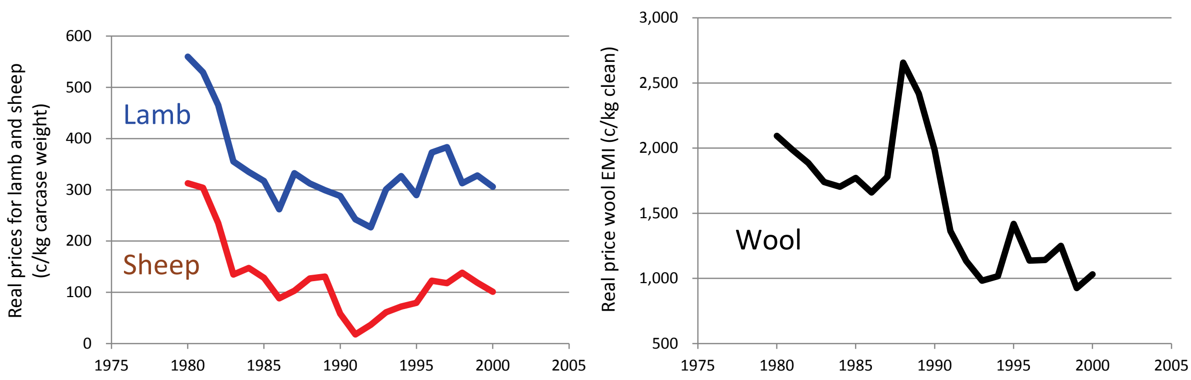


Figure 1.1: Real prices (adjusted to 2018-19) for lamb, sheep and wool (EMI) between 1980 and 2000 (source ABARES).

The changing dynamics of the prime lamb industry

In 1982, according to the Australian Bureau of Agricultural and Resource Economics and Sciences (ABARES), the average sale price was 105c/kg carcase, or $17 based on the year's carcase average of 16.9kg. It was depressing stuff.

In 2017, South Australian producer Gerald Martin recalled the frustration and anger and the huge amount of pressure on the leaders of farm organisations to do something. Gerald was one of the leaders appointed to the Sheepmeat Council of Australia, a commodity group of the new National Farmers Federation formed in 1979.

"Without money nothing is going to change," was the message he would tell producers.

In 1982, when the prime lamb industry was operating on miniscule industry funding of $3.2 million, the Sheepmeat Council of Australia supported the push for a further two cent slaughter levy, which was to be matched dollar for dollar by the Federal Government, to establish a Sheepmeat Market Development Fund to be administered by the Australian Meat and Livestock Corporation, chaired by Dick Austen.

"The two cents was meagre but at least it was a start," Gerald recalled.

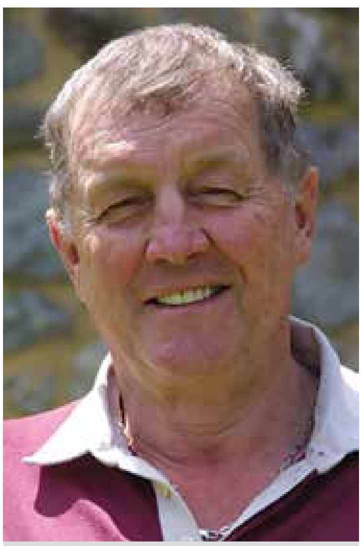
Gerald, who was appointed an inaugural member to the Market Development Fund Advisory Committee, said the 2 cent levy was enough to trigger sufficient funding for a range of projects and just a year later the Sheepmeat Council of Australia was successful in lobbying the Federal Primary Industries Minister, John Kerin, to lift the slaughter levy to 10 cents. This was despite the opposition of the processors, who believed they would be the ones to carry the additional impost.

It was the beginning of a period of extraordinary change in the way research was viewed and managed. By the late 1980s, collaborative approaches to RD&E co-investment between the meat and wool RDCs emerged, albeit in the field of pasture management research. Then

On-Farm R&D Manager in the Australian Meat and Livestock Research and Development Corporation (AMLRDC), Ian Johnsson, worked with David Conley, his equivalent in the Wool Research & Development Corporation (WRDC), and colleagues in the Dairy Research & Development Corporation (DRDC) to rationalise producer funding of pasture plant breeding programs by state departments and CSIRO. AMLRDC took lead responsibility for the perennial species lucerne, phalaris, and leucaena, DRDC for white clover and ryegrass, whilst WRDC focussed on subclover and medics. AMLC and WRDC also co-funded a number of animal health and weed bio-control projects of major concern to the sheep industry.

Then during the 1990s, the industry leadership pushed hard to move lamb away from a highly seasonal, low image, wool by-product of variable quality. The major political and economic change drivers, and the responding marketing and RD&E programs funded with producer levies are described in detail in the MLA publication *We love our lamb* (Michael Perry et al, 2012). But of particular relevance to the Sheep CRC research that followed a decade later were the foundation collaborative partnerships developed through a series of AMLRDC-instigated 'key programs'. This was the first attempt in southern Australia to adopt the staged project cycle process used by the World Bank to address large complex issues using a multi-disciplinary, multi-organisational program approach based on program logic.

The Prime Lamb Key Program was launched in 1990 and set an industry target of 'supplying 25,000 tonnes of lamb per annum to higher value markets (primarily USA, Japan and the local food restaurant sector) by 1994'. It was designed to support emerging market opportunities such as AMLC's Fresh Australian Range Lamb promotions in the USA. This required development and promotion of a new carcase specification, designated Large Lean Lamb (LLL) of 18–22 kg with fat score 2–3, which at that time was only met by a few percent of total lambs slaughtered. Producers were also actively discouraged to pursue these specifications by price penalties in the markets — this was due to the majority of heavy lambs being vastly overfat.



Gerald Martin, AMLC/AMLRDC Board Member and inaugural member of the Sheepmeat Market Development Fund established in 1982.

Four sub-programs were also created focussing on: genetics (LAMBPLAN ASBV validations and progeny testing of top rams); reproduction (AI using high ASBV rams); growth and production (cryptorchids; grain-finishing); and processing and supply chain development (to link the few producers interested in this specification with the few buyers willing to pay a premium). Under these sub-programs 18 research projects were contracted to State Departments of Agriculture in Victoria (Ron Harris), New South Wales (Bill O'Halloran), South Australia (Bruce Hancock), Tasmania and CSIRO, plus some private companies. The state governments committed significant research and extension personnel for field days and demonstrations combined with a concerted promotional campaign in the rural media.

Domestic criticism of the promotion of LLL carcases — which many domestic butchers and supermarkets considered too big for the traditional cuts demanded by traditional domestic consumers — led AMLC to launch the Trim Lamb promotional program in 1992. The 15 new cuts in the initial Trim Lamb product range were developed in response to consumer research finding lamb as unhealthy, 'old-fashioned' and poor value due to excessive fat and bone. The irony was that these boneless, minimal fat cuts were only profitable if derived from a LLL.

Some 13 of the 15 cuts benefited from the National Heart Foundation 'tick of approval' and AMLC registered Trim Lamb as a brand. Retailers were invited to apply for accreditation as licensed distributors, receiving extensive point-of-sale material and promotion through consumer competitions and award-winning television advertising. An estimated 70% of butchers eventually held licences to sell Trim Lamb.

KEY PROGRAMS DELIVER

An industry review in 1994 concluded that the Key Programs initiative had met its targets and created an environment for change in the lamb industry.

The success stimulated a strategic planning process, led by AMLC/AMLRDC Board member Gerald Martin, from which the first Lamb Industry Strategic Plan was launched in 1995, with a vision to achieve annual sales of $2 billion by the year 2000.

The seven critical success factors identified were:

1. Moving from a commodity focus;
2. Eliminating inconsistency of product and supply;
3. Improving communication along supply chains;
4. Establishing a quality assurance culture;
5. Value-based payment;
6. Education and training; and
7. Improving market information.

Maintaining the momentum

The Meat Research Corporation (MRC — in 1991 the AMLRDC changed its name) responded to the 1995 Lamb Industry Strategic Plan by funding an interim industry R&D program to December 1996 to maintain momentum and collaboration amongst RD&E organisations. The program focussed on quality assurance; traceback information and product development officers in each state; and linking producers with those processors/exporters wanting LLL year round. This impetus was led not only by the industry bodies, but by processor champions including Tatiara Meats, WAMMCO, Hillside Meats and Castricums.

It was at this time that MRC Program Manager, Ian Johnsson, and Laurie Thatcher, the Key Program Coordinator, initiated the Branded Lamb Alliance sub-program with input from Ashley Manners of Clover Meats, and AMLC managers who critiqued the business plans of a dozen companies interested in establishing branded lamb products. With the exception of Q Lamb, led by Peter Trefort in WA, few had considered how they would procure lambs meeting LLL specifications year round. Seven alliances received funding support, primarily through part-funding procurement officers to build supply, educate producers, and to promote the trial of elite genetics, forward contracts and finishing systems.

With growing overseas demand, the Lamb Consistency Key Program (1996–2001) had the objective to increase the consistency of supply and quality of lamb from specialist producers with a target of 500,000 LLL per month. The program also placed an increased emphasis on value-based marketing, quality assurance and best-practice production systems. This R&D investment program was incorporated into the structure of the newly formed Meat & Livestock Australia (MLA) in 1998 and provided an established collaborative R&D platform for the formation of the first Sheep Cooperative Research Centre in 2001.

Industry bodies change again

The creation of MLA came as a result of the next big change in the research funding model. The Federal Government decided to deregulate the AMLC and merge it with the commercially administered MRC in 1998.

South Australian lamb producer and Poll Dorset breeder Jim Martin was leading the Sheepmeat Council of Australia at the time and recalled the most pressing agenda item on the Howard Government's primary industries portfolio was to get rid of — or at least replace — the statutory agricultural authorities, such as the AMLC and the Australian Wool Research and Promotion (AWRAP) organisation, due to the bitter lessons learnt from the collapse of the wool Reserve Price Scheme.

"We want you to run and control your own marketing and research companies," Jim said in 2017, quoting the Minister for Primary Industries, John Anderson. "That provided a lot of challenges. What type of organisation do we want to run our marketing and research? What type of funding levies do we set?"

Ian Johnsson, AMLRDC/MRC Program Manager and member of the task force responsible for developing the 1995 Lamb Industry Strategic Plan.

The levies on sheepmeat and lamb were already a contentious issue between producers and processors, but the one concession that government would provide was to legislate for producer levies to fund their new industry companies.

A slaughter levy of 20 cents per lamb was already in play. Due to the fact that it was collected by processors, they believed they should have a say in how those levy proceeds, particularly marketing, should be expended by the MRC. The Sheepmeat Council of Australia and producers argued otherwise saying that the 20 cents was a cost built into the buyer's price to producers. John Anderson gave the producers a choice — either a statutory levy or a voluntary levy.

"The Minister was also emphatic the industry would have to consult widely among the industry's estimated 65,000 producers before any decision would be made," Jim said.

There was general agreement for a statutory levy because a voluntary levy simply wouldn't work. There was also agreement for an *ad valorem* transaction levy of 2 per cent up to a maximum of $1.50 for lambs and 20 cents for sheep — this was much more acceptable to Merino breeders who were still in the process or reducing numbers in the wake of the wool floor price crash.

The net effect at the time, with saleyard prices struggling to top $40, was to lift the slaughter levy equivalent from 30c to about 70–80 cents. That in turn generated additional funding to drive domestic programs such as the Sam Kekovich Australia Day television advertisement. It also opened the way for major international campaigns, with the development of the North American market under the Fresh Australian Range Lamb, which was a major breakthrough. US producers were struggling to supply the domestic market where annual per capita consumption was about 0.6kg. The program commenced in the Washington and Baltimore areas, and subsequently spread to Boston, and Vancouver and Montreal in Canada. Here was a market that would pay a premium price for packaged chilled lamb in gourmet cuts.

The North American market provided processors with the opportunity to re-invest in exports following the collapse of Australia's market share in the UK, when the latter joined the European Economic Community (EEC) in 1973. Both the US and Canadian markets have grown steadily since the first imports in 1989 and in 2016–17 the US imported 53,000 tonnes and Canada 7,000 tonnes accounting for 25 per cent of Australia's total lamb exports. Growth in the export market and strengthening of demand in the domestic market created a solid foundation for further development.

The processors go their own way

Another organisation created in the late 1990s, that was equally important to the establishment of the Sheep CRC a few years later, was the Australian Meat Processor Corporation (AMPC). Also formed in 1998, AMPC was slightly different to MLA in that the Memorandum of Understanding (MoU) signed with the Commonwealth set out that Federal funding would be aligned to voluntary meat processor contributions — a situation which continued until 2007 when AMPC's funding model was brought into line with other rural research and development corporations using a mandatory levy system.

Prior to the formation of AMPC, the MRC was allocating a proportion of its funding to post farm-gate activities. Under the new arrangements, AMPC — as well as the Live Exporter Corporation (Livecorp) — were able to manage their sector's levy funds and contract RD&E services from MLA, with the Red Meat Advisory Council (RMAC) set up to be custodian of the MoU between these parties and the Government.

The Government's policy agenda at the time was to minimise its involvement in industry affairs. While the changes did not go through without debate or disagreement, the processing sector supported the new arrangements as it gave them greater control of their own destiny. From 1999 to 2006, AMPC collected $13–$14 million a year in voluntary levies. This opened new opportunities for R&D collaboration that could identify ways of making onshore processing an attractive alternative to the growing live sheep export industry. There was also new interest in sheep processing with investment in plant and equipment for the larger carcases being produced for the US market.

Among the leading processing figures at the time was Roger Fletcher, whose rise to prominence in the 1990s was particularly influential in shaping what was to come when the Sheep

CRC was formed at the turn of the century. His integrated sheep processing plant at Dubbo included fellmongering and top making in order to add value to the wool component of the operation and complement the meat enterprise. The integrated approach was a logical fit with the proposed integration of R&D for meat and wool production in the new CRC.

Turbulent times for the wool industry in the 1990s

Meanwhile there were three key factors at play in the wool industry during the 1990s that had an influence on the Sheep CRC bid in 2000:

- The impact of the wool Reserve Price Scheme and its suspension in February 1991;
- Repeated restructuring of the wool industry during the 1990s; and
- The CRC for Premium Quality Wool operating between 1993 and 2000.

At the time that the wool reserve price scheme was suspended in 1991 there were 4.7 million bales of wool in the Australian Wool Corporation's stockpile. The size of the stockpile, combined with falling demand for wool and increasing competition from cotton and man-made fibres, contributed to a significant fall in wool prices and a major decline in sheep numbers. Dr Bob Richardson, who played a key role in the sale of the wool stockpile, reflected in an article published in the *Australian Financial Review* (July 1999), that while the sale of the stockpile was blamed for lower wool prices, this partially masked the reality of fundamental changes in the demand for wool associated with the rise of competitive fibres and productivity improvements in the cotton and synthetic fibre industries.

As significant as the decrease in the size of the Merino flock from 1991 was the change in its structure. It changed rapidly from having a high proportion of wool-producing wethers, to a focus on ewes and lambs. This shift in the balance between wool and meat production marked the start of the 'sheep' industry. Further to changing flock structure, rising prices for lamb and mutton during the 1990s helped to consolidate the importance of meat production as an essential component of the Australian sheep industry. The increased proportion of ewes in commercial flocks brought new management challenges and many questions about genetics and nutrition to support balanced wool and lamb enterprises. These were researchable issues ideal for a sheep industry R&D program.

During the decade from 1991 to 2001 the process of restructuring wool industry organisations was almost continuous. The first move, in 1991, was to create three new organisations to replace the Australian Wool Corporation that had overseen the Reserve Price Scheme. The Wool Realisation Commission was set up to manage the dispersal of the wool stock pile. A new look Australian Wool Corporation continued to manage core functions and a Wool Research and Development Corporation was established.

Two years later, in 1993, there was a further restructuring following the Garnaut Review that resulted in formation of the Australian Wool Research and Promotion Organisation replacing the Wool Research and Development Corporation. Then, in 1997, the Woolmark Company was formed as a subsidiary of the Australian Wool Research and Promotion Organisation.

Next was the Future Directions Taskforce, established in December 1998 by the Minister for Agriculture Fisheries and Forestry, Mark Vaile, and chaired by Ian McLachlan. The Taskforce was mandated to examine the competiveness of wool as a textile fibre, identifying options for increasing its profitability and recommending ways to improve the funding and administration of promotion and research functions. In September 1999 the Minister announced changes in response to the Taskforce findings. These included the introduction of the WoolPoll 2000 to give wool growers the opportunity of determining their preferences for services and associated wool tax arrangements. The result of the poll indicated producer support for a 2% levy on wool sales to support a services model.

Two groups were put in place to supervise the development of an appropriate model; the Woolgrowers Advisory Group and an Interim Advisory Board which established Australian Wool Services Ltd together with the Australian Wool Innovation company, a subsidiary organisation responsible for managing the wool levy funds and investing in research and development. The new companies commenced operation in 2001 with the goal of increased contestability and competition in the application of the wool levy. There was also the expectation that AWI would commercialise R&D and become self-funding.

The CRC for Premium Quality Wool

In parallel with the turmoil of lower prices and wool industry restructuring during the 1990s, the CRC for Premium Quality Wool provided important continuity for wool industry research and education. The Wool CRC was established with the goal of undertaking strategic research focussed on improving productivity and product quality and building an innovative education program.

The Wool CRC research programs focussed on genetic technologies, wool biology and methods for reducing the problem of low tensile strength in wool produced under variable seasonal conditions. While new knowledge on managing staple strength proved to be very useful for large sections of the sheep industry, a number of the genetic technologies involved cutting edge research on cloning and transgenic breeding that were difficult to convert to commercial industry outcomes.

The Wool CRC's education program was set up to create a national network involving four universities with lectures delivered via live video links and recorded for future use. The lecture material stored on video was further supported by electronic files of PowerPoint slides developed with lecture notes for presenters. The initiative was very successful while the lecturing positions at four universities were supported by the CRC, but lost momentum once these positions were no longer funded. The Australian Wool Education Trust (AWET) took over the education resources at the end of the Wool CRC and established the Woolwise program that continues today.

Although successful in a number of areas, the Wool CRC was not successful in its application for a second term. Feedback on the bid indicated that more industry support was needed for a successful application and there was also the perception that the proposed research program was not adequately focussed and placed too much emphasis on strategic rather than applied research.

The experience gained by the joint venture partners in the Wool CRC played a role in planning the application of the first Sheep CRC in 2000. It was, however, unfortunate that the positive support received from the Australian Wool Research and Promotion Organisation during the preparation of the bid was spectacularly withdrawn when the newly formed AWI was asked to confirm their commitment to the new CRC in 2001.

The role of new technologies

As well as the changing dynamics of the wool, lamb and sheepmeat industries there were a number of technical and scientific developments taking shape during the 1990s that helped to set the scene for an integrated sheep industry and a new CRC.

The role of quantitative genetics in transforming the lamb industry was well underway by the end of the 1980s and an important landmark was the launch of LAMBPLAN in 1989. At this stage Australian sheep breeding values (ASBVs) were provided for weight and fat. The 1990s saw increasing momentum in the use of quantitative genetics with the introduction of across-flock evaluation of Terminal sires in 1996 and the launch of Merino Genetic Services in 1998. The power of rapid and well-targeted genetic gain for prime lamb production was on the move.

Changes in the meat industry included reforms to the meat processing sector. Larger carcases and semi-automated processing technologies paved the way for further in-plant fabrication and a focus on a range of options for marketing individual cuts into numerous markets, domestically and overseas. As former *Weekly Times* sheep and wool editor Brian Clancy noted: "Turning a basic commodity of 'chops, legs and sides' into a range of gourmet cuts minus excessive fat was one of the industry's greatest achievements."

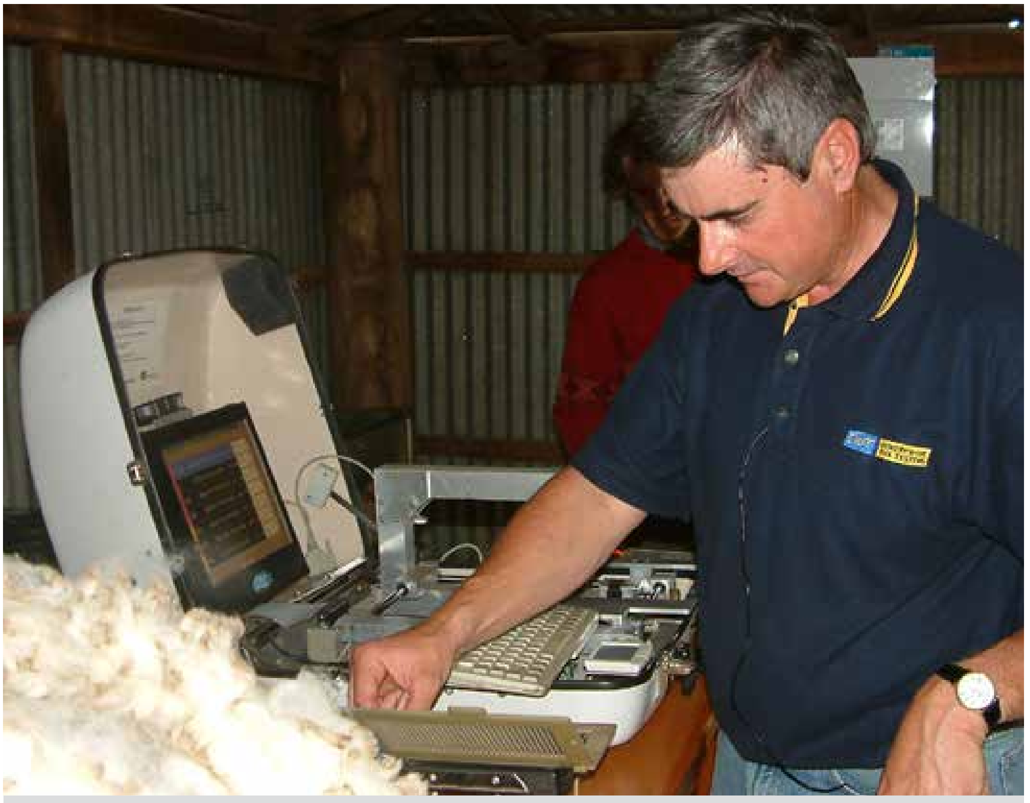
During the 1970s and '80s there was little if any incentive for abattoirs to upgrade their processing chains or even to invest in boning and packaging rooms. But things began to change rapidly for processors in the 1990s with the advent of the larger lean lamb and the opening up of export opportunities. Several of the big processors, with an eye to the US, invested not only in semi-automating their processing chains, but also in boning and packaging plants. The latter was also encouraged by a major shift in the domestic retailing of red meat.

The US market gave exporting processors their first real opportunity to offer producers some meaningful forward contract prices particularly for securing supplies during the late autumn and winter. Against these prices producers could assure those supplies by adjusting their lambing times and opting to feed lambs during those months of low supply.

In the wool industry a major development was new technology for measuring fibre diameter. The Laserscan and OFDA 100 instruments made it possible and cost-effective to measure this key aspect of wool quality on individual fleeces. The impact for ram breeding and for within-flock selection was significant. With attractive premiums paid for lower micron wools, use of the new measurement systems became widespread and resulted in a rapid reduction in the diameter of the Australian wool clip.

Advances in electronics meant improved quality and reduced cost of ultrasound pregnancy scanning, electronic weighing systems and eID technology. The possibility of pregnancy testing using ultra-sound scanning had been heavily researched in the 1980s and subsequently became commercially feasible in the mid-1990s with contractor rates around 50c per ewe. Electronic scales linked to eID readers and bar-code scanners introduced new opportunities for easier measurement and more accurate data collection for ram breeders and management of commercial flocks.

Structural changes to the grains industry were also flowing through to the way mixed farmers managed their sheep. When restrictions were removed in the 1980s from grain growers as to what types of wheat they could grow and how they could market them, there was a massive expansion in grain production, an expansion which was no doubt boosted by the collapse of the wool market in 1991. For livestock producers, including sheep producers, there developed an increased availability and diversity of feed grains that contributed to growing use of supplementary feeding for out of season lamb production.



The OFDA 100 instrument, operated by Paul Vallely, for in-shed measurement of wool fibre diameter.

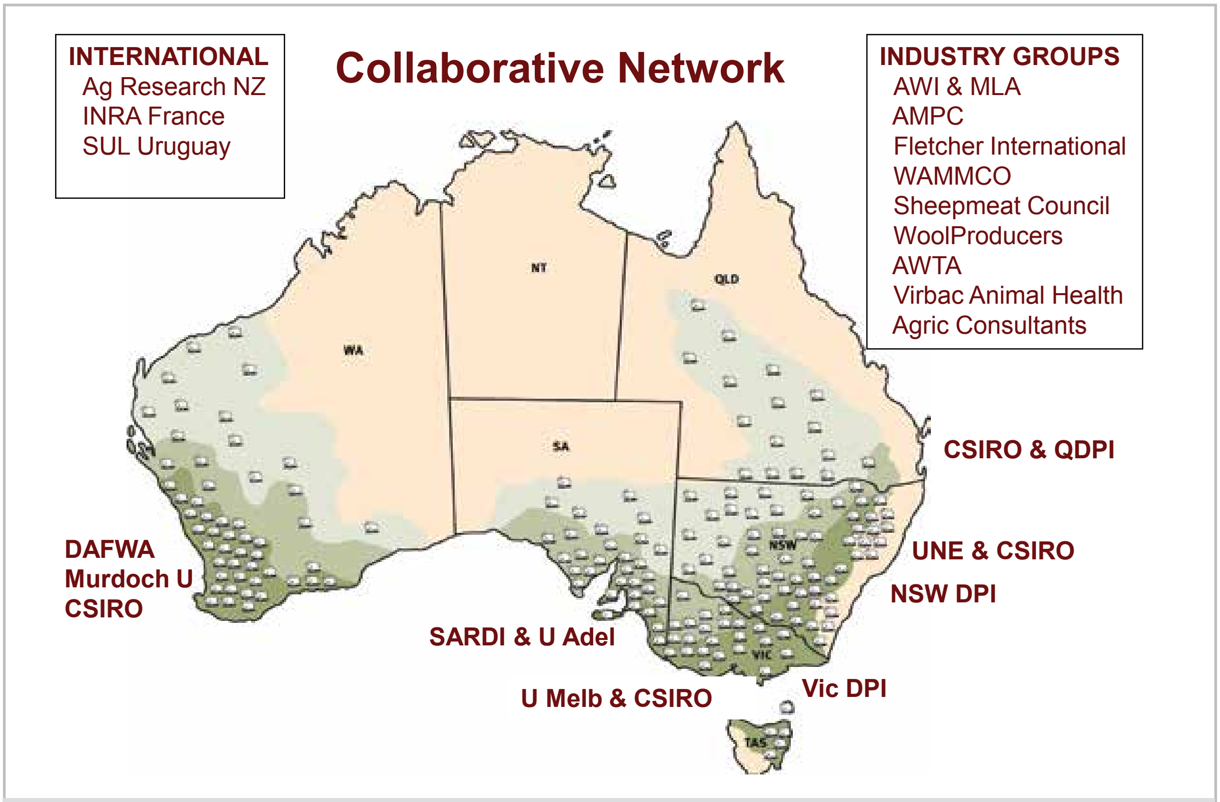


Figure 1.2: The collaborative network involved in planning and establishing the first sheep industry CRC.

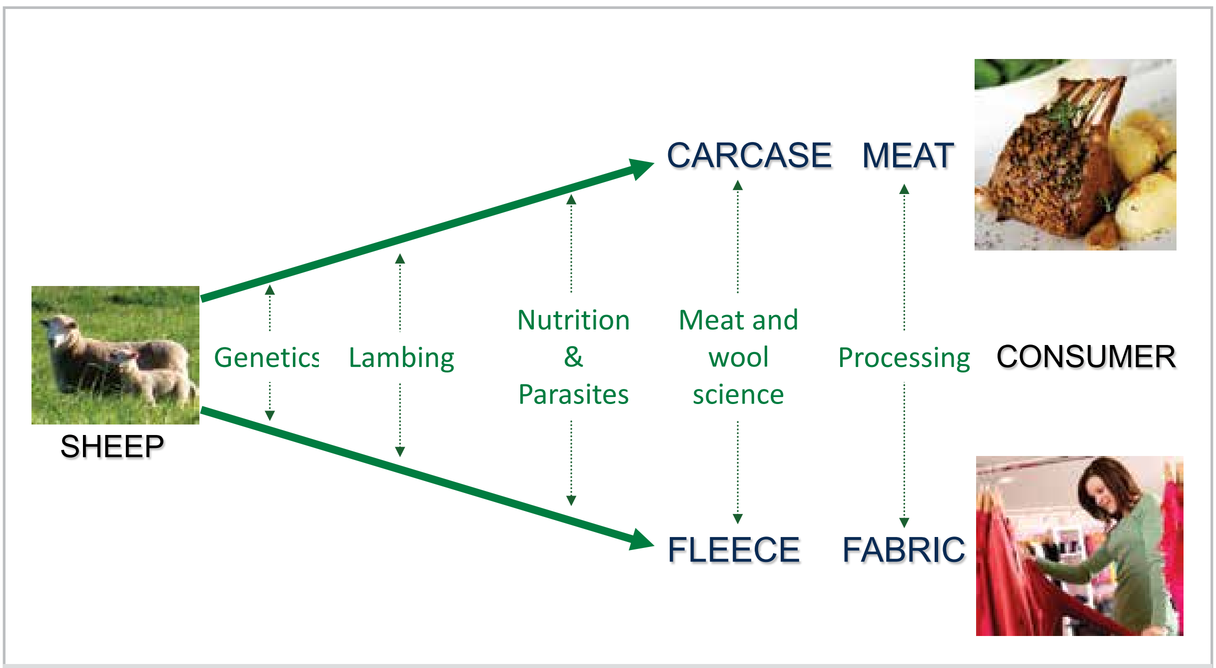


Figure 1.3: A diagram used in the interview with the Commonwealth CRC assessment panel when applying for Sheep CRC1. It explains the proposal for an integrated approach to sheep industry development.

Time for a Sheep CRC

The consolidation of the prime lamb industry, the tumultuous changes in the wool industry and the technical developments occurring during the 1990s, all combined to create the perfect opportunity for a CRC to take the Australian sheep industry forward. As seen in Figure 1.1 prices were starting to stabilise around 2000 but there was considerable room for improvement and there was an appetite for change and innovation.

Principles for planning a sheep industry CRC were based on the importance of developing a national collaboration with international links (see Figure 1.2) and designing research programs that focused on the integration of wool and meat production (see Figure 1.3). The importance of the consumer was emphasised as the corner stone of both the wool and sheepmeat value chains. Education and training were also identified as key factors required to build the capability for sustained industry transformation.

The journey commenced in 2001 with the establishment of the seven-year Australian Sheep Industry CRC based on its concept of understanding the end-user and providing industry the tools it needed to deliver to customer needs. It also presented its 'whole-of-sheep' approach to research, learning from the experience gained from the 'wool only' CRC for Premium Quality Wool and recognising the rapidly changing balance in the value of Australian wool, lamb and sheepmeat production.

The series of three iterations of the Sheep CRCs had the scale required to tackle complex problems and an adequate time frame for completing research, beyond the proof of concept stage, to the point of achieving utilisation and delivering lasting industry impact.

But as the chapters following demonstrate, getting the first Sheep CRC off the ground would have its fair share of challenges.

2 THE WISDOM OF HINDSIGHT

The Sheep Cooperative Research Centre almost died — twice — before it was even born.

The first near death experience came in 2000 when the bid team faced the Commonwealth's interview panel to pitch its plans. These plans for Australia's first Sheep Cooperative Research Centre (Sheep CRC) were started around December 1998, developed during 1999 and by mid-2000 a full submission had been prepared. But if it wasn't for Roger Fletcher's statement that the industry would find additional resources —"if necessary"— all of that planning may not have made it past the interview panel. However, it was just enough to get the bid over the line. Before the end of 2000 the Planning Committee had been informed that the bid was successful and that agreements should be drawn up for a June 2001 commencement.

Then, during the final stages of planning, around March 2001, the CRC had its second near-death experience following the Australian Wool Innovation (AWI) appointment of a new CEO, Col Dorber. The first time that most of the CRC team met Mr Dorber was when he attended the final planning meeting involving all prospective Sheep CRC Participants in March 2001. At that meeting Mr Dorber explained to the Participants that his view of the CRC model was that it had no merit and that AWI would not be investing any funds in the program. As AWI had been the major source of industry investment in the CRC proposal, this new and unexpected position was not well received by the other Participants.

CRC1 official launch February 2002 at UNE with L to R: Professor Ingrid Moses (UNE, Vice Chancellor), ProfessorJames Rowe (Sheep CRC CEO designate) and Minister Brendan Nelson.

It was clear that the proposal required major restructuring — and fast — if it was to survive.

With AWI's withdrawal from the CRC, the Commonwealth CRC Program gave the Sheep CRC six months to affect a restructure and prepare a new submission. This new plan was delivered in December 2001 and approved by the Commonwealth Secretariat.

With such a long and unusual conception and birth, it was only apt that the official launch into the world was equally odd, albeit far briefer. The new Sheep CRC agreement was signed early in 2002 and the new CRC launched by The Hon. Brendan Nelson, Minister for Education (and the Commonwealth CRC Program), in February 2002.

The launch was organised at very short notice when news arrived that Mr Nelson was visiting Armidale for a number of meetings at the University of New England (UNE). The Vice Chancellor generously allowed 10 minutes on the day's program for the launch of the new CRC, provided it could be done as the Minister moved between two locations on his planned itinerary. A lectern was set up next to the path outside the UNE library and a brief open-air ceremony was held. It must have left a lasting impression with the Minister as he subsequently took great interest in the progress of the Sheep CRC.

The long life that followed

After this inauspicious beginning, the Cooperative Research Centre (CRC) for Sheep Industry Innovation went on to have three terms, each with a different focus, but with important strands of research providing continuity throughout the 18-year period.

Sheep CRC1 (2001–2007), with its head office at CSIRO's Chiswick laboratories, focussed on understanding options for making the most of the dual sheep products – wool and meat. Until the start of the Sheep CRC, research had largely focussed on either wool or meat, rather than on the biological and business factors needed for profitable integrated sheep production systems. In addition to a wide range of basic research, Sheep CRC1 included a major initiative to develop technologies associated with electronic identification systems to facilitate improved management of the more complex production goals accounting for factors important to both wool and meat production.

Sheep CRC2 (2007–2014), based at UNE, was set up with the ambitious goal of transforming wool, meat and the sheep that produce them. Central to the second CRC was the Information Nucleus Program designed to enable the sophisticated use of genomic technologies in the Australian sheep industry, as well as creating a most valuable database for better understanding practically all aspects of sheep biology. Wool and meat programs focussed on understanding consumer requirements for high-value products and how to reliably deliver the required combination of characteristics needed to position both wool and meat as high-value niche products.

Sheep CRC3 (2014–19) was designed to continue the transformation commenced during CRC2 and deliver industry impact through making the possible practical. The three closely integrated programs covering enhanced sheep wellbeing, the quality-based meat value chain and faster affordable genetic gain have achieved the goal and delivered a strong finish and logical end point for the Sheep CRC's term.

Getting started — Sheep CRC 1

Planning for the first Sheep Cooperative Research Centre (Sheep CRC) started in early 1999 with a meeting at CSIRO's Chiswick Research Station attended by local sheep producers Hugh Sutherland and Hugh Nivison; Dennis Watson, providing advice based on his experience with the Beef CRC; and two researchers, Rob Woolaston, leader of CSIRO's Livestock Production section at the Chiswick laboratories, and James Rowe, Professor of Animal Science at UNE. The next step was to approach Ian Sinclair with the request that he chair the bid process. Another priority was to engage with a number of industry leaders, the peak bodies WoolProducers Australia and Sheepmeat Council of Australia (as it was known at the time) and the Rural Development Corporations, Meat & Livestock Australia (MLA), Australian Wool Innovation (AWI) and the Australian Meat Processor Corporation (AMPC).

Rob Woolaston agreed to take on the role of bid coordinator and during 1999 organised a number of planning meetings to structure the application and, by early 2000, the full proposal was submitted. The active engagement of industry in setting research priorities was a key selection criterion and the role of leading sheep producers and the Rural Development Corporations was hugely important. In particular, Roger Fletcher, representing AMPC and the broader sheep industry at the selection interview, was able to assure the selection panel that the new CRC would have all of the industry support required for its proposed activities. In December 2000 we were informed that the bid was successful and that agreements should be drawn up — but as mentioned above, there were still some issues ahead.

The meeting of all Participants convened in early 2001 was intended to fine-tune the program and confirm the commitment of all parties prior to drawing up the program agreements. The proposed contribution of Australian Wool Innovation (AWI) to the CRC bid had been subject to final approval following appointment of a new managing director — history now records that Mr Dorber's (AWI) decision not to support the CRC left the proposal requiring a major restructure.

James Rowe, The Right Honourable Ian Sinclair & Roger Fletcher.

Then, during the six months that the Commonwealth CRC Program gave the Sheep CRC to affect a restructure and prepare a new submission, there was a further setback for the new CRC. Rob Woolaston withdrew from the role of CEO designate to take up the position of Deputy Chief of CSIRO's Division of Animal Production. It was at this stage that James Rowe was asked by the Participants to prepare a revised program and secure industry support to fill the gap created by AWI's departure.

Important new industry support for the bid came from Fletcher International Exports, Elders, WoolProducers Australia and AWTA's Education Trust. CSIRO also made a significant commitment to fund the position of CEO for the seven-year term of the CRC. A revised plan was delivered in December 2001, approved by the Commonwealth Secretariat, and the Sheep CRC was underway.

The leadership and guidance provided by Ian Sinclair during the difficult planning and establishment phases was invaluable and made a major contribution to the successful outcome. Ian also had the skills and experience to ensure that the large representative Board functioned effectively and that Participant organisations maintained their commitment to the program.

A feature during early years of the CRC was the position of 'Visitor', with the role of advising the Board and providing liaison between the CRC and the Commonwealth. John Vercoe was appointed as 'Visitor' to the Sheep CRC and his CRC experience was valuable in the early stages of establishing the CRC and assisting with the formal Second Year Review by the Commonwealth. The Review provided a good opportunity to vary the Commonwealth Agreement to again include AWI as a new Participant, following Mr Dorber's infamous departure. The restructure and additional resources allowed the CRC to place more emphasis on wool research, undergraduate education and individual animal management. With the sudden death of John Vercoe in 2005, Rob Woolaston re-joined the CRC team in the position of 'Visitor'.

Progression to CRC2

There were major changes between CRC1 and CRC2 in terms of the structure of the organisation and the focus of the research program.

CRC2 was established in 2007 with 20 organisations, including MLA, AWI, AMPC, most state departments of primary industry, two universities and several private sector companies with interests in the sheep industry. The number increased to 21 when Deakin University joined the CRC in 2009.

An important requirement, stipulated by the Commonwealth CRC Program Committee, was that CRCs established during the 2006 Round needed to be incorporated entities with skills-based Boards. Moving from the representative Board in CRC1 to an independent skills-based Board was a major step for many of the Participant organisations. The process for setting up the Participants Agreement and Constitution to reflect these changes was therefore quite complex and time consuming, to ensure that the interests of all Participants were adequately protected. Despite the cost and time involved in establishing the new entity most organisations agreed that the end result was worth the effort.

Dr John Keniry AM was appointed Chair of the new Board and he brought to the position an excellent balance of experience in research, corporate governance, the CRC Program and sheep production. The smaller, skills-based Board helped to provide good focus on delivering against agreed outcomes and less emphasis on interests of individual Participants. The incorporated structure also helped to streamline the execution of agreements and strategic decisions.

After an initial meeting of potential Participants to plan an application for a second Sheep CRC, John Gibson was engaged to develop a detailed proposal. John's concept of an Information Nucleus Program, developed with input from Julius van der Werf and Rob Banks, formed an excellent core for an integrated portfolio covering genetics, genomics, meat quality, improved sheep husbandry and wool production. There was also good alignment between the wool and meat programs focussing on understanding the consumer requirements for next-to-skin comfort and eating quality respectively.

An important aspect of CRC2 was the strong emphasis on industry engagement, adoption and commercialisation. The coordinated approach involving media releases, industry events, training programs, development of the lamb supply chain group and engagement with industry networks proved to be highly effective.

The application process for CRC2 progressed very smoothly from submission of the proposal in March 2006 to interview in September and start up in July 2007. The strong industry support included MLA and AWI, each committing to contribute $10 million cash over the seven-year program and AMPC contributing $0.7 million. The Commonwealth contributed $35.5 million to make this one of the largest CRCs at that time.

The launch of CRC2 was far more formal than for CRC1. Then Deputy Prime Minister, The Hon. John Anderson, officially launched the new Sheep CRC in UNE's Wright Lecture theatre with all of the CRC Board, Executive and a number of Participants and industry leaders in attendance.

Although there was a very productive collaboration during CRC2 there were still several periods of turbulence. These included the withdrawal of CSIRO from a range of activities due to their very high funding requirements; concerns from AWI about the CRC's investment in genetic and genomic research; and AWI's objection to the CRC's plans for commercialisation of the wool measurement systems through AWTA. However, with the CRC's broad Participant base and with strong support from MLA, the CRC was able to complete the planned program of work and deliver on all commitments.

Professor Alan Pettigrew (UNE Vice Chancellor), The Honourable John Anderson (Deputy Prime Minister), Dr John Keniry AM (Sheep CRC Chair) and Professor James Rowe (Sheep CRC CEO) at the launch of Sheep CRC2 in 2007.

Sheep CRC3 — making the possible practical

Development of the case for the third CRC was governed by changes to the Commonwealth CRC Program guidelines setting a limit of a five-year term for any existing CRC applying for an extension. It was also made clear in discussion with the Commonwealth CRC Program Managers that a component of a new application should address rising concerns about animal welfare. Further constraints on the scope of the new application resulted from AWI indicating that they would not provide any co-investment for a new CRC bid. There was however strong wool industry support for the bid from WoolProducers Australia, MerinoLink and MerinoTech WA whose co-investment targeted the sheep wellbeing and genetic improvement programs. Continued support from MLA and AMPC targeted genetic improvement and the sheepmeat programs and ensured that these activities had appropriate resources.

The most difficult program to design, and then to implement, was the sheep wellbeing initiative. The original hypothesis was that close monitoring of animal weights, weight change and behaviour would provide useful predictions of situations where animals might need preventative care or targeted treatment. Research during the first two years showed that measuring and monitoring, however intensive, did not provide sufficient time for management response. This finding led to re-designing the program to use climate data and weather forecasting in conjunction with models of soil moisture, pasture production, animal growth, worm and fly lifecycles to predict (and help manage) complex risks that threaten sheep wellbeing. The major initiative termed 'ASKBILL' was made possible through additional funding secured through the Department of Agriculture and through AMPC.

While the planning and start of CRC3 was very smooth, the CRC struck a 'period of turbulence' in the second year of operation. To this day, it is still not entirely clear what triggered MLA's threat to withdraw from the CRC immediately prior to the November Participants Forum in 2016. The issues appeared to relate to the CRC's success with the RamSelect.com.au app development and our plans to develop the ASKBILL program. With encouragement from Sheep Producers Australia, MLA agreed to remain in the CRC, but the incident proved to be quite a distraction and damaged what had been a harmonious and productive working relationship.

The web-based apps, designed to help make complex decisions easier for producers and processors, were a major development during CRC3. The first 'big-data' product developed by the CRC, with assistance from Telstra and technical expertise from Pivotal Labs in San Francisco, was RamSelect.com.au. The success of this approach justified the development of an app-building team based at UNE that has been responsible for construction of the ASKBILL program and other apps.

One of the most productive aspects of CRC3 was the significant integration of all three research programs: Enhanced Sheep Wellbeing and Productivity; Quality-based Meat Value Chain; and Faster Affordable Genetic Gain. The level of integration was an important development contributing to the CRC's impact. The transition from having over 40 quite disparate projects in CRC1, to having just three highly integrated projects in CRC3 represented a major advance and helped to create synergies and efficiencies that were highly beneficial to industry.

The 'cooperative' component of the research centre

The Commonwealth CRC Program initiated in 1990 evolved into a sophisticated, tried-and-tested model. Two features of the Commonwealth CRC Program set it apart from many other funding initiatives. Firstly, each CRC must include a good balance of industry commitment and research expertise. This ensures that the industry participants play a leading role in setting the design and formulation of the program. Secondly, detailed planning required prior to submission of any successful proposal ensures that details of milestones, outputs and outcomes, staff resources and cash and in-kind budgets are all defined before work starts. Outside the Commonwealth CRC Program very few major projects have this level of rigour in the planning phase and are the poorer for this lack of preparation.

Planning a detailed seven-year program involving numerous organisations was a very significant challenge. Completing a professional submission with appropriate detail and reaching agreement across multiple parties had challenges, but it was essential to the success of the CRC's programs. The 'Impact Tool' developed by the Commonwealth CRC Program provided a useful structure to define the linkage between planned activities, the anticipated research outputs, how those outputs would be used by industry and the way in which their use would deliver benefits and impact. Analysis of each step required to deliver impact and the risks involved in each stage helped to inform and refine the plan. It was also a big advantage to know, before starting a project, which Participant organisation would take successful research outcomes to market.

Collaboration takes work

While the logic and benefits of collaboration were easily identified, cooperation and collaboration were not the natural state for industry organisations or for researchers, universities and research institutions. Competition, autonomy and academic freedom still rule the day in these sectors. The sheep industry today is served by three RDCs investing levy and government funds for wool producers, sheepmeat producers and meat processors; multiple organisations represent producers at regional, state and national levels; there are six State and Commonwealth departments of agriculture; plus a number of universities, CSIRO, breed societies, numerous private sector consultants and a range of state and private sector training organisations.

Reaching consensus on the major opportunities and threats facing the sheep industry was the first challenge. Assembling a multi-disciplinary, multi-organisational team was the next challenge. Keeping the team together to finish the job was the third and most challenging aspect.

The Participants Agreement and the Sheep CRC's policies and procedures provided the structure to keep things on track, but it was leadership provided by the Board and Executive that determined the culture of the organisation and ensured that all participants and collaborators stuck to the agreed rules of engagement, focussed on agreed projects, and contributed to a productive collaboration. The scale of a CRC budget and level of Commonwealth co-investment was also a very significant factor. As a source of research funding it represented an

SHARING THE TAXI

The principles of sharing a taxi provided a useful set of guidelines to address effective collaboration. It was often espoused to our Participants that a successful taxi sharing experience involves three components:

- You must be going to the same place (shared goals);
- You must be willing to share the fare (co-investing) and this is not unreasonable if you have a genuine desire to reach the same destination; and
- You have to enjoy the company and the quality of the 'vehicle' — if not, you're better off making alternative arrangements.

All three aspects proved to be important but 'enjoying the company' was the key factor. This was all about the quality of the team and whether individuals and organisations were proud to be part of it.

amount of money that no organisation or researcher could ignore and helped to bind the parties together.

An integrated program of work — not another funder of research projects

The Sheep CRC always worked to an integrated plan, agreed with the Commonwealth and Participants, and used this to set the direction. However, research outcomes were not always predictable and required regular review and refocussing. The Sheep CRC's annual planning conference and detailed annual operational plan played important roles in maintaining a flexible but well-focussed approach.

Coffs Harbour (NSW) proved to be an ideal venue for the annual 2–3 day planning meeting as it was cost-effective, with competitive airfares and out-of-season prices for accommodation and the beachside location proved attractive to Participants and conducive to productive discussion. Having all Participants plus the Board and Executive present to review progress and plan the activities and budgets for the coming year created a valuable transparency, as well as encouraging collaboration and linkages between projects.

Centre IP, not Project IP

Another mechanism to encourage collaboration and linkage between projects and organisations was the decision not to manage IP project-by-project but to share it across the portfolio. Having all IP classified and managed as Centre IP made it easy for organisations to collaborate and to move in and out of projects without any restrictions related to IP.

Open sharing of research data

Data, like IP, needed to be shared openly with all Participants with clear rules so that it could be effectively used and responsibly managed. For most Participants the open sharing of data between organisations was quite a novel experience and, like collaboration, did not come naturally to many researchers, but when data was shared in a secure and responsible way, the benefits were considerable.

The annual planning meeting to produce a detailed operating plan and budget

Having all proposed activities and their anticipated costs clearly defined before the start of each financial year ensured that there was no confusion about tasks, milestones and resources.

Industry engagement in the annual planning process was extremely important. The depth of experience and expertise of our various advisory groups helped shape the discussion and had a big impact on the program. In CRC1 the Industry Advisory Group included a diverse group of producers and consultants and their broad range of experience was complemented by the independent Research Advisory Group and the Education Committee. During CRC2, the role of the advisory groups for each of the Information Nucleus sites added very valuable depth and industry relevance to the program. In CRC3, while less structured, the practice of inviting a range of industry leaders to the annual planning meeting maintained a high-level reality check and more outward looking focus when reviewing progress and fine-tuning the programs for the coming year.

The Sheep CRC used the Centric project management software to prepare the annual plan and to monitor progress each quarter. By ensuring that all project tasks were defined to address Commonwealth Milestones, there were few surprises when it came to annual reporting.

This structured approach emphasised the importance of carefully defining the planned outputs and milestones. With a formal quarterly review of progress for each task and monthly meetings of the Executive, there were mechanisms for quickly intervening when activities or budgets needed updating.

The annual planning meetings held each year included a large group of participants with diverse backgrounds.

Pay actual project costs against invoices

The budget documented as part of the annual operating plan was used to set upper limits for expenditure but it was quite normal for actual project expenditure to be below the predicted levels. This approach created a pool of funds available for re-allocating during the year to accelerate activities or invest in new opportunities. This approach did, however, require careful financial management and accurate budget forecasting.

Good communication with all stakeholders

The art of effective communication with the sheep industry and related community interests was something that the Sheep CRC was quite slow to learn. It was not until CRC2 commenced in 2007 that the CRC invested in professional assistance to develop and implement an integrated communication strategy targeting government, participants and all sectors of the sheep industry. The assistance provided by the Cox Inall team, particularly David Dawson and Michael Thomson, increased awareness and helped deliver impact in a number of areas. Importantly, effective communication contributed significantly to maintaining participant and industry ownership.

Good governance

One of the best investments for the CRC was in good governance, with clear policies and transparent accountability. The resources managed by the CRC on behalf of its Participants were significant and the responsibility considerable. The Sheep CRC was very fortunate with the quality of the Board leadership and its experience in the key area of finance and compliance.

Deliver what the Commonwealth and Participants expect

As the major investor in CRCs, the Commonwealth closely monitored progress against agreed milestones and the contributions, cash and in-kind, being made by the Participants. Through second and fifth-year reviews for CRC1, and a third-year review for CRC2, the Commonwealth made it clear that on-time delivery of agreed outcomes should be regarded by all parties as firm commitments.

It was also critical that each Participant organisation, funded as part of the program, delivered what they said they would contribute to the outcomes of the centre. In the first Sheep CRC considerable time was spent working out metrics to assess what each organisation got out of the CRC in terms of funded positions and operating expenses, compared to what they contributed in terms of in-kind staff resources. It was important for all Participants to feel that they were on an equal footing. Interestingly, there was far less attention by Participants in CRC2 and 3 with respect to the allocation of funds to different organisations. The focus was more on outcomes and which organisations were able to deliver.

The CRC office team

The quality of the head office team was a major asset contributing to the success of the Sheep CRC.

Catherine Holmes, working with Rob Woolaston, was responsible for preparing the documentation for the first CRC application and for the revised submission. This was a major job and was very well done. Catherine was also responsible for coordinating the selection process for the CEO position and the CRC's office staff — Executive Assistant and Finance Manager.

CRC1 was run as a joint venture with CSIRO as the 'centre agent'. That meant that all CRC staff were employed through CSIRO and based at the Chiswick laboratories. When James Rowe was appointed as CEO he was seconded from UNE to the CRC (CSIRO) for the term of CRC1. Similarly, the first Executive Assistant, Debra Lane, and Finance Manager, David Simmons, were appointed as CSIRO staff members on fixed-term contracts.

The Right Honourable Ian Sinclair, James Rowe and Rob Woolaston at the CRC1 office launch at CSIRO Chiswick.

Debra Lane and David Simmons

Initially, the CRC was allocated two offices in the main Chiswick administration building but it soon became clear that a more independent location was needed and CSIRO constructed a purpose-built CRC office adjacent to the canteen. This new facility provided two offices, a reception area and a meeting room, with 'street access' and parking for visitors. Debra Lane contributed to the design of the office and its set up. She did a great job and the office had a smart functional feel that all members of the growing CRC team and visitors appreciated. It gave the CRC the identity that it needed and was formally opened by our Chair, The Rt. Hon. Ian Sinclair, on 28 November 2002. The office continues to be called 'The Sinclair Centre'.

David Simmons was appointed as Finance Manager and made a major contribution setting up and managing the accounts during the early years. David's dress code was suit and tie and this helped establish the CRC's professional image. Debra Lane brought a lot of organisational experience to the CRC and took the lead in drafting all committee charters, as well as very efficiently managing the large Board, Executive Committee and numerous CRC industry events and functions. Debra's organisational skills were also invaluable in helping to coordinate the transition from CRC1 to CRC2. She decided to move to Newcastle at the end of CRC1 but fortunately before leaving found an excellent replacement in Janelle Holzberger.

When David Simmons left the CRC after four years in the position, Ching Gee was appointed and moved from Sydney to take up the position. Ching's business management and accounting skills made an excellent contribution to the CRC's developing processes. Ching returned to Sydney soon after the commencement of CRC2 and worked remotely for several months before it became clear that we really needed the financial management located within the CRC office and Steve Potts was subsequently appointed to the position of CFO and Company Secretary. Steve's commercial experience and wide range of skills contributed to many aspects of the CRC's activities.

Ching Gee

The establishment of CRC2 brought with it a robust discussion about the location of the head office. The WA-based CRC Participants were planning to establish an integrated livestock research centre at Murdoch University, with co-location of the Department of Agriculture, University of WA and CSIRO on the Murdoch campus. There was a strong push to have the CRC head office as part of this new conglomeration. At the same time UNE prepared a case for co-locating the head office with the Beef CRC in the Homestead building on the UNE campus and it was eventually agreed by the Participants that this provided the best option.

Steve Potts

With a new company structure for CRC2 and a new Board, the position of CEO was readvertised and a recruitment firm engaged to coordinate the search and appointment process. James Rowe was appointed and employed directly by the CRC. The new Chair, John Keniry, declared that the Board had to be able to fire the CEO without any complexities of employment contracts with other organisations.

With the expanded CRC2 program, the volume of bookkeeping work increased, and it was clear that an additional staff member was needed. Rhonda Brooks joined the team in 2007 and has played an increasingly important role ever since. Soon after starting with the CRC Rhonda's skills in design became apparent, with material prepared for the foyers and her offer to prepare the 2007–08 Annual Report. Rhonda's skills have continued to be most valuable in book-keeping, human resource management, the preparation of the Annual Reports and even in the area of song-writing, recording artist and video director for the ASKBILL song.

Helen Sisson, Rhonda Brooks and Janelle Holzberger

With the increasing emphasis on communication in CRC2, Janelle's contribution moved to managing the website and organising CRC events around each of the Information Nucleus sites, as well as the annual planning meetings and Participant forums. Helen Sisson joined the team as Executive Assistant and continued in this role until leaving Armidale for the coast in 2014. The CRC was very fortunate to recruit Polly Ward, when she was 'between jobs' at UNE, to take on the role of Executive Assistant. Polly's exceptional efficiency and

Polly Ward

attention to detail has made a significant contribution to preparation of meeting papers and reports, as well as to the organisation of CRC events.

When Steve Potts was poached by MLA in 2008, he left a considerable gap, but the office team felt proud about the training provided for Steve during his time with the CRC. Kate Woodland-Smith was appointed to replace Steve and performed an excellent job in keeping the accounts in good shape and a close eye on matters relating to the Company Secretary portfolio.

The CRC office team expanded in 2011 when the CRC started coordinating the DNA testing service with Marg Shedden, Bec Macarthur-Onslow and Andrea Simpson working part-time to run the 'DNA Office' supported by Steve, Rhonda, Kate, Polly and Lu Hogan.

Kate Woodland-Smith

The head office team has always functioned very smoothly and the positive work environment has always set the tone for rest of the CRC. Getting meeting papers out on time, organising CRC events with flair and attention to detail, as well as being totally professional in dealing with our very broad range of stakeholders has made a major contribution to the success of the CRC by underpinning point #3 of the shared taxi analogy — 'enjoying the company'.

John Keniry retired at the start of CRC3 and the position of Chair was filled by Duncan Fraser, ex-president of the National Farmers Federation. Duncan's knowledge of the sheep industry and extensive network through many levels of agricultural politics brought a new dimension to the CRC. Duncan retired after completing his three-year appointment, with the MLA issues resolved and with the CRC well-positioned to deliver on all of its commitments. Ian Wilton, appointed to the Board as Chair of the Finance and Compliance Committee at the commencement of CRC3 in 2014, was elected Chair in November 2017. With Ian's strong background in corporate governance and financial management, he was well-placed to guide the CRC though its final years including the windup process.

Bec Macarthur-Onslow, Lu Hogan and Marg Shedden

The CJ Hawkins Homestead at the University of New England England became the new home for the Sheep CRC office.

THE SHEEP CRC CHAIRS

Right Hon. Ian Sinclair	2000–2007
Dr John Keniry AM	2007–2014
Duncan Fraser	2014–2017
Ian Wilton	2017–2019

The Sheep CRC Chairs from left Duncan Fraser, John Keniry, Ian Wilton and Ian Sinclair at the Sheep CRC Final Conference in 2019.

SHEEP CRC STRUCTURE

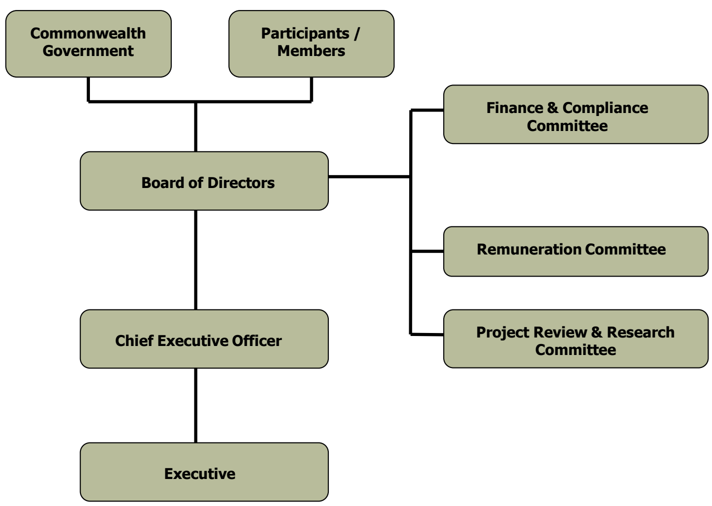
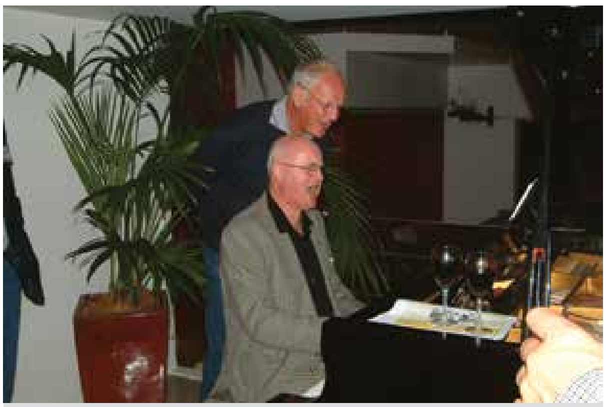


Figure 2.1 The Sheep CRC organisational structure.

The Project Review and Research Committee (PRRC)

Two questions are critical when considering whether research programs are making satisfactory progress: firstly, has the research team done what was expected from their description of the proposed activity; and secondly, is the quality of the research, or relevant report, of a satisfactory standard. These questions are particularly important when funding and payment are subject to delivering a satisfactory outcome.

To manage this issue and also as a means of monitoring progress on a quarterly basis, the Sheep CRC established an independent committee reporting directly to the Board, that was responsible for evaluating progress and the quality of research. In CRC1 it was simply called the 'Research Committee' and in CRCs 2 and 3 it became the Project Review and Research Committee (PRRC). From the outset it was recognised that members of the Committee needed to have an appropriate level of experience and independence to ensure that they had the respect of researchers, investors and the Board. In addition to an independent Chair, the committee had one independent research specialist and another specialist in the area of utilisation of new technologies. Additional members of the Committee included representatives of Participant organisations contributing tied funding. The CEO and CFO attended all meetings to provide interpretation or additional information if required.



Sas Douglas (at the piano) and Peter Chambers relaxing after a full day of planning meetings in Coffs Harbour.

The Committee met each quarter and reviewed progress being made in each Task described in the annual operating plan. Prior to the meeting all Project Leaders were required to prepare brief project reports in the online Centric project management system. In situations requiring a full report or a scientific paper, the specified document would be uploaded and available for review. Key parts of the assessment included whether the project team were adequately focussing their effort on the task as described, progress towards completion and the quality of research. In some situations the Committee requested further specialist input to review a report or assess an area of research when they had concerns about the technical feasibility or potential impact.

Dennis Watson and James Rowe

The work of the Committee over the years highlighted just how important it is for researchers to be clear and specific when describing a task and what they expect to deliver as an output. Without a clear description, objective assessment of progress and deciding whether invoices would be paid for work completed is problematic.

The work of the PRRC in reviewing task descriptions as part of the process of completing the Operational Plan made subsequent assessment of quarterly reports easier and more objective. The PRRC also made it much easier for CRC co-investors, with tied funding, to assess progress and authorise — or withhold — scheduled payments. The success of the CRC owes a lot to the PRRC.

The first Chair of the Committee was Sas Douglas, following his retirement from AWTA. His decisive and uncompromising style established how the Committee would function for the remainder of the CRC. The independent research specialist was Dennis Watson, a senior scientist previously with CSIRO. Advice on adoption and utilisation was initially provided by Michael Goldberg, a marketing specialist with experience in the field of veterinary pharmaceuticals, as well as being a past MLA employee. As a very accomplished jazz pianist, Sas showed another side with his informal after-dinner performances at the Coffs Harbour planning meetings, usually joined by Peter Chambers and Kevin Bell from the Industry Advisory Committee.

At the start of CRC2 Dennis Watson accepted the position as Chair of the Committee and was joined by Andrew Burgess as specialist in innovation adoption. Andrew's experience as a producer, law graduate and past sales manager in the veterinary pharmaceutical industry was most valuable. Neal Fogarty joined the Committee in 2011 as the research specialist, having played a significant research role with NSW DPI. The next change to the Committee resulted from Dennis Watson's retirement and the appointment in 2012 of David Masters. David had an impressive research career with CSIRO before retiring and his contribution to the CRC has been most valuable. In 2015 Andrew Burgess stepped down from the Committee and Jenny O'Sullivan was appointed to fill the position of adoption specialist. Jenny's experience as a producer and her numerous roles on industry advisory groups brought a perspective to the Committee that complemented the expertise of David and Neal.

Andrew Burgess and Andrew Johnston

The continuity of PRRC membership was a positive feature in that it resulted in Committee members developing a good understanding of the background to various initiatives and provided invaluable insights when assessing the quarterly reports.

The quarterly meeting schedule provided sufficient time between reports to expect reasonable progress but frequent enough to identify and respond to delays or technical problems.

With a clear over-arching understanding of each research program, the PRRC was well placed to provide an informed, yet arms-length, assessment of the Impact Tool as it was updated and finalised towards the end of the CRC.

David Masters and Jenny O'Sullivan

The Centric project management system, developed by ACG Consulting specifically for the Commonwealth CRC Program, proved to be of great assistance in preparing the annual Operational Plan and tracking progress through the year. With customised reports for the Operational Plan and for quarterly reporting, Centric reduced the administrative burden of project management.

Focussing on commercial delivery

In line with the Commonwealth CRC Program's charter to ensure use of new research products and benefits for the Australian economy, delivery Milestones were always structured in two strands: one strand covering research outcomes, and the second describing adoption goals. This dual focus made it essential to link research activities with the outputs expected from the research, and how the new products and information would be used by industry. Most of the Sheep CRC's Program Leaders were from research backgrounds and the Board always ensured that additional expertise was available to give the activities an appropriate commercial adoption focus.

Peter Silk joined CRC1 and helped establish the IP management systems and addressed all issues relating to the CRC's freedom to operate. The work that Peter did to secure the transfer of CRC1 IP in 2007 helped to set up the smooth wind up of the CRC's IP in 2019. As mentioned in Chapter 6, the commercial team of Ian Champion and Bill Hiscox, working with Mark Coupland , provided new insights for planning the precision sheep production initiative.

In CRC2 Graham Truscott was appointed Deputy CEO with the responsibility for coordinating adoption and commercialisation activities. Graham's experience in the Angus society in the expansion and adoption of genetic products proved valuable when it came to planning the roll-out and promotion of the CRC's new genomic products. Graham was a strong advocate for the successful pilot projects to encourage early use of the genomic products on a subsidised basis. This approach allowed the CRC and its Participants to start using the new technologies and gaining experience, as the value of the new products continued to develop.

In CRC3 David Faulkner's commercial experience and engagement with his extensive network provided insights into the commercial scope of ASKBILL and the design features important to end-users.

This commercial expertise was a key plank in ensuring the focus on end-user delivery and path to market.

Peter Silk

Mark Coupland

Graham Truscott

David Faulkner

The Impact Tool for planning and review

Economic evaluation was an integral part of the Commonweatlh CRC Program and the Sheep CRC approached this requirement in a number of ways. When establishing the CRC in 2001, the CRC approached the Rural Innovation branch of NSW DPI to assist with the economic evaluation of the portfolio. David Vere, with Garry Griffith and Luke Silvester, undertook the task using two approaches. The first involved an ex-ante top-down industry model analysing areas of productivity growth expected as a result of CRC R&D. The second stage was based on a bottom-up model developed by MLA and AWI to evaluate their investment projects.

The top-down approach generated good information on the likely value of different R&D targets but was quite abstract in its connection with specific R&D activities. The bottom-up approach achieved good engagement with the R&D project teams, but still contained a number of high-level assumptions that were subject to dispute and debate. The good news was that both the top-down and bottom-up approaches gave similar results and provided confidence to the Board and stakeholders that the CRC was on the right track.

In preparing the case for Sheep CRC2 in 2006, the top-down modelling approach was used again. This provided a high-level analysis and indicated that the R&D targets were well-defined and anticipated to deliver valuable industry outcomes.

Soon after commencing CRC2 in 2007, the Commonwealth CRC Program introduced a standard methodology for economic evaluation. The Excel-based Impact Tool, mandated by the Commonwealth CRC Program for use by all CRCs, was based on an input-impact chain model. The Impact Tool soon became a key part of Sheep CRC planning, monitoring and reporting.

The Impact Tool helped to provide a structured approach linking research milestones with utilisation metrics and CRC outcomes. It was also valuable in defining what output and adoption parameters should be measured in order to track progress.

Given the extent of industry involvement in the Sheep CRC, and the transformational nature of a number of CRC outcomes, national sheep industry statistics were also utilised, such as gross value of sheep products, to monitor and report impact of the Sheep CRC's activities. For example, the situation where interactions between programs or synergies developed, such as the impact of genetic technologies on the improvement of sheepmeat eating quality, the changes in national statistics proved to be most helpful.

One aspect of the CRC's portfolio which has always been difficult to quantify, but which is considered to be one the most valuable aspects, was the investment in undergraduate and postgraduate education. While costs of these programs were easily defined, the many different ways that graduates contributed to the ongoing development of the industry, and the length of time over which this contribution had and would continue to create value even well after the CRC ended, was easily recognised but difficult to quantify.

In the following chapters the transformation delivered by the Sheep CRC and the related impacts have been mainly described in terms of changes in the gross value of sheep products, or changes in product volumes and categories.

3 INTEGRATING WOOL & SHEEPMEAT PRODUCTION

It is incredible to think that in 2001 the Sheep CRC became the first organisation in Australia to focus research and development on 'the sheep' rather than on either wool or meat. It may seem obvious today, but at the time this approach was regarded by many as quite unusual. At the start of CRC1 — the beginning of the 21st century! - there were considerable gaps in knowledge of genetic parameters and dual-purpose production systems.

It was significant that the CRC started with neither wool (AWI) nor meat (MLA) industry research bodies being Participants. However, a number of meat processors already recognised the integrated nature of their 'sheep' business. With abattoirs processing increasing numbers of lamb and reduced ewes and wethers their business interests aligned with a Sheep CRC concept. The Australian Meat Processor Corporation (AMPC) has supported and maintained strong links with the Sheep CRC from start to finish.

As described in Chapter 2, the industry support for the Sheep CRC continued to grow with each CRC. Starting with six Participants in 2001 for the first CRC, numbers grew to 21 for CRC2 and to 41 Participants by the end of CRC3. With this increasing number of partner organisations, establishing a well-balanced R&D portfolio focussing on the integration of wool and meat production was a good challenge for the Sheep CRC. But their input was vital to delivering initiatives to help producers and their advisors plan and manage the transition to a more integrated sheep industry.

The CRC's new approaches to an integrated sheep industry included:

- Managing new flock structures for wool and meat production;
- Within-flock selection for wool, meat and lambs;
- Environmental constraints to wool and meat production enterprises;
- Genetics for wool and meat production systems; and
- Case studies and benchmarking.

More detailed information on these and other related topics is provided in the proceedings of the Sheep CRC's 2006 conference *Wool Meets Meat — Tools for a Modern Sheep Enterprise* (Edited by Pierre Cronje and Deborah Maxwell, ISBN 0-9752198-1-2).

A strategy aligned with industry reality

During the planning and startup phase of the first Sheep CRC between 1999–2001 the gross value of wool production was over three times the value of lamb production and many in the industry regarded wool as the 'senior' partner (see Figure 3.1). However, this position changed quite rapidly and by 2008 the gross value of lamb and wool production was almost identical. Importantly, since 2008, there have been similar rates of growth in the value of both products and integration has become well accepted. The CRC's research strategy was perfectly aligned to support this rapid transition in the industry structure.

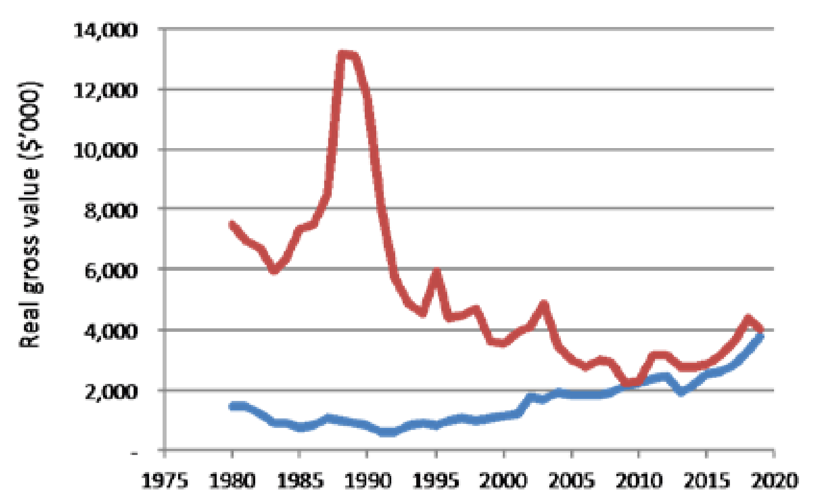


Figure 3.1: Changes in the real gross value of Australian wool and lamb production adjusted to 2018–19 dollars (ABARES 2019).

Managing new flock structures for wool and meat

As the program title suggests, some serious thinking was required to support the transition in a range of business models and three key activities stood out as delivering against this challenge.

Maintaining a self-replacing flock with increasing use of Terminal and Maternal rams

Following suspension of the wool Reserve Price Scheme in 1991 there were major changes in the size and composition of the Australian sheep flock. The decrease in the flock size was massive (see Figure 3.2). At the start of the CRC, the size of the Australian sheep flock was relatively stable with around 120 million sheep but during the 10 years from 2000 to 2010 there was a 40% reduction in the size of the flock before it again stabilised at around 70 million sheep and it has remained relatively constant around this level through to 2018–19.

The changes in the structure of the flock were also important. The proportion of wethers, kept principally for wool production, decreased from around 30% of the flock to around 10%, and this was balanced by an increase in the proportion of ewes. At the same time there was an increase in the proportion of Merino ewes joined to Terminal sires.

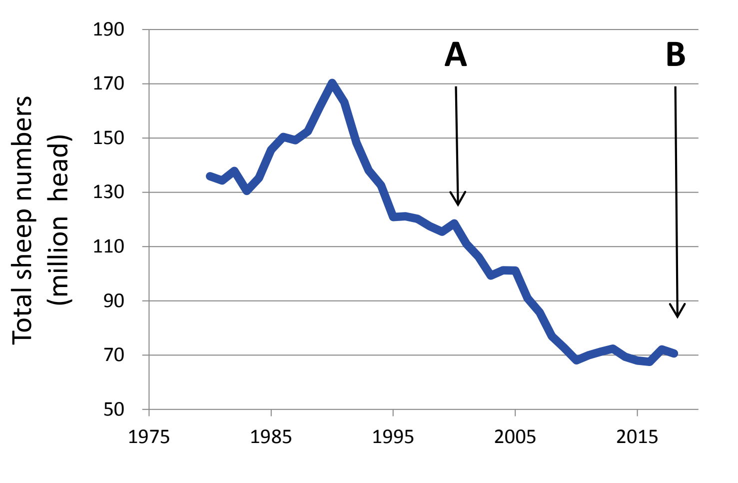


Figure 3.2: The decline in the total Australian sheep flock from around 120 million at the start of the CRC in 2001(A) to around 70 million (B) at its completion in 2019. The population was relatively constant from 2010 to 2019 (Source: ABARES).

Kimbal Curtis led a project supported by the CRC in 2004-05 to coordinate development of a national flock structure model to provide information on the supply of wool and meat. The study helped to set priorities for the CRC's portfolio and the focus of a number of related projects. With these changes in flock structure many producers wanted advice on the proportion of ewes to be mated to Merino and Terminal sires in order to capture the benefits of prime lamb production, while still maintaining a self-replacing ewe flock.

Lisa Warn, Ken Geenty and Sandy McEachern undertook a study using CSIRO's 'GrassGro' model. With assistance from Libby Salmon and John Donnelly, they investigated the optimal wool-meat enterprise mix. Their conclusions were very valuable for producers considering a range of options, and emphasised the fact that while a dual-purpose enterprise based on Merino ewes all joined to Terminal sires would provide resilience against variable prices, there were risks in buying in replacement ewes with unknown genetics and the possibility of disease. They also found that pure Merino production could be as profitable as cross-breeding programs for prime lamb production and that existing systems should be optimised before considering any radical changes in enterprise.

Andrew Swan and Matt Kelly at CSIRO's Chiswick laboratories, working with Kevin Atkins and Jess Richards at NSW DPI's Orange institute, developed a series of useful models to help determine optimal percentages of ewes for mating to Terminals and Merinos in order to maintain a stable flock structure without the need to buy in replacement ewes. In studying optimal flock structures, they also developed models to optimise the proportion of wethers contributing to high-value wool production. Their research produced a number of software tools to plan flock structures for optimal income from wool and meat. One of the most important aspects of this early research was that it identified the potential value of smart within-flock selection and the benefits of precision sheep production technologies (see Chapter 6).

Yearling Merino production — an option for wool and meat enterprises

A novel approach to integrating wool and meat production was investigated in a feasibility study undertaken for the CRC in 2004 by Sandy McEachern of Holmes Sackett. As well as estimating gross margin returns for prime lamb production and self-replacing Merino flocks, the study investigated the potential production of yearling sheepmeat as a means of achieving increased income from wool production and removing some of the risks through not finishing lambs in under 12 months. Even with discount meat prices for yearling compared to lamb, the 'dual purpose' production system showed considerable promise and compared favourably with the per hectare returns from fine wool and crossbred lamb production.

The possibility of a commercial yearling wool and meat production system was again investigated during CRC3 as a potential alternative to the live sheep export market. With an increased understanding of cuts-based MSA grading and the hypothesis that some of the meat cuts would not be affected by the increased age of yearling animals compared to lambs, Dave Pethick, Robin Jacobs and their colleagues undertook a comprehensive analysis of consumer perceptions of lamb and yearling meat in 2017. The study showed that for higher quality cuts such as loins and rumps there were only minor differences between lamb and yearling meat. However, for cuts such as topside, the differences were more pronounced. Although technically feasible to extend the MSA grading system to include the yearling product the industry decided not to extend the scope of the new grading system.

2006

WOOL MEETS MEAT CONFERENCE

This conference held in Orange was a major step in industry recognising the shared objectives and profit drivers of the wool and meat sectors. The Sheep CRC presented papers on a range of topics applicable to the 'whole-of-sheep' approach, including enterprise planning, genetic selection, managing parasites, meat science, animal nutrition and wool production.

Wool Meets Meat Conference Organiser Neal Fogarty.

Increased proportion of ewes — tender wool and reproduction

With the significant increase in the proportion of ewes, Jen Smith, Ian Purvis and Greg Lee confirmed during the first two years of the CRC that pregnancy and lactation had a significant effect on variation of fibre diameter and staple strength and suggested that further work on the management of wool fibre diameter was justified. The follow-up work examined grazing management to even out nutrition as well as options for genetic selection. Based on this research, nutritional management was suggested as a short-term option for reducing discounts resulting from tender wool, and the coefficient of variation in fibre diameter considered an option for selecting for improved staple strength.

Within-flock selection for wool, meat and lambs

With the increasing importance of dual-purpose wool and meat production enterprises, the job of sheep classing or within-flock selection was about to move to the next level. Kevin Atkins, working with Steve Semple and Jess Richards in Orange and with Andrew Swan and Matt Kelly in Armidale, focussed on questions of within-flock selection to achieve the best balance of characteristics for ewes to produce either replacement ewes or crossbred lambs. A series of Excel-based models proved to be valuable in helping to select animals for combinations of traits for:

- Ewes to be kept or culled;
- Joined either to Merino or Terminal sires; and
- High-value wethers to be kept for wool.

These tools, first developed towards the end of CRC1, and subsequently refined, could be downloaded from the archived CRC website and remained useful for many years to come. Several of the selection algorithms were also embedded in the software systems associated with commercial automatic drafting systems helping to ensure their widespread use.

Once preliminary studies confirmed the amount of variation present in all commercial flocks with respect to the value of wool, meat and the number of lambs weaned present, the new approach to within-flock selection gained momentum. Improvements are made by selecting the most productive animals, irrespective of their age, and using a range of measurements, rather than selection and management decisions based purely on age group. With ewes best suited to wool production used for breeding replacements and those with higher liveweights joined to Terminal sires, income from both wool and meat can be increased.

SOFTWARE TO OPTIMISE FLOCK STRUCTURE

The Sheep CRC delivered decision-support software to assist in planning a Merino-based enterprise, using four integrated tools:

MERINO VS TERMINAL FLOCK CALCULATOR — estimated the number of ewes to allocate to self-replacing Merino matings and first cross matings, with the aim of maintaining a sustainable self-replacing flock.

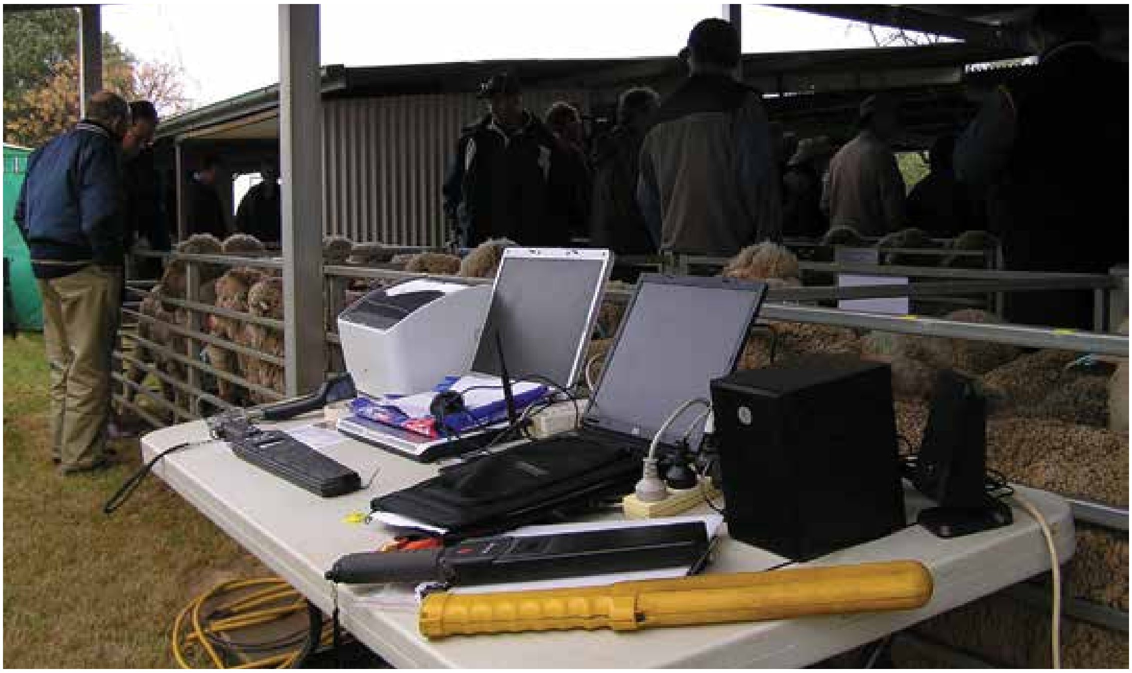
ON-FARM FIBRE MEASURE (OFFM) CALCULATOR — determined whether fleece measurement was likely to be a profitable practice for the flock. Based on flock structure and performance, likely profit was shown in four areas of production — hogget clip preparation; adult clip preparation; ewe selection and wether selection. A graphical format was provided over a 10-year period along with suggestions for increasing profit by altering structure or selection method.

WETHER CALCULATOR — estimated the optimal economic proportion of wethers within the flock.

FLOCK STRUCTURE TOOL — examined potential flock changes over time and estimated economic results from changes in selection strategies and flock structures.

The package enabled producers to calculate the optimal numbers of ewes joined to Merino and Terminal sires for a self-replacing Merino flock, as well as how to optimise hogget clip preparation, adult clip preparation, ewe selection and wether selection.

It also provided advice on how to balance the number of wethers in the flock and manage the flock age structure.



On-farm fibre measurement (OFFM) and Simultaneous Assortment

At the time that the CRC commenced in 2001, premiums for finer micron wools were significant and OFFM was a technology being widely used throughout the Merino industry with varying levels of sophistication and variable benefits. An early CRC product, the OFFM calculator formed an important foundation for a number of other tools to assist producers in making better decisions on within-flock selection and subsequently ram-buying decisions.

Using information about the flock structure (ewes and wethers) and the cost of wool testing, the calculator provided 'what if' scenarios for options such as different levels of culling of ewes and wethers, as well as changing the number of age groups in the flock. One of the benefits identified through this modelling was the option of keeping both ewes and wethers that were highly productive for an extra year rather than culling them with the rest of the age group. The addition of another age group cohort of highly productive animals often produced important gains in profitability.

The OFFM calculator and subsequent models provided estimated benefits over a 10-year period. This helped to emphasise to producers and breeders the long-term implications of any selection decisions. Figure 3.3 shows how the use of OFFM data for clip preparation was a relatively minor component of the benefit. Major improvements in profitability resulted from smarter selection of ewes and wethers on the basis of their ability to contribute to the income of the enterprise. As indicated elsewhere, within-flock selection works synergistically with genetic selection and choice of rams. The OFFM calculator presented a clear summary of the value proposition of selecting for finer wool production and made a major contribution to the rapid transition towards a finer national wool clip (see Figure 3.4).

The next stage was to develop the decision tool to include information on body weight and to make better decisions on which ewes should be mated to Merino sires and which should be mated to Terminal sires. The 'Simultaneous Assortment' allowed producers to sort sheep into two groups with different degrees of merit for either wool or meat. This approach allowed producers to separate groups of animals into two sub-flocks, one a better wool production group with finer diameter wool but slightly smaller animals, and the other a better meat production group with broader fibre diameter but higher live weight. This was shown to provide short-term benefits in lamb production and longer-term benefits for the wool characteristics of the ewe flock.

The automated measurement systems using electronic identification and automated drafting systems assisted the implementation of these decisions and are described in more detail in Chapter 6.

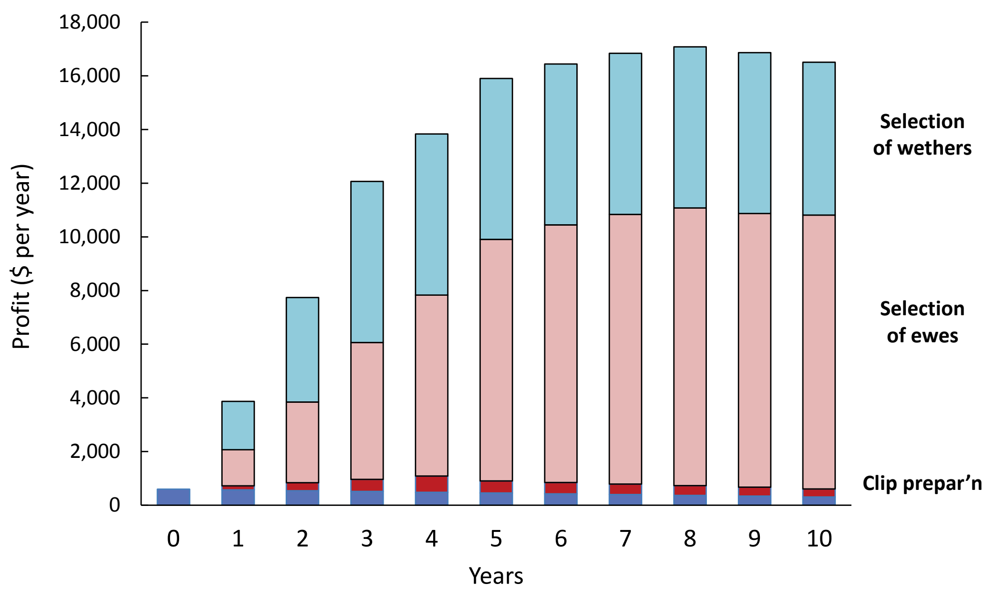


Figure 3.3: A screen shot of results produced by the OFFM Calculator with estimated benefits from using OFFM measurements for clip preparation (CP) or for culling less productive ewes and wethers. 'What-if' options included the number of age groups (retaining highly productive animals for an additional year) and ability to vary reproductive efficiency and culling percentages.

Nutritional management for integrated sheep production and lamb finishing

With the fast-moving integration of wool and meat, there was an early recognition that nutrition would become increasingly important for feeding:

- ewes for enhanced reproductive performance, and improved lamb and weaner survival; and
- lambs to meet growth targets and production specifications.

Out-of-season finishing and year-round supply were also identified as important issues for the expanding lamb market.

Early CRC research coordinated by Robyn Warner on the quality of meat from Merinos showed that it was considered to be high quality in terms of tenderness, flavour and juiciness, but had some problems with shorter shelf life than meat from crossbred lambs and also had a higher incidence of dark cutting. Both problems could be significantly reduced through improved nutrition prior to slaughter. This finding was important in supporting the use of Merinos as part of the expanding prime lamb production system and provided clear guidance on the importance of nutrition prior to slaughter.

Supplementary and confined feeding has always represented a major expense and the importance of selecting low cost feeds and understanding the feed conversion efficiencies were a high priority. Consequently, the CRC investigated a number of ways of utilising cheaper feeds, low cost processing systems and more efficient ways of feeding.

Loose mixed diets compared to full processing

Rachel Kirby joined the CRC in 2002 and with her colleagues in Western Australia made good progress in investigating cost-effective ways of feeding concentrate rations for out-of-season finishing of lambs. An early breakthrough was the finding that lamb performance on a loose mixed diet was very similar to that achieved when feeding a fully processed pelleted diet. This information provided producers with a useful option for out-of-season finishing of lambs without the capital cost of processing equipment or the expense of buying in pelleted feed.

Sorghum as a feed grain for sheep

Sorghum had not been widely used as a grain in sheep diets, and even though there was a lot of data available for cattle feedlot rations based on steam flaked sorghum, there was little information on the improvement of performance in sheep production associated with various forms of processing sorghum grain. Virginia Beretta, working at the University of New England during 2004 as a post-doctoral researcher, on sabbatical leave from the National University of Uruguay at Paysandu, coordinated a number of studies in pens and under paddock conditions to evaluate performance of animals fed diets containing high levels of sorghum. The results showed relatively small improvements in feed conversion and growth rates as a result of grinding and steam flaking. These results provided producers in areas close to sorghum production districts with a further option when selecting feeds for lamb finishing rations.

Targeted feeding

With the advent of eID and auto-drafting technologies, the CRC investigated the option of targeted feeding based on an animal's individual requirements. This concept was explored by Dave Jordan and Maree Bowen in Queensland, and by Greg Lee and his colleagues in NSW. The studies commenced in 2005 with pen studies, before undertaking a paddock scale trial demonstrating commercial proof of concept in 2006. The systems developed by these researchers were based on animals moving to water across electronic scales and through a drafting gate. Those animals requiring additional feeding were automatically drafted into a pen or small paddock with a self-feeder, and those not requiring supplementation passed straight through to the water trough and then back to the paddock with their movement controlled by a series of spear gates. Differential levels of nutrition could also be provided by this system through controlling how often animals were drafted into the pen with the self-feeder. The targeted feeding system was designed to reduce the cost of feed by ensuring that it was only available to those animals requiring it most. With reduced cost of the eID and drafting technologies and with improving reliability of the equipment, targeted feeding attracted interest for cattle production systems as well as for sheep.

SIMPLE YET INNOVATIVE — THE COWRA BALE FEEDER

Feeding hay and silage on the ground can be extremely wasteful and result in lower than optimal lamb growth rates. Wastage, mainly due to spoilage by urine, faeces and trampling, can have rain as an added complication.

The Sheep CRC backed a simple yet innovative solution to the problem by funding the development of the Cowra Bale Feeder and Chop Feeder. During the first two years of the CRC the NSW DPI team, based at Cowra and led by Peter Holst, designed a feeder suitable for large square or round bales of hay or silage that was easy to build and reduced wastage significantly.

David Stanley, Technical Officer with NSW DPI at Cowra, worked with Lachlan Steel Industries, a local metal fabricator, to design the feeder. With critical input from farmers in the district, the team produced a versatile and efficient feeder.

The design featured one swinging side with a covered feed bay and could be constructed in two sizes — the smaller feeder holding one round bale of hay or silage (up to 1.5 metres long), while producers with large square bales of hay (2.4 metres long) could use the larger feeder.

In Sheep CRC trials, instead of losing as much as 45% of the bale, the Cowra Bale Feeder lost only 7% and the Chop Feeder 3%. Lambs also grew faster on the cleaner feed.

To enable maximum uptake, the Sheep CRC published detailed construction plans and photographs on its website so that producers could either purchase the feeders from a commercial provider or build it themselves.

Dave Stanley with the Cowra Bale Feeder.

Grain feeding options

Variation in growth rates in response to diets that appeared to be quite similar highlighted the wide range of genetic potential for growth. It was also evident that while most of the nutritional research conducted in Australia before 2000 had been undertaken with Merinos, most production feeding of lambs was for crossbreds which had the potential for faster growth rates and more muscling. Therefore, although many of the nutritional principles were well defined, predictions of absolute growth rates and feed conversion factors were not as precise as many producers would have liked.

In order to capture the existing knowledge and the increasing experience of producers and researchers, the Sheep CRC organised a workshop hosted by Murdoch University and the WA Department of Agriculture in October 2004. The aim was to review results of grain feeding experiments and commercial practice throughout Australia to understand more about the relative value of different grains, how the grains should be prepared for best economic returns and responses of different classes of sheep to various diets and methods of feeding.

The recommendations and guidelines reviewed at the meeting were subsequently edited by Helen Chapman of Murdoch University and published by the CRC through the WA Department of Agriculture. The booklet 'Grain Feeding for Sheepmeat Production' proved to be a valuable source of information for many producers and researchers.

2007

THE FEEDLOT CALCULATOR GOES ONLINE

Drawing on information from the Western Australia review of grain feeding and a wealth of experience in NSW, Geoff Duddy, Geoff Casburn and their colleagues in the NSW DPI, developed a feedlot calculator. The spreadsheet cost calculator for feeding sheep became widely used for preparing budgets for grain feeding lambs and for providing supplementary feed for ewes. Users enter up-to-date prices of feeds and livestock, and the calculator then produces estimates of the likely financial outcomes of the feeding regime, allowing producers to make informed decisions before committing to supplementary feeding or feedlotting.

CHEAP AND EFFECTIVE GRAIN AND HAY FEEDING

The practice of lot feeding lambs was known for its tight margins, so keeping costs to a minimum was essential.

Sheep CRC research demonstrated that feeding the hay and grain components of the ration separately was cheaper than, and as effective as, the more expensive pelleted or total mixed rations.

Lambs fed hay and grain separately had similar growth rates, carcase weights and carcase traits to those fed pellets and better carcase weights than those fed a total mixed ration.

As part of a series of 'Nutrition Notes' the Sheep CRC produced a Practical Wisdom fact sheet to ensure producers could maximise this opportunity, starting with the basics of how to safely introduce stock to grain rations and providing a good understanding of the exact nutritional content of the dietary supplements.

Rations could then be formulated to meet the specific nutritional requirements of the class, weight and growth target of the sheep to be fed.

The cost of feed and the equipment and labour required to mix and feed out rations was a significant factor for producers, however, the option of feeding hay and grain separately overcame this barrier as it required much less equipment.

As such, it was especially relevant in temporary low-cost feedlots, in droughts and in dry seasonal conditions, to produce increased weights of light lambs so as to achieve critical carcase targets for improved market returns.

The Practical Wisdom series also included detailed advice on the use of sorghum, and how to determine the economic viability of feeding options for lightweight spring-drop lambs.

Genetics for wool and meat production systems

At the start of the CRC there were a number of questions in relation to genetic strategies for an integrated sheep industry for efficient production of quality wool and meat. Would it be more efficient to develop a dual-purpose line or continue to rely on cross-breeding from a Merino ewe base? Was there sufficient knowledge of the genetic parameters to select for the broad range of traits for wool, meat and reproduction? Also, were there any biological limits that needed to be considered in selection programs?

Dual-purpose breeds or cross-breeding?

With many examples of dual-purpose sheep breeds it was essential to review the evidence for-and-against this option. Computer modelling undertaken by Julius van der Werf indicated that for a wide range of wool and meat price scenarios, maintaining specialist breeds with cross-breeding was more profitable than a system based on a dual-purpose breed.

This work also indicated priorities for selecting for increased growth rate in the Terminal sire meat breeds and for increased wool production, with minimal increase in body size, for wool breeds that also serve as dams for prime lamb production. The study showed the benefits of increasing reproductive rates for both wool and meat breeds. These recommendations from the early modelling became well accepted during the ongoing development of the Australian sheep industry. Importantly, these principles for genetic selection were well aligned with the practice of within-flock selection, discussed earlier in this chapter, and the two approaches were synergistic in capturing the benefits of improved wool and meat production.

The strategy of focussing on specialist breeds also provided a form of risk avoidance because cross-breeding allows more flexibility to respond to changing price signals while, at the same time, retaining the ability to express traits characteristic of a breed selected for dual-purpose production.

The modelling indicated that the only situation where a dual-purpose breed would deliver a better economic result than specialist breeds and cross-breeding would be in the case of a significant decline in the wool price. This has not occurred and the recommendation to focus on specialist breeds has helped to position the industry well.

Genetic parameters for wool and meat

The design of effective breeding programs targeting improvements in wool, meat, disease resistance and reproductive efficiency required a sound knowledge of genetic parameters in order to develop selection indexes and to design appropriate methodology for genetic evaluation of animals.

An initial review of world literature was undertaken by Neal Fogarty and Alex Safari to gather all available information on genetic parameters for all recorded sheep production and disease traits. The study highlighted the lack of accurate estimates of genetic parameters especially for genetic correlations between trait groups. To remedy this situation the Sheep CRC1 quantitative genetics team analysed a dataset compiled from seven Australian Merino research flocks. The combined dataset included information on more than 2,000 rams with more than 100,000 records, including measurements on a large number of traits. The result was a very accurate set of estimates for genetic parameters that would prove to be incredibly useful in improving genetic selection for Merinos for improved wool, meat and reproductive efficiency.

Alex Safari did an excellent job of coordinating the national team and in working with Neal Fogarty and other colleagues to complete the documentation of the findings in a series of publications including the *NSW Agriculture Technical Bulletin 49 in 2003* — a landmark reference resource. More details of this work are provided in Chapter 4.

Biological limits to selection for wool and meat?

Norm Adams and Pierre Cronje, based at CSIRO's Floreat Park laboratories in Western Australia during the early 2000s, reported reduced reproductive and growth performance when selecting sheep for wool production and low fibre diameter. Through this research they posed the challenging question of whether there were limits to selecting sheep for any particular production trait including extreme levels of wool growth. The question was examined in a fascinating workshop, organised early in CRC1, where the results of extreme genetic selection in a wide range of species were reviewed and discussed.

As well as reviewing the findings of Adams and Cronje in sheep and goats, the group examined results of studies in Drosophila (a fruit fly used as a model organism in numerous genetic development and evolutionary studies), as well as case studies taken from the poultry and dairy industries where intensive selection for increased production had resulted in unexpected developments. The conclusions from the workshop were encouraging and most helpful in setting guidelines for sheep breeding programs.

It was clear that problems in selection programs had invariably developed through not having a well-balanced breeding objective accounting for all the important aspects of production as well as fitness and wellbeing. There was evidence that when selection for fibre production in goats and sheep ignored negatively correlated traits such as growth, muscling and fatness, animals became less resilient to periods of under nutrition. In dairy cows, selection focussing only on increased milk production led to poor reproductive performance. Selection in poultry focussing on growth and muscling resulted in increasing health problems.

The take-home message was to give careful consideration to all aspects of production, product quality and wellbeing in preparing selection indexes and when planning animal measurements in any breeding program.

The precision sheep production tools (see Chapter 6) and genomic technologies (see Chapter 4) proved to be extremely valuable for measuring and predicting a very wide range of traits in young animals in order to maintain a good balance between traits, while still achieving good rates of genetic gain.

2012

WOOL AND MEAT MANAGEMENT AND BREEDING

Independent advice on equipment and a well-planned approach to an eID system was delivered to producers, through the course 'Using eID for Sheep Management and Breeding' rolled out in NSW and Victoria. The course was developed by the Sheep CRC and delivered through a number of licensed training providers. Training was delivered through three face-to-face group sessions on-farm, followed by a one-on-one session with the course facilitator to ensure that the outcomes were customised to individual requirements.

INTEGRATING WOOL AND MEAT PRODUCTION AT 'WARRANE'

The release by the Sheep CRC of the 'Precision Pays' booklet was one of the first collections of case studies on how Precision Sheep Management (PSM) technologies could be used to support both wool and meat production within an integrated business model.

Fourteen different farm businesses were profiled on their use of eID technologies, and how the use of objective performance data was assisting in maximising value from all aspects of the business.

Among them was the profile of Maurie Stephen of 'Warrane', Armidale, NSW, who was running 28,000 Merinos, and profiting from a 16.8-micron wool clip as well as turning off up to 6,000 first-cross lambs each year.

"We use RFID tags for monitoring and recording at classing, shearing and weaning and they are a huge improvement on the old visual/manual method. They have been an absolute boon for our sheep, as we work on optimizing returns from wool and lamb", Maurie said.

The improvement in the accuracy of the information enabled the genetic quality of the Stephens' sheep, especially the stud, to go ahead in leaps and bounds. Such was the improvement that Warrane's highest ranked stud sire from 1998 would not be good enough to make the commercial flock in 2008.

Mr Stephen used the data in combination with the Sheep CRC's On-Farm Fibre Measurement Software, as well as PSM hardware including autodrafters, to maximise profit from animal selection and minimise labour use in the yards.

Similarly, Rod and Jenny Shaddick, 'Hillbine', Pingelly in Western Australia, used PSM to fine- tune their prime lamb breeding and finishing program in which 2,600 Merino ewes were joined to Poll Dorset and SAMM sires, with lambs finished on grass, grain and pellets for sale over-the-hooks to the Q Lamb Alliance.

Maurie Stephen

They used eID technologies to identify the better performing lambs — on-farm and over-the-hooks — and used that information in selection of the rams for their crossbreeding program.

"We are seeking as much information as possible on the performance of our rams due to the three-way cross we use in our lamb production," Rod said. "In particular, we are looking at lamb growth rate in the feedlot and carcase characteristics at the abattoir."

Case studies to explain the Merino wool-meat interface

The appointment of Ken Geenty to head up the CRC's Wool Program saw more focus on understanding dual-purpose sheep production systems. Ken worked with Andrew Swan and colleagues at Chiswick and AGBU to measure relationships between wool and meat traits under a large range of environmental conditions to help develop improved breeding and management guidelines.

The project was established in 2005 with 27 Merino breeders across Australia covering production systems from Central Queensland to Victoria on the East Coast as well as producers in South Australia and Western Australia.

Measurements were made on 16,000 Merino ewe and ram hoggets over a period of two years. Data was also collected on rainfall and pasture growth rates. The results confirmed that although there were genetic antagonisms between wool traits (fibre diameter and fleece weight) and between wool and meat traits (fleece weight and body weight), careful selection and monitoring could be used to ensure concurrent improvement of all key production traits.

An important finding from the research highlighted significant genetic variation within each region for both wool and meat traits, indicating opportunities for breeders and producers to source improved genetics for key traits without having to purchase rams from other districts.

Ken Geenty

THE BENCHMARKING FLOW ON EFFECTS

Errol and Candy Brumpton, the principals of Well Gully Merinos, were among the producers who participated in the wool-meat interface project and they recalled the value the results provided in helping to benchmark their flock and breeding objectives with other breeders across a range of environmental conditions.

Although the Mitchell area of Southern Queensland is not normally associated with production of the highest quality fine micron wool, the Brumptons showed that these features could be developed without compromising impressive fleece weights, excellent growth and carcase characteristics, and good fertility. In addition, the plain-bodied sheep did not require mulesing.

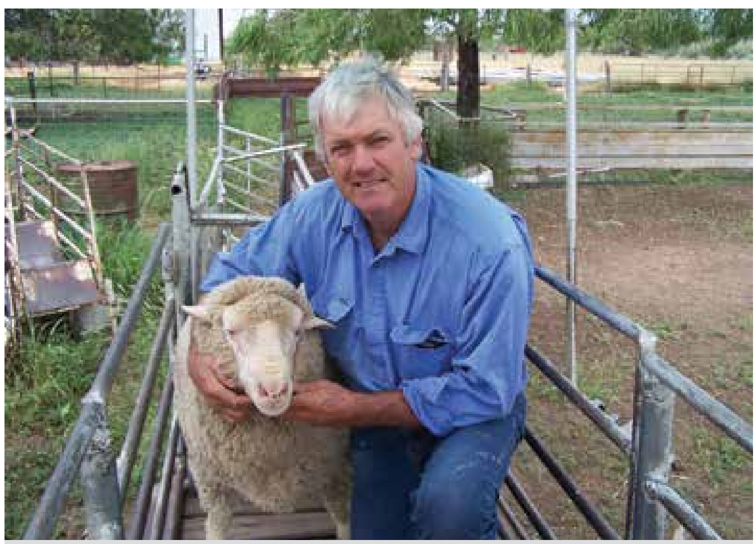
Their rams were in high demand by producers throughout Australia confirming the versatility of Merinos selected for a well-balanced set of traits.

The impact of their initial involvement flowed on to other Sheep CRC activities and industry initiatives with Errol sought out by Queensland sheep breeders for his advice on how to use ASBVs to select the right rams for their breeding objectives.

One such client was Sheep CRC Board member, Stuart Mitchell, who switched to purchasing his rams from the Brumpton's stud as he moved to breed plain-bodied sheep with a 19-micron flock average while maintaining or improving fleece weight.

"Errol had a really good understanding of what we were trying to achieve and he really understood our breeding objectives," Stuart said in 2015. "The process was we would ring Errol and tell him what we were looking for because we don't always buy the same style of rams. We could go to Errol and say we needed half a dozen rams that are going to put a bit of size into them, plus I need 10 rams that are going to give me the fatness and crimp and the fleece weight and the micron that I'm looking for across the rest of the flock."

Mr Brumpton would present his clients with a group of rams which met the description and had supporting ASBV data leaving the clients like Mr Mitchell to make the final selection.



Errol Brumpton

UNDERSTANDING MERINOS EQUALS MEAT PROFIT

By 2015 the 'whole-of-sheep' approach was truly taking hold within the industry, with a growing appreciation of the Merino sector's contribution to the Australian sheepmeat industry.

A MerinoLink conference held at the Riverina Institute of TAFE in Wagga Wagga, NSW, provided Merino sheep producers, focussed on the combined wool and meat benefits of the breed, with new information including opportunities to supply high quality Merino and yearling lamb to consumers.

The theme of the conference was 'Improving the profitability of your Merino enterprise' and included a presentation from Sheep CRC Meat Program Leader David Pethick, who said that with careful management, Merino lamb and yearling lamb could deliver high quality carcases and excellent eating quality.

"Sheepmeat eating quality is not hugely affected by breed," Dave said. "The eating quality of Merino lambs can be comparable to other breeds, but they do require more stringent pre-slaughter management than the other breeds in Australia.

"Good meat colour can be achieved from Merinos providing they have adequate nutrition and minimal stress prior to slaughter."

Dave provided an overview of Merino lamb and yearling sheepmeat eating qualities and explained how Merino breeders could tap into these opportunities by focussing on genetic advancement.

"The advent of DNA testing and Australian Sheep Breeding Values (ASBVs) has contributed to vast improvements to the growth, muscling and intramuscular fat (IMF) breeding objectives of producers," he said. "Better breeding objectives result in better genetics and better quality meat for the consumer."

Emily Anderson, Josh Molloy and Craig Wilson at the MerinoLink Conference.

Building on the principles of an integrated wool and meat sheep industry

The results of practically all of the original scoping studies indicated that there were many good opportunities for better integration of wool and meat production, without any radical departure from existing breeding programs, based on Merinos as the specialist wool breed and a range of Maternal and Terminal breeds. The industry trends over the 18 years confirm how successful this approach was.

While Australian wool production decreased significantly from just over 660mkg in 2000 to around 300mkg in 2019, the gross value of the wool was maintained through a dramatic increase in production of higher priced finer micron wools (18um and below). The main decrease was in the lower value broader micron wools (21 to 24um) (see Figure 3.4).

Without careful selection and genetic management such a significant change in wool fibre diameter would result in a reduction in wool production per head. However, average fleece weights were maintained at around 4.3kg/head throughout this period.

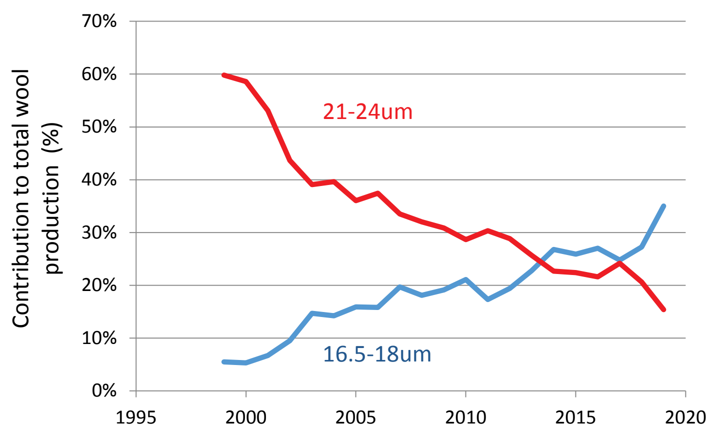


Figure 3.4: Changing percentage contribution to the Australian wool clip of finer diameter wool (18 um and below) and broader micron wools (21-24 um). Source: Data taken from AWI Wool Forecasting Report April 2019.

In the case of lamb production, MLA reports document increasing lamb turn-off during the reduction in flock size. There were around 18 million lambs slaughtered in 2000, increasing to 22.5 million lambs in 2019. Over this period, the average carcase weight also increased from just above 18kg to over 23kg. The combination of more lambs slaughtered and heavier carcase weights resulted in an increase in production from 300,000t in 2000 to more than 500,000t in 2019.

Further evidence of the integration of the sheep industry was the fact that reproduction efficiency increased (see Chapter 7) in parallel with the changes in wool production and increased lamb production. Well-balanced genetic selection and good nutrition were important factors contributing to these changes.

The combined results for lamb and wool production indicate that the transition to a highly productive sheep industry made very significant progress over the 18 years of the CRC. While many factors contributed to these changes, there's no doubt that the rate and extent of the change was assisted by the tools and research information developed by the CRC.

Cam Banks

FIND OUT MORE

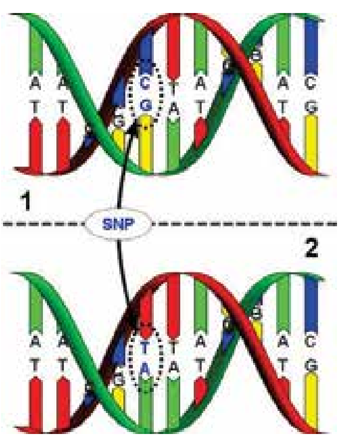
For more information on how the 'whole-of-sheep' strategy played out in specific areas of Sheep CRC research, go to:

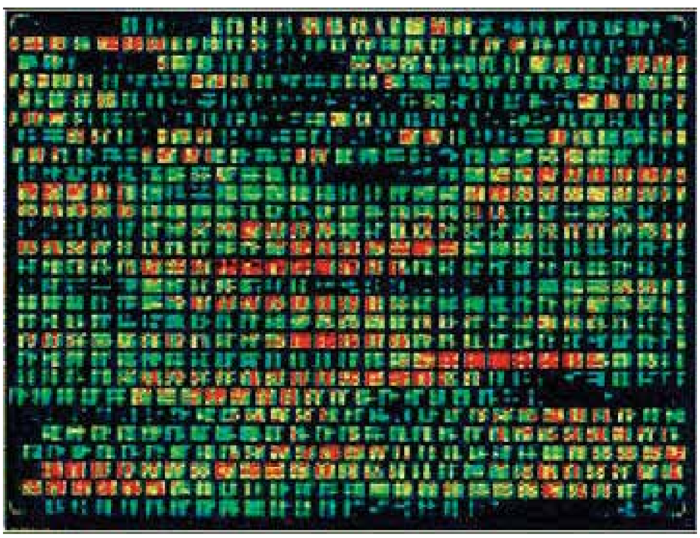
- Chapter 4 — Introduction of Genomic Technologies
- Chapter 5 — Managing Sheep Parasites
- Chapter 6 — Precision Sheep Management
- Chapter 7 — Transforming Sheep Wellbeing
- Chapter 11 — Implementing Innovation

4 INTRODUCTION OF GENOMIC TECHNOLOGIES

Improved prediction of the outcome of selection decisions was a core element of the Sheep CRC's portfolio from start to finish because it had the power to deliver faster genetic gains in industry flocks and set the foundation for more profitable sheep production.

From the outset, the CRC took on the challenge of developing more accurate estimates of genetic parameters and, in particular the genetic associations between wool, meat, reproduction and disease traits in animals, knowing that in turn this would lead to better prediction of the outcome of selection decisions and faster genetic gains in industry flocks. The major achievement was probably the introduction of genomic selection, allowing a change in the direction of the breeding program towards producing a better-quality product.





Advances in analysis of DNA created the opportunity to measure many thousands of single nucleotide polymorphisms (SNPs) in a single assay to provide the data for genome wide association analysis and prediction of genetic merit.

CRC1 — Setting the foundation and filling genetic gaps

At a time when genomic technologies were still in their infancy, the first step in implementing the strategic shift to 'whole-of-animal' genetic research was a comprehensive review of the world literature on genetic parameters for wool and meat production, product quality and parasite resistance traits. This was undertaken by a group of researchers led by Neal Fogarty during the early stages of CRC1 and has been described in Chapter 3.

This research delivered important early impacts for the CRC. By filling major gaps in world-wide knowledge, it provided more accurate genetic parameters for use by Sheep Genetics in their national evaluation programs, LAMBPLAN and MERINOSELECT. Improvements to the parameters allowed more accurate estimates of breeding values, faster genetic gain and better ability to balance the interactions between meat and wool breeding objectives. In addition, the new information was of value to many of the service providers in their role in the implementation of genetic improvement programs in industry.

Perhaps the most important feature of this project was that it initiated productive cooperation between five organisations — Departments in NSW, Victoria, South Australia and Western Australia and CSIRO — to combine datasets for the common goal of improved genetic parameters for the Australian sheep industry. This collaboration, and the results that it generated, made a major contribution to the design of the Information Nucleus program that was a central component of CRC2.

The delivery of the genetic parameter information to the industry was also timely as the genetic evaluations in Merinos that were previously somewhat scattered in different places and organisations were now combined into one MERINOSELECT evaluation, and the responsibility of the service was now combined with that of LAMBLAN in a new organisation called Sheep Genetics, which was jointly operated by MLA and AWI.

EARLY PROJECT LEADERS

- The 'whole-of-animal' genetic research collaboration was led by Neal Fogarty and Arthur Gilmour;
- Alex Safari was responsible for much of the Merino analyses;
- Veronica Ingham and Raphael Afolyan were responsible for coordinating the MCPT analyses;
- Johan Greeff made a major contribution through information on WA resource flocks and related analyses.

Leading on from the major review paper the project team published more than 25 papers on the research in high-profile international journals.

CRC2, Sheep Genomics and the first SNP chips

Genomic technology and genetic marker research became the focus of animal genetics research around the turn of the century and the Sheep Genomics Project, funded by MLA and AWI, aimed to capture the rapid developments in genomic technologies brought about by the first sequencing of the complete human genome in 2001. There were now large efforts to also sequence the genome of other mammalian species and in livestock that was the genomes of cattle, pig and chicken in the first instance, with sheep soon to come.

But the first Sheep CRC had existed alongside the Sheep Genomics Project and had largely stayed out of 'genomics' and focussed on the more classical approach of estimating heritabilities and correlations between sheep production traits. An exception was the excellent work by Belinda Norris, from CSIRO in St Lucia, Queensland. Belinda discovered the genetic basis of Agouti, the gene responsible for pigmentation in sheep — in other words 'black wool'. Unfortunately, the cause of this genetic 'defect' is a gene duplication, which cannot be easily tested by a simple genotype at genetic markers. DNA testing for this condition was therefore difficult to automate as the DNA-based methodology moved rapidly to the use of SNP chips.

Genomic studies shifted the focus from finding genetic markers to identify major genes for production traits, towards comparing genome sequences across species and understanding the function of certain genomic regions. Major genes with a large effect on quantitative traits are termed QTL (quantitative trait loci).

An important aspect of the Sheep Genomics Project was the mapping flock. This was a resource of 4,000 lambs born over two years (2005 and 2006) at AWI's Falkiner Memorial research station at Deniliquin, NSW. The lambs were the progeny of only 20 sires, hence large progeny groups were formed with the aim to do a proper QTL mapping study. At the time it was thought that to really identify these major genes with large effect, a properly designed experiment with a large number of progeny per sire was required. Many traits were measured on these animals in wool, meat and reproduction, and in a sense, this was a predecessor of the Information Nucleus Flocks and the Resource Flocks as we know them now.

During the Sheep Genomics Project a lot of basic biology of the main sheep traits was being studied, and a new method of measuring the expression genes was tested. At the same time, it slowly became clear in the genetics research community that few QTL were found that had a consistently large effect on traits in livestock. Towards the end of the Sheep Genomics Project in 2007, at the same time when the first SNP chips were coming out in livestock, a new method to use DNA information was gaining momentum. This method was termed 'genomic selection'. The idea was to use many genetic markers across the whole genome, rather than markers surrounding some specific QTL with a large effect. The first SNP chips that would allow the cheap collection of genotype information on so many markers were starting to be developed. It was decided to use the DNA samples from the Sheep Genomics Falkiner flock for that purpose, and to reserve a budget for analysing these samples with a sheep SNP chip.

Along with the genetic outputs from the Sheep Genomics Project — the Falkiner flock database and the associated set of DNA samples — came the expertise of the bioinformatics team at CSIRO in Brisbane. Under the leadership of Brian Dalrymple, they coordinated the development of the livestock genomics database containing the location and sequence around thousands of SNPs available in the genotyping tools, and later they played a big role in the development of the first sheep reference genome. The CSIRO group, in which James Kijas was a key player, was central to the International Sheep Genome Consortium, with scientists from New Zealand, the USA and Europe. This group coordinated the international effort to develop genetic markers from sequence information in sheep and from that information the first sheep SNP chip was developed. This ovine 50k chip contained more than 50,000 genetic markers (in the form of SNPs, single nucleotide polymorphisms) and was first produced by the Illumina company and launched in January 2009.

The Sheep CRC was not directly involved in the development of the 50k SNP chip, but together with the New Zealanders, the CRC became the first major user of this chip. Together with the 4,000 samples from the Falkiner flock, the first samples from the CRC's Information Nucleus Flock became the first batch large enough in size to allow the testing of genomic prediction in sheep.

INFORMATION NUCLEUS FLOCK OBJECTIVES

- estimation of genetic parameters (heritability, genetic correlations);
- validation of gene markers;
- estimation of management effects/treatments;
- estimation of genotype x environment interactions;
- prediction of whole genome selection and genotyping; and
- linking outcomes directly to industry breeding through enhanced ASBVs.

The Information Nucleus Flock

The first Sheep CRC's work focussed mainly on estimating genetic parameters for sheep traits from historical data. While this was a very useful exercise, it was clear that no information was available on 'new traits'. For example, there was little known about the variation that existed in Australian lambs for meat quality traits such as lean meat yield, intramuscular fat, meat colour, and nor was there much known about the nutritional components of lamb such as fatty acids, and minerals.

Robert Banks from MLA, influenced by various other people including Dave Pethick, Julius van der Werf and John Gibson, was the main proponent of developing a large dataset that would allow estimation of genetic parameters for a lot of new traits related to sheep meat. Such a dataset could also serve to collect traits other than meat — e.g. in wool and reproduction. A good dataset would measure such relationships in the main breeds used in Australia, but a wide variety of genetic lines would need to be tested to obtain a clear picture of the genetic variation that was available for selection.

Therefore, the main idea of a CRC rebid in 2006 was to set up a large dataset that would inform many future selection decisions in sheep. This concept was termed the Information Nucleus for sheep, and the Information Nucleus Flocks (INF) were set up across eight different sites in Australia (see Figure 4.1). Each year, nearly 5,000 ewes were mated by artificial insemination from a total of about 100 sires from Terminal, Maternal and Merino breeds. The sires were chosen to represent the genetic diversity of the Australian flock in order to test a wide range of the genetic resources. The design of the INF, where each year there were approximately 40 progeny born from 100 different sires, was suitable to estimate genetic parameters for traits measured in all animals. No other pastoral livestock industry anywhere had attempted such a comprehensive and coordinated system for genetic improvement.

Of the sires used, 40% were Terminal (mainly Poll Dorset and White Suffolk but rams from some smaller breeds were also used), 40% Merino and 20% Maternal. The Terminal sires were mated to 50% Merino dams and 50% Border Leicester x Merino crossbred dams. So, of all matings, about 40% resulted in pure Merino offspring (from superfine wool to broader wool types) and the remainder of progeny were all crossbreds. This distribution closely reflected industry practice in lamb production. By the end of the five mating rounds from 2007-2011, about 18,500 lambs were born and slaughter information on about 10,000 lambs had been collected.

It is important to emphasise the importance of the electronic data collection technologies that were fundamental to the success of the program, and the fact that they were largely developed during CRC1. A major activity at the start of the Information Nucleus program was to train the technical teams at each of the Information Nucleus sites to use the electronic data collection equipment and then prepare the data for submission to the database. Developing the complex protocols and standardised methodologies was a major challenge as there was a wide range of measurements and numerous organisations involved. Regular meetings of the technical teams were organised to share expertise and experience. An essential part of the data collection was its management and checking by Klint Gore who set up the database and managed it throughout the Information Nucleus program.

The commercial focus of the CRC2's skills-based Board was also important to the success of the program. The Board's policy of only paying the site teams for data collected according to the protocols, and submitted within tight time-lines, was not popular but ensured effective and timely data collection.

One of the first outcomes of the CRC work was the development of a new breeding value for breech cover. The CRC data showed that it was quite heritable, and a breeding value was launched in 2008. This was a major and timely development given the level of public discussion about the phasing out of mulesing.

Soon, interesting genetic parameters for meat quality traits were also produced. One of the main outcomes was the negative correlation between growth and lean meat yield with intramuscular fat and tenderness. It appeared that the current selection path in LAMBPLAN, with a strong focus on growth and lean meat yield, was going to drive down the meat quality of lamb. The industry responded strongly to this message and within a couple of years a new selection target had been developed with a new eating quality index. By changing the emphasis towards eating quality traits, and with the help of genomic selection, a negative trend could be turned around.

During the five-year duration of the Information Nucleus program, the CRC Board visited each site for high-profile industry meetings where local breeders and producers were invited to discuss the program and its results. These meetings helped to create awareness of the program and the role of the CRC in managing this coordinated national research initiative.

2008

LAMBS EMERGE FROM 'WORLD FIRST' RESEARCH

The first draft of prime lambs from the Information Nucleus had their vital carcase quality statistics measured.

The INF provided a whole new set of information to the entire lamb industry supply chain, collecting information including weight, muscling and fat as well as new consumer-orientated eating quality traits, such as for tenderness, intramuscular fat (marbling), iron, zinc and fatty-acid composition. All of these lambs were genetically linked — through common sires allowing the CRC to account for environmental and genetic variations.

Fully utilising data from the Information Nucleus Flock was a high priority. The Sheep CRC Executive worked with researchers in all Participant organisations to develop discussion papers using data collected as part of the Information Nucleus program. This helped to coordinate the information published on the research program. The quality of information and the range of scientific papers published using Information Nucleus program results was most impressive. Special editions in the journals *Meat Science* and *Livestock Production* were made possible through the range and quality of the data.

Reflecting on the effective way that the Information Nucleus data was shared across disciplines and institutions to stimulate the amount of research analysis and publication provides an excellent example of the benefits of collaboration and of shared data usage. The Information Nucleus data is likely to continue to be a valuable research and development resource for many years to come.

DESIGNING THE INFORMATION NUCLEUS

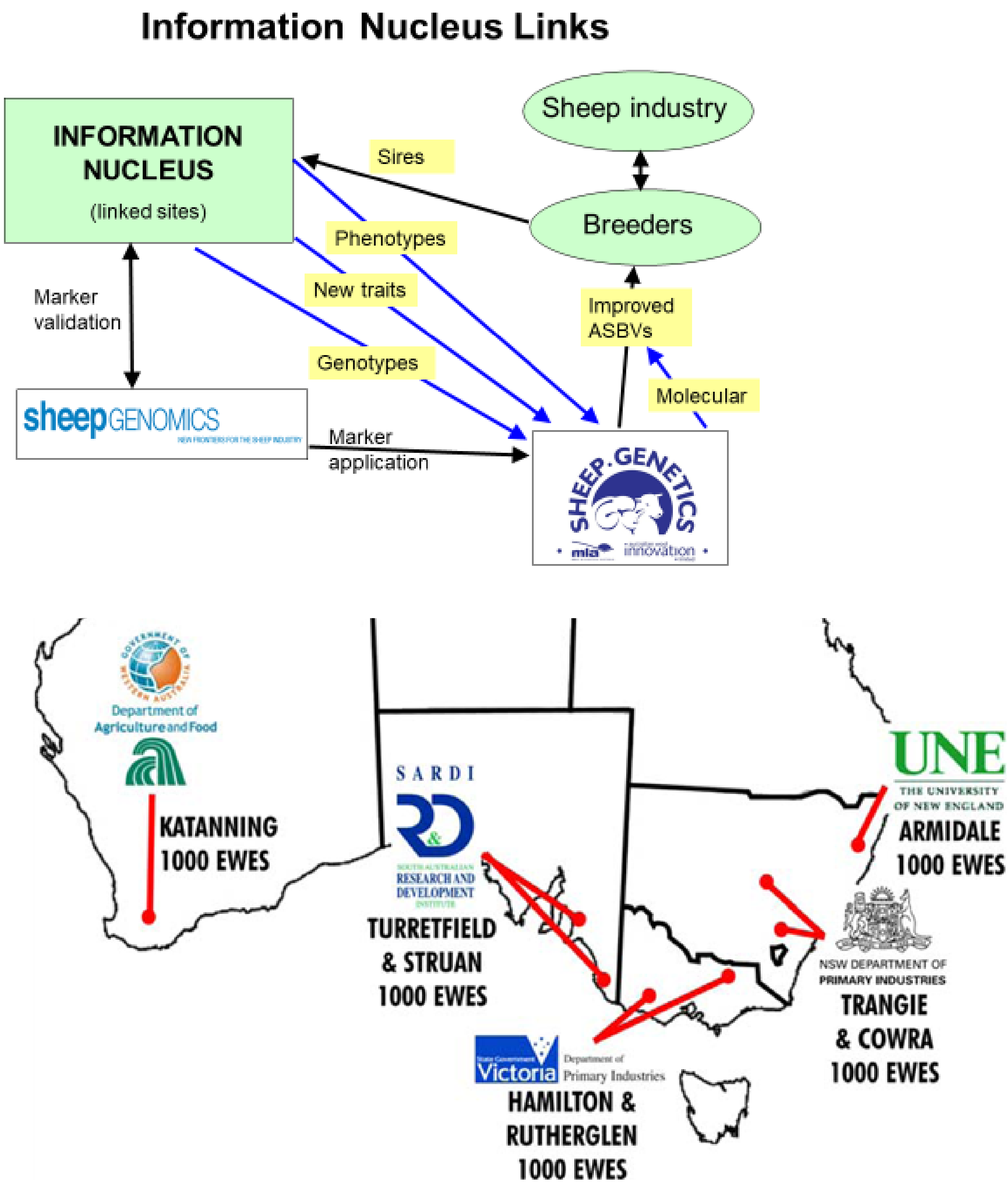


Figure 4.1: The logistical challenges included coordinating eight sites: NSW (Cowra, Trangie and Armidale), Victoria (Hamilton and Rutherglen), SA (Turretfield and Struan) and WA (Katanning), which covered the spectrum of sheep environments in Australia. They were also required to follow precisely consistent management, measurements and data recording protocols, and use e-sheep technology.

At the coal-face of the Information Nucleus

- Given the scale and complexity of the task, implementing the ambitious Information Nucleus program was no mean feat.
- Neal Fogarty was the initial coordinator of the program.
- Neal worked closely with Ken Geenty to organise the logistics and the detailed documentation of measurement protocols.
- Ken Geenty coordinated the data collection and worked in collaboration with Klint Gore to set up the database.
- Selection of sires was led by Alex Ball, with breeders supplying frozen semen.
- The technical teams at each of the eight research stations made a major contribution to the success of the program.
- Training activities were supervised by Steve Semple who was involved in developing the electronic data collection systems during CRC1.

Genomic Selection

An important aim of the Information Nucleus project was that, in the first instance, it was designed to estimate genetic parameters for new traits, but it was clear from the start that the same resource could be used for genotyping, therefore creating a large dataset where phenotypes and DNA markers could be analysed and used to test the concept of genomic prediction and selection.

Genomic selection was still in the very early stages of development in 2006 when the INF was designed. A theoretical paper introducing the concept of genomic selection by Meuwissen, Hayes and Goddard was published in 2001. The paper noted that 'recent advances in molecular genetic techniques will make dense marker maps available and genotyping many individuals for these markers feasible'.

The first SNP chip in dairy cattle was launched around 2005 by Affymetrix and contained 10,000 markers. This was the tool used by the Dairy CRC. By the end of 2007, the first Illumina chip with 50,000 markers became available for cattle, and the main scientist behind that development, Curt VanTassel from the USDA, was invited to speak about it at the Armidale meeting of the Association for the Advancement of Animal Breeding and Genetics (AAABG) in September 2007. The first SNP chip for sheep became available towards the end of 2008 and by June 2008, the Sheep CRC's Julius van der Werf wrote a paper with Ben Hayes and John Henshall for the CRC Board with the following information.

> *A whole genome SNP chip for sheep is expected to be available around October 2008, allowing genotyping of an ovine individual for 60,000 SNPs. This is a research chip and the cost of genotyping one animal with a SNP chip will be ~$270 (including the chip, genotyping, DNA extraction and handling). The SNPs have been developed through the International Sheep Genomics Consortium (ISGC). The chip will be available from Illumina, but all information about building this chip is in the public domain.*

The Sheep CRC purchased 3,648 chips for genotyping of INF animals and the Sheep Genomics Project purchased 4,848 chips — 4,200 to genotype animals from the Falkiner flock, and 648 to genotype industry sires with accurate ASBVs. The industry sires were used as a validation dataset. Their estimated breeding values were very accurate, so by simply correlating genomically predicted breeding values with the accurate EBVs, the research team was effectively able to measure the accuracy of the new genomic breeding values.

The interesting observation here was the initial cost of SNP chip testing, and especially the high cost of DNA extraction and genotyping. Initially, DNA extraction was done in Australian labs, and the extracted DNA samples were sent to Nebraska to be genotyped by the Geneseek company. The cost was considerably less than the figure used in the planning of the CRC in 2005, when it was expected that the genotypes generated by a SNP chip for one sample would cost around $500. So, the chip turned out to be cheaper than initially expected, although it did not help that the Australian dollar collapsed against the American dollar around that time. It turned out that 10 years later the cost of SNP chip genotyping had become nearly 10 times cheaper.

The first genotyping results were available in 2009 and the first paper to describe results appeared in 2010 in Animal Production Science: 'Accuracy of estimated genomic breeding values for wool and meat traits in a multi-breed sheep population', with Hans Daetwyler as first author and DPI Victoria, UNE and CSIRO as the contributing institutions. More than 7,000 genotyped samples were used in the analysis.

The reported accuracies varied from 0.05 to 0.70, depending on the trait and the breed. The highest accuracies were obtained in Merinos, but it was soon clear that it mattered whether accuracy was determined within or across the various Merino types. In other words, the DNA test could predict very well where a Merino sheep would rank for its fibre diameter or fleece weight when considering the complete Merino population, but ranking correctly within their own Merino type was more difficult. Further theoretical work was done to understand the accuracy of genomic predictions, and we found that not only the size of the reference population was important, but also the relatedness of an animal to the reference population was a strong determining factor.

Now that it was possible to predict breeding values from a genomic test, it became relevant to use this information in the sheep genetic evaluations delivered through Sheep Genetics. This was first achieved during 2011, when genomic breeding values were combined with the usual ASBVs that were based on pedigree and performance information. These two sources of information were combined using a relatively simple blending method. It was important that these sources used independent datasets, as otherwise the best sires would be greatly over predicted, and their estimated breeding values would likely drop if they had progeny data.

In New Zealand, the reference population was based on the common progeny testing scheme and it was hard to separate genomic predictions from pedigree-based predictions. The relative independence of the Australian INF made it much easier to provide unbiased blended breeding values. However, the introduction of the new predictions was initially carefully orchestrated and these blended breeding values were called 'Research Breeding Values', to protect the integrity of the ASBV, just in case something went wrong in these genomic predictions. However, this term was later dropped when it became clear that genomic testing was reliable, but only one of several possible sources of information, for predicting ASBVs.

Industry implementation

Now that genomic testing was feasible and could be included in the genetic evaluation, it became relevant to implement the technology in industry. By 2011, the cost of genotyping had been reduced to about $100/test. This was due to the ongoing use and development of the technology and a much-improved exchange rate for the Australian dollar.

A price of $100 was considered too high for sheep breeders and the Sheep CRC decided to start a pilot project where breeders could genotype their animals for $50 — i.e. half of the cost was subsidised. This pilot project allowed breeders to obtain some experience with the technology and to initiate and develop the pipeline for commercial genomic testing. DNA samples were collected on-farm on a specially developed blood card, which was sent to the Geneseek Laboratory in the United States for processing. The genotype data was then sent back to the CRC database and turned into genomic predictions to be merged with the Sheep Genetics evaluations.

In the meantime, the CRC had also developed a 'commercial' SNP chip that had only 12,000 (12k) markers and this became available in 2012. This smaller set of markers could be genotyped at a lower price, while effectively providing the same information — the markers that were not genotyped could be predicted by imputation using the 7,000 samples that had been genotyped for the full set of 50k markers. The new test was called the low-density SNP test or the 12k test and could be made available to breeders at an unsubsidised cost of $50.

By this stage modelling studies showed that more genetic gain could be obtained when applying genomic selection in sheep. In general, traits that are hard to select — i.e. the traits that are difficult to measure — could benefit greatly if they could be predicted based on a DNA test. Carcase and eating quality in meat sheep and lifetime wool, parasite resistance and reproductive performance of Merino ewes were the obvious targets of genomic selection. Quite a few breeders enthusiastically embraced genomic testing, although in the first instance they were more excited about genomic breeding values for new traits such as IMF (intra-muscular fat) and LMY (lean meat yield) than the fact that they obtained somewhat more genetic gain overall. The development of these new eating quality breeding values and indexes has assisted the industry arrest a decline in eating quality and in some cases created new product opportunities around high-quality meat value. These achievements were made possible through a very successful long-term collaboration between the meat scientists, the geneticists and Sheep Genetics, all facilitated through the CRC.

2009

RAMPING UP SHEEP INDUSTRY GENETIC POWER

Productivity improvement in the Australian sheep industry was recast by linking the three platforms of Sheep Genetics, the Sheep Genomics Program and the CRC's Information Nucleus Flock. Together they provided the infrastructure for ramping up the power of genetic improvement on key traits. For the first time, a DNA sample taken at birth could be used to predict an animal's genetic merits without the need for extensive, time-consuming progeny testing.

2012

SHEEP CRC TAKES CRCA INNOVATION AWARD

The CRC was recognised for its exceptional work in the area of genetic improvement for the sheep industry for its Information Nucleus program. It was awarded an Inaugural Australian Collaborative Innovation Award in the category rewarding significant innovation in the area of agriculture and food. Collaboration with industry was a key element in the success of the Information Nucleus, with more than 75 researchers and 18 organisations involved in this program throughout Australia.

The level of uptake was quite rapid. In the first years, a couple of thousand animals were genotyped by breeders each year. Julius van der Werf undertook some modelling of genotyping strategies and came up with the '20% rule', suggesting that genotyping the top 20% of the males was a good strategy to have, almost the maximum benefit of genomic selection for only a fraction of the cost of genotyping a whole drop of males and females. Most breeders that ventured into genotyping tested fewer animals. Some only tested the sires they were going to use anyway, somewhat defying the purpose of genomic selection, but perhaps benefiting from the marketing effect of having DNA tested sires with breeding values for new traits.

Towards the end of CRC2 in 2014, genomic testing had been successfully implemented in the Australian sheep industry as 'genomically enhanced breeding values', albeit at lower accuracies than in the dairy industry where the reference populations were much larger. There was a realisation that a large reference population was a key to accurate prediction. Although the INF had produced 18,500 lambs, they were not all measured for all traits, and more importantly they were from several breeds. Since information from other breeds turned out to be not very useful in genomic prediction, there was a realisation that large reference populations were needed for each breed, at least for each of the major breeds. Therefore, the reference populations formed by the Falkiner Flock and the years of INF were not going to be enough in the long term.

The industry well understood the importance of a resource flock such as the INF. MLA supported further matings of the Resource Flock in 2012 and 2013 and in 2014 MLA decided to support a five-year Resource Flock program to follow the INF. This flock was based on the same principle as the INF, but now only at two sites (Kirby and Katanning) and more sires were tested each year (150) with fewer progeny per sire, aiming for about 2,000 slaughter lambs per year. Unfortunately, wool and reproduction traits were no longer measured as AWI decided not to co-fund the Resource Flock with MLA. To help in part to fill this void the CRC collaborated with Sheep Genetics and industry ram breeders to genotype animals with good on-farm phenotypes for hard to measure traits like reproduction and worm egg count. This has helped inform genomic breeding values and flock profile predictions.

From RamSelect to ramselect.com.au

Given the scale of investment that the CRC was making in the Information Nucleus program, and the significance of the results being generated in terms of their potential impact on the Australian sheep industry, the Board determined that more effort should be directed to the uptake and utilisation of genetic information.

One of the criticisms of the delivery model through Sheep Genetics was that only a relatively small proportion of Merino breeders were members of the Sheep Genetics MERINOSELECT program. The CRC therefore undertook to work with Sheep Genetics and its other Participants to develop a strategy to increase the membership of MERINOSELECT.

In 2010, the CRC commissioned a comprehensive needs analysis, supported through co-funding and expertise from Agrifood Skills Australia and input from MLA, AWI and Sheep Genetics. The aim of the market research was to understand the impediments to more widespread utilisation of Australian Sheep Breeding Values (ASBVs) by ram breeders and buyers. The analysis produced recommendations including better definition of the value proposition for using ASBVs; development of training and support programs; and the need for easy-to-use intuitive tools that simplified the process of effectively utilising ASBVs in ram-buying decisions, which many producers found to be a difficult and/or complex process.

One of the first tasks was to clearly define the value proposition for the sheep industry to adopt the use of ASBVs to facilitate faster genetic gain. The CRC commissioned Anne Ramsay to collate all available information demonstrating the benefits of using ASBVs to predict genetic merit. This study provided comprehensive evidence in support of the findings of Swan et al 2009, indicating that best practise use of ASBV information had the potential for cumulative genetic gain of around $2/ewe/year, which had been realised in the Terminal breeds, but this compared to an average genetic gain of around $0.70/ewe/year in the Merino breed. The implications associated with these differences in genetic gain were analysed by Rowe and Banks (2015) and again confirmed the significant benefits for individual producers and the industry as a whole, associated with using ASBV information effectively in ram-buying decisions.

RAMSELECT WORKSHOPS

The main activity in response to the needs analysis, was the creation of the RamSelect training program delivered to more than 3,000 producers between 2012 and 2015. The impact was impressive and is seen in the increasing membership of MERINOSELECT during this period (see Figure 4.2). The training workshops were supported by a well- coordinated media campaign that included numerous case studies as well as promotion of the workshops.

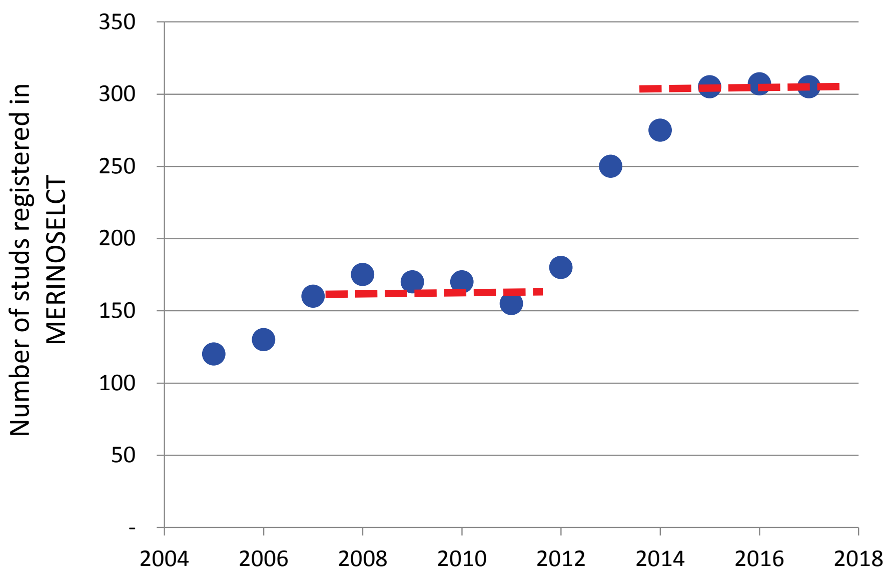


Figure 4.2: In 2010 the Sheep CRC commenced planning a campaign to increase the use of ASBVs by Merino ram breeders and their commercial clients. The RamSelect workshop program commenced in 2011 under Lu Hogan's leadership and ran through to 2015 when the web-based app ramselect.com.au was launched. Introduction of the app largely replaced the need for the workshops and continued the momentum.

Despite the success of the RamSelect training program, feedback from participants was that using ASBVs in ram-buying decisions remained a complex task. In addition, the high cost of delivering the course, to relatively small groups, was unsustainable as an on-going activity. An alternative approach was needed to assist producers to undertake the complex task of identifying suitable rams. The answer came during CRC3 with the development of the RamSelect app. Building the app with this objective was essentially an experimental pilot project to determine if the approach would be effective.

Before commencing work on developing the app to assist ram buyers using ASBVs, a team of experts at Pivotal Laboratories based in San Francisco first conducted an independent evaluation of the need for such a product. Once the need and potential value of such an app was established, the new tool was developed with significant involvement of end-users. The involvement of producers in the design and development phases was crucial to the success of the app.

Developed during 2015, the RamSelect app quickly achieved its objective of reducing the need for the RamSelect training program. Since its launch there has been very little demand for further training events as use of the app became widespread. More than 15,300 rams were listed for the 2016–17 ram-selling (an increase of 28% compared to the same stage in 2015–16 selling season) and in excess of 5,000 searches conducted. At the end of its first season of use, the app was used by nearly double the size of the audience reached during four years of workshop delivery.

As a 'concept' product, the app was delivered free to industry by the CRC during 2015 and 2016. The widespread use of the app and the fact that it was used in transactional decision making indicated there was likely to be a commercial market for ramselect.com.au. It was recognised that maintenance and delivery of the app would require ongoing funding and that a commercial revenue stream was likely to be the most reliable mechanism to ensure its sustainable delivery.

The CRC reviewed the options of commercialisation for RamSelect through the Australian Innovation Company (AIC), or to undertake further development of the app with a 'pilot scale' commercial delivery on a cost-recovery basis. Introduction of a fee for listing rams in 2018 acted as a clear deterrent reducing use by around 25% but established the fact that RamSelect could be run on a cost-recovery basis. Based on the level of usage, and the links between RamSelect and the ASKBILL app, UNE developed a commercialisation plan for the RamSelect software and provided an undertaking to maintain and deliver the app post-CRC.

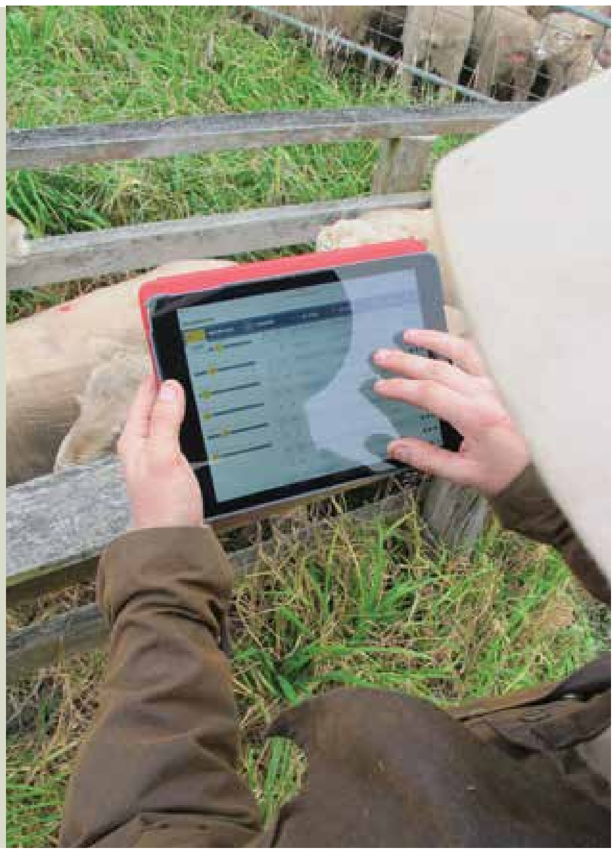
2015

RAMSELECT CHANGES THE GAME FOR SHEEP GENETICS

The web-based selection tool, www.ramselect.com.au, was launched to industry at a special event at Telstra's Sydney offices, forever changing the way ram buyers select the genetics they need to bolster production and profit.

RamSelect was developed by the Sheep CRC in conjunction with Telstra and Pivotal Labs in San Francisco, one of the leading software development companies in the world. The NSW Department of Primary Industries also provided expertise from the initial concept to the final product.

It was the first time commercial sheep breeders were able to select rams using Australian Sheep Breeding Values (ASBVs) without a detailed understanding of the data.



Parentage testing

Another important DNA tool introduced by the CRC was the parentage test. Based on parentage SNP lists developed by the International Sheep Genomics Consortium (ISGC), three panels were selected, each of 60k SNP markers, to form a 180 SNP panel. The cost of a parentage test was initially $17. The hope was that the parentage test could be delivered for less than $10 based on various new technologies that were becoming available.

Genotyping by sequencing was one of those promising technologies, potentially able to genotype 1,000 markers for just $5. However, at the end of the day, the alternative technologies were less reliable than hoped and costs of sample handling and reporting of results as well as reliability needed consideration.

Geneseek, which in the meantime had been bought by Neogen, was actively exploring new technologies for cheap genotyping. The chip technology was deemed the most reliable and by 2017 a chip-based parentage test became available based on 800 SNPs, albeit for a slightly higher price of $21. The parentage panel also contained single gene tests such as some well-known genetic defects (Spider lamb), or major genes (Myostatin or double muscling).

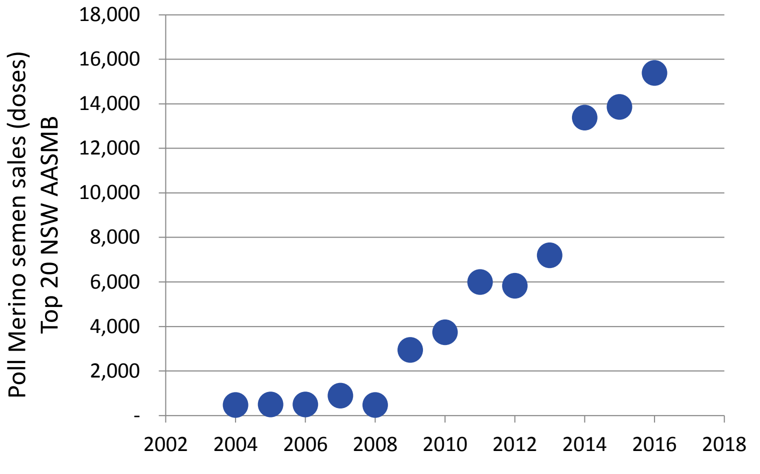


Figure 4.3: Increase in the sale of Poll Merino semen following introduction of the DNA test for horn-poll status (Source – NSW AASMB Top 20 List 2018).

The most important single SNP test was for horned/polled and this was also based on a SNP that was found by the Sheep CRC. Although the SNP was in a well-known area of a gene associated with polledness, it was not the same marker as described in other sheep populations, illustrating that it was useful to test a marker in the breed where it would be used. Another major-breakthrough was the quantitative understanding of how the polled gene is expressed differently through males and females. The impact of the accurate genomic test for horn/poll has been dramatic. Confidence in the genomic test sales of poll-ram and their semen continued to increase rapidly (see Figure 4.3). The long term industry benefits in animal welfare and occupational safety will be very valuable.

The human value of genomic testing for horn/poll

The number of polled Merino rams increased dramatically as a result of the introduction of DNA testing, as producers embraced the workplace safety and animal welfare benefits of hornless sheep.

Although early results were available from 2009, the Sheep CRC first commercially released its Horn-Poll DNA test in 2012, following several years of trials with producer participants. The number of polled rams sold and the volume of semen sales from polled rams began to grow dramatically at that time, as producers sought out breeding stock that were safer and easier to handle than their horned equivalents.

The 'Top 20' studs identified in the NSW Stud Merino Breeders Association publication 'Top Sire 2017–2018' reported sales of 16,000 doses of semen from polled rams in 2016, up from less than 1,000 in 2008, and almost 5,000 polled rams were sold in 2016, up from approximately 1,500 in 2008.

It was clear that commercial sheep breeders wanted polled rams, but they needed more information than the physical absence of horns before investing in polled semen or polled rams. This was due to the fact that many polled rams are carriers of the recessive horn gene — so the genomic test was essential to driving this change in the Merino industry. The test for the horn gene is based on a set of markers that are close to the gene and when using PP tested rams there is a 97% probability that male progeny will be free of horns and a 99% probability for female progeny.

EMBRACING PURE-POLLED GENETICS

Western Australian mixed farmer Rob Egerton-Warburton is a participant in the Merinotech breeding group, which took the decision to embrace pure-polled genetics in 2014 and since then has almost completely removed the horned gene from its flocks.

"We made the decision to transition to a polled flock once the technology became available and we could be sure that the genetics we were selecting wasn't going to take our flocks backwards or retain any horned genes — before DNA testing that transition would have been hit-and-miss," Rob said in 2018. "The DNA testing for horn-poll and a range of other genetic traits has been the key to making that transition without too much disruption to our breeding program."

He said the technology has also made the farm a safer place for both workers and animals.

"From an OH&S point of view, polled rams are much easier to handle in the race and this is really important for the safety of our workers and for our animals at a time when finding experienced stockmen is quite difficult," he said.

"While we still see some flystrike as a result of polled rams fighting and opening each other up, the damage is nothing like what it was with horned rams in the flock. In the past we had to keep our horned rams apart from the polled rams because they had such a significant advantage when they fought — now our rams are left to their own devices.

"We also used to have to remove the tips of the rams' horns each year — that was a terrible job and rams used to get caught in the fence with their horns and it wouldn't take long on a hot summer's day for them to lose their life. We were able to transition away from all of that very quickly through DNA testing."

Rob Egerton-Warburton

CRC3 — Accelerating adoption and impact

The final five-year term of the CRC began with the accuracy of using DNA data to predict breeding values moderately high (between 0.20 and 0.50), and with the price of genomic testing around $50/test. With these levels of accuracy and cost of DNA testing there were well defined benefits for sheep breeders using the new technology to achieve faster genetic gain.

However, the genomic testing (based on 50k SNP-chip data) did not allow prediction for animals that were genetically distant from the reference populations. Denser marker information, such as that provided with high-density SNP chips and full-sequence information, was expected to improve prediction over a longer genetic distance to unrelated animals and also maintain better prediction accuracies over time.

The goal of the proposed research program for the final five years was to increase the reliability of genomic predictions in sheep and at the same time to reduce the cost of DNA testing to breeders. Julius van der Werf developed the research program with Ben Hayes who had already undertaken similar work in the Dairy CRC. The program also set out to develop new designs for breeding programs to ensure that breeders were able to capture the full benefits of the new technologies.

The 'bio-bank' of DNA stored from the Information Nucleus program provided an invaluable and globally unique resource for assessing the value of full-sequence DNA analysis. Research on full-sequence databases at that stage was a relatively new field of science and close collaboration with the Dairy CRC was planned, as this group was in the process of evaluating full-sequence data for a large number of dairy bulls. The collaboration also extended to a range of international groups with expertise in this area.

Cheaper genotyping methods in the area of plant breeding provided some encouragement that methods such as genotyping by sequencing and other new technologies may help to reduce the cost of sheep genotyping and make the value proposition for using the new technologies more attractive for ram breeders.

2015

WORLD QUEUES UP TO LEARN FROM AUSTRALIA'S ANIMAL GENETICS PROGRAM

Some of the world's leading animal geneticists, as well as the next generation of researchers, attended a Genetics Summer School in Armidale, NSW, to learn from leading scientists about the latest methods in genetics research. The summer school was hosted by Julius van der Werf, leader of the Sheep CRC Information Nucleus Program, and was attended by more than 50 scientists and researchers from Australia, New Zealand, the United Kingdom, Mexico, The Netherlands, Philippines, Brazil, Korea, Egypt and France.

BREEDING IN A HURRY - THE ANDREW MICHAEL STORY

Leahcim was a very handy South Australian racehorse in the 1920s. "He was a good safe bet," says Andrew Michael. In fact, the horse belonging to Andrew's grandfather, helped them buy a farm.

Andrew Michael

So, when the Michaels' established their Merino stud in 1983 at Snowtown in South Australia's Clare Valley, they named it Leahcim hoping for the same safe returns and they haven't been disappointed. Forty odd years later, the Leahcim Poll Merino Stud is among the nation's top performers in genetic advancement and more importantly for the Michaels', in topping the ram sales. In September 2016, the Leahcim stud sale from an offering of 200 achieved a complete clearance and an average $2,800. Their 730 flock rams were also cleared in seven weeks.

For Andrew and his wife Rosemary and sons, Luke, Stewart and Alistair this was no gamble, but rather a big investment in technology and a trust in science.

For someone who has no tertiary qualifications having left school after year 11, Andrew has a magnificent understanding of genetics and the latest breeding technologies.

Andrew's quest to breed a better Merino began in 1995 when he took control of the stud and called in Jim Watts, the former CSIRO livestock research scientist turned sheep classer. Jim promoted the selection concept that a Merino with a soft rolling skin was more productive than a sheep with a thick tougher skin. Andrew was immediately convinced after Jim classed out two thirds of the 600 Merinos based on the Green Ridge bloodline. The 200 selected ewes with the softer skins were two to three microns finer and cut a heavier fleece. Andrew said the rationale was that a sheep with tougher skin had a higher energy requirement to produce collagen.

But Andrew was not about to rest on his laurels. Having seen the genetic gains achieved by the LAMBPLAN measurements in his White Suffolk stud, he saw no reason why the same disciplines couldn't be applied to his Merinos. In 2002, Leahcim was one of the first Merino studs to sign up to MERINOSELECT - the Merino equivalent to LAMBPLAN. Fleece weight, fibre diameter and liveweight were among the initial measurements.

In 2005, Leahcim rams were included in the $30 million five-year Sheep Genomics program for identifying DNA markers. The program, funded by Meat and Livestock Australia and Australian Wool Innovation, involved the mating of 4,400 ewes at an AWI research station at Conargo, NSW. Semen for the program came from 15 commercial sires which were trait leaders for fertility, parasite resistance, muscle or wool characteristics.

From this work Andrew and the geneticists developed a healthy respect for each other's work. That respect spilled into the Sheep CRC and its program, particularly with the Information Nucleus Flock, where extensive DNA testing was used to find and validate correlations between gene markers and Australian Sheep Breeding Values.

Andrew was one of the Sheep CRC's strongest supporters and just about every technology the CRC researched was either used or adopted in the Leahcim stud.

Included among those technologies is a JIVET (juvenile in-vitro embryo transfer) program, whereby eggs can be extracted from a ewe lamb at about 6–10 weeks of age. These eggs are then fertilised with semen from top quality ram lambs. In both instances the donor ewe and ram lambs have been DNA tested and carry trait leading breeding values. The fertilised embryos are then transplanted into surrogate mothers. At Leahcim most of the surrogate mothers are older Merino ewes. The net results of the JIVET program are that in a space of six months a new drop of high-performance lambs are on the ground, whereas traditional breeding methods would have taken up to two years.

Another of the CRC technologies used in the Leahcim Merino stud was the Pedigree MatchMaker program for identifying which lamb belongs to which ewe. The absence of full pedigrees has been the bane of the Merino stud industry. Because many Merino stud ewes are run in large mobs on broad to sparse areas, the task of matching ewes and lambs was either nigh impossible or too costly in time and effort, particularly when trying to match by drifting ewes and lambs around yards.

The Pedigree MatchMaker program involved monitoring electronically tagged ewes and lambs as they passed through an electronic scanning raceway. The theory is that when ewes and lambs are left un-herded, individual lambs will stay close to their mothers when walking, particularly to a watering point. Proponents of the system say that over several weeks of scanning, 85–95 percent of ewes and lambs can be matched.

Andrew said he used the system over several seasons but found it difficult in the drier times when ewes and lambs had to walk longer distances.

Accordingly, Andrew switched to a pedigree program using DNA testing to provide 100% matching. He regarded the DNA test as an investment in genetic improvement rather than a cost.

"You can't achieve real genetic gains unless you know the full parentage of a lamb."

All of the Leahcim sheep go through a visual classing including a score for breech wrinkle. The sheep also undergo a laboratory test to identify the soft rolling skin characteristic. Traditional measurements are taken for micron, staple length, staple strength, and fleece weight, while the Michaels' also measure for fat depth, eye muscle area and growth rates. All of these measurements are used in assigning Australian Sheep Breeding Values (ASBVs). Measurements to improve meat eating quality such as intramuscular fat and shear force of the eye muscle were also added to Leahcim ram catalogues. Buyers attending the Leahcim Merino ram sales have a catalogue with no fewer than 28 measurements for a range of features.

Andrew makes no apology for the abundance of information.

"This information and technology is driving the clients to our sales. The days of feeding and housing sale rams are over, not that we ever did."

He estimated that 90 per cent of buyers before they got to the 2016 sale had made up their minds, based on the figures, as to what rams they would be buying.

CRC3 – GENETICS PROGRAM

The main research activities focussed on full-sequence genomic information to better predict breeding values for a range of animals including predictions for animals not closely linked to the Resource Flock and for minor breeds. There was close collaboration between groups based in Armidale and Melbourne.

The Armidale team, involving:

- Julius van der Werf
- Andrew Swan
- Daniel Brown
- Sam Clark
- Nasir Moghaddar
- Naomi Duijvesteijn

worked with the Melbourne team initially led by:

- Ben Hayes
- Hans Daetwyler
- Iona McLeod
- Amanda Chamberlain
- Bolormaa Sunduimijid
- Majid Khansefid

A second research activity, led by Tom Granleese, examined options for new breeding program design and exploiting the use of genomic information to make faster genetic gain.

This work involved close linkages with breeders, consultants and Sheep Genetics to ensure a high level of engagement and interaction. Sally Martin and the MerinoLink group were important collaborators, assisted by the MLA Donor Company co-investment.

Hans Daetwyler, Jason Signolet and Julius van der Werf

The third focus was identifying opportunities for cheaper genomic testing and faster turnaround of results. This work involved liaison with Neogen through Jason Lilly and with the CRC's DNA testing service coordinated by Lu Hogan and Bec Macarthur-Onslow.

Full-sequence information

At the start of CRC3 the decision was made to experiment with denser marker panels. Prediction across breeds was probably not working because the SNPs on the chips that were used were not close enough to the actual genotype that caused the QTL effect. Technically speaking there was not enough 'linkage disequilibrium'. A high density (HD) SNP was developed by the ISCG with more than 500,000 SNPs and this became available in 2013. This chip was mainly used for research purposes, and lower density genotype data could be imputed to a higher density. However, it turned out that the HD panel did not give a large improvement in prediction accuracy, except for animals that were lowly related to the reference population.

In the meantime, obtaining a full-sequence of the complete genome, consisting of 3 billon base pairs, became increasingly feasible. The cost of sequencing in the Human Genomic Project in the 1990s was several billion dollars for six sequences. By 2014 it was possible to obtain a sequence for about $3,000. Full sequencing was rapidly becoming more affordable and several research groups started to sequence key sires in their populations. Sequence information was theoretically sure to contain the actual mutations that cause the effect that breeders wanted to select for — if they could be found, then genomic selection should become more accurate, and importantly, information from other breeds could be used as well. The Sheep CRC extension bid (CRC3) proposed to undertake full sequencing in order to make genomic selection more accurate, more affordable and more sophisticated. It was a robust proposal that fitted exactly in the development phase of the technology, as well as the implementation phase of genomic selection in the Australian sheep industry.

The plan was to sequence 400 sires from the INF. It took some time before the sequencing work could start. After some shopping around the world, including China, it turned out that DPI Victoria could deliver this to the CRC, and they already had experience with such an activity in dairy. Ben Hayes was leading the international 1,000 Bulls project, and Hans Daetwyler was heavily involved as well having also taken-part in a USDA project that produced a few hundred sequences from sheep breeds world-wide.

Program Leader Julius van der Werf and geneticist Iona McLeod in deep discussion at the 2017 Sheep CRC Annual Review.

Due to some patent arguments between DPIVic, MLA and the CRC, the sequencing project was delayed by almost one year. An advantage of this delay was that the price of sequencing had dropped to about $1,400 per sample. An efficient collaboration between Agriculture Victoria Research (then DEDTJR), UNE and AGBU was set up to quickly turn out the results.

The sequence information could be imputed in all 50,000 samples that had been genotyped in Australia so far, coming from the SG Flock, the INF, MLA Resource Flock and industry, so we ended up with a very valuable dataset of 50,000 animals, each with an imputed genotype for

30 million markers. The power of finding QTL had much improved, and the best predicting SNPs added much value to the genomic prediction accuracy. At the World Congress for Genetics Applied to Livestock in Auckland in 2018, the CRC presented this work and created a lot of interest with these results – the Sheep CRC showed more improvement than the dairy results published a few years before, probably because in sheep the team worked with multiple breeds. An important outcome was also that Neogen was prepared to take on a list of top SNPs and develop a new SNP chip for the sheep industry, based on these selected SNPs, increasing the number of SNPs on the industry panel from 15,000 to 50,000. Iona McLeod led the CRC team responsible for developing this new chip with Neogen.

Another important development was the impressive effort that had been made by the AGBU team to introduce the so-called 'single step' genetic evaluation method. This method seamlessly merges performance information with information from pedigree for non-genotyped animals and information from the DNA test for genotyped animals. The method was an improvement over the old blending method, as it would not be biased by double counting of information and it would propagate genomic information from tested animals to relatives via the pedigree. Under Andrew Swan's leadership, AGBU was the world's first to implement this into their national genetic evaluation for sheep, and a short time later AGBU also introduced it for beef.

Arthur Gates, Poll Dorset breeder, near Armidale, NSW.

Cheaper tests and faster turnaround

Throughout the Sheep CRC there was close collaboration with Geneseek/Neogen to achieve fast turnaround for DNA analyses and the lowest possible prices. Through introduction of new testing technology in 2017, it was possible to reduce the retail price of the 15k genotyping test from $50 to $35/test. Then again in 2018 the price of the test was reduced further from $35 to $27/test.

When the new list of 4,000 'top SNPs' were identified as a result of the full-sequence analysis Neogen again responded positively to the CRC's request to expand the genomic test to include these new SNPs. Again, drawing on new technology, Neogen were able to expand the SNP list to include the new 'top SNPs' without increasing the cost of the test. In fact, the number of SNPs in the new test, under development for a launch in 2019, includes 50k SNPS. It is anticipated that the new test will improve accuracy, particularly in predictions for minor breeds and distantly related animals.

One of the problems encountered in the DNA testing service was the variable turnaround time for samples. This variable time was a result of sending all test samples to the US for analysis at Neogen's main laboratory. There were also secondary problems associated with the parentage test where the assay system was not totally reliable and batches of samples occasionally needed to be re-analysed. During 2018, the turnaround time and reliability of the parentage test were both resolved.

Neogen established an Australian-based laboratory in Gatton, Queensland and the on-shore processing system has meant far more reliable sample turnaround times. Neogen also introduced a new parentage and major gene test by increasing the SNP content of the test from the original 180 SNP to a total of 800 SNP. Unfortunately, the increased quality and reliability of the new parentage test meant an increase in the cost of testing from $17 to $21 per test.

Merino Flock Profiling

In addition to new genomic tests for ram breeders the Sheep CRC extension also introduced some novel ways to use DNA testing in the commercial sector. An important product was the DNA Flock Profile test.

Commercial Merino producers could take DNA samples from only a small part of their flock — a sample of 20 animals — to provide an estimation of the genetic merit of the flock. This provided a tool to sheep breeders that were unaware of the genetic merit of the rams that they had used and therefore would give them clear information on what to look for in their next ram purchase, to improve on possible weaknesses in their flock.

The concept was well received by many producers and the biggest industry gain was that many of them became much more aware of the potential benefit of purchasing good rams. This had a strong pull through effect on ASBVs and more breeders became aware of the value of having strong ASBVs.

The Flock Profiling test fitted hand in glove with another initiative of the Sheep CRC that had been developed a few years before. The RamSelect tool was developed with the assistance of app builders in California, who knew little about sheep but everything about delivering information to a user in an app-friendly way. It was the key to unlocking complicated ASBV information and providing ram selection advice in a user-friendly format to sheep breeders no matter how big or small.

Andrew and Barbara Read

THE SIMPLE QUESTION THAT SPARKED DNA FLOCK PROFILING

"If you can DNA test rams, why can't you test a commercial ewe flock as well so we can verify in the market place the quality of our stock?'"

This was the question asked by Barbara and Andrew Read that encouraged the CRC to work with Sheep Genetics to develop the Genomic Flock Profiling test. Although the Reads had ram team records, what they didn't know was which rams had been most active and exerted the most influence on their flock and this additional information was found to be extremely valuable.

As a result of the Sheep CRC's response to this problem, the Reads later became among the first producers to trial the Flock Profile DNA test, with their detailed records of all rams purchased over the last 10 years (including their ASBVs and what years they were used) proving incredibly useful in verifying the accuracy of the genomic predictions generated by the test.

The Impact of the DNA revolution on commercial breeders

The impact of the DNA revolution was also felt on commercial properties, with the Merino Flock Profile test changing the way breeders like Victoria's Stuart Warner undertook their genetic selections and pursued their breeding objectives.

"It was a real eye opener and it definitely changed the way we think about our genetic selection," Stuart said in 2017. "We put a little more emphasis on selection for fleece weight, although we didn't do that at the expense of carcase traits, but we wouldn't have even contemplated doing that without the data from the Flock Profile test."

As a registered deliverer of 'Bred Well Fed Well' and 'RamSelect' workshops, Stuart already had a close understanding of the power of Australian Sheep Breeding Values (ASBVs) as an objective genetic selection tool. The additional information available through the DNA Flock Profile test provided him with new insights into how well his flock was tracking in the pursuit of his breeding objectives and opened his mind to new ways of pursuing those goals.

"It was also good to see confirmation, presented in the Flock Profile test data that the investment we had put into rams with the right ASBVs over the previous 15 years was really paying off. We weren't surprised that using ASBVs works, but it was nice to have confirmation of exactly how that approach has changed the genetic composition of our flock."

BREEDING PROGRAM DESIGN AND IMPLEMENTATION

Amid the industry excitement about the possibilities offered by genomic testing, it was Tom Granleese, working closely with Julius van der Werf, who developed a number of software tools to help breeders determine options for the most cost-effective use of DNA information to improve the efficiency of their breeding programs. Tom and Sam Clark, working with Sheep Genetics, held an annual workshop for sheep breeding consultants to discuss implementation of genomic testing in breeding programs.

The impact of this work was significantly enhanced by co-investment by the MLA's Donor Company and a number of breeders in genotyping projects. Sally Martin and the MerinoLink group undertook a significant amount of genotyping to improve pedigree information in a number of studs, as well as genotyping of young rams. The project also focussed on working with commercial ram-buying clients to evaluate the impact of genomic flock profile data on ram-buying decisions. The $uperBorder$ group coordinated by George Carter, the Meat Elite Poll Dorset group headed by Dale Price and the White Suffolk breeders coordinated by Murray Long, have all run similar programs.

There is evidence of rapid uptake of genomic testing in the sheep industry and with improving accuracy of the predictions and lower costs of testing, use of the technology and its flow-on impacts are expected to continue for many years to come.

Tom Granleese and Sally Martin

DNA TESTING DRIVES EWE COMPETITION REVIVAL

In 2018, the traditional ewe competition entered the innovation era, with the inclusion of DNA Flock Profile tests as part of the Doug Bicket Memorial Ewe trial in Parkes, NSW. The Sheep CRC provided complimentary DNA profiling for all flocks entering the event as a means of supporting improved genetic selection decisions by competitors. The result was a doubling of crowd numbers, as producers from outside the district flocked to the farm tour to hear the results of the DNA tests, which were presented to competitors along with the traditional visual assessments by judges Craig Wilson and Graham Wells.

Organisers Gary O'Brien and Graeme Ostini said interest in the competition grew as the event moved to empower entrants and local producers with new information and modern tools and technologies to bolster their profitability.

"There's technology out there we need to learn about and put into practice if we're to improve our flocks and take this industry forward," Graeme said. "Events like ours are a great opportunity to challenge producers to consider new ideas and try new things as part of a competitive sheep assessment.

"The inclusion of the DNA Flock Profiling technology has producers very excited and thinking about how to use the information to improve their genetic selections and improve their business. Here are technologies that aren't way out in the future anymore but are at their fingertips.

"After we shear our wool and it goes out into the world, figures measuring quality are paramount in driving sales — we need to be using figures to our advantage at farm level as well in order to improve our productivity."

Farm manager, Richard Rice, said the test was a great addition to the competition, with the results identifying an opportunity to select more heavily for weaner weight in future, as well as confirming that their focus on body weight and fleece weight in recent years had in fact paid dividends.

"After we received the results and spoke with Lu Hogan, I was very pleased that I had put myself up to be involved and it will really help with our next steps in ram selection and breeding decisions," Richard said.

The DNA Flock Profile test was able to benchmark the Rice family flock's performance against ASBV standards based on the relatedness of the Overland genetics to the database's reference population.

"As we have done to improve our grain growing, our strategy is to look at the top producers and see what they are doing and try to emulate their practices wherever it's possible within our business," Richard said.

He intends to repeat the DNA Flock Profile test every three to four years to continue to track the impact of genetic selection and identify areas for improvement in his flock's performance.

2018

GENOMIC IMPACT MEASURED

At CentrePlus, a cooperative Merino stud based at Tullamore, NSW, adoption of DNA technologies in combination with Pedigree MatchMaker and Matesel, resulted in a 50% increase in the rate of genetic gain over the five years to 2018. Sheep CRC analysis of data comparing the 10-year period pre-genomics to the five years of using DNA testing to 2018, revealed the full impact of this decision to embrace the technology early - CentrePlus increased rates of genetic gain for the Australian Sheep Breeding Value (ASBV) selection indexes Merino Production Plus (MP+) and Dual Purpose Plus (DP+) by 47% and 53%, respectively.

Partnership with Neogen

In 2007, at the start of the Sheep CRC's Information Nucleus program, the CRC explored options for DNA extraction and testing. At that stage the technology was reasonably new, and a variety of laboratories had been set up in Australia and internationally with specialist skills and appropriate equipment for the SNP analyses. In 2007, as a result of the International Sheep Genomic Consortium (ISGC), a new 50k SNP array specifically for the sheep industry was produced by Illumina and made available to a number of genotyping laboratories.

Having investigated several options in Australia and internationally, it was decided to work with Geneseek and their laboratories in the US as they were considered to have a good reputation for both quality and price. Starting off genotyping of the first 4,500 Information Nucleus progeny at a price of USD250 and a falling Australian dollar, the first batch of analyses represented a considerable investment. Although the price of the 50k test had fallen to below USD100 by 2012, the research genotyping of the Information Nucleus flock constituted a major investment for the CRC and the sheep industry.

The first CRC-designed genotyping product was a selection of 12k SNPs made by Ben Hayes and Julius van der Werf. Geneseek quoted a price of USD40/test for an order of 14,000 tests. This was a big decision for the CRC as it required accurate forecasting of demand and careful consideration of the foreign exchange management for a contract of that scale. This proved to be a very good decision as the demand for genotyping was increasing steadily as a result of the pilot projects the CRC had underway with producers.

In 2016, Neogen/Geneseek introduced the new 15k SNP test that had been formulated by the ISGC. As this was a generic product for the international sheep industry there was no minimum order requirement. This made management of genotyping using this product easier than it had been with the CRC's proprietary product, but the testing was still priced in USD and the logistics of sending samples to the US still presented challenges in terms of reliable turnaround time.

One of the best examples of problems associated with the logistics of sending samples to the DNA lab in the US was the large batch of samples sent in from the Pooginook Merino Stud. Although correctly labelled, the parcel was initially dispatched, shortly before Christmas to Armadale in Western Australia, instead of Armidale in NSW. When the batch finally arrived at the correct address and was dispatched to the US, the samples were intercepted by the quarantine services and only released two weeks later following checking. Needless to say, the stress levels at Pooginook, as well as in the CRC DNA office and Neogen's US laboratories, remained high right through to early February when the results were available.

THE DNA TESTING TEAM

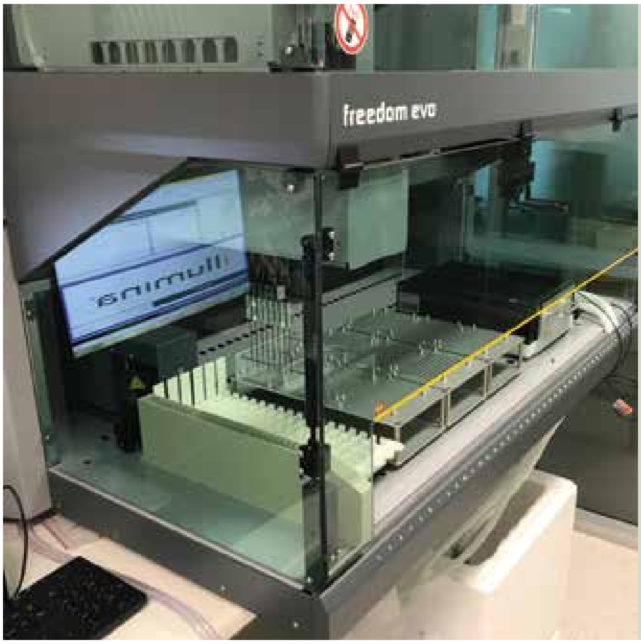
The business of coordinating DNA testing is reasonably complicated and has evolved over time with the assistance of an exceptional team covering the different aspects of the process. Marg Shedden and Bec Macarthur-Onslow were the mainstay of the client interface and, later joined by Andrea Simpson, oversaw the number of samples per client increase significantly since the first commercial trials. Klint Gore was responsible for downloading and screening all DNA test results prior to analysis — maintaining quality control over all aspects of the database and the parentage analysis was a significant contribution to the DNA service provided by the CRC. Lu Hogan provided oversight of the end-to-end process and took responsibility for troubleshooting and overseeing the logistics.

While the business process and client service were initially coordinated by Steve Potts, Lu Hogan then managed the process with rapidly increasing sample numbers.

During the first pilot trial DNA was sampled using both swabs and blood cards. Blood cards were quickly identified as the sampling method of choice and were the standard for many years. Allflex developed the Tissue Sampling Unit (TSU) but this option was initially considered too expensive for a price-sensitive market. However, when Neogen negotiated a global price for TSUs and the multiple benefits for sampling and sample management were better understood, TSUs became the preferred method for taking and managing samples.

Due to the manual nature of the ordering system and the significant amount of time involved in interacting with clients and Sheep Genetics, the CRC decided to build an online ordering system. This proved to be a big undertaking but the efficiencies for all parts of the sample management and processing side made the investment a valuable one for the industry.

Andrea Simpson and Bec Macarthur-Onslow



2018

NEW AUSTRALIAN GENOMICS LABORATORIES OPEN

The resolution to the tyrannies of distance came in 2018 when Neogen set up their Australian laboratory based at Gatton in Queensland. The new Australian company, Neogen Australasia (NAA) was established with state-of-the art equipment and testing services priced in AUD. Dealing with NAA as an onshore entity has numerous advantages for the Australian sheep industry, in particular the faster and more reliable turnaround time for sample analysis.

End of the CRC and transition arrangements

At the end of the CRC the genomic IP resources developed by the CRC were transferred to MLA for continued delivery via Sheep Genetics.

MLA took control of the DNA samples, including the database and the parentage assignment and imputation software. MLA's commercialisation plans were to maintain a single genomic database for the industry with Sheep Genetics providing DNA-based parentage assignment as well as the ASBV analyses.

The Australian Innovation Company (AIC), which was set up by the Sheep CRC to act as a commercial vehicle for delivery of new genomic technologies, was wound up at the end of the CRC. The ordering and sample management tasks were transferred to Neogen Australasia (NAA) so that it could provide an efficient end-to-end genotyping service. This arrangement meant NAA would deal directly with Sheep Genetics for the DNA data analytics required for parentage, major gene information and ASBVs.

FIND OUT MORE

For more information on how the CRC's genomics research interlinked with other programs, go to:

- Chapter 5 — Managing Sheep Parasites
- Chapter 6 — Precision Sheep Management
- Chapter 7 — Transforming Sheep Wellbeing
- Chapter 8 — Quality Sheepmeat
- Chapter 11 — Implementing Innovation

5 MANAGING SHEEP PARASITES

Sheep CRC parasitology program

Parasites of sheep have been a continual impost on industry profitability in Australia, with heavy productivity losses caused by worms, blowflies and body lice, and the significant costs of control. However, despite Australia's strong record in research and extension, there had been a major decline in the national parasite management capacity by the early 2000s, due largely to continued funding cuts by governments. In particular, the active extension of parasite control information to industry had reduced in most states. With increasing threats to parasite control related to the widespread dependence on chemical control there was an urgent need to harness national research and extension resources.

Here was an obvious role for the new, multi-institution Sheep CRC to integrate the available sheep parasite management expertise to develop new strategies and ensure their adoption by industry. The title of the parasitology program for the first CRC encapsulated the focus: 'Minimising chemical use in parasite management for sheep production', aiming to preserve the effective life of control chemicals while ensuring that control strategies were ethical and environmentally acceptable.

At initial planning workshops, parasitologists from organisations representing all states — agricultural agencies, CSIRO and universities — identified several key thrusts for R&D investigations, and importantly, the need for national coordination of parasite management extension and information access. With Brown Besier from the Western Australian Department of Agriculture as Program Leader, CRC activities commenced on a range of approaches: better diagnostic technologies, practical and sustainable control strategies, effective non-chemical management methods, and the first of the extension websites, WormBoss. In addition, a strong CRC-sponsored parasite management extension program was developed, to ensure that research results led directly to improved control recommendations.

Tanya Norman counting parasite eggs in faecal samples.

Improved parasite diagnostics

Effective parasite diagnosis is the key to efficient treatment and prevention, especially for sheep worm control, but available methods have generally been under-utilised by sheep producers. CRC research was aimed at new techniques, offering greater accuracy, lower cost, rapid turn-around, and where feasible, on-farm testing.

The 'Haemonchus Dipstick Test' for the diagnosis of Barbers Pole worm (Haemonchus contortus) burdens was the first successful commercial outcome of collaboration between several institutions:

- CSIRO Armidale (Ian Colditz and Leo le Jambre);
- Departments of Primary Industry NSW (Gareth Hutchinson);
- Department of Primary Industry Queensland (Maxine Lyndall-Murphy); and
- Department of Agriculture of Western Australia (Jill Lyon and Brown Besier).

The plastic 'dipstick' measured haemoglobin in sheep faecal samples, thereby indicating the number of the blood-feeding Barbers Pole worms. The on-farm Dipstick Test was licensed by the CRC to an animal health company, enabling the rapid assessment of worm burdens and timely treatment of sheep. Unfortunately, false positive readings with animals on the lush green pastures limited the usefulness of this test.

In another successful CRC-initiated project, the efficiency and speed of identification of Barbers Pole worm eggs in faecal samples were significantly increased. Modifications of the previously under-utilised Lectin Binding test, developed by Dieter Palmer and others at the WA Department of Agriculture's South Perth laboratory, increased the practicality of the test for routine laboratory use, leading to wide uptake locally and overseas.

Especially intriguing was the potential for parasite diagnosis via odour analysis, demonstrated in CRC projects for both sheep worms and blowflies. Experiments at La Trobe University by Mark Sandeman and postgraduates Jacquie Burgess and Kate Richards first showed that dogs could be trained to indicate whether sheep carried worm burdens on the basis of odour detection, and later used sophisticated technology to demonstrate specific "odour signatures" associated with different worm species. The characteristic odour from blowfly strikes was also investigated as a detection technology, with encouraging odour-detection results at CSIRO Armidale (Ian Colditz) (co-funded by

2008

NEW QUICK TEST FOR WORMS

A new rapid testing tool was developed for sheep graziers in regions where Barbers Pole Worm was a known or potential risk to sheep health and productivity.

It was hoped that the Haemonchus Dipstick Test would significantly lower the risks to animal health and productivity caused by this parasite.

The test was aimed squarely at Barbers Pole Worm, a major problem in northern NSW and Queensland, and at times in southern higher rainfall areas of Victoria and south-west Western Australia.

Deborah Maxwell demonstrating the dipstick test in Kingston.

the Bett Trust). An "electronic nose", later developed at the Brisbane Queensland Department of Primary Industry laboratories (Peter James), confirmed that specific odour patterns could be distinguished using sophisticated algorithms, with the potential for flystrike alerts at both flock and individual-sheep level.

In addition, a series of CRC investigations into novel parasite detection technologies provided proof of concept as the basis for further research:

- Faecal Antigen Detection tests, based on immunological assays of compounds shed by worms into the sheep faeces, simultaneously quantifying and identifying worm burdens. (Projects at Department of Agriculture of Western Australia (leader, Dieter Palmer), and La Trobe University (leader, Mark Sandeman, with postgraduate student Steve Cotton);
- Molecular (DNA-based) technologies: initially investigated at CSIRO Armidale (leader, Peter Hunt) for measuring numbers of worm larvae on pasture, and later the basis of a successful MLA-funded project which developed techniques for worm species identification;
- Near Infrared Reflectance Spectroscopy (NIRS) to detect haemoglobin concentrations, as an indicator of Barbers Pole worm burdens (Queensland Department of Primary Industry, Rockhampton, led by Rob Dixon); and
- Biochemical tests for anthelmintic resistance, investigated at the CSIRO's Brisbane laboratories (Andrew Kotze), leading to improvements in current laboratory tests.

A comprehensive review of parasite diagnostic tests, commissioned by the CRC, provided a detailed summary of progress towards alternative sheep worm detection technologies, and the potential for their further development (edited by Ian Colditz, Douglas Gray and Stephen Page) and available on the web-based Livestock Library.

Impact of nutrition

The concept of non-chemical parasite control to minimise chemical use has been advocated for many years, but with variable practical adoption. A challenge for the Sheep CRC was to assess the availability of various technologies for development into viable strategies at industry level. The role of nutrition for parasite management in the Australian context was reviewed at a CRC-sponsored workshop, with findings published in 2003 as a Special Edition in the *Australian Journal of Experimental Agriculture*.

As direct outcomes, a series of field experiments examined the relationship between nutritional supplementation and the resistance and resilience (tolerance) of ewes to sheep worms across a range of environments: Northern NSW (CSIRO, Armidale; Malcolm Knox as leader); South Australia (SARDI, Adelaide; Ian Carmichael); and Western Australia (Department of Agriculture WA, Albany; Greg Hood and Brown Besier).

Responses varied between sites and in relation to the nature of supplemental nutrition, but consistent relationships were shown between body condition scores and worm resistance (ability to limit worm intake) and resilience (tolerance of worm effects).

The parasite management guidelines subsequently developed are consistent with Lifetime Ewe condition score recommendations, and hence required no additional nutritional inputs above those required for optimal sheep production. Of particular note, the nutritional projects provided the basis for studies by several postgraduate students, Caroline Jacobsen, Alison Healy and Anne Carlyle.

Genetic selection to increase parasite resistance

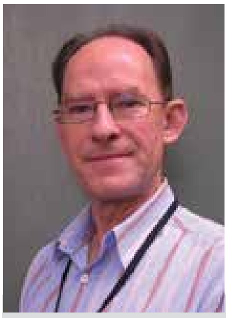
The improvement of genetic approaches was a key direction throughout the Sheep CRC term, including for parasite management.

Strategies to increase the efficiency of selection for genetic worm resistance and resilience aimed to encourage greater uptake by industry, with consequent reductions in the requirement for chemical control. Cooperation between the genetics and parasitology programs, and later through the Information Nucleus Flocks, led to the comprehensive definition of hereditability and correlations of worm resistance with other traits across a range of environments and sheep breeds, with postgraduate projects investigating the complex immunological responses involved (Emma Doyle, Sarah Preston).

At a fundamental level, investigations into the potential for resistance to blowfly strike at CSIRO Armidale, led by Ian Colditz, defined a novel trait of immunologically-mediated resistance to growth of blowfly larvae.

The immunological approach to blowfly strike prevention was further explored in innovative research into vaccine targets in the Queensland Department of Primary Industry laboratories in Brisbane (Tim Mahoney and team). The demonstration of a candidate protein, characterised in terms of cellular effector mechanisms and the molecular genetics, was a major achievement.

TARGETED TREATMENT AGAINST PARASITES



Brown Besier

One of Australia's leading sheep parasitologists, Brown Besier, made many contributions to the management of worms and was instrumental in the development of the targeted treatment approach to worm control.

The 'targeted treatment' approach came out of an industry push to develop new strategies to control scour worms in sheep while avoiding drench resistance.

Drench resistance was becoming more prevalent Australia-wide, and with the higher cost of new combination drenches, it was critical to develop resistance management strategies.

Murdoch University (WA) postgraduate student Meghan Cornelius found that sheep with higher body condition scores of approximately 3+ (1 being extremely lean and 5 carrying excessive fat) were able to tolerate moderate worm burdens and were less likely to require drenching than animals in poor condition. By drenching only those in need, the direct cost of treatment was reduced while potentially prolonging the effectiveness of chemical products.

"Depending on the degree of severity of worm burdens, producers may be able to leave those sheep with the higher condition scores in the flock without treatment, which will minimise input costs and save valuable time for farmers," Meghan said. "They can then focus on targeting the lower condition score sheep in the flock (under 3) which are less resilient and far more likely to be adversely affected as a result of scour worm burdens."

The decision to utilise targeted treatment strategies needs to be made on a flock-by-flock basis. Producers can also pair targeted treatment worm management with use of genetic selection to achieve better resistance to worms, by selecting sires with negative worm egg count ASBVs.

Meghan Cornelius

Integrated Parasite Management

Field work to translate new research into sustainable 'integrated parasite management' recommendations commenced in 2005, based largely on insights from the parasite-nutritional investigations, and incorporating genetic worm resistance.

A series of investigations ran in different environments over a number of years:

- Northern NSW — University of New England (Lewis Kahn and Steve Walkden-Brown) and CSIRO (Malcolm Knox and Joanne Lello);
- Western Australia — Department of Agriculture WA (Brown Besier); and
- South Australia and Victoria — SARDI, Adelaide (Ian Carmichael).

The studies were assisted by extensive computer simulation modelling conducted by CSIRO and Murdoch University led by Rob Dobson.

These projects also provided fertile ground for postgraduate studies defining parasite epidemiology and cost (Justin Bailey, Gareth Kelly) and testing new strategies (Meghan Cornelius, Michelle Dever).

Key outcomes were the development of sustainable worm management recommendations for different worm species and environments, including for the 'targeted treatment' concept for adult sheep in winter rainfall regions.

The demonstration that integrated parasite management strategies are efficient and practical to implement has led to significant changes to worm control programs routinely used by sheep producers, and the numerous reports in scientific publications and conference presentations have made a substantial contribution at an international level.

The Sheep CRC played a major part in the transformation over recent years towards greater efficiency and sustainability of parasite management in the Australian sheep industry.

New tools and concepts developed during the CRC term, and a vastly expanded and nationally coordinated communication effort (notably through ParaBoss), have led to the adoption of strategies delivering both productivity gains and rational chemical use.

CRC research has provided platforms for the further development of a number of novel diagnostic technologies, identified the potential for novel blowfly strike prevention methodologies, and facilitated the greater application of non-chemical worm control.

Through numerous publications, technical workshops and conference presentations, the parasitology program has made a major scientific contribution at national and international levels.

Of particular note, the large contingent of postgraduate students have provided an excellent resource of parasitology expertise that has been well-integrated into the livestock industries.

As an enduring CRC legacy, national research and communication collaboration has continued, facilitating the development and adoption of approaches to efficient sheep parasite management.

From WormBoss to ParaBoss

When the Sheep CRC was being planned, a program to deal with parasites was always a high priority. After all, the number one animal health problem for sheep is worms, followed closely by flystrike.

The issue of worm control for farmers, and a tool that could tell them whether they should drench, was an intriguing idea. At that stage Deborah Maxwell was working for the Queensland Department of Primary Industries (QDPI) and leading the Sheep CRC's Communication and Extension, which led her to suggest that QDPI colleague and extension officer, Arthur Le Feuvre, could bring together such information.

Arthur's gregarious and outcome-focussed nature made him a logical choice to lead the troops from other states and drive the development of this world-first resource.

A national team of extension staff, consultants, parasitologists and web developers was formed, including state representatives:

Stephen Love	NSW DPI
Noel Dempsey	DPI Victoria
Maxine Lyndal-Murphy	DPI Queensland
Andrew Bailey	DPIWE Tasmania
Ian Carmichael	SARDI
Rob Woodgate	DAFWA

and a support cast including:

Charles De Fegely	MS&A Consultants Victoria
Scott Williams	AWI
Tristan Viscarra-Rossel	AWI
Ramon Dodd	AWI
John Larsen	University of Melbourne
Norman Anderson	University of Melbourne
Ian Barger	Consultant Parasitologist

The mission: to bring the knowledge of the ages together into a comprehensive, national, practical, easy-to-use, web-based resource on sheep worm control. 'WormBoss' became the name of this new and ambitious creation.

A tremendous supply of base information, particularly on the parasites themselves, came from SCIPS — Sustainable Control of Internal Parasites in Sheep, an earlier web-based repository on worms developed by Nick Sangster, University of Sydney, and supported by Australian Wool Innovation. WormBoss— www.wormboss.com.au — was successfully launched at the big Western Australian sheep industry event, Wagin Woolarama. Australian Wool Innovation was a co-funder of the initiative with additional resources provided by Avcare/Animal Health Alliance (now Animal Medicines Australia). This financial support allowed the use of specialist expertise from Charlie and Mark Paterson, of Currie Communications, and web-development company, Fresh Web Media.

Currie brought a modern marketing approach to extension and the team went to the frontline to involve rural merchandise staff. Arthur fast became a marketing 'expert', bringing new and unusual ideas from the advertising world into agricultural extension. One highpoint was his writing and recording of the WormBoss song, an iconic Aussie ballad of the woes of worms and the benefits of WormBoss, which can still be downloaded from the WormBoss home page.

WormBoss delivered producer-friendly information on worms, drenches and control methods, as well as the first decision support tool, 'Ask the Boss', to provide tailored recommendations for individual mobs of sheep. The monthly email newsletter, *WormBoss News*, contained outlooks on the worm situation from numerous contributors across Australia, and was soon going out to thousands of subscribers. That legacy continues, with *ParaBoss News* being one of the most popular products from ParaBoss.

In 2010, Sheep CRC2 initiated a major upgrade of WormBoss, initially led by Rob Woodgate at DAFWA, and later Lewis Kahn at UNE, and Deborah Maxwell (who was at the time working directly for the Sheep CRC). The upgrade saw the launch in 2012 of eight regionally based annual worm management programs that clearly stated what to do and when to do it. The corresponding regional WormBoss Drench Decision Guides — detailed decision trees for day-to-day drenching decisions for any mob of sheep — accompanied the programs. The regional guides provided the foundation of a series of workshops receiving excellent feedback from producers.

2005

WORMBOSS WEBSITE IS LAUNCHED AT WOOLARAMA

WormBoss — www.wormboss.com.au — was launched at the big Western Australian sheep industry event, Wagin Woolarama in 2005.

The aim of WormBoss was to reduce unnecessary drenching and minimise the onset of drench resistance while increasing productivity.

The WormBoss website was redesigned in 2012 to help producers develop management plans specifically for their local environment and to access advice and worm control tools.

James Rowe, Rob Woodgate and Arthur Le Feuvre at the WormBoss launch at Wagin Wooloorama, 2005.

Lewis Kahn and Deborah Maxwell, along with Stephen Love (NSW DPI), Steve Walkden-Brown (UNE) and Maxine Lyndal-Murphy (formerly DPI Qld), created the first regional program, which served as a template for the others. They coordinated contributors from across Australia to provide the content for these other regions. These contributors were:

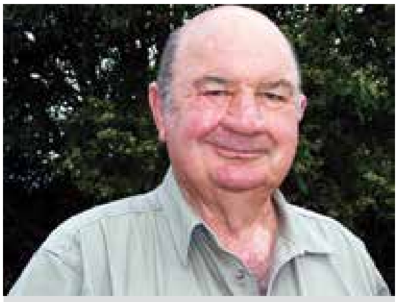
Brown Besier	DAFWA
David Hucker	Para-Tech Veterinary Services Victoria
John Larsen	Mackinnon Project, University of Melbourne
Graham Lean	Graham Lean & Associates
Ian Carmichael	SARDI
Colin Trengove	University of Adelaide
Greg Johnsson	Kangaroo Island Veterinary Clinic
Simon Ellis	Ellis Farm Consultancy
Paul Nilon	Nilon Farm Health
Dan Salmon	Riverina LHPA
Jim McDonald	Tablelands LHPA
Bill Johnson	Tablelands LHPA
Tony Morton	Hume LHPA
Belinda Edmonstone	Lachlan LHPA
Greg Curran	NSW DPI
Noel O'Dempsey	Industry Consultant, QLD

Deborah Maxwell who had the idea to create the national WormBoss program and who became the Executive Officer for ParaBoss.

It is essential to acknowledge that WormBoss evolved from the solid foundations and earlier parasite management programs, such as WormKill (NSW DPI), and that many researchers, extension staff, veterinarians, parasitologists and livestock officers hailing from the state departments of agriculture, district veterinary services, universities, and CSIRO, contributed to this legacy over the last 50 or more years .

THE MAN BEHIND WORMBOSS AND THE SONG

Arthur Le Feuvre helped establish the WormBoss program but was better known for the colourful lengths to which he would go to grab producer attention and encourage practice change.



Arthur Le Feuvre

Most famously he penned the WormBoss song, which included lyrics like "The Boss says test resistance — to be sure which drenches kill, it's much more cost-effective than guessing like a dill!"

"I needed to do something that was different to attract some attention and promote our message a bit harder," he said. "I sat down on the verandah with my guitar one Saturday afternoon and was just messing around and then I just wrote the song in about 10 minutes flat. I got a professional to do the backing tracks and recording, but was told I had to sing it — that certainly made it a bit different and it did the rounds pretty quickly after that."

Arthur worked for Queensland's various departments of primary industries from 1964 to 2005, before moving into private consultancy with an ongoing role assisting with the WormBoss newsletter. His career posts included time in Julia Creek and Charleville before he took the opportunity to complete a Graduate Diploma in Rural Extension at Hawkesbury College, NSW, which exposed him to new theories of communication. He then moved to Cunnamulla and Warwick.

He became a regular on ABC rural radio and television programs, and in 1974 tried to put his new communications skills into action by starting a district newsletter for sheep producers in Queensland's South West.

"When this was floated to branch management, it was rejected on the grounds of 'no budget'. However, during a visit to the Brisbane head office, I found there was a room full of unused Roneo machines, paper and the necessary stencils. A six-pack of beer and a friendly chat to the relevant clerk resulted in my returning to Cunnamulla with the acquired goods under the tarp. The monthly newsletter was a hit. It was six months before management found out what was happening and by then it was too late."

He said trying new ways of engaging producers with industry research was essential when many sheep breeders had an entrenched reluctance to change.

"In my entire career, I was most frustrated by the reticence of producers to change their management," Arthur said. "So we tried to get people talking about these ideas because the more people hear about a practice, the more they think it's normal and something they should do. It's much more effective than having an expert or government official telling them what to do, which they always resist."

The WormBoss program was the stand out achievement of his career.

"There has definitely been a change in worm management practices in the sheep industry, and I think that we succeeded with WormBoss because we were able to recruit all facets of the industry to back this as a good thing to do and to tell producers to think about the issue of parasite resistance," he said.

FlyBoss and LiceBoss

Even before the launch of WormBoss, Arthur Le Feuvre believed the WormBoss concept could be applied to the industry's other parasite problems: flies and lice, and so it was that FlyBoss and LiceBoss were ultimately created.

From 2004 to 2007, AWI, with the strong support of their Animal Health and Welfare Project Manager, Johann Schroder, funded Peter James (DPI Qld), Brian Horton (DPIPWE), Noel Campbell (DPI Vic) and Di Evans (DAFWA) to conduct major studies on lice. These studies were on the rate of development and spread of lice (Peter James) and long wool lice treatment (Noel Campbell), with modeling to develop desktop computer decision support tools and advice on lice management. It was only named LiceBoss very late in the project, at the suggestion of Scott Williams, Program Manager at AWI, as it seemed to be comparable to the (by then) well-known WormBoss.

The interactive tools developed by Brian Horton allowed the user to investigate a range of lice issues such as:

- treatment options for ewes with lambs;
- calculation of costs of treatment versus cost of losses associated with lice in long wool;
- assessment of the likelihood that the last lice treatment was actually successful;
- probability that rubbing sheep had lice; and
- calculation of likely chemical residues in wool after specific treatments. These were later converted to web-based tools.

Brian Horton

About 2010, in a second AWI project, LiceBoss was revised with more detailed advisory notes, similar to those found in WormBoss, and the web-based tools were revised and rewritten. Jenny Cotter (DAFWA) replaced Di Evans and Gary Levot (NSW DPI) joined the team. In 2012, the information was brought under the Sheep CRC to create the latest LiceBoss site, similar to WormBoss. The site includes a wealth of information about the parasite, biosecurity and treatment options and a 'Products' tool to serve both LiceBoss and FlyBoss, with all currently registered lice and fly treatment chemicals.

The development of FlyBoss was coordinated by Lu Hogan during Sheep CRC2 in 2008/2009, primarily as a centrepiece for a national program of workshops, to assist producers to develop an integrated flystrike management plan. Considerable new information was presented on breeding for flystrike resistance sourced from earlier work by Kevin Atkins, NSW DPI, the QPLU$ project, and the AWI Breech Strike Project led by Jen Smith at CSIRO and Johan Greeff at DAFWA.

Decreasing use of mulesing

FlyBoss provided a one-stop shop for information to assist producers manage the risk of flystrike when deciding to stop mulesing. Available on the FlyBoss site the FlyBoss tools software program was particularly useful for exploring 'what-if' management options such as shearing, crutching and chemical application to minimise risk.

FlyBoss was well-tested during the Information Nucleus program when it was decided that no mulesing would be undertaken on any of the eight sites and that risk of flystrike would be managed using FlyBoss guidelines. The strategy proved to be highly effective with very few sheep needing treatment for flystrike.

With more and more producers ceasing mulesing, FlyBoss had played its part providing critical information for those making the change. Figure 5.1 shows that wool from non-mulesed and ceased-mulesing flocks was increasing at around 1,800 t/year between 2011 and 2019. With price premiums of $0.5 to $1.00/kg available in 2019 for wool from non-mulesed sheep, the trend was expected to continue.

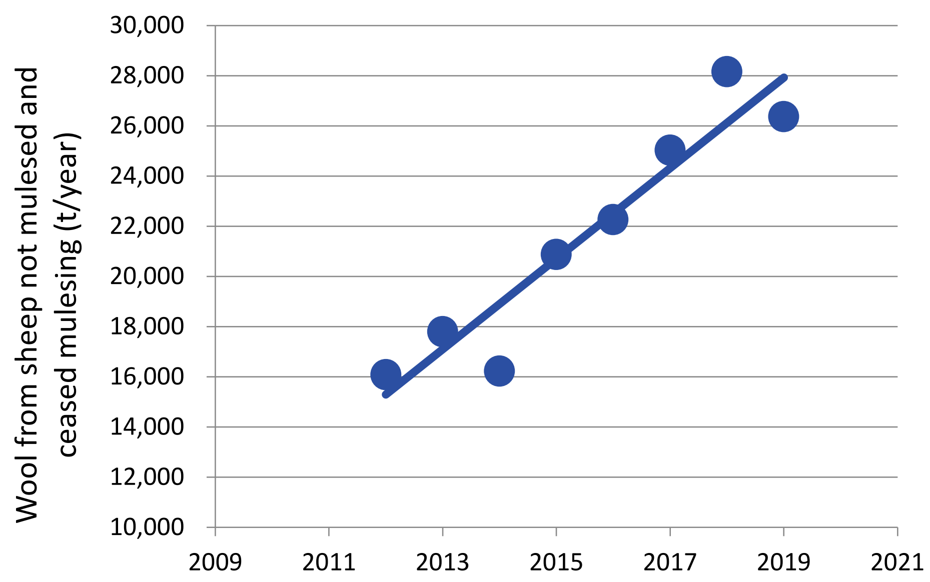


Figure 5.1: Production of wool from sheep declared to be non-mulesed and from flocks that have ceased mulesing (source AWEX).

The FlyBoss national team included:

Lu Hogan	Sheep CRC
Arthur Le Feuvre	DPI QLD
Peter James	DPI QLD
Brian Horton	UTAS
Allan Casey	NSW DPI
Gary Levot	NSW DPI
Alex Russell	NSW DPI
Jess Richards	NSW DPI
Mandy Curnow	DAFWA
Brown Besier	DAFWA
Di Evans	DAFWA
Garry Armstrong	DPI VIC
David Counsell	Consultant QLD
Deborah Maxwell	Sheep CRC

Two sophisticated tools were developed by Brian Horton for use in FlyBoss workshops, and were later converted for use on the web. They enabled producers to assess the risk of flystrike — body, breech and other — using long-term weather records from their local town and allowed the user to customise options including breech modifications, the time of shearing and crutching and the type and time of chemical flystrike-prevention applied, including optimising the best time for application.

Sheep producers assessing wrinkle scores as part of a FlyBoss workshop (source NSW DPI).

GENETIC TRANSFORMATION

Stuart Mitchell was able to achieve results by transforming the genetic makeup of his flock in just six years through the use of objective selection tools. Stuart and his wife, Ba, ran Merinos at 'Cashelvale', Bollon, and dramatically transformed the flock's appearance and performance so they could cease mulesing without putting the flock at risk of flystrike, while also achieving finer micron wool.

Stuart Mitchell

The keys to success were having a clear breeding objective, selecting rams against those objectives using Australian Sheep Breeding Values (ASBVs), and buying teams of similar rams for across the board genetic impact.

"We had a really typical South West Queensland flock, mainly 21 micron, quite wrinkly sheep, but we made a conscious decision to stop mulesing and we went looking for plainer sheep," Stuart said. "Over the years they've become a lot plainer but we haven't lost any since and we've been able to reduce our micron down to around a 19 micron flock."

LESS WRINKLE LESS FLYSTRIKE

As part of the SRS Group, Bruce Taylor and sons Geoff and Hugh, of Boxleigh Park Merinos, were continually selecting for body type resulting in less wrinkle, a major reduction in flystrike incidence and lower use of chemical treatments for the problem.

"We had fewer fly problems after we changed to breeding plainer bodied sheep," Bruce said. "The main thing is to breed out the wrinkles. The warm humid conditions provided by wet wrinkles are really an ideal breeding ground for bacteria and an appealing place for flies. By breeding out the wrinkle, we have been able to reduce the stress on our sheep and minimise the risk of flystrike."

ParaBoss

At the end of Sheep CRC2, a new home for the 'Bosses' was needed. In 2014, ParaBoss was created to manage WormBoss, FlyBoss and LiceBoss post-Sheep CRC. The University of New England agreed to take over the management of ParaBoss with MLA and AWI jointly funding the operations. Lewis Kahn and Deborah Maxwell continued as the Executive Officer and Operations Manager respectively.

2013

PARABOSS DELIVERS THREE-IN-ONE PARASITE SUPPORT FOR SHEEP PRODUCERS

A new ParaBoss website was launched to provide sheep producers with advice on tackling the costly challenges presented by worms, blowflies and lice. This website remains a source of detailed management information that assists sheep producers in managing major parasite risks.

ParaBoss acts as a single entry point to three existing specialist websites — WormBoss, FlyBoss and LiceBoss — allowing easier delivery of effective and financially efficient parasite treatment information to producers.

www.paraboss.com.au

Rob Egerton-Warburton and Lewis Kahn

The ParaBoss Technical Committee was formed to ensure the integrity and currency of the content. The Committee included a cross-section of experts from industry comprising of consultants and pharmaceutical company staff including:

Justin Bailey	Novartis
Brown Besier	DAFWA/Brown Besier Parasitology
Ian Carmichael	SARDI
Brian Horton	UTAS
Peter James	DPI Queensland & University of Queensland
John Larsen	University of Melbourne
Stephen Love	NSW DPI
Jane Morrison	Coopers Animal Health
Maxine Lyndal-Murphy	Parasitology Consultant
Paul Nilon	Nilon Animal Health
Noel O'Dempsey	Sheep Consultant
Matt Playford	Dawbuts
Johann Schroder	MLA
Rahul Shankar	Riverina LLS
Berwyn Squire	DPI Victoria
Bruce Watt	Central Tablelands LLS
Andrew Whale	Livestock Logic
Rob Woodgate	Charles Sturt University

Significant improvements have been added to the ParaBoss suite and the numbers of unique users across all Boss sites has steadily climbed every year from under 5,000 per month in late 2013 to just over 15,000 per month in late 2017. Unsurprisingly, many users were from overseas as there was no global parallel that was comparable in depth, breadth or quality to the Boss resources.

WormBoss News became *ParaBoss News*, covering lice and flies, and evolved into two editions per month, compiled by Arthur Le Feuvre until his retirement, followed by Maxine Lyndal-Murphy as editor. ParaBoss also made its Facebook debut in 2016 and continued to do four posts per week with a sheep page and a goat page. A ParaBoss Technical Web Forum was created to provide technical development for industry professionals and was complemented by a biennial conference — the first in 2016 was a great success and was booked out. The second conference was held in August 2018.

By the end of the Sheep CRC the 'Bosses' were no longer confined to sheep with MLA funding the inclusion of goats into WormBoss in 2016 and later expanding the initiative to cattle sites for WormBoss, FlyBoss (buffalo fly), LiceBoss and a new TickBoss, all due for launch in 2019.

A major project was implementation of a national training strategy to upskill advisors, particularly rural merchandise staff. With Lewis Kahn's resignation at the end of 2017, Deborah Maxwell moved into the Executive Officer role and a new Technical Manager, Lillian Mukandiwa, was appointed in April 2018. The ParaBoss project is currently funded until 2020 and it is hoped that it will continue to provide a beneficial service to the sheep, goat and cattle industries for years to come.

ParaBoss Technical Committee. Back: (left to right) Justin Bailey, Paul Nilon, Rob Woodgate, Brown Besier, Peter James, Brian Horton, Johann Schroder, Berwyn Squire, Bruce Watt. Front: Ian Carmichael, Arthur Le Feuvre, Deborah Maxwell, Lewis Kahn and John Larsen.

INVESTING IN THE FUTURE OF PARASITE CONTROL

The Sheep CRC's parasitology program was dedicated to solving 'here and now' problems faced by producers, but it always maintained an eye on the long-term challenges.

Its investment in supporting postgraduate students was a strategic decision to back the best and brightest young researchers in tackling industry problems, while ensuring the industry had a pipeline of high-quality scientists.

Among the Sheep CRC-sponsored PhD researchers was Michelle Dever, who was awarded the University of New England Chancellor's Doctoral Research Medal in 2016 for her work in improving the effectiveness of gastrointestinal nematode control for meat-breed lamb production systems on the Northern Tablelands of New South Wales.

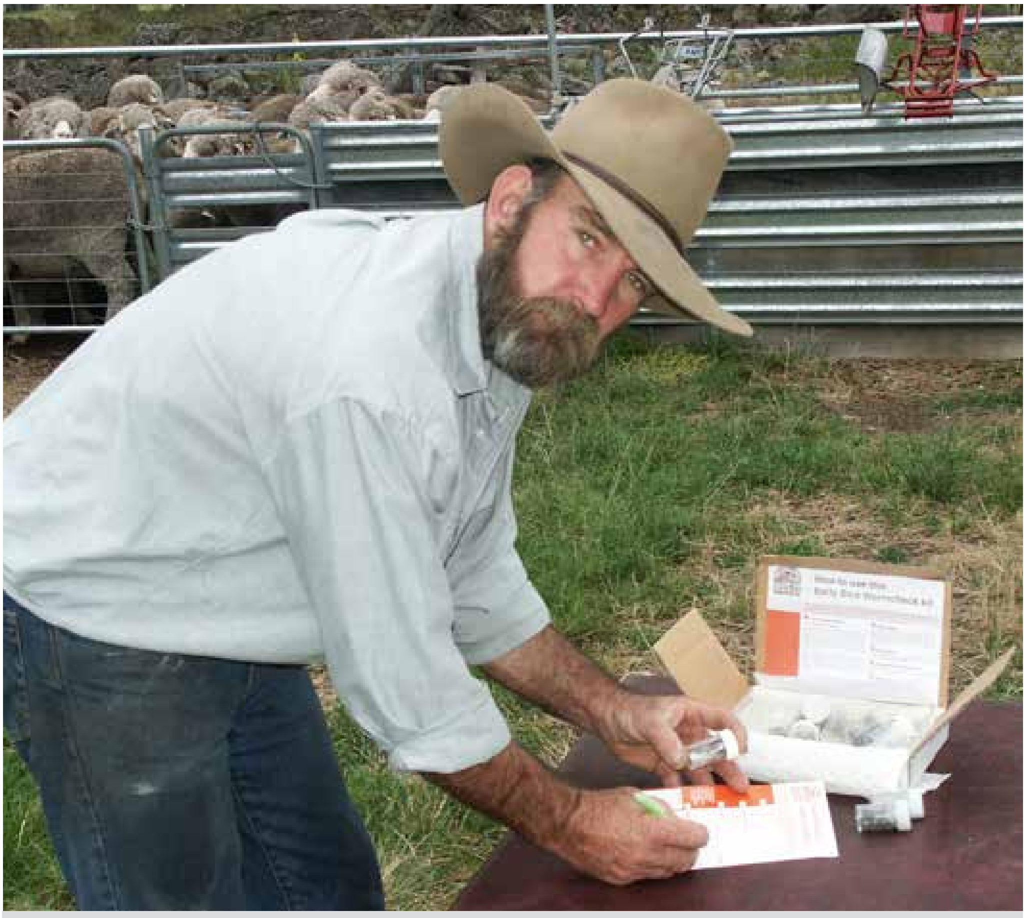
"The study showed the effects of worms on meat-breed lamb and ewe performance are small, indicating considerable resilience of these breed types to parasite infection," Michelle said. "Integrated parasite management programs were shown to reduce worm egg counts while at the same time reducing the number of drenches required to control the parasites."

She hoped the combination of fewer drenches and more effective control would slow the development of drench resistance as well as increasing profitability.

"Outcomes from these experiments have provided a solid platform to improve intestinal parasite control programs appropriate to the breed types and production systems in a summer-dominant rainfall region," she said.

After completing her doctoral research Michelle worked for Coopers Animal Health as a Technical Advisor (Ruminants), based in Armidale. Graduate tracking surveys completed between 2009 and 2013 demonstrated that 70 per cent of postgraduates found employment directly within the sheep and cattle industries, and that 90% were retained more broadly within agriculture.

Michelle Dever (at her graduation on 30 April 2016) with UNE's Chancellor James Harris and Vice-Chancellor Annabelle Duncan.



Worm tests are an integral part of an effective worm control program. Pictured — Cameron Peardon, Guyra NSW.

FIND OUT MORE

The Sheep CRC's parasite research program interlinked with a number of other areas:

- Chapter 4 — Introduction of Genomic Technologies
- Chapter 6 — Precision Sheep Management
- Chapter 7 — Transforming Sheep Wellbeing
- Chapter 11 — Implementing Innovation

6 PRECISION SHEEP MANAGEMENT

Embedded in the vision for an integrated sheep industry was the need to measure and manage a broader range of traits than historically required for improvements in separate lamb or wool production systems.

Accurate measurement of production, product quality and animal wellbeing are fundamental requirements for efficient genetic gain as well as for management and marketing. But measurement comes at a cost. Moreover, measurement requires subsequent data analysis and record keeping that are not popular activities for most farmers. Automating the process of collecting and managing data was therefore identified as an essential component of the technology and know-how required to support the transformation of the sheep industry.

A team of researchers in NSW DPI, led by Kevin Atkins, was already making good progress in automating data collection for sheep breeding trials. The Trangie Agricultural Research Station, as an important centre for breeding and selection, had already made a significant investment in radio-frequency identification (RFID or eID) tags. With a cost of around $14/tag the value proposition was based on more accurate data collection and reduced labour requirements. This was due to the fact that manual reading, recording and transcription of data resulted in errors of over 5%, thus reducing value of the data as well as requiring time-consuming double-checking.

Questions for the Sheep CRC to address were whether development of the electronic data collection systems for the sheep industry was feasible and, if so, would the technology make a sufficient contribution to productivity and profitability to warrant a major program of research, training and extension. This proved to be a controversial question for the CRC Board and for CRC stakeholders. The eID tags were regarded as being too expensive for sheep and there was also considerable pushback from the industry fearing that, as in the cattle industry, electronic tags may become compulsory for biosecurity and traceability and, if this happened, it would add an unwanted cost on the industry.

As a sheep producer and Chairman of the Board, Ian Sinclair wanted to inspect the technology first hand. Soon after the start of the CRC in 2002 a visit to the Trangie Agricultural Research Centre was arranged. The demonstration of automated capture of animal identification and live weight, with the information immediately used for automated drafting, provided an impressive proof of concept. It was a bit 'Heath Robinson' (an English cartoonist best known for drawings of whimsically elaborate machines to achieve simple objectives) but an impressive demonstration, nonetheless.

The next step was to develop a proposal for a new data management project and review this with the Sheep CRC's stakeholders. A workshop was organised at the Masonic Conference Centre in Sydney and produced a robust debate covering all aspects of the technologies and their implications for the industry. Stud breeders attending the workshop recognised the potential of the new technology and were enthusiastic about the project. Commercial producers and consultants were more cautious about its potential, but the consensus was to give it a go.

Towards the end of 2002 the CRC Board approved what became known as the 'e-sheep' project. Over time it developed to become a major theme within the portfolio of Sheep CRC1 activities. It was a project that was never short of strong supporters as well as vociferous detractors. Only time would tell how it would contribute to the sheep industry.

Value proposition

Variation within sheep flocks had long been recognised, with the role of the sheep classer considered to be extremely important in any stud or commercial enterprise. The difficult job of rapidly assessing each sheep for its conformation, faults, size and its quality of wool, and then sorting them into lines for breeding or culling, required great skill. Despite the best efforts of even the very best sheep classers, both stud and commercial flocks still contained significant variation between sheep in terms of production of wool and meat, and the ability of ewes to rear lambs.

It was easy to see how measurement and data management could provide a better outcome. But it had to be both possible and practical.

An early task was for Kevin Atkins and Jess Richards to analyse the costs and benefits of exploiting within-flock variation for a range of targets. Their paper on the subject, 'Where can I be in 10 years' time?', provides an excellent summary of the value proposition, particularly for the Merino flock. Table 6.1, sourced from that paper, illustrates the differences between the top and bottom quartiles in the flock for different aspects of production.

Table 6.1. Variability within a Merino flock of sheep. Source: Atkins, Richards and Semple 2006 report.

Trait	**Production level of flock**		
	Average	**Top 25%**	**Bottom 25%**
Wool traits			
Fleece weight (kg)	4.6	5.3	3.9
Fibre diameter (µm)	20.4	18.9	21.9
Staple strength (N/ktex)	35	42	28
Meat traits (crossbred lambs)			
Growth rate (g/day)	284	357	200
Fat depth (mm)	10.6	8.9	12.5
Reproduction			
Lambs weaned per ewe joined	0.86	1.43	0.28
Profitability traits			
Fleece value per ewe ($)	$54	$82	$37
Carcase value per ewe ($)	$33	$56	$12

The three main opportunities identified by Atkins and Richards were:

1. Stud selection. The variation indicated massive scope for selection and genetic improvement within studs provided that all necessary parameters could be accurately recorded in a cost-effective way.
2. Commercial flock selection. The same variability was important within commercial flocks because further increases in productivity could be achieved from ewe selection with the benefits complementing those provided through stud rams. Accurate, low-cost measurement was considered essential to capture these benefits.
3. Management. In addition to the scope for selection, the variation within a flock offers an important opportunity to identify segments of the flock for specific management and marketing purposes. Successful application involves increasing the value of the most valuable 25% of animals and minimising the costs of the least valuable 25% of the flock. This was a very different approach to minimising the costs of managing the whole flock.

An important point made by Atkins and Richards was that benefits accumulate over a period of at least 10 years following introduction of the measurement and selection processes. There were immediate benefits in culling the least productive sheep and then cumulative, longer term benefits as the value of the more productive animals retained in the flock was realised and was also expressed in their progeny. The principle of retaining and investing in the most productive animals and culling those that were least productive, irrespective of their age, could be combined with carefully selected rams to achieve synergistic gains in the performance of the flock.

The major costs associated with the practice of within-flock selection relate to measurements and data analysis. The study considered various options for data collection, including manual measurement and recording, compared with automated data capture and its associated capital costs. Irrespective of the method of data collection, the benefits identified in the analysis out-weighed the costs and it was clear that the automated systems would be more attractive for producers and breeders.

The value proposition documented by Atkins and Richards was based on a cost of tags at $3.50 and relatively expensive data collection and sheep handling equipment. With prices of hardware likely to get significantly cheaper over time, together with improved reliability, the conclusion was that the new initiative would create value for the sheep industry and should be pursued.

The accumulation of these discounted returns from measurement and selection in a specialist wool-producing enterprise is shown in Figure 6.1. The time sequence shows a relatively rapid build-up to a relatively stable Net Present Value per year. The continuing contribution of genetic improvement over time adds to the contributions of current generation improvement to deliver sustained improvement in profitability. All investment costs in equipment and additional measurement were covered within 2-3 years. It is important to point out that the analysis was conducted in 2003 when there were significant premiums paid for finer micron wool — but the principle of the approach is still very clearly illustrated (see Figure 6.2).

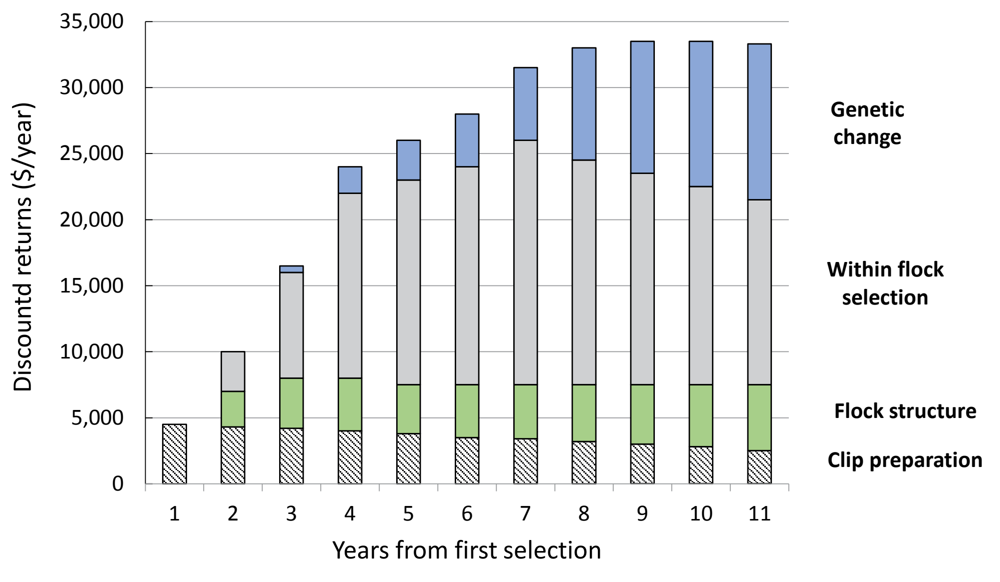


Figure 6.1: Benefits of implementing precision sheep production for selection and management of a fine wool production enterprise. Note: Benefits are discounted and presented as net present value and assume micron premiums in place around 2001–03.

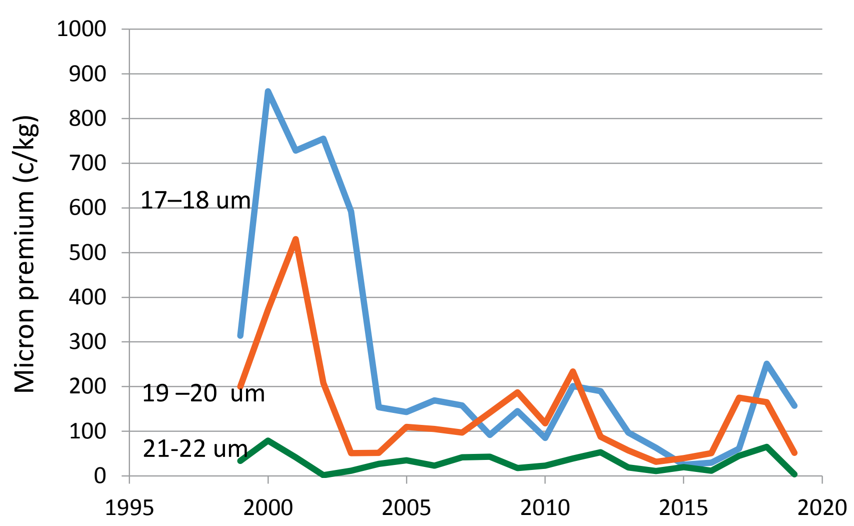


Figure 6.2: Changes in the micron premium for wool over time as the difference in nominal price (c/kg clean wool) between: 17um and 18um (blue line); 19um and 20um (orange line) and between 21um and 22um wool (green line). The finest wools attracted the highest premiums with far less difference in prices between micron categories higher than 20um (Source: AWEX).

Early feedback and planning

A number of commercial producers, including the Stephen family of Warrane near Armidale, NSW, collaborated with the CRC in early pilot trials to investigate the practicality of the eID data collection and use of the data for selection and management decisions. When reviewing data collected on a flock of ewe hoggets during shearing, Gerard Stephen remarked that knowing the dollar value of wool from each animal was just like "turning on the light" to identify differences between $20, $50 and $100 bank notes. Measurement of the fleece weights and fibre diameter of individual animals had revealed a range in actual value of the wool varying between $20 and $90 per head. Normally the whole year group would have been retained but, based on the individual animal data collected, 30% of the hoggets were culled before their first joining.

As well as the commercial pilot trials, the CRC organised an 'e-Sheep Forum' in 2003 where a wide cross-section of hardware and software companies were invited to set up working demonstrations of their equipment in order to 'compare notes' on eID system, body and fleece weighing equipment, ultrasound scanning for pregnancy as well as for muscle and fat. The forum was run in conjunction with the Armidale Wool Expo on the Armidale creeklands. There was space for large-scale demonstrations involving mobs of sheep, a large marquee for equipment and software demonstrations and a conference venue for presentations and discussion.

The forum was invaluable as an opportunity for the CRC to engage with a broad cross-section of hardware and software companies as well as to understand producer and consultant requirements in terms of end-to-end solutions that would be required for their operations. The forum was also an opportunity to learn more about the potential of eID technologies being explored in New Zealand and applications in the dairy industry.

Jeremy Absalon, from New Zealand, shared his group's experience in managing a large genetic improvement program where eID had been introduced to ensure accurate data collection and to facilitate the logistics of tracking samples taken at various stages of the measurement process. He described their experience in pioneering the use of the new technology in their breeding program as "operating at the bleeding-edge". There were problems that made use of the new technology uncomfortable — but it was also so clearly valuable that they persisted with its use and achieved significant progress as a result. There was also productive discussion of case studies from the dairy industry where accurate data had helped with breeding programs and also in monitoring individual animal performance and wellbeing.

The forum provided the CRC with a much clearer understanding of the practical issues that would need to be resolved and streamlined. It was also clear that training and support would be needed for the early adopters, and that collaborative arrangements would be needed between the CRC and numerous hardware and software providers to facilitate the introduction of this new approach to the modern sheep industry. It was clear that there was a lot to do but that success would deliver long-term benefits. It was an ideal challenge for the CRC.

The early parallel lines of work were:

- Understanding the eID technology and linkages between different measurement and drafting systems;
- Developing software tools for best use of the data;
- Engaging with hardware and software companies to develop integrated solutions for end-users;
- Developing training programs and skills development for using the new technology; and
- Pilot projects to evaluate the technology and investigate its application with ram breeders, commercial producers and meat processors.

The CRC also developed new uses of eID technologies, such as:

- Walk-over weighing, and
- Pedigree MatchMaker.

These applications extended the scope of eID technologies to monitoring wellbeing and production, as well as providing a new way of determining links between ewes and their lambs to contribute to genetic improvement.

Understanding eID for sheep industry applications

Around the time that the CRC was developing its e-sheep program there was a significant level of interest in RFID for supply chain and logistics applications. The Australian cattle industry was also investigating options for the proposed eID-based traceability program. The wide range of technologies for radio frequency identification made it necessary to thoroughly understand the pros and cons of various options for sheep applications.

The key issues to understand were the technical features of different wavelengths of the electronic signals in terms of proximity of the reader, interference with metal structure in handling races and collision interference (the interaction between signals from two or more tags when they are close together and being read simultaneously by a single reader). There was also the question of read/write tags able to store information compared to simple ID tags, and there were significant differences in the cost of tags and readers for each RFID system.

Tags and readers for supermarket products and their supply chains were the cheapest option due to high volumes and numerous providers but they had problems of very short read distances and the electronic signal being blocked by animal tissue. The read distance needed to be long enough for automated reading in single file races, but not too far to cause collision interference when identifying individual sheep in shearing sheds and when sampling.

The final decision on the electronic tag technology was made in consultation with the cattle industry in order to have a single product for both sheep and cattle, as it was recognised that many producers have both species and two systems of electronic ID would be totally impractical. Once a standard had been set, a number of manufacturers focussed on the potential of the combined Australian sheep and cattle market. The increased volume of the market and with competition between manufacturers, prices continued to fall and reliability of the tags and readers continued to improve.

As well as differences between tags, there were also significant differences between tag-readers and their compatibility with tags from different suppliers. To evaluate different tags and readers the CRC and NSW DPI established a research centre at the Orange Agricultural Institute, headed up by Steve Semple, to evaluate different RFID technologies and related readers. Steve's skills and meticulous approach to the process of evaluating new options established this facility as a national resource for assessing tags both for sheep and the cattle industry.

Allflex, as a leader in livestock tag manufacturing and technology, became an early CRC collaborator and Pat Gunston, their technical manager, made a major contribution to the CRC's approach to evaluating the technology and recommending technical solutions. One of the first technical developments was the 'portal reader', with the tag-reading antenna forming a loop through which sheep passed down the race or when entering a weighing crate. This was

Steve Semple and Tony Thompson

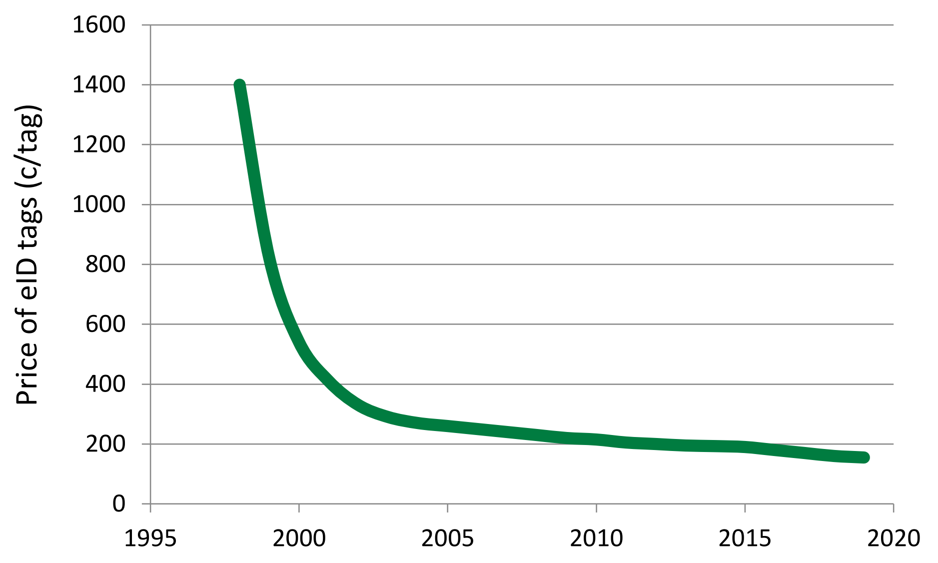


Figure 6.3: Changing price of sheep eID tags over time. Apart from issues of reliability and service, cost of implementation was always viewed as a significant impediment to the widespread use of precision sheep technologies. The graph demonstrates the significant reduction in the price of electronic tags that has contributed to increased use of eID technologies (Source: Pat Gunston, Allflex).

a significant breakthrough and overcame many of the problems associated with interference caused by metal structures in the race or the weighing scales.

Steve Semple also worked with numerous manufacturers to ensure that data delivered by the tag readers was compatible with the format of data delivered by other measurement devices. The importance of compatibility between devices was particularly significant when using eID and barcodes for tracking fleece data in a shearing shed. Steve's contribution was outstanding in developing integrated systems involving multiple hardware devices providing information to a single database — one of the key reasons for the CRC's industry impact in this program.

Then there was the advent of blue-tooth technology providing wireless links between different measurement systems and a computer — with variable reliability! This was followed some years later by automatic upload of data into cloud data management systems, but fundamental to the success of all of these systems was the foundation work coordinated by the CRC in setting the standards for data collection. Tim Dyall and his CSIRO colleagues helped to develop the first data dictionary, with input from George Waldthausen at AWI. The data standards were subsequently amended by Sheep Genetics for submission of genetic data and these have been further refined by Gallagher's 'data schema' but the sheep industry remains well-placed with consistent conventions for naming and formatting data by different manufacturers.

Developing software tools for best use of data

Discussion of the value proposition at the start of this chapter (also see Figure 6.1) illustrated the benefits anticipated from using data on measurement of different aspects of production and product quality in order to make within-flock selection and management decisions. The data analysis required to implement the selection decisions and realise the benefits now needed to be converted into software management tools easy to use by producers, ram breeders and advisors.

Kevin Atkins, Jess Richards and Steve Semple took the lead in developing a number of software tools based on Excel macros that could be downloaded from the internet and used to analyse structured datasets, prepared by the end-user, in Excel files. These tools proved popular and at the end of CRC1 in 2007, they were assigned to NSW DPI with a back licence to the CRC to make them available from the CRC's website, free of charge, subject to users completing a click-through licence covering terms and conditions.

Kevin Atkins and Maurie Stephen

SOFTWARE TOOLS FOR PRECISION SHEEP MANAGEMENT

SELECTION ASSIST enabled producers, their advisors or classers, to compare results from different breeding directions, so as to choose which is most applicable to their flock. The program predicted the likely outcome of selected breeding objectives. It also showed the impact of reproductive rates and where the progress could come from within a flock.

SIMULTANEOUS ASSORTMENT was developed to allocate animals into their most appropriate 'meat' or 'wool' groups according to individual information on the animals, e.g. fibre diameter (FD) and body weight (BW). In combination, the wool animals would have a lower average micron and the meat group a higher average body weight, rather than just a 'select' group and an alternative group.

THE LAMB GROWTH PREDICTOR was a tool for making management decisions in lamb production systems. It used repeated live-weights to calculate individual growth rates and adjusts these (for expected conditions) for future weight predictions. It predicted how many animals would reach a target weight by specified dates.

THE MERINO V TERMINAL FLOCK MODEL assisted producers to decide the appropriate number of ewes to allocate to self-replacing Merino matings and first-cross matings, with the aim of maintaining a sustainable self-replacing flock.

THE WETHER CALCULATOR showed the economic consequences of varying the proportion of wethers within flocks of varying fibre diameter over a range of meat values for surplus stock. A range of selection options were also available for consideration. It relied on base flock information to be entered and used these to make predictions on future fibre diameter (FD), fleece weight (FW) and body weight (BW). Meat and wool pricing options were then applied to these predictions to determine gross margins, showing the optimal economic proportion of wethers within the flock (the decision for including wethers or not was determined on more factors than just economics).

THE OFFM CALCULATOR assisted commercial wool producers to determine whether fleece measurement is likely to be a profitable practice for their flock. Using basic information on flock structure and performance, the calculator showed the likely profit from four areas of production: hogget clip preparation, adult clip preparation, ewe selection and wether selection. The returns were shown in a simple graphical format over a 10-year period and offered some suggested changes for increasing profit by altering structure or selection method.

SMART MERINO was a decision support software system designed to assist in planning a Merino-based wool and meat production enterprise, using four integrated tools: Merino vs Terminal Flock Calculator; On-Farm Fibre Measure (OFFM) Calculator; the Wether Calculator; and the Flock Structure Tool. It examined potential flock changes over time and estimates economic results from changes in selection strategies and flock structures.

EARLY ADOPTION OF PSM DELIVERED GENETIC GAIN FOR STUDS

A willingness to try something new and to adopt technology early dramatically changed for the better in the Mortimer family's sheep breeding operation, Centre Plus, in Central West NSW. Mark Mortimer (right) said their eagerness to be at the cutting edge of R&D was built on the belief in new technology as an enabling mechanism for lifting the performance of individual producers, their flocks and the industry as a whole.

"For me there is a real excitement in finding something new, something that hasn't been discovered before," Mark said. "Certainly, you go down some blind roads before you find the path that you need, but by the time we have bedded down one technology and are using it efficiently, we'll be trying our the next tool."

The Mortimers, based at 'Devondale' at Tullamore in Central West NSW, run the breeding nucleus of 1,200 ewes for the Centre Plus Ram Breeding Group. In 2003, the Mortimers were among the first to invest in precision sheep management systems combining electronic identification and an autodrafting system, which allowed them to select sheep based on up to 200 criteria.

It also resulted in time and labour savings – prior to the investment it took three people an hour to weigh 180 sheep; using the automated system it took two people an hour to weigh 250 head.

Working with the Sheep CRC he was able to use RFID tags to match pedigrees, record and monitor body weights, monitor faeces samples for worm control, and record fleece measurements. The Mortimers subsequently built on their objective measurement systems by incorporating DNA testing into the business, allowing them to introduce proven genetics to the nucleus flock a full year earlier than under traditional management systems.

"We are objectively measuring what I call the economic traits – the ones that make you your money, while we need to give up some of our visual selection pressure," he said. "The breeding objectives for Centre Plus have always been focussed on the 'all-purpose Merino'. At the beginning it was growth rate, fertility and lowering micron, while holding fleece weight steady. Then the focus moved from reducing micron to increasing fleece weight and improving other traits such as worm egg counts, eye muscle and staple strength."

Mark said there had been an understandable wariness in the industry about new technology, as it was human nature to be hesitant about relying on a technology when not knowing exactly how it worked.

"There are times where you have to force yourself to make changes, and back it up with measurements afterwards to make sure that it worked as expected," he said.

"The bottom line is that if you want to advance you normally need to change what you are doing and it is important to take action. If you are presented with an opportunity to try something, you need to have a go at it, but you also need to measure the outcomes very carefully, so you don't blindly accept that something new is working — if it isn't. Make a decision based on the action required."

Engaging and collaborating with industry

The CRC's first contact with industry was made with the Ruddweigh electronic weighing company based at Guyra, NSW, where Mike Hemsley and his colleagues were studying options for expanding their product lines into using electronic identification with their weighing systems. Ruddweigh was also working with a local engineering company, Ramage Engineering, to build an automated drafting system utilising electronic weighing, ID capture and programmed drafting.

The CRC also worked closely with Allflex and the Tru-Test companies based in New Zealand to ensure that the export of data from the measurement and data-capture equipment was in a form compatible with the software programs developed by the CRC for enhanced use of the data. The interaction also resulted in these companies developing proprietary software programs for data management and with file export functions that were suitable for additional analysis.

The strong links the CRC developed with Ruddweigh continued following acquisition of Ruddweigh by Gallagher, with Mike Hemsley transferred to continue the work on precision management systems with Gallagher.

As important as the CRC's close working relationship was with the hardware manufacturers were the links that developed with Practical Systems and Sapien Technology, companies specialising in data management and analysis. Hugh Beattie, the founder of Practical Systems, followed the developments in the CRC's approach with many positive suggestions for ways to improve data transfers to their clients. A similar positive relationship developed with Rob Wyld, the founder of Sapien Technology. It soon became clear these data management companies would become the key routes for commercial delivery of value-adding data management. Both organisations joined the CRC for its third term from 2014–2019 and continued to contribute to product development and to provide valuable delivery of CRC information and new products to their clients. A good example is the commercial delivery by Sapien Technology of a fully integrated Pedigree MatchMaker service that includes a software package for pedigree assignment plus tag-reading panels and data capture software.

Ruddweigh's first automated weighing and drafting system (2003) — Rodney Ramage (Ramage Engineering), Guy Newell (Qld DPI) & Mike Hemsley (Ruddweigh).

The CRC always valued the opportunity to host joint field days, training events and seminars with these commercial companies. This approach recognised that the commercial companies provided the products and after-sales service and that the role of the CRC was to develop and explain the value proposition of the data and its use.

Delivery, training and commercial delivery

Once most of the technical issues had been resolved, to the point where automated data collection was a reasonably routine procedure for anybody with a good understanding of the hardware and appropriate skills in data management, the CRC invested in a number of initiatives to engage with end-users and expand the use of the new technology.

With the cost of eID tags decreasing (see Figure 6.3) the next challenge was to increase the number of people able to use the eID technology and related software programs. To do this the CRC prepared a structured 'Learner's Guide' to support TAFE lecturers and high school teachers include the key aspects of precision sheep production into their courses. Integrated with the 'Learners Guide' was the 'Precision Pays' booklet of case-studies and the 'Glovebox Guide'.

PRECISION SHEEP PRODUCTION TRAINING RESOURCES

INDIVIDUAL ANIMAL MANAGEMENT LEARNER GUIDE (2007) was developed by Nicole Sallur and Cheryl Pope to help vocational and educational trainers deliver up-to-date information on the topic of individual animal management and related decision support tools.

THE PRECISION PAYS booklet featured case studies describing innovative ways that different producers, ram breeders and meat processors used eID and precision sheep production principles. The booklet could be downloaded from the CRC's website.

THE GLOVEBOX GUIDE was a booklet designed as a starting guide for producers who wanted to implement precision sheep management. The guide dealt with the most basic level of data collection and the most common hardware. While computer assisted data collection options were possibly more varied, most software programs came with their own specific instructions for use. The guide included a collection of proven methods that allowed accurate and timely data collection which could then be used to assist in informing management and selection decisions. The procedures covered the major classes of data:

- Fleece data — collecting fleece weight, diameter, wool classing data in the shearing shed;
- Weighing and reproductive data; and
- Visual Classing scores such as conformation, fleece rot and breech score.

PSM training with Steve Semple.

PSM Masterclass

In addition to encouraging vocational training programs, the CRC initiated a number of training programs and masterclasses at the NSW DPI research facility at Orange and a major industry conference and demonstration day in WA, 'Towards Individual Animal Management - 2004'. Another popular hands-on training initiative was coordinated by Deborah Maxwell in conjunction with the Information Nucleus program. Whenever staff working on the Information Nucleus resource flocks were taking measurements and collecting data, local producers were invited to drop in and participate in the activity. This approach provided the opportunity for small group discussions on a regular basis at each of the eight sites around Australia.

At the start of CRC2 in 2007, the Board was keen to see the precision sheep management technology expanded. The CRC approached Ian Champion and Bill Hiscox, both highly respected marketing specialists in the area of animal health and animal management systems, to help develop a plan for commercial expansion of the e-sheep systems. One of the first steps was to appoint Mark Coupland to implement the plan. Mark did an excellent job in defining the value proposition for different segments of the sheep industry and was also responsible for development of the 'Glovebox Guide'. This proved to be a useful resource and helped many new users of the technology to set up the system on their own properties and use the new information for selection decisions in breeding programs and for marketing.

PRECISION SHEEP MANAGEMENT CHANGES COMMERCIAL PRODUCTION AT COOLBAROO

There was a time at 'Coolbaroo' when sheep classing was a long and drawn out process that involved pots of paint and plenty of frustration at the race, but that all changed with the advent of RFID tags and the adoption of precision sheep management technologies.

David Strong was manager of 'Coolbaroo' in the early 2000s when the system was implemented and said PSM put into the history books many of the old practices associated with classing with lots of people working along the race.

"Someone would call out a tag number, someone would retrieve the hard copy of the information and then the sheep would be marked accordingly. We always had errors with that system," David said. "With the advent of the RFID tag we could readily access the data on the computer in the yards or at the race."

David's first experience with RFID tags was in 2003 but the family had been recording individual animal performance for many years prior to that.

"We had the book work on fleece weights and micron for pretty much the entire ewe flock, so it was great to be able to combine the data," he said. "It meant we could easily re-use the information and importantly, the data could be accessed at the race and used in our classing decisions."

David was involved in RFID tag trials and 2005 was the first year that all the Merino ewes at 'Coolbaroo' were RFID tagged. The family-owned property is located at Ladysmith near Wagga Wagga, NSW, and had been in the Strong family since the 1950s. Their sheep flock at the time comprised 2,300 Merino breeders, 500 wethers and 900 hoggets. Of the ewe flock 1,300 were joined to Merino rams, while 1,000 were joined to Terminal sires to produce prime lambs sold at 40–45kg (live).

Lambs were RFID tagged at marking, with electronic records kept of which mob the lamb was born into. Lambs were then weighed at various stages throughout the year to generate growth rate information that was used for genetic comparison and selection.

An autodrafter was used to ensure slaughter sheep were at their target weight prior to sale, while for the wool business a mid-sample was taken at crutching in October with a barcode printer labelling each sample to match it to the RFID tag. Wool testers could read the barcode with the matched data emailed back to Mr Strong. Mr Strong could then run the hoggets, for example, through an autodrafter prior to shearing according to micron to achieve specified bales of wool.

"This meant we could very accurately target a specific market," David said. "Our notional fleece value at the time ranged from $15–$90 a head — this huge variation was largely hidden until we captured and accessed that data."

Hoggets were ranked according to their fleece value which was combined with bodyweight to inform what management option would be taken with those sheep, such as whether to become a dam for crossbreeding or for Merino breeding.

"The RFID tags are a great selection aid that undoubtedly helped the genetic advancement of our Merino ewe flock," David said. "It definitely makes running the enterprise much more interesting. For example, in a drought we know very quickly where to start culling. My finger is right on the pulse."

Spreading the cost of precision sheep production hardware

Recognising the cost of the hardware associated with measuring systems, the CRC examined the option of setting up a mobile data collection and drafting unit as a means of a contractor sharing the cost of the equipment across several clients. The first prototype was built by the CSIRO's Chiswick team and included electronic scales, a tag reading panel and auto-drafting.

The second prototype operation was developed with Cousins Merino Services based in Burra, South Australia. Paul and Michelle Cousins carefully reviewed the new opportunity and agreed to collaborate with the CRC by providing enhanced eID data capture services for a number of their stud breeder clients. The technology proved to be particularly useful for sheep classing and pregnancy scanning, where data could be integrated from past measurements to make better-informed decisions implemented via the autodrafter.

In another initiative, the CRC negotiated an introductory financing arrangement through Tru-Test and Elders' merchandise division. A number of large stud breeders were the first to take up the use of the new equipment and the CRC provided good back-up support to ensure that data was collected efficiently and used effectively. The scheme created a significant level of interest that led to longer term investment once a broader range of stud breeders gained confidence from observing the results in the pilot trials.

Pregnancy scanners

In parallel with the new commercialisation initiative was a CRC2 program to work with pregnancy scanners and their clients to make better use of the ultrasound scanning data. The success of this initiative with commercial pregnancy scanners drew on the information that could be stored and subsequently used through eID-based systems. One of the scanners, George Sim, developed his own very impressive scanning and animal drafting system that allowed simultaneous measurement of weight, pregnancy status, number of twins and condition score, with the information used to draft animals at time of scanning and for subsequent nutritional management.

Mandatory use of eID tags in Victoria

A major change in the eID landscape came in 2017 when the Victorian government made the use of eID mandatory for sheep. This decision was based principally on the need to have best practice tracking for biosecurity but included consideration of the potential benefits that would result from increased implementation of precision sheep management. In implementing compulsory use of eID, the Victorian Government provided subsidies for producers to purchase measurement and drafting equipment and also provided training programs drawing on the CRC's material. The widespread use of eID tags also stimulated an increase in the number of people skilled in the use of the equipment and able to provide professional support in set up and data management.

2009

PSM WINS CRCA AWARD

Precision Sheep Management (PSM) was hailed as a nationally significant innovation in the field of science and technology when it received a CRC Association Excellence in Innovation Award. PSM was recognised for delivering a new approach to livestock management with proven impact in improving productivity.

Further value from eID and related equipment

The CRC investigated a number of additional opportunities to value add the investments of producers in eID tags, readers, electronic scales and an automatic drafter. The potential value in these new applications was anticipated through more efficient use of labour and cost-effective systems to monitor and measure sheep.

Walk-over-weighing

One of the goals was to develop a system for automated walk-over-weighing and this work was initially led by the team at CSIRO under the leadership of David Miron. The CSIRO project defined how to convert the electrical signal produced by a sheep walking over the platform to an estimate of its liveweight. Bill Murray subsequently developed a successful prototype at NSW DPI's Trangie Agricultural Research Station. Despite the demonstration of a successful prototype in 2003, the process of automated walk-over-weighing remained an elusive challenge for the industry in terms of developing a cost-effective, easy-to-use, reliable system.

Pedigree MatchMaker linking ewes and lambs by association through reading eID tags as they pass into and out of a fenced off watering point.

The Tru-Test company developed the first commercial walk-over-weighing system and various options for using the equipment in commercial settings were investigated by Tony Thompson at Bourke, NSW, as well as a number of other producers. The challenges were to achieve an even movement of animals over the platform, keeping a reliable source of power in remote areas, storing the data and/or sending it back to base for processing.

Abattoir hook tracking

A prototype eID hook tracking system was developed and installed in the Hillside Abattoir that facilitated measurement and reporting of carcase weights and fat depth against individual live animal data identified by eID ear tags from participating Q Lamb suppliers. Following establishment of proof-of-concept by the CRC in 2003, MLA contracted Gerry Wind of Sunshine Technology and Rob Shephard of E-Stock to design and work with Peter Trefort and his staff to install a permanent abattoir hook tracking system in 2005. The project provided design information and experience to contribute to later hook tracking systems working with DEXA equipment to provide feedback on lean meat yield on individual animals.

PSM YIELDED CARCASE CONSISTENCY AT HILLSIDE

The evolution of Precision Sheep Management (PSM) technology changed the way sheepmeat and lamb exporter Peter Trefort managed his feedlot and abattoir, 'Hillside Meats' in Narrogin, Western Australia. In just 12 months after deployment, PSM was delivering improvements in product consistency and financial returns from accurately identifying the best and worst feedlot performers and linking this performance with carcase characteristics and sire lines.

Peter Trefort, Hillside Meats, Narrogin WA.

For Peter, who was also a long-serving member of the Sheep CRC Board, PSM was a logical step forward for his business that exports mutton and lamb to countries throughout the Middle East and Asia.

"Not only could we see the lamb's performance in the feedlot, we can record carcase traits and how these relate to the animal's breeding," Peter said at the time. "The abattoir was running trials with simple weight gain such as liveweight into the feedlot and weight out, but as the drought forced feed costs to rise by about 40%, we had to look much closer at the whole feeding system to get the most out of it. So, we started researching breeding and the use of different sires and to make sure the trials were accurate we decided RFID tags were the best option."

The RFID tags were combined with walk-over-weighing technology to provide 'Hillside' with performance data.

"Now not only could we see the sheep's performance in the feedlot, we could easily record carcase traits and relate these to the animal's breeding," he said. "And we could quickly see the effect of the environment - for example, a hot spell of weather - so we could ascertain the best conditions for the sheep to gain weight."

All sheep that entered Hillside's feedlot were RFID tagged and automatically weighed with data logged every time they fed. This provided a quick and accurate way of identifying the best and worst performers, with management then altered accordingly.

"We had variation in carcase yields of 41 to 50pc and most of that was genetic. So, the PSM and RFID tags were able to help us minimise that," Peter said. "There are many parameters that go into providing a good eating experience and PSM helped us take the guesswork out of much of it. The best time to sell a lamb is when it is ready. The more we know about that, the better. Even if you keep a lamb for a few days on more feed than needed, that could be your profit margin gone."

Pedigree MatchMaker

Pedigree MatchMaker established links between ewes and their lambs based on the natural behaviour of a lamb to follow its mother. By fencing off a watering point and allowing single file access of sheep, the distance between an ewe and her lamb could be automatically recorded as they walked to and from water. Ewes and lambs were fitted with "electronic" radio frequency identification tags (RFID) and the tags were recorded automatically at the entry point as well as the time interval between tags. A software program then matched ewes with lambs based on closeness of association. That is, a lamb that closely follows an ewe walking into the watering point or back out to the paddock on a number of occasions was identified as a lamb belonging to that ewe. The accuracy of prediction increases with the number of measurements and is more than 92% after seven data collection events.

The traditional method of linking lambs with their ewes involved close observation during lambing. This method was very labour intensive, could disrupt ewes and lambs leading to mismothering, and could be inaccurate if not performed by experienced operators. The 'gold standard' DNA technology, while very accurate, was more expensive than the Pedigree MatchMaker system.

2009

PEDIGREE MATCHMAKER ON ABC NEW INVENTORS

Steve Semple and Mark Mortimer, the inventors of the Pedigree MatchMaker system, featured on the ABC's New Inventors program to showcase Pedigree MatchMaker, an electronic system which accurately determines which lamb belongs to which ewe.

Mark Mortimer and Steve Semple

Pedigree MatchMaker uses eID tags to measure data about the proximity of particular lambs to particular ewes as they pass through a gate to a water source. The design of the system was based on the natural tendency of lambs to follow their mother.

Sheep CRC representatives Stuart Mitchell (left), Kevin Atkins, John Gibson and Steve Semple (right) discuss PSM hardware with sales representatives at an agricultural field day.

Use of e-Nose for flystrike detection

With the expanded use of walk-over-weighing and Pedigree MatchMaker by producers, the CRC set out to explore the use of electronic odour detection pioneered through the e-Nose company based in Sydney. Graham Bell, the founder of the company, was confident that the electronic odour detection unit could pick up the smell of flystrike in sheep passing the reader and weighing assembly. Preliminary results indicated that the e-Nose could not only detect the odours associated with flystrike but was also able to detect urine stain and dags. Due to limited resources, the CRC decided not to pursue this initiative but further work by the Queensland DPI, in a project led by Peter James, demonstrated proof of concept for the e-Nose technology under experimental conditions.

Patent covering integrated animal management systems

It was clear that the CRC was investigating a novel area in pursuing automated animal measurement and implementation of management decisions based on data collected. In order to protect the CRC's position and provide freedom to operate, a decision was made to lodge a patent for the business system.

The key claim was to use a combination of animal identification, at least one measurement system together with a database and decision support system, that could then feed into a method for implementing a management strategy through an automated drafting system. The patent was lodged with a true CRC-style team of inventors that included 12 researchers and four organisations. The patent was granted in Australia and New Zealand, although it attracted little attention at the time.

However, prior to the conclusion of the CRC in 2019, five organisations had applied for licences and two further organisations had requested licences. MLA, as the assignee of the patent, took on the responsibility to maintain and manage the patent and negotiate licences.

IMPACT OF THE E-SHEEP INITIATIVE

- The new electronic data collection systems underpinned the success of the CRC's new Information Nucleus program that commenced in 2007. In this program measurements were made of practically every aspect of animal production and product quality. The quality of the data and the accuracy with which it was recorded and stored ensured that the value of the information from the program was without precedent. Without the skill and experience in eID-based measurement technologies developed during CRC1, the scope and success of the Information Nucleus program in CRC2 would not have been possible.
- The significant increase in the production of fine wool (18um and finer) without any reduction in average per head fleece weight, and with increasing lamb carcase weight and turnoff numbers between 2001 and 2019, could only have been achieved through genetic improvement and within-flock selection enhanced by eID data collection and use of precision sheep management software tools.
- The CRC's deliberate engagement of hardware and software supply companies fast-tracked the development of robust and reliable equipment and programs at a time when there was little market imperative to do so. Much of that endeavour arose because the CRC was able to articulate a potential industry vision that the suppliers could relate to, even though the predicted uptake was significantly into the future.
- From zero usage in 2000, by 2019 almost 100% of studs in Sheep Genetics use eID tags for data collection. This has resulted in:
    - More accurate data collection leading to higher accuracy ASBVs and faster rates of gain for production traits;
    - More data on additional traits being collected leading to a wider range of ASBVs on stud and commercial animals; and
    - Expanded use of DNA technology for pedigree assignment and for genomic evaluation. Without eID technology, the collection, storage and analysis of DNA data was almost impossible or severely compromised.
- Coincidental to this period of uptake of eID technology by studs, Sheep Genetics (Swan et al 2003, 2009, 2017) reported substantial increases of 50–150% across breed groups in the rates of genetic gain being achieved by studs. This increased effective genetic gain came from a number of sources, but it would be easy to argue that some part, perhaps 10–20%, of the additional gain is the direct result of electronic technology improving selection accuracy.
- The precision management tools for decisions on profitable flock structure and selection had a positive impact on guiding the re-structuring of the national flock over the period of the Sheep CRC. While the tools themselves did not produce the outcomes, they identified and facilitated the decision process required to improve flock productivity in the face of drought, changing market conditions and competition from alternative enterprises. That decision process was communicated effectively through the activities of those who participated in the various training and awareness programs run by the CRC.

FIND OUT MORE

Precision Sheep Management underpinned a number of the CRC's research initiatives. To find out more on how PSM was linked to other major outcomes go to:

- Chapter 3 — Integrating Wool and Sheepmeat Production
- Chapter 4 — Introduction of Genomic Technologies
- Chapter 7 — Transforming Sheep Wellbeing
- Chapter 8 — Quality Sheepmeat
- Chapter 9 — Measuring the Magic of Wool
- Chapter 11 — Implementing Innovation

7 TRANSFORMING SHEEP WELLBEING

There was no doubt that Sheep CRC research and training programs led to transformational improvements in sheep and their wellbeing management. The improvements could partly be attributed to individual initiatives — such as selection for animals that were better adapted to their environment, improved monitoring of ewe condition score and better nutritional management through applying Lifetime Ewe Management (LTEM), better use of scanned ewe data, information from ParaBoss and the forecasting functionality of ASKBILL. But in reality, the transformation was built upon an entirely different approach to managing the sheep flock which was the basis for these tools that facilitated change.

The Sheep CRC first focussed on the major issues of sheep wellbeing, in the context of consumer and community expectations, when planning the program for the second term in 2007. The title of the new program defined the aspirational goal of 'Transforming sheep and their management'. The broad transformational agenda included projects on breeding better-adapted sheep, improved reproductive efficiency, precision sheep production and improved parasite management. The program even investigated methane production in light of increasing consumer focus on the contribution that ruminants make to greenhouse gas emissions.

From 2007 through to 2014 the program was led by Andrew Thompson and included an active group that he built following his move to Murdoch University, but with strong ties with members of the Victorian Department of Agriculture, Rural Industry Skills Training (RIST) and Jason Trompf, with whom he had worked for a number of years on the Lifetime Wool program. Mark Ferguson led the initiative to provide the tools for producers and breeders to better match genetic selection to the requirements of different environments and the demands of varying production objectives. Andrew's postgraduate group, including Andrew Kennedy, Gus Rose, Sarah John and Kirsty Thomson, helped shape the program. This was a period of rapid progress largely due to the success of the LTEM initiative and the scanned ewe workshops that were very popular and produced significant levels of practice change.

There was also a lot of new information that came out of the Information Nucleus program such as new breeding values for selecting against wrinkles and horns. However, it was disappointing that despite careful research there were very few new major leads for genetic selection for lamb survival.

When planning the final five-year term for the CRC, the Commonwealth Department of Agriculture and the RSPCA suggested more focus on management systems specifically designed to improve sheep wellbeing outcomes, as opposed to research with joint production and wellbeing outcomes.

Andrew Thompson left the CRC in 2014 to continue working on LTEM and Geoff Hinch took on the program leadership to design the sheep wellbeing program for the final five years. The hypothesis developed for the final term was based on the use of automated animal measurement systems for early detection of problems and intervention before clinical problems developed. However, due to complexity of the measurement and data capture systems the approach was revised during the third year of operations.

Andrew Thompson

The new tack was to apply our growing capability in web-based predictive models, based on experience with RamSelect. The new focus was based on using actual and forecast weather data to predict risks likely to compromise sheep wellbeing — such as worm and fly population dynamics, cold stress and restricted feed availability and under-nutrition. This was the start of ASKBILL and saw a significant expansion of the project team and an enhanced ability to predict risks far enough ahead to take appropriate management action.

Overall, these initiatives provided multiple approaches to addressing a complex and interconnected set of challenges that involved the sheep, it's environment, the manager, and the community. The process of transforming sheep wellbeing management will continue for as long as there are sheep and there will always be strongly divergent views on the right way to do things. Although proponents of individual initiatives may have promoted a particular approach as a panacea, the CRC never attempted to promote any new approach as a 'silver bullet' but rather as another part of an integrated solution.

Better adaptation of sheep

The importance of balancing genetic selection for production and for adaptation to the environment has long been recognised. During the first Sheep CRC, Norm Adams raised the question of whether selection for increased wool production might compromise adaptive ability of sheep to the variable nutritional conditions that are so common in sheep producing regions of Australia. As a result, during CRC2 there was a large program of work targeting a better understanding of traits that help sheep survive under difficult nutritional conditions. The work led by Mark Ferguson built on findings from his PhD research program that muscling and fat were traits predictive of better reproductive performance, particularly during dry seasons and poor nutrition.

The results of this work were incredibly important in achieving greater awareness of the value of maintaining an appropriate selection pressure for fatness and muscling, particularly for the ewe flock. These principles were integrated into the Bred Well Fed Well workshop series and have become integral to the strategies of many leading breeders. Given the focus of LAMBPLAN on less fat, increased growth and more muscling, there was a good level of debate over how much selection for fat was appropriate. It was another example of where a balanced approach was required and leading breeders and producers readily grasped this fact.

In addition to fat and muscling there were other traits considered under the general category of adaption and impact on the environment. There was considerable debate over whether reduced rate of weight loss, exhibited by some sheep, was sufficiently heritable and of sufficient economic importance to warrant further study by the CRC, with a view to developing a new breeding value for Sheep Genetics. The Western Australian group led by Mark Ferguson, Andrew Thompson and John Young, devoted considerable effort to define the trait and its economic significance. John Young assisted with economic modelling studies to show the potential impact of breeding for animals that had lower rates of weight loss under poor nutritional conditions.

However, the east coast geneticists including Julius van der Werf (as Genetics Program Leader) and members of Sheep Genetics and AGBU, were not convinced about the heritability of the trait and how it could be defined and measured. The CRC called upon the Project Review & Research Committee (PRRC) to provide advice on the proposal. Neal Fogarty conducted a comprehensive review and concluded that due to the complexity of the trait, the difficulty

System for measuring methane production.

of measuring it under commercial conditions and the low heritability, it was not a target that the CRC should pursue.

CRC2 also tackled the hot-button community issue of greenhouse gas emissions from agriculture and the question of ruminant methane production. The Information Nucleus program provided a perfect resource for measuring the genetic and environmental/nutritional factors influencing methane production. As all animals were also being measured for a wide range of other production characteristics, there was further value through being able to study cross-correlations between methane production and other traits. The challenge for the research team was to measure methane production without too much disruption of the normal grazing regime.

Andrew Thompson and a group led by Roger Hegarty, developed a system of methane measurement based on the 'butter box'. This involved running sheep into the yards and down a race. Once in the race, large perspex boxes were lowered over each animal and gas emissions measured over a two-hour period. This new method for measuring methane proved to be sufficiently accurate and repeatable to provide useful information for the study of the genetic and environmental components of methane production.

The research successfully defined the genetic characteristics of methane production and its correlations with other traits. However, the cost of measuring methane production and its complex relationship with the quality and amount of feed consumed, made it very difficult to develop an estimated breeding value to incorporate into breeding programs.

Changing industry practice

While the researchers debated what was possible, the focus for our interactions with producers was on what was practical. Mark Ferguson and his group developed the highly successful Bred Well Fed Well one-day course that focussed on creating better awareness of the management requirements of sheep with different genetic characteristics. The course highlighted the key production benefits of superior genetics, plus feed management for improved reproductive performance and livestock productivity. As a result of the workshop, producers were able to analyse and plan genetic selection to better match the nutrition regime characteristic of their environment. Once successful pilot trials had been developed by the CRC, MLA took the lead in supporting and promoting the course for sheep producers and later adapted the course for cattle producers. The workshop was still being delivered by Mark Ferguson and Jason Trompf and continues to be well attended by sheep producers and breeders, even after the CRC's closure.

Another significant product was the 'ASBVs — A guide for ram buyers'. Mark Ferguson took the lead in designing the booklet, which provided practical information about the implications of selecting for different traits for which ASBVs are available through Sheep Genetics. Of considerable interest was the description of related traits and interaction between traits. The clearly presented contents, and the attractive layout by Rhonda Brooks, resulted in a publication that continued to be extremely popular with sheep producers. It was first released as a joint Sheep CRC and Sheep Genetics' publication in 2011 and a further four editions of the publication were produced between 2014 and 2019, with several print runs for each edition. (See Chapter 11 for more information on the Sheep CRC's extension programs).

Making best practice common practice

Before the arrival of the CRC, there was already a huge amount of knowledge and innovative practices in the hands of consultants and leading producers. Creating more widespread use of this knowledge seemed to be a simple approach to accelerate transforming sheep breeding, management and animal wellbeing.

The first initiative undertaken by the CRC to understand and document details of successful sheep enterprises was the benchmarking project conducted during CRC1 and coordinated by Ken Geenty and Deb Maxwell. Despite a number of interesting findings that were presented at the CRC's 2006 Wool meets Meat Conference in Orange, NSW, the approach didn't deliver any messages that were easily translated into recommendations for widespread industry adoption. The benchmarking approach was seen as being more appropriate for consultants and their network of clients for fine-tuning their enterprises under a range of production systems targeting different market opportunities.

The next CRC initiative to capture and disseminate 'best-practice' information on sheep management was developed by Bob Hall and Mandy Curnow. This turned out to be an excellent plan and was very well implemented.

Bob Hall AM, the legendary sheep industry consultant based in Darkan in south western WA, offered to document some of the management principles that he had developed with his clients to improve efficiency of labour inputs and profitability. Mandy Curnow, extension specialist in the WA Department of Agriculture, encouraged Bob and worked closely with him to develop a booklet entitled *Sheep — the simple guide to making more money with less work*. It was produced for farmers wanting to quickly update themselves on the technology and infrastructure needed to get back into the industry or, for those currently in the industry, to lift the efficiency of their system to increase their flock size and/or profitability. Staff in the WA Department including Mark Ferguson and Andrew Thompson also made significant contributions to the publication.

'Sheep: the simple guide' covered topics including:

- manage for ease & success
- less droving, more driving
- headache-free husbandry
- healthy sheep save time
- well-fed sheep
- money grows in paddocks.

Starting with a cautious print run of 500 copies it was not long before reprints and new editions were needed to satisfy the demand for this very popular publication.

It was recognised that much of the advice and experience was drawn from the higher-rainfall areas of WA and attention quickly turned to adapting it for other major sheep production regions. The next version of 'The Guide' was developed for production systems in the cereal sheep zone, with subsequent editions prepared for the High Rainfall regions in Victoria and Summer Rainfall zones of northern NSW and Queensland. Many specialists contributed to each edition with their local knowledge and experience. Ian McFarland of Rural Solutions SA, Jim Shovelton of Mike Stephens and Assoc. (now Meridian Agriculture), and Chris Shands from NSW DPI, all provided significant input to the versions tailored to their regions.

Although development of the new information, training programs and publications was an important CRC achievement, it was the CRC's commitment to promoting these resources that was equally significant. The well-integrated and consistent approach of promoting events and new material in a coordinated way through media releases, the CRC website, newsletters, industry events and social media proved to be incredibly effective (see Chapter 11 for more detail).

Bob Hall

Improving sheep reproductive efficiency

One of the key commitments of the 2007 Sheep CRC was to reduce lamb and weaner mortality. Given the community and industry sensitivities to what others may have viewed as an animal welfare failure, and the fact that most producers did not see a need to change their on-farm practices, the CRC's goal was defined in the more positive light of improving reproductive efficiency. The target was set at 10% more lambs marked in at least 25% of the Australian ewe flock.

The challenge of achieving industry practice change to realise improved reproductive efficiency was enormous and was highlighted in the findings of a major MLA review undertaken by Russell Barnett in May 2007. The main conclusion of the review was that, while many of the technical constraints to reproductive efficiency were well known, most sheep producers did not consider that there was a compelling case to change their current practices.

In order for the Sheep CRC to have any impact on reproductive efficiency at a national level it was clear that the 'compelling case' for practice change had to be thoroughly understood. It was also apparent that the compelling case was likely to vary between different sheep enterprises and in different parts of Australia and would require clearly defined benefits and practical ways to make improvements.

The project team approached the challenge by developing a strategy with three coordinated strands. The first involved work on the value proposition estimating benefits and costs of increasing lamb marking percentages and of increasing the survival rates of weaners. The second area focussed on better understanding the relative merits of various technical options for improving reproductive efficiency in lambs and weaners. The third strand of the strategy involved examining the constraints to achieving adoption and new approaches that might be more effective. The broad range of expertise and multiple organisations involved in the CRC made this coordinated approach possible and effective.

The value proposition

John Young, a farm economist operating out of Kojonup in WA, was well known for his analyses using the whole farm 'Model of an Integrated Dryland Agricultural System' (MIDAS) developed by David Pannell and his colleagues in WA. John was an obvious person to help answer the question of 'how much is an extra lamb worth' to a producer? The path to the answer involved significant analysis and debate as there were numerous variables involved. A parallel investigation, led by Angus Campbell and his colleagues at the McKinnon Centre at the University of Melbourne, explored the question of 'how much is an extra weaner worth?'. This also proved to be a complex issue. The only thing that was clear was that headline values for additional lambs weaned and additional weaners surviving during their first year would not provide a compelling case on their own.

At this stage findings from AWI's Lifetime Wool Project provided excellent data on which to construct the value proposition. Conclusions from the Lifetime Wool Project pointed to improved lifetime nutritional management producing a wide range of production benefits that, when considered together, formed the basis of a compelling case that could be applied to managing reproductive efficiency. Nutritional management to maintain ewes at a condition score of 3 or above did not only result in more wool production by the ewe but had multiple flow on benefits such as: reduced ewe mortality; increased lamb marking percentages; improved lamb wool production; and finer micron lamb fleeces. Taken as a combined package of benefits resulting from better nutritional management more than covered the costs of additional feeding and improved management of stocking rates. The package started to look like a firm basis for developing a compelling case.

Technical options

In 2008 Geoff Hinch completed an excellent review of the technical factors contributing to lamb losses and reproductive inefficiency. As anticipated, the review highlighted the fact that there were numerous factors that contribute to lamb mortality and that there was significant variation in losses and marking percentages between flocks, regions and years that made it difficult to pin-point the precise cause of losses in each event. Where this review was most helpful was in identifying the two major factors to consider in developing a campaign to reduce losses.

Firstly, a consistent factor responsible for low lamb birth weights, difficult births, and low levels of colostrum, was poor nutritional management of the ewes. Secondly, a factor confirmed over many years, was that rates of perinatal losses of twin-born lambs were 2-3 times higher than for lambs born as singles. By confirming and quantifying the importance of these two factors, the CRC was in a position to start formulating a strategy.

In parallel with the review by Geoff Hinch on lamb mortality, the CRC asked Angus Campbell to review the major causes of loss in weaners. The Campbell review was extremely informative and highlighted two factors having the most impact on weaner survival: weaning weight; and rate of growth (liveweight gain) from weaning to 15 months of age. Again, both factors are predominantly influenced by nutritional management.

Geoff Hinch, Program Leader Sheep Wellbeing CRC2.

Clearly identifying long-term nutritional management as the key factor for reducing mortality of lambs and weaners was useful in narrowing the scope and providing a focus for developing strategies to commence a process of practice change on a meaningful scale.

In addition to nutritional management, there was hope that the Information Nucleus Program would provide new leads for genetic selection to help achieve better lamb survival. For this reason, the CRC made a significant investment in the measurement of ewes and lambs around the time of lambing. Every conceivable aspect of lambing was measured, recorded and analysed. This included measurements on the ewe, the interaction between a ewe and its lambs, and many measurements on the lambs themselves. There were also detailed records of lamb mortalities, linked to their dams by DNA analysis where necessary, and post-mortem examinations were conducted on each dead lamb based on protocols developed by Peter Holst of NSW DPI. It was an extremely detailed search for leads that might enable genetic selection for increased reproductive efficiency.

Although at the time the research was not able to identify any easy to use indicator traits for selection, the work created a database for future analysis and genomic predictions. Subsequent work on the Information Nucleus data by Forbes Brien, Michelle Hebart and staff at AGBU and CSIRO (Kim Bunter, Andrew Swan, Daniel Brown and Jen Smith) identified the importance of accounting for the much higher genetic variation in survival of twin and multiple-born lambs than those born as singles. AGBU also demonstrated that the Maternal Behaviour Score and Lambing Ease were useful indicators for genetic improvement of reproduction. Along with the inclusion of genomic information, these findings were incorporated into Sheep Genetics analyses either as full ASBVs or Research Breeding Values and were expected to have long term benefits.

Adoption models

As emphasised in the Barnett review, reproductive efficiency of the Australian sheep flock hadn't improved over many decades largely because the value proposition was not simple. A new approach was needed.

Lifetime Ewe Management (LTEM)

As an extension of AWI's Lifetime Wool program, Andrew Thompson and Jason Trompf worked with Victoria's Regional Industry Skills Training (RIST) group to develop the Lifetime Ewe Management (LTEM) program. RIST developed this as a course running over two years covering a complete sheep reproduction cycle from weaning to weaning. The model was based on long-term support for small groups (4–6) of producers as they shared their experience in managing their flocks through an entire annual cycle of joining, pregnancy, lambing and weaning with assistance provided by the coordination by a trained facilitator. It was a model that RIST had trialled with Victorian sheep producers focussing on whole flock nutritional management and the results were very impressive. Participants reported increased stocking rates, decreased ewe mortality and increased lambing percentages.

Andrew Thompson introduced the CRC to the LTEM initiative at the 2009 CRC annual planning workshop and a decision was made to give this new adoption model a go. It was a combination of peer group support (and pressure) as well as trusted specialists working alongside the group providing reassurance that the investments would pay long-term dividends. Although an expansive model, the concept gained momentum within the CRC and it was taken to the next level for implementation.

Peter Silk, who led the CRC's commercialisation and IP management work, first approached AWI to gain formal approval for the CRC to take on this initiative. With this approval, the next step was for the CRC to develop a formal collaboration agreement with RIST and with the Victorian DPI, representing the 'lifetime wool consortium' — the co-owners of the Lifetime Wool IP.

The collaboration agreement made provision for inclusion of additional CRC technical advances in the course material and provision for all groups to keep checking the key messages and their impact. All three organisations agreed to work together to promote the program and help to organise new groups.

Further support for the joint initiative was provided by funding from a national skills development program accessed by RIST, as a registered training organisation, and the successful accreditation of LTEM as a registered course. The CRC's main investment was in the promotion of the program, active support for the formation of new groups and part-funding of the facilitators.

The momentum built rapidly rising from 60 producers registered for LTEM in the first year of the CRC's involvement to 350 in 2011 and 690 by 2012. The cumulative reach of the project included some 1,380 farmers responsible for managing 5.5M ewes. It was an initiative with an incredible impact as producers completing the LTEM course consistently reported significant improvements in stocking rate, reduced ewe mortality and increased lamb marking percentages. Importantly, most improvements continued for years after they had completed the course and were expected to be ongoing.

Towards the end of the CRC's second term in 2013, the Board considered that the LTEM program was well-established as a commercial product provided via RIST and with proven benefits for participating producers and wound-back CRC support. When the CRC withdrew from the project, AWI stepped in with a level of support that resulted in renewed expansion of enrolments and further increases in the significant impact of the initiative.

High Performance Weaners (HPW)

Following the success of LTEM, the CRC extended the collaboration with RIST and commissioned development of the High Performance Weaner (HPW) program based on the same model. Technical information for the HPW course material came largely from the review by Angus Campbell and the quantitative relations that he had developed with well defined targets for weaning weights and for post weaning growth and easy to follow strategies to achieve these targets.

Many producers having completed the LTEM program were keen for further development and enrolled for the HPW course. Although popular with producers, the HPW course never attracted quite the same levels of enrolment as the LTEM. Like the LTEM course, it continued to be offered through RIST.

Managing Scanned Ewes Workshops

The Hinch review highlighted the increased risk of mortality in twin-born lambs and the importance of identifying twin-bearing ewes and managing them to decrease the risk of mortality.

Managing Scanned Ewes Workshop (photo courtesy of Chris Shands).

Chris Shands, based at Glenn Innes with the NSW DPI, was long recognised nationally as a specialist in the management of ewes during pregnancy and through the perinatal transition. Chris was therefore an obvious choice to develop and deliver a course for pregnancy scanning contractors and their clients on the management of twin-bearing ewes. The model of working through professional pregnancy scanning contractors was developed to capitalise on the credibility of these professionals in providing management advice to their clients.

Chris built up a national network of about 105 sheep pregnancy scanning contractors. The aim was to enable the scanners to pass on more targeted information to their clients with the aim of lifting lamb survival in their flocks. An important component of the initiative was to convene a national scanning conference, attended by 65 scanners and focussing on how to improve scanning accuracies for detecting twins and to reach consensus on the best management option for the twin-bearing ewes.

The format for the workshops was for the collaborating scanner to seek approval from one of their clients to run the workshop on their property with other clients attending. The CRC's contribution was to cover the costs of Chris and the scanner to attend, as well as covering the cost of a light lunch. This environment enabled producers to discuss the best management practices they could adopt to improve lamb survival. The workshops were supported with comprehensive technical information for the scanners and appropriate resource material and technical backup for producers.

A total of 88 workshops were run over a three-year period and these were attended by some 1,800 producers owning 3.33 million sheep.

A survey of all producers attending the scanning workshops indicated that over half made significant changes to their annual flock reproduction programs. The most significant change was an increase from 49% to 79% of producers requesting scanners to identify twin-bearing ewes rather than just reporting 'pregnant or dry'. The surveys also found lamb marking percentage increases of up to 15%, which across the board represented some 500,000 more lambs. This was mainly due to better nutrition of the twin bearing ewe and more targeted management of single bearing ewes. An additional benefit was that around 40% of attendees indicated an interest in enrolling in the LTEM course.

The success of the Managing Scanned Ewes program was recognised by the award of one of the Commonwealth CRC Program's prestigious STAR Awards. The award was presented for high-level engagement with small and medium size scanning businesses. Michelle and Paul Cousins, through their South Australian business Cousins Merino Services, supported the application with evidence of an impressive growth of 20% in their scanning business, as a result of collaboration in the

2014

LTEM AND MANAGING SCANNED EWES WIN WITH PRODUCERS

A national survey of 1,000 sheep producers revealed the tangible impact the Sheep CRC's training programs have had on farming practices.

More than 80 per cent of attendees changed management strategies after attending Managing Scanned Ewe workshops. It was estimated that improved use of pregnancy scanning data and increased uptake of testing has led to an additional 500,000 lambs being born per year.

The Lifetime Ewe Management (LTEM) program also delivered a number of improvements:

- whole-farm stocking rates by up to13%;
- increased lamb marking percentages by up to 14%;
- decreased annual ewe mortality rates by up 43%; and
- increased number of lambs weaned per hectare by up to 30%.

program and confirmation of the benefits realised by their clients through making better use of the scanned ewe information.

Accurate post-mortem diagnosis

Another effective 'new approach' was the initiative to help producers develop a better understanding of the reasons for lamb mortality in order to plan preventative management intervention in the future.

Peter Holst, a senior veterinarian with NSW DPI, developed an excellent post-mortem guide that the CRC published in collaboration with NSW DPI. This publication was used to standardise the post-mortem analysis of all Information Nucleus lamb losses and proved a useful resource for subsequent workshops and training programs.

Gordon Refshauge, a research scientist with NSW DPI based at Cowra, continued to run a number of lamb autopsy workshops that complemented the illustrated publication prepared by Peter Holst which was later reprinted in an updated version by AWI under the title of *Lambs Alive*.

Improvement in lamb marking percent

Surveys of producers completing the LTEM course and attending the Managing Scanned Ewe workshops confirmed that they had introduced new management practices as a result of those programs, which led to increased lamb survival and improved marking and weaning rates. These results were supported by national statistics collected by the Australian Bureau of Statistics (ABS) and the Australian Bureau of Agriculture and Resource and Sciences (ABARES) that confirmed a considerable improvement in the numbers of lambs marked per ewe joined between 2007 when the CRC programs commenced through to 2018 (see Figure 7.1). The

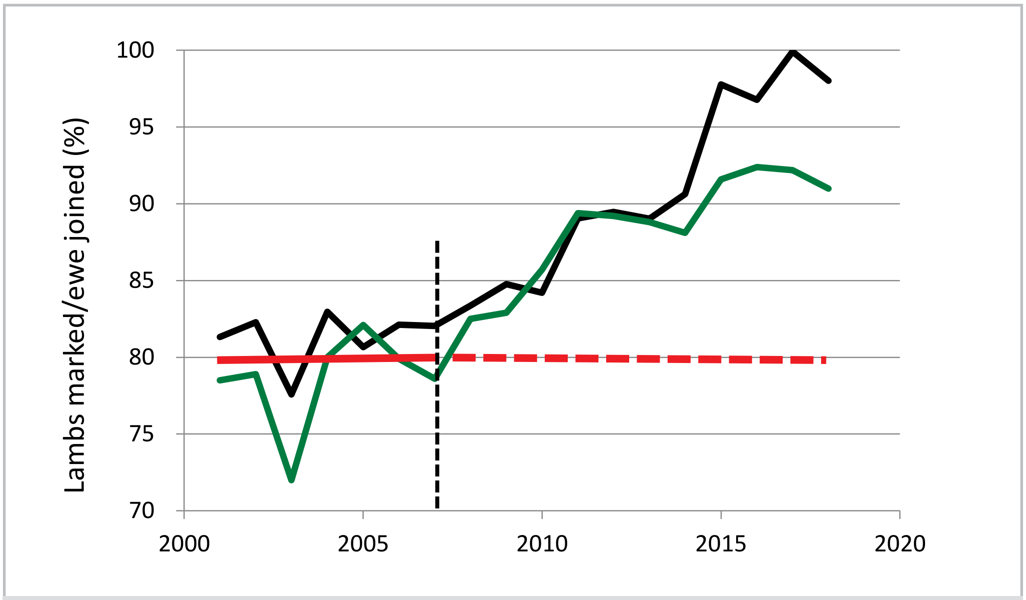


Figure 7.1: Increased lamb marking percentages reported by ABS (black line) and ABARES (green line). The solid red line is the average for the period 2001– 2007.

two independent survey approaches used by ABS and ABARES both told the same story.

Lifetime Ewe Management Course (Photo courtesy of Mandy Curnow).

The improvement in reproductive efficiency following introduction of the CRC initiatives in 2007 was particularly impressive given the challenges documented in Barnett's 2007 assessment of the barriers to change. Lamb marking percentages in the Australian sheep flock had been consistently between 75 and 80% for many years, despite the fact that there were known technical options for increasing these levels to 100% and above.

There were two important outcomes from this achievement. Firstly, the results demonstrated a sustained industry improvement in the management of ewes and lambs to achieve a 15–20% increase in lamb survival through to marking. Secondly there were implications for sheep industry productivity. During the period from 2007 to 2018 the number of ewes in the Australian sheep flock decreased by around 20% from 41.5 million to 33.3 million. Over the same period the numbers of lambs marked only decreased by 4% — an incredible statistic.

Sheep wellbeing using predictions from 'big-data' analysis

Although significant advances were made in understanding and improving aspects of sheep health and wellbeing there was still some criticism that the CRC's goal in that work had been to better manage factors limiting production, rather than actively focussing on improvement of sheep wellbeing as a key factor in its own right.

The complexity of early detection of problems in the sub-clinical stages, in order to implement preventative action, while an aspirational goal, had been beyond reach for generations. In 2014 the CRC set out to tackle this challenge.

At this time there was a growing understanding of the power and practical implications of 'big data'. The potential application of easier data collection, cheaper storage and more powerful analytics had the potential to contribute solutions to complex agricultural production problems. This new era of data-based solutions was therefore investigated as a means of enabling management systems to enhance sheep wellbeing.

The new program was initially designed around the potential for automated data collection, based on eID technologies and data analysis systems, to provide feedback to producers and advisors with alerts of sub-clinical conditions likely to compromise sheep wellbeing early enough to allow intervention and prevention. The proposed approach relied on robust, easy-to-use data collection methodology as well as sophisticated data analytics.

The feasibility of an eID approach to identifying at risk animals involved four avenues of research:

- An investigation of systems for on-farm data collection and how to make it easier from the perspective of a producer.
- An investigation of options for automated data management using cloud-based analytics as opposed to on-farm processing.
- Analysis of the Information Nucleus database to determine if there were predictive trends that could be used to forecast risks to sheep wellbeing using conventional regression-style analysis, a machine-learning approach and measurement of cortisol on retained wool samples.
- An investigation of whether behaviour changes could be automatically detected and used to predict sub-clinical conditions with future implications for sheep wellbeing.

There were several parallel activities to explore the feasibility of using big data for better sheep management decisions.

Recognising that advanced skills and experience in big data systems lay outside the Sheep CRC, the first step was to establish cooperative linkages with organisations that could contribute the skills and knowledge required for this initiative.

In the same CRC Round, when the Sheep CRC was awarded a third term in 2014, a new CRC was established for development of big data solutions. The Data to Decisions (D2D) CRC was established in June 2014 and discussions commenced almost immediately with its CEO, Sanjay Mazumbar, over ways that the two CRCs could collaborate to develop this opportunity.

The second group that the CRC approached was Telstra's big data group. The first meeting with Rob Forsyth, Business Technology Executive with Telstra, focussed on the technical aspects of options for remote (in paddock) data collection and cloud storage and computing solutions. Rob set up the initial high-level discussion with Telstra management and the Sheep CRC in mid-July 2014. From this discussion a steering group was set up, chaired by Les Targ, to explore a range of new technologies and their potential application, as well as possible business models for long-term project and product development.

As both the D2D CRC and Telstra were not Sheep CRC Participants, a Memorandum of Understanding (MoU) was put in place between these organisations, the Sheep CRC and MLA. Alex Ball and Sam Gill represented MLA on the steering committee with the interest of understanding opportunities for the Livestock Datalink project, development of the Data Integrity Unit within MLA, and potential applications in managing the Sheep Genetics and other related databases. The steering committee met regularly to scope out details of potential projects that would enhance the interests of all organisations participating under the MoU. Lavina Muscat and Kent Ramchand represented Telstra, and Markus Stumptner from the D2D CRC joined James Rowe and Lu Hogan, who represented the Sheep CRC. All agreed that Les Targ had the appropriate skills and arms-length involvement to chair the joint committee and help guide the discussions between organisations.

DEFENCE TECHNOLOGY COMES TO THE AID OF SHEEP

For the Sheep CRC to improve management of sheep well-being and deliver innovative products like ASKBILL, it first had to tap into the data science used in Australia's national security systems.

The partnership with the Sheep CRC was the first time the Data to Decisions Cooperative Research Centre had ventured into the agriculture sector.

"The D2D CRC's main focus has been on defence and national security; however, we can take our research and data skills and apply them to other sectors of the Australian economy. Our work is very applicable to any data-intensive industry," D2D CEO Dr Sanjay Mazumdar said in 2016.

The two CRCs worked together to define opportunities for big data applications in livestock industries, with a view to making sheep management easier and deliver better wellbeing and productivity outcomes.

This approach was only possible through a number of new developments in the rapidly changing data technology landscape - faster computing, cheaper data storage, cloud-based data technologies and increasingly powerful machine-learning algorithms.

For the Sheep CRC to get the most out of these new technologies highly specialised skills were required, and an ambitious project of the nature of ASKBILL would have been impossible without the high-level data science experience of the D2D CRC.

Sheep CRC CEO James Rowe; D2D CRC CEO Sanjay Mazumdar; D2D CRC Research Director, Brenton Cooper; D2D CRC Chief Technology Officer, Troy Wuttke D2D CRC Senior Data Scientist and D2D CRC Machine Learning Specialist, Jason Signolet.

Machine to Machine (M2M) automated data collection and management

The first project to get underway as a result of the steering committee planning was to investigate options for automated data capture, both on-farm and in-abattoir. Telstra's experience in M2M data capture, linked to cloud storage and computing, brought a lot of value to the planning of the trials. As part of this process there was also the challenge of identifying whether existing farm data collection systems, such as Gallagher's TFI system, would link with automated M2M systems. Initial results from this work were very encouraging.

The second question related to ease of use of the measurement systems. Liz Roan, working with Lu Hogan and a number of companies manufacturing data collection hardware — such as Gallagher (Mike Hemsley), Allflex (Pat Gunston) and companies such as Practical Systems and Sapien Technology specialising in data management — collaborated in a major initiative to assess the practical aspects of collecting data automatically, capturing the data and using it to identify animal wellbeing risks.

Unfortunately, the results of this investigation were not all positive. It became clear that while the on-farm data collection systems were sophisticated and reliable, the end-user still needed to make a significant investment in the end-to-end use of the systems to ensure that they were familiar both with the data capture and the data management systems. While the investment was considered worthwhile by expert users such as ram breeders, commercial producers were not convinced about the ease of use for management decisions.

In order to understand current attitudes to improving management of sheep for enhanced wellbeing outcomes, the CRC worked with the Animal Welfare Science Centre at the University of Melbourne to conduct a comprehensive survey of producers and industry professionals. Results of this survey indicated that many producers and industry professionals regarded the current practises in animal management to be satisfactory in terms of managing sheep wellbeing. These results were further investigated in a series of workshops in three of the key sheep producing areas of Australia: Katanning (WA); Dubbo (NSW); and Wellington (NSW). The workshops facilitated by Mark Gardner of Vanguard Business Services, confirmed that, by and large, the industry felt that sheep wellbeing was adequately managed and that to make any changes in on-farm practise would require either a technology that was easy to use or evidence of significant additional benefits.

STUDYING BEHAVIOUR AS AN INDICATOR OF WELLBEING — THE TECHNICAL TEAM

Trials investigating wellbeing in animals often require the study of behavioural changes and this work tends to be very time consuming. The technical team involved in the wellbeing project did a great job and included Laura Kemmis and Masters student Tellisa Kearton.

Special mention goes to Rowdy Ballagh, who is of course, rather quiet. Rowdy, a dedicated dairy man, embraced working with sheep and undertook most of the training for the 'movement' trial. This involved him walking for 2km several times a week with a bucket of feed calling for 'the girls' to follow him. He made a great sheep leader, became very fond of his flock and even made special trips to check on his favourites at lambing time!

Rowdy and his girls.

Option of using routine data collection with smarter predictive analytics

At this stage it was clear that widespread adoption of new practises to improve sheep wellbeing would only be achieved if they were based on use of existing practices or fully automated measurement systems with off-farm predictive analyses.

To this end, the first avenue of research involved analysis of the Information Nucleus database. The question asked was whether it was possible to work backwards from the mortality data from all Information Nucleus sites to identify key information that might have been overlooked in terms of indicators of compromised wellbeing setting up a future risk of death. This approach involved analyses of parameters such as changes in live weight and condition score.

Amanda Doughty and Geoff Hinch used regression analyses to investigate potential predictive relationships and Jason Signolet, of the D2D CRC, used machine learning and artificial intelligence algorithms to search for key predictive factors. Allan Tilbrook and his colleagues at the University of Adelaide made an extensive study of cortisol levels in wool samples taken during the Information Nucleus program.

Amanda Doughty

Another avenue of research was coordinated by Amanda Doughty and Geoff Hinch to determine whether changes in behaviour or body temperature could provide early signs of compromised wellbeing. Three different approaches were examined. The first involved measuring the flow of sheep past set points in the paddock or moving between paddocks, as well as in and out of yards. Research focussed on changes in the order of animals moving within a flock as certain sheep in the flock developed controlled levels of internal parasites. A second approach was the use of video image analysis to determine whether it was possible to automatically detect lameness or to use information from social networks to identify early problems. The final approach used temperature measurement implants to monitor temperature changes in animals experiencing different aspects of compromised wellbeing.

Because of the importance of managing the condition score for the wellbeing of sheep and their lambs, the CRC explored the automated measurement of body condition score. The Swedish company DeLaval had patented the use of a 3-D camera system for automatically assessing the condition score of dairy cows. The CRC contacted the inventors and visited Sweden to inspect the system and to propose a collaborative project to adapt the camera calibration for assessment of body condition score in shorn sheep. Despite initial interest in collaboration, DeLaval pulled out of the proposal. A careful review of the Australian patent literature confirmed that the CRC had freedom to operate if it was possible to calibrate a generic 3-D camera system.

The CRC then discussed the project with colleagues in the D2D CRC and decided to go ahead. Asanga Wickramasinghe from the D2D CRC led the project with help from Janelle Hocking Edwards and her South Australian Research and Development Institute (SARDI) colleagues, to explore if camera technology could be calibrated to automatically estimate the condition score of sheep after shearing. The approach used a Microsoft Kinect V2 depth camera to collect images of sheep and machine learning techniques to estimate condition scores from these images. The approach was found to have potential but there were a number of significant practical obstacles such as poor image quality under direct sunlight, the confounding effects of shearing patterns disguising the shape of the skin surface, and complex data analyses.

It was therefore reluctantly concluded that none of these approaches using routine measurements or new automated data collection systems provided good enough leads in the search for predictive information relating to the future risks to wellbeing. A new approach was needed.

Web-based apps and ASKBILL

On 27 March 2015, Lavina Muscat contacted the CRC with an invitation to participate in an internal Telstra trial to develop a web-based app for farmers. This was to prove to be a major turning point for the CRC's program on better management of sheep wellbeing.

Although the case study selected by the CRC was not directly related to management of sheep wellbeing, it exposed the Sheep CRC team to world class expertise in the design and development of web-based apps. Working with Pivotal Labs in their San Francisco head office, and with support from Telstra, the CRC completed the design and development of RamSelect in just 13 weeks.

The power of web-based computing function with a simple user interface appeared to be a good fit for our need for predictive analytics. There were clear parallels between the RamSelect app and the proposed development of an app for better management of sheep wellbeing. The main functionality of the RamSelect app was enabled by access to the large dynamic Sheep Genetics database. In the case of sheep wellbeing, most factors with a negative impact on the animal are associated in some way with climatic events. Climate data, like the genetic information, was also available in large dynamic databases. In this case, created and managed by the Australian Government Bureau of Meteorology.

With weather data the key to developing an app for animal wellbeing, a formal collaboration with the Bureau of Meteorology was essential. Vernon Carr, as the National Manager of Public and Agricultural Weather Services, was enthusiastic when first asked to consider the concept. Vernon enlisted Alister Hawksford to act as the project coordinator on behalf of the Bureau of Meteorology and it was Alister who did much of the work in coordinating the data access and effective research collaboration with the Bureau.

At this stage the links with the D2D CRC also proved to be valuable as Troy Wuttke, Senior Researcher with the D2D CRC, made a huge contribution to the initial design of the data platform for utilising the significant volume of weather data via a series of biophysical models.

Building the team to build the app

The most important lesson taken from the experience with Pivotal Labs and Telstra was to focus on the needs of the end-user. The problem of better sheep wellbeing needed management factors to be defined and understood from the perspective of the user and there needed to be a clear understanding of how the user would like the solution to be delivered. Lu Hogan had spent four weeks in San Francisco as part of the RamSelect design phase and took on the role of coordinating the end-user engagement as part of the design process for the new wellbeing app.

The first job was to identify and engage with producers who were happy to contribute their time and expertise. Another lesson learnt from Pivotal Labs was to really value end-users' time and pay them for their contribution. Lu also established a reference group of consultants and leading producers to contribute to the technical design elements of the new app. The next group to engage in the project was the software experts and the data scientists. Johan Boshoff and the team of software developers that he had engaged for RamSelect was the obvious choice to lead this new app development for wellbeing management.

Johan Boshoff

The scale of the climate files available from the Bureau of Meteorology varied, being up to 250 square kilometres for the longer-term forecasts. The Bureau of Meteorology were already well underway to releasing their next generation of seasonal forecasts through the ACCESS-S global model that would bring the resolution down to 60 square kilometres. At this point in development, the CRC provided the funding support to allow the Bureau of Meteorology to downscale this further so that historic, near-term and long-range forecasts were all provided on a 5km x 5km grid across Australia. This allowed for the first time, a standardised climate database to be compiled by Johan's app development team at the University of New England (UNE) that reached back 32 years into history and projected forward six months into the future.

Reaching this point, handling daily updates from over 270,000 grid points across the continent, ensuring data quality and working with the Bureau of Meteorology to provide feedback on their climate models, represented a major challenge in terms of data science and database management. In this area the CRC was also fortunate to have expert input from the D2D CRC led by Troy Wuttke and his colleagues to help with the initial design of the data management systems.

The third element involved the content specialists and the preparation of biophysical models covering the key elements of the integrated program. These models take climate information for a particular location, and in combination with information provided by sheep producers, provide the forecasts that allowed early detection and management of threats to sheep wellbeing and productivity. The technical approach taken to identifying the risks to sheep wellbeing recognised the importance of the interconnected nature of the agricultural ecosystem and the schematic summary of this system developed by Bill McClymont served as an excellent template for the technical design.

Lewis Kahn, with his strong background in parasite management and pasture and livestock systems was recruited, initially on a part-time basis from his consulting business, to coordinate the technical design and its development. Lewis subsequently took on the leadership of the program at the start of 2017 when Geoff Hinch retired.

The initial goal was for the new wellbeing app to be able to predict risks associated with worms, flies and extreme weather events. Brian Horton from the Tasmanian Institute of Agriculture had previously developed a model to predict risks of flystrike for the CRC's earlier FlyBoss initiative and undertook to adapt this generic model to utilise the dynamic climate data information to provide farm specific forecasts. Brian was also able to contribute his expertise in the study of extreme weather events to develop appropriate indexes and models for cold stress for off-shears sheep and for lambs and for heat stress.

Yan Laurenson from UNE had considerable experience in modelling the lifecycle of major nematode parasites (worms) and was able to adapt these models to use the comprehensive climatic information available to support farm specific dynamic predictions of the risks of the four major nematode worms of sheep.

For modelling soil moisture, pasture production and animal growth the experience of the highly respected mathematical modeller Ian Johnson proved to be invaluable. Ian undertook to develop a new integrated model of these three key components of the grazing ecosystem incorporating the latest information, using an approach that required the user to input only a few parameters and ensuring that the CRC would be able to use the models without any IP encumbrance.

The technical development team started working on their individual models as well as on the integration of the models on a single computer platform. Meanwhile, Johan's team was busy developing the user interface and building the back end of the platform to ensure the time taken to process the models would be as brief as possible. Progress across these streams was

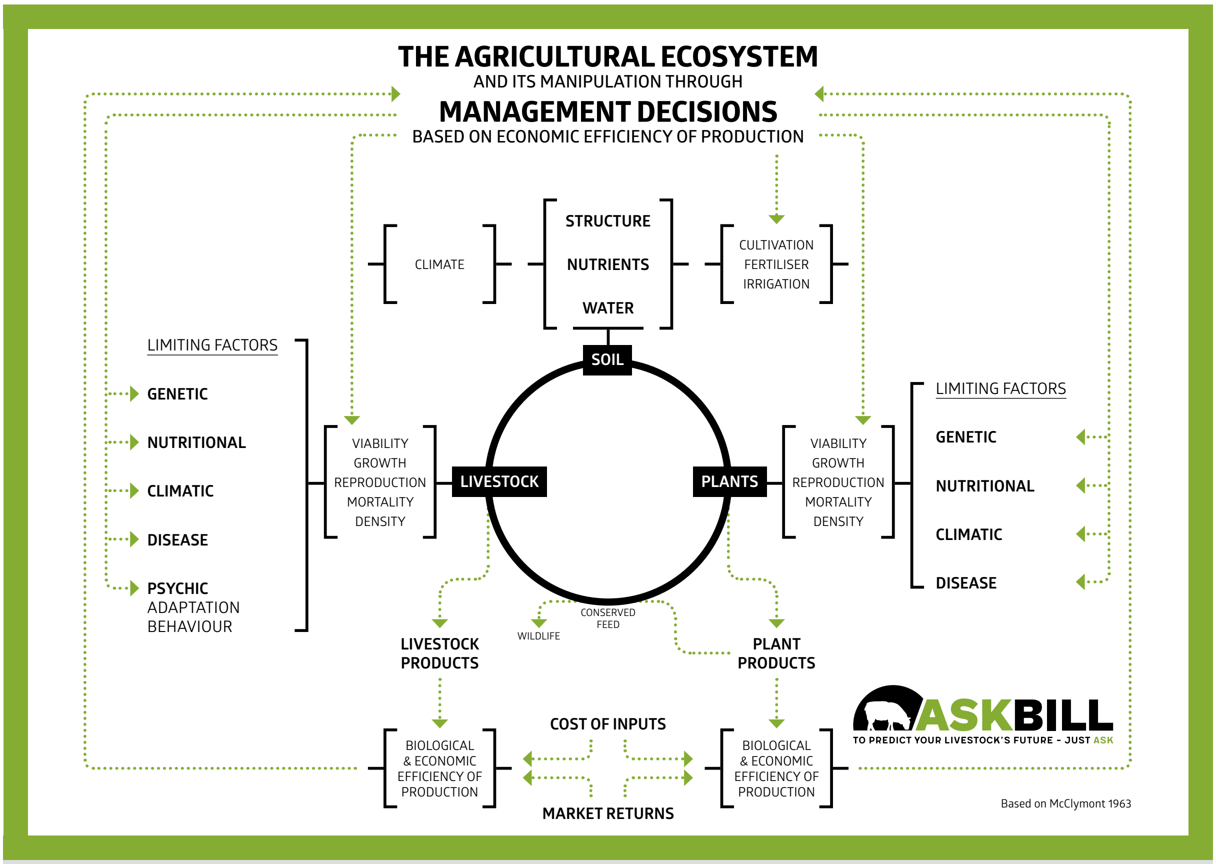


Figure 7.2: Professor Bill McClymont's Agricultural Ecosystems model was brought to life by the ASKBILL app, which was named in McClymont's honour.

Lewis Kahn

impressive and by June 2016 it looked like there would be sufficient functionality to test the proof of concept before the end of the year.

The fourth area important for the new app was to establish a group to develop the commercialisation and business plans. Les Targ again agreed to help the CRC with this process and, together with Mike van Blommestein, ex-Zoetis and now CRC Director, led the process of identifying the commercial potential of the CRC's new data products and the new app. One of the first steps was to appoint David Faulkner as commercialisation coordinator. David joined the CRC around July 2016 and was quick to develop an understanding of the potential that the new data products had in contributing to the management of complex agricultural problems.

There was an internal launch of the new wellbeing app at the Sheep CRC's annual planning meeting in March 2017, but before the launch the app needed a name. David Faulkner and Michael Thomson led the process to define a name for the new wellbeing app. There was much debate about how to capture, in a single word, the predictive nature of the app and its application to livestock. There was also a strong desire to be bold to capture the attention of industry, and not to fall into the trap of a generic, catch-all descriptor. The name ASKBILL started to gain momentum — most liked it, some loathed it, but everyone remembered it. Catchy, curious and with a name like Bill, it was perfect for the rural market.

The name also carried with it an incredible back story. Named in honour of Professor Bill McClymont and his visionary explanation of the agricultural ecosystem, the name also implied the concept of 'asking a friend' that resonated with many of the end-users involved in the design phase.

THE PREDICTIVE POWER OF ASKBILL IMMORTALISED IN SONG

An off-the-cuff comment and a spur of the moment decision to "have a go" resulted in the sheep industry's new predictive app, ASKBILL, being brought to life in song by CRC staff member and Uralla musician Rhonda Brooks.

Performed in a bush ballad style by Coffs Harbour musician Mal Winckle, the track proved a popular addition to the ASKBILL website, helping to capture producers' imagination as to the possibilities on offer through the use of predictive data technologies.

But it may never have happened if it wasn't for a staff member at the Sheep CRC jokingly suggesting that the app promotional campaign needed a song. Rhonda, who also worked as the Sheep CRC's office manager, caught her co-workers off guard a week later when she arrived at an ASKBILL project meeting with song lyrics in hand.

"There was passing comment at a meeting about an ASKBILL song, and I thought 'I can do that' and decided to give it a go," Rhonda said. "I arrived at our next team meeting fully prepared for everyone to say, 'Oh no, we were only joking,' but the team read the lyrics and were excited by them, and decided it was worth recording. The song came together quite quickly and easily because I knew the background quite well through working at the Sheep CRC on the ASKBILL project, and I knew where the inspiration for the app came from."

Rhonda's usual style was modern folk/indie music but felt the traditional bush ballad style was better suited to the story of ASKBILL and drew on some personal inspiration in bringing the story to life.

"My father was a shearer and very much into that style of music and poetry, so I grew up on farms listening to him reciting the likes of Banjo Paterson," she said. "As the ASKBILL app has been developed in Australia for people who work in the bush, it made sense to write it as an Australian bush ballad. There was a story to be told about how the app came about and how it can assist producers with their farm management decisions — a song is a great way to communicate this."

The catchy song lyrics also captured the inspiration behind the app - Dr Bill McClymont's agricultural ecosystem map, as well as its many uses in helping to understand more precisely how various factors interact to create risks and opportunities.

Rhonda performed the song live for the first time at the 2017 Coffs Harbour Planning Meeting where the product was first announced to Participants and received a rapturous ovation.

The next step was to develop the music video (www.askbill.com.au).

In the studio recording the ASKBILL song — Barry Mannall, Mick Parker, Mal Winckle and Martin van Veluwen.

Commercial launch — LambEx 2018

Progress between the internal launch in March 2017 and the commercial launch at LambEx in Perth, August 2018, was hard work.

One of the key challenges was management of the climate data and its download from the Bureau of Meteorology, while the service provided by the Bureau remained in the 'pre-commercial' phase. The strength of the relationship developed between the CRC and the Bureau ensured that both worked together to address inconsistencies in data format between historic, near term and forecast climate datasets, that required development of further software solutions to provide a consistent format for all three components. A further challenge was the sheer volume of data and completing the necessary processing of these data within the day was solved through significant input from data scientists and software developers. However, this diverted resources from other areas of the app development and pushed out the timeline.

2018

ASKBILL LAUNCHED TO MARKET

ASKBILL and its powerful predictive technologies became available for use by sheep producers across Australia following its commercial launch at LambEx in August 2018.

The online tool, that provided timely and accurate predictions for sheep wellbeing and productivity using climate, stock and pasture information, was made available for sheep producers throughout Australia at an annual subscription of $110/year (inc. GST).

James Rowe, Brad Wooldridge, Mary Goodacre, Lewis Kahn and Mike Hyder

Meanwhile, the project team remained focussed on engaging users of ASKBILL to ensure that the application and the user interface met their needs. Mary Goodacre interviewed hundreds of sheep producers and advisors and provided expert advice to the app development team.

Expansion in the scope of ASKBILL to include the prediction of lamb growth rates and carcase composition, with growth models linked to RamSelect to identify the genetic merit of the animals, as part of a separate project with Australian Meat Processor Corporation, added to the workload. This work was initiated based on the preliminary findings of the validation trials pointing to sufficient accuracy in predicting growth for the information to be useful in supply chain management. In fact, managing the seemingly endless options for further developing ASKBILL models and user interface was a key challenge for the team in order to stay focussed on delivering ASKBILL to industry.

A key point in the development of ASKBILL was to test the accuracy and usefulness of the forecasts on 15 commercial farms located in some of the main sheep producing regions of Australia. This meant being able to compare the ASKBILL forecasts for wellbeing and production against that measured on each of the farms. A detailed protocol for the comparison was developed and Laura Kemmis had the responsibility to oversee the data collection and work with the UNE team to develop the ASKBILL database in which the data was stored for analysis.

This was a significant undertaking involving pasture sampling, testing for pasture quality, recording liveweights and condition score of both ewes and lambs, carcase traits, worm egg counts, records of flystrike and supplementation and any worm or fly treatment details. These measurements allowed the data scientists to compare the accuracy of a range of forecast periods, for example one week, one month, or up to three months into the future. Pleasingly, the validation confirmed that ASKBILL predictions were accurate for up to seven weeks in advance, helping sheep producers to make better and earlier decisions about managing wellbeing and productivity of their flocks. The ASKBILL database also provided a valuable resource, providing a range of case studies useful for improving the models.

With the additional software development involved in managing the climate data and the expanded scope of works, the CRC needed to engage additional software developers. However, this was very difficult given the strong demand for these skills in many areas of the Australian economy. It was not easy to attract software developers away from the capital cities without being able to offer long-term contracts and high levels of pay. A solution that was explored was to base software developers in Sydney, but it quickly became apparent that good programmers were constantly receiving offers from other companies and this meant difficulties in maintaining continuity.

The final area that needed redevelopment was the 'on-boarding' process. During the validation trials it became apparent that producers required professional support to get the model settings correct for their particular property and production system and to make best use of the forecasts in their management. This meant that it was not just a case of advertising the web address and sign-on process, it required engagement with a consultant or other ASKBILL specialist to help set up each account. This approach proved to be effective and resulted in a steady increase in accounts and an expansion of expertise in the use of ASKBILL.

Laura Kemmis explains the benefits of ASKBILL to delegates at LambEx in August 2018.

The commercial launch of ASKBILL at LambEx in August 2018 was recognised as a major achievement and an important milestone. ASKBILL has been recognised as a world first in the livestock sector for linking climate, farm data and genetics to provide a dynamic forecasting service for the sheep industry.

ASKBILL KEEPS WA GRAZIER AHEAD OF WORM BURDEN RISK

Leading West Australian sheep producer Brad Wooldridge was one of the first adopters of ASKBILL, providing him with increased peace of mind and confidence in his management decisions, thanks to the app's ability to alert him in advance to parasite risks to his flock.

Brad, who hailed from 'Warialda', Arthur River, said the online tool was like having a "real sheep person in the paddock with you every day" to check decisions and provide reminders of urgent issues requiring attention.

"The complexity of the modelling is what sets ASKBILL apart from other tools and its predictions mean you can plan ahead — if you're not planning, you're reacting and from a management perspective that's a whole lot harder," he said. "If you know a couple of weeks in advance, or even a couple of months, then you get on top of things before they become a problem. For example, if you need labour to help out, it means you can organise labour."

Brad was running 2,200 ewes across two properties in southern WA, turning off composite lambs at 100–120 days and average live weight of 30–35kg. At 'Warialda' he has 300 hectares devoted to pasture and 200ha to crop, while his Albany farm, 220 kilometres south, has 230ha of pasture.

To carry this stocking rate from joining through to market, Mr Wooldridge maintains a strict focus on pasture availability, calculating biomass weekly to stay in front of forward contract obligations. For this reason, Brad's operation was used as part of the Sheep CRC's validation trials of ASKBILL which tested the system's predictions against actual data measured on farm.

"We really need to have a good grasp on pasture availability into the future and having a tool that will calculate this for me will make life a whole lot easier," he said. "It's all about dollars per kilogram liveweight and we need to know if our lambs are going to make it to market on time and if not, what do we need to do?"

But it was ASKBILL's worm forecasting tool that Brad believed would be most useful to him, with his Albany property carrying a high-risk of Barbers Pole worm and the resident population becoming increasingly resistant to chemical treatment.

"Our property on the South Coast is the one that stresses me most. I've been travelling 1500km a week to feed sheep there, which is a lot of driving, but it's been a decision backed by the alerts from ASKBILL and it's pleasing to achieve good results in a challenging season," he said in 2018. "I feel ASKBILL will help keep me on top of things while I'm away as I'm very confident in the long-term predictions for worms, plus the alerts ASKBILL provides keep me focussed on what I need to act on right now."

Brad was impressed with the complexity of the ASKBILL calculations, in particular the model used to calculate worm infection risk on pasture, which was based on the weather forecast, pasture availability and the drench program on-farm, and could take into account risk of re-infection.

"I don't think you can afford to make mistakes these days. A lot can happen in a week and on the coast Barbers' Pole worm can take off quickly, or if you're a fortnight late in spotting that your lambs and ewes are losing condition, then you're really losing money. Acting on the alerts from ASKBILL is the key — it's mucking around and not making a decision is what costs you.

ASKBILL's big opportunities for expansion

By the end of the CRC ASKBILL provided a new way to approach the management of the sheep industry's longstanding problems of parasites, feed budgeting and cold exposure at shearing and lambing. Moreover, ASKBILL met the end-user's expectation of not requiring significant work to produce valuable information to assist with better decision making. ASKBILL therefore delivered one of the key outcomes that the CRC was funded to achieve during its final term.

The rate of uptake had been a bit slower than initially anticipated but was nonetheless encouraging, especially for a product involving a new approach to assisting farm management. Leading producers, consultants and advisory networks had discovered the value of ASKBILL for feed budgeting and better decision-making about parasite management and extreme weather events. With these capabilities it was anticipated that rapid uptake of ASKBILL would occur amongst producers familiar with the LTEM program. By adding forecasting information for feed budgeting, live weight and condition score, ASKBILL had the potential to add a new dimension to the successful application of LTEM principles in commercial sheep production systems.

The use of ASKBILL in the lamb supply chain had passed the proof of concept evaluation for predicting turn-off dates and carcase specifications from a wide range of production systems and at the close of the CRC, plans were well advanced for commercial-scale trials supported by AMPC and JBS Australia.

Mary Goodacre (centre) demonstrating the benefits of ASKBILL to producers.

The potential expansion of ASKBILL to include predictions to inform management of cattle production and mixed grazing systems had long been recognised as a logical extension of ASKBILL's scope but had been considered to be beyond the boundaries of the Sheep CRC's remit. With the app transferred to UNE at the end of the CRC, and no constraints on its development, it was likely that this capability would be added.

The opportunity to establish regional models of production trends and predicted risks had also been identified as being of potential value to a wide range of agricultural resellers supplying seed, feed and animal health products. Forecasts from such models might also assist in the inventory management and in planning promotional activities for resellers. It was also considered that ASKBILL may also be of value in the insurance industry and for banks concerned about monitoring natural capital assets on properties for which extensive loans have been made.

The use of ASKBILL in undergraduate teaching had significant potential and part of the CRC's legacy arrangements included the use of ASKBILL for this purpose. At the time of the CRC's closure, UNE had already started development of practicals for undergraduate students based on the use of ASKBILL in the management of the University's grazing property. UNE's plans for its use in teaching include students being able to study ASKBILL predictions and 'what-if' scenarios against measurements of pastures, parasites and production on the University's properties. Emma Doyle had taken the lead in developing these practicals, and with the Australian Wool Education Trust has agreed to provide support for the promotion and delivery of these resources in schools and universities throughout Australia.

Paul Arnott checking details for ASKBILL.

PRODUCTS TO ENHANCE SHEEP WELLBEING

The transformation of sheep wellbeing was achieved as a result of five major initiatives of the Sheep CRC.

1. Better focussed genetic selection to ensure that sheep are well adapted to their environments (Bred Well Fed Well and 'A User's guide to ASBVs').
2. 'Sheep – the simple guide to making more money with less work' was widely distributed throughout the sheep industry as a user's handbook to good sheep management.
3. LTEM and High Performance Weaners expanded the understanding and skills required to manage the nutrition of ewes throughout their lifetime to improve reproductive efficiency and survival of both ewes, lambs and weaners.
4. Better use of real time ultrasound scanning data to identify and then better manage twin bearing ewes was recognised as desired standard practise throughout the industry, resulting in better management of twin bearing ewes.
5. ASKBILL provides an important forecasting tool for managing all of the major risks likely to have a negative impact on the wellbeing of sheep. Although only in its early stages of commercial delivery when the CRC closed, it was anticipated that this new product would be increasingly used by sheep producers, consultants and in the various supply chains.

FIND OUT MORE

For more information on how the 'sheep wellbeing' research interacted with other specific fields of Sheep CRC Research, go to:

- Chapter 3 — Integrating Wool and Sheepmeat Production
- Chapter 4 — Introduction of Genomic Technologies
- Chapter 5 — Managing Sheep Parasites
- Chapter 6 — Precision Sheep Management
- Chapter 8 — Quality Sheepmeat
- Chapter 11 — Implementing Innovation

8 QUALITY SHEEPMEAT

When the Sheep CRC commenced, its meat researchers were confronted with a fast-evolving Australian sheep meat industry challenged by a lack of consistent quality, a shift in focus from wool to meat, and market access issues.

The industry also changed dramatically in the 1990s thanks to the opening of the US market for large lean lamb; new packaging technologies for shipping chilled lamb; and a trend to direct selling on contract or over-the hooks (OTH), which helped encourage producers to be conscious of the type of lambs they were turning off. The Castricum family was among those who took advantage of these opportunities, working with the then Australian Meat and Livestock Corporation to promote lamb in the US through the FARL (Fresh Australian Range Lamb) program. The larger lamb provided processing efficiencies — they were easier to bone-out and pack and it cost exactly the same to process a 12kg lamb carcase as a 28kg carcase. They were also at the forefront of shoring-up year-round supplies of larger lambs by establishing the Casmark program which included working with producers for a direct supply at contracted prices and providing product feedback. At the same time LAMBPLAN (now Sheep Genetics) under the direction of Rob Banks, was the genetic platform developed to drive the larger and leaner carcases with objective genetic evaluation involving the weighing and scanning of seedstock. All of this resulted in the re-naming of 'fat lambs' to 'prime lambs'.

A feature of the feedback for producers was an estimate of saleable meat yields calculated by the VIASCAN imaging equipment. Castricums was one of two Australian plants to take up this technology. But, as Stuart Castricum described it, the concept was excellent but it was difficult to get cost recovery and the imaging time hindered the processing chain. The Casmark program was abandoned in the early 2000s when volatile prices in the saleyard made it difficult for producers to maintain commitment to contracted prices.

Graham Gardner, David Pethick, Mick Crowley and Josh Hancock at the launch of the Lean Meat Yield manual.

The challenge was set for the new Sheep CRC: to deliver innovation that provided product consistency, market security and viable systems for assessing saleable meat yield and eating quality. The sheepmeat industry changed dramatically over the following 18 years as the CRC progressively delivered on this challenge.

CRC1: 2000–2007

From the outset of the Meat Program the goal was to link the scientific understanding of meat characteristics to the person eating the product and their feedback regarding quality and consistency. The first decade of the CRC saw an unprecedented connection initiated between researchers, leading breeders and prime lamb producers, with major extension initiatives undertaken in collaboration with MLA including the Prime Time, Prime Time for Merinos, Its Ewe Time plus CRC conferences. These forums connected to thousands of producers and shaped the focus of future Sheep Industry Strategic Plans to focus on the combination of effcient and resilient production of lamb matched to the modern demands of consumers.

As such, the CRC's Meat Program started out as a fundamental scientific research, initially targeting muscle biology. This involved working with the CRC's genetics research activities with MLA and AWI. The aim was to understand the genetic and environmental mechanisms regulating muscle growth, carcase yield, tenderness, flavour, colour, shelf life and processing attributes. The initial program also explored meat processing to understand and contribute to both reducing losses and building quality through new technologies.

The ambitious and broad scope of the CRC1 program brought together expertise and resources never seen before. In total, three resource flocks were utilised based on the need to study lambs with varying but defined genetics (as determined by the Estimated Breeding Values in use at the time for growth, muscle and fat). The first flock was established under MLA's Management Solutions program and managed by Roger Hegarty just prior to the commencement of the CRC and included high versus low nutrition regimes for crossbred lambs from Poll Dorset sires with varying ASBVs. The second flock was established at the start of the CRC and was designed around five different "genotypes" and the serial slaughter of lambs between 4 to 18 months of age. Animals across this age range had never been studied before in Australia. The third flock was established to study the interaction between sire ASBVs and growth restriction followed by re-alimentation. The management of the latter two flocks was led by David Hopkins.

This concept of combining defined genetics with meat science, a strongly supported concept by then MLA managers Rob Banks and Alex Ball, would be a defining feature of the CRC which created a sustained collaboration in these disciplines for years to come. Moreover the CRC, at the instigation of Frank Dunshea, began to use medical DEXA calibrated to CT scanning as a tool to accurately predict carcase composition. Little did the meat team realise that this general methodology would become a commercial outcome at line speed in abattoirs in years to come.

Alex Ball

By 2004 the program began to consolidate around three major prime lamb and yearling mutton growth experiments, as the basis of a comprehensive study of the interactions of genotype (based on genetic variation as assessed through Estimated Breeding Values) and the environment on meat science outcomes. The program described diagrammatically in Figure 8.1 summarises the effects of genetics and nutrition which are represented as 'on-farm' levers that vary outcomes for the supply chain.

The integrated approach combined several scientific disciplines such as molecular biology (gene expression and proteomics), metabolic biochemistry, cellular and fascicular structure and traditional physiology of growth and development of muscle, fat and bone led by Robyn Warner. There were also studies on factors which influence lamb and sheepmeat quality, including work on glycogen metabolism and stress sensitivity in disparate genotypes, so as to understand the factors influencing the dark cutting syndrome, retail colour display and the response to electrical stimulation.

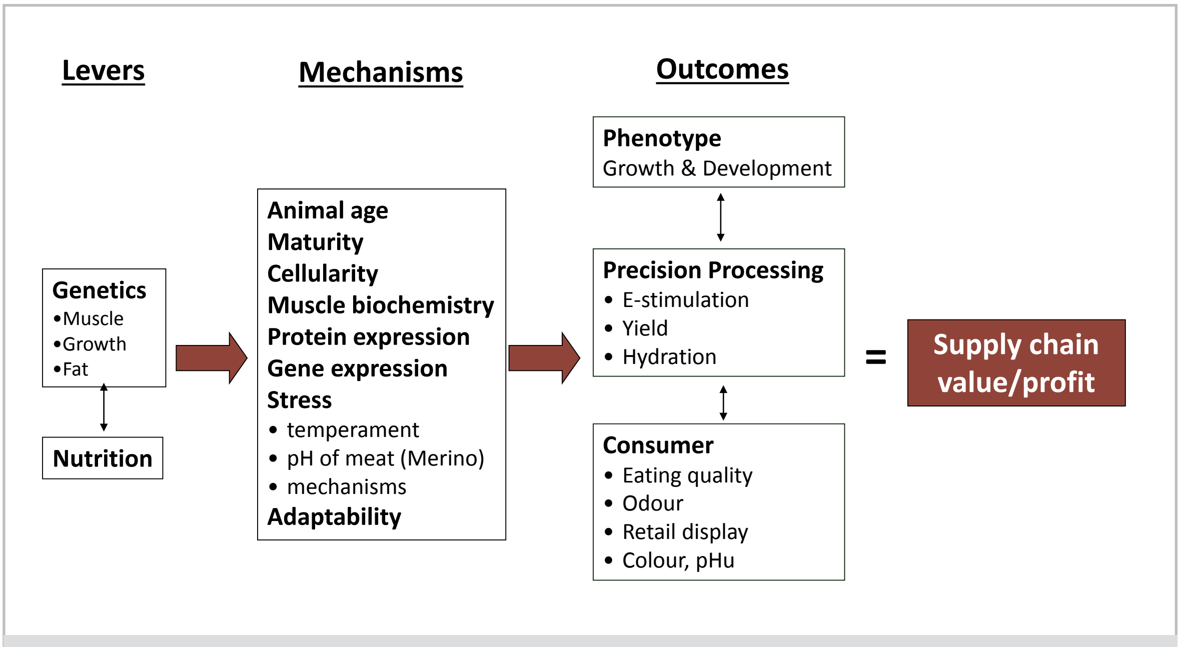


Figure 8.1: Structure of the Meat Science Program.

During CRC1 the program targeted three outcomes:

- Understanding growth and subsequent carcase value (weight, muscle yield and fatness) realised by producers;
- Development of precision meat processing including reducing losses due to dehydration and optimising the effectiveness of electrical stimulation for increasing the tenderness and improving colour stability of the final product; and
- Defining consumer satisfaction in terms of overall eating quality, colour and odour outcomes.

CORE PROJECTS

- Heather Channon and Liliana Salvatore worked to identify the major genetic and production factors affecting sheepmeat flavours.
- Dave Pethick coordinated a project to optimize sheepmeat eating quality, collaborating closely with MLA's Sheepmeat Eating Quality program with the aim to further develop MLA's consumer model.
- David Hopkins, Robin Jacob and Kelly Pearce coordinated the CRC's work with meat processors to improve both quality and efficiency.
- Paul Greenwood and Greg Harper led work on muscle cellularity and connective tissue showing that extreme selection for muscling can shift the meat to be tougher and have different 'fast twitch' muscle fibres.

The factors affecting muscle and fat

Understanding the factors affecting muscle and fat development (lean meat yield) was targetted as a key for both prime lamb and yearling mutton. Early findings of the program included the discovery that nutrition plays a very powerful role in the expression of genetic potential for growth, whereas selection for increased muscling programmed the animal to produce muscle and not fat, regardless of nutritional inputs. Furthermore, highly muscled lambs showed profound changes in the biochemistry and cellularity of muscle which are likely to have many positive effects (more muscle, less fat, greater efficiency, better colour) for the whole supply chain. However, it was recognised even at this early stage that factors contributing to improved lean meat yield may have a negative influence on eating quality.

Given these early and profound discoveries there was a renewed focus to fully understand the scientific basis for the genetic and environmental influences.

The focus on Merino meat production included development of a bone maturity index by Martin Cake and Mal Boyce, to help define the impact of 'physiological maturity' on tenderness and eating quality of yearling Merino mutton in the 2–4 dentition category. Secondly, a targeted consumer tasting program was undertaken to understand the consumer acceptance of commercial cuts derived from prime lambs, yearling mutton and older mutton. This work aimed to define the value adding options needed to deliver a consumer acceptable product from older animals.

The CRC, through the work of Liliana Salvatore and Peter Watkins, also made good progress in understanding the chemical basis for mutton flavours and cooking odour. The compounds associated with these aromas and flavours had been previously identified as branched chain and unsaturated fatty acids (BCFA) and a method assessing the odourous volatiles including some BCFAs derived from heated sheep fat was successfully developed by Watkins and his colleagues. This new method allowed a detailed study of factors contributing to the odour compounds and the proposal that the method could be used to define differences between lamb and mutton. Although early results looked promising, there were concerns about the lack of a clear differentiation as well as cost and complexity of the analytical methods.

For the processing sector the program led by David Hopkins, with assistance from Kelly Pearce and Edwina Toohey, helped to develop the new generation of mid-voltage electrical technologies for managing the pH/temperature window post-slaughter to optimise tenderness of meat for a variety of market end points. Some 12 collaborating processors in NSW, Victoria and WA were involved with the CRC to adopt electrical stimulation and optimise the use of the technology to guarantee tenderness of their product without increasing drip loss or reducing colour stability.

The first major commercial installation of the new technology was in the Junee abattoir operated by the Newton family and this was followed by installations across Australia. The largest change in slaughter floor electrical inputs occurred at the Fletcher International Exports plant at Dubbo, NSW, which saw an updated immobilisation system installed, electronic bleeding and the replacement of a high-voltage electrical stimulation system with a new generation medium-voltage system developed by MLA under the leadership of Ian Richards. Underlying this new approach was the electrical stimulation of individual carcases on segmented electrodes in a dose-responsive way with electricity that has short pulse widths and low to medium voltages. This methodology was much safer than the original high-voltage systems. This technology allowed stimulation units to be fitted into abattoirs where this was not previously possible, and validation showed that the technology could reduce toughness in lamb destined for the domestic market and some export markets.

Roger Fletcher, Fletcher International Exports, Dubbo NSW.

Of these participating abattoirs only one previously had any form of stimulation and by the completion of the program more than 80% of the throughput of sheep and lambs on a tonnage basis per year in Australia were being stimulated. The CRC's initiative to assist the uptake and use of electrical stimulation had a profound long-term impact on the consistency of sheepmeat quality and was a major milestone for the industry.

Another major development in the Meat Program during 2004-05 was the significant co-investment by MLA in the research into consumer acceptance of commercial cuts from lamb, yearling mutton and older mutton. The research built on MLA's Sheepmeat Eating Quality (SMEQ) protocols for consumer testing of product prepared using grill and roast cooking methods, and investigated a number of commercial cuts to examine effects of level of fat trim, different muscle and animal age (lamb vs hogget vs ewe mutton). These initial studies formed the basis of the subsequent MSA testing systems that underpinned much of the CRC's definitive work on eating quality, as well as industry extension programs which were crucial to the adoption of this research.

CRC1 Major Findings

David Hopkins

The volume of data generated from the first three research flocks provided the basis of two special editions of scientific journals. The first was published in 2006: *Growth and carcase characteristics of lambs – nutrtional and genetic influences* (Journal of Agricultural Research, Editor David Hopkins); and the second in 2007: *Sheep growth, carcase composition, muscle biochemistry and meat quality — influence of genetics, animal age and nutrition* (Australian Journal of Experimental Agriculture, Editors David Hopkins, Chris Anderson and Lauren Webb).

The salient findings of the work were distilled into a series of 'Practical Wisdom Notes' published by the Sheep CRC to support industry awareness and adoption, while the invaluable results from the resource flock initiatives helped to pave the way for the Information Nucleus Program in CRC2.

THE MAJOR OUTCOMES OF CRC1

- Electrical stimulation is crucial for maximising lamb eating quality in product aged for less than 10 days and the CRC assisted with its installation in plants .
- Nutrition is very important to realise the genetic potential for growth. A national workshop and publication provided definitive 'benchmark' data on grain feeding and responses for different classes of sheep.
- Muscling genetics helps to balance growth and reduce the frame size and bone length and is less influenced by nutrition.
- Even at this early stage of research, some muscling genetics were shown to have negative effects on eating quality (EQ) attributes, but positive effects on fresh and retail colour and pHu. The negative effects on EQ was a wakeup call for the lamb industry and was paramount in the consideration of future CRC work.
- Merino lambs were shown to produce meat of high quality, but a key issue for Merinos was identified in the need to select positive growth genetics so as to finish stock within the lamb age window. In addition, positive muscling genetics was beneficial to reduce the incidence of high pHu meat, a problem already well recognised in Merino slaughter lambs.
- Genetics for reducing carcase fatness have a powerful effect and also reduce intramuscular fat (IMF) if used alone.
- Feed restriction at weaning (approximately three months of age) had little long term negative effects with a period of 're-feeding' allowing the lambs to fully recover and exhibit normal carcase characteristics.
- IMF is an early maturing depot in lambs and increased carcase weight and/or fatness deliver only modest increases in IMF.

CRC2: 2007–2014

The meat program for CRC2 was designed to underpin continuous improvement in high quality lamb and sheepmeat for domestic and international consumers. The well-defined goal was to increase the retail meat yield per head while at the same time improving eating quality and the human nutritional value of the meat.

The Information Nucleus Flock program was the transformational vehicle which allowed the CRC to achieve this goal. It created the infrastructure for developing genomic breeding values for a number of hard-to-measure sheepmeat phenotypic characteristics contributing to lean meat yield and eating quality.

Meat & Livestock Australia collaborated with the CRC and Sheep Genetics to support the roll-out of these research breeding values with 20 Producer Demonstration Sites used to demonstrate their impact. Sires of varying genetic potential were mated to ewes based across farms around southern Australia. The lambs were slaughtered at market weights at processors in NSW, Vic, SA and WA where estimates of actual LMY and IMF were undertaken by local research teams. The program, led by Janelle Hocking Edwards, was a huge undertaking and clearly showed the impact of breeding for LMY and IMF on the product quality for modern consumers.

The meat program's activities were undertaken in tandem with the CRC's genetics research program, using the Information Nucleus. The industry extension programs such as 'Lamb Prime Time' and 'It's Ewe Time', were used to demonstrate the importance of genetic selection on meat eating quality.

The Information Nucleus also allowed the study of genetic and environmental factors affecting human nutritional value of lamb — particularly iron, zinc and Omega-3 fatty acids. Linked to this goal was the importance of being able to measure key attributes of carcase quality at line-speed in commercial abattoirs and this was introduced as a component of the project.

The Information Nucleus Flocks (INF), which had many features of a large progeny testing scheme, involved the production of around 18,000 lambs. The INF provided the lambs for measurement of meat eating and nutritional qualities while simultaneously increasing meat yield. Approximately 10,000 INF lambs were slaughtered and measured for a large range of carcase and meat quality parameters. The large task of coordinating the logistical effort of specialists with expertise in meat quality experimentation was led by Robin Jacob. With the eight INF flocks located in four states, samples were collected at the time of slaughter in a range of commercial abattoirs by different research teams. They were then transported to a range of meat quality laboratories, which were required to follow very clear protocols and standardized analytical techniques documented in a CRC manual prepared by Kelly Pearce.

Expert scientific panels were assigned to each of the phenotype trait groupings of eating quality, minerals/aerobicity, lean meat yield and lipids. There was also an abattoir panel and a group to help coordinate management of the central database.

Measuring lean meat yield

Murdoch University's Graham Gardner led a project to develop systems for objective measurement of lean meat yield and adopted a three-pronged approach:

- Working with early adopter processors to measure and benchmark lean meat yield (e.g. VIASCAN plants);
- Working with early adopter processors to underpin alternative measures of lean meat yield; and
- Using data from benchmarking activities with early adopter processors to develop industry-relevant descriptive statistics around lean meat yield.

One of the options investigated was to develop a bone-out data-set in collaboration with Peter Trefort and the Hillside abattoir. Using boning protocols specific to the Hillside operation (for Q-lamb product developed by Barry McDonald) lambs were sourced for bone-out based on having live animal information linked to RFID tags prior to slaughter. The data-set was generated to predict yield for a full range of product and selected based upon the following criteria:

- Carcase weight range — lamb: 17–25kg; hogget 20–25kg
- Fat (GR): 2 (6–10mm), 3 (11—12mm), high 3 (13—15mm)

Bill O'Hallohan contributed to this initiative in NSW, SA, VIC and WA by coordinating state agency expertise to build relationships with key processors, with the intention of providing support for the initiative to increase lean meat yield.

All carcases were CT-scanned at Murdoch University prior to bone out after which all cuts were weighed, and saleable meat yields estimated for each carcase. While the results were promising the approach had logistical problems and insufficient predictive accuracy for valuing carcases as a basis for differential payment.

2013

SUPPLY CHAIN GROUP DELIVERS

With co-funding from the Sheep CRC, JBS appointed Mark Inglis as the first of the CRC's Lamb Supply Chain Group's (LSCG) 'lamb supply chain coordinators', continuing a proven process established by MLA and delivered by the likes of Rob Davidson. Mark Inglis, who developed the JBS Farm Assurance Scheme, was instrumental in developing Livestock Data Link as a feedback tool (which for the first time included LMY) well before DEXA was establised. Mark developed benchmarking performance across the supply chain with particular focus on quantifying value, meat quality, eating quality, lean meat yield and optimal fat levels, as well as providing feedback to producers.

Mark Inglis

Using Genomics to 'Meat' Future Expectations

In 2013, towards the end of CRC2, the CRC began working directly with leading breeders to implement genomics into their breeding programs, well before market signals drove widespread adoption. Nine stud breeding groups participated in commercial-scale DNA trials being conducted through the Sheep CRC's Genomics Pilot Project.

During the pilot project more than 1,500 DNA tests were allocated for use by these early-adopting studs with a further 1,500 tests allocated for smaller-scale testing by sheep breeders across the country, as part of research aimed at defining the most effective use of the new technologies in practical breeding programs. As a result of the program, breeding values for intramuscular fat and tenderness became a priority when selecting ram lamb sires for use across the Superwhites group.

Among them was a syndicate of leading White Suffolk breeders which undertook large-scale DNA testing to identify breeding animals carrying genes for tenderness and eating quality. By placing meat quality traits at the forefront of its genetic selection during ram breeding, the Superwhites group aimed to position itself as a key supplier of rams to help industry continue to meet consumer demands for tender and flavoursome lamb.

"Meat eating quality is too important to ignore. As consumer choice increases you can't have your genetics years behind market demand," Australian White Suffolk Association President and Superwhites spokesperson Murray Long said at the time. "Good scores for meat eating qualities may lead to the selection of an animal that wouldn't have been chosen for weight, fat and muscle alone. Similarly if an animal is strong across these ASBVs but has poor results for intramuscular fat and tenderness, it won't be selected."

Murray Long, White Suffolk breeder from Ardlethan NSW, and member of the Superwhites group, participated in the Genomic pilot programs to evaluate meat quality markers.

Robin Jacob was responsible for coordinating the meat data collection and laboratory analyses for the Information Nucleus program.

CRC2 MAJOR FINDINGS

- Electrical stimulation must undergo regular and fastidious pH x temperature auditing to assure its effectiveness.
- Intramuscular fat concentration (IMF) was found to be a key element of eating quality that interacts both positively and negatively with a range of other factors.
- Sires selected for leanness and muscularity have reduced IMF, increased shear force and lower Fe content.
- Merinos in general have higher IMFs than Maternal and Terminal lambs.
- Shear force, IMF, colour stability and docosahexaenoic acid (DHA) were deemed likely to respond to genetic selection whilst other Omega-3 fatty acids require nutritional intervention — namely green feed.
- Australian lamb meat can generally be regarded as a good source of the minerals iron and zinc; and a source of Omega-3 fatty acids when finished on green pasture.
- Breeding priorities for meat quality are dependent on breed type, with improvement of meat colour stability more important for the wool-focussed Merino breed and improvement of sensory quality for the Terminal-sire breeds.
- As a result of this work the meat progam delivered its third special edition, this time published in *Meat Science* (editors David Hopkins and Robin Jacob), with articles based on the outcomes of the slaughter data from the INF.

DNA TESTING REALISES MEAT QUALITY DREAM FOR PROCESSORS

The long-held dream of guaranteeing the eating quality of every single sheep that comes off his farm became a reality for Western Australian sheep breeder Dawson Bradford through the Sheep CRC's genomic research program. Dawson was an early adopter of genomic testing to identify rams in his flock that possess genes for desirable but hard-to-measure traits such as intramuscular fat, tenderness and lean meat yield.

"Previously we weren't able to monitor or record these traits until after slaughter. DNA testing allows us to identify rams when they are young that meet these selection criteria so that we can build that population up," Dawson said in 2014. "That is where we are now, getting the foundations to launch into a breeding program focussed on consumer needs."

Mr Bradford runs Hillcroft Farms, a mixed operation on 4500 hectares at Narrogin, 150km south east of Perth, with a stud flock of Poll Dorsets for Terminal sire use, a piggery and broadacre crops. His involvement in performance recording began in the 1990s with LAMBPLAN — from there it was a natural progression that he would be one of the first to put his hand up to be involved in DNA trials run by the Sheep CRC.

As the then Chairman of West Australian Meat Marketing Cooperative (WAMMCO), Dawson was in the rare position of understanding the sheep meat industry from both a producer's perspective and that of a processor. He foresaw that in the future it would become increasingly necessary to be able to guarantee eating quality.

"One thing the consumer doesn't like is variability in what they buy," he said. "They want consistency, whether consistently average or consistently good. It is absolutely critical as we go forward into the next 10 years to be able to consistently offer a product with superior quality to the run of the mill."

Dawson said genetic testing offered producers and industry a huge opportunity to increase the value achieved from certain cuts, mainly the middle value parts of sheep. In 2014 he DNA tested all of his elite rams to find those carrying the desirable genes for meat eating quality, while also utilising data gathered from the abattoir's in-line testing for desirable traits which could be traced back to the Maternal flock.

"It will take three generations to really change our flocks once we identify the breeding stock, so it is absolutely paramount that we get the selections right now," he said. "If we are producing meat sheep, then we need to produce the best meat sheep and so the sooner we can identify the carriers of these genes in our flocks the sooner we can get it filtered right throughout the flock."

Dawson Bradford of WAMMCO, used DNA testing to pursue improved eating quality.

CRC3: 2014–2019

The CRC3 Meat Program built on the previous 14 years of research and took its impact to another level.

Research based on the CRC's Information Nucleus Flock program quantified critical control points that determine eating quality and meat yield of different cuts from individual carcases. Understanding the significant effects of genetics on yield and eating quality led to new breeding values for intramuscular fat (influencing juiciness and flavour), shear-force (a measure of tenderness) and lean meat yield.

Both yield and quality have a profound effect on profitability at every stage in the supply chain, but historically the industry had used a very simple measure of fatness to predict lean meat yield, meaning that lamb was traded as a weight-based commodity, poorly reflecting the value of the saleable meat that consumers demand. Additional research was needed to develop a measurement and knowledge system to be used as the basis for abattoir grading of carcases to underpin value-based trading in sheepmeat supply chains. This 'holy grail' of the sheepmeat supply chain was a major objective of CRC3.

Over the previous 14 years there had been little investment in technologies for measuring carcase yield and the CRC's research had highlighted the inadequacy of existing systems. The CRC's earlier meat science research findings re-kindled industry's desire to move to value-based trading and to develop new measurement technologies to make this possible.

Accordingly, the Australian Meat Processor Corporation (AMPC) and Meat & Livestock Australia (MLA), working with the CRC meat science researchers, initiated projects with a number of companies undertaking development of carcase grading technologies. For example the Danish company, Frontmatec, was developing prototype sheep carcase measurement systems, building on technology developed for the pork industry. It was just one of a number of methods tested — including the ultimately successful Scotts Technology dual x-ray absorbtiometry (DEXA) system - in seeking out the 'holy grail'. The methods for predicting quality and yield were then developed into a new prototype cuts-based Meat Standards Australia (MSA) grading system.

Richard Apps (left) represented MLA on the PRRC and chaired the Lamb Supply Group and Graham Gardner (right) contributed to the meat program and was coordinator of the postgraduate program.

The research was also extended to establish a new science-based system for grading cuts from larger lean carcases (>25kg) that were otherwise falling outside lamb specifications, particularly for some domestic markets, and for grading cuts of yearling Merino carcases that were classified as 'mutton'.

The end result, it was envisaged, was to reduce labour in trimming overfat carcases in the abattoir, and assist producers breeding higher-value animals suited to the specific market specifications.

Calibration and evaluation of carcase grading tools required a rigorous approach that encompassed

2014

PETHICK'S NUTRITION RESEARCH RECOGNISED

The outstanding contribution to nutrition and its applications to people and animals by Sheep CRC Meat Program Leader Dave Pethick (right), was recognised with the award of a prestigious Fellowship from the Nutrition Society of Australia.

Dave's PhD in the field of ruminant biochemistry and nutrition set him on a research path that involved many different animal species and research into many problems involving nutrition, biochemistry and physiology.

Through Dave's leadership, the sheep industry was able to understand the role and development of IMF, the causes of high pHu in lamb and show that lamb is a significant source of beneficial Omega-3 fatty acids while low in saturated fats — key factors for modern consumers concerned about eating quality and their health.

the wide range of carcase types found in Australia (14-30+ kg carcase weight) derived from diverse genetic backgrounds. An Information Nucleus design (by this time called the MLA Resource Flocks) at the University of New England, Armidale and Department of Agriculture and Food Western Australia — now DIPIRD, Katanning, was the ideal structure to underpin genetic and carcase prediction.

The original Sheep CRC Information Nucleus design generated a unique resource whereby large numbers of slaughter lambs with full pedigree linked to an extensive series of phenotypes for traits related to lean meat yield and eating quality, were in a centralised database. The database had approximately 10,000 lamb records, which through extrapolation could be linked to bone-out data and measures of meat colour, shear-force tenderness, intramuscular fat and other biochemical indicators. With the drive and vision of Alex Ball the database was further supported by sensory evaluation of two cuts (short loin and topside) from approximately 1,500 progeny thus allowing the team to develop associations between objective carcase parameters and the actual sensory score of the meat.

As part of this project, further sensory evaluation in combination with the objective carcase measures was undertaken on an additional 1,000 carcases using the MLA Resource Flocks. These flocks were producing 2,000 slaughter lambs per year. These large datasets (existing and to be generated) represented a world-leading and globally unique resource putting Australia at least a decade ahead of international competitors.

Q Lamb founder Peter Trefort inducted in WA Ag Hall of Fame

Long-serving Sheep CRC Board member and leading Western Australian lamb producer, Peter Trefort, was inducted into the WA Royal Agricultural Society's Hall of Fame in 2017 for his extensive services to the sheep industry and agricultural education.

Peter, whose family property is at Narrogin, WA, was successful in developing and commercialising an innovative new range of lamb cuts to extend markets both domestically and internationally, and served for 20 years on WA's Combined Advisory Council of Agricultural Colleges, including three years as Chairman. He also served for 14 years on the Board of Meat & Livestock Australia and in 2007 received an honorary doctorate from Murdoch University for his contribution to industry innovation and participation in meat quality and lamb supply chain research projects.

"I never thought I would be in line for receiving anything like this," Mr Trefort said upon receiving the award in 2017. "It's a great surprise and a great honour."

Peter's career included more than 40 years' experience in sheep and cattle production, as well as management across the meat supply chain, including the establishment of the Q Lamb brand in conjunction with the likes of Allan Jarman, Reg Crabb and Graham Sutherland.

"Q Lamb really changed the concept of lamb from being a bi-product of the wool industry to being a product in its own right," Peter said. "Lamb went from being available for just three months a year in spring time to something that was prepared and available 12 months of the year.

"It started off when I secured a contract to supply lamb to the Bi-Lo supermarket in Mandurah and I took that contract on the one condition that they labelled the product 'Fresh from Narrogin farmers'. It was a success and we had to call in help from other local producers. We then went from working with 11 farmers around Narrogin to 250 producers from across WA and from processing 250 lambs a week to processing 1,500 lambs a day.

"It was a great success because we offered producers a guaranteed minimum price through forward contracting, and the farmers were involved in all stages of the business — they would visit markets in the Middle East and Asia and that customer feedback would help us to deliver a better product."

Peter Trefort (centre) was inducted into the WA Royal Agricultural Society's Hall of Fame in 2017.

Leader of the Sheep CRC's Meat Value Chain Program, David Pethick of Murdoch University, said Peter and the Q Lamb program had kick-started the industry's closer attention to lamb carcase specifications with the consumer in mind.

"Peter really was one of the early visionaries of interconnected supply chains with advanced feedback and a focus on carcase specifications for meeting customer needs," David said.

"He tackled the problem from a number of directions, developing seasonal finishing systems for our Mediterranean climate to improve the consistency of lamb supply; he was a great believer in LAMBPLAN and the use of appropriate genetics; he pioneered best practice processing and was the first domestic focussed processor to use electrical stimulation; plus Q Lamb offered a whole range of cuts, not just chops and roasts."

Peter also worked extensively developing on-farm and processing R&D strategy with the Department of Agriculture and Food (WA), University of Western Australia and Murdoch University.

Yearling Merino and large lamb grading

A major goal of the CRC's meat program was to capitalise on the capability of the cuts-based MSA grading system to develop new products that complemented conventional lamb, in particular to benefit:

- Yearling Merino production system with slaughter at 18 months to 2 years of age providing a combination of income from wool and meat.
- Lamb carcases over 25kg that were being produced in increasing numbers associated with genetic improvement for growth rate, carcase weight and leanness.

Yearling Merino carcases were being significantly discounted because they did not meet the tight specifications for lamb that set maximum age and dentition requirements. The CRC showed that cuts of meat from yearling animals retain high-value eating quality and were being 'unfairly' downgraded by the blanket carcase classification of hogget, of course providing they were well fed pre-slaughter. This was especially the case for the loin cuts (rack and short loin). While the leg cuts typically did not eat as well as lamb, they were typically good every day.

The importance of addressing this problem was that yearling Merino production fits well into many Australian farming systems. It provided income from wool harvested at its highest quality from young animals plus a carcase that was likely to be highly valued in many of our export markets. This production system would become even more attractive if the carcase was fairly valued according to its true eating quality. The cuts-based grading system developed by the CRC could provide the underpinning technology for assessing this value of individual cuts in yearling Merino carcases should this become a desirable production pathway.

It was a similar conundrum facing lamb producers. As a result of improved genetics and improved management practices, the carcase weights of Australian lamb were steadily increasing from a mean carcase weight of ~17 kgs to a mean carcase weight of ~23 kgs and there were no signs that this trend was going to abate. The production of lambs weighing >25 kg had a number of efficiencies associated with faster growth and reduced processing costs per kilogram of carcase. However, these heavier carcases were often discounted or non-preferred on domestic markets, partly due to problems of fatness and also simple fabrication which was leading to portion sizes that were too large.

2015

TESTING US AND CHINESE TASTEBUDS FOR NEW LAMB LINES

Chinese and American consumers gave Australian sheepmeat the thumbs up after MSA eating trials were conducted as part of a research project run by Liselotte Pannier and Rachel O'Reilly exploring international market opportunities for 'yearling sheepmeat' cuts from yearling Merinos and lambs over 25kg. The consumer tests used short loins, topsides and forequarters, with all cuts aged for 10 days then boxed and frozen for export. In all countries the meat was grilled, with an additional hotpot method used in China, which is more common than grilling. Overall, the loin samples for both lambs and yearlings received the highest rating from consumers across the three countries. However, as in previous research the topside samples from yearling animals scored lower than lamb meat by up to 10 consumer points, whereas in these trials the gap between yearling and lamb scores was less than 3 points.

This was confirmed by a large survey of consumers with a focus on the shoulder led by David Hopkins. A total of 868 respondents participated in this study and they represented a range of demographics. As the number in a household increased the 'ideal weight' of a roast increased, and there was an impact on the 'ideal weight' of the frequency of shopping such that respondents who shopped daily preferred the heaviest roasts. The 30 to 64-year-old respondents preferred the heaviest roasts, with the 18—29 and over 65-year age groups preferring the lighter roasts. The lower weight considered ideal for these age groups suggested a preference for smaller cuts. Furthermore, households with fewer people also preferred lighter roasts with an ideal weight of ~1.0 kg. These findings supported development of new smaller forequarter lamb roasts in line with the increase in 1—2 person households.

Based on this knowledge a new cut from the forequarter was developed called the compact shoulder roast (CSR) (adapted from the pork Boston butt) and was delivered to industry with full preparation specifications. The CSR was created by further value-adding a square cut shoulder, with the neck and the top of the leg removed by cutting between the scapula and the humerus.

This body of work was underpinned by the development of the resource called 'The nutritive value and eating quality of Australian lamb cuts', led by Dave Hopkins of NSW DPI. This document compared pork, beef and sheep cuts from several countries and this compilation was used in a discovery program for adapting new cuts to the Australian lamb industry. Further, the nutritive profile (where known) and the eating quality (where known) of every cut in the Australian Handbook of meat was documented.

DEXA delivers added value of up to $20/carcase

One of the systems evaluated by CRC research led by Graham Gardner, was dual energy x-ray absorptiometry (DEXA), which used x-rays to measure exactly how much bone muscle and fat was within each carcase — the basis for estimating lean meat yield.

The ability to take these measurements at line speed in the processing plant, allows the processor to tailor the boning room activities to align saleable meat yield with customer preferences. Together with the CRC's cuts-based calculator and the use of modern robotics in the processing plant, the DEXA system enabled a transformation in the sheepmeat industry in which producers could be paid for the volume and quality of saleable meat yield from each carcase.

The research collaboration which developed DEXA was led by Graham Gardner and included:

- Sheep CRC
- Murdoch University
- Scott Automation and Robotics
- JBS Australia
- Meat & Livestock Australia (MLA)
- Sheep Producers Australia
- Coles
- Australian Meat Processor Corporation
- AgBiz Solutions
- South Australian Research and Development Institute
- the Victorian Department of Economic Development

Economic estimations in 2018 determined that a shift to value-based pricing brought on by the adoption of DEXA technology at meat processing plants could deliver up to $20 per carcase in added value to the supply chain. The analysis using the 'cuts-based calculator' was based on the real value difference to a processor between a 27 kg score 2 carcase and a 21kg score 5 carcase — under traditional systems these animals would have achieved the same value in dollars per kilogram.

2018

'HOLY GRAIL' OF DEXA WINS CRCA AWARD

The sheepmeat industry's role in developing the new DEXA meat grading system was awarded the prestigious 2018 Award for Excellence in Innovation from the Cooperative Research Centres Association. Dual energy x-ray absorptiometry (DEXA) allows abattoirs to accurately measure carcase lean meat yield at line speed — an innovation which changed the structure of the Australian sheepmeat industry through a shift to value-based pricing of carcases. The award was presented to the Sheep CRC on behalf of its collaboration with Murdoch University, Scott Automation and Robotics, JBS Australia, Meat & Livestock Australia (MLA), Sheep Producers Australia, Coles, the Australian Meat Processor Corporation, AgBiz Solutions, South Australian Research and Development Institute and the Victorian Department of Economic Development.

The cuts-based calculator used the carcase weight and its DEXA values to estimate the weight of any commercial cut specified by a processor. The weight per cut information is then combined with the wholesale or retail price per kg for each cut to value each carcase. The processor could also use the cuts-based carcase calculator to determine what cutting specifications to apply to maximise the return per carcase.

However, the advent of DEXA also presented a challenge to producers to consider how they would gain their fair share of that extra value by ensuring they produced sheep that met tighter specifications. The CRC's meat research to date had shown there were three factors contributing to the value of lean meat yield: carcase size, fatness and the extent of 'fabrication' (the breakdown of a carcase into cuts for sale). With increasing fat content, at any given carcase weight, there was a corresponding decrease in the value of the carcase to the processor, because as the carcase was broken down into more specific retail cuts, with increasing levels of fabrication, higher levels of fat had an increasingly negative impact on the value of the carcase due to the extra labour involved. At the same levels of fat, heavier carcases have higher levels of saleable meat, but the benefits of heavier carcases were eroded if the additional weight was a result of increasing fat and not lean meat.

As a result, the CRC program recommended producers focus on genetics and nutrition to ensure they deliver to processors animals at a premium weight with the right amount of fat, and recognise that selecting fast growing genetics had implications for eating quality.

Why lamb is a good source of Omega-3

Research drawing on data from the sheep industry's Information Nucleus Flock program revealed the potential for lamb to be marketed to consumers as a 'good source' of beneficial Omega-3 fatty acids, iron and zinc.

The CRC research on the fatty acid profile of lamb, led by Eric Ponnampalam, was reviewed in 2016 by Neil Mann, of RMIT University, an expert human nutrition professional and Fellow of the Nutrition Society of Australia. In conjunction with the Sheep CRC, he agreed that in most instances Australian lamb met the requirements to be classified as 'low in saturated fat' and a source of iron, zinc and Omega-3.

"Given the positive nutritional aspects of lean lamb in terms of iron, zinc, Omega-3 fats and low saturated fat levels, along with its potential to deliver useful levels of Vitamin B12 and other vitamins and minerals, there is great scope for promoting the health aspects of lean lamb regardless of the diet the animals have been fed," Neil said.

The research revealed that beneficial saturated fats and Omega-3 fatty acids were more evident in lambs fed green foliage, but these levels declined as the amount of grain or dry feed in their diet increased.

"However, the variation in Omega-3 content in lean lamb is minimal in absolute terms between the longest and shortest grain and/or dry feeding situations in this study, and when lamb is consumed at moderate levels it may make a small but important contribution to our intake of Omega-3 fats, with positive effects on human health," Neil said.

The research consolidated earlier international studies which showed that the lean portion of lamb meat has no negative effect on human markers for cardiovascular disease. This research was important in redefining lamb as a healthy product given its historical reputation of being fatty, but given modern leaner carcases and that most consumers remove salvage fat either before or after cooking, this traditional view point is now strongly challenged. In the future, human consumption trials would be warranted to quantify the impact of lamb in the diet on a range of human health measures.

CRC3 MAJOR FINDINGS

After 18 years, the cumulative impact of the CRC meat program resulted in the integration of multiple lines of research:

- A comprehensive understanding of consumer tastes and preferences both within Australia, as well as the US and China, allowing producers and processors to more profitably meet their needs through MSA for lamb and the cuts-based calculator.
- The rollout of DEXA at processing plants across Australia. It was estimated that this solution could return a gross value of up to $420 million annually to the red meat industry by 2035, based on shared use of DEXA information to predict lean meat yield and robotic carcase processing.
- The provision of breeding and management tools to producers, including DNA and ASBV selection tools, to allow them to maximise production and value without compromising eating quality.
- Numerous Technical presentations to industry forums including LambEx.
- Lamb Supply Chain Group collaboration, cooperation and co-investment legacy.
- Livestock Data Link (LDL), LMY Technical Manual – Versions 1 and 2, LMY and eating quality workshops.
- As of March 2019, LSCG had 100 members attend the group, and 45 invited guests.
- The nutritive value and eating quality of Australian lamb cuts.
- The Lamb Value Calculator.
- The MLA PGS Lean Meat Yield and Eating Quality workshop – developed and piloted in readiness for when DEXA LMY feedback commences.
- Collaboration in MLA's 20 Lean Meat Yield and Eating Quality Producer Demonstration Sites.
- Technical presentation and LSCG membership contributions and commitment to the highly successful LambEx.

Beef builds on Sheep CRC Supply Chain Group legacy

The Sheep CRC left a legacy of meat processing innovation that will benefit not just lamb producers for years to come, but the beef industry as well.

The Lamb Supply Chain Group (LSCG) was established to remove blockages in the information flow between producers, processors, retailers, researchers, governments and consumers, and it succeeded in achieving this by building strong partnerships along the value chain and embedding R&D with end-users. The inaugural Chair, Alex Ball, and the incumbent Richard Apps, both agree the initial breakthrough which really drove the long-term success was the expansion of the MLA-initiated 'innovation managers' driven by Rob Banks. These were individuals embedded within companies to facilitate R&D adoption and act as a conduit for collaboration. The Sheep CRC co-funded such positions with lamb processors including JBS, Thomas Foods, the Australian Lamb Company, Gundagai Meats, and the Australian Meat Processor Corporation (AMPC), as well as establishing close working relationships with WAMMCO, Fletchers, Frews, VV Walsh and Australia's major retailers.

As a result, by July 2019, it was expected that the LSCG would have facilitated lean meat yield measurement and MSA grading of 4 million lambs per annum — a magnificent achievement in adding value to the industry.

In 2018 the Lamb Supply Chain Group, which was formed in 2007 by the Sheep CRC in partnership with Meat & Livestock Australia (MLA) and Australian Meat Processor Corporation (AMPC), transitioned to become the red meat industry's National Supply Chain Group. The Lamb Supply Chain Group was responsible for delivering major innovations to industry including: the implementation of Meat Standards Australia (MSA) systems across five major supply chains; development of a Lean Meat Yield Technical Guide; the Lamb Value Calculator; establishment of 20 national demonstration sites showcasing elite sheep genotypes and assisting in the development of ASBVs for meat eating quality traits; and enhanced feedback to producers using tools such as MLA's Livestock Data Link.

So successful was the model that it was adapted to drive innovation across both beef and lamb, and continue the process of ongoing industry transformation following the Sheep CRC's closure. As part of the CRC legacy strategy, the Supply Chain Group transitioned to 50:50 Sheep CRC-Advanced Measurement Technologies for Globally Competitive Australian Meat (ALMTech) funding in 2017—18, then to 25:75 this year, and will be fully funded by ALMTech after the Sheep CRC concludes in 2019. This funding is supplemented by contributions from the collaborating partners.

Looking back and looking forward

The research, development and extension undertaken by the program(s) was adventurous, sustained and transformative. The scale of the effort was the envy of colleagues and industry players globally — a tribute to the vision of the collaborating RDC's (MLA, AMPC), the national CRC Program and of course the many partners who have come together. No other country could boast such close and focussed collaboration to deliver outcomes for lamb and sheepmeats (indeed for any other meat) across all sectors of the supply chain. Moreover, the evolution of the lamb and sheepmeat industry saw a sustained and remarkably united effort across all sectors of the industry for many years. Continuing this united approach focussed on not just productivity, but on the consumer, always paid dividends.

In singling out key outcomes from the pack, the MSA Mark II prototype was a standout. It clearly showed processors could grade cuts of lamb into different eating quality grades that the consumer was willing to pay for. To underpin such grading at the processor level was enormously challenging, requiring accurate assessment of LMY and IMF at line speed. Even the idea that LMY and eating quality needed to be measured together was novel in lamb on a global stage, despite the clear antagonism between the two traits. Precision assessment of LMY became real with the advent of the DEXA technology; the IMF methodologies were still in R&D phase at this time with promising signs from the use of hyperspectral cameras, near infra-red (NIR) and other technologies being developed by commercial companies rapidly approaching reality.

The 'on-farm' aspects of carcase composition and intramuscular fat development have been well defined with evidence that they were determined by both nutrition and genetics, and new breeding values for the management of these traits had become main stream within Sheep Genetics. At the end of the CRC the industry was about to enter an exciting phase of lamb and sheepmeat brands being underpinned by clear quality metrics combined with carcase feedback to allow lamb and sheepmeat producers to target market metrics suited to their production systems.

The effort to bring all of the CRC's work to fruition in the shorter term was being underpinned by the new ALMTech program which offered a CRC-type platform to progress objective carcase measurement across lamb, beef and pork. Further effort was warranted to showcase the broader credentials of lamb as a healthy red meat product as had been shown by CRC research.

The future of lamb and sheepmeat as high-value consumer products remains assured with a united and collaborative industry future which must be treasured and preserved at all costs.

FIND OUT MORE

For information on how the Quality Sheepmeat research program was underpinned by complementary CRC research in other fields go to:

- Chapter 3 — Integrating Wool & Sheepmeat Production
- Chapter 4 — Introduction of Genomic Technologies
- Chapter 6 — Precision Sheep Management
- Chapter 11 — Implementing innovation

9 MEASURING THE MAGIC OF WOOL

When planning started for the Wool Program in the second term of the Sheep CRC in 2007 there were high hopes of a technological breakthrough that would enhance the entire value chain by improving consumer comfort and the precision of fabric processing. But even with the collaboration of the leading wool research minds, few in the industry would have thought that a simple guitar string would hold the secret to the biggest breakthrough seen since the arrival of the Merino.

The design of the Program focussed on the customer and the factors contributing to consumer satisfaction with wool. Paul Swan, Mark Dolling and John Stanton all played important roles in defining the new program with its focus on three major issues for wool in the expanding market for lightweight knitwear: next-to-skin comfort, bright white colours and predictable handle.

The program had a clear aim: to increase the demand for, and value of, Australian wool. Results of consumer surveys commissioned by Australian Wool Innovation (AWI) and conducted by Millward Brown were important in identifying the positive and negative consumer attitudes towards wool. There were many positive aspects of wool identified by consumers such as: worth paying extra for; allows body to breathe; high quality; available in casual styles; soft to touch; classic fabric; a symbol of status; durable; and natural.

Unfortunately, there was one major attribute that negatively impacted wool's appeal. More than 60% of people surveyed associated the problem of "itchy/prickly" with wool. This problem was becoming more important with the rise in popularity of light-weight, trans-seasonal, next-to-skin knitwear through the early 2000s. This garment category was perfectly suited to wool, in fact, you could say it was the calling card for superfine and ultrafine wool, but it was a market segment dominated by cotton and synthetics.

Not enough supply chains were taking advantage of the new, finer wool being produced by Australian wool growers, and knitters could not ensure their knitwear was 'prickle free'. To overcome this the CRC needed to give the industry the technology to guarantee next-to-skin comfort. Key to this was the ability to measure next-to-skin comfort in fabric and garments in order to develop and guarantee the performance of wool products. Prickle was by far the most important attribute for consumers and there was nothing available to measure garment prickle.

Softness was the other attribute contributing to next-to-skin comfort and it also had no simple measurement. It was widely believed that softness was a good proxy predictor of prickle. The softer the fabric the lower the prickle was assumed to be. While there were many examples that showed this relationship did not hold, it was not until the fourth year of the CRC2 research in 2011 that the team could measure both properties and demonstrate categorically

that there was no relationship between prickle and softness. This helped explain why there were such widespread problems with industry making and selling next-to-skin wool garments with soft handle but poor next-to-skin comfort, and thereby reinforcing the negative consumer perceptions.

Wool whiteness was the third factor of commercial importance. The preferred colours for light-weight, next-to-skin knitwear were bright whites and pastels. To produce the brightest pastel colours depends on a very white base. Wool has a slightly yellow base colour and this means that for wool to be dyed to form bright pastel colours it must first be bleached. The bleaching process is very damaging to wool and makes wool sensitive to photo-yellowing in sunlight.

The Program designed under the leadership of Paul Swan, while at AWI, had well-defined goals to provide industry with the instruments to measure and manage prickle and softness and the technology to produce bright white wool. When Paul Swan left, the CRC was fortunate to recruit David Tester to take on the leadership of the Program. David's industry experience as General Manager of Manufacturing at Macquarie Textile Group was invaluable in bringing a commercial focus to the research and product development. The CRC was also fortunate to have Peter Silk's experience in the area of commercialisation and IP management. Peter's background with AWI and its predecessor wool R&D organisations contributed further depth to the already strong linkages with industry.

THE PROJECT TEAMS – SPECIALISTS FOR EACH ASPECT

- Program Leaders: Paul Swan (2007–2008) and David Tester (2009–2014);
- Wool Comfort Instrumentation: Geoff Naylor and a team from the CSIRO Division of Materials Science and Engineering at Geelong;
- Wool Comfort Wearer Trials: John Stanton at the Department of Agriculture & Food Western Australia (DAFWA) and the Design for Comfort Laboratory carrying out the wearer trials;
- The textile group at Deakin University led by Xungai Wang assisted with instrument testing and validation with Maryam Naebe and Bruce McGregor responsible for many of the key publications;
- Wool Handle project: Trevor Mahar at the Australian Wool Testing Authority (AWTA);
- Wool Whiteness project had Keith Millington of the CSIRO Division of Materials Science and Engineering at Geelong as the project leader.

Objective measurement of wool comfort

The first task was deciding the most appropriate approach to take in developing equipment for measuring the next-to-skin comfort of fabric.

While the scientific basis of wool fibres causing prickle was clearly understood, the supply chain had not been able to utilise this knowledge to remove this problem from wool garments.

It was known that the cause of the prickle sensation were stiff fibres able to push into the skin with a force of at least 0.075 grams — sufficient to trigger nerve receptors in the skin and cause irritation. However, the CRC team needed to appreciate that fibre stiffness was a function of both diameter and length. This threshold value equates to a 30-micron fibre protruding 1.5mm in length from its anchoring point in the yarn. This fact alone led to the term "Comfort Factor", a term used in greasy wool measurement that is defined as the percentage of fibres over 30 micron.

What was not considered at the time was that much finer wool fibres could reach the threshold prickle force if they were shorter than 1.5mm and therefore more difficult to bend.

It was the CSIRO Division of Materials Science and Engineering, formerly the Division of Wool Technology, which was home to research on wool prickle and had developed a number of approaches for measuring the prickle propensity of fabrics. The following options were identified as the most promising.

- SIROSkin — A technique whereby a thin polymer film was placed on the fabric surface and deformation of the film by the protruding fibres was 'measured'. This was championed by Graham Higgerson.
- The Guitar String — A technique whereby a fine guitar string was traversed across the fabric surface and the interaction of the string with the protruding fibres was 'measured'. This was championed by Donald Ramsay.

- Optical measurement of protruding fibres using a projection microscope and fabric draped over a sharp edge was also developed by Graham Higgerson.

The three techniques were evaluated and all results correlated well against human responses to prickle. The results and the concept designs were reviewed in August 2008 by the Wool Program's Commercialisation and Adoption Advisory Committee chaired by John Lewis of AWTA. There was a clear winner: the 'guitar string' technology was considered to be superior to both the image analysis and pressure sensitive film options. Only with the benefit of hindsight can one now appreciate how that simple guitar string technology helped the CRC team to understand the complexity of the fabric surface and how it causes prickle. This instrument was in essence counting the number of prickle-causing fibre ends on the fabric surface such that the lower the value the more comfortable the garment.

With the decision to develop the guitar string concept, Don Ramsay and his CSIRO colleagues responsible for the invention, were asked to prepare design drawings for construction of a prototype instrument together with documentation for a Provisional Patent application.

As important as being an accurate measurement system was its calibration against a range of fabrics of known user acceptance and appeal. The CRC was fortunate to have the expertise of Geoff Naylor and the CSIRO group as well as the experience of John Stanton and his DAFWA colleagues who had established the Design for Comfort Laboratory in South Perth. The wearer trials began by fine-tuning a consumer evaluation protocol and planning the manufacture of fabric and garments for evaluation.

The journey to measure wool handle

When a fabric or a garment was judged by a consumer it was colour and design that were first assessed. This was quickly followed by the handle when it is touched. Lastly, were the other attributes associated with performance and durability.

All characteristics, apart from handle, could be accurately measured and were therefore not subject to argument. It was only the handle that was subjectively evaluated by consumers and experts alike and therefore prone to disagreement. This caused a commercial problem because subjectively assessed fabric handle was regularly used to reject deliveries, while at the same time being critical in fabric development and brand establishment.

The CRC had to ensure that the words used to describe fabric handle were clearly understood by all users. Unlike the Wool ComfortMeter, which provided a single value for the measurement of a single fabric attribute, the measurement of fabric handle was a complex combination of numerous properties determining 'what a fabric feels like'. To identify these words, the team surveyed textile experts from different backgrounds and nationalities to determine what English words were used in their normal day-to-day description of the handle of lightweight knitted fabrics. The survey quickly revealed why there were problems associated with the interpretation of fabric handle: a total of 89 different words were used by 'experts' to describe the handle of knitted fabrics.

The wool team needed to reduce this number of words to a manageable list that could be the language of the Wool HandleMeter. The words were grouped into basic handle attributes to identify like terms and eliminate the less commonly used words without losing information. The 89 descriptors were grouped under basic handle attributes such as Surface Properties, Stiffness, Compression, Mass, Heat/Cool sensation, and Stretch/Recovery.

Across different experts and companies there were 45 different words used just to describe the surface properties of a fabric. Words such as raspy, scroopy, slinky, soapy, bare, coarse, raw, sheer and 19 others were only used once by the experts in the survey. From this exercise it was apparent that the majority of words used to describe fabric handle were associated with specific individuals and/or companies, and potentially not universally understood.

Fortunately, there were 14 of the 89 words that were used by most experts. These words covered all of the basic handle attributes and were used to form the basis of the Wool HandleMeter language. It was also agreed that each property of handle should have an opposite in order to be able to describe a graded range. The CRC team settled on a series of seven categories with their opposite descriptors and added an eighth for overall liking of the handle.

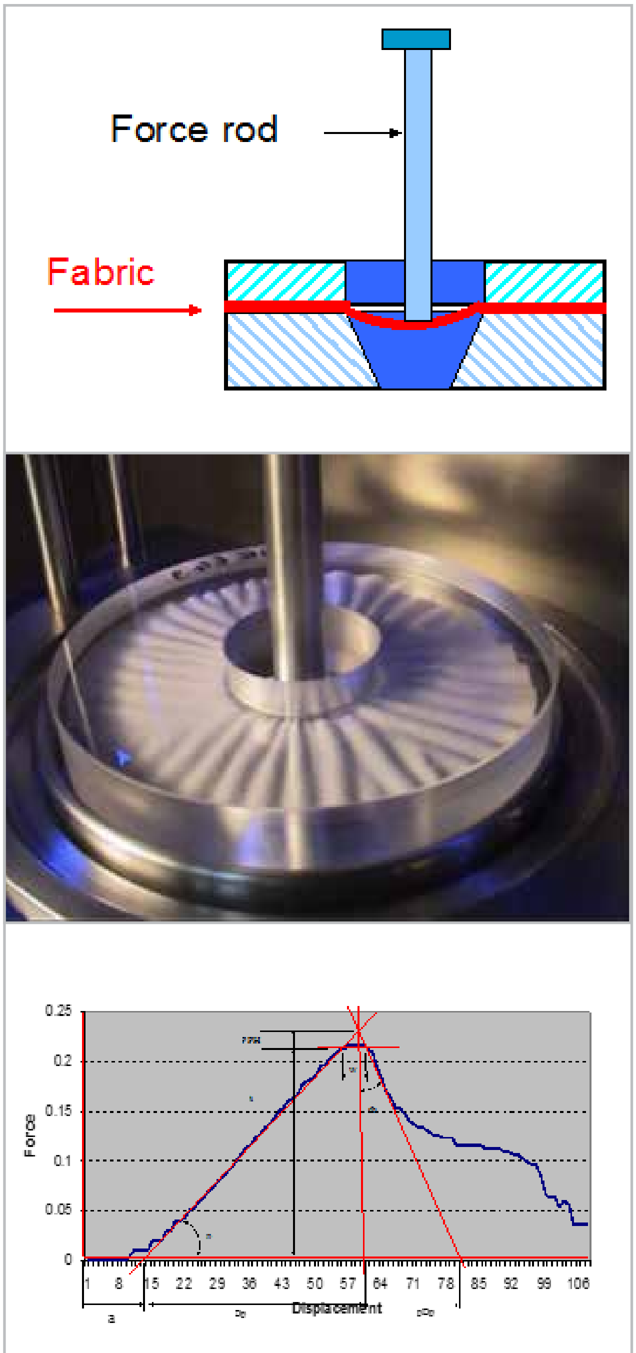
With this set of handle descriptors and a range of fabrics representative of different handle characteristics the research team was in a position to evaluate objective measurement options.

The PhabrOmeter, produced by the company Nu-Cybertek, measured the pattern of force required to push a circular disk of fabric through a nozzle using the age-old principle of pulling a silk scarf through a ring in order to judge its quality. Although not calibrated for knitwear measurement, it looked like a good starting point and AWTA acquired an instrument to start our investigations. However, there were two problems. Firstly, the company manufacturing the PhabrOmeter would not give the CRC access to the primary data of force by time, and calibration of the instrument was restricted to the standard machine outputs. Secondly, when the CRC purchased a second instrument to assess consistency of results when the same fabric was measured on different machines, significant between-instrument differences were found. It was also subsequently discovered that the design of the nozzle had been changed – without informing the CRC.

THE LANGUAGE OF WOOL HANDLE

Rough-Smooth:	The feeling of undulations on the fabric surface. The finer the yarn and the finer the knit structure, the smoother the fabric.
Hairy-Clean:	The feeling of the amount of long and short fibres on the fabric surface. Some knitwear intentionally has lots of fibre on the surface to make it feel softer.
Hard-Soft:	The feeling of how easy a fabric compresses when pressed. This can be influenced by many processes during spinning, knitting and finishing.
Warm-Cool:	The feeling of coolness when fabric is first touched. The finer and smoother a fabric surface the cooler the touch. Silk has a cool touch.
Heavy-Light:	The feeling of the weight of the fabric. Some fabrics that are very thin feel lighter than they really are.
Loose-Tight:	The feeling of how a fabric stretches and recovers. Cotton and synthetic fabric have little stretch without Lycra. Wool has natural stretch due to its crimp.
Greasy-Dry:	The feeling of greasiness on the fabric. This is a feeling associated with the addition of chemical softeners to knitwear to make them feel 'better'.

With significant investment at stake in calibrating and commercialising handle measurement technology, the CRC obtained advice from IP specialists about freedom to operate in designing and building our own HandleMeter. With no patent registered in Australia, the CRC was advised it had complete freedom to operate in developing the new equipment. With the first prototype built the CRC had full access to the output data and ability to fine-tune the design — calibration could start. The principle of the HandleMeter is the shape of the curve of force against distance when forcing the test fabric through the nozzle is characteristic of different aspects of fabric handle.



Figures 9.1: The top panel shows the HandleMeter principle. In the middle is a photograph of a sample of fabric 'puckering' as it is forced through the nozzle and the diagram at the bottom provides an example of the output and options for analysis.

In search of whiter wool

Wool has difficulty competing with cotton and synthetics in markets requiring bright white and pastel colours because of wool's slightly yellow colour and inferior photostability (tendency to yellow when exposed to sunlight — particularly when wet).

The White Wool project established two clear commercial targets: the first was to be able to grow a wool fibre of sufficient whiteness to not need bleaching; and the second was to improve the photostability of wool.

Through samples of wool obtained from the Information Nucleus flocks, the CRC was able to explore the potential for improving these two important wool properties through genetic selection and environmental or nutritional management.

Colour of wool was already known to be a heritable trait and there was a test method available for measuring fleece wool colour, as brightness (Y) and yellowness (Y-Z). Therefore, an initial study was undertaken to determine the amount of variability explained by the broad range of genetics and the diverse production environments across the seven Information Nucleus sites.

To complete the assessment of variation in wool whiteness the CRC team had to develop a measurement system for photostability. Keith Millington and his colleagues at CSIRO developed a novel test procedure for screening large numbers of wool samples for stability.

Wool yellowing is caused by the UV components in sunlight, which create yellow oxidation products in wool. Both processes occur concurrently when natural wool is exposed to sunlight. Although it is easy to produce simulated sunlight in the lab, samples would need to be exposed for weeks to compare rates of yellowing and the test would be dependent on the original wool colour.

PHOTOSTABILITY TEST RESULTS

Photostability test results showed that the whitest fleece wools generally experienced the largest change in yellowness, and that there was significant variation in photostability.

Environmental effects, such as trace elemental content of wool, were shown to affect its photostability. It was also found that photostability had a moderate heritability (0.17) and therefore could be improved by selection.

Photostability test rig.

To avoid these issues, an Ultra Violet Blamp (UVB) was used in the test method. UVB is the major cause of sunburn on human skin, and it also yellows wool (regardless of its initial colour) more rapidly than the lower energy UVA in sunlight. Typically, a 4-hour UVB exposure increased the yellowness value by up to 7 units which was obvious to the naked eye.

The scoured wool samples already prepared for wool colour measurement were used in photostability testing. A 0.5g sample of wool was packed into UV-transparent cuvettes and arranged around a central UVB fluorescent tube in a rotating carousel. The change in yellowness after 4 hours UVB exposure, was the key photostability parameter obtained. This method was used to test more than 2500 Information Nucleus progeny.

The results showed that the whitest fleece wools generally experienced the largest change in yellowness, and that there was significant variation in photostability. Environmental effects, such as trace elemental content of wool, were shown to affect its photostability. It was also found that photostability has a moderate heritability (0.17) and therefore could be improved by selection.

It was of interest to see whether the higher photostability of certain fleece wools was maintained after hydrogen peroxide bleaching, since bleaching was known to significantly reduce wool photostability. Unfortunately, no improvement in photostability after bleaching was found, suggesting that genetic selection of sheep for higher photostability would only offer a commercial benefit for production of bright whites and pastel shades if wool colour was improved to such an extent that peroxide bleaching was unnecessary. Such a large improvement in wool colour, even if it were possible to achieve, would require many generations of selective breeding along with sheep coats or shedding, to avoid photo-yellowing during growth.

With no evidence that breeding would provide a solution, the focus moved to improving current commercial practices to produce white, photostable wool by applying a UV absorber to bleached wool. Initial attempts of applying UV absorbers resulted in excessive wool yellowing.

Keith Millington

Finally, a method was developed that allowed the UV absorber to be applied in small concentrations during bleaching that resulted in what the CRC defined and promoted as the 'Everwhite' process. Although a number of wool textile manufacturers from China, Europe and New Zealand expressed strong interest in the new 'Everwhite' wool process, it did not convert to a commercial success. This was mainly due to the difficulty in establishing standard test systems to demonstrate the decrease in photo-yellowing.

There was initially interest in patenting the 'Everwhite' process but with technical difficulties around defining the benefits, the CRC decided to publish the details of the technology and place it in the public domain. It was believed this information may have helped in the development of the Enciel white wool process in 2015 and in early 2018 an Italian company took up further trialling and development of the process.

Parallel development of the Wool ComfortMeter and Wool HandleMeter

With both comfort and handle characteristics being of significant importance in determining quality from a consumer perspective, all knitwear fabrics were assessed for these key attributes. The design and selection of test fabrics and the evaluation and calibration of the new measuring systems all proceeded in parallel.

There were also parallel, and similar challenges, in developing the comfort and handle measurement systems from research prototypes to pre-commercial instruments. The design specifications needed to be developed in order to get quotes from engineering companies and instrument makers. Software details and user interface systems needed to be developed on commercial platforms and the calibration and accuracy of the new instruments established to rigorous industry standards. The fact that they were both novel measurement systems added to the complexity in that there were no standards to use for comparison.

Over a four-year period the guitar string instrument was refined from a simple hand held system as an experimental prototype, to a fully automatic commercial testing instrument. Over a similar period the HandleMeter developed from design to a reliable test system. Both instruments were being manufactured commercially by Milspec Manufacturing in Australia.

With the measurement systems in place calibration continued to improve and delivery of research information started to accelerate.

The wearer trials

The wearer trials were an essential component of calibrating the Wool ComfortMeter so that the numbers that came from the instrument could be related to a person's perception of next-to-skin comfort.

The wearer trials were managed and analysed by a team based in Perth including John Stanton, Sara Perruzzini, John Bielby and Jane Speiers. The Designed for Comfort Laboratory evaluated and analysed consumers' responses to a number of garment tactile properties including prickle using a West Australian Department of Agriculture and Food (DAFWA) developed protocol.

Each wearer trial evaluated 4–6 different garments, one of which was a 'link' garment that had been used in a previous trial and enabled the results of each individual trial to be pooled for analysis. Approximately 24 women were used for each garment evaluation and each participant was asked to rate a range of comfort sensations at 15 different times during the 1 hour 30 minutes of the evaluation. During this time the participant was put through a range of environmental and exercise protocols that ranged from seated and comfortable to hot, sweaty and exercising.

The initial fine-tuning of the protocol discovered that male participants were inconsistent in their garment evaluation, whereas female participants were more consistent. This was put down to different levels of body hair, and therefore different levels of interaction between the garment and skin — it meant that male participants were subsequently excluded from the protocol.

Test participants were 25 to 35-year-old women, untrained in fabric testing, healthy, and with a body mass index (BMI) between 20 and 30. This was important as each test lasted 90 minutes and included periods of exercise at both standard air-conditioned conditions, as well as hot dry conditions of 40°C and 24% relative humidity. Each wearer trial involved up to 43 participants per fabric and up to six garments.

The CRC was very fortunate to have The Merino Company as a Participant and industry partner. Through their New Zealand knitting mill, Levana, the CRC was able to start the wearer trials using a number of experimental yarns spun by CSIRO. This was the perfect starting point as there was a full knowledge of the diverse raw wool characteristics and the processing settings used to produce these yarns.

During the fourth year the wearer trials started to incorporate garments made from commercial fabrics and also garments purchased through retail. The 11th and final wearer trial was completed and incorporated the 14- and 15-micron wool garments produced from the wool processed by the CRC. This was an important final inclusion for both the comfort and handle research as it enabled a benchmark superior product to be included. A total of 59 different garments were evaluated over a four-year period giving almost 200,000 separate data points for each comfort property rated.

An early analysis of the wearer trial data and Wool ComfortMeter data showed that average wool fibre diameter only explained about 60% of the wearer trial response. Other characteristics such as fabric construction, yarn structure and fabric finish were also important. Later, a

UNEXPECTED INSIGHTS FROM THE WEARER TRIALS

- Cashmere garments were not significantly better than the fine wool (<18.5 micron) garments.
- In general, yarn and fabric structures did not cause significant modification in consumers' responses. The exception was the pique knit which was better than all of the other knit structures.
- Cashmere garments did not perform as well as the finest wool garment (16.3 micron) in the hot environment.
- While the cotton garments were best for prickle, they were also considered more uncomfortable than the fine wool and cashmere garments. This confirms that factors other than tactile components contribute to a consumers' response to garment comfort.

Helen Sisson (right) with Madeleine Keaton at Curves Gym, Armidale, NSW, recording comfort levels while wearing different fabric sleeves during exercise.

linear model was developed to predict the response of a wearer to prickle with 90% accuracy. The major factor in the model was the Wool ComfortMeter value along with some minor factors related to fibre, yarn and fabric construction.

Some of the more interesting findings from these wearer trials were not that surprising but nice to confirm under a stringent testing protocol. The first was that people were very different in their response to garment comfort, and due to this, some people found all garments prickly including cotton, polyester, cashmere and fine wool. The second was that when the body was hot and sweating the skin was more sensitive to irritation. This related to all people, and in all cases the rating of garment comfort decreased significantly when the person was hot and sweaty.

To cover future fabric developments, it was important to extend both the comfort and handle measurements beyond available commercial and research fabrics. To this end the CRC processed some 14- and 15-micron wool sourced from farms in the New England Tablelands, into yarn, fabric and garments. The garments from this trial produced the lowest values of any wool fabric on the Wool ComfortMeter and some of the best values for Softness and Smoothness seen on the Wool HandleMeter.

The wearer trials also answered an important commercial question about the application of the instrument results when they demonstrated that the perception of prickle was essentially the same irrespective of ethnicity.

Deakin University joined the program in 2009 and brought significant expertise and resources for the next stage of development of the Wool ComfortMeter. This development was overseen by Xungai Wang, Bruce McGregor and Maryam Naebe. Amongst other projects the Deakin group conducted innovative trials testing yarns on the ComfortMeter and showing close correlations between comfort measurement of yarn and fabrics made from the yarn. Bruce McGregor also brought a lot of experience, as well as samples of yarn and fabric made with other fibres.

By 2010 the CRC had collaborative arrangements with major Chinese spinners and knitters to make yarns, fabrics and garments to our specifications for wearer trials and for further calibration of the Wool ComfortMeter.

EVALUATING COMMERCIAL FABRICS

Major players participating in next-to-skin knitwear research included:

- Smart Wool (USA);
- Joha (Germany);
- Michells (Australia);
- Nameson, Jockey, Crystal Sweaters and McCall Knitters (Hong Kong); and
- Levana (New Zealand).

The study of Handle

A set of test fabrics was prepared for calibration of the HandleMeter with assistance from a group of textile experts. The group were asked to grade a set of 74 lightweight knitted fabrics on a scale of 1 to 10 for each of the seven handle categories:

- Rough-Smooth;
- Hairy-Clean;
- Hard-Soft;
- Warm-Cool;
- Heavy-Light;
- Loose-Tight;
- Greasy-Dry; and
- Overall Handle.

These fabrics included wool, wool blend, cotton, synthetic and cashmere fabrics to ensure there was a wide range of values for each handle category. The same fabrics were then measured using the Wool HandleMeter and the average values of the experts were used to calibrate the Wool HandleMeter.

There were a number of important findings from this calibration work. First, there was consistency between the experts in their ranking of fabrics for each handle category. This was good news and essential to be able to calibrate the Wool HandleMeter to the expert values.

Second, the experts did not always agree on the absolute value for a fabric in a handle characteristic. There was a range of up to three units between them, but this was less of a problem for calibration as the average of three judges' scores was used.

Third, the experts did not always score the same fabric with the same value, when assessing it on another day.

Natalie Skubel, of Country Road, stressed the need for between-day consistency as part of the process for identifying quality and maintaining a consistent 'brand' handle for retail knitwear. This was a problem that the HandleMeter overcame.

Calibration of the HandleMeter using the results from the expert panel resulted in the instrument being more reliable than the average results from the panel of experts, mainly due to day-to-day consistency.

An important aspect of the scoring system was that a value of 10 for any attribute represents an extreme and was not necessarily the best. For example, a value of 10 for softness was associated with a knitted fabric that was too loose and open to make a functional and durable product. In practice a balanced combination was required and this was confirmed by scores for the fabrics rated most highly for overall handle. The fabric rated most highly by the experts for overall handle was the knitwear made by the CRC from 13.8-micron wool. This fabric also had the lowest score on the Wool ComfortMeter. The Wool HandleMeter values for this fabric, confirmed by the expert panel, were as follows:

Hard-Soft	7.4
Rough-Smooth	7.5
Loose-Tight	4.6
Heavy-Light	4.1
Hairy-Clean	4.7
Warm-Cool	5.1
Greasy-Dry	5.1

These values provided a template for the development of future best quality products.

By this time the software and algorithms for the Wool HandleMeter had been completed and showed a superior level of accuracy and consistency when compared by a group of three experts. This was seen as a real game changer for companies in the wool textile supply chain as it was the subjective hand feel of fabric that was often the cause of dispute between parties when two or more people were trying to agree on how a fabric feels. To have an independent, objective assessment for these specifications would make a big difference.

Pre-commercialisation: Taking the ComfortMeter and HandleMeter to the world

From the start of the program strong partnerships were developed with key companies in the wool textile supply chain. These links helped to ensure a commercial focus for the research and created a situation where our industry partners were involved in design of the work and were ready to utilise the results when they became available.

Numerous commercial collaborators contributed yarn, fabric and/or garments for the project, as well as supplying technical and commercial expertise to the design of test fabrics. This resulted in a widespread engagement with the R&D and many organisations keen to test the new measurement systems.

With the potential significance to the wool industry of the two new measurement systems, the CRC recognised the need for a structured approach to commercialisation. Les Targ was asked to assist in planning the commercialisation strategy, and later engaged Sam Guthrie to provide specialist advice with our communications. Les and Sam worked closely with John Lewis, as chair of the CRC Board's Commercialisation Committee to steer the planning and implementation of the commercialisation strategies.

By the time pre-commercialisation trials commenced the instruments were being used in some of the biggest knitting mills in the world. AWI helped make introductions to two of the largest and most influential companies in the global wool knitting pipeline, Crystal Sweaters in South China and Floreal Knitwear in Mauritius. The Wool ComfortMeter was taken to their mills and used as part of a two-week evaluation and development trial. It became obvious from these trials that the best way to demonstrate the application and value of the instruments was to work with knitters in their premises and on their products. This fact would influence the CRC's future commercialisation activities.

Trialling of the comfort and handle instruments continued in Australia with Country Road, Macquarie Textiles and Michells to evaluate production and delivery and establish protocols for the use of the instruments in a commercial situation.

In addition to engagement with potential users of the new measurement systems was the job of identifying an Australian manufacturer for the instruments. An Australian SME, Milspec Manufacturing in Albury, had experience in developing mechanical and electronic instruments for the Defence Department and doing very small production runs. In conjunction with CSIRO and AWTA they designed and manufactured the first production run of both the Wool HandleMeter and ComfortMeter. Measurement trials were then done with the prototype and new production instruments to confirm consistency between them.

In parallel with arrangements for commercial manufacturing of the instruments was the process of establishing new test methods for consideration by the International Wool Textile Organisation (IWTO). Acceptance of the new methods by the IWTO would enable companies to set specifications in contracts based on these tests. To further support the introduction of the new tests, AWTA began pilot trials of the Wool ComfortMeter and Wool HandleMeter in their test houses in Melbourne Australia, and Nanjing China. To assist the uptake in China a series of seminars and demonstrations were held to introduce the tests to the wool textile companies in China. The Chinese seminar attracted 15 major Chinese knitters and spinners and a lot of positive feedback about the application and benefits.

The final year of the Wool Program (2013–14) began with a successful Wool Week seminar in Melbourne promoting the Wool ComfortMeter and Wool HandleMeter to the Australian wool textile industry. This included a presentation by a major Chinese knitwear supplier, Diyang Merino, sharing information on the use of the instruments in their business. The CRC also completed filming and interviews for a feature on the ABC *Landline* program and promotion of the instruments through a feature article in the global textile magazine Twist.

This was followed up by a series of successful retail workshops organised by David Tester and Les Targ held in Seattle, New York and London. The US workshops were attended by 15 global retailers/brands including Brooks Brothers, Columbia Sportswear, New Balance and Nike as well as the US Textile Press. The London workshop was attended by 10 of the largest wool brands in the UK including Marks & Spencer and Burberry. These workshops were aimed at the retail end of the supply chain to create demand for the tests, as the CRC had already introduced and educated the manufacturing end of the supply chain.

At the same time, the pilot trial begun by AWTA had gained momentum and the first companies to take advantage of this service also received a report from the CRC giving more details and feedback, with test results that would help them make better use of the results. This led to requests to purchase and arrangements being finalised to lend instruments on a ‘try before you buy’ deal.

In the last three months of the Wool Program, the CRC had a successful Australian launch of the Wool ComfortMeter and Wool HandleMeter in Melbourne followed by the global launch of the Wool ComfortMeter and Wool HandleMeter technologies at the International Textile Machinery Association (ITMA) exhibition in Shanghai. The demonstrations at the ITMA exhibition were well attended and resulted in many expressions of interest.

There was, however, one hitch at the ITMA event with Nu-Cybertek approaching the organising committee with the claim that the HandleMeter infringed their Chinese patent for the PhabrOmeter. The HandleMeter had to be withdrawn from display until advice from a Chinese patent attorney confirmed that the HandleMeter was sufficiently different to the PhabrOmeter and did not infringe the claims of the patent. All ended well — but it was a setback at the time.

2013

COMMERCIAL TESTING UNDERWAY FOR WOOL COMFORTMETER AND HANDLEMETER

The next-to-skin wool knitwear trade was all set to be revolutionised by the two groundbreaking new fabric testing devices, the Wool ComfortMeter and Wool HandleMeter, which were available for the first time for commercial use through the Australian Wool Testing Authority (AWTA).

Used together these devices allowed manufacturers and retailers to produce and market greatly improved next-to-skin garments.

Henry Wang and David Tester with the Wool ComfortMeter in 2019.

2014

WOOL COMFORTMETER ON SALE TO GARMENT MAKERS

Blue-sky research aimed at guaranteeing the comfort of wool to the consumer is now a commercial reality, with the Australian Wool Testing Authority (AWTA) launching the Wool ComfortMeter and Wool HandleMeter.

Developed by the Sheep CRC, the technology is set to revolutionise the production and marketing of wool garments, with strong interest already received from leading fashion and sports brands, as well as wool processors and mills.

Sheep CRC Wool Program Leader David Tester demonstrates the Wool ComfortMeter at the Sheep CRC Melbourne showcase event in 2013.

The final key to acceptability of the instruments and their associated tests was the acceptance of the test methods by an accrediting body. This hurdle was overcome at the IWTO congress in South Africa in 2014 with the test methods for the Wool ComfortMeter and Wool HandleMeter both transitioned to full draft test methods. The end result of the years of hard work was two instruments that were supported by a recognised and accredited test method that allowed trading between commercial parties based on the results of the Wool ComfortMeter and Wool HandleMeter test results. Not a bad effort!

Arrangements for commercialisaton

During the initial stages of developing the ComfortMeter and HandleMeter AWI was actively engaged and very supportive. There were plans for incorporating the instruments in new promotional campaigns. AWI was also proactive in making the introductions to many of the international supply chain partners who engaged in the pre-commercial trials.

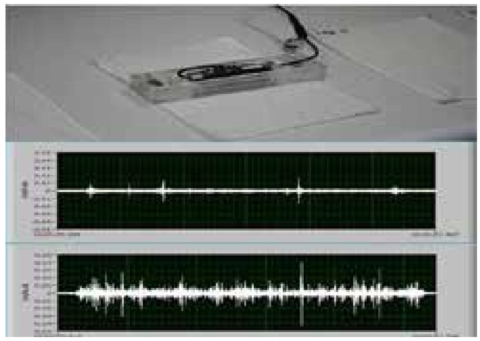
A draft plan was prepared by the CRC for commercialisation of both the Wool ComfortMeter and Wool HandleMeter, as a pair of instruments that would support promotion of both comfort and handle. However, AWI was more interested in the Wool ComfortMeter as it had an immediate role as the final specification for products in their Mothers and Babies program, and it was not prepared to commit to commercialisation of the Wool HandleMeter. The CRC Board, however, was keen to see both measurement systems commercialised together.

What followed was a breakdown in negotiations between the CRC and AWI over the commercialisation plan and an awkward period where AWI technical people would promote the Wool ComfortMeter as a game changer for the wool industry, while at the same time the AWI Executive was very negative in their appraisal of the CRC work.

The CRC then opened negotiations with the Australian Wool Testing Authority (AWTA) with a view to commercialisation of both instruments. AWTA's experience in development and marketing wool measurement equipment was seen as appropriate for commercialisation of the ComfortMeter and HandleMeter. Commercialisation plans and licensing arrangements were finalised in 2014.

DEVELOPMENT OF THE WOOL COMFORTMETER

A pictorial display of the progression of the Wool ComfortMeter from the guitar string concept prototype in 2008 to the latest version developed by AWTA on display at the Sheep CRC Final Conference in 2019.



AWTA then did an excellent job of promoting, supporting and selling the technology. Their presence and industry credibility in China helped them sell 10 instruments in Europe, Asia, and Scandinavia by early 2018. This helped to ensure that wool garments intended to be worn next to the skin were of the best quality. In 2019 AWTA released a new version of the ComfortMeter with significant improvements to the design of the guitar string detector head and a sophisticated new user interface with touch screen.

Quality science underpins commercial innovation

With most of the research complete, the CRC approached two major international textile research journals, the *Journal of the Textile Institute* (JTI) and the *Textile Research Journal* (TRJ). They both agreed to publish special editions comprising solely of papers from the CRC Wool program. The JTI special edition was published in March 2013 and the TRJ special edition in February 2015. Xungai Wang, of Deakin University, helped oversee the review and publication of the CRC papers.

These scientific publications highlight the advances made to the understanding of wool knitwear comfort, handle and whiteness and document the meticulous research underpinning the technical innovations.

Prior to the CRC's research, attempts to produce prickle-free knitwear had been directed at reducing the percentage of fibres coarser than 30 µm. CRC research showed that much finer fibres — even those finer than 20 µm — were capable of triggering the prickle response if the free length of fibres protruding above the fabric surface were sufficiently short. The CRC's results showed mean fibre diameter to be the best predictor of the incidence of prickle response and that neither the incidence of coarse fibres, nor the coefficient of variation of fibre diameter, were significant factors.

Another important finding was that prickle response continued to decline as the mean fibre diameter went from 21 to 13 µm. Fabrics made from ultrafine wool (13.8–15 µm) were shown to be close to the limits of even the most sensitive wearer's ability to detect any prickle sensation. It was also significant that the Wool ComfortMeter provided a more accurate prediction of fabric-evoked prickle response of pure wool fabrics than mean fibre diameter (see Figure 9.2).

The scale of the wearer trials and accuracy of ComfortMeter measurements produced some clear and practical guidelines for companies manufacturing or retailing next-to-skin knitwear. Garments with a ComfortMeter measurement of below 300 would be acceptable to more

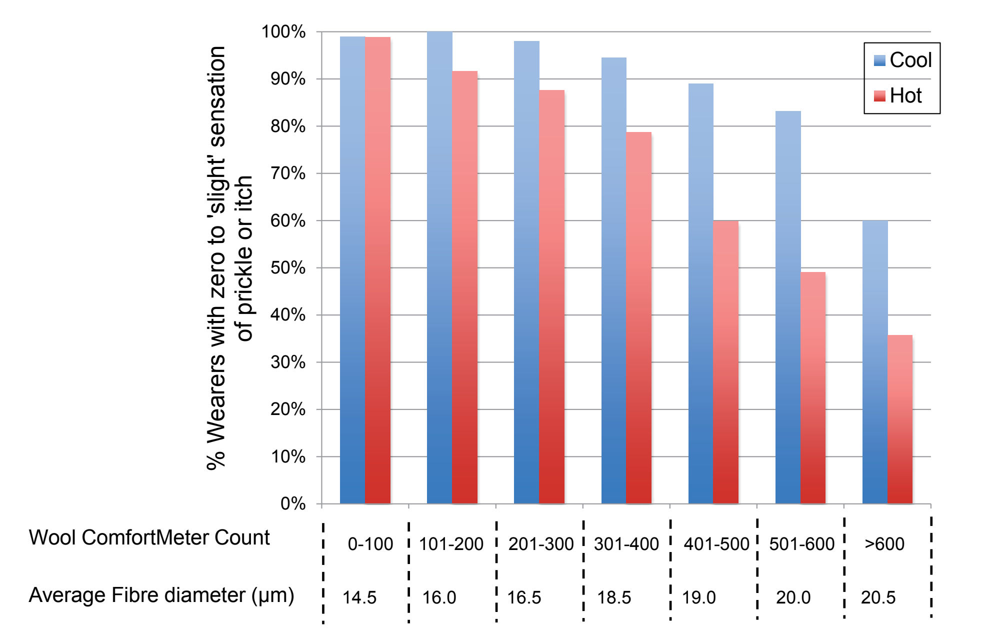


Figure 9.2: Summary of the effect of wool diameter on percentage of wearers that find next-to-skin wool knitwear free of prickle and itch under different conditions: 'cool' (19° and passive office activities) or 'hot' (40° and walking on a treadmill). Also shown are results of Wool ComfortMeter measurements, where the higher the count of protruding fibres, the more likely it is for a wearer to feel a prickle or itch sensation.

than 80% of the consumers and garments with measurements above 600 could only expect 20% of consumer satisfaction.

Les Targ and Philip Attard

The wearer evaluations showed that garments made using finer diameter wool were associated with preferred consumer assessment of fabric comfort with respect to sweaty and clingy sensations. Further papers documented fabric, yarn and fibre properties associated with improved comfort properties that can be used by the textile industries.

The research also defined the importance for consumers of handle, measured as eight fabric tactile properties by the HandleMeter. Two papers reported how these parameters, usually assessed by experts, could be measured for lightweight knitted fabrics using the new instruments. Two further papers concluded that these tactile properties were not related to prickle discomfort perceived by wearing next-to-skin wool garments.

As wearer trials were expensive to run, several papers investigated a simple sleeve test worn during exercise to quantify skin feel.

The results showed that the rapid evaluation of fabrics using sleeve trials could provide cost-effective ranking of consumer preferences. Another rapid assessment method was investigated involving measurement of yarn prickle prior to knitting, to avoid the cost of knitting fabrics for next-to-skin garments with yarn that was not fit for purpose.

Papers on the whiteness of raw Merino wool reported the effects of trace minerals and provided details of genetic variation in wool whiteness and photostability.

FIND OUT MORE

The Sheep CRC's wool research program interacted with research conducted in a number of fields, including:

- Chapter 4 — Introduction of Genomic Technologies
- Chapter 6 — Precision Sheep Production
- Chapter 11 — Implementing Innovation

10 EDUCATION FOR AN INDUSTRY WITH GROWING POTENTIAL

If the Sheep CRC was to have a long-lasting influence, it needed to think beyond its R&D extension and communications programs. So, the CRC aimed high, setting a goal of empowering a generation of young farmers and researchers through education programs to ensure the transformation of the sheep industry continued well into the future.

Investing in education as an agent of change wasn't a new idea. Prior to the commencement of the Sheep Industry CRC in July 2001, the CRC for Premium Quality Wool (Wool CRC) had a significant education program targeting a range of wool-focussed educational opportunities for undergraduate students.

The Wool CRC initiated an innovative process of delivering lectures across multiple campuses using video conferencing. This proved to be effective but was very expensive in terms of the resources required, and the re-use of video-taped lectures proved to be an unpopular option amongst students. The main teaching resource remaining as a legacy at the end of the Wool CRC was the 'Woolwise' collection of power-point slides with attached notes. This resource continues to be used by a small number of universities and remains a resource for experts and lecturers, rather than a self-directed study option for students.

As part of this process four lecturers had been employed, however at the termination of the Wool CRC none of these positions were retained at any of the universities. The main reason for this was the low numbers of students specialising in wool. This was the first among many challenges facing the Sheep CRC's education program.

The industry was also grappling with an ageing workforce, not just among the farmer population, but the network of ag industry professionals who provided research and advice. Australian universities were only turning out 800 agricultural graduates each year for an industry estimated to need 2,000 new employees annually. There were 50% of agricultural industry professionals approaching retirement age and this loss of knowledge needed to be filled. The problem wasn't limited to undergraduate enrolments — a 2004 report by Taylor Nelson Sofres Plc found that industry would need to find 222 new postgraduates in the period from 2004–2009. With the relatively depressed state of the wool and sheepmeat industries during the 1980s and 1990s the sheep industry was not well placed to compete with other agricultural industries for this declining pool of graduates.

For many years there had been no formal programs to support and encourage postgraduate research students into the sheep industry, and there was a shortage of highly trained research and extension personnel with expertise in the sheep industry. This shortage was emphasised to the Sheep CRC when seeking to fill positions for research scientists, post-doctoral fellows and specialist technical staff. During the recruitment process, numbers of applicants were well below expectation with very few having skills and experience in the appropriate field. There was clearly a need to develop education and training opportunities linked to good career prospects — specifically for the sheep industry.

Developing the Sheep CRC Education Program

From the outset, the Sheep CRC took a broad approach with research, education and training programs, targeting both the meat and wool industries. There was also recognition of the need for engagement at the school, vocational education and training (VET), undergraduate and postgraduate levels.

Planning the education and training program was made more difficult by withdrawal of Australian Wool Innovation (AWI) support at the start of the CRC – it took time to develop a well-funded united industry approach to building a skilled sheep industry workforce. In the end though, AWI, Meat & Livestock Australia (MLA), the Australian Wool Education Trust (AWET) and the Sheep CRC collaborated closely to develop a comprehensive education program.

After commencement of the CRC, AWET commissioned Sas Douglas to review gaps in the wool education system, particularly in light of the closure of the UNSW Wool and Pastoral Science degree. Sas was instrumental in aligning the AWET and CRC planning processes and in setting up joint funding for a Chair in sheep and wool production to provide leadership in developing an integrated education and training program. The new position was located at the University of New England (UNE) and David Cottle was appointed to coordinate undergraduate, VET and school programs.

Responsibility for coordinating the postgraduate program was entrusted to Graham Gardner at Murdoch University. Graham had started to develop a very successful postgraduate program with the Beef CRC and quickly integrated aspects of the two programs via a joint annual postgraduate conference.

Evolution of the 'hub and spoke model'

With the demise of the undergraduate degree in Wool and Pastoral Science provided by the University of NSW, there was no university-level specialisation for students planning to enter the sheep and wool industry. The aim was to fill this significant gap and provide high-quality education resources for use throughout Australia.

Even though no university in Australia provided a full range of specialist courses in wool or sheepmeat production, science or marketing, UNE did offer full semester units on wool and meat production, and wool and meat marketing. Other universities offered a limited range of sheep and wool units — e.g. University of Adelaide had a single wool unit that covered a wide range of topics in restricted depth under the direction of Phil Hynd. La Trobe University offered wool growing and lamb production as one case study out of six in one final-year subject.

So, a different model was created for development and delivery of educational material nationally to universities. The aim of the CRC's undergraduate program was to:

- Coordinate the development and delivery of resource materials for 220 undergraduate lecture topics in sheep and wool science during the first term of the Sheep CRC;
- Coordinate undergraduate teaching of sheep and wool units at UNE with national delivery and via external mode;
- Negotiate and facilitate use of CRC teaching materials by other universities and other organisations throughout Australia;
- Provide a program of undergraduate and honours scholarships to encourage students into postgraduate study in the sheep and wool industry.

Over the years, many of the universities offering agriculture-based degrees incorporated the CRC units into their course programs. This national delivery was made possible by using a format for units including detailed notes, CD ROM and WebCT delivery combined with three- to four-day residential schools. There was very close collaboration between the CRC and AWI in developing this program via co-funding, joint participation in the Education and Training Advisory Committee and strategic planning.

The Sheep CRC also worked closely with AWI to provide a coordinated approach to the provision of undergraduate scholarships. The CRC participated in the allocation process for all AWI undergraduate scholarships. It was anticipated that about 50–80% of AWI undergraduate scholarship holders would be placed in CRC core or supporting party universities.

The degree units that were developed comprised a number of smaller sub-units that could be studied for certificates and diplomas. This opened up the opportunity for many producers and industry workers to study the material externally.

David Cottle

The 'hub and spoke model' was also implemented for the Vocational and Industry Training Resources Program. Led by Michael Bourke (NSW Department of Agriculture) and Tony Hamilton (Department of Primary Industries, Qld) the program created and disseminated new resources in sheepmeat and wool education based on national competencies for the vocational and industry sectors, and developed and maintained an improved communication network among sheepmeat and wool VET stakeholders nationally.

Vocational training provided by private organisations, such as RIST, AusGro etc., in wool and sheep management mainly targeted wool classers, shed hands and producers. The vocational material at hand at the time tended to be traditional and in urgent need of updating. New VET resource material was developed in a range of areas including wool handling, breeding ewe management and on-farm fibre measurement (OFFM). The Sheep Production Guides and Lamb Production Guides of NSW Agriculture and MLA publications were modified to integrate with the competency-based system, made more interactive, and were customised for each state for national distribution. The CRC also collaborated with the Rural Training Council of Australia to update their sheep and wool-learning guides as appropriate. Following a scoping study funded by AWI, it was expected VET resource material would be developed and added to the knowledge warehouse for wider distribution.

The final piece to the 'hub and spoke delivery model' was offering school-age students from both rural and city areas the opportunity to participate in residential schools at UNE. These included demonstrations in the use of modern technology in the sheep industry and access to experts. Undergraduate scholarships, co-funded by industry, were publicised and made available to high performing students with leadership potential. VET material was re-written to appeal to a school audience. The CRC collaborated with AWI to develop school resource kits and work with other groups, such as Sustainable International, to ensure greater participation and publicity.

FROM HIGH SCHOOL TO AG DEGREE

For Ellie Noon, the opportunity to learn through a rural placement scholarship not only confirmed her ambition to pursue a career in the sheep industry but opened her mind to the potential gains genetic research offers. Ellie, from Armidale, NSW, was one of the first students to be offered a Sheep CRC-sponsored UNE PICSE Industry Placement Scholarship and as a result was able to pursue her interest in research in sheep genetics through a Rural Science degree at UNE.

The partnership between the Sheep CRC and UNE Primary Industries Centre for Science Education (PICSE) was designed to encourage students to enter a career in rural science and the sheep industry. One of the core activities of the PICSE program was its Industry Placement Scholarship offered to selected tertiary bound motivated school leavers. The scholarship consisted of a one week residential camp, involving one week of industry placement where students worked as a scientist alongside researchers, culminating in a report on the experience and a scholarship cheque for $300.

In 2011, they supported 24 students from across Australia to commence their careers with a student camp at UNE, followed by placements with researchers in Armidale, Tamworth, Walcha, Inverell, Guyra and Breeza. Her experience allowed her to work out that she wanted to move into a science-based career in agriculture as opposed to working in the business of agriculture. Ms Noon's industry placement was hosted by Sheep CRC and UNE Associate Lewis Kahn who guided and supported her project on the relationship between breech cover and wrinkle with the resistance and resilience to gastrointestinal worms in Merino ewes.

"This placement showed me that over time and with further research there may be a genetic approach to make it easier to manage Merino sheep for flystrike," she said in 2011. "I feel the industry is on the edge of some exciting new discoveries which will improve animal welfare. Since doing my industry placement I now have a much clearer future pathway in mind and an interest in research, as I want to help improve agriculture and help production to be done more efficiently and effectively."

Coursework for undergraduates and graduate certificates

With the demand for specialist training in all aspects of sheep and wool production being too low for any university to justify the cost of employing specialist staff teaching small groups, a new approach was required. Sas Douglas's review of undergraduate course materials resulted in a new strategy for providing detailed undergraduate education covering all aspects of the wool pipeline, from production, to processing, metrology and marketing. The proposal by AWET was to develop a model whereby high-quality teaching material, developed with input from all universities and industry specialists, could be delivered nationally via a distance education model. AWET and the Sheep CRC agreed to combine resources in order to develop the model. Overseeing the delivery of this activity was David Cottle's position at UNE, co-funded by AWET and the CRC.

The team also conducted a full review of the Australian education and training landscape for sheep and wool production and processing. A separate survey involved a wide range of employers of agricultural graduates to determine the attributes most highly valued when employing staff with university or vocational training.

With the background research completed, the work commenced on developing 10 courses for national delivery. This involved preparation of 220 undergraduate lecture topics with input from a range of specialists including university academics, researchers and industry specialists. The format for lectures was carefully designed to meet uniform standards and a structure was designed to achieve clear learning outcomes. Initially produced as hard copy books – one for each course – the material was also available electronically and, as internet speeds developed, the delivery mechanism moved from print to online.

Uptake of the new courses

To attract enrolments in the units that were offered online and via distance education through UNE and AWET, the CRC set up a number of undergraduate cooperative scholarships for students to study sheep and wool education. Initially, the one-year scholarships required students to undertake at least four of the new courses in a single year of study. The scholarships were provided by a range of industry sponsors with support from AWET and became the mainstay of the promotional program.

Subsequently, following a report in 2006 by Bob Richardson commissioned by AWET, and after consulting with wool academics from the universities participating in the 'hub and spoke model', AWET decided to fund up to 15 honours scholarships per year, each worth $6,000, for students specialising in sheep and wool. The name of these scholarships was later changed to 'undergraduate project scholarships' in recognition of the different structures of four-year degrees at different universities. In 2019, the value of these scholarships was $7,000, with the funding split by agreement between the student and the university to cover project costs.

A second dimension to consider was the university funding model. In his report Bob noted that loss of funding of about $2,500 per student unit discouraged the transfer of students to UNE. To encourage enrolments in the courses from students studying at universities other than UNE, AWET paid those universities $1,000 per student for the first 10 students and $1,200 for each additional student as compensation for their loss of income when students enrolled externally in the sheep and wool units delivered by UNE. From 2016 the subsidy was $1,000/student/unit for the first 10 students rising to $1,500/student/unit per institution once student enrolments exceeded 10.

In 2006, the Trust decided to provide additional funding to UNE to support the employment of a junior lecturer, with Emma Doyle appointed in 2007.

In 2007, towards the end of the first CRC, arrangements were made to assign the IP and related materials for the new courses to AWET on the understanding that they would continue to support the delivery and update of these units via a licence agreement with a selected university, namely UNE. The long-term success of this program has been remarkable. AWET has continued to support the initiative and Table 10.1 summarises the average number of students enrolled in each course per year, between 2007 and 2017. Between 2007 and 2017 $3.24 million was invested in the delivery of wool and sheep modules, with further investment in upgrading and maintaining the teaching resources. This commitment to specialist education in the area of wool and sheep production made an invaluable contribution to the maintenance of skills and knowledge required for the successful progression of the Australian sheep and wool industries.

Emma Doyle and Peter Sommerville

Table 10.1: Average number of students enrolled in each course per year. Note: The tenth unit developed as part of the CRC-AWET initiative 'sustainable land management' was discontinued.

Course title	Average no. of students enrolled per year (2007 - 2017)
Sheep Production	48
Wool Biology and Measurement	12
Wool Marketing	15
Wool Processing	11
Fundamentals of Sheep & Wool	27
Applied Animal Nutrition	44
Meat Technology	23
Genetic Evaluation and Breeding	10
Managing Sheep Enterprises	16

Vocational Education and school-aged training

During CRC1 several new vocational training resources were developed, principally covering three main topics:

- Trainer guide for Merino sheep breeding;
- Internal parasite management (industry short course);
- Grazing management guide.

These courses were widely adopted in the TAFE and agricultural high school programs, as well as being used for industry short courses delivered by TAFE trainers.

The CRC also worked with the Armidale Rotary Club to develop a 'Youth in Agriculture' course focussing on the sheep industry. Rotary ran a number of camps for Year 10 students exposing them to different aspects of agriculture through a range of hands-on practical experiences and farm visits. The Sheep Production program proved to be very popular and was extended beyond the Armidale district, drawing in students from many rural regions.

The CRC used information from several sheep and lamb production guides originally prepared by NSW DPI and MLA. The core information provided in these publications — known as the schools to industry links pack was modified to integrate with the competency-based system and made more interactive using computer and web-based systems. The work also involved expanding the materials developed for individual states to make it suitable for national distribution. The CRC's vocational and industry training resources program was led by Michael Burke, NSW Department of Agriculture and Tony Hamilton, Department of Primary Industries, Queensland. Overall coordination of this program was provided by Michael Williams of TAFE NSW.

A Careers Information Toolkit was also developed to be used by secondary teachers and careers advisors to provide information about careers in the sheep and wool industry to high-school students interested in a career in the industry. The resource also provided activities to be undertaken by the students so that they could learn more about the careers available. These materials were transferred to AWET and are available on the Trust's website: www.woolwise.com.

STUDENTS DRIVE FARRER HIGH TO THE TOP OF RAMSELECT

The development of new technologies created a wave of excitement among young people interested in pursuing careers in agriculture.

Farrer Memorial Agricultural students Angus Wolfgang Wicks, Tim Mitchell and Lachlan Finlay take blood samples for DNA testing of their stud White Suffolk flock.

Listing their school's stud sale catalogue via the RamSelect Plus app in 2016 showcased to students at Farrer Memorial Agricultural High School, Tamworth, NSW, the value of early adoption of new breeding technologies by opening new markets for their rams.

The school's agriculture subject offering included a Year 9 and 10 'animal management course' in which students take on the tasks associated with running the Farrer White Suffolk stud.

In delivering the course, Stud Manager Darren Smith introduced the students to the latest in flock management and breeding technologies, including the use of Australian Sheep Breeding Values (ASBVs), DNA testing, optimising joining decisions using MateSel and now marketing via the RamSelect Plus app.

The result of this early-adoption strategy were rams ranked at the very top of the White Suffolk breed for the new Lamb Eating Quality index (LEQ).

"We've been focussed on high performance genetics and the use of measurement ever since we started back in 1984," Darren said. "We're trying to incorporate as much technology as we can in the program, be that artificial insemination, embryo transfer, Superwhites, DNA testing, eID or the RamSelect app — we will use all of the programs we possibly can to enhance the stud and the learning of the students.

"I keep looking out for the next thing to introduce because the students are pretty quick at picking up on new technology and putting it to use."

Farrer was among the earliest and most active adopters of new technologies developed by the CRC. During 2016 all 130 of its mature stud ewes, as well as the following year's 60 replacement ewes, were DNA tested to identify those carrying superior genetics for 'the traits you can't see' such as intramuscular fat and shear-force, which determine the eating quality of lamb carcases.

Graduate Certificate course for agricultural consultants

When planning the second Sheep CRC it was clear that more focus needed to be placed on industry training in order to ensure that innovation was adopted by the industry. One of the changes occurring in all State Departments of Agriculture was a decrease in resources allocated to extension programs. The traditional route for delivery of research outputs via State Department extension services was therefore no longer a viable option for research programs to rely on to achieve adoption and impact.

The CRC undertook market research to determine the demand for commercial advisory services in the sheep industry and to determine the training needs of advisors and consultants in this sector. The next step was to convene a workshop with experienced industry consultants to define the type of training required for an effective industry consultant and to determine the content of such a program. This workshop included the likes of David Sackett, Bob Hall, Mike Stevens and Jim Shovelton.

The CRC then contracted a number of consultants to develop the resource material. This process was initially coordinated by Steve Walkden-Brown and then taken over by John Goopy before being coordinated by Lu Hogan and Deborah Maxwell. Two new full-semester courses were designed and developed, one focussing on business-related skills for the agricultural consultant and the second, focussed on client-oriented skills required for providing effective advice. Details of these two courses are summarised below.

The Graduate Certificate in Agricultural Consulting was designed for delivery through UNE as part of their formal Graduate Certificate program. Requirements for the certificate included completion of the two specialist consulting units and a further two units that could be selected from offerings at any university around Australia, provided that the content was relevant to the agricultural interests of the consultant.

Deb Maxwell, Steve Walkden-Brown and Lu Hogan

The Graduate Certificate was first offered in September 2009 and by 2012 there had been 117 enrolments.

At the end of the second CRC in 2014, UNE took on the responsibility for ongoing promotion and delivery of the Graduate Certificate. This continued successfully for several years until in 2016 the decision was made to consolidate both units into a single course in order to increase the number of students taught in any cohort group.

TWO NEW UNITS FOR AGRICULTURAL CONSULTANTS

Business related skills for the agricultural consultant (CSLT501)

This unit was designed to help consultants set up and run an advisory business.

Critical thinking and Analysis in Problem Solving

- Decision making through analysis and strategic thinking
- Problem diagnosis, analysis, choice and implementation
- Practical application

Media and Marketing

- Marketing the Business
- Media Relations

Legal Issues

- Issues for clients
- Duty of Care & Ethics
- Professional Development

Client oriented skills for the agricultural consultant (CSLT502)

This unit was designed to develop skills required to be an effective agricultural consultant based on the experience of a number of Australia's leading farm management advisors.

Whole of Enterprise Planning

- Farm plan, Resources
- Enterprise Analysis
- Benchmarking
- Strategic Resource Allocation
- Introduction to Succession Planning

Communication

- One-to-one conversation
- Facilitation
- Negotiation (peers, community and government personnel)
- Dispute resolution

ANTHONY SHEPHERD, CONSULTANT, SHEEP MATTERS, MOLONG, NSW

As a self-employed consultant providing an advisory service to the sheep and wool industry, Anthony Shepherd (right) embraced the opportunity to improve his skills and return to study some 20 years after first graduating from university.

"I saw this course as an opportunity for me and for my clients and I found the course to be of value in relating aspects of the units I have studied to real life situations," Anthony said at the time.

He said the knowledge gained helped him to become more critical of his own business and of how to apply knowledge to his clients' businesses.

"I am using aspects of the Sustainable Land Management unit with clients, in particular establishment of drought lots and more sustainable grazing practices," he said. "The Animal Nutrition unit has given me a greater respect for the rumen, and how we can benefit the sheep long term by looking at the rumen as the factory of the sheep".

DEBBIE MILNE, SHEEP PRODUCER/CONSULTANT, BRANXHOLME, VIC.

Combining university study with part-time work and running a successful sheep stud is a demanding task, but the new skills acquired paid dividends for western Victorian producer Debbie Milne (right).

She completed the Graduate Certificate in Agriculture (Agricultural Consultancy), before setting up her own consulting company, focussing on sheep management.

"I think there is a big gap in the market for services in agriculture and there are real opportunities for graduates in many areas of agricultural consulting," she said in 2011. "Farmers have access to so much technology, but they often need a hand getting set up to make the most of the management systems and information that is available.

"I hope to be working with sheep producers in areas such as electronic identification systems, data management, LAMBPLAN and MERINOSELECT and helping them maximise profitability."

Debbie owned and operated Waratah Whites White Suffolk stud with her husband Steve near Hamilton, Victoria and said the online and distance courses made further study possible within her busy lifestyle.

"While I have the industry experience, the extra study was very useful in teaching me the formal processes involved in assessing a client's business and strategic planning, as well as skills in communication, facilitation and negotiation, amongst many other topics," she said. "I think it's important to keep learning and improving, and it's never too late to take on further study".

Industry Training Programs

As detailed in the previous chapter, the CRC's industry training programs were highly impactful and received numerous awards for the positive change they made to the industry.

During 2008 a revised Industry Training Plan for the Sheep CRC was developed, identifying a number of priority training areas for producers and farm advisers: Genetic technologies training for Merino stud breeders and commercial producers; Integrated breeding and management solutions to address reproductive performance, weaner performance, flystrike risk, internal parasites, and precision sheep management; and skills development for sheep industry service providers including consultants, contractors and students forming the next generation of service providers.

Skills development was regarded as one of the keys to achieving successful utilization of new technology and practice change. In financial year 2010–11 the CRC coordinated the delivery of 33,058 hours of training to 4,400 individuals. Evaluation of these courses indicated that they were well structured, professionally delivered and useful to those attending. The training of industry consultants continued via the Graduate Certificate in Rural Science course delivered via UNE's distance education program. This training program was an important step towards developing a cohort of agricultural consultants to fill the gap, as traditional extension services were gradually withdrawn by various State Governments.

During 2011–12, all Sheep CRC programs continued to place significant emphasis on the delivery of new skills and knowledge to sheep producers, their advisors and service providers. The Sheep CRC successfully delivered training to industry in the following areas:

- Skills in agricultural consulting through the Graduate Certificate in Agriculture (Agricultural Consulting);
- Professional development for young and emerging advisors and consultants in the sheep industry;
- Improved reproductive performance through Lifetime Ewe Management, High Performance Weaner and Managing Scanned Ewes workshops, and
- Flystrike management and breeding to reduce the risk of flystrike.

2008

COUNTING THE TRAINING HOURS

More than 20,000 individual hours of training (training time x participants) were delivered across the Sheep CRC that year alone, with some 8,000 hours delivered by the Industry Training Project and the balance by the research programs with varying levels of involvement of the industry training project.

New courses in worm management and using electronic identification for breeding and management were also developed and delivered throughout the year.

In 2017–2018 it was recognised that the CRC's education and training programs had evolved significantly over the previous two to three years. With increasing sophistication and use of web-based apps developed by the CRC there was a transition from expensive training programs, designed to help producers and breeders to undertake difficult tasks, to the development of web-based apps that helped make these tasks much more intuitive and widely used. The training conducted by the CRC focussed on skills development for service providers and consultants to act as the retail support group for use of CRC products and apps.

These training activities were targeted at consultants, livestock agents and producer groups. Wherever possible the CRC used Zoom video conferencing for group and individual training programs. While this approach was cost-effective and recognised for its flexibility by all participants, there was also effective use of 'kitchen table' discussions to provide training and support for major farm decisions such as investment in genomic technologies. This was particularly effective in the development and uptake of the DNA Flock Profile test. Working directly with several producer groups, the CRC co-funded the use of genomic testing and provided group and one-on-one feedback sessions as a key component to assist producers interpret results and change practices.

Postgraduate Education

Postgraduate training was an essential requirement of the Commonwealth CRC Program. Although the primary aim was to prepare the next generation of researchers and academics to support long term industry innovation, there were also significant benefits through students contributing to all CRC research activities.

The challenge was: How does the CRC compete for top-quality intellects, and then retain them within the sheep and agriculture industries?

The solution started with lucrative scholarships. Throughout its term the CRC financed 81 PhD students researching a range of topics. AWET also funded six PhD students and four teaching fellowships, although, because of the high costs AWET discontinued this funding in 2011. These scholarships were targeted at the very top-end of the industry-based stipends available to higher degree students, ultimately enabling the CRC to attract students that already had established careers and incomes. For example, Andrew Kennedy, David Brown and Mark Ferguson were all high performing professionals working in consultancies or state departments of agriculture when they undertook their PhDs.

Within their applications, the CRC also assessed their experience and connection to the sheep industry and their expressed future career intent, with preference given to those with some rural background and professional sheep industry experience. Lastly, all projects had to be completely aligned to key Sheep CRC research projects. This ensured that the output of all students was focussed on research of value to the CRC, but more importantly was relevant to the sheep industry. By definition, this was hardwired by the industry alignment of all CRC projects.

Over the seven-year life of CRC1, the aim was to provide 30 PhD and 10 Masters scholarships for the next generation of sheep industry professionals. After a slow start in year 1, applications picked up and 16 postgraduate students were enrolled by the end of year 2. This number was slightly behind our target of 20, but with increasing interest from prospective students it was expected to make up the shortfall during year 1. Interest was mainly in PhDs with fewer applications for Masters programs embedded in industry. End-user involvement in postgraduate training was significant, with several students conducting their studies based in industry organisations, and many supervisors coming from non-university institutions such as CSIRO and State DPIs. However, embedding of Masters students in industry proved more difficult than PhD students due to the practical difficulties in recruiting suitable candidates, and managing financial, academic and work priorities.

By 2015–2016 the CRC3 postgraduate numbers reached the target of 12 and all students were embedded within Sheep CRC project teams. The increased stipend of $40k/year helped to create interest in postgraduate study at a time when there was near full employment of agricultural graduates in industry. As of 2016–2017 there were no more rounds of scholarship offers.

As well as the scholarships, the postgraduate program, led by Graham Gardner, featured two key elements: annual professional development workshops and an annual student conference.

Although all universities have a standard training program for enrolled postgraduate students, the CRC sought to value-add to this training by running professional development workshops, focussed on topics often not covered by standard university offerings. This provided the opportunity to focus students on the efficacy of their research, its industry impact, and their ability to sell their message to industry to encourage participation in research and adoption of outcomes. The workshop topics included:

- Research design to enhance technology adoption, run by Russell Barnett;
- Research extension methodology and ways to sell your research to industry, run by David Faulkner;
- Analysis of personality types to enhance workplace collaboration, run by Hugh Wakefield;
- Communication techniques to optimise the delivery of your message to an industry audience or the media, run by Michael Thomson and Kaaren Latham of Cox Inall Communications;
- High level scientific writing skills run by David Lindsay.

2013

PhDs DELIVER FOR INDUSTRY

A graduate tracking survey of 23 Sheep CRC-sponsored postgraduates from CRCs 1 and 2 revealed over 90% were working in agriculture and 62% in the sheep industry — a major achievement against the situation outlined by the Sofres report in 2004. The majority were involved in research or academia, with smaller numbers being consultants, primary producers, or working for agri-industry. Sheep CRC2 students reported good levels of income with 67% earning over $80,000/year and 11% earning over $100,000/ year.

Maddison Corlett

2016

POSTGRADS STAR ON INTERNATIONAL STAGE

Five Murdoch University scientists were chosen to deliver oral presentations, all linked to research they were conducting through the Sheep CRC, at the International Symposium on Energy and Protein Metabolism and Nutrition in Krakow, Poland. It is highly unusual for an international conference to feature such a large representation from a single organisation — a testament to the quality of training they had received. The five researchers were: Fiona Anderson, Khama Kelman, Sarah Stewart, David Miller and Graham Gardner.

Khama Kelman

Run in conjunction with the professional development workshops, every year students were assembled and asked to present a 10-minute conference style presentation. This event was run in collaboration with the Beef CRC, MLA, APL, and AMPC, and modelled the exact format of an international conference, providing students with invaluable presentation experience. Prior to the event students submitted a one-page paper, written according to formal instructions to authors, which was compiled into a 'conference proceedings' for the meeting.

Crucial to the success of this event was the participation of a panel of top-level CRC scientists, usually numbering 7–8 individuals at each event. This panel provided extensive written and verbal critique for all students and participated in an extensive question-time following every presentation. Over the years, many students have remarked that this format was the most intensive question time that they have ever been exposed to, making their performance robust to the 'real event' at international conferences.

One of the hidden outcomes of this conference was the network that it created for students that would otherwise be working in relative isolation within their universities. This network has helped to forge collaborative links, as these students have graduated and entered the animal production research community. The collaboration between Sheep CRC-sponsored students, and those supported by MLA, AMPC and Australian Pork Ltd, provided a critical mass of students required to implement such a training conference and it is hoped that this will ensure its continued delivery following the wind-up of the CRC in 2019.

Wherever possible the CRC also looked for opportunities for students to attend and present at industry events. Over the years this has included student presentations at industry field days, as well as all students participating in a postgraduate session at the 2014 Sheep CRC conference in Adelaide. This provided students with first-hand opportunities to engage with industry, and practice selling their message at an applied level for producers.

In the final year of CRC3 a survey was completed to track the employment destination of CRC postgraduates. The results of this survey were outstanding. In the years following graduation, about 65% of former postgrads surveyed had been retained in careers directly focussed on enhancing the sheep industry. A number had gone on to pursue careers in other areas of agriculture, so when considering retention within the ag industry as a whole, the figure rose above 90%. Given the flux of professionals across the agriculture sector (i.e. as many trained agricultural professionals are likely to enter the sheep industry as are leaving it), this represented an excellent result. Similar surveys were conducted at the end of CRCs 1 and 2, with the retention rates remarkably similar throughout the history of the program.

Over the three Sheep CRCs a total of 81 students enrolled in the postgraduate training program, with the costs of stipends and the annual Postgraduate Conference estimated to be \$7.12 million. The return on this investment could be quantified by the contribution of these professionals back to industry following graduation. Graduates were asked what portion of their professional time since graduation had been spent focussed on the sheep industry. When this was applied to the number of years since graduation, the cumulative total was equal to 194 years of total work. This figure will continue to grow over time as their careers mature, representing a legacy of ongoing impact to industry from the Sheep CRC's investment in education.

Annual workshops an intense challenge for postgrads

The annual postgraduate training workshop rotated its content over a three-year cycle to ensure the young scientists were able to apply their research findings in real world situations, including how to communicate their work to industry and to the media.

The two-day intensive communications training led by Cox Inall Communications' Kaaren Latham and Michael Thomson (and later with CQUniversity) was designed to arm researchers with the knack of translating complicated science into everyday language. This was considered a vital component of the professional development of a researcher as it emphasised the importance of dealing with livestock producers and industry partners, and therefore ensuring high-quality science research was grounded in the real world.

Postgraduate conference group photo from 2016.

As well as receiving media and social media training to support better engagement with the public, students also received training from an academic panel who judged written, oral and poster presentations. While many students found the week-long training programs challenging and at times confronting, the breadth of knowledge gained and the willingness of trainers to push students to excel was well received by the PhD researchers.

In 2017 Murdoch University's Rachel O'Reilly was awarded best presentation by the academic panel, after demonstrating her research into Chinese consumer responses to quality indicators of sheepmeat.

"The postgraduate training conference was a unique opportunity to learn from the expert panel, improve my research communication skills, and build networks with the next generation of agricultural researchers. It has been a fantastic learning experience and I am very thankful I was given the opportunity to participate," she said.

The same year Claire Payne, also of Murdoch University, was awarded the prize for best poster presentation by a first-year PhD researcher. Her project is also focussed on eating quality of sheepmeat and will use new DEXA technology to assess bone mineralisation in sheep carcases to give a prediction of age.

"The postgraduate conference has been a fantastic opportunity to meet other students and broaden my knowledge of other agriculture research topics. Receiving feedback from leading researchers and possible future employers is an invaluable opportunity and I feel incredibly grateful for the time taken to help us hone our research skills."

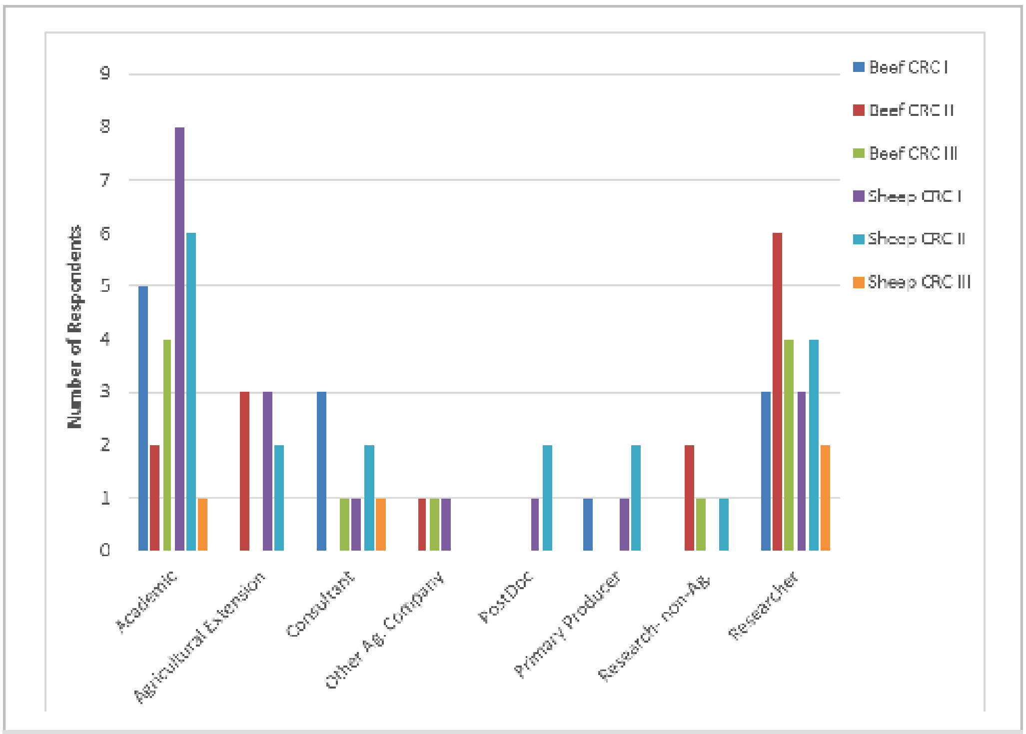


Figure 10.2: Numbers of postgraduate students working in different professions at the time of the April 2019 graduate tracking survey.

FROM PhD STUDENT TO PhD SUPERVISOR

Fiona Anderson

Fiona Anderson witnessed the value of the Sheep CRC postgraduate training program from both sides of the fence, as both a sponsored student and later as an academic supervisor to students following in her footsteps.

Fiona commenced her CRC-sponsored PhD in July 2010, focussing on measuring carcase composition in lambs using computerised tomography (CT). Her research produced important new information on factors determining lean meat yield, and the distribution of muscle, fat and bone throughout the lamb carcase.

"The extensive data available from CT scans of around 2,000 carcases allowed me to very accurately determine factors associated with variation of muscle and fat composition in the carcase," she said upon graduation in 2015. "The results from the progeny of a diverse range of sires were then compared back to the Australian Sheep Breeding Values, or ASBVs, of the parents."

From her research, Fiona ascertained that sires with high breeding values for post-weaning eye muscle depth and reduced C-site fat depths were more likely to produce lambs with higher lean meat yield. This had financial implications for the changes in carcase composition — for example, progeny from high muscling sires can have a carcase worth more than $20 more than those from low muscling sires.

After completing her PhD, Fiona went on to become a lecturer in physiology at Murdoch University, teaching courses in the Veterinary and Animal Science degree programs and continuing her research in the area of meat science with Graham Gardner and David Pethick. Through this ongoing association with the CRC's meat research program, Fiona and Khama Kelman — another CRC-program graduate working at Murdoch University — later supervised Steve Connaughton's PhD research into the calibration of the game-changing DEXA system.

FIND OUT MORE

Postgraduate researchers supported nearly every facet of the Sheep CRC's research activities. For more information and specific examples of PhD projects, go to:

- Chapter 3 — Integrating Wool and Sheepmeat Production
- Chapter 4 — Introduction of Genomic Technologies
- Chapter 5 — Managing Sheep Parasites
- Chapter 6 — Transforming Sheep Wellbeing
- Chapter 7 — Precision Sheep Management
- Chapter 8 — Quality Sheepmeat
- Chapter 9 — Measuring the Magic of Wool
- Chapter 11 — Implementing Innovation

11 IMPLEMENTING INNOVATION

An important component of the CRC's activities through each phase of the program was to ensure that the industry obtained maximum benefit from existing and new knowledge.

The ability of the CRC to make an effective contribution to achieve this goal was due to the cooperative nature of the CRC and the shared focus of both industry and researchers to change the industry for the better. This joint approach helped to utilise resources developed by various state departments and training organisations to provide simplified consensus-based information for a number of complex management decisions. This practical information was delivered to industry using a range of techniques, from tried and tested field days and fact sheets, through to the social media channels which took hold in our communities during CRC2 and the use of apps developed in CRC3.

Translating science to make the possible practical

Before the headlines were printed trumpeting CRC scientific breakthroughs and new tools for producers and processors, some aspects would get lost in translation.

Quite a few things actually…and quite deliberately.

Take for example the phrase 'single nucleotide polymorphisms' — a favourite topic for Julius van der Werf, but a set of words that confounded the ordinary producer. At the other end of the spectrum, there was Dave Pethick, whose language was littered with the types of colourful phrases more commonly heard in the saleyards.

Communicating the work of the Sheep CRC team was firstly about working as a translator to capture the essence of the science in easier-to-understand language, and secondly (although just as important) explaining how that knowledge would be useful to producers and industry.

The starting point for translating the research information was nearly always, 'What does this mean to the end-user?' This was made much easier by the fact that the CRC's research was so focussed on industry needs and always designed with input from the end-users. With such a range of Participants at the table, it was never too hard to define the value proposition for promotion or to identify a producer to testify to the benefits on offer.

At the outset it was Wendy McLeish of the Qld Department of Primary Industries who assisted the CRC with its communications, logo development and branding strategy. Wendy did an outstanding job in designing the CRC's first promotional material on the individual animal management initiative, as well as doing the first two annual reports. When Wendy was no longer available to assist the CRC in this role, Deborah Maxwell took on the role of coordinating the media releases and was assisted by Heidi Hoffman in managing the newsletters and the CRC's webpage.

The work done by Graeme Wright to develop and manage the website — through its various iterations and archiving processes — was highly professional. By 2019 the CRC website was receiving more than 3,000 visitors and over 7,000 pages views each month.

Janelle Holzberger and Rhonda Brooks played less visible but equally important roles behind the scenes in organising events, desktop publishing Practical Wisdom notes, designing and updating multiple websites, managing databases of key contacts, and distributing newsletters and e-bulletins. Rhonda, who joined the CRC in 2007 to assist with the bookkeeping and accounting functions, had experience in design which allowed her to contribute extensively to the CRC's promotional publications, technical reports, the annual report and the management of our website.

At the start of CRC2 a decision was made to engage a specialist communications consultant and John Lamont was contracted to help develop this aspect of the CRC's portfolio. Following some initial planning, John was no longer able to assist and the CRC approached David Dawson of Cox Inall Communications to join the team to develop and deliver the communications strategy. When David left Cox Inall in 2010, Michael Thomson took over the position and played a significant role in the CRC's successful communications program until the very end.

While CEO James Rowe was the media figurehead of the CRC, Lu Hogan was often the public face of the CRC on the ground, working with producers in her capacity as Program Leader for Industry Engagement and Training. Lu's knowledge of grassroots producers and their needs was critical to turning public interest in programs like RamSelect into practice change through in-field workshops and training days. Similarly, Lewis Kahn and Deborah Maxwell drove adoption of ParaBoss from the ground up.

The decision to engage specialist communications consultants opened the path to new ways of getting the news out there, over and above the traditional method of pursuing coverage in the rural and regional media. Over time, methods became more sophisticated, although Michael Thomson — who led the communications program from 2010–2019 through both Cox Inall Communications and later through CQUniversity — recalled a look of nervous reticence he received when he first met James Rowe and Graham Truscott at the CRC's head office in Armidale. The 'ring in' from Rockhampton ('what could he possibly know about sheep?' they thought) boldly suggested that the sheep industry's 'innovation' body should open Facebook and Twitter accounts. It took a while, but once convinced that it wasn't a good look for an innovation centre to not be using the most modern communications tools, the team was all in. James Rowe even convinced the Executive Committee to undertake social media training, where Dave Pethick was excited by the fact that he could keep a closer eye on his children by joining Facebook. By the end of the CRC approximately 11,000 people were following the Sheep CRC on Facebook, and 3,300 were following its updates via Twitter.

This push into digital media was followed by the creation of promotional videos, led by Cox Inall's Angus Rutherford and James Tolmie. Cox Inall was at the core of 'professionalising' the CRC's communications, with support provided by David Dawson, Peta MacDougall and Melissa Aisthorpe, and of course Lucy Broad, who played a key role in facilitating the pitch messages for the CRC's 2014–2019 extension bid.

As the CRC grappled with its understanding of the needs of its various audiences, its processes in this space also became more sophisticated. Ivana Crestini from the Rider Self Group was engaged on a number of occasions to conduct market research surveys and focus groups, to reveal the factors holding back uptake of new products and how they could be better positioned in the market place.

Despite the sophistication of the communications processes, things didn't always go to plan. There were occasional differences of opinion with Participants, threats to withdraw funding, and even the odd public slanging match with our own Participants — for example, the dispute with AWI over genetic research and the Wool ComfortMeter. However, the fact that the CRC survived all of these and continued on for almost 20 years was testament to the people of substance in its team who were able to communicate their way through the most difficult disagreements.

AN INTEGRATED APPROACH TO SUPPORT TRANSFORMATION

The CRC activities spanned five areas:

- Consolidating existing research information and making it readily available, in multiple formats, for use by researchers, training and education specialists and by industry practitioners.
- Development of industry training programs specifically targeting the uptake of existing and new technologies.
- Formal education in the form of undergraduate courses, postgraduate course work and postgraduate research to provide a flow of well-trained specialists into the sheep industry (see Chapter 10).
- Development of web-based apps integrating information on specific aspects of sheep production in a form readily usable by sheep breeders and commercial producers.
- Communication programs spanning media, social media and promotional material to raise awareness of the value propositions for changing practices.

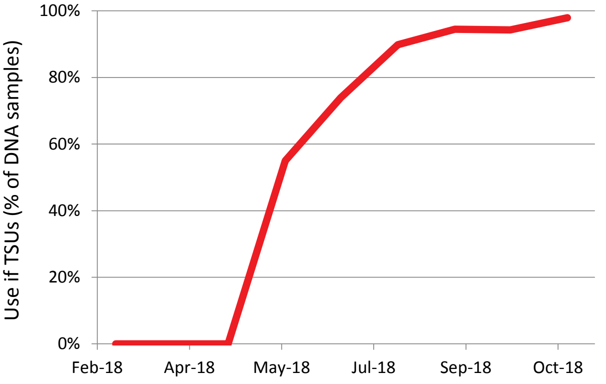


Figure 11.1: A powerful example of the impact of an integrated approach to implementing innovation within the sheep industry was the transition from blood cards to the use of tissue sampling units (TSUs) for collecting sheep DNA for testing. Producers had been seeking a simpler and easier method than blood cards for DNA testing. By working with both TSU manufacturer Allflex, and Neogen's DNA testing laboratories, the Sheep CRC promoted both the on-farm and test processing efficiencies of adopting TSUs, and provided a clear economic signal to producers through cheaper DNA tests for samples provided in TSUs. The result was Neogen's implementation of a robotic de-capper (left) which improved sample handling efficiency in the lab and reduced test turnaround times, and an immediate increase in the use of TSUs by farmers (right).

POSTGRADUATES IMPORTANT PART OF INNOVATION PIPELINE

Sam Clark was the beneficiary of the sheep industry's investment in postgraduate education, and paid dividends forward to a new generation of genetic researchers and industry advisers. Sam undertook his postgraduate studies through the University of New England (UNE) in the field of quantitative genetics and later passed those skills on to a new generation of sheep industry experts as a lecturer in animal breeding and genetics at UNE.

Sam Clark

Sam was proof of the ongoing return on investment this delivers for industry. As well as continuing his research work with the Sheep CRC, he lectured to students who were to become rural Australia's future producers, consultants and researchers.

Some of the key knowledge he was able to pass on was how pedigree-based information and genomic technology could be used to improve rates of genetic gain and productive potential of animals in a livestock breeding program.

Consolidating existing research information

One of the early initiatives in the first CRC was to establish the Livestock Library. It was recognised that many of the research publications produced prior to the mid 1990s were only available in paper form, at a stage when most young researchers and students were relying solely on electronic searches in reviewing existing information and knowledge on aspects of sheep production.

The CRC negotiated copyright arrangements with CSIRO and with various organising committees responsible for key industry conference series such as the Australian Society of Animal Production (ASAP), Recent Advances in Animal Nutrition in Australia, and the Australian Association for Advancement in Animal Breeding and Genetics (AAABG), to allow scanning and electronic reproduction of the paper journals and conference proceedings, going back to the early 1950s. The new technology of character recognition scanning software made it possible for semi-automated conversion of the paper copies to electronic documents. A number of senior researchers donated their paper copies of journals and conference proceedings to the process. All of the CSIRO journals on aspects of sheep and wool production were delivered to CSIRO Publishing on the basis that they would be accessible via the Livestock Library.

Ruth McIntyre, a trained librarian, coordinated the electronic resources at the start of CRC2 and opened up the material to the Google Scholar search engine, thus significantly reducing the cost and complexity of maintaining the site. It became an important repository for CRC publications including technical reports, Practical Wisdom notes and a range of promotional material. The Livestock Library was assigned to MLA at the end of the CRC with management to continue under the Animal Genetics Breeding Unit (AGBU) at the University of New England, ensuring that the resource would continue to benefit the industry long after the CRC closed.

Another activity in CRCI was to consolidate all of the genetic data on research flocks kept by various organisations around Australia. Neal Fogarty and Alex Safari compiled the records of data available on these flocks and prepared a publication with a comprehensive summary of all genetic parameters available for sheep traits. While this was primarily an activity designed to underpin the genetic research program, it was also crucial in allowing Belinda Norris at CSIRO to coordinate the development of a DNA repository with samples from all available animals. A number of CRC conference reviews were then organised to bring together all of the information on particular topics and to reach consensus conclusions on the technical aspects associated with each field of research and its application. A conference on the responses to grain feeding was organised by Dave Pethick and colleagues in WA and resulted in a publication summarising results of all available grain feeding experiments involving sheep. A mini conference on the impact of nutrition of parasite infection and subsequent effects on sheep was organised in 2002 and the outcomes of that conference published in a special edition of the *Australian Journal of Experimental Agriculture*. The CRC also supported a number of reviews such as the examination of all factors contributing to weaner survival prepared by Angus Campbell that were also loaded into the Livestock Library.

Understanding the importance of ensuring information from research studies was available for future application also resulted in the CRC setting high standards for its own publication process, and making sure that all relevant information from research programs was available for future use via refereed publications and conference proceedings.

CRC Concept to Impact Conference 2014

Industry training programs

A number of training programs summarised below are discussed in more detail in other chapters.

The Lifetime Ewe Management program, developed by Andrew Thompson and his colleagues, was built on information developed by the AWI Lifetime Wool program. An innovative workshop program was designed to assist producers to improve reproductive efficiency by ensuring adequate nutritional management of ewes and lambs. The training program was based on strong evidence for improved reproductive efficiency resulting from maintaining the condition score of ewes throughout the year in order to ensure that they had the nutritional reserves for pregnancy and lactation.

The program's success was also based on the innovative approach to the training program. A series of consultants were trained to provide support for groups of four or five producers in the same area who were comfortable sharing information about their properties. Each program lasted for 12 months in order to complete a full cycle of ewe management. Rotating the monthly meetings around the various producer sites helped to create a good understanding and a productive process of peer support for implementing the changes required for a successful outcome. AWI took over support and coordination of the Lifetime Ewe Management program, and their investment in its ongoing delivery has ensured a very significant and ongoing impact on the sheep industry.

Bred Well Fed Well workshop in WA (Source DAFWA)

Similarly, the Bred Well Fed Well program developed by Mark Ferguson and Andrew Thompson also proved to be successful and was taken up for ongoing delivery with support from MLA. Bred Well Fed Well workshops were designed to focus on the key production benefits of superior genetics, feed management for improved reproductive performance and livestock productivity. The workshop achieved this through practical tips and tools including how to use ASBVs, how to develop a breeding objective and how to develop simple energy budgets for the breeder flock.

The WormBoss program, initiated by Deborah Maxwell and coordinated by Arthur Le Feuvre, was the CRC's initiative to develop a national approach to intestinal parasite management. The innovative approach of Arthur Le Feuvre and his early song on WormBoss helped to create an awareness and level of use that has developed over time. The WormBoss program became the cornerstone of the ParaBoss initiative that is described in Chapter 5. This integrated approach was a hallmark of FlyBoss and LiceBoss, which came together under the ParaBoss banner for ongoing delivery by UNE at the end of CRC2.

The RamSelect program was developed by a team led by Lu Hogan and was designed to increase the use of genetic information in selecting flock rams based on ASBVs rather than purely on traditional selection methods of blood lines and visual assessment. The program was established by the CRC recognising the very significant investment in genetic technologies during CRC2 and the importance of ensuring that the results were used by industry to achieve faster and better targeted genetic improvement. Its success in increasing the use of ASBVs in ram selection was a major achievement of the CRC.

A number of training initiatives on data collection and its organisation for genetic improvement programs were developed and coordinated by Debbie Milne. This helped a number of ram breeders make the transition to using the Sheep Genetics evaluation programs and contributed to widespread use of quantitative genetics and genomic technologies.

On-farm training crucial to adoption

Many of the CRC programs featured in-field training workshops to allow producers to learn in the environment in which they were most comfortable. This was a vital cog in encouraging producers to understand new technologies and change to more productive practices.

It was a highly effective strategy, with a national survey of sheep producers revealing the tangible impact the Managing Scanned Ewe workshops had, resulting in more than 80% of attendees changing management strategies. Similar results were also recorded for programs including Lifetime Ewe Management, RamSelect, High Performance Weaners and Bred Well Fed Well workshops.

Managing Scanned Ewes workshops/conferences led by Chris Shands were very popular with producers.

A survey of 1,000 sheep producers, conducted nationwide by Mandy Curnow and her colleagues in WA towards the end of the first CRC, demonstrated that producers and advisers were hungry for high-quality, independent research that was focussed on improving farm profits and flock performance.

Almost 90% of producers surveyed had heard of at least one of the Sheep CRC training programs, and 40% of producers had attended at least one CRC event, with most attending more than one event. Each type of workshop resulted in practice change from at least 51% of participants, with that figure rising to 68% for Bred Well Fed Well, 77% for Lifetime Ewe Management and 82% for Managing Scanned Ewes.

The Managing Scanned Ewes program was a great example of the impact that these training courses had on industry. This program led by Chris Shands, formerly Senior Research Officer at NSW DPI, was delivered in partnership with pregnancy scanning businesses to help sheep producers improve lambing performance. Some 88 scanning workshops were delivered around Australia to 1,800 sheep producers and it was estimated that improved use of pregnancy scanning data and increased uptake of testing led to an additional 500,000 lambs born per year — a 15% increase in reproduction efficiency.

eID and the evolution of train the trainer

As detailed in Chapter 6, during CRCs 1 and 2 there were large investments in developing electronic identification technology for the sheep industry. It was hard work to develop integrated hardware and software systems to automate data recording systems for individual animal management. The initiative was strongly supported by commercial companies, Gallagher and Tru-test, by service providers such as Paul and Michelle Cousins and by State DPIs through Steve Semple, Phil Graham, Guy Newell, Ian McFarlane and Megan McDowell. The perseverance with the research and championing of the technology by leading producers, led to steady growth and eventual successful commercialisation and uptake of the technology.

A number of user case studies and Practical Wisdom notes were published, detailing the practical application and business benefits of the technologies. A series of these case studies were published in the Precision Pays booklet, which included stories on prominent producers such as Peter Trefort, Mark Mortimer, Tony Thompson, Maurie Stephen, Malcolm Peake, Rod Shaddick, Stuart and Ba Mitchell, Sue Jarvis, Rod Peart and David Strong.

Adoption of Electronic Identification (eID) was achieved by not only creating this network of producer champions, but by targeting the seed stock sector in the first instance as it was believed these producers had the most to gain from the technology. This uptake was supported by CRC investment in training materials and upskilling of service providers in collaboration with Nathan Scott of AchieveAg Solutions.

The idea of 'training the trainers' was novel at the time, but it proved an effective mechanism for creating a network of trusted advisers to spread the message to farmers on the CRC's behalf. It was a strategy that was replicated in a number of other campaigns to great effect.

2011

SHEEP — THE SIMPLE GUIDE

One of the most popular and enduring extension products was the publication 'Sheep — the simple guide to making more money with less work'. First launched in Western Australia in 2011, it was adapted in 2013 for use across the country to provide practical advice on smarter management practices and tips on breeding easy care, labour saving sheep. Its straightforward tips and simple layout made it easy to digest and a great reference point for sheep management decisions.

In the case of eID, the strategy worked, and the broader industry widely adopted the technologies. Use of eID became standard technology in ram breeding operations as did semi-automated weighing of prime lambs to monitor growth rates and ensure compliance with processor grids. The commercial success of this technology meant that CRC support for extension and training could be discontinued in 2015. Further momentum for use of eID developed following the decision in Victoria for compulsory use of electronic tags for lambs born from the beginning of 2017. A number of incentives and training programs were introduced in Victoria and the CRC's resource material was extensively used.

The impact of training the trainers

Sheep industry service providers surveyed in 2014 provided an average rating of 4.2 out of 5 for the Sheep CRC as a source of credible information and a leader in innovation, providing independent and high-quality information. More than 73% of service providers indicated they had changed their recommendations to farmers as a result of Sheep CRC research, with a further 17% indicating the research had validated their beliefs and practices. The survey also found that on average 77% of their farmer clients had changed one or more aspects of their sheep production as a result of the information and training provided by the Sheep CRC.

Activities undertaken as part of the 'train the trainer' program included workshops for livestock consultants to equip them with the skills and tools to use the latest genetics technology. The Future Livestock Consultants project was funded through participating consulting firms and the Meat & Livestock Australia Donor Company (MDC) and provided two-year internships for nine young professionals seeking a career in red meat and livestock consultancy.

Recognising the reduced investment by State Government in agricultural extension, the overall goal of the initiative was to trial a new approach to attract and retain professional private consultants for the red meat and livestock industries, by creating a national network of consultants underpinned by training and professional development to the interns. The training included an on-farm sheep genetics workshop delivered by the CRC's Lu Hogan and Steve and Debbie Milne of Waratah White Suffolks, Hamilton (Vic). The interns, who were located across Australia within existing businesses, also completed the UNE Graduate Certificate in Agricultural Consulting, a course developed by the Sheep CRC.

Another activity was the 2014 'Effective Use of Genomics' three-day training course in Armidale, NSW, which was delivered to 25 sheep breeding advisors on how to use DNA testing and design effective breeding programs. The course provided participants with an update on genetic theory, including data collection, trait measurement, the application of DNA testing, and how to incorporate that knowledge into the design of a breeding program to maximise flock productivity. The participants were also trained in the use of a number of diagnostic tools to assist in data analysis when advising sheep breeders.

The 'Effective Use of Genomics' course featured a number of industry specialists including Sheep CRC Genetics Program Leader Julius van der Werf; Senior Animal Scientist at the University of Tasmania Brian Horton; and Stephen Lee from the School of Animal and Veterinary Sciences, The University of Adelaide. Stephen had also been part of the Sheep CRC's team of experts responsible for documenting the value proposition for use of genomic information in breeding programs.

The goal of training the advisors in the use of new genomic technologies was to ensure that sheep breeders used DNA testing on the right animals, and optimised the number of animals tested, so that they could achieve the biggest possible benefit in terms of genetic gain for their investment in the technology. In applying the theoretical lessons, the workshop participants used a number of real-life case studies to test themselves against 'what if' scenarios and the impact on genetic gain from altering aspects of the design of a breeding program.

Capturing the knowledge

All CRC training programs were supported by customised printed materials to ensure producers had an ongoing reference point available to reinforce what they had learned and to support them in applying the knowledge. For example, a Pocket Guide to ASBVs was developed with the support of Sheep Genetics, MLA and AWI. The CRC, through the Western Australian group led by Mandy Curnow, developed the very popular publication, 'Sheep – the simple guide' to making more money with less work. The first edition was so popular that various editions of this book were prepared for different climatic regions around Australia. It generated a lot of interest and continues to be a valuable resource for producers and advisors. The Precision Pays publication was another example and it was supported by the very popular Glove Box Guide to Precision Sheep Management.

The Practical Wisdom series of fact sheets and scientific notes proved a valuable resource not just for producers but also researchers. As the name suggests, they were designed to cut to the nub of what research meant to the end-user and how it could be applied in the 'real world'. More than 150 Practical Wisdom notes were developed over the life of the CRC.

As the CRC evolved and research increasingly resulted in commercial product offerings, so too did the printed products evolve to take on a more commercial look and feel. Rhonda Brooks' design skills made a big contribution to the sharp stylings of the RamSelect and ASKBILL brands, and their presentation on brochures, fact sheets, user guides and websites. As noted in the introduction to this chapter, the content of these documents and websites often went through many iterations being 'translated' and simplified from detailed scientific information, to simple texts and images that described the value of the technology and how producers could easily make use of it. Michael Thomson would remind researchers that almost nobody knew how a mobile phone was able to transmit data and voice signals; all they cared about was whether it worked.

2014

TRAINING PROGRAMS WIN MAJOR AWARDS

The Sheep CRC scooped the pool, winning two major research awards and being shortlisted for a third at the 2014 CRC Association Awards. The Sheep CRC received the Commonwealth CRC Program's STAR Award for high-level engagement with small and medium size businesses through its highly successful program 'Managing Scanned Ewes' and the award for Excellence in Innovation for the 'RamSelect' initiative, both of which have resulted in dramatic uptake of new research and major improvements to industry productivity.

Steve and Debbie Milne of Waratah White Suffolks, Hamilton, Victoria, helped Lu Hogan run an on-farm genetics workshop.

Raising awareness with digital delivery

Compiling materials to support training and extension programs was only half of the equation; the other half was ensuring that as many people as possible saw them and engaged with their content. The CRC used a number of methods to reach as many end-users as possible and these methods evolved and expanded over the 18 years of operation.

During CRC2, Cox Inall was engaged to provide professional advice and support for our communications initiatives. Initially led by Dave Dawson, the CRC began to regularly produce and distribute media releases to the firm's database of more than 1,000 journalists across the country.

The strategy was simple. In the early 2000s media companies around the world began cutting staff from their newsrooms as they struggled to remain viable with advertising moving from traditional media to the internet. This left editors short-staffed and desperate for well-written articles — the CRC team was happy to oblige with a regular flow of stories about research activities, producer case studies, and promotion of upcoming workshops and events. The media releases were also picked up by radio and this avenue had a valuable multiplier effect.

Regular, high-quality media releases remained a core business tactic throughout the Sheep CRC's term, and achieved between 240 and 1,000 'clips'/year in the traditional print and radio channels.

However, the CRC was not immune to the effects of the digital revolution and adapted accordingly. One very simple yet effective method of multiplying the impact of each media release, was through direct email. Early on the CRC began building a database of people interested in the CRC's activities. This formed the first postal and email list for the CRC's monthly newsletter, *From the Homestead*. By the end of CRC2, this newsletter was delivered exclusively by email, marking the end of the printed edition that was formerly posted to thousands of people.

There were two significant advantages of the email distribution. The first was its integration with the CRC website, seamlessly linking readers to more information on topics that they were interested in, such as downloading copies of the guidebooks developed for the training courses. The second advantage was the ability to quickly send short bulletins to alert our network to upcoming events or communicate urgently and directly on difficult issues facing the organisation.

These notions of multiplying the impact of materials and communicating directly with the CRC community were two of the core reasons behind the shift into social media. The third, and more pragmatic reason, was that traditional media audiences were declining and the CRC had to move its materials to where the eyeballs were now resting: Facebook, Twitter and YouTube.

As with the email bulletins, these channels were used to directly communicate to CRC followers and link them to more detailed information, keeping them updated with the progress of research activities, raising awareness of opportunities to improve their practices, and providing them with links to more detailed information on the CRC website to support their practice change. The other benefit was that the CRC was communicating directly to people it knew were interested in its activities. Effort wasn't being wasted on trying to sell the merits of the CRC's work to mainstream audiences, uninterested in sheep, who consumed traditional media.

Building audiences that the CRC 'owned' was the first objective of the move to social media delivery. Through a combination of paid advertising on Facebook and the good use of images, videos and messages, the CRC's following grew to more than 11,000 between 2010 and 2019. Paid promotions were also used on YouTube to ensure Sheep CRC videos stood out from the crowd and were reaching people genuinely interested in sheep research. The CRC's Twitter following reached more than 3,000 people by 2019, built on the back of near daily messages linking to CRC online materials, such as the media releases, publications and videos.

The value of this integrated approach was demonstrated not just in the exceptional reach of CRC materials, but also in an enhanced reputation for the CRC as a leader in this field. Monthly communication activity reports were provided to the CRC Association, politicians and the Commonwealth CRC Program, which regularly commented that the Sheep CRC was the stand-out among all other CRCs for its media and communications activity.

Extension in action - the Genetics Training Initiative

The Genetics Training Initiative was supported through co-funding and expertise from Agrifood Skills Australia and input from MLA, AWI, Sheep Genetics and a range of specialists in sheep production and agricultural education and training. The Initiative's Steering Committee commissioned a Genetics Training Needs Analysis in March 2011. This project was funded by Sheep CRC and Agrifood Skills Australia and was undertaken by a consortium of consultants including:

Ian Rogan	Ian Rogan Consulting
Scott Williams	SED Consulting
Jason Trompf	JT AgriSource
Charles de Fegely	Mike Stephens and Associates
Robbie Sefton	Sefton and Associates

The needs analysis identified the following barriers to uptake of ASBVs within the sheep industry:

1. A lack of awareness and understanding of ASBVs amongst commercial ram buyers.
2. A lack of understanding of the value proposition and benefits from using ASBVs for ram selection.
3. No simple method by which to benchmark the genetic merit of a commercial flock.
4. Complexity in using ASBV information to set a breeding objective and selection criteria.
5. A lack of confidence amongst ram breeders to explain and promote ASBVs to their clients.
6. A lack of advocates for ASBVs amongst key influencers such as stock and station agents, sheep classers, advisors and processors.

The consultants concluded:

"The major obstacle to further uptake of ASBVs and related technologies by the Australian sheep industry was a lack of demand from commercial ram buyers. This lack of demand is driven by a range of factors, the most important of which seems to be a perceived lack of demonstrated benefit in using ASBVs to select rams, complexity of the technology and a lack of clear market signals for ASBV-related traits."

Key elements of the recommendations made by the consultants were as follows:

- Education and training programs designed to improve the understanding of ASBVs by the sheep industry and facilitate more effective use of ASBVs when buying rams;
- Develop improved decision support tools for using ASBVs;
- Develop and support a network of advisors, service providers and commercial agribusiness specialists able to promote and support the utilisation of ASBVs by sheep producers;
- Establish a coordinated communication program with producer advocates and case studies to support the training programs and promote the use of ASBVs in ram-buying decisions.

As a consequence of these recommendations, the CRC, with support from the Steering Committee set about designing a 'hands-on' RamSelect workshop that could improve producer understanding of breeding values and the benefits they provided. Allan Casey, Lu Hogan and a team of service providers developed, trialled and rolled out more than 150 workshops to 2,500 participants between 2012 and 2015. The workshops were hosted by ram breeders and engaged a range of service providers including stock and station agents, merchandise managers and industry advisors. These events were always supported with communication activities using the newly created social media channels.

THE GENETICS TRAINING INITIATIVE STEERING COMMITTEE

Lu Hogan	Sheep CRC
Graham Truscott	Sheep CRC
Richard Apps	MLA
Sam Gill	MLA
Hamish Chandler	Sheep Genetics
Luke Stephen	Sheep Genetics
Geoff Lindon	AWI
Ben Swain	BCS Agribusiness
Glen Tilley	Producer SA
Mark Ferguson	Murdoch University
Michael Claessens	Agrifood Skills Australia
Neil Jacobsen	Agrifood Skills Australia
Alex Russell	NSW DPI
Allan Casey	NSW DPI

RamSelect shifts from workshops to desktops

The RamSelect app evolved through a number of related initiatives. Whilst the RamSelect workshop program had gone part of the way to addressing the recommendations of the 2010 Genetics Training Needs Analysis, there were still underlying constraints to the uptake of genetic technologies. These constraints were primarily around the complexity of ASBV technology and the need for producers to have a genetic benchmark in order to start using ASBVs in ram purchasing decisions. The ongoing cost of workshop delivery was also a cost that industry would not be able to bear after the CRC funding ceased.

An alternative approach to delivering expensive training programs to assist producers undertake the complex task of identifying suitable rams was to develop an app to make the task much easier. Building the app with this objective was essentially an experimental pilot project to determine if the approach would be effective.

In March 2015, after scoping various opportunities for more effective data utilisation, the CRC was given the opportunity to work with Telstra to develop a case study app in conjunction with the software specialists Pivotal Laboratories, based in San Francisco. Telstra's financial support for the pilot project meant that the cost to the CRC was greatly reduced and the CRC had the opportunity of working with some of the best and most experienced app developers in the world.

The RamSelect app development team from left Campbell Watts, Kevin Atkins, Lu Hogan and Luke Stephen.

The selection of RamSelect as a case study with co-funding from Telstra and its subsequent development was a collaboration initiated and coordinated by the Sheep CRC involving Sheep Genetics, AGBU and NSW Department of Primary Industries. Before commencing the project, the need for such an app was rigorously reviewed by specialists at Pivotal Labs. Their review involved in-depth interviews with around 20 Australian sheep producers and ram breeders selected for their divergent views on the potential value of ASBVs and their wide range of experience in using ASBVs in ram-buying decisions. The conclusion by Pivotal Labs, following their review, was that there was a clear need for an app to assist producers to use ASBVs in their ram-buying decisions.

The app, ramselect.com.au was also built by Pivotal Labs with technical input from the CRC in relation to genetic algorithms for ranking of rams based on ASBVs and associated indexes. The development was substantially guided by the CRC's experience in developing and delivering the RamSelect workshops. A number of the producers and breeders, interviewed as part of the review process, remained involved in the project throughout the development of the app, providing end-user advice on its design and functionality. This process of end-user engagement was also crucial to the app's design and subsequent success. It was a process which significantly influenced future digital technology developments.

The RamSelect app immediately achieved the objective of reducing the need for the RamSelect training program. At the end of its first season of use, the app had been used by nearly double the size of the audience reached during four years of workshop delivery. Use of the app quickly became widespread, with more than 17,700 rams listed for the 2016–2017 ram-selling — an increase of 28% compared to the same stage in the 2015–2016 selling season — and in excess of 5,000 searches conducted.

As a 'concept' product the app was delivered free to industry by the CRC during 2015 and 2016. The fact that it was used in transactional decision-making indicated there was likely to be a commercial market for ramselect.com.au. It was also recognised that maintenance and delivery of the app would require ongoing funding and that a commercial revenue stream was likely to be the most reliable mechanism to ensure its sustainable delivery.

In 2018, RamSelect operated on a user pays basis, with ram breeders paying to list rams and users paying a nominal account fee. The introduction of a pay wall resulted in a small reduction in use in the first two years. However, the CRC believed that in the longer term the value of the app, particularly with its additional functionality for ram team and Flock Profile management, would outweigh negativity about the user pays model. At the conclusion of the CRC, RamSelect was assigned to UNE to continue as a commercial service to the industry.

Before handing it over to UNE, the CRC again changed the business model, returning to free listing of rams to ensure the site's popularity and high numbers of ram listings, with revenue to be generated through user account subscriptions.

MERINOSELECT numbers on the rise

The impact of the integration of extension methods — genetics workshops, media case studies, and social media delivery — was evidenced in the increase in adoption of MERINOSELECT (see Figure 4.2).

Between 2010 and 2014 the number of sheep recorded with MERINOSELECT increased by more than 50 per cent as more and more commercial producers demanded objective data when buying rams. The result was only possible through the sustained training and communications activities conducted over a long period.

In 2014 Hamish Chandler, then manager of Sheep Genetics, which administered the MERINOSELECT program, said MERINOSELECT had reached a critical mass that proved that the use of estimated breeding value technology was widely accepted as something that works well and should be part of a breeder's decision-making process when selecting rams.

"A number of new MERINOSELECT members made the decision to join after commercial clients requested more objective data. We also heard reports of ram breeders having new clients come to them looking for rams with breeding values, and then returning year after year because they could see the impact that those rams have had in their breeding programs," he said at the time.

The Sheep CRC worked hand in hand with Sheep Genetics in promoting the uptake of ASBVs and other objective genetic tools. As well as RamSelect training workshops, the CRC published countless case studies and media releases quoting commercial and stud producers on the benefits ASBVs had brought to their business. The end result was a 'normalisation' of a practice which for many years was viewed with some scepticism by traditional Merino breeders.

One of those media releases featured Riverina breeders Stephen and Carol Huggins, of Woodpark Poll Merinos, who joined MERINOSELECT in 2011 to take their flock benchmarking data to another level, having previously provided clients with their own sire indexes.

"We have definitely grown our business because we have joined MERINOSELECT," Stephen said in 2014. "Part of that has been because we have been out and about at field days with our sheep and discussing with producers what the ASBV figures mean. But there have also been some commercial breeders who have proactively asked for that extra level of information and have really utilised it ahead of auction day and private selections as they seek sheep with strong figures for specific traits."

A key factor in convincing producers to adopt ASBVs was emphasising that they were not a replacement for traditional visual selection methods; rather an additional and complementary tool in the toolbox. For example, Stephen Huggins was quoted in his media release as saying: "The sheep still have to stack up visually as well — the difference is we're now providing another layer of information that's helping breeders make better decisions."

A TIMELINE FOR IMPLEMENTING INNOVATION

The integration of DNA testing into the traditional stock evaluation format of the Doug Bicket Memorial Ewe Competition in Parkes was a classic example of the process and timelines for helping industry to test and use new technologies.

- Late 2015 — competition organiser Graeme Ostini, of Ostini Wool, discussed the use of objective breeding technologies while visiting Errol Brumpton's Well Gully stud at Mitchell, Qld.
- Mr Brumpton connected Mr Ostini with local woolgrower and CRC Board member Stuart Mitchell, who recommended Mr Ostini invite the CRC to present at the next Parkes ewe competition.
- February 2016 — CRC CEO James Rowe spoke at the competition, encouraging the local woolgrowers to adopt modern genetic selection tools, including RamSelect and DNA testing, to improve their productivity.
- March 2017 — the CRC's Lu Hogan returned to Parkes to present to producers on DNA Flock Profiling and announced a Sheep CRC offer to sponsor the 2018 event by providing free Flock Profiling to all competitors.
- October-November 2017 — competitors submitted DNA samples for Flock Profiling.
- February 2018 — Lu Hogan provided DNA test result analysis and RamSelect guidance to each competitor. Crowd numbers at the Parkes Ewe Competition doubled as a result of the inclusion of the technology alongside the traditional visual assessment.

"The inclusion of the DNA Flock Profiling technology really got producers very excited and thinking about how to use the information to improve their genetic selections and improve their business. Here are technologies that aren't way out in the future anymore, but are at their fingertips," Graeme Ostini said following the 2018 competition.

Lu Hogan (centre) with Gary O'Brien and Graeme Ostini at the Doug Bicket Memorial Ewe Competition in Parkes NSW.

Applying a recipe for success to ASKBILL

Development of the ASKBILL app and the massive team involved to build the models and the related software has been described in Chapter 7. The CRC took an iterative approach to building the app, developing and adding new features in response to user feedback and results from testing its functionality by a large team of producers and researchers. In the software trade this is known as developing an MVP (Minimum Viable Product) and it allows software developers to quickly respond to feedback and changing industry priorities.

ASKBILL uses a comprehensive long-term weather forecast and farm-specific information to predict pasture availability, animal growth, and the risks associated with flies, worms, heat and cold up to six months out. Once the first commercial version of ASKBILL was released at LambEx in August 2018, the CRC set about designing a comprehensive marketing and training program to raise awareness of the new product and encourage producers and their advisors to open an account and trial the software.

The CRC used a well-tested integrated approach of social media, print media and case studies together with training activities and events for producers and their advisors. Train the trainer workshops coordinated with organisations such as Local Land Services in NSW and BestWool BestLamb Coordinators in Victoria were also a feature. Private consultants were contracted to work with a small number of clients to set up ASKBILL accounts and monitor farm conditions using the software, with the aim of building trust in the new technology. Trust was also given a boost through detailed validation of ASKBILL on 20 properties across Australia. Validation activities were expertly coordinated by Laura Kemmis as a CRC contractor. Through the ASKBILL website the CRC also provided phone access via a free 1800 number and online support services for users, who regularly contacted the CRC for on-boarding support and to provide feedback.

An AMPC-funded project delivered additional software to enable sheep producers to share information about animals available for sale with processors and others in the supply chain. As a result, ASKBILL account holders had the option to share information about their property and sheep through MobSelect; processors or other intermediaries with authority could then search for lambs or sheep according to requirements, such as number, weight, breed and distance from works. Effective use of MobSelect had the potential to improve scheduling of animals for processing, improving compliance with grids and other customer-based requirements. A priority at the close of the CRC was implementing plans for future engagement with supply chain partners to demonstrate the value of ASKBILL and MobSelect to the industry and increase demand for the software.

2017

COMMERCIAL PRODUCT MARKETING

During the final term of the CRC, the communications focus evolved from promoting technologies to a new phase of selling products, like ASKBILL and the suite of DNA tests, as well as charging for use of RamSelect, to ensure they all had long lives after the CRC ended.

Responsibility for the future management and deployment to industry of ASKBILL and RamSelect was taken on by UNE, and included ongoing input from the CRC's Lewis Kahn, its app development team led by Johan Boshoff, and the CRC's industry engagement and training coordinator Lu Hogan. ASKBILL was one of the most innovative products ever developed for Australian agriculture and through the extension and training programs a core group of users had been established. At the close of the CRC the app was squarely placed ready to deliver impact to industry well into the future.

Understanding why farmers press the app buttons

Despite the proliferation of new technology in agriculture, very little was known about the effectiveness of these new tools in improving productivity and adoption of new practices. The Sheep CRC decided to find out more about the digital extension approach by evaluating the use of smartphone apps in the industry and producer attitudes towards these tools, in order to ensure future tools and technologies met their needs.

CRC sponsored postgraduate student Penny Schulz said the aim of her research was to develop a guide for app developers to follow to ensure new tools were relevant and widely adopted.

"In rural industry there is a big focus on data, information and technology, but I saw a gap in the extension of these tools and how useful they may be to farmers," Penny said. "So I set out to gain a better understanding of how producers made their decisions about what technology to use, the decisions they made as a result of using technology, and whether that was the same use as what the app developer intended."

As part of her three-year PhD, supervised by Julian Prior and Geoff Hinch at the University of New England (UNE), Penny used the Sheep CRC's popular web-based app, RamSelect, as a cornerstone for her research. One of the features of the RamSelect development was the extensive end-user interviews undertaken at the start of the process to understand producer needs and how they interacted with the app design. Penny also monitored the development of ASKBILL which was constructed through UNE's Agile App team.

"Apps and online tools like this that utilise big data technology, have huge potential for simplifying complex information and enabling producers to make more informed and timely decisions to improve productivity, animal wellbeing and profitability," Penny said.

Having delivered industry extension programs for more than a decade for both government agencies and as an independent consultant, Penny had seen first-hand the difficulties the research community had encountered in achieving adoption of new technologies and practice change among producers.

"There has been a big decrease in government funding for extension programs and it has been largely left up to industry bodies and private enterprise to deliver new research to producers," she said.

"The evidence suggests that adoption of some 'best management practices' in the Australian sheep sector have not been as fast as they could have been, which has resulted in the sheep industry missing out on productivity, profitability and wellbeing gains. Within this landscape, apps and online tools may be a more cost-effective method of delivering new knowledge and helping producers to apply best management practices. But, if this was to be the case, we needed a validated framework to assist in the development and delivery of new apps and increase the likelihood of successful adoption by the sheep industry."

VIRAL VIDEO UNLOCKED LAMB LEG SECRETS

The Sheep CRC's Meat Program Leader Dave Pethick became an unlikely internet sensation in 2016 when he starred alongside butcher Rafael Ramirez in a YouTube video showing consumers how to debone a lamb leg.

The video, produced for the Sheep CRC by Cox Inall Communications, was viewed more than 14,000 times on YouTube and a similar number of times on Facebook, and continued to attract new followers to the CRC's YouTube channel many years after its first release.

Titled, 'Lamb leg secrets with the Butcher and the Doc', the video unlocked the secrets of the lamb leg so consumers could understand its versatility and the many cuts it can yield beyond a traditional roast. The pair demonstrated how to identify cuts including the chump or rump, silverside, round, shank, topside and how to debone a lamb leg to produce an easy-carve roast.

"When you start working with lamb and breaking it down into all these cuts, it becomes quite exciting for consumers to maybe buy a whole piece like a leg and start doing a bit of their own butchery using these simple steps," Rafa said in 2016.

Key to its popularity was the good-natured banter between the 'Butcher and the Doc', including some priceless comedic moments such as Pethick holding up five fingers when explaining how many shanks are on each carcase.

It also interweaved some serious messages, including explanations of how various cuts rate in the Meat Standards Australia (MSA) consumer testing scores, and the best cooking methods to use for each cut. The video aligned with other extension activities, including helping producers improve the lean meat yield obtained from each carcase and assisting processors and retailers to save time in preparing meat for sale.

In 2014, an industry manual was jointly published by the Sheep CRC and Meat & Livestock Australia (MLA) to assist the supply chain to extract maximum value from this important measure. The manual, 'Improving Lamb Lean Meat Yield — A technical guide for the Australian lamb and sheepmeat supply chain', was a key resource for producers and processors to refer to for all of the technical information they need.

Photo Source: Meat & Livestock Australia

ACCELERATING CHANGE WITH SOCIAL MEDIA

The Sheep CRC opened Facebook, Twitter and LinkedIn accounts in 2013. At closure in June 2019 the CRC had:

- more than 11,000 Facebook followers, and
- more than 3,200 Twitter followers.

These were used to drive traffic to the Sheep CRC website for more information about research and technology.

- By February 2019, more than 3,000 people were visiting the website each month, viewing more than 7,000 pages.

Notably, the Sheep CRC did not build a large following on LinkedIn (280-odd followers), which may have been a reflection on the fact that R&D was heavily focussed on end-users.

YouTube was an essential tool in promoting video reports to the public, including user tutorials for apps, simple steps for implementing new tools, and celebrating our love for all things sheep. More than 50 videos were produced for the YouTube channel.

- The most popular video on the Sheep CRC YouTube channel was 'Lamb leg secrets with the Butcher and the Doc', showing how to de-bone a leg of lamb. It was viewed more than 14,000 times.

Sheep CRC Communications Manager Michael Thomson addressing the 2019 Final Conference in Dubbo, NSW.

Targeted partnerships

While many of the communications and extension activities were highly visible, another layer of activity was conducted behind closed doors to ensure commercial partners adopted new technologies. Building these partnerships followed a similar approach to that of working with producers — understanding the end-user needs, responding accordingly, and communicating value.

Good examples of this 'direct approach' to building relationships with key commercial decision makers in order to deliver impact to industry, was the relationship with Neogen Australasia in the sale of genomic tests, and the efforts to ensure retailers and manufacturers adopted the Wool ComfortMeter and HandleMeter.

Building strong corporate relationships can take some time, which was why an integrated communications strategy was essential, linking public events and private meetings through consistent messaging.

In the case of the Wool ComfortMeter, a major breakthrough came when representatives from Country Road Australia, and China's Mengdi knitwear company came together to headline a mini-conference hosted by the Sheep CRC as part of AWIS Wool Week 2013. The keynote speakers provided their perspectives on how the objective measurement instruments were likely to build demand for Merino wool, especially the finer microns that are used in lightweight, next-to-skin woolwear. These third-party testimonials were incredibly influential in convincing other companies to follow suit and thereby encourage a commercialisation pathway for the technology.

The event was also a great opportunity for the wider industry to see the Wool ComfortMeter and HandleMeter in use, to better understand how the information they generate could define functional quality that can be used to set price points and product type.

Captilising on producer interest

One of the outcomes of the communication and extension activities was the creation of large audiences eager to use — and potentially purchase — products developed by the CRC. The leap from extension to commercialisation of technologies such as the Wool ComfortMeter, DNA tests, RamSelect and ASKBILL required specialist skills in engaging corporate partners. The CRC acquired these skills through both in-house employees and consultants including:

- Les Targ and Sam Guthrie, who consulted on the Wool ComfortMeter commercialisation.
- Graham Truscott, who was appointed as Deputy CEO during CRC2 to focus on engagement with commercial partners.
- Peter Silk, who joined CRC1 from AWI, and brought extensive knowledge in preparing IP agreements.
- Mark Coupland, who promoted the integrated animal management technologies.
- David Faulkner, who developed licensing models for ASKBILL and put the app in the sights of a number of big corporations.

Bringing it all together at CRC Conferences

The Sheep CRC held four major conferences to connect producers, industry and CRC Participants with researchers to demonstrate benefit and encourage uptake of research outcomes.

In 2006 the CRC organized a major conference at the Orange Civic Theatre attended by around 300 delegates to report back to industry on progress made during the previous 6 years and to outline plans contained in the proposal for CRC2.

Under the title 'Wool Meets Meat' this was a major event for the CRC and our stakeholders. Neal Fogarty chaired the local organizing committee and ensured that all local arrangements were to a very professional standard. Proceedings of the Conference were printed before the event thanks to Pierre Cronje and Deborah Maxwell organizing all contributing authors and managing a thorough editorial and review process.

In addition to the main presentations all postgraduate students presented posters and short summaries of their work. The energy of the students and diversity of their research topics created a lot of interest and positive feedback. The Civic precinct also allowed space for commercial demonstrations of eID technologies and sheep handling equipment as well as Participant trade displays.

The Orange conference was the largest event that the CRC had organized. It was very well attended by a wide cross-section of leading producers who were suitably impressed by the quality of the presentations and the range of achievements. The event did a lot to inspire confidence in the industry that the CRC was an organisation capable of tackling industry issues and that it was worthy of further support.

The second major Sheep CRC conference was held at the Shores Function Complex in Adelaide during October 2010. The event attracted widespread interest and support from industry with the theme of the conference focussed transformation within the sheep industry.

After three years of activity the CRC's researchers had a lot to report on. The first results from the Information Nucleus program created a lot of interest as there had already been substantial progress in developing the genomic technologies. There was also new information from the Meat Program on eating quality and the Wool Program had results from the prototype Wool ComfortMeter. In the Sheep Wellbeing Program there had also been a good start in understanding the importance of selecting sheep for adaptation to their environment.

The CRC's postgraduate students also made an important contribution to the Conference with each student delivering a brief summary of their research in the context of how it contributed to the CRC's objectives.

The papers presented at the Conference were all prepared for peer-reviewed publication in a two-volume Special Edition of the journal Animal Production Science. Key aspects of the new information was also prepared in the form of Practical Wisdom Notes.

Gerald Martin, Philip Clothier, John Cooper and Paul Blackburn at the Sheep CRC conference held in Adelaide in 2010.

At the close of CRC2, the 'Concept to Impact' Conference was held in Adelaide, showcasing the practical tools and technology developed in the areas of genetics and genomics, wool and meat quality, sheep management, and education and training. In a break from traditional conferences with long presentations and even longer keynote addresses, the conference deliberately limited all presentations to just 10 minutes — it had the desired effect of keeping the atmosphere upbeat and presenters focussed on delivering the essence of what was important to the listener. The conference was a precursor to LambEx, which maximised attendance and impact for industry.

Speakers at the 'Concept to Impact' Conference included the The Hon. Bob Baldwin, Parliamentary Secretary to the Minister for Industry; Natalie Skubel, Country Road Australia; genomics researchers Julius van der Werf and Stephen Lee; farm advisers Debbie Milne and Nathan Scott; and leading producers Andrew Michael and Murray Long.

Topics covered included:

- How to use new DNA testing in state-of-the-art breeding programs;
- How the new Wool ComfortMeter and Wool HandleMeter would impact the market for different types of wool; and
- How to optimise both lean meat yield and meat eating quality through genetic selection and on-farm management.

The same format was employed at the Sheep CRC's Final Conference in Dubbo in 2019, which also featured short, sharp presentations covering the gamut of researchers and producer adoption and benefit. Planning was aligned with the Sheep Genetics Leading Breeder Forum, which was held at the same venue immediately following the conference to maximise attendance for both events.

The final conference took a 'whole of CRC' perspective with speakers including previous CRC Chairs Ian Sinclair (CRC1) and John Keniry (CRC2), and all presenters were encouraged to articulate just how far the industry had come in the space of 18 years. All delegates received a copy of *Concept to Impact: The Story of the Sheep CRC 2001–2019* as a final extension and communications legacy.

The Sheep CRC has demonstrated the value of an integrated approach, operating at many levels and with different dimensions, to ensure that research results were utilised and delivered impact. There was integration between research planning and end-users, between organisations, and between various communication and training strategies. Integration, collaboration and delivering impact are the essential attributes of a CRC and the effectiveness of this approach will hopefully be recognised and adopted by all participants in the sheep industry long after the CRC is gone.

Delegates at the Sheep CRC Final Conference held in Dubbo NSW in 2019.

FROM RESEARCH TO IMPLEMENTING INNOVATION

The Sheep CRC's top 10 industry changers:

1. Information Nucleus Flock
2. Genomics Testing
3. Objective measurement of meat eating quality
4. Wool ComfortMeter and Wool HandleMeter
5. RamSelect
6. ASKBILL
7. Precision Sheep Management Technologies
8. ParaBoss
9. Lifetime Ewe Management
10. Managing Scanned Ewes

FIND OUT MORE:

For more detailed examples of how extension and communications activities were integrated with specific research projects, go to:

- Chapter 3 — Integrating Wool and Sheep Meat Production
- Chapter 4 — Introduction of Genomic Technologies
- Chapter 5 — Managing Sheep Parasites
- Chapter 6 — Transforming Sheep Wellbeing
- Chapter 7 — Precision Sheep Management
- Chapter 8 — Quality Sheep Meat
- Chapter 9 — Measuring the Magic of Wool

12 IMPACT

The concept for establishing the CRC was to develop a profitable sheep industry by understanding consumer preferences and expectations, as well as delivering the technological advances needed to enable producers and industry to deliver wool and meat products that consistently surpassed these expectations. This is the benchmark against which the success and impact of the Sheep CRC should be measured.

An investment in change

The Sheep CRC was established by its industry and research participants and so the benefits and impact delivered by the CRC over its 18 years should be identified as successes of industry. They would not have been achieved without a joint commitment to a long-term, coordinated and whole-of-industry approach to innovation. Also, the Sheep CRC's success should be seen as a tribute to the Commonwealth CRC Program's visionary concept of bringing industry and researchers together to solve major problems and develop new and significant opportunities.

The total investment in the CRC, summarised in Table 12.1, indicates the scale of the program over its 18-year lifespan. The size of the investment, $252 million in cash and in-kind, is a tangible demonstration of the commitment of the sheep industry and the Commonwealth Government to the goal of transformation.

Table 12.1: Summary of the cash and in-kind investment by the Commonwealth Government and by Sheep CRC Participants between 2001 and 2019

	CRC1	CRC2	CRC3	Total
Commowealth Program Funding	17,800	35,500	15,500	68,800
Industry Funding				
- AWI	2,816	10,204		13,020
- MLA	3,111	15,085	7,750	25,946
- AMPC	-	740	2,476	3,216
Other Research and Contracts	5,357	1,529	750	7,636
Genomic Pilot Programs		573	3,830	4,403
Other Cash		888	2,025	2,913
Total Funding/Resources	29,084	64,519	32,331	125,934
In-kind FTEs	180	301	148	
In-kind $ value (at $200k/FTE)	36,040	60,120	29,640	125,800
Total investment ($'000)				251,734

The structured cooperation facilitated by the CRC model also meant that organisations from all sectors of the Australian sheep industry contributed the resources and expertise required to tackle the major integrated research challenges that no single organisation could undertake on its own (see Table 12.1 and Figure 12.1). Better connections between different sectors of the industry also helped to create benefits for the entire sheep industry.

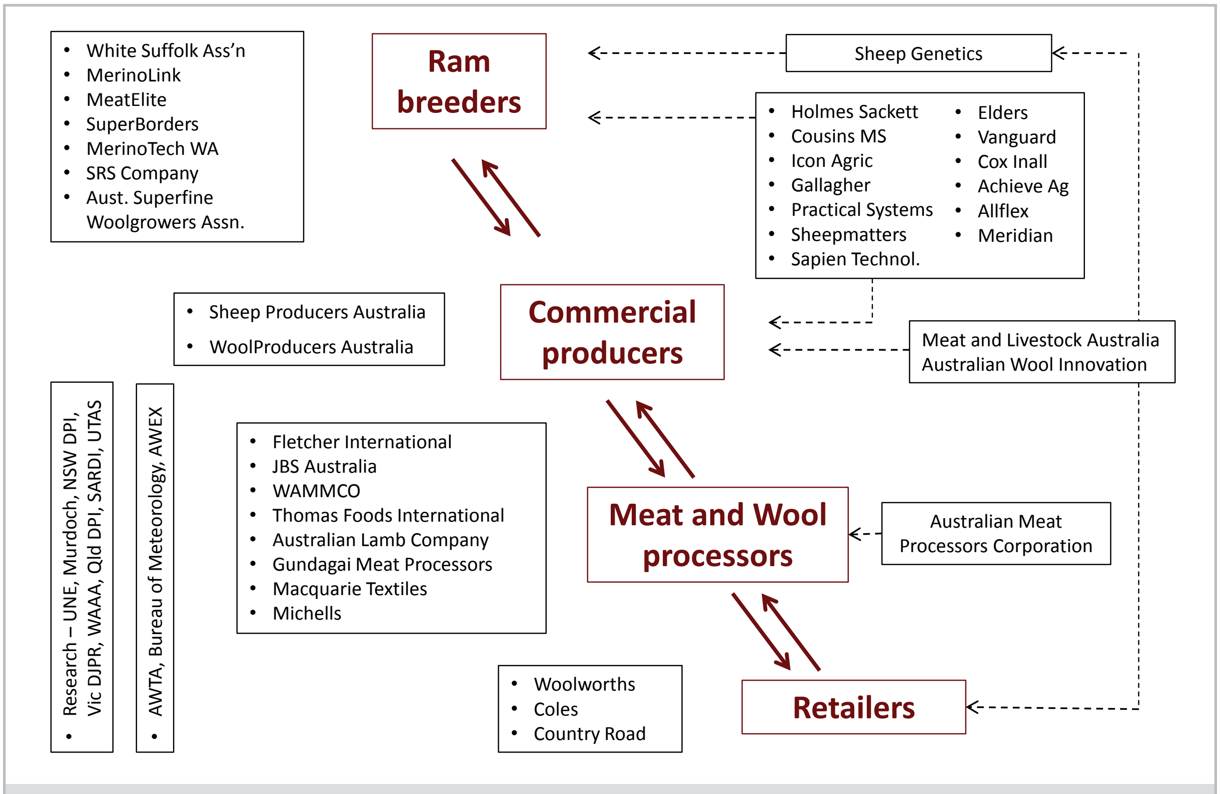


Figure 12.1: Schematic summary of the CRC Participants and supporters represented in each sector of the sheep industry.

A rigorous assessment of costs, utilisation and impact is an integral part of any CRC. The input costs of each program within a CRC are easily defined but the extent to which the outputs and products are utilised, estimating the costs of usage and the scale of subsequent benefits, tends to be more uncertain because it relies on forecasts and predictions. There are also complexities resulting from different 'products or outcomes' having very different timelines for their development, the rates at which their utilisation increases and the time scale over which benefits are realised. Quantitative analysis of impact is further complicated by linkages between the development of enabling technologies, such as eID measurement systems and genetic selection, and the flow-on benefits such as improved product quality.

The Sheep CRC conducted detailed analyses of its key research programs using the Commonwealth CRC Program's Impact Tool. However, analysis of individual research programs only tells part of the story when analysing the impact of an integrated portfolio of activities with many cross-linkages and whole-of-industry implications. The additive, synergistic and cumulative nature of benefits is difficult to quantify. There are also factors such as the long-term impact of undergraduate and postgraduate education that need to be recognised, as this determines the capacity of an industry to use new technologies and maintain momentum in discovery and innovation well into the future.

Impact amid a changing economic landscape

In assessing the impact of the Sheep CRC it is necessary to also describe the massive structural changes that occurred within the industry during this period. To investigate the CRC's role in the context of the national sheep industry, the following analysis of industry changes has drawn on data provided by the Australian Bureau of Agricultural and Resource Economics and Sciences (ABARES) (March 2019 Agricultural Commodities Report), various MLA reports, the AWI's April 2019 Wool Forecasting Report and information on wool prices provided by AWEX.

Changes in the real gross value of the sheep industry during the term of the CRC provides a good starting point to discuss the impact of the CRC. Figure 12.2 shows the changes in the real gross value of the sheep industry from 2001 to 2019. The dotted line at 2010 separates two distinct phases. During the period 2001 to 2010 there was a significant level of restructuring as the size of the flock decreased by 40% from 120 to 70 million sheep. From 2010 the size and structure of the flock remained reasonably stable and the benefits of a better integrated sheep and wool industry began to gain momentum. Importantly, during this period, the improvements in gross value of both wool and lamb progressed in parallel.

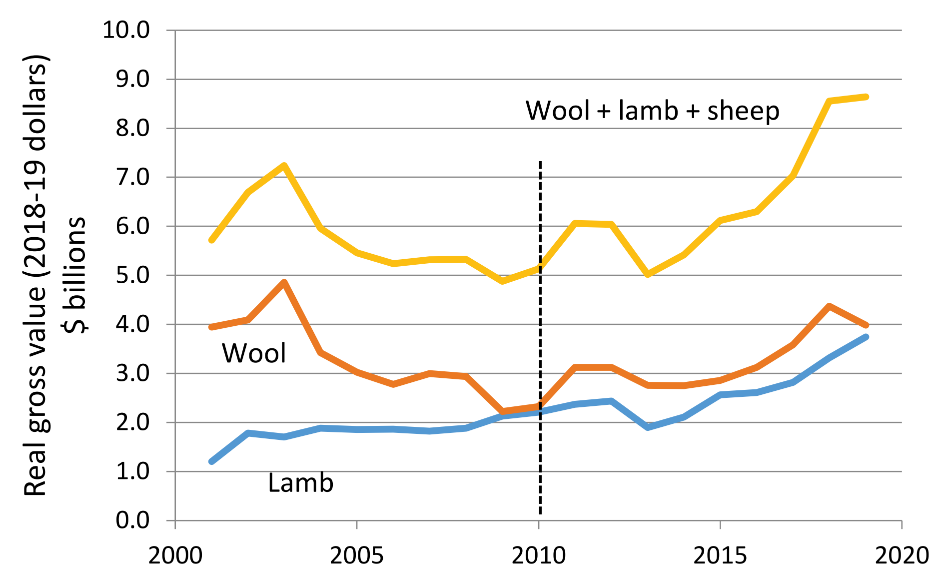


Figure 12.2: Changes in real farm-gate gross value of the sheep industry during the term of the CRC from 2001 to 2019. The dotted line marks the point in 2010 when the size of the flock stabilised at around 70 million sheep and remained relatively constant through to 2019.

The data summarised in Figure 12.2 indicates that the gross value of the Australian sheep industry (wool, lambs and sheep) increased from an average for the period 2000–2002 of $5.6 billion/year (adjusted to 2018–2019 dollars) to over $8.5 billion by 2019.

The real increase in total gross value of the industry by around 49% occurred despite a 40% reduction in the flock size. The combination of increased gross value and decreasing flock size are taken into account in Figure 12.3 that shows the increase in gross value produced per sheep over the 18 years of the Sheep CRC. The 2.6-fold increase in the real farm-gate value of production per sheep from $49/year in 2001 to $129/year in 2019 indicates the significant level of transformation occurring in the sheep industry.

It is also significant that the supply of the products contributing most to the increased gross value of the sheep industry — lamb and finer micron wools — increased in volume between 2001 and 2019. During that time lamb production increased 1.5-fold from 342 to 517kt/year and production of finer wools, in the 16.5–18μm category, increased 2.6-fold from 40 to104kt/year. The increased value per sheep is therefore a result of the sheep industry changing its focus to produce larger amounts of higher value products, rather than through prices being forced up through scarce supply due to the declining flock size.

The increased value of the sheep industry has not been the result of any single factor, but is rather the end result of improvements in many different areas resulting in a synergistic effect.

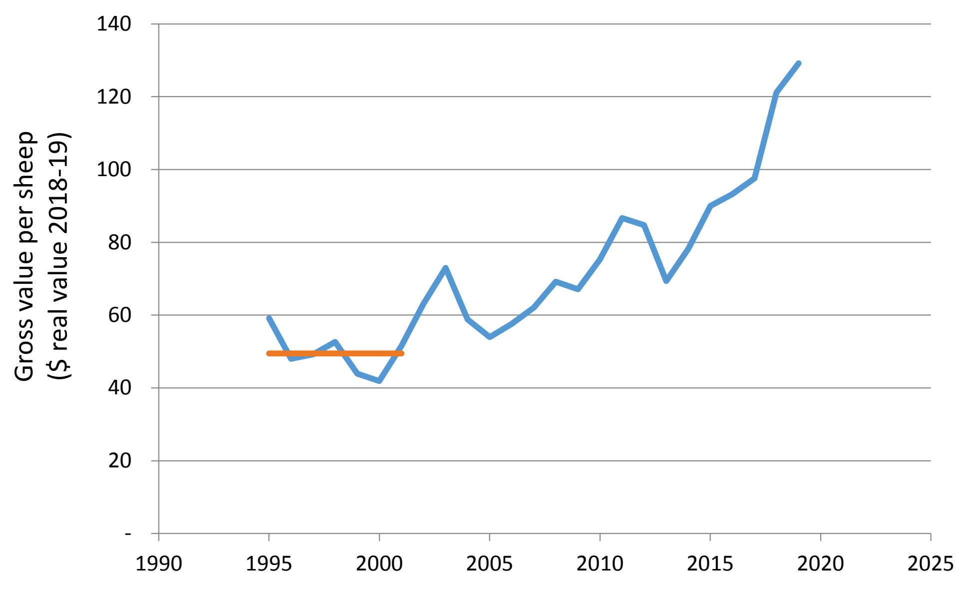


Figure 12.3: Real farm-gate gross value of production (wool, meat and sheep) divided by the total sheep population each year. The red line represents the average for the period 1995 to 2001.

Assessing the impact

Understanding consumer preference

Understanding and responding to consumer preferences was central to the CRC's programs. In the meat program consumer eating quality testing was a major research activity. Large scale consumer trials were conducted in Australia, the USA and China, to determine the effect of different cuts of meat and different cooking methods on consumers 'liking' and 'willingness to pay'. The close correlation between 'liking' and 'willingness to pay' has become well understood and the industry has the technologies at hand in genetics, management and processing to deliver the levels of quality that consumers desire and for which they are willing to pay higher prices (see Chapter 8).

In the wool program comprehensive consumer trials evaluated consumer comfort and liking of next-to-skin knitwear fabrics made from a wide range of wools and manufactured with different processing techniques. The garments were tested under a range of conditions including passive activities in an air-conditioned 'office' environment and active exercising at high temperatures. Testing also included people from different ethnic backgrounds. Again, the results demonstrated close links between comfort, liking and willingness to pay, and provided clear information on the wool and manufacturing specifications required to achieve different levels of comfort. With the Wool ComfortMeter, the industry has the technology it needs to ensure that consumers can identify and pay for the quality that they want (see Chapter 9).

Consumer expectations regarding the wellbeing of sheep did not require research. All that was needed was to pay attention to reports and views expressed in the public media. Every effort was needed to stop mulesing and every effort was needed to ensure the wellbeing of sheep through managing risks from parasites, under-nutrition and exposure to extreme weather conditions. The FlyBoss program, developed as a one-stop source of information for producers ceasing mulesing, was an early priority. As new technologies were developed, the CRC was at the forefront of research to determine how new approaches could be developed to enhance sheep wellbeing. Understanding the breeding of better-adapted sheep, moving from flock to individual animal management, and using web-based applications such as ParaBoss and ASKBILL, the industry is well placed to continue to deliver improved wellbeing outcomes. Importantly, through constructive communication, the consumer has a better understanding of the complexity and challenges involved in transforming sheep wellbeing and appreciates industry's genuine commitment to improvement (see Chapters 5, 7 and 11).

Increasing gross value of lamb (Real $1.2 billion in 2001 to $3.7 billion in 2019)

As shown in Figure 12.2, the value of lamb production continued to increase throughout the period from 2001 to 2019. All factors influencing the gross value of lamb increased: the average carcase weight; the number of lambs slaughtered; and the price per kilogram carcase weight. These trends were in place prior to the start of the CRC and continued to be supported by MLA strategies and investment. The CRC's R&D activities have also supported the upward trajectory in a number of ways. Improved understanding of eating quality and recognition that Merino lambs could produce high-quality meat have had a major impact on the expansion and profitability of this sector of the industry.

Increasing carcase weight (19 kg in 2001 to 23 kg in 2019)

The continued increase in lamb carcase weight (equivalent to approximately 350g/carcase/year) can be largely attributed to MLA's LAMBPLAN initiative and the effective selection for increased growth, increased muscling and decreased fat. The CRC's development of genomic technologies and improved genetic parameters has contributed to faster genetic gain particularly for the expanding Merino-based lamb production sector.

More lambs (18 million in 2001 to 22.5 million in 2019)

The CRC's Information Nucleus program clearly demonstrated that carcase characteristics and meat quality from Merinos and Merino-cross lambs were very similar to lambs from specialist prime lamb production dams and sires. The data collected under eight different production environments over five years provided unambiguous evidence that Merino-based lambs could, with the right genetics and nutrition, consistently meet stringent lamb quality specifications.

The CRC's initiatives to improve lamb survival and improve reproductive efficiency through the LTEM and Managing Scanned Ewes initiatives made a significant contribution to the number of lambs produced during the period from 2007 to 2018 (see Figure 7.1). The increase of between 15 and 20% in the number of lambs marked per ewe joined meant that despite a reduction in the number of ewes by nearly 20% (between 2007 and 2018), the total number of lambs produced only declined by 4%.

The within-flock selection of ewes most suited for lamb production to be joined to Terminal sires likely had an impact on the number of lambs from Merino ewes meeting turn-off specifications. The work on genetic selection options for balanced improvement in growth rate and carcase characteristics, as well as for wool production, was also likely to have contributed to the increased number of Merino and Merino-crossed lambs meeting lamb specifications each year and contributing to the total number of lambs slaughtered.

The CRC's information on nutrition for lamb finishing highlighted the need for additional nutrition for Merino-based lambs and may also have contributed to more lambs meeting the tight specifications for age, carcase weight and quality.

"The Sheep CRC's legacy will last for many years to come. We are in such an exciting period for the sheep industry and the work the Sheep CRC has done will allow us to take full advantage of rising prices. The creation of DNA testing, continued development of ASBVs, focus on meat eating quality and accurate data collection through eID has equipped commercial and seedstock sectors to take advantage of strengthening markets. We have been fortunate to be involved in many trials and technology innovations with the Sheep CRC. The leadership, focus and willingness to collaborate with producers has been a highlight of their work. With a whole of industry focus, from producers, processors, facilitators, researchers and consumers, the Sheep CRC has positioned our sheep industry beautifully."

Ben Duxson, Principal of Glendemar MPM, Marnoo, Victoria

It is interesting to note the significant reduction in live export of sheep from five to six million sheep in 2001 to around one million in 2019. Part of this reduction was likely to have been influenced by the attractive profitability of the lamb industry and new information on prime

"The use of eID by both our stud and commercial clients has made data collection easier and more accurate. It has allowed for selection decisions based on individual animal management to be made in real time, allowing for identification of the more profitable animals and culling of less valuable animals — this has been of significant importance during drought conditions. The Managing Scanned Ewe and LTEM programs have also helped our clients increase lamb marking percentages — many of them to around 100%. In our business we pregnancy scan a significant number of ewes throughout SA and parts of NSW and Victoria and have seen the benefits of better management of twin bearing ewes."

Paul and Michelle Cousins, Cousins Merino Services, Burra, South Australia

lamb production from Merino ewes with good nutritional management. CRC research quantifying the relative eating quality of Merino yearlings also points to alternative marketing opportunities if the live export trade continues to decline.

Increased price of lamb (Real $3.07/kg in 2001 to $7.25/kg carcase weight)

The CRC's work on electrical stimulation contributed to product consistency. The CRC assisted with the first installation of mid-voltage electrical stimulation systems and in the assessment of improved product quality. Research in the Information Nucleus program highlighted differences between processing plants in terms of meat tenderness measured by shear force. Variation in shear force in meat from different processing works was traced back to variable efficiency of the electrical stimulation processes used. In collaboration with AMPC the CRC helped develop protocols for calibration and testing electrical stimulation systems and provided training for staff.

The Information Nucleus program confirmed the genetic antagonism between selecting for faster growth and muscling and the corresponding decrease in eating quality, principally due to decreasing levels of intramuscular fat. As a result of this work Sheep Genetics released new 'research' breeding values for eating quality traits that created awareness of the variation that existed in the industry.

The next step was the release of a new lamb eating quality selection index based on CRC research data that balances selection for intramuscular fat and shear force while improving the major production traits of growth, muscling and fat. This new index was widely adopted as specialist meat breeds changed the focus of their breeding programs to place more emphasis on eating quality traits. This change in genetic selection was expected to have significant long- term benefits for the industry based on the research showing a clear positive relationship between consumer willingness to pay and eating quality of the product.

"The CRC coordinated widespread industry innovation that has, without doubt, improved the supply and quality of lambs. The CRC also contributed to improved processing systems to ensure consistent quality through electrical stimulation. New carcase measurement systems like DEXA and the MSA cuts-based grading program will contribute to future value-based trading."

Mark Inglis, Farm Assurance and Supply Chain Manager, JBS Australia

Change in gross value of wool (Real \$2.3 billion in 2010 to \$4.0 billion in 2019)

There were three major changes in wool production during the period 2001 to 2019. Firstly, there was a significant reduction in the amount of wool produced due to the decline in sheep numbers between 2001 and 2010. Secondly, there was a change in the type of wool produced with decreasing focus on medium wools and increasing production of fine wool. The third point was the average wool cut per head remained constant at around 4.4 kilograms during the change to production of finer wool.

Reduction in amount of wool produced

The decrease in the amount of wool produced from around 600 million kilograms (mkg) in 2001 to 340mkg in 2010 is largely explained by the 40% reduction in sheep population during this period. The gross value of wool production was consequently reduced from around \$4 billion per year to around \$2.3 billion per year during this period.

The change in production towards finer diameter wools

As discussed in Chapter 3 (see Figure 3.4) the production of wool in the micron categories 21-24 declined significantly and production of finer wools in the 16.5-18 micron categories increased rapidly. When the changes in volume of wool produced is considered in combination with the increasing premium paid for finer micron wools during the five years to 2019, it is clear that the increased value of finer micron wools has had a major impact on the gross value of wool production (see Figure 12.4). Between 2010 and 2019 the gross value of wools between 16.5 and 18 micron increased from \$1 billion to \$2.6 billion.

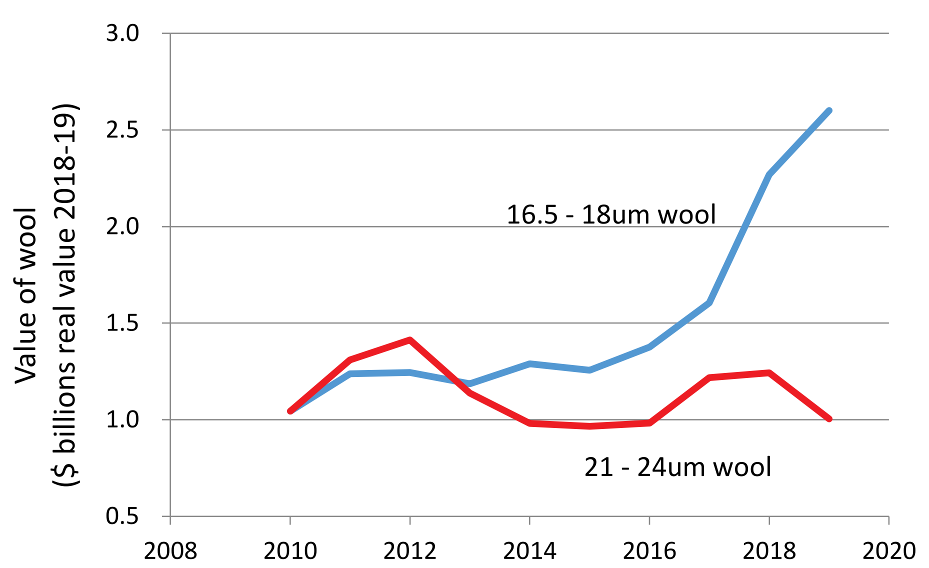
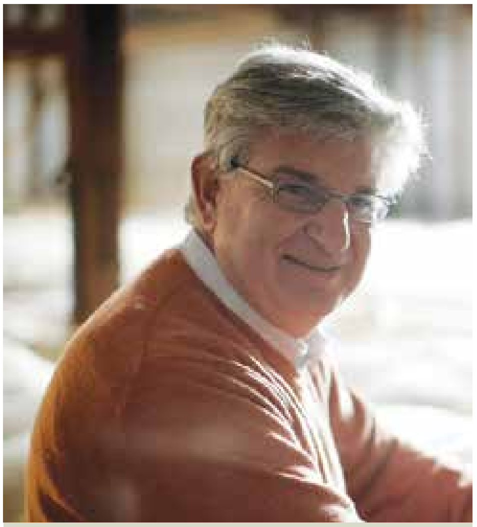


Figure 12.4: Value of wool of different micron categories based on wool production data reported by the AWI Wool Forecasting Committee and prices by micron provided by AWEX and adjusted to real 2018-19 dollars using ABARES data.



"Our 'Henry and Grace' brand for mothers' and babies' knitwear relies on the Wool ComfortMeter for quality control to ensure total next-to-skin comfort. From our experience all results point to the need for finer micron wools to meet the stringent comfort specifications for these products and there is increasing demand in the market for wool in this category."

Philip Attard, Director of Gostwyck Merino and Henry and Grace

The Sheep CRC's activities had some impact on this change through its research showing the importance of finer micron wools to deliver next-to-skin comfort, and through providing tools for genetic and within-flock selection to facilitate increased production of wools of finer fibre diameter. Once Merino breeders understood the extent of variation that existed across different strains they were able to make significant changes in their breeding programs towards finer fibre diameter and heavier fleeces.

Results of consumer testing of lightweight next-to-skin wool knitwear showed that the wearer's perception of prickle, as the main determinant of comfort, decreased with finer diameter wools. Improvements in comfort with increasing fineness were demonstrated for fibre diameters going down to 16 micron, as discussed in Chapter 9 and summarised in Figure 9.1. Moreover, the CRC developed the Wool ComfortMeter to assist quality assurance in the wool supply chain by being able to measure prickle in finished garments, fabric and in samples of yarn. Demand and premiums for finer wool are expected to continue to increase as knowledge of the CRC's research on next-to-skin comfort and the use of the Wool ComfortMeter become more widespread.

In parallel with the higher demand for finer diameter wools was the industry's capacity to rapidly increase production of these wools. The CRC's research on precision sheep production (see Chapter 6) developed methods for using within-flock selection in combination with careful ram selection to rapidly change the characteristics of wool production. Moreover, eID technologies for accurate data capture and new genomic technologies, based on DNA analysis, have provided tools for faster genetic change.

Maintaining fleece weight

Due to the strong negative correlation between fibre diameter and fleece weight, selecting for finer fibre diameter tends to lead to reduced fleece weight. Medium and coarse wool strains of Merinos tend to produce heavier fleece weights compared to finer wool strains.

It is therefore remarkable that the average fleece weight remained constant at around 4.4kg during a period when there was a reversal in the relative importance of medium wools and fine wools. It is doubtful that this rapid change from medium to finer micron wools, while maintaining fleece weight, could have been achieved without major changes in genetic selection and faster genetic improvement supported by use of eID technologies within studs. Genetic information through MERINOSELECT, more easily accessed using RamSelect, contributed significantly to simultaneous improvement in multiple traits, particularly through selection of sire across different strains of Merinos. Use of eID technologies, described in Chapter 6, made it significantly easier to measure fleece weights and relate these to micron measurements of the fleece, in order to identify and select animals that produce heavier fleeces and finer micron wools.

Building momentum and looking to the future

A large proportion of the increased gross value of sheep production occurred from 2015 to 2019. During this four-year period there was a cumulative increase of $9 billion in the value of sheep and wool production (see Figure 12.5).

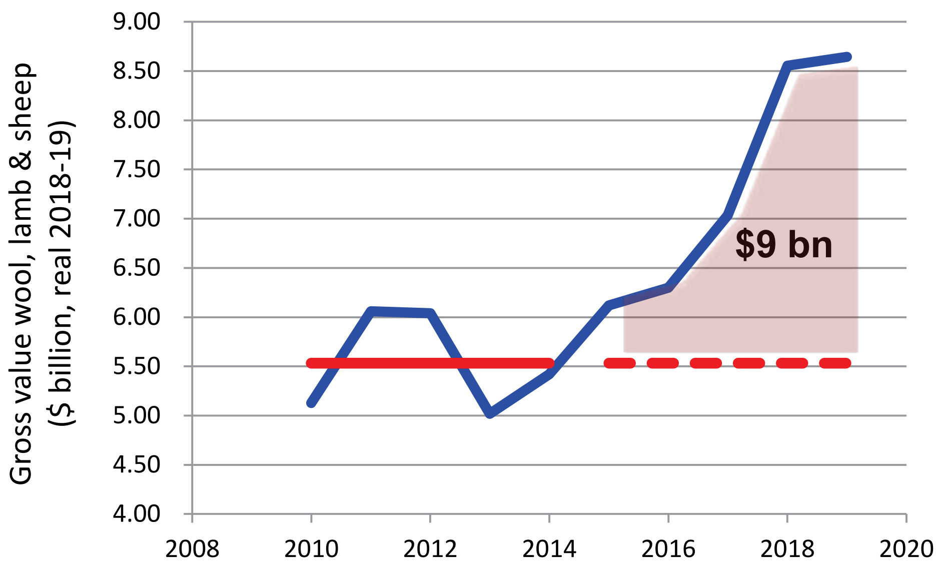


Figure 12.5: The real gross value of wool + lamb + sheep ($ billions/year in 2018 – 19 dollars) between 2010 and 2019, when the size of the flock was relatively constant at around 70 million head. The solid red line is the average for the five-year period 2010-2014. The cumulative gross value between 2015 and 2019 was $9 billion over and above the projected average earnings from the preceding five years. (Source: ABARES Commodities Tables March 2019)

However, a number of innovations developed over the CRC's 18 years, such as the genomic technologies, have long lead times before their impact will be fully reflected in the national sheep industry statistics and for this reason the upward trends shown in Figures 12.2, 12.3 and 12.5 can be expected to continue for many years. This is but one example. When the Sheep CRC wound up in 2019 there was strong momentum to ensure that the Australian sheep industry could consolidate and expand on the gains made during the previous 18 years through a range of initiatives. Further examples of commitment and momentum that will continue at the end of the CRC are described below.

Meat production and quality

- MLA, working with all sectors of the supply chain, has committed to implementing the cuts-based grading system for eating quality and lean meat yield that the CRC was so close to delivering. The new grading system will be underpinned by the carcase measurement systems that formed part of the CRC's portfolio for many years. Delivery of these measurement systems to support quality assurance and the capacity for value-based trading were to be completed by the industry's ALMTech project.

- The increased sophistication of abattoir measurement combined with eID carcase tracking was very close to commissioning at the time of the CRC's closure. They will provide enhanced feedback of data to fine-tune production systems, as well as valuable information for faster genetic gain.
- The increased use of the new selection index for balanced improvement of eating quality and productivity is expected to contribute to continued improvement in product quality and the consumer's willingness to pay.
- The extended definition of lamb, supported by the CRC's research on eating quality and changes with age, will contribute to more lambs meeting specifications and increased production volume.

Wool production and next-to-skin comfort

- Expanding industry interest in the Wool ComfortMeter is expected to be further enhanced by the new model released by AWTA in 2019, and will contribute to the increased demand for the finer wool that Australia provides.
- The use of precision production, genomic selection and eID should continue to give the ewe-based wool production enterprise the ability to simultaneously select for finer wool, heavier fleeces and efficient reproduction.
- The increasing value of mutton provides additional incentives for the Merino-based breeding flock to balance the genetic selection for both meat and wool outcomes. The strategy of having both specialist wool and meat breeding programs has placed the sheep industry in a position to capitalise on the value of both.

Sheep wellbeing

- The ParaBoss program, with its information on fly, worm and lice control, underpins the continued effective management of these parasites.
- In 2019 production of wool from flocks that do not mules made up just under 10% of the wool clip and was increasing at a rate of 1.8mkg/year. With premiums of between $0.50 and $1.00/kg for wool from non-mulesed sheep, it was anticipated that this trend would continue.

"ParaBoss was the central source of trusted information for everybody involved in managing sheep parasites: producers, veterinarians, animal health companies, researchers, academics and students. When I worked at Novartis, we used ParaBoss as an integral part of our training program for resellers and the company's sales force as it gave them confidence in the quality of the information when providing technical advice to producers. With 15,000 active users it has well and truly been adopted by the sheep industry."

Dr Justin Bailey, former National Technical Manager for Novartis Australia and New Zealand

- Benefits of the Lifetime Ewe Management (LTEM) program and the 'Managing Scanned Ewes' initiative, promoting the importance of adequate nutrition and careful management of twin-bearing ewes, have contributed to reduced lamb losses and an increased number of lambs marked by 15 to 20% since 2007 (see Figure 7.1).
- Numbers of poll rams, selected using the DNA test, have increased rapidly (see Figure 4.2). The change from horned rams has positive benefits for safety and wellbeing of ram teams, as well as contributing to safer working conditions for sheep handlers.
- ASKBILL has significant potential to transform the management of sheep to ensure their wellbeing in the face of variable climatic conditions, sub-optimal nutrition and risks of parasites.

Genetics and genomics

- The eID technologies, pioneered by the Sheep CRC for accurate data collection and record management have been widely adopted in ram breeding enterprises. They are expected to continue to support fast, well-balanced, genetic gain in the foreseeable future.
- The rapidly increasing membership of Sheep Genetics and expanding use of tools such as RamSelect and genomic profiling, point to sustained increase in the rate of genetic gain and the capacity of the industry to balance selection for wool, meat, reproduction and disease resistance.
- The introduction of genomic testing also saw a rapid increase in the use of DNA tests from 2016, with around 700 breeders using 27,000 tests by 2019. The production impact of better-balanced genetic gain and faster rates of improvement through use of genomics is only expected to be measurable post-2021 after which point benefits are forecast to increase exponentially (see Figure 12.6). The use of genomic flock profiling in commercial flocks was increasing before the end of the CRC in 2019 and could be expected to deliver additional gains.

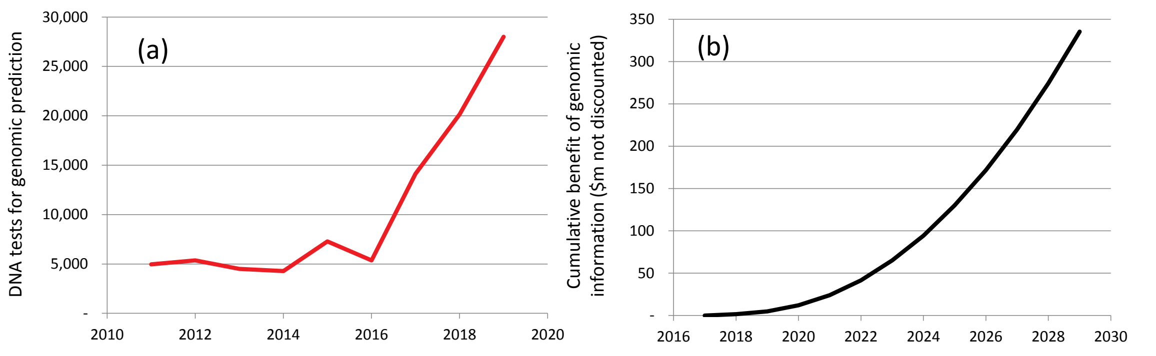


Figure 12.6: (a) Number of DNA tests to predict breeding values informed by genomic information and (b) the predicted impact of faster and better-balanced genetic gain delivered through increased value of sheep products.

“The speed with which the Australian sheep industry introduced DNA technologies, from a zero base in 2007, has provided a great example for other industries to follow. I haven’t seen anything quite like this in our global livestock genotyping business — considering the value per animal versus dairy or beef cattle, it is clear the sheep industry in Australia truly recognises the value of genomics. From the long-term thinking of investing in the development of the Information Nucleus resource flock, to the efficient and economic genotyping and reporting pipeline, it has set a new benchmark for implementing innovation. The clear value proposition for genomic technologies for ram breeders and commercial sheep producers, and the rate of uptake by industry, were important considerations in Neogen’s decision to establish an Australian laboratory and acquire the CRC’s SheepDNA business.”

Dr Jason Lilly Vice President – International Business for Neogen Corporation

Education and training

- Ongoing support for undergraduate training programs through the Australian Wool Education Trust should ensure that specialist training in sheep and wool subjects, developed by the CRC, continues for many years. New practical classes based on the use of RamSelect and ASKBILL apps will be used to prepare school leavers and graduates as they enter the workforce in years to come.
- Postgraduate students trained during the CRC will continue to contribute to innovation and technical development for the sheep industry throughout their careers.
- The Livestock Library, developed by the Sheep CRC in collaboration with the Beef CRC and AWI, will continue to be hosted by MLA to provide ongoing access to conference proceedings, CRC publications and reports.

Legacy arrangements

The CRC, with support from MLA and all CRC Participants, made formal arrangements for the assignment of all IP generated over its 18 years to ensure that the IP and related products would continue to be accessible and used for the benefit of the industry.

The business of coordinating sheep DNA testing through the Australian Innovation Company (AIC) was transferred to Neogen Australasia and a smooth transition had already occurred at the time of the CRC's closure.

The CRC, with approval from the Commonwealth, also made a number of grants to ensure continued delivery of CRC products and support for future industry planning and collaboration. These included:

- The Southern Australian Livestock Research Committee (SALRC) accepting responsibility for coordinating an industry-wide planning workshop during 2020 to review opportunities and risks for the sheep industry, with a view to developing collaborative initiatives to tackle major issues.
- A grant to the University of New England for the maintenance and commercialisation of the web-based apps, ASKBILL and RamSelect.
- A grant to Murdoch University to continue the coordination of professional development and an annual conference for postgraduates working in the sheep and related livestock industries.
- Unspent funds from the AIC were distributed to the Australian Wool Education Trust (AWET) to support the continued development and delivery of teaching materials that utilise the web-based apps, ASKBILL and RamSelect.
- Funds available from AIC were allocated to the University of New England to upgrade server software to support the DNA ordering system and the web-based apps.

From Concept to Impact and Beyond

The sheep industry can look back with pride on the 18 years of the Sheep CRC as a period of effective collaboration and dramatic transformation.

The industry should also look forward to the ongoing benefits that will accrue into the future from the transformational changes delivered by the Sheep CRC. With formal legacy arrangements enacted prior to the CRC's closure, including a 2020 planning workshop to identify new collaborative research initiatives, the sheep industry is set to continue its transformation for many years to come.

APPENDICES

Appendix I — Sheep CRC Participants

Sheep CRC1

Essential Participants

Australian Meat Processor Corporation
Commonwealth Scientific and Industrial Research Organisation
Department of Agriculture, Western Australia
Department of Primary Industries, Queensland
Department of Primary Industries, New South Wales
University of New England

Supporting Participants

Australian Wool Education Trust
Australian Wool Innovation
Bett Trust
Department of Primary Industries, Water and Environment, Tasmania
Elders
Fletcher International Exports
Interactive Wool Group
La Trobe University
Meat & Livestock Australia
Merino Benchmark
Murdoch University
Primary Industries and Resources South Australia
Sheepmeat Council of Australia
TAFE NSW
University of Melbourne, The Mackinnon Project
University of Sydney
WoolProducers Australia

Sheep CRC2

Essential Participants

Australian Wool Innovation
Commonwealth Scientific and Industrial Research Organisation
Department of Agriculture & Food, Western Australia
Department of Primary Industries, New South Wales
Meat & Livestock Australia
Murdoch University
University of New England
Allflex Australia
Australian Meat Processor Corporation
Australian Wool Testing Authority
Deakin University
Department of Primary Industries and Fisheries, Queensland
Department of Environment & Primary Industries, Victoria
Holmes Sackett
JRL Hall & Co (Icon Agriculture)
Mike Stephens & Associates
Sheepmeat Council of Australia
South Australian Research & Development Institute
University of Tasmania
University of Western Australia
WoolProducers Australia

Contributors

AgriFood Skills Australia
Beijing Spinning Mill
Country Road
Crystal Knitwear
Farming Systems Analysis Service
JT Agri-Source
Macquarie Textiles Group
Rural Industries Skill Training
The CIEL Group
The Merino Company

Sheep CRC3

Essential Participants

Australian Meat Processor Corporation
Department of Primary Industries, New South Wales
Department of Jobs, Precincts & Regions, Victoria
Meat and Livestock Australia
Murdoch University
Sheep Producers Australia (formerly Sheepmeat Council of Australia)
South Australian Research and Development Institute
University of New England
Western Australian Agricultural Authority
WoolProducers Australia

Supporting Participants

Achieve Ag Solutions
Allflex Australia
Australian Superfine Wool Growers' Association
Australian White Suffolk Association
Australian Wool Exchange
Australian Wool Testing Authority
Bureau of Meteorology
Coles Supermarkets Australia
Cousins Merino Services
Cox Inall Communications
Food Processing Equipment
Frontmatec A/S (formerly Carometic A/S)
Gallagher Australia
Icon Agriculture
JBS Australia
Meat Elite Australia
Meridian Agriculture
MerinoLink
Merinotech (WA)
Practical Systems
Sapien Technology
Sheepmatters
SuperBorders Inc
The SRS Company
Thomas Foods International
University of Adelaide
University of Melbourne
University of Tasmania
Vanguard Business Services Pty Ltd
Western Australian Meat Marketing Cooperative
Woolworths

Contributors

Telstra
D2D CRC

Appendix II — Sheep CRC Boards

Sheep CRC1 Board

Sheep CRC1 operated as a joint venture with six Participants. The Board had an independent Chair and four independent members. Each Essential Participant had one representative on the Board with an alternate appointed to attend meetings if the appointed member was not available. There were four industry representatives.

Sheep CRC1 Board of Directors: 2001-2007

Chair

The Rt. Hon. Ian Sinclair (Independent Chair)

Essential Party Representatives

CSIRO	Ian Purvis
	Rob Woolaston
NSW DPI	Helen Scott-Orr
	Nick Austin
	Stephen Thomas
UNE	Peter Flood
	Margaret Sedgley
AMPC	Roger Fletcher
	Ross Graham
	Joanne Sillince
QLD DPI	Barry McDonald
	Greg Robbins
	Paul Grieve
DAFWA	Renata Paliskis-Bessell
	Mark Dolling

Industry Representatives

Sheepmeat Council	Warwick O'Connor
	Julie Lloyd
MLA	Ben Russell
	Reuben Rose
	Rob Banks
AWI	Len Stephen
	Ian Rogan
WoolProducers	Graham Peart
	James Kennedy

Independent Board Members

Christine Hawkins
Hugh Nivison
Steven Read
Andrew Vizard

Sheep CRC 2&3 Board

Sheep CRCs 2 and 3 operated as an incorporated entity, Sheep CRC Ltd, with independent skills-based Boards.

Sheep CRC2 Board of Directors: 2007–2014

Chair

Dr John Keniry, AM (Chair)

Directors

Rob Egerton-Warburton
John Gibson
Ian Johnsson
Kate Joseph
John Lewis
Stuart Mitchell
David Sackett
Roger Fletcher (2007–2009)
Peter Trefort (2009–2014)
Christine Hawkins (2007–2011)
Phillip Rose (2011–2014)

Sheep CRC3 Board of Directors: 2014–2019

Chair

Duncan Fraser (Chair, 2014–2017)
Ian Wilton (Chair, 2017–2019)

Directors

John Gibson
Ian Johnsson
Peter Trefort
Stuart Mitchell
Kate Joseph (2014–2015)
Mike van Blommestein (2015–2019)
Phillip Rose (2014–2015)
Ian Wilton (2015–2017)
Catherine Hayne (2017–2019)

Appendix III — Committees

EXECUTIVE COMMITTEE

The Executive Committee was responsible for overseeing the operational aspects of the CRC, and for providing recommendations to the Board regarding technical issues and resource implications. In addition to the CRC Research and Education Program Leaders, membership of the Committee included the CEO, the Finance Manager (CFO) and representatives of MLA and AWI (CRC1 and CRC2). The Executive Assistant was responsible for coordinating meetings and associated documentation.

Sheep CRC1

James Rowe	CEO, Chair
Debra Lane	Exec Assistant
Kevin Atkins	Precision Sheep
Brown Besier	Parasitology
Julius van der Werf	Genetics
David Pethick	Meat Science
Dave Jordan	Nutrition
Ian Purvis	Wool (2001–2003)
Ken Geenty	Wool (2003–2007)
David Cottle	Education
Deborah Maxwell	Communication
Ian Rogan	Technology Evaluation
Peter Silk	IP & Licensing (2005–2007)
David Simmons	Finance (2001–2005)
Ching Gee	Finance (2005–2007)
Paul Swan	AWI Rep (2003–2007)
Christine Hawkins	Board Observer

Sheep CRC2

James Rowe	CEO, Chair
Janelle Holzberger	Exec Assistant (2007–2008)
Helen Sisson	Exec Assistant (2008–2014)
Andrew Thompson	Animal Management
Neal Fogarty	Information Nucleus
Julius van der Werf	Genetics
David Pethick	Meat Science
Paul Swan	Wool Science
David Tester	Wool Science
Steve Walkden-Brown	Education
Graham Truscott	Commercialisation
Peter Silk	IP and Licensing
Alex Ball	MLA Rep
Lu Hogan	AWI Rep (2007–2008)
Geoff Lindon	AWI Rep (2008–2009)
Jane Littlejohn	AWI Rep (2009–2014)
Ching Gee	CFO (2007–2010)
Steve Potts	CFO (2010–2014)

Sheep CRC3

James Rowe	CEO, Chair
Helen Sisson	Exec Assistant (2014–2015)
Polly Ward	Exec Assistant (2015–2019)
Geoff Hinch	Sheep Wellbeing (2014–2017)
Lewis Kahn	Sheep Wellbeing (2017–2019)
David Pethick	Meat Science
Julius van der Werf	Genetics
Lu Hogan	Industry Engagement
David Faulkner	Commercialisation (2016–2017)
Alex Ball	MLA Rep (2014–2016)
Richard Apps	MLA Rep (2016–2017)
Jane Weatherley	MLA Rep (2017–2018)
Michael Crowley	MLA Rep (2017–2019)
Steve Potts	CFO (2014–2015)
Kate Woodland-Smith	CFO (2015–2019)

PROJECT REVIEW & RESEARCH COMMITTEE

The Project Review and Research Committee (PRRC) was responsible for monitoring progress and providing an independent assessment of research quality. The Committee Chair, and the 'research' and 'adoption' specialists, were appointed by the Board. The Committee was also responsible for recommending quarterly payments by Participants contributing funding allocated to specific activities. Participants contributing targeted funding, such as MLA, AWI and WoolProducers Australia, all had representatives on the Committee in order to have direct input to discussion on progress and related payments. The CEO and CRC finance staff attended meetings to provide supporting information where needed. Rhonda Brooks was the Executive Officer for the Committee.

Sheep CRC1

Chair

Sas Douglas

Independent members

Dennis Watson
Keith Entwhistle
Phil Hynd
David Masters
MLA representative
Ben Russell
Hutton Oddy
AWI representative
Paul Swan
CRC Visitor
John Vercoe (2001–2005)
Rob Woolaston (2005–2007)

Sheep CRC2

Chairs

Sas Douglas (2007–2008)
Dennis Watson (2008–2010)
David Masters (2010–2014)

Independent - adoption

Michael Goldberg (2007–2009)
Andrew Burgess (2009–2014)

Independent - research

Neal Fogarty (Research)

MLA representative

Alex Ball

AWI representative

Lu Hogan (2007–2009)
Paul Swan (2009–2010)
Jane Littlejohn (2010–2014)

Sheep CRC3

Chair

David Masters

Independent - adoption

Andrew Burgess (2014–2015)
Jenny O'Sullivan (2015–2019)

Independent - research

Neal Fogarty

MLA representative

Alex Ball (2014–2016)
Richard Apps (2016–2019)

WoolProducers Australia representative

Andrew Johnston

EDUCATION & TRAINING ADVISORY COMMITTEE
Sheep CRC1

The commitment to developing education resources during CRC1 required integration of university, vocational and industry training programs. Membership of the Education Advisory Committee reflected the range of end-users of the educational resources under development. Given its substantial investment in this field, the committee also included representative of the Australian Wool Education Trust.

Chair (A Sheep CRC Board Member)

Margaret Sedgley	(2001-2005)
Andrew Vizard	(2005-2007)

Members

Cameron Archer	Vocational Education and Training (VET) sector
Tony Audley	Vocational Education and Training (VET) sector
Nick Costa	University sector
David Cottle	University sector and CRC Program Leader sector
Duncan Fraser	AWI Rep
Paul Comyn	AWI Rep
Hilary Heffernan	MLA Rep
Neale Price	MLA Rep
Michael Jackson	AWTA/Australian Wool Education Trust
Peter Sommerville	AWTA/Australian Wool Education Trust
David Ward	AWTA/Australian Wool Education Trust

WOOL COMMERCIALISATION & ADOPTION COMMITTEE
Sheep CRC2

The Wool Program during CRC2 focussed on development of new measurement systems for comfort and handle of light-weigh next-to-skin knitwear. It was clear that use of the new measurement systems would have widespread implications for the wool supply chain and the Board appointed an Advisory Committee to help set specifications and user requirements for the new systems. The Committee also helped to assess the prototype proof-of-concept measurement devices. The Committee was chaired by John Lewis, who was a CRC2 Director and Chair of the Board's Adoption and Commercialisation sub-Committee.

Chair

John Lewis	CRC Director

Members

Jimmy Jackson	AWI Rep
Stuart Lucas	Industry Rep
Natalie Skubel	Industry Rep
Kenny Wallace	Industry Rep
Jim Marler	Consultant
Paul Swan	CRC Wool Program Leader
Geoff Naylor	CRC Project Leader
Peter Silk	CRC Commercialisation
James Rowe	CRC CEO

Appendix IV — Office Staff and Management Team

The office team was located at CSIRO, Chiswick, during CRC1 and UNE, Armidale, for CRC2 and CRC3. In addition to the office staff there were a number of CRC employees and consultants who worked off-site. The office management team was responsible for the day-to-day administration of CRC finances, for the organisation of all CRC Board and Committee meetings, conferences and workshops, as well as for all associated reporting to CRC stakeholders and the Commonwealth. Good teamwork and flexibility were essential selection criteria for members of the team.

Sheep CRC1

CSIRO, Chiswick

James Rowe	Chief Executive Officer
Debra Lane	Executive Assistant
David Simmons	Finance Manager (2001–2005)
Ching Gee	Finance Manager (2005–2007)

Off-site members of the management team:

Deborah Maxwell	Communications, UNE
Peter Silk	IP and licensing (2005–2007), Melbourne
Heidi Hoffman	Desktop publishing and website, UNE

Sheep CRC2

UNE, Armidale

James Rowe	Chief Executive Officer
Rhonda Brooks	Office Manager, Finance Assistant, Graphic Designer
Janelle Holzberger	Executive Assistant (2007–2008) Communications Coordinator (2008–2014)
Helen Sisson	Executive Assistant (2008–2014)
Ching Gee	Finance Manager (2007–2009)
Steve Potts	Finance Manager (2010–2014)

Off-site members of the management team:

Lu Hogan	Industry engagement, Sydney
Peter Silk	IP and licensing, Melbourne
David Dawson	Communications, Cox Inall, Sydney
Michael Thomson	Communications, Cox Inall, Rockhampton
Les Targ	Business planning, Sydney

Sheep CRC3

UNE, Armidale

James Rowe	Chief Executive Officer
Rhonda Brooks	Office Manager, Finance Assistant, Graphic Designer
Janelle Holzberger	Communications Coordinator (2014–2015)
Helen Sisson	Executive Assistant (2014–2015)
Polly Ward	Executive Assistant (2015–2019)
Steve Potts	Chief Financial Officer (2014–2015) Consultant for transition and wind-up (2019)
Kate Woodland-Smith	Chief Financial Officer (2015–2019)
Lu Hogan	Industry engagement
David Faulkner	Commercialisation Manager (2017–2018)

Off-site members of the management team:

Michael Thomson	Communication, CQU, Rockhampton
Janelle Holzberger	Communications and publicity, Urunga
Les Targ	Business Planning, Sydney

Sheep DNA Processing and Australian Innovation Company

James Rowe	Chief Executive Officer
Lu Hogan	Coordinator and Chief Executive Officer
Rhonda Brooks	Finance Assistant
Kate Woodland-Smith	Finance Manager
Bec Macarthur-Onslow	Office Manager
Marg Shedden	Sample Coordination and client liaison
Andrea Simpson	Sample Coordinator and client liaison
Klint Gore	Database Manager and Data Analyst

Appendix V — Program and Project Leaders

* Denotes 'Program Leader'

Sheep CRC1

1.1 Genetics

Neal Fogarty
Johan Greeff
John Henshall
Timothy Mahony
Belinda Norris
Julius van der Werf*

1.2 Wool science

Kimbal Curtis
Ken Geenty* (2003–07)
Sue Hatcher
Graham Higgerson
Arthur le Feuvre
Trevor Mahar
Ian Purvis* (2001–02)
Tony Schlink

1.3 Meat Science

Heather Channon
David Hopkins
Bill O'Halloran
David Pethick*
Liliana Salvatore
Robyn Warner

1.4 Parasite management

Brown Besier*
Ian Colditz
Peter Hunt
Peter James
Malcolm Knox
Andrew Kotze
Dieter Palmer
Mark Sandeman
Rob Woodgate

1.5 Nutrition

Norm Adams
Maree Bowen
David Jordan*
Rachel Kirby
David Pethick*

2.1 Precision sheep production

Kevin Atkins*
Andrew Swan
Col Scrivener

2.2 eID Hardware and software

Tim Dyall
Steve Semple*
David Miron

2.3 On-farm implementation

Kevin Atkins*
James Skerritt

3.1 Communication

Deborah Maxwell*
Wendy McGleish

3.2 Extension Support

Patrick Page*

3.2 Technology Evaluation

Garry Griffith
Ian Rogan
David Vere*

3.3 Knowledge Management

Ruth McIntyre
John Thompson

4.1 Postgraduate Education

Graham Gardner

4.2 Undergraduate resources

David Cottle*

4.3 Vocational training

Paul Comyn
Tony Hamilton*
Michael Williams

Sheep CRC 2

1 Transforming sheep and their management

Kevin Atkins
Russell Barnett
Ralph Behrendt
Brown Besier
Mark Coupland
Mark Ferguson
Geoff Hinch
Lu Hogan
Dave Jordon
Deborah Maxwell
Geoff Naylor
Chris Shands
Andrew Thompson*
Phil Vercoe
Rob Woodgate

2 Next generation wool quality

Sue Hatcher
Phil Hynd
Trevor Mahar
Bruce McGregor
Keith Millington
Jen Smith
Andrew Swan
Paul Swan* (2007–09)
David Tester* (2009–14)

3 Next generation meat quality

Blair Brice
David Hopkins
Robin Jacob
Matthew McDonagh
Bill O'Halloran
David Pethick*
Liliana Salvatore

4 Information Nucleus

Forbes Brien
Hans Daetwyler
Neal Fogarty
Ken Geenty
Julius van der Werf*
Lu Hogan

5 Education

David Cottle
Graham Gardner
John Goopy
Steve Walkden-Brown*

6 Communication and Administration

David Dawson
James Rowe*
Peter Silk
Michael Thomson
Graham Truscott

Sheep CRC3

1 Sheep Wellbeing

Johan Boshoff
Mary Goodacre
Geoff Hinch* (2014-16)
Lu Hogan
Lewis Kahn* (2017-19)

2 Quality meat

Graham Gardner
David Hopkins
Robin Jacob
David Pethick*

3 Genetic gains

Hans Daetwyler
Tom Granleese
Iona McLeod
Julius van der Werf*
Lu Hogan

4 Communication and Education

Graham Gardner
James Rowe*
Michael Thomson

Appendix VI — Advisory Groups

Industry Advisory Committee – Sheep CRC1

Prior to the annual planning meeting in 2003, the CRC established an Industry Advisory Committee to work with the research teams to ensure that programs were designed to address issues of significant industry importance.

The Committee was chaired by a Board Member: Hugh Nivison (2003-2005); and Jim Kennedy (2005-2007). Membership of the Committee included leading sheep producers and consultants from different geographic regions with experience covering a range of sheep and wool production systems.

Committee Members met each year at the time of the CRC planning meeting in Coffs Harbour and participated in the process of reviewing projects and fine-tuning the program for the coming year.

The following members served on the Committee during Sheep CRC1.

Jim Alexander
Katrina Blomfield
Peter Chambers
Andrew Crawford
Shane Edwards
Carol Godfrey
Tom Hawker
Sue Jarvis
Jim Kennedy
Geoff Lindon
Robert Lindsay
Michael McBride
Gerard McShane
Denzil Mills
Hugh Nivison
Warwick O'Connor
David Sackett
Maurie Stephen
Peter Young

Information Nucleus Advisory Groups

In order to ensure that management of each Information Nucleus flock was consistent with local best practice for commercial wool and lamb production, the CRC established advisory groups at each site. Each group was made up of three to four local producers or consultants and aimed to have a combination of ram breeders and commercial wool and lamb specialists.

In addition to providing advice to assist in management of the flock, members of the advisory groups played an important role in communication with local producers and in helping to plan the annual open days held at each site.

Kirby, Armidale, NSW

Andrew Burgess
Lachie Fulloon
Maurie & Gerard Stephen

Cowra, NSW

Murray Long
Charlie Merriman
Robert Standridge

Trangie, NSW

Jennifer Bradley
Kevin Flinn
Rob Lindsay

Hamilton, Victoria

Shane Arnold
Tim Johnstone
Tom Silcock

Rutherglen, Victoria

Andrew Bouffler
Leigh Hartwig
Phil Toland

Turretfield, South Australia

Don Blesing
Troy Fischer
Ian Rowett

Struan, South Australia

Lynton Arney
Kym Staude
Lachie Stewart

Katanning, Western Australia

Dawson Bradford
Bob Hall
Brett Jones
Sarah Wiese

Lamb Supply Chain Group

The Lamb Supply Chain Group was established in 2012 during Sheep CRC2. Under the Chairmanship of Dr Alex Ball, and with Bruce Hancock as the Executive Officer, it was set up as a joint CRC/MLA initiative. The aim was to have regular meetings between processors, producers and researchers to review new information coming out the CRC's programs, as well as planning future research training and implementation.

Over time, attendance at these Supply Chain meetings expanded as word got around that the information exchanged was of real value to all attendees. At the end of the CRC in 2019, MLA expanded the scope of the Supply Chain Group to include beef processors, producers and researchers. The list of attendees during the period from 2012 to 2019 demonstrates the widespread interest.

Clara Bradford	Graham Gardner	Demi Lollback	Stephen Pocock
Bec Austin	Verity Gilbertson	Richard Lower	Jo Quigley
Peter Bailey	Sam Gill	Matthew Martin	Hayley Robinson
Rob Banks (Chair)	Chloe Gould	Brad Mathers	Christian Ruberg
Robert Barker	Dean Gutzke	Garry McAlister	David Rutley
Simon Bawden	Sarita Guy	Peter McGilchrist	Andrew Slack-Smith
David Bevis	Bruce Hancock	Brent McLeod	Chris Smith
Blair Brice	Andrew Hay	Doug McNicoll	Sean Starling
Daniel Brown	Ravi Hegde	Jon Meggison	Sarah Stewart
Honor Calnan	Michelle Henry	Dale Miles	Sarah Strachan
Hamish Chandler	Janelle Hocking-Edwards	Murray Miller	Warren Straw
Steve Chapman	Tim Hollier	Sean Miller	Ashley Strom
Clara Collison	Ben Holman	Rodney Minute	Andrew Thompson
Regan Crooks	David Hopkins	Bruce Mullan	Kara Tighe
Michael Crowley	Hannah Hudson	Melissa Neal	Edwina Toohey
Rob Davidson	Pat Hutchinson	Chris Nicklin	Graham Treffone
Megan Davies	Mark Inglis	Matt O'Bryan	Graham Truscott
Matt Dorney	Robin Jacob	Bill O'Halloran	Ben Verrall
Richie Dulin	Renelle Jeffrey	David Packer	Stuart Warner
Tim Elwin	Shaun Johnston	Lis Pannier	Jane Weatherley
Jonathon England	David Jones	Murray Patrick	Jose Webb
Fahri Fahri	Kate Joseph	Kelly Pearce	Josh Whelan
Dave Falepau	Tracy Lamb	Dave Pemberton	Ashley White
Terry Farrel	Janine Lau	Mick Pendergast	Emma Winslow
Doug Faulkner	David Lean	Jess Perovic	Lisa Wishart
Dale Flanigan	Carmella Lee	Dave Pethick	
Steph Fowler	Stella Lee	Wayne Pitchford	

Appendix VII — Sheep CRC Postgraduate Program

Postgraduate Conference and Professional Development Program

The annual Postgraduate Conference and Professional Development program, coordinated by Graham Gardner, made an important contribution to ensuring postgraduates, trained through the CRC program, emerged 'industry ready'.

The audience for each Postgraduate Conference included a panel of 6-10 senior researchers. Panel members were primed to ask challenging questions following each presentation and to provide a detailed critique and feedback for each student.

Over the years, the following people participated in the Postgraduate Conferences as members of the panel:

Chris Anderson	Peter Dundon	Caroline Jacobson	Nick Sangster
Alex Ball	Frank Dunshae	Ian Jenson	Sean Starling
Alan Bell	Drewe Ferguson	Ian Lean	Andrew Thompson
Bernie Bindon	Cedric Gondro	Ala Lew-Tabor	John Thompson
Cindy Bottema	Paul Greenwood	Matthew McDonagh	Julius van der Werf
Daniel Brown	Garry Griffith	David Pethick	Duncan Veal
Heather Burrow	Wayne Hall	Wayne Pitchford	Steve Walkden-Brown
Nick Costa	Greg Harper	Ian Purvis	Dennis Watson
David Cottle	Ben Hayes	Jim Rothwell	Jane Weatherley
Daryl D'Souza	John Henshall	James Rowe	Henry Zerby

The Professional Development Workshops included three topics: project planning and management; scientific writing; and communication skills. These three topics were presented over a three-year cycle ensuring that each student had an opportunity of participating in workshops on each topic.

Specialists delivering the workshops included:

David Lindsay - Scientific writing
Michael Thomson - Communication skills, targeted to the audience
Russell Barnett - Planning projects to deliver value
David Faulkner - How to sell your skills and your results
James Rowe - Using the CRC's Impact Tool for planning and assessing research
Jenni Metcalfe – Professional development
Hugh Wakefield - Project management and performance

Sheep CRC Postgraduates

COMPLETED BY 30 JUNE 2019

Alkalaldeh	Mohammad	UNE	PhD	Using genomic information for genetic improvements of gastrointestinal parasite resistance in Australian sheep
Anderson	Fiona	Murdoch	PhD	The impact of lamb genotype on carcass composition and the relationship with intramuscular fat.
Anderson (nee Martin)	Kirstie	UNE	PhD	Effect of selection for muscling on muscle structure and function in sheep
Bailey	Justin	UNE	PhD	The ecology of Trichostrongylus colubriformis in summer rainfall regions and the environmental factors which affect the development and survival of its free living stages.
Barnett	Mark	UNE	PhD	Impact of digestive physiology on methane production in sheep.
Barwick	Jamie	UNE	PhD	On-animal motion sensing using accelerometers for sheep behaviour and health monitoring
Beasley	Anne	UNE	PhD	Periparturient relaxation of immunity to sheep worms: causes, control and implications for development of immunity in lambs
Behrendt	Karl	UNE	PhD	Bioeconomics of pasture resource development in sustainable sheep production systems
Bird-Gardiner	Tracie	UNE	Masters	Fly strike in mulesed and unmulesed sheep and genetic relationships with production and visually assessed traits.
Broomfield	Madeleine	UNE	Masters	Factors influencing immunity and effects on wellbeing and production in Merino ewes and lambs
Brown	David	UNE	PhD	The factors affecting the commercialisation of remote sheep weighing technology.
Burnard (nee Dodd)	Cathy	Adelaide	PhD	Measures of behavioural reactivity and their relationships to carcass and meat quality in sheep
Calnan	Honor	Murdoch	PhD	The influence of phenotypic and genotypic factors on the colour of lamb meat during retail display.
Campbell	Angus	Melbourne	PhD	The effect of time of shearing on wool production and quality in a self-replacing merino flock
Clark	Samuel	UNE	PhD	The analysis and use of genomic data in the genetic evaluation of livestock
Colvin (nee Healey)	Alison	UNE	PhD	Intensive rotational grazing reduces gastrointestinal nematodosis in sheep in a summer rainfall climate
Cotton	Steve	La Trobe	PhD	Analysis and diagnostic potential of faecal antigens from sheep infected with T.colubriformis
Cotton (nee Burgess)	Jacqueline	La Trobe	PhD	Faecal odour analysis of gastrointestinal nematodes in sheep
de Graaf	Simon	Sydney	PhD	Development of sperm sexing technology in sheep
Dever	Michelle	UNE	PhD	Improving the effectiveness of gastrointestinal nematode (GIN) control for meat-breed lamb production systems on the Northern Tablelands, New South Wales
Doyle	Emma	UNE	PhD	Physiological responses to GIN in sheep selected for Haemonchus contortus

Elliott	Joanne	UWA	PHD	The roles of attitudes, social influence and human behaviour in the adoption of strategies to improve lamb survival by sheep producers
England (nee Cornelius)	Meghan	Murdoch	PhD	Targeted selective treatment strategies for sustainable nematode control and delay of anthelmintic resistance in adult Merino sheep
Farrell	Liz	UNE	PhD	Duddingtonia flagrans as a biological control agent for parasitic nematodes
Ferguson	Mark	Murdoch	PhD	Impact of selection for carcass and growth on maternal performance in merinos
Fischer	Troy	UNE	PhD	Genetic analysis of growth and carcase development in sheep
Fuller	Paula	Murdoch	PhD	Physiological understanding of new generation post slaughter electrical technologies
Granleese	Tom	UNE	PhD	Optimised livestock breeding programs using female reprodutive technologies an genomic selection
Haynes	Fay	UNE	PhD	Body composition and growth in lambs
Hergenhan	Rachelle	UNE	PhD	Assessing neonatal lamb vigour
Hillbrick	Linda	Deakin	PhD	Softness of wool fibres
Jacobson (nee Bath)	Caroline	Murdoch	PhD	Nutrition and parasite interaction in scouring adult sheep
Jones	Robert	UNE	Masters	Genetic indicator traits to improve lamb survival
Jose	Cameron	Murdoch	PhD	The anti- and pro-oxidant interaction with lamb myoglobin for improved shelf life
Kearton	Tellisa	UNE	Masters	Body temperature as a remote measure of health in sheep
Kelly	Gareth	UNE	PhD	Effect of gastrointestinal worms on sheep production
Kelman	Khama	Murdoch	PhD	Lamb growth impact on muscle oxidative capacity and meat quality
Kennedy	Andrew	UWA	PhD	Transforming sheep and their management: robust ewes in alternative lambing systems.
Kennedy (nee Thomson)	Kirsty	UNE	PhD	Processing and Genetic factors that affect the post-mortem tenderisation of beef and lamb carcasses
King	Alison Lee	Deakin	PhD	The influence of trace metals on the colour and photostability of wool
Li	Li	UNE	PhD	Quantifying protein turnover in Merino sheep with differing wool growth and meat production
Mahony (nee Barton)	Sally	UNE	PhD	Selectively breeding Merino sheep for wool that does not shrink when processed
Monk	Jessica	UNE	PhD	Assessing resilience and its genetic basis in sheep
Mounter	Stuart	UNE	PhD	An equilibrium displacement model of the Australian sheep and wool Industry
Paganoni	Beth	UWA	Masters	Foetal programming of fat and muscle in merino sheep
Plush (nee Lennon)	Kate	Adelaide	PhD	Relationships between maturity, vigour and thermoregulation in neonatal lambs

Preston	James	Deakin	Masters	Coming to grips with greasy wool handle
Preston	Sarah	Monash	PhD	Identification and modulation of cells and mediators upregulated in parasite resistant sheep
Refshauge	Gordon (Peter)	UNE	PhD	Relationships between clean fleece weight, reproduction and fatness in adult Merino ewes
Rickard	Jessica	Sydney	PhD	Studies on the function, composition and variation of seminal plasma
Robertson	Matthew	Melbourne	PhD	Nutrient Sensing Pathways in Sheep
Rosales Nieto	Cesar A.	UWA	PhD	The effect of muscling genotype on reproductive performance of Merino ewe lambs
Rose	Gus	Wageningen, Netherlands	PhD	Breeding low input sheep
Santos	Bruno	UNE	PhD	The value of information from commercial operations for more accurate selection of breeding livestock
Starkey	Colin	UNE	Masters	Quantification of the biological factors that determine lamb ternderness
Stockman	Catherine	Murdoch	PhD	Studies on heat stress and nutrition in sheep
Taylor	Lee	UNE	PhD	The facilitation of shelter use by sheep
Tighe	Kara	UNE	PhD	Determinants of Australian consumer meat demand
Walkom	Samuel	Adelaide	PhD	Breeding for robustness in maternal sheep
Watkins	Peter	Murdoch	PhD	The role of volatiles in mutton flavour
Whale	James	Melbourne	Masters	Is it physically possible and economically feasible for Merino ewes to lamb at one year of age
Wilkes	Michael	Adelaide	PhD	Understanding physiological drivers of resilience in sheep

STILL ENROLED AND COMPLETING AS AT JUNE 2019

Blumer	Sarah	Murdoch	PhD	The biology of resilience to nutritional restriction in breeding ewes.
Connaughton	Steve	Murdoch	PhD	Calibration and standardisation of Dual Energy X-Ray Absorptiometry to predict Lamb carcass composition
Corlett	Maddison	Murdoch	PhD	Consumer perceptions towards lamb meat colour and eating quality
Grant	Emily	Murdoch	PhD	Behavioural assessments of sheep from video footage for the remote assessment of health and wellbeing
O'Reilly	Rachel	Murdoch	PhD	International consumer perceptions of sheepmeat eating quality: a comparison of American, Chinese and Australian consumers
Payne	Claire	Murdoch	PhD	Prediction of sheep age and eating quality using Dual Energy X-Ray Absorbiometry; comparisons of new and old season lamb
Richards	Jessica	UNE	PhD	Implementation of genomic principles in the sheep industry.
Schulz	Penelope	UNE	PhD	Computer APP's can significantly contribute to the future of training and extension in the sheep industry

Appendix VIII — Sheep CRC Awards

PRECISION SHEEP MANAGEMENT TAKES OUT MAJOR AWARD (2009)

A revolutionary approach to sheep management that was hailed as a nationally significant innovation in the field of science and technology.

The Sheep CRC received the Excellence in Innovation award for its developments in Precision Sheep Management, a whole new approach to livestock management, enabling monitoring and management of each animal in the mob according to its needs and merits.

SHEEP CRC RECEIVES CRC PROGRAM STAR AWARD FOR GENETICS (2011)

The Sheep CRC's efforts in working with industry in the key area of genetics was recognised with this prestigious award, which acknowledged cooperation between researchers and industry, specifically in the CRC's Information Nucleus program.

The Information Nucleus was central to the CRC's work and delivered new and far-reaching genetic information and data for genomic predictions of sheep breeding values.

INFORMATION NUCLEUS WINS CRC ASSOCIATION INNOVATION AWARD (2012)

The CRC was recognised for its exceptional work in the area of genetic improvement for the sheep industry for its Information Nucleus Program. The CRC received the Inaugural Award in the category rewarding significant innovation in the area of agriculture and food.

Collaboration was a key component of the Information Nucleus and this award was a credit to all partner organisations, researchers, industry organisations and producers.

RAMSELECT WINS CRC ASSOCIATION EXCELLENCE IN INNOVATION AWARD (2014)

The RamSelect program was presented with the CRCA Excellence in Innovation Award for its role in providing a 'hands on' practical approach to using Australian Sheep Breeding Values (ASBVs), so that sheep breeders can maximise genetic gain and therefore increase profit from their wool and meat businesses.

This program, led by Lu Hogan, delivered 73 workshops to 1,389 participants, with more than 95% indicating they had a better understanding of how to make better use of ASBVs and 85% indicating they would use ASBVs to select rams in the future.

STAR AWARD PRESENTED TO CRC FOR MANAGING SCANNED EWES (2014)

The CRC Program STAR Award was presented to the Sheep CRC for high-level engagement with small- and medium-sized businesses through its highly successful Managing Scanned Ewes program.

Coordinated by Chris Shands (NSWDPI), this program delivered 88 scanning workshops around Australia to 1,800 sheep producers, resulting in approximately 80% of attendees changing management practices.

RAMSELECT WINS ANOTHER PRESTIGIOUS CRC ASSOCIATION AWARD (2016)

The popular RamSelect app, which assists sheep breeders to select superior genetics specifically matched to their flock needs, was presented with a prestigious CRC Association award.

The web-based app RamSelect.com.au was developed by the Sheep CRC, Telstra, Pivotal Labs and NSW Department of Primary Industries. The appeal of RamSelect.com.au was its use of plain English and intuitive design to enable sheep breeders to quickly rank rams available for sale.

'HOLY GRAIL' OF DEXA WINS CRC ASSOCIATION AWARD FOR EXCELLENCE (2018)

The sheep meat industry's role in developing the new DEXA meat grading system was awarded the prestigious CRC Association Award for Excellence in Innovation.

The award was recognition for the benefits being delivered to the industry by dual energy x-ray absorptiometry (DEXA) which allows abattoirs to accurately measure carcase lean meat yield at line speed.

Appendix IX — Industry and extension publications

The Sheep CRC consistently published material suitable for producers and end-users with the latest information from the research programs. There were a number of comprehensive industry publications in the form of books and booklets, as well as shorter publications focussing on individual topics under the category of 'Practical Wisdom Notes' and 'Fact Sheets'. These publications were available in print and also online. The fact that a number of industry publications needed to be re-printed indicates the interest that these publications generated and their usefulness for many sectors of the sheep industry.

Industry books and booklets

Feeding Grain for Sheep Meat Production (2004)
Improving productivity through Precision Sheep Management systems (2004)
Precision Pays – Producer profiles on how precision sheep management is achieving accuracy, confidence and on-farm profitability (2006)
Sheep Focus 2006 (Summary of Sheep CRC research)
Individual Animal Management – Learners Guide (2007)
Concept to Impact - Sheep CRC Conference Proceedings 2007 (Orange)
Merino Sheep Breeding – Trainer Guide (2008)
Glovebox Guide - Precision Sheep Management (2008)
Sheep Industry Transformation - CRC Conference Booklet 2010 (Adelaide)
Sheep Focus 2010 (Summary of Sheep CRC research)
Products and Services to improve your sheep business (2011)
Sheep - the simple guide to making more money with less work (2011-2013) Special editions for: • Western Australia; • Cereal Sheep Zone; • High Rainfall Zone; and • Spring-summer rainfall zone
Australian Sheep Breeding Values (ASBVs) - A guide for ram buyers (Five editions published between 2013 and 2017)
Improving Lamb Lean Meat Yield - A technical guide for the Australian lamb and sheep meat supply chain (2016 and second edition in 2019)

Practical Wisdom Notes and Fact Sheets

Improving sheep & their management

Optimising stocking rate - the key to increasing pasture utilisation and profit
Profitability of sheep enterprises in southern Australia
Lambing at the right time in southern Australia

Nutrition

Options for light weight spring lambs
Sorghum grain for lot feeding of sheep
Feedlot calculator
Feeding grain and hay separately in lamb feedlots cheap and effective
The Cowra Bale Feeder for hay and roughage feeding

Reproduction

Getting the most from each ewe
Managing ewes for joining
Managing ewes in late pregnancy
Managing Merino weaners in southern Australia
Successful pregnancy scanning
The value of pregnancy scanning - should I do it?

Parasite management

WormBoss - Australia's sheep worm control resource
FlyBoss - resources for integrated flystrike control in Australian Sheep
LiceBoss - Australia's sheep lice control resource

Precision sheep management

Effective use of electronic identification for precision sheep management
Profiting from Individual Electronic Identification (eID)
Pedigree MatchMaker – determining dam pedigree
Individual Electronic Identification (eID)

Measuring & managing wool quality

Knitted wool fabrics can have soft handle but still prickle
Wool Comfort factor does not predict garment comfort
Wools of 18 microns and finer provide next-to-skin comfort
Staple strength - use genetics to make real progress

Quality Meat

Achieving target pH and temperature declines to improve meat quality
Bone growth and selection for muscling
On-farm impacts on meat eating quality
Growth and carcase characteristics of the major sheep breeds in Australia
Selection for growth and lean meat yield
Taking the mutton out of lamb
Reducing dehydration in slaughter lambs
Achieving a brilliant finish to your lambs
Merinos can deliver
Intramuscular fat: The key to maintaining eating quality and lean meat yield
Electrical stimulation for improved eating quality
Meat colour & shelf life
Preparing the market for larger lamb carcases

Genetics & genomics

Genomic & DNA testing: new tools for ram breeders to accelerate genetic gain
Breeding towards a poll flock with the Sheep CRC Poll test
Sheep CRC genomic test for Merinos - what are the benefits?
Sheep CRC genomic test for maternal breeds - what are the benefits?
Sheep CRC genomic test for terminal breeds - what are the benefits?
Using Australian Sheep Breeding Values
Fat and eye muscle depth in Merino breeding programs Sept 2015
Benefits of Reproductive Technologies Apr 2016
Strategies to achieve a 100% PP nucleus Apr 2016
Using selection decisions to improve ASBVs
Genomic testing ram lambs helps increase rates of genetic gain
Genomic testing and artificial insemination helps increase genetic gain
Benefits of genomic selection in Merino, Terminal and Maternal indexes
The cost-benefit of a Merino Flock Profile test

Education & training

Postgraduate training - careers and contribution to industry
Delivering innovation to industry - training and skills development

Fact sheets produced with AMPC - Meat and Meat Processing

The process to optimise Electrical Stimulation
Lamb Carcase Composition
Intramuscular fat %
Lamb Eating Quality (Fact sheet & technical note)
Lamb Nutritional Value (Fact sheet & technical note)
Lean Meat Yield Current & Future Technologies
Meat colour & shelf life
Meat colour stability
Optimising Electrical Stimulation
Research breeding values
Sheep CRC Projects
Types of Electrical Stimulation
What is electrical stimulation?
Lamb weight and growth rate (Technical note)
New breeding values for eating quality (Technical note)

Appendix X — Research Publications

The Sheep CRC encouraged publication of research results through refereed scientific journals and through papers presented at national and international conferences. In addition to refereed papers and conference proceedings a number of internal CRC reports and project review documents have been published online through the Livestock Library.

The CRC made arrangements with a number of research journals for the publication of special edition volumes comprising collections of peer-reviewed papers focussing on different aspects of the Sheep CRC's research portfolio.

Details of the CRC's peer-reviewed publications are listed in this appendix under three categories:

- journal special editions;
- full scientific papers; and
- published conference papers.

Peer-reviewed Sheep CRC Special Editions

Australian Journal of Experimental Agriculture (Sheep CRC Special Issue – Nutrition-Parasite Interaction in Sheep), Volume 43, Number 1, 2003.

Australian Journal of Agricultural Research (Sheep CRC Special Issue - Growth and Carcass Characteristics of Lambs—Nutritional and Genetic Influences), Volume 57, Number 6, 2006.

Australian Journal of Experimental Agriculture (Sheep CRC Special Issue – Sheep Growth, Carcass composition, muscle biochemistry and meat quality – influence of genetics, animal age and nutrition), Volume 47, Number 10, 2007.

Animal Production Science (Sheep CRC Special Issue - Sheep Industry Transformation - Proceedings of the 2010 Research Conference CRC for Sheep Industry Innovation), Volume 50, Numbers 11 & 12, 2010.

Animal Production Science (Beef CRC, Dairy CRC and Sheep CRC Special Issue - Applied Genomics for Sustainable Livestock Breeding), Volume 52, Numbers 2 & 3, 2012.

Journal of the Textile Institute (Sheep CRC Special Edition), Volume 104, Issue 6, 2013.

Animal Production Science (Sheep CRC Special Issue - Sheep Reproduction: Part 1), Volume 54, Issue 6, 2014.

Meat Science (Sheep CRC Special Edition), Volume 96, Issue 2, Part B, February 2014.

Textile Research Journal (Sheep CRC Special Issue – Wool Research in Australia), Volume 85, Issue 11, July 2015.

Animal Production Science (Sheep CRC Special Issue - Sheep Reproduction: Part 2), Volume 56, Issue 4, 2016.

Peer-reviewed research papers

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Appendix XI — Acronyms

AAABG	Association for the Advancement of Animal Breeding and Genetics
ABARES	Australian Bureau of Agricultural and Resource Economics and Sciences
ABC	Australian Broadcasting Corporation
AGBU	Animal Genetics and Breeding Unit
AIC	Australian Innovation Company Ltd
AMPC	Australian Meat Processor Corporation Ltd
APL	Australian Pork Limited
ASAP	Australian Society of Animal Production
ASBV	Australian Sheep Breeding Value
AWET	Australian Wool Education Trust
AWI	Australian Wool Innovation Ltd
AWTA	Australian Wool Testing Authority Ltd
BCFA	Branched Chain Fatty Acids
CEO	Chief Executive Officer
CRC	Cooperative Research Centre (Sheep CRC Ltd)
CT	Computed tomography
CRCA	Cooperative Research Centres Association
CSIRO	Commonwealth Scientific & Industrial Research Organisation
DAFWA	Department of Agriculture and Food, Western Australia
DEXA	Dual-energy X-ray absorptiometry
DHA	Docosahexaenoic acid
DNA	Deoxyribonucleic acid
DPI	Department of Primary Industries
EAAP	European Federation of Animal Science
eID	Electronic Identification
EQ	Eating Quality
FY	Financial Year
HD	High Density
ICoMST	International Congress of Meat Science and Technology
IMF	Intramuscular fat
INF	Information Nucleus Flock
IP	Intellectual Property
ISGC	International Sheep Genomics Consortium
ITMA	International Textile Machinery Association
IWTO	International Wool Textile Organisation
JIVET	Juvenile In-Vitro Embryo Transfer
LDL	Livestock Data Link

LEQ	Lamb Eating Quality
LHPA	Livestock Health & Pest Authority
LLS	Local Land Services
LMY	Lean Meat Yield
LSCG	Lamb Supply Chain Group
MCPT	Maternal Central Progeny Test
MDC	MLA Donor Company Limited
MLA	Meat & Livestock Australia Limited
MSA	Meat Standards Australia
NAA	Neogen Australasia
NIRS	Near-infrared spectroscopy
NSW	New South Wales (Australia)
NZSAP	New Zealand Society of Animal Production
OFFM	On-Farm Fibre Measurement
PICSE	Primary Industries Centre for Science Education
PRRC	Project Review & Research Committee
QLD	Queensland (Australia)
QLT	Quantitative Trait Locus
R&D	Research & Development
RDC	Rural Research & Development Corporation
SA	South Australia
SARDI	South Australian Research Development Institute
SCIPS	Sustainable Control of Internal Parasites in Sheep
SG	Sheep Genomics
SMEQ	Sheepmeat Eating Quality
SNP	Single nucleotide polymorphism
TSU	Tissue Sampling Unit
UNE	University of New England
USDA	United States Department of Agriculture
UTAS	University of Tasmania
VET	Vocational Education & Training
VIC	Victoria (Australia)
WA	Western Australia
WAMMCO	West Australian Meat Marketing Cooperative
WAAVP	World Association of the Advancement of Veterinary Parasitology
WCGALP	World Congress of Genetics Applied to Livestock Production

SHEEP CRC

CONCEPT TO IMPACT

The story of the SHEEP CRC 2001–2019

During the 1980s and '90s, Australia's sheep and wool industries were lurching from crisis to crisis—with variable prime lamb prices and the collapse of the wool reserve price scheme—and something had to give.

By the turn of the century the industry had sufficiently organised itself and its resources and was investing heavily in marketing, but a new approach to R&D was needed to restore the iconic status of sheep in Australian agriculture.

Over the course of 18 years the Cooperative Research Centre for Sheep Industry Innovation (Sheep CRC) helped transform the industry into a global powerhouse of efficient production of consistently high-quality meat and wool based on incredible new technologies.

But it almost never existed, with the Sheep CRC surviving two early scares which could have killed off one of Australian agriculture's highest performing research agencies before it was even born.

Concept to Impact records the people, the politics and the powerful new technologies that have changed the face of Australian sheep production forever.

Australian Government
Department of Industry, Innovation and Science

Business
Cooperative Research Centres Program